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# **Advanced Java 2 Platform HOW TO PROGRAM**

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PRENTICE HALL, Upper Saddle River, New Jersey  
07458

**Library of Congress Cataloging-in-Publication Data  
on File**

Vice President and Editorial Director: ***Marcia Horton***  
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Upper Saddle River, New Jersey 07458

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Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-034151-7

Prentice-Hall International (UK) Limited, *London*  
Prentice-Hall of Australia Pty. Limited, *Sydney*  
Prentice-Hall Canada Inc., *Toronto*  
Prentice-Hall Hispanoamericana, S.A., *Mexico*  
Prentice-Hall of India Private Limited, *New Delhi*  
Prentice-Hall of Japan, Inc., *Tokyo*  
Pearson Education Asia Pte. Ltd., *Singapore*  
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

In loving memory of our Uncle and Granduncle  
Joseph Deitel:

“His pleasure was giving.”

*Harvey and Paul Deitel*

For my brother Tim, who, by his example, always has  
challenged me to excel.

*Sean*

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# Preface

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*Live in fragments no longer. Only connect.*

Edward Morgan Forster

Welcome to *Advanced Java 2 Platform How to Program* and the exciting world of advanced-programming concepts with the three major Java platforms—*Java™ 2 Enterprise Edition (J2EE)*, *Java 2 Standard Edition (J2SE)* and *Java 2 Micro Edition (J2ME)*. Little did we know when we attended the November 1995 Internet/World Wide Web conference in Boston what that session would yield—four editions of *Java How To Program* (the world’s best-selling Java textbook), and now this book about Java software-development technologies for upper-level college courses and professional developers.

Before Java appeared, we were convinced that C++ would replace C as the dominant application-development language and systems-programming language for the next decade. However, the combination of the World Wide Web and Java now increases the prominence of the Internet in information-systems planning and implementation. Organizations want to integrate the Internet “seamlessly” into their information systems. Java is more appropriate than C++ for this purpose—as evidenced by Sun Microsystems’ announcement in 2001 that over 96% of enterprise application servers support J2EE.

*Advanced Java 2 Platform How to Program* is the first book in our *Advanced How to Program* series. We discuss Java technologies that may be unfamiliar and challenging to the average Java programmer. We structured each chapter discussion to provide the reader with an introduction to leading-edge and complex Java technologies, rather than provide a detailed analysis of every nuance of each topic. In fact, each topic we present could be a 600–800 page book in itself.

We use a different approach with the examples in this book than that of programming examples in our previous books. We provide fewer programs, but these programs are more substantial and illustrate sophisticated coding practices. We integrate many technologies to create a book for developers that enables you to “go beyond” and experiment with the most

up-to-date technologies and most widely employed design concepts. What better way to learn than to work with actual technologies and code?

When determining the appropriate topics for this book, we read dozens of journals, reviewed the Sun Microsystems Web site and participated in numerous trade shows. We audited our material against the latest technologies presented at the JavaOne conference—the leading Java-developer conference sponsored by Sun Microsystems—and at other popular Java conferences. We also reviewed books on specialized Java topics. After this extensive research, we created an outline for this book and sent it for professional review by Java experts. We found so many topics we wanted to include that we wound up with over 1800 pages of material (several hundred of those pages appear as PDF documents on the CD that accompanies this book). We apologize if this is inconvenient, but the material and the number of topics are voluminous. We will most likely split the next edition into two volumes.

This book benefitted from an unusually large pool of excellent reviewers and the detailed documentation that Sun makes available on their Web site ([www.sun.com](http://www.sun.com)). We were excited to have a number of reviewers from Sun and many other distinguished industry reviewers. We wanted experienced developers to review our code and discussions, so we could offer “expert advice” from people who actually work with the technologies in industry.

We are pleased to include a discussion of application servers in Chapter 21. The three most popular application server software products are BEA’s *WebLogic*, IBM’s *WebSphere* and Sun/Netscape’s *iPlanet*. Originally, we had planned to include all three on the book’s accompanying CD, but we have included only WebLogic and WebSphere. iPlanet was about to publish a new version as this book went to publication. By mutual agreement between iPlanet and Deitel & Associates, Inc., we decided not to include this software, but iPlanet provides a link to a site specific to this book—[www.iplanet.com/ias\\_deitel](http://www.iplanet.com/ias_deitel)—where readers can download the latest iPlanet software. We also include a discussion of how to deploy our case study on the iPlanet server. You can find this discussion on our Web site—[www.deitel.com](http://www.deitel.com).

We moved four chapters from *Java How to Program, Third Edition*—RMI, Servlets, JavaBeans and JDBC—to *Advanced Java 2 Platform How to Program*. Prentice Hall has published a paperback supplement (ISBN: 0-13-074367-4) containing these four chapters for readers who have purchased *Java How to Program, Fourth Edition*.

The world of Java is growing so rapidly that *Advanced Java 2 Platform How to Program* and its companion text, *Java How to Program, Fourth Edition*, total 3400 pages! The books are so large that we had to put several chapters from each on the accompanying CDs. This creates tremendous challenges and opportunities for us as authors, for our publisher—Prentice Hall, for instructors, for students and for professionals. We hope you enjoy the results of these challenges as much as we have enjoyed the process of tackling them.

## Features of *Advanced Java 2 Platform How to Program*

This book contains many features including:

- **Full-Color Presentation.** This book is in full color to enable readers to see sample outputs as they would appear on a color monitor. Also, we now syntax color all the Java code, as do many of today’s Java integrated development environments and code editors. Our syntax-coloring conventions are as follows:

```
comments appear in green
keywords appear in dark blue
constants and literal values appear in light blue
JSP delimiters appear in red
all other code appears in black
```

- “**Code Washing.**” This is our own term for the process we use to format the programs in the book with a carefully commented, open layout. The code is in full color and grouped into small, well-documented pieces. This greatly improves code readability—an especially important goal for us given that this book contains almost 40,000 lines of code.
- **Advanced Graphical User Interface (GUI) Design.** Starting with Chapter 2, we use advanced Java Swing features to create real-world Java components, including a Web-browser application with a multiple-document interface. In Chapter 3, we introduce the Model-View-Controller (MVC) architecture and its implementation in the Swing API. In Chapters 4 and 5, we create 2D graphics and 3D worlds. The Java 2D Drawing Application with Design Patterns Case Study in Chapter 5 presents a complex drawing program with which the user can create shapes in various colors and gradients. We are also pleased to add Java 3D coverage. One of the book’s adopters said these chapters were ideal for a course in advanced GUI programming. (We wanted to include multimedia programming with the Java Media Framework, but instead we decided to include this material in the companion book, *Java How to Program, Fourth Edition.*)
- **Enterprise Java and Our Enterprise Java Case Study.** Developers use Java for building “heavy-duty” enterprise applications. Chapters 7–11, 14–16 and 21 explore the necessary components for implementing enterprise solutions—including security, database manipulation, servlets, JavaServer Pages, distributed transactions, message-oriented middleware and application servers. In Chapter 7, Security, we discuss secure communications and secure programming. Chapters 17–20 showcase an Enterprise Java Case Study that integrates many technologies, such as Enterprise JavaBeans, servlets, RMI-IIOP, XML, XSLT, XHTML, (and for wireless application development) WML and cHTML—into an online-bookstore application. The Deitel Bookstore demonstrates how to use the MVC architecture introduced in Chapter 3 to build enterprise applications. This bookstore uses technologies to provide support for almost any type of client, including cell phones, mobile devices and Web browsers. In this world of networks and wireless networks, business information must be delivered securely and reliably to the intended recipients.
- **Distributed Systems.** Enterprise applications are usually so complex that they run more efficiently when program components are distributed among different machines in organizations’ networks. This book introduces several technologies for building distributed systems—Remote Method Invocation (RMI), Jini, JavaSpaces, Java Management Extensions (JMX), Jiro and Common Object Request Broker Architecture (CORBA). CORBA, controlled by the Object Management Group (OMG), is a mature distributed computing technology for integrating distributed components written in many disparate languages. Java was originally intended for networks of programmable devices—Jini assumes that technology role

now. JMX and Jiro are technologies specifically for network management (LANs, WANs, intranets, the Internet, extranets, etc.).

- **Java 2 Micro Edition (J2ME) and Wireless Applications.** It is estimated that by 2003, more people worldwide will access the Internet through wireless devices than through desktop computers. The Java platform for wireless devices with limited capabilities such as cell phones and personal digital assistants is Java 2 Micro Edition (J2ME). Chapter 12, Wireless Java-Based Applications Development and J2ME, contains a case study that sends content from a centralized data store to several wireless clients, including a J2ME client.
- **Web Services.** Web services are applications that expose public interfaces usable by other applications over the Web. The area of Web services builds on existing protocols, such as HTTP, and communicate with XML-based messages. Directory services enable clients to perform lookups to discover available Web services. The Simple Object Access Protocol (SOAP) uses XML to provide communication in many Web services. Many of the technologies in this book can be used to build Web services.
- **Employing Design Patterns.** The book's largest case studies—such as the Java 2D drawing program in Chapter 5, the three-tier servlet and JavaServer Pages case study in Chapter 11, the three-tier wireless application in Chapter 12 and the Deloitte Bookstore Enterprise Case Study in Chapters 17–20—each contain thousands of lines of code. Larger systems, such as automated teller machines or air-traffic control systems, can contain hundreds of thousands, or even millions, of lines of code. Effective design is crucial to the proper construction of such complex systems. Over the past decade, the software engineering industry has made significant progress in the field of *design patterns*—proven architectures for constructing flexible and maintainable object-oriented software.<sup>1</sup> Using design patterns can substantially reduce the complexity of the design process. We used many design patterns when building the software in this book. Chapter 1 introduces design patterns, discusses why they are useful and lists those design patterns we use throughout this book
- **XML.** XML (Extensible Markup Language) use is exploding in the software-development industry and we use it pervasively throughout the text. As a platform-independent syntax for creating markup languages, XML's data portability integrates well with Java's portable applications and services. If you do not know XML, Appendices A–D of this book provide an introduction to XML. Appendices A and B introduce XML basics and DTDs, which define standard XML document structures. Appendix C introduces the Document Object Model (DOM) API for manipulating XML documents. Appendix D covers XSLT (Extensible Stylesheet Language Transformations—an XML vocabulary for transforming XML documents into other text-based documents).
- **Peer-to-Peer Applications.** Peer-to-peer (P2P) applications—such as instant messaging and document-sharing programs—have become extremely popular. Chap-

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1. Gamma, Erich, Richard Helm, Ralph Johnson, and John Vlissides. *Design Patterns; Elements of Reusable Object-Oriented Software*. (Massachusetts: Addison-Wesley, 1995).

ter 28, Peer-to-Peer Applications and JXTA, introduces this architecture, in which each node performs both client and server duties. JXTA (short for the term “Juxtapose”), defines protocols for implementing peer-to-peer applications. This chapter includes two P2P application case studies—one written with Jini and RMI and the other written in multicast sockets and RMI. Both implement a P2P instant messaging application. We wanted a capstone example for Jini and decided this chapter should have it. The first case study is somewhat centralized—and therefore not a “true” P2P application (some developers think that Jini has too much overhead for a peer-to-peer application). We developed the second to demonstrate a lighter-weight, decentralized implementation.

- **Appendix H, Career Opportunities.** This appendix introduces career services on the Internet. We explore online career services from both the employer’s and employee’s perspectives. We suggest Web sites at which you can submit applications, search for jobs and review applicants (if you are interested in hiring someone). We also review services that build recruiting pages directly into e-businesses. One of our reviewers told us that he had just gone through a job search largely using the Internet and this chapter would have expanded his search dramatically.
- **Appendix I, Unicode.** This appendix overviews the *Unicode Standard*. As computer systems evolved worldwide, computer vendors developed numeric representations of character sets and special symbols for the local languages spoken in different countries. In some cases, different representations were developed for the same languages. Such disparate character sets made communication between computer systems difficult. Java supports the Unicode Standard (maintained by a non-profit organization called the *Unicode Consortium*), which defines a single character set with unique numeric values for characters and special symbols in most spoken languages. This appendix discusses the Unicode Standard, overviews the Unicode Consortium Web site ([unicode.org](http://unicode.org)) and shows a Java example that displays “Welcome” in many different languages.
- **Bibliography and Resources.** Chapters in this book contain bibliographies when appropriate and URLs that offer additional information about the technologies. We did this so those readers who would like to study a topic further could begin with the resources we found helpful when developing this book.

## Some Notes to Instructors

### A World of Object Orientation

When we wrote the first edition of *Java How to Program*, universities were still emphasizing procedural programming in languages like Pascal and C. The leading-edge courses were using object-oriented C++, but these courses were generally mixing a substantial amount of procedural programming with object-oriented programming—something that C++ lets you do, but Java does not. By the third edition of *Java How to Program*, many universities were switching from C++ to Java in their introductory curricula, and instructors were emphasizing a pure object-oriented programming approach. In parallel with this activity, the software engineering community was standardizing its approach to modeling ob-

ject-oriented systems with the UML, and the design-patterns movement was taking shape. This book takes a 100% object-oriented approach and emphasizes Java design patterns and adherence to Java idiom.

The prerequisite for this book is *Java How to Program, Fourth Edition* (or equivalent Java knowledge), which provides a solid foundation in Java programming. *Java How to Program, Fourth Edition* includes the following chapters and appendices, for a more detailed Table of Contents, visit [www.deitel.com](http://www.deitel.com): Introduction to Computers, the Internet and the Web; Introduction to Java Applications; Introduction to Java Applets; Control Structures: Part 1; Control Structures: Part 2; Methods; Arrays; Object-Based Programming; Object-Oriented Programming; Strings and Characters; Graphics and Java 2D; Graphical User Interface Components: Part 1; Graphical User Interface Components: Part 2; Exception Handling; Multithreading; Files and Streams; Networking; Multimedia: Images, Animation, Audio and Video; Data Structures; Java Utilities Package and Bit Manipulation; Collections; Java Media Framework and Java Sound; Java Demos; Java Resources; Operator Precedence Chart; ASCII Character Set; Number Systems; Creating HTML Documentation with **javadoc**; Elevator Events and Listener Interfaces; Elevator Model; Elevator View; Career Opportunities; Unicode; Bibliography.

### ***Students Like Java***

Students are highly motivated by the fact that they are learning a leading-edge language (Java) and a leading-edge programming paradigm (object-oriented programming) for building entire systems. Java immediately gives them an advantage when they head into a world in which the Internet and the World Wide Web have a massive prominence and corporations need enterprise systems programmers. Students quickly discover that they can do great things with Java, so they are willing to put in the extra effort. Java helps programmers unleash their creativity. We see this in the Java and advanced Java courses Deitel & Associates, Inc. teaches.

### ***Focus of the Book***

Our goal was clear—produce an advanced Java textbook for higher-level university courses in computer programming for students with intermediate-level Java programming experience, and offer the depth and the rigorous treatment of theory and practice demanded by professionals. To meet these goals, we produced a book that challenges Java programmers. We present clear examples of advanced topics and often overlooked topics. We adhere to Java idiom and follow sophisticated coding style and practices (i.e., not just the code formatting, but the idiomatic use of Java API's, constructs and technologies). This book presents substantial Java applications that readers can use to start working with these technologies immediately.

### ***Evolution of Advanced Java 2 Platform How to Program***

*Advanced Java 2 Platform How to Program* was finished fresh on the heels of *Java How to Program, Fourth Edition*. Hundreds of thousands of university students and professionals worldwide have learned Java from our texts. Upon publication in September 2001, *Advanced Java 2 Platform How to Program* will be used in universities, corporations and government organizations worldwide. Deitel & Associates, Inc. taught Java courses internationally to thousands of students as we were writing the various editions of *Java How to*

*Program and Advanced Java 2 Platform How to Program.* We carefully monitored the effectiveness of material and tuned the books accordingly.

### ***Conceptualization of Java***

We believe in Java. Its conceptualization by Sun Microsystems, the creator of Java, was brilliant. Sun based the new language on C and C++, two of the world's most widely used implementation languages. This immediately gave Java a huge pool of highly skilled programmers who were implementing most of the world's new operating systems, communications systems, database systems, personal-computer applications and systems software. Sun removed the more complex and error-prone C/C++ features (such as explicit pointers, operator overloading and multiple inheritance, among others). They kept the language concise by removing special-purpose features used by only small segments of the programming community. They made the language truly portable for implementing Internet-based and Web-based applications, and they included features developers need such as strings, graphics, GUI components, exception handling, multithreading, multimedia (audio, images, animation and video), prepackaged data structures, file processing, database processing, Internet and Web-based client/server networking, distributed computing and enterprise computing. Then they made the language available *at no charge* to millions of potential programmers worldwide.

### ***2.5 Million Java Developers***

Java was promoted in 1995 as a means of adding “dynamic content” to Web pages. Instead of Web pages with only text and static graphics, Web pages could now “come alive” with audios, videos, animations, interactivity—and soon, 3D imaging. But we saw much more in Java than this. Java's features are precisely what businesses and organizations need to meet today's information-processing requirements. So we immediately viewed Java as having the potential to become one of the world's key general-purpose programming languages. In fact, Java has revolutionized software development with multimedia-intensive, platform-independent, object-oriented code for conventional, Internet-, Intranet- and Extranet-based applications and applets. Java now has 2.5 million developers worldwide—a stunning accomplishment when considering that it has been available publicly for only six years. No other programming language has ever acquired such a large developer base so quickly.

## **Teaching Approach**

*Advanced Java 2 Platform How to Program, First Edition* contains a rich collection of examples, exercises and projects drawn from many fields to provide readers with a chance to solve interesting real-world problems. The book concentrates on the principles of good software engineering and stresses program clarity, especially important when creating substantial programs like those covered in this book. We avoid arcane terminology and syntax specifications in favor of teaching by example. Our code examples have been tested on popular Java platforms. We are educators who teach edge-of-the-practice topics in industry classrooms worldwide. The text emphasizes good pedagogy.

### ***Learning Java via the live-code™ Approach***

The book is loaded with live-code™ examples. This is how we teach and write about programming, and is the focus of each of our multimedia Cyber Classrooms and Web-based

training courses. We present each new concept in the context of a complete, working Java program, immediately followed by screen captures that show the program's output. We call this style of teaching and writing our ***live-code™ approach***. *We use the language to teach the language.* Reading these programs (almost 40,000 lines of code) is much like entering and running them on a computer.

### ***Java Programming from Chapter Two***

*Advanced Java 2 Platform How to Program*, “jumps right in” with substantial programs right from Chapter 2. This is the beginning of an aggressive pace that challenges readers with graphical, multithreaded, database-intensive, network-based programming. Throughout the book, readers learn by implementing impressive projects.

### ***World Wide Web Access***

All the code for *Advanced Java 2 Platform How to Program* is on the CD that accompanies this book. The code also is available at the following Web sites:

**`www.deitel.com`**  
**`www.prenhall.com/deitel`**

### ***Objectives***

Each chapter begins with *Objectives* that inform the reader what to expect and provides an opportunity, after reading the chapter, to determine if the reader has met these objectives. It is a confidence builder and a source of positive reinforcement.

### ***Quotations***

The learning objectives are followed by quotations. Some are humorous, some are philosophical and some offer interesting insights. Our readers enjoy relating the quotations to the chapter material. The quotations are worth a “second look” after you read each chapter.

### ***Outline***

The chapter outline helps the reader approach the material in top-down fashion. This, too, helps students anticipate what is to come and set a comfortable and effective learning pace.

### ***Almost 40,000 Lines of Code in 126 Example Programs (with Program Outputs)***

We present Java features in the context of complete, working Java programs. The programs in this book are substantial, with hundreds to thousands of lines of code (e.g., 10,000 lines of code for the bookstore case study example). Students should use the program code from the CD that accompanies the book and run each program while studying that program in the text.

### ***841 Illustrations/Figures***

Many of the figures are code examples, but this book still offers many charts, line drawings and program outputs. For example, Chapter 4 and 5, Graphics Programming with Java 2D and Java 3D, provides stunning graphics, and the architectural overview of the Enterprise Java case study in Chapter 17 is impressive.

## 235 Programming Tips

We have included programming tips to help students focus on important aspects of program development. We highlight numerous tips in the form of *Good Programming Practices*, *Common Programming Errors*, *Testing and Debugging Tips*, *Performance Tips*, *Portability Tips*, *Software Engineering Observations* and *Look-and-Feel Observations*. These tips and practices represent the best we have gleaned from decades of programming and teaching experience. One of our students—a mathematics major—told us that she feels this approach is like the highlighting of axioms, theorems and corollaries in mathematics books; it provides a basis on which to build good software.



### Good Programming Practices

*We highlight Good Programming Practices techniques for writing programs that are clearer, more understandable, more debuggable and more maintainable.*



### Common Programming Errors

*Focusing on these Common Programming Errors helps readers avoid making the same errors.*



### Testing and Debugging Tips

*When we first designed this “tip type,” we thought we would use it strictly to tell people how to test and debug Java programs. In fact, many of the tips describe aspects of Java that reduce the likelihood of “bugs” and thus simplify the testing and debugging process.*



### Performance Tips

*We have included 13 Performance Tips that highlight opportunities for improving program performance—making programs run faster or minimizing the amount of memory that they occupy.*



### Portability Tips

*One of Java’s “claims to fame” is “universal” portability, so some programmers assume that if they implement an application in Java, the application will automatically be “perfectly” portable across all Java platforms. Unfortunately, this is not always the case. We include Portability Tips to help readers write portable code and to provide insights on how Java achieves its high degree of portability.*



### Software Engineering Observations

*The object-oriented programming paradigm requires a complete rethinking about the way we build software systems. Java is an effective language for performing good software engineering. The Software Engineering Observations highlight architectural and design issues that affect the construction of software systems, especially large-scale systems.*



### Look-and-Feel Observations

*We provide Look-and-Feel Observations to highlight graphical user interface conventions. These observations help readers design their own graphical user interfaces in conformance with industry norms.*

## Summary (949 Summary bullets)

Each chapter ends with additional pedagogical devices. We present a thorough, bullet-list-style summary of the chapter. On average, there are 26 summary bullets per chapter. This helps the readers review and reinforce key concepts.

**Terminology (1904 Terms)**

We include in a *Terminology* section an alphabetized list of the important terms defined in the chapter—again, further reinforcement. On average, there are 51 terms per chapter.

**394 Self-Review Exercises and Answers (Count Includes Separate Parts)**

Self-review exercises and answers are included for self-study. These reinforce the knowledge the reader gained from the chapter.

**189 Exercises (Count Includes Separate Parts)**

Each chapter concludes with a set of exercises. The exercises cover many areas. This enables instructors to tailor their courses to the unique needs of their audiences and to vary course assignments each semester. Instructors can use these exercises to form homework assignments, quizzes and examinations. The solutions for most of the exercises are included on the *Instructor's Manual* CD that is *available only to instructors* through their Prentice-Hall representatives. [NOTE: Please do not write to us requesting the instructor's manual. Distribution of this publication is strictly limited to college professors teaching from the book. Instructors may obtain the Instructor's manual only from their Prentice Hall representatives. We regret that we cannot provide the solutions to professionals.] Solutions to approximately half of the exercises are included on the *Advanced Java 2 Platform Multimedia Cyber Classroom* CD, which also is part of *The Complete Advanced Java 2 Platform Training Course*. For ordering instructions, please see the last few pages of this book or visit [www.deitel.com](http://www.deitel.com).

**Approximately 3,080 Index Entries (with approximately 4648 Page References)**

This book includes an extensive index. This helps the reader find any term or concept by keyword. The index is useful to developers who use the book as a reference. The terms in the Terminology sections generally appear in the index (along with many more index items from each chapter).

**"Double Indexing" of Java live-code™ Examples and Exercises**

*Advanced Java 2 Platform How to Program* has 126 live-code™ examples and 189 exercises (including parts). Many exercises are challenging problems or projects that require substantial effort. We have "double indexed" the live-code™ examples. For every Java source-code program in the book, we took the file name with the **.java** extension, such as **WebBrowser.java** and indexed it both alphabetically (in this case under "W") and as a subindex item under "Examples." This makes it easier to find examples using particular features.

## Software Included with *Advanced Java 2 Platform How to Program*

There are a number of for-sale Java products available. However, you do not need them to get started with Java. We wrote *Advanced Java 2 Platform How to Program* using the *Java 2 Software Development Kit (J2SDK) Standard Edition Version 1.3.1 for Windows and Linux (Intel x86)* and other software programs that we include on the CD that accompanies this book. For your convenience, Sun's J2SDK also can be downloaded from the Sun Microsystems Java Web site [java.sun.com/j2se](http://java.sun.com/j2se). We include some of the most popular

server software so you can set up and run live systems. This software includes *BEA WebLogic Server™, Version 6.0 (Windows/Linux) with Service Pack 2, 30-Day Trial, Enterprise Edition, 6.0, Testdrive; IBM® WebSphere® Application Server, Advanced Single Server Edition, Version 4.0 for Windows NT® and Windows® 2000 Evaluation Copy*, and *Apache Tomcat 3.2.3 from the Apache Software Foundation*. We also include Informix Software's *Cloudscape 3.6.4* database software. With Sun's cooperation, we also were able to include on the CD a powerful Java integrated development environment (IDE)—Sun Microsystem's *Forte for Java Community Edition*. *Forte* is a professional IDE written in Java that includes a graphical user interface designer, code editor, compiler, visual debugger and more. J2SDK 1.3.1 must be installed before installing *Forte*. If you have any questions about using this software, please read the introductory *Forte* documentation on the CD. We will provide additional information on our Web site [www.deitel.com](http://www.deitel.com).

The CD also contains the book's examples and a Web page with links to the Deitel & Associates, Inc. Web site ([www.deitel.com](http://www.deitel.com)), the Prentice Hall Web site ([www.prenhall.com/deitel](http://www.prenhall.com/deitel)) and the many Web sites listed at the end of each chapter. If you have access to the Internet, this Web page can be loaded into your Web browser to give you quick access to all the resources. Finally, because we wrote much more than we originally intended, a number of chapters and appendices have been off-loaded to the CD.

## Ancillary Package for Advanced Java 2 Platform How to Program

*Advanced Java 2 Platform How to Program* has extensive ancillary materials for instructors teaching from the book. The Instructor's Manual CD contains solutions to the vast majority of the end-of-chapter exercises. We also provide PowerPoint® slides containing all the code and figures in the text. You are free to customize these slides to meet your own classroom needs. Prentice Hall provides a Companion Web Site ([www.prenhall.com/deitel](http://www.prenhall.com/deitel)) that includes resources for instructors and students. For instructors, the Web site has a *Syllabus Manager* for course planning, links to the PowerPoint slides and reference materials from the appendices of the book (such as the character sets and Web resources). For students, the Web site provides chapter objectives, true/false exercises with instant feedback, chapter highlights and reference materials. [NOTE: Please do not write to us requesting the instructor's manual. Distribution of this publication is strictly limited to college professors teaching from the book. Instructors may obtain the solutions manual only from their regular Prentice Hall representatives. We regret that we cannot provide the solutions to professionals.]

## Advanced Java 2 Platform Multimedia Cyber Classroom (CD and Web-Based Training Versions) and The Complete Advanced Java 2 Platform Training Course

We have prepared an interactive, CD-based, software version of *Advanced Java 2 Platform How to Program*, called the *Advanced Java 2 Platform Multimedia Cyber Classroom*. It is loaded with features for learning and reference. The *Cyber Classroom* is wrapped with the textbook at a discount in *The Complete Advanced Java 2 Platform Training Course*. If you already have the book and would like to purchase the *Advanced Java 2 Platform Multimedia Cyber Classroom* (ISBN: 0-13-091276-x) separately, please visit [www.infor](http://www.infor)

**mit.com/cyberclassrooms.** All Deitel *Cyber Classrooms* are generally available in CD and Web-based training formats.

The CD has an introduction with the authors overviewing the *Cyber Classroom*'s features. Many of the live-code™ examples in the textbook truly "come alive" in the *Cyber Classroom*. If you are viewing a program and want to execute it, you click the lightning bolt icon and the program will run. You will immediately see—and hear for the audio-based multimedia programs—the program's outputs. If you want to modify a program and see and hear the effects of your changes, simply click the floppy-disk icon that causes the source code to be "lifted off" the CD and "dropped into" one of your own directories so you can edit the text, recompile the program and try out your new version. Click the audio icon and one of the authors will talk about the program and "walk you through" the code.

The *Cyber Classroom* also provides navigational aids including extensive hyperlinking. The *Cyber Classroom* is browser based, so it remembers recent sections you have visited and allows you to move forward or backward among these sections. The thousands of index entries are hyperlinked to their text occurrences. You can search for a term using the "find" feature and the *Cyber Classroom* locates its occurrences throughout the text. The Table of Contents entries are "hot"—so clicking a chapter name takes you to that chapter.

Students tell us that they particularly like the fact that solutions to about half the exercises in the book are included with the *Cyber Classroom*. Studying and running these extra programs is a great way for students to enhance their learning experience.

Students and professional users of our *Cyber Classrooms* tell us they like the interactivity and that the *Cyber Classroom* is an effective reference because of the extensive hyperlinking and other navigational features. We received an email from a person who said that he lives "in the boonies" and cannot take a live course at a university, so the *Cyber Classroom* was the solution to his educational needs.

Professors tell us that their students enjoy using the *Cyber Classroom*, spend more time on the course and master more of the material than in textbook-only courses. We have published (and will be publishing) many other *Cyber Classroom* and *Complete Training Course* products. For a complete list of the available and forthcoming *Cyber Classrooms* and *Complete Training Courses*, see the *Deitel™ Series* page at the beginning of this book or the product listing and ordering information at the end of this book. You can also visit [www.deitel.com](http://www.deitel.com) or [www.prenhall.com/deitel](http://www.prenhall.com/deitel) for more information.

## Acknowledgments

One of the great pleasures of writing a textbook is acknowledging the efforts of the many people whose names may not appear on the cover, but whose hard work, cooperation, friendship and understanding were crucial to the production of the book.

Several people at Deitel & Associates, Inc. devoted long hours to this project. We would like to acknowledge the efforts of our full-time Deitel & Associates, Inc. colleagues Jonathan Gadzik, Tem Nieto, Su Zhang, Kyle Lomeli, Matthew Kowalewski, Rashmi Jayaprakash, Kate Steinbuhler, Abbey Deitel and Betsy DuWaldt.

- Jonathan Gadzik, a graduate of the Columbia University School of Engineering and Applied Science (BS in Computer Science) co-authored Chapter 1, Introduction, and Chapter 12, Java-Based Wireless Applications Development and J2ME, and contributed to Chapter 4 and the design patterns material throughout the book. He also reviewed Chapter 28, Peer-to-Peer Applications.

- Tem Nieto, a graduate of the Massachusetts Institute of Technology, is Director of Product Development at Deitel & Associates. Tem teaches XML, Java, Internet and Web, C, C++ and Visual Basic seminars and works with us on textbook writing, course development and multimedia-authoring efforts. He is co-author with us of *Internet & World Wide Web How to Program (Second Edition)*, *XML How to Program*, *Perl How to Program* and *Visual Basic 6 How to Program*. In *Advanced Java 2 Platform How to Program, First Edition* Tem updated Chapters 5, 6, 8 and 12 of *XML How to Program* for inclusion as Appendices A–D—Creating Markup with XML, XML Document Type Definitions, XML Document Object Model (DOM) and XSL (Extensible Stylesheet Language Transformations)—respectively.
- Su Zhang, a graduate of McGill University with a Masters in Computer Science, co-authored Chapters 22, 23, 24 and 25—Jini, JavaSpaces, Jiro and JMX, respectively.
- Kyle Lomeli, a graduate of Oberlin College in Computer Science co-authored Chapters 24 and 25 (JMX and Jiro). He contributed to Chapter 3, MVC; Chapter 7, Security; Chapter 13, RMI and Chapter 23, JavaSpaces, and he reviewed Chapter 12.
- Matthew Kowalewski, a graduate of Bentley College with a major in Accounting Information Systems and Director of Wireless Development at Deitel & Associates, Inc., contributed to Chapter 12.
- Rashmi Jayaprakash, a graduate of Boston University with a major in Computer Science, co-authored Appendix I, Unicode.
- Kate Steinbuhler, a graduate of Boston College with majors in English and Communications, co-authored Appendix H, Career Opportunities, and managed the permissions process.
- Abbey S. Deitel, a graduate of Carnegie Mellon University with a BS in Industrial Management and President of Deitel & Associates, Inc., co-authored Chapter 7, Security.
- Betsy DuWaldt, a graduate of Metropolitan State College of Denver with a degree in Technical Communications (Writing and Editing Emphasis) and a minor in Computer Information Systems, is Editorial Director at Deitel & Associates, Inc. She co-authored the Preface, helped prepare the manuscript for publication and edited the index.

We would like to thank the participants in our Deitel & Associates, Inc. College Internship Program.<sup>2</sup>

- Chris Henson, a Masters student at Brandeis University (Computer Science), co-authored Chapter 6, JavaBeans Component Model, and Chapter 29, Web Services. He contributed to the accessibility section of Chapter 2, reviewed Chapters 21
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2. The *Deitel & Associates, Inc. College Internship Program* offers a limited number of salaried positions to Boston-area college students majoring in Computer Science, Information Technology, Marketing, English or Technical Writing. Students work at our corporate headquarters in Sudbury, Massachusetts full-time in the summers and part-time during the academic year. Full-time positions are available to college graduates. For more information about this competitive program, please contact Abbey Deitel at **deitel@deitel.com** and check our Web site, **www.deitel.com**.

and 22, 23, 25 and Appendix I and applied technical reviews to Chapters 2, 6, 8, 14, 15 and 29.

- Audrey Lee, a Senior at Wellesley College in Computer Science and Mathematics, co-authored Chapter 16, Java Message Service and contributed to Chapters 7, 13, 18 and Appendices F and I.
- Jeffrey Hamm, a Sophomore in Computer Science at Northeastern University, co-authored Chapter 21, Appendix E and Appendix G, Java Native Interface (JNI).
- Varun Ganapathi, a Sophomore in Computer Science and Electrical Engineering at Cornell University, co-authored Chapter 28, contributed to Chapter 12 and implemented the i-mode and WML clients in the Chapter 18 case study.
- Sasha Devore, a graduate of Massachusetts Institute of Technology in Electrical Engineering and Electrical Science, 2001, co-authored Chapter 4, Graphics Programming with Java 2D and Java 3D.
- A. James O'Leary, a sophomore in Computer Science and Psychology at Rensselaer Polytechnic Institute, co-authored Chapter 7, Security.
- Susan Warren, a Junior in Computer Science at Brown University, worked on the Instructor's Manual and ancillary materials for Chapters 9 and 10.
- Eugene Izumo, a Sophomore in Computer Science at Brown University, worked on the Instructor's Manual and ancillary materials for Chapters 9 and 10.
- Vincent He, a Senior in Management and Computer Science at Boston College, worked on the Instructor's Manual for Chapter 8.
- Christina Carney, a Senior in Psychology and Business at Framingham State College helped prepare the Preface and the bibliography for several chapters.
- Amy Gips, a Sophomore in Marketing and Finance at Boston College, co-authored Appendix F, Java Community Process, and researched URLs for several chapters. Amy also researched the quotes for the entire book and helped prepare the Preface.
- Fabian Morgan (a Summer 2000 intern from MIT) wrote the initial versions of the examples for Chapters 5, 8, 14, 15 and the Enterprise Java case study in Chapters 17–20.
- Josh Gould (a Summer 2000 intern from Clark University) worked on Chapters 9 and 10.

We also would like to thank two business colleagues who contributed to the book.

- Carlos Valcarcel co-authored Chapters 26 and 27. Carlos is an independent OO/Java/CORBA architect with EinTech, Inc., in New York. Carlos has been working with Java since November 1995 and CORBA since mid-1996. His clients range from investment banks and insurance companies to software vendors. Please feel free to send questions and comments to Carlos at [carlos@eintech.com](mailto:carlos@eintech.com). Carlos would like to thank his wife Becky and daughter Lindley for their patience and understanding during the writing of these two chapters.

*"If there is a bright center to the universe, the two of you are it."*

- Kelby Zorgdrager served as a technical consultant on Chapter 22, Jini, Chapter 23, JavaSpaces, Chapter 24, JMX and Chapter 25, Jiro. He has been working with Java since its beginning stages of JDK 1.0. Over the past 5 years, Kelby has worked for Sun Microsystems as a Java Instructor where he developed course materials and presented to over 3500 students worldwide. During Kelby's last year at Sun, he worked as a Software Engineer on the development of the Jiro Technology. Kelby has spoken at internationally recognized industry conferences, including JavaOne. Currently, Kelby is working as the Director of Architecture for **eCarCredit.com**, where he uses Java to create cutting-edge technological solutions for the Auto Finance Industry. In Kelby's spare time, he provides independent consulting services, and enjoys spending time with his wife Beth, daughter Aubreigh, and Winston the St. Bernard. Kelby can be reached at **advanced\_java@zorgdrager.org**.

We also would like to thank those people who helped us obtain commercial application server software for the CD that accompanies this book and those people who helped us complete the deployment instructions for our Deitel Bookstore case study on the three most popular application servers. Our thanks to Katherine Barnhisel of BEA Systems; Sheila Richardson, John Botsford, Jason McGee and Kevin Vaughan of IBM; and Holly Sharp, Heather Sutherland, Sharada Achanta, Patrick Dorsey and Deepak Balakrishna of iPlanet.

We are fortunate to have been able to work on this project with the talented and dedicated team of publishing professionals at Prentice Hall. We especially appreciate the extraordinary efforts of our computer science editor, Petra Recter and her boss—our mentor in publishing—Marcia Horton, Editor-in-Chief of Prentice-Hall's Engineering and Computer Science Division. Vince O'Brien and Camille Trentacoste did a marvelous job handling production.

The *Advanced Java 2 Platform Multimedia Cyber Classroom* was developed in parallel with *Advanced Java 2 Platform How to Program*. We sincerely appreciate the “new media” insight, savvy and technical expertise of our e-media editor-in-chief, mentor and friend Mark Taub. He and our e-media editor, Karen McLean, did a remarkable job bringing the *Advanced Java 2 Platform Multimedia Cyber Classroom* to publication under a tight schedule. Michael Ruel did a marvelous job as Cyber Classroom project manager.

We owe special thanks to the creativity of Tamara Newnam Cavallo (**smart\_art@earthlink.net**) who did the art work for our programming tips icons and the cover. She created the delightful bug creature who shares with you the book's programming tips. Barbara Deitel contributed the bugs' names on the front cover.

We sincerely appreciate the efforts of our reviewers:

Jeff Allen (Sun Microsystems)  
Dibyendu Baksi (Sun Microsystems)  
Tim Boudreau (Sun Microsystems)  
Paul Byrne (Sun Microsystems)  
Onno Kluyt (Sun Microsystems)  
Peter Korn (Sun Microsystems)  
Petr Kozel (Sun Microsystems)  
Jon Nyquist (Sun Microsystems)  
Tomas Pavek (Sun Microsystems)

Martin Ryzl (Sun Microsystems)  
Davanum Srinivas (JNI-FAQ Manager, Sun Microsystems)  
Brandon Taylor (Sun Microsystems)

Vicki Allan (Utah State University)  
Javaid Aslam (Analyst/Application Developer, Tektronix)  
Henry Balen (CORBA author)  
Kathy Barshatzky ([Javakathy.com](#))  
Don Benish (Ben-Cam Intermedia)  
Keith Bigelow (Lutris)  
Darrin Bishop (Levi, Ray and Shoup, Inc.)  
Ron Braithwaite (Nutriware)  
Carl Burnham (Southpoint)  
John Conley (DeVry Institute)  
Charles Costarella (Antelope Valley College)  
Jonathan Earl (Technical Training Consultants)  
Jesse Glick (NetBeans)  
Ken Gilmore (Amdocs, Inc.)  
Jason Gordon (Verizon)  
Christopher Green (Colorado Springs Technical Consultants)  
Michele Guy (XOR)  
Deborah Hooker (Mnemosyne Consulting)  
Elizabeth Kallman (Los Alamos National Library)  
Salvi Karuppaswamy (EDS)  
Jodi Krochalis (Compuware)  
Anthony Levensalor (Compuware)  
Derek Lane (President of Gunslinger Software and Consulting, Inc.)  
Rick Loek (Callidus Software)  
Ashish Makhijani (Senior Analyst, Programmer)  
Paul McLachlan (Compuware)  
Randy Meyers (NetCom)  
Paul Monday (Imation)  
Steven Newton (Lead Programmer/Analyst, Standard Insurance Company)  
Victor Peters (NextStepEducation)  
Bryan Plaster (Valtech)  
Brian Pontarelli (Consultant)  
Srikanth Raju (Staff Engineer, Sun Microsystems)  
Robin Rowe ([MovieEditor.com](#))  
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Joshua Sharff (Joshua Sharff Associates)  
Dan Shellman (Software Engineer)  
Jon Siegel (OMG)  
Uma Subbiah (Unigraphics)  
Arun Taksali (jataayusoft)  
Vadim Tkachenko (Sera Nova)  
Kim Topley (Author of *Core Java Foundation Classes* and *Core Swing: Advanced Programming*, both published by Prentice Hall)  
John Varghese (University of Rochester)  
Xinju Wang (Emerald Solutions)  
Karen Wieslewski (Titan Insurance)  
Jesse Wilkins (Metalinear Media)

Under a tight time schedule, they scrutinized every aspect of the text and made countless suggestions for improving the accuracy and completeness of the presentation.

We would sincerely appreciate your comments, criticisms, corrections, and suggestions for improving the text. Please address all correspondence to:

**deitel@deitel.com**

We will respond immediately. Well, that's it for now. Welcome to the exciting world of Java programming. We hope you enjoy this look at leading-edge computer applications development. Good luck!

*Dr. Harvey M. Deitel*

*Paul J. Deitel*

*Sean E. Santry*

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**Dr. Harvey M. Deitel**, CEO of Deitel & Associates, Inc., has 40 years experience in the computing field including extensive industry and academic experience. He is one of the world's leading computer science instructors and seminar presenters. Dr. Deitel earned B.S. and M.S. degrees from the Massachusetts Institute of Technology and a Ph.D. from Boston University. He has 20 years of college teaching experience including earning tenure and serving as the Chairman of the Computer Science Department at Boston College before founding Deitel & Associates, Inc. with his son Paul J. Deitel. He is author or co-author of dozens of books and multimedia packages and is currently writing many more. With translations published in Japanese, Russian, Spanish, Italian, Basic Chinese, Traditional Chinese, Korean, French, Polish and Portuguese, the Deitel's texts have earned international recognition. Dr. Deitel has delivered professional seminars internationally to major corporations, government organizations and various branches of the military.

**Paul J. Deitel**, Chief Technical Officer of Deitel & Associates, Inc., is a graduate of the Massachusetts Institute of Technology's Sloan School of Management where he studied Information Technology. Through Deitel & Associates, Inc. he has delivered Internet and World Wide Web courses and programming language classes for industry clients including Sun Microsystems, EMC<sup>2</sup>, IBM, BEA Systems, Visa International, Progress Software, Boeing, Fidelity, Hitachi, Cap Gemini, Compaq, Art Technology, White Sands Missile Range, NASA at the Kennedy Space Center, the National Severe Storm Laboratory, Rogue Wave Software, Lucent Technologies, Computervision, Cambridge Technology Partners, Adra Systems, Entergy, CableData Systems, Banyan, Stratus, Concord Communications and many other organizations. He has lectured on Java and C++ for the Boston Chapter of the Association for Computing Machinery, and has taught satellite-based courses through a cooperative venture of Deitel & Associates, Inc., Prentice Hall and the Technology Education Network. He and his father, Dr. Harvey M. Deitel, are the world's best-selling Computer Science textbook authors.

**Sean E. Santry**, Director of Software Development with Deitel & Associates, Inc., is a graduate of Boston College where he studied computer science and philosophy. At Boston College he performed original research on the application of metaphysical systems to object-oriented software design. Through Deitel & Associates, Inc. he has delivered advanced and introductory courses for industry clients including Sun Microsystems,

EMC<sup>2</sup>, Dell, Compaq, Boeing and others. He has contributed to several Deitel publications, including *Java How to Program, Fourth Edition*; *XML How to Program*; *C++ How to Program, Third Edition*; *C How to Program, Third Edition*; *e-Business and e-Commerce How to Program* and *e-Business and e-Commerce for Managers*. Before joining Deitel & Associates, he developed e-business applications with a leading Boston-area consulting firm.

## About Deitel & Associates, Inc.

Deitel & Associates, Inc. is an internationally recognized corporate training and content-creation organization specializing in Internet/World Wide Web software technology, e-business/e-commerce software technology and computer programming languages education. Deitel & Associates, Inc. is a member of the World Wide Web Consortium. The company provides courses on Internet and World Wide Web programming, object technology and major programming languages. The founders of Deitel & Associates, Inc. are Dr. Harvey M. Deitel and Paul J. Deitel. The company's clients include many of the world's largest computer companies, government agencies, branches of the military and business organizations. Through its publishing partnership with Prentice Hall, Deitel & Associates, Inc. publishes leading-edge programming textbooks, professional books, interactive CD-ROM-based multimedia *Cyber Classrooms*, *Complete Training Courses* and Web-based training courses. Deitel & Associates, Inc. and the authors can be reached via e-mail at

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To learn more about Deitel & Associates, Inc., its publications and its worldwide corporate on-site curriculum, see the last few pages of this book and visit:

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Bulk orders by corporations and academic institutions should be placed directly with Prentice Hall. See the last few pages of this book for worldwide ordering details.

## The World Wide Web Consortium (W3C)

 Deitel & Associates, Inc. is a member of the *World Wide Web Consortium (W3C)*. The W3C was founded in 1994 “to develop common protocols for the evolution of the World Wide Web.” As a W3C member, we hold a seat on the W3C Advisory Committee (our Advisory Committee representative is our Chief Technology Officer, Paul Deitel). Advisory Committee members help provide “strategic direction” to the W3C through meetings around the world. Member organizations also help develop standards recommendations for Web technologies (such as HTML, XML and many others) through participation in W3C activities and groups. Membership in the W3C is intended for companies and large organizations. For information on becoming a member of the W3C visit [www.w3.org/Consortium/Prospectus/Joining](http://www.w3.org/Consortium/Prospectus/Joining).

# 1

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# Introduction

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## Objectives

- To understand the organization of the book.
- To understand various setup issues in deploying the book's examples.
- To understand the elements of design patterns and how they are used throughout the book.
- To tour the book.

*Before beginning, plan carefully.*

Marcus Tullius Cicero

*Things are always at their best in the beginning*

Blaise Pascal

*High thoughts must have high language.*

Aristophanes

*Our life is frittered away be detail ... Simplify, simplify*

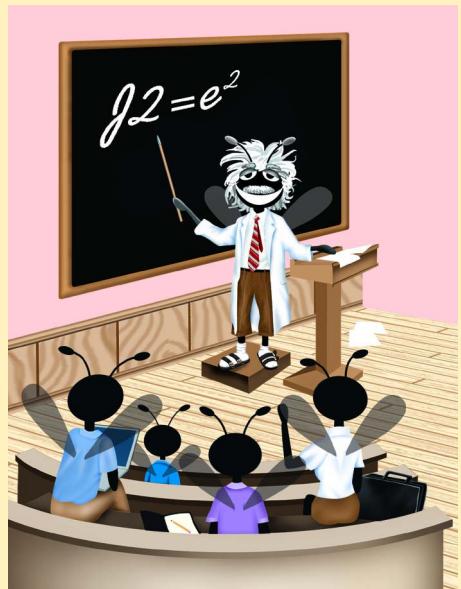
Henry Thoreau

*Look with favor upon a bold beginning.*

Virgil

*I think I'm beginning to learn something about it.*

Auguste Renoir



## Outline

- 1.1 Introduction**
- 1.2 Architecture of the Book**
  - 1.2.1 Advanced GUI, Graphics and JavaBeans**
  - 1.2.2 Distributed Systems**
  - 1.2.3 Web Services**
  - 1.2.4 Enterprise Java**
  - 1.2.5 Enterprise Case Study**
  - 1.2.6 XML**
- 1.3 Tour of the Book**
- 1.4 Running Example Code**
- 1.5 Design Patterns**
  - 1.5.1 History of Object-Oriented Design Patterns**
  - 1.5.2 Design Patterns Discussion**
  - 1.5.3 Concurrency Patterns**
  - 1.5.4 Architectural Patterns**
  - 1.5.5 Further Study on Design Patterns**

*Works Cited • Bibliography*

## 1.1 Introduction

Welcome to the world of advanced Java 2 Platform programming! We have worked hard to create what we hope will be an informative, entertaining and challenging learning experience for you.

The Java technologies you will learn are intended for developers and software engineers. *Advanced Java 2 Platform How to Program* presumes knowledge of either *Java How to Program: Fourth Edition* (ISBN: 0-13-034151-7) or *The Complete Java Training Course, Fourth Edition* (ISBN: 0-13-064931-7), which teach the fundamentals of Java and object-oriented programming. *Advanced Java 2 Platform How to Program* presents many advanced Java topics and introduces many new topics, using almost 40,000 lines of complete, working code and numerous illustrations to demonstrate the concepts. We integrate these technologies into substantial applications and enterprise systems that demonstrate how the pieces fit together. We call this our *Live-Code™ approach*.

We introduce technologies from the three Java editions—*Java 2 Standard Edition (J2SE)*, *Java 2 Enterprise Edition (J2EE)* and *Java 2 Micro Edition (J2ME)*. The beginning chapters of this book demonstrate several high-end concepts from J2SE (*Java How to Program, Fourth Edition* presents J2SE through the intermediate level). *Advanced Java 2 Platform How to Program* highlights many advanced features of J2EE, providing enterprise applications as examples. Finally, we introduce the exciting, leading-edge technologies of J2ME and wireless applications programming.

Object-oriented programming and design patterns are essential for building applications using the many technologies introduced in this book. These tools encourage modularity, allowing programmers to design classes and programs effectively. Design patterns in particular have proven critical to producing the substantial programs we present in this book.

Many of the book's applications integrate the *Extensible Markup Language (XML)*, the standard for creating markup languages that describe structured data in a platform-independent manner. Everything from common Web pages to complex order-tracking and *business-to-business (B2B)* systems can use XML. XML's data portability complements the portability of programs built for the Java 2 Platform. XML's capabilities for describing data enable systems built with disparate technologies to share data without concerns for binary compatibility, which is key to developing interoperable distributed systems in Java. We assume knowledge of XML and Java's XML APIs. However, Appendices A–D also provide an introduction to XML and Java's XML APIs for those of you who are not yet familiar with these topics. It is highly recommended that you read these appendices first, if you are not already familiar with XML.

As you read this book, you may want to refer to our Web site [www.deitel.com](http://www.deitel.com) for updates and additional information on the cutting-edge technologies you will be learning.

## 1.2 Architecture of the Book

There are several broad technology categories that comprise *Advanced Java 2 Platform How to Program*. Many of these technologies are inter-related. We begin with a discussion of these categories and an overview of the architecture of the book. The chapters can be grouped into several advanced topics—advanced GUI and graphics, distributed systems, Web services, Enterprise Java and XML technologies.

### 1.2.1 Advanced GUI, Graphics and JavaBeans

#### *Chapters 2–6*

Graphical user interfaces help users interact effectively and efficiently with applications. When creating substantial client applications, it is important to create simple and attractive user interfaces that enable users to work with your application in an intuitive and convenient manner. Java's Swing API provides graphical user interface components common to many windowed applications and platforms. *Java How to Program, Fourth Edition* provides an introduction to GUI concepts with Swing. In Chapter 2 of *Advanced Java 2 Platform How to Program*, we introduce several more advanced Swing components and use them to create substantial applications such as a Web browser with a multiple-document interface. We also introduce Java's capabilities for building applications for global deployment (through *internationalization*) and for building accessible applications for people with disabilities (using the *Accessibility* APIs).

A fundamental theme in *Advanced Java 2 Platform How to Program* is the importance of design patterns for building object-oriented systems. We use several design patterns when building the programming examples in this book. This chapter (Section 1.5) introduces design patterns, discusses why they are important and lists by chapter those design patterns we use in the book. Chapter 3 introduces the *Model-View-Controller (MVC)* archi-

tecture, which is based on several design patterns. This widely applicable architecture separates the presentation of data (e.g., a bar-chart showing bank-account information) from the underlying data representation (e.g., tables in a database) and the control logic for those data (e.g., event handlers for buttons and text fields in a user interface). In Chapter 3, we discuss the MVC architecture and its implementation in the Swing API. In later chapters, we revisit the MVC architecture and use it to build substantial Enterprise Java applications.

In Chapter 4, we present Java’s support for graphics. Java provides the Java 2D™ API for creating two-dimensional graphics and the Java 3D™ API for creating three-dimensional, virtual worlds. We introduce and demonstrate these APIs and provide examples including a three-dimensional game.

Chapter 5 contains a substantial case study—a Java 2D drawing application with design patterns—in which we present a complex drawing program as a capstone for the advanced GUI portion of the book. Using MVC and several other design patterns, and the capabilities of Java’s Swing components and Java 2D, our drawing application provides several types of shapes, various colors, gradients, image capabilities and more. Users can choose multiple views for a drawing, including a zoomed detail view.

The *JavaBeans component model* enables developers to “componentize” their applications, making those applications more flexible and the application components more reusable. We introduce JavaBeans (often called simply *beans*) in the context of an animation application in Chapter 6. JavaBeans allow programmers to create components for building applications; programmers called *component assemblers* then can assemble these components, along with existing components, to create applications, applets or even new beans. In fact, most of the GUI components presented in earlier chapters are JavaBeans.

## 1.2.2 Distributed Systems

### *Chapters 13, 22–28*

When creating substantial applications, often it is more efficient, or even necessary, for concurrent tasks to be performed on different computers. Distributed systems technologies enable applications to execute across several computers on a network. For a distributed system to function correctly, application components executing on different computers throughout a network must be able to communicate with one another. *Advanced Java 2 Platform How to Program* presents several technologies for building distributed systems.

Chapter 13 introduces Remote Method Invocation (RMI), which allows Java objects located on different computers or executing in different virtual machines to interact as if they were on the same computer or in the same virtual machine. Each object invokes methods on the other objects and RMI handles the *marshalling* (i.e., collecting and packaging) of arguments and return values passed between *remote objects*. We present several RMI examples, including a distributed chat application.

Java also provides higher-level APIs for building distributed systems, including Jini and JavaSpaces. Jini (Chapter 22) enables devices or software programs on a LAN to interoperate without the need to install special device drivers, and with reduced administrative overhead. Jini provides true “plug-and-play” support for devices—just plug a printer into a network and that printer’s services become available to everyone on that network. JavaSpaces is a Jini service that provides a simple but powerful API for building distributed systems. We demonstrate JavaSpaces technology by building a distributed image processing application.

As networks grow in complexity and as companies depend on those networks more heavily for conducting business, network management grows in importance. The Java Management Extensions (JMX, Chapter 24) and Jiro (Chapter 25) are two complementary technologies for building distributed network management applications in Java.

In Chapters 26–27, we introduce *CORBA*—the *Common Object Request Broker Architecture*. CORBA allows programs written in various languages, with varying implementations running in disparate locations, to communicate with each other as easily as if they were in the same process address space. In these chapters, we introduce the fundamentals of CORBA and compare CORBA with other distributed-systems technologies, such as RMI. We also introduce *RMI-IIOP*, which enables RMI to interoperate with CORBA.

In Chapter 28, we discuss fundamental concepts of peer-to-peer (P2P) applications, where each application performs both client and server functions, thus distributing processing and information across many computers. We present two different implementations of a P2P instant-messaging application. The first implementation uses Jini technology and the second uses multicast sockets and RMI.

### 1.2.3 Web Services

#### *Chapters 9–12, 29*

The popularity of the Web and its importance for conducting business have exploded in recent years. The field of *Web services* is concerned with building services that enable information sharing, commerce and other interactions between businesses, between businesses and consumers, etc., using standard Web protocols. Web services have come about through an evolution of existing Web technologies, such as HTML forms, and enterprise technologies, such as messaging and Electronic Document Interchange (EDI) systems. Web services rely upon existing protocols and standards.

Chapter 9 introduces *servlets*. Servlets can generate documents dynamically (e.g., XHTML documents) to send to clients in response to requests for information. Chapter 10 introduces *Java Server Pages (JSP)*, which also deliver dynamic content to clients. JSPs dynamically serve Web content by using *scriptlets* and JavaBeans components in the context of a document. These documents are translated into servlets by the *JSP container*—i.e., the server application responsible for handling requests for JSPs. Chapter 11 presents a case study that serves as a capstone to the technology presented in Chapters 9 and 10. The case study integrates JavaBeans, servlets, JSPs, XML and XSLT to create an online bookstore.

Several new technologies, such as the *Wireless Application Protocol (WAP)*, *Wireless Markup Language (WML)*, *i-mode* and Java 2 Micro Edition (J2ME) have emerged for use with wireless devices. Chapter 12 introduces these wireless technologies, and uses them to construct a three-tier application that uses servlets and XML to deliver content to several wireless devices.

Chapter 29 introduces *Web services*—applications that expose public interfaces usable by other applications over the Web. Web services are accessible through HTTP and other Web protocols, and communicate with XML-based messages. Directory services enable clients to perform lookups to discover available Web services. The *Simple Object Access Protocol (SOAP)* uses XML to provide communication in many Web services. SOAP allows applications to make remote procedure calls to a Web service’s public methods. In this chapter, we implement a weather service that provides local forecasts from the National Weather Service, using SOAP.

## 1.2.4 Enterprise Java

### *Chapters 7, 8, 14–16, 21*

Java has become enormously popular for building enterprise applications. Sun originally conceived of Java as a programming language for building small programs embedded in Web pages; since its inception, Java has grown into an industrial strength, enterprise-development language. At the 2001 JavaOne conference, Sun Microsystems announced that over 96% of enterprise application servers support the Java 2 Enterprise Edition.

Security is a primary concern for Java applications of all types, including enterprise applications. In Chapter 7 we introduce the fundamentals of security, including cryptography, digital signatures, authentication, authorization and public-key infrastructure. We also introduce Java’s *sandbox security model*, the *Java Cryptography Extensions (JCE)*, the *Java Secure Sockets Extensions (JSSE)* and the *Java Authentication and Authorization Services (JAAS)*.

An integral part of powerful software applications is the storage, retrieval and display of data. Substantial amounts of data are organized and stored in databases. Programmers often need to interact with databases to update or retrieve information. Chapter 8 introduces Java Database Connectivity (JDBC) for manipulating databases. We present examples that interact with the Cloudscape database management system from Informix Software. Cloudscape is available for download at [www.cloudscape.com](http://www.cloudscape.com).

Business logic forms the core functionality of an enterprise application. Business logic is responsible for implementing the complex business rules that businesses require for transaction and information processing. In Chapter 14, we introduce the *Enterprise Java-Bean (EJB)* component model for building enterprise application business logic. In particular, we discuss *session EJBs* for business logic, and *distributed transactions*, which enable EJBs to work across multiple databases and still maintain data integrity. In Chapter 15, we present *entity EJBs*, which enable developers to build an object-based layer for accessing information in long-term storage, such as a database.

Enterprise applications require extensive services and support at runtime for accessing databases, enabling distributed transactions, maintaining performance, etc. Application servers provide a rich runtime environment for enterprise application components. In Chapter 21, we introduce the three most popular commercial application servers—BEA’s WebLogic, IBM’s WebSphere and the iPlanet Application Server. We also provide complete instructions for deploying an enterprise-application case study on BEA’s WebLogic and IBM’s WebSphere.

## 1.2.5 Enterprise Case Study

### *Chapters 17–20*

Chapters 17–20 present a capstone application for the Enterprise Java topics presented in *Advanced Java 2 Platform How to Program*—an Enterprise Java case study that integrates many Java technologies into a substantial 10,000 lines of code online bookstore application. In this case study, we build the Deitel Bookstore enterprise application using Enterprise JavaBeans with container-managed persistence, servlets, RMI-IIOP, XML, XSLT, XHTML, WML and cHTML. A fundamental feature of this example is that the bookstore uses XML and XSLT to provide support for virtually any type of client, including standard

Web browsers and mobile devices, such as cell phones. The modular, extensible architecture enables developers to implement support for additional client types simply by providing appropriate XSLT documents that translate XML documents into content appropriate for those client types. The Deitel Bookstore case study also demonstrates the Model-View-Controller (MVC) architecture in the context of an Enterprise Java application.

## 1.2.6 XML

### Appendices A–D

Many examples throughout *Advanced Java 2 Platform How to Program* use XML. As a platform-independent language for creating markup languages, XML integrates well with Java applications. Unlike HTML, with which Web designers use to format information for display, XML provides structure and semantics for application data, but it does not format data. Developers can create XML grammars that define the structure for data and make those data interoperable with other applications. The *Java API for XML parsing (JAXP)* provides the Java 2 Platform with a common API for manipulating XML parsers and XML data across platforms. The *Document Object Model, Level 2 API (DOM)* is backed by the World Wide Web Consortium (W3C) as a standard API for building and manipulating XML documents. Using this API, developers can leverage the cross-platform capabilities of Java and XML to build powerful distributed systems.

We introduce the basics of XML in Appendix A, Creating XML Markup. Appendix B introduces Document Type Definitions (DTDs) for defining standard document structures against which XML parsers can validate XML documents. DTDs are crucial for building XML documents that interoperate across many applications. Appendix C introduces the Document Object Model (DOM) API and its use in the Java API for XML Processing (JAXP). Appendix D introduces Extensible Stylesheet Language Transformations (XSLT), which is an XML grammar for transforming XML documents into other XML documents. We use XSLT in several examples to transform raw XML data into appropriate markup for Web clients, such as standard Web browsers and cell phones.

## 1.3 Tour of the Book

In this section, we include walkthroughs of each chapter and outline the many Java technologies discussed in *Advanced Java 2 Platform How to Program*. There will be terms in these sections that are unfamiliar to you—they will be defined in the chapters of the book. Many chapters end with an Internet and World Wide Web Resources section that provides a listing of Web sites you should visit to enhance your knowledge of the technologies discussed in that chapter. You may also want to visit the Web sites [www.deitel.com](http://www.deitel.com) and [www.prenhall.com/deitel](http://www.prenhall.com/deitel) to keep informed of the latest information, book errata and additional teaching and learning resources.

### Chapter 1—Introduction

This chapter overviews the technologies presented in *Advanced Java 2 Platform How to Program* and introduces the architecture of the book—advanced GUI and graphics, distributed systems, Web services, Enterprise Java and XML technologies. We include a tour of the book with a brief overview of each chapter. We provide installation, and execution in-

structions for the examples in this book. We also discuss design patterns and how we use them to architect our examples.

### ***Chapter 2—Advanced Swing Graphical User Interface Components***

Advanced Swing components enable developers to build functionally rich user interfaces. The Swing graphical user interface components were introduced with the Java Foundation Classes (JFC) as a downloadable extension to Java 1.1 and became standard in the Java 2 Platform. Swing provides a much richer set of GUI components than Java's original Abstract Windowing Toolkit (AWT), including advanced features such as a pluggable look-and-feel, lightweight component rendering and an enriched component set. This chapter introduces Swing components with which you can enrich your application GUIs.

Many of the examples in this chapter use the **JEditorPane** class extensively, which is capable of rendering styled content, such as HTML pages. We also present the first of our inline design patterns discussions. Swing **Actions** implement the Command design pattern to build reusable user interface logic. We also introduce useful Swing components such as **JSplitPane**, **JTabbedPane** and multiple-document-interface components for organizing GUI elements. Swing provides mechanisms for building applications for multiple languages and countries, and for disabled users. Building internationalized applications ensures that applications will be ready for use around the world in many languages. Accessibility ensures that users with disabilities will be able to use applications through commonly available utilities, such as screen readers. We show how developers can use Swing to build Java applications that are accessible to users in other countries and users with disabilities.

### ***Chapter 3—Model-View-Controller***

Advanced Swing components, including the **JTree** and **JTable** components enable developers to build flexible, data-driven graphical user interfaces in Java. The *Model-View-Controller (MVC)* architecture abstracts the GUI (the *view*) from the underlying data (the *model*). A *controller* determines how the application handles user interactions, such as mouse and keyboard events. The Swing components implement a variation of the MVC architecture that combines the view and controller to form a *delegate*. For example, a **JTree** is a delegate (i.e., combined view and controller) for its **TreeModel** (the model). The **TreeModel** contains the raw data to be presented in, and modified by, the **JTree**. The **JTree** provides a visual representation of the data and processes user interactions, such as renaming nodes in the tree. The benefit of this architecture is that each component can change without requiring changes in the other components. Furthermore, several delegates, views and controllers may be associated with a single model. MVC has many uses in desktop applications, enterprise applications, simulations and other types of programs. In this chapter, we discuss MVC in general and its variant, the *delegate-model architecture*. We also introduce the Observer design pattern, which is one part of the MVC architecture. After reading this chapter, you will be able to take advantage of advanced Swing components that use the delegate-model architecture, such as **JList**, **JTable** and **JTree**.

### ***Chapter 4—Graphics Programming with Java 2D™ and Java 3D™***

The graphical features provided by the Java 2D API and the graphical user interface enhancements available in the Swing GUI components provide many tools for developing rich graphical content by incorporating line art, text and imaging in a single graphics model.

Developers can use these tools to build custom graphics and images as well as visual representations of data. The Java 2D API also provides advanced capabilities for text layout and manipulation. Imaging technology in the Java 2D API allows for manipulation of fixed resolution images, and includes filters for blurring and sharpening images as well as other image-processing tools. The Java 2D API also provides support for delivering graphical content to different devices by defining a logical coordinate system that is translated appropriately for a given output device such as a printer or monitor. We also introduce the Java 3D API for developing three-dimensional, virtual worlds in Java. The Java 3D API provides technologies for manipulating 3D objects. For example, the programmer can rotate, scale and translate 3D objects. Other advanced features include applying textures to 3D objects using texture mapping and varying the lighting effects on 3D objects by changing the colors and positions of light sources. We implement an application that allows the user to manipulate a 3D object with the mouse. We then present a substantial 3D game in which the user navigates a shape through a 3D scene full of “flying” obstacles. The goal of the game is to move this shape to a specific target point without colliding with any of the moving obstacles.

### ***Chapter 5—Case Study: Java 2D Drawing Application with Design Patterns***

The case study in this chapter implements a substantial Java application that integrates the many Java features and techniques presented in Chapters 2–4. We present a graphics application case study that uses the GUI capabilities of Chapters 2 and 3 and the two-dimensional graphics capabilities of Chapter 4, as well as the flexible capabilities of XML. The case study emphasizes the Model-View-Controller architecture (Chapter 3) to provide multiple views of a single drawing such as a detail view and a complete view. A multiple document interface (Chapter 2) allows users to modify multiple drawings in parallel. Swing Actions (Chapter 2) provide reusable user-interaction logic for menu and toolbar functionality. The case study also uses the Drag-and-Drop API to enable users to move shapes between drawings and to drop JPEG images onto a drawing from the local file system. We use several design patterns including the Factory Method, Adapter State and Template Method design patterns.

### ***Chapter 6—JavaBeans Component Model***

In this chapter, we take a deeper look into developing Java components based on the *JavaBeans component architecture*. JavaBeans (*beans*) allow developers to reap the benefits of rapid application development in Java by assembling predefined software components to create powerful applications and applets. *Graphical programming and design environments* (often called *builder tools*) that support beans provide programmers with tremendous flexibility by allowing programmers to reuse existing components. A programmer can integrate these components to create applets, applications or even new beans for reuse by others. JavaBeans and other component-based technologies have led to a new type of programmer—the *component assembler*, who uses pre-built components to create richer functionality. Component assemblers do not need to know the implementation details of components, but they need to know what services the components provide. Component assemblers can make beans communicate through the beans’ well-defined services (i.e., methods), typically without writing any code (the builder tool often generates code, which is sometimes hidden from the component assembler—depending on the tool). Indeed, a component assembler can create complex applications simply by “connecting the dots.”

This chapter shows you how to use existing beans and how to create new beans. After studying this chapter, you will have a foundation in JavaBeans programming that will enable you to develop applications and applets rapidly using the more advanced features of integrated development environments that support beans.

### **Chapter 7—Security**

Security is a primary concern in the development of software systems. This chapter discusses the issues associated with security and introduces Java technologies to that ensure successful, secure transactions. Among these technologies is the *Java Cryptography Extension (JCE)*, which supports *secret-key encryption* and *digital signatures*. The *Java Secure Socket Extension (JSSE)* supports the *Secure Sockets Layer (SSL)* protocol—one of the most widely used tools for securing Internet communications. JSSE provides encryption, message integrity checks and authentication of servers and clients. Java also provides the *Java Authentication and Authorization Service (JAAS)* for authenticating users and granting permissions. The basis for Java security is the *sandbox security model* in which applets and applications execute. The sandbox is a protected environment that prevents Java programs from accessing protected resources. The program must be granted specific permissions to access system resources, such as the files on a user’s computer and servers on the Internet. Permissions may be granted through *policy files*.

### **Chapter 8—Java Database Connectivity (JDBC)**

Access and storage of data are integral to creating powerful software applications. This chapter discusses Java’s support of database manipulation. Today’s most popular database systems are *relational databases*. We present examples using *Cloudscape 3.6.4*—a pure-Java database management system from Informix Software. Cloudscape is available free for download (for learning and development purposes) at [www.cloudscape.com](http://www.cloudscape.com) and is on the CD that accompanies this book. Java programmers communicate with databases and manipulate their data using the *Java Database Connectivity (JDBC) API*. A *JDBC driver* implements the interface to a particular database. This chapter introduces JDBC and uses it to connect to a Cloudscape database, then to manipulate its content. We use the *Structured Query Language (SQL)* to extract information from, and insert information into, a database. We then use JDBC and SQL to create an address-book application that stores, updates and deletes addresses. Several later chapters use the techniques shown in this chapter to build data-driven Web and enterprise applications.

### **Chapter 9—Servlets**

Servlets extend the functionality of servers—typically Web servers. Servlets are effective for developing Web-based solutions that interact with databases on behalf of clients, dynamically generate custom content to be displayed by browsers, and maintain unique session information for each client. Many developers feel that servlets are the right solution for database-intensive applications that communicate with so-called *thin clients*—applications that require minimal client-side processing capability. Clients connect to the server using standard protocols, such as *HyperText Transfer Protocol (HTTP)*, available on most client platforms through Web browsers (and other applications). Thus, the application logic can be written once and reside on the server for access by clients. The *Java Servlet API* allows developers to add functionality to Web servers for handling client requests. Unlike the *Common Gateway Interface (CGI)*, in which a separate process may be started

for each client request, servlets typically are threads in a single JVM process. Servlets also are reusable across Web servers and across platforms. This chapter demonstrates the Web's request/response mechanism (primarily with HTTP **get** and **post** requests), session-tracking capabilities, redirecting requests to other resources and interacting with databases through JDBC.

### **Chapter 10—Java Server Pages (JSP)**

This chapter introduces an extension of servlet technology called *Java Server Pages (JSP)*. JSPs enable delivery of dynamically generated Web content and are used primarily for developing presentation logic in Enterprise Java applications. JSPs may contain Java code in the form of *scriptlets* and may also use JavaBeans components. *Custom tag libraries* enable Web-page designers unfamiliar with Java to enhance Web pages with powerful dynamic content and processing capabilities created by Java developers. To increase performance, each JSP is compiled into a Java Servlet—this normally occurs the first time each JSP is requested by a client. Subsequent client requests are fulfilled by the compiled servlet.

### **Chapter 11—Case Study: Servlets and JSP Bookstore**

This chapter is a capstone for our presentation of JSPs and servlets. Here, we implement a bookstore Web application that integrates JDBC, XML, JSP and servlet technologies. We discuss additional servlet features as they are encountered in the case study. This chapter deploys the bookstore application on the J2EE 1.2.1 reference implementation application server software. The J2EE 1.2.1 reference implementation includes the Apache Tomcat JSP and servlet container. After reading this chapter, you will be able to implement a substantial distributed Web application with many components, and you will be able to deploy that application on the J2EE 1.2.1 application server.

### **Chapter 12—Java-Based Wireless Applications Development and J2ME**

One topic of particular interest in e-business and e-commerce applications is wireless Internet technology. Wireless technology turns e-business into *m-business*, or *mobile business*. It allows you to connect to the Internet any time from almost any place. You can use it to conduct online transactions, make purchases, trade stocks and send e-mail. New technologies already enable the wireless office, where computers, phones and other office equipment are networked without cables. This chapter introduces some of the more popular wireless technologies, including WAP, i-mode and the *Java 2 Platform Micro Edition™ (J2ME)*. J2ME brings Java technology to embedded devices and consumer devices that have limited processing power and memory. J2ME includes specialized APIs for many consumer devices, including cellular phones, smart cards, Internet appliances and PDAs (personal digital assistants), such as Palm™ and PocketPC. The *K Virtual Machine*—a trimmed-down version of the Java virtual machine for consumer devices—provides the essential features for executing Java code on these devices. Using servlets and XML, we present a case study of a three-tier application that sends a game for several wireless device types.

### **Chapter 13—Remote Method Invocation (RMI)**

This chapter introduces *Remote Method Invocation (RMI)*—a technology for building *distributed systems* in Java. Using RMI, Java objects can be located on computers across a network, yet still interact as if they resided on a single computer. Java objects can perform *lookups* to find remote objects on the network and invoke methods across a *local area net-*

*work (LAN)* or even the Internet. RMI allows Java-object-to-Java-object distributed communication. Once a Java object registers as being remotely accessible (i.e., it is a *remote object*), a client can “look up” that Java object and obtain a reference that allows the client to use that object remotely. The method call syntax is identical to the syntax for calling methods of other objects in the same program. RMI handles the marshalling (i.e., collecting and packaging) of data across the network; RMI also enables Java programs to transfer complete Java objects using Java’s object-serialization mechanism. The programmer need not be concerned with the details of transmitting data over the network.

### **Chapter 14—Session Enterprise JavaBeans (EJBs) and Distributed Transactions**

*Enterprise JavaBeans (EJBs)* enable Java developers to build robust *multi-tier applications*. In a multi-tier application the responsibilities of providing services to a *client* can be divided among multiple servers. A typical *two-tier* application consists of the *client-tier* and the *server-tier*. A *three-tier* architecture often makes use of an *application server* as a middle-tier between the *client Web browser* and a *database server*. Enterprise JavaBeans provide a framework for building middle-tier business-logic implementations. Using RMI and *EJB Containers*, Enterprise JavaBeans also allow for business logic to be distributed across a network. We introduce *Enterprise JavaBeans (EJBs)*, which provide a component model for building business logic in enterprise Java applications. We discuss *session EJBs* in their two forms: *stateful* and *stateless*. We demonstrate how to develop both stateless and stateful session EJBs. We also introduce EJB support for *distributed transactions*, which help to ensure data integrity across databases and across application servers. We show how to build EJBs that take advantage of J2EE’s distributed transaction support to update data across multiple databases atomically.

### **Chapter 15—Entity Enterprise JavaBeans (EJBs)**

This chapter continues our discussion of Enterprise JavaBeans with an introduction to *entity Enterprise JavaBeans*. Unlike session EJBs, entity EJBs store data in long-term storage, such as in a database. Entity EJBs provide an object-oriented representation of persistent data, such as data stored in an RDBMS or legacy application. Entity EJBs can be used to build powerful and flexible data applications. There are two types of entity EJBs—those that use *bean-managed persistence* and those that use *container-managed persistence*. Entity EJBs that use bean-managed persistence implement code for storing and retrieving data from the persistent data sources they represent. For example, an entity EJB that uses bean-managed persistence might use the JDBC API to store and retrieve data in a relational database. Entity EJBs that use container-managed persistence rely on the EJB container to implement the data-access calls to their persistent data sources. The developer must supply information about the persistent data source when deploying the EJB. This chapter provides a demonstration of both types of entity EJBs.

### **Chapter 16—Java Message Service (JMS)**

The *Java Message Service (JMS)* provides an API for integrating enterprise Java applications with *message-oriented middleware (MOM)* systems. Message-oriented middleware enables applications to communicate by sending messages to one another. Message-oriented middleware is a popular technology for building loosely coupled applications. This chapter introduces the two basic messaging system models—*point-to-point* and *publish/subscribe*. We demonstrate Java’s interfaces for both of these models. We also provide an introduction to *message-driven EJBs*—a new feature of J2EE version 1.3.

### **Chapter 17—E-Business Case Study: Architectural Overview**

The technologies that comprise the Java 2 Enterprise Edition (J2EE) enable developers to build robust, scalable enterprise applications. In this case study, we build an e-business application using several features of J2EE, including servlets, Enterprise JavaBeans, XML and XSLT. We also integrate wireless technology, including WAP/WML and i-mode/cHTML. In this chapter, we present an overview of the Deitel Bookstore case study architecture, which uses the MVC design pattern in an enterprise application context. In the following chapters, we present the controller logic implementation with servlets (Chapter 18) and the business logic and data abstraction implementation with EJBs (Chapters 19 and 20).

### **Chapter 18—E-Business Case Study: Presentation and Controller Logic**

This chapter presents the implementation of the controller and presentation logic for the Deitel Bookstore case study. *Controller logic* in an application is responsible for handling user requests. The Java servlets in the Deitel Bookstore implement the controller logic for the application. Every user request is handled by a servlet that takes the appropriate action, based on the request type (e.g., a request to view the store catalog) and presents content to the client. We use XSLT transformations to implement the *presentation logic* for the application—the view in MVC. After invoking business-logic methods to process a client request, the servlets generate XML documents that contain content to be presented to the client. These XML documents are not specific to any particular type of client (e.g., Web browser, cell phone, etc.); they simply describe the data supplied by the business logic. An XSL transformation is applied to the XML documents to present the information to the user in the appropriate format. For example, an XSL transformation might generate an XHTML document to present to a Web browser, or a WML document to present to a WAP browser. XSL transformations are needed for each type of client the application supports. We could enable the application to support other types of clients simply by implementing additional sets of style sheets and editing a configuration file.

### **Chapter 19—E-Business Case Study: Business Logic Part I**

In this chapter, we present the EJB business logic for the shopping-cart e-business model and entity EJBs for maintaining product inventory of the Deitel Bookstore case study. The primary goal of an on-line store application is to enable customers to purchase products. EJB business logic implements the business rules that govern this process. We implement the business logic for managing the set of products a customer wishes to purchase as a **ShoppingCart** EJB. The **ShoppingCart** EJB enforces business rules that define how products are added to the shopping cart, how shopping carts are created and how customers complete their purchases. We also present entity EJBs that represent on-line store products and orders. After reading this chapter, you will understand the use of EJBs in an e-business application context, as well as more advanced EJB topics, such as custom primary-key classes and many-to-many relationships.

### **Chapter 20—Enterprise Java Case Study: Business Logic Part 2**

In this chapter we present the business logic for managing customers in our Deitel Bookstore case study. Maintaining information about the customers of an online store can make purchases more convenient by storing billing and shipping information on the server. The online store's marketing department may also use gathered data for distribution of marketing materials and analyzing demographic information. We also present an entity EJB that

generates unique IDs for the Customer, Order and Address EJBs. Instances of these EJBs are created when new customer's register and when customer's place new orders. Relational databases require unique primary keys to maintain referential integrity and perform queries. We provide the **SequenceFactory** EJB to generate these unique IDs because not all databases can generate these primary-key values automatically.

### **Chapter 21—Application Servers**

This chapter introduces several commercial *application servers*—an application server is software that integrates server-side logic components to allow communication between components and tiers of a software architecture. Application servers also manage the persistence, life cycles, security and various other services for logic components. We discuss the concepts behind application servers and introduce three popular commercial application servers, including BEA's WebLogic, IBM's WebSphere and the iPlanet Application Server. We present a detailed walkthrough of deploying the Deitel Bookstore application on BEA's WebLogic and IBM's WebSphere, both of which we include on the CD-ROM that accompanies this book. As we went to publication, iPlanet was about to release a new version of their application server. Please visit [www.iplanet.com/ias\\_deitel](http://www.iplanet.com/ias_deitel) to download the latest version. We also will provide complete deployment instructions for the Deitel Bookstore case study on iPlanet at our Web site, [www.deitel.com](http://www.deitel.com).

### **Chapter 22—Jini**

Jini Technology is an advanced set of network protocols, programming models and services that enable true plug-and-play interactions between networked Jini-enabled devices and software components. Jini technology allows distributed-systems developers to discover and use Jini-enabled resources on the network. The heart and soul of Jini comes from its robust and standardized network protocols, including multicast request protocol, multicast announcement protocol and unicast discovery protocol. Jini-enabled resources—or *services*—use these three protocols to locate and interact with other services. Beyond the network protocols, Jini technology provides the infrastructure required to use the protocols. This infrastructure exists as a set of classes that hide the low-level details of the protocols, allowing developers to focus on functionality instead of implementation. This chapter overviews Jini technology, introduces the network protocols that support Jini services and demonstrates Jini technology with a substantial Jini application. Later in the book (Chapter 29, Peer-to-Peer Applications and JXTA) we use Jini to build an instant-messaging application.

### **Chapter 23—JavaSpaces**

Objects that take part in distributed systems must be able to communicate with one another and share information. The *JavaSpaces service* is a Jini service that implements a simple, high-level architecture for building distributed systems using a distributed repository for objects and three simple operations—*read*, *write* and *take*. JavaSpaces services support transactions through the Jini transaction manager, and a notification mechanism that notifies an object when an entry that matches a given template is written to the JavaSpaces service. In the first half of this chapter, we present fundamental JavaSpaces technology concepts and use simple examples to demonstrate operations, transactions and notifications. The case study at the end of this chapter uses JavaSpaces services to build an image-processing application that distributes the work of applying filters to images across many programs on separate computers.

**Chapter 24—Java Management Extensions (JMX) (on CD)**

This chapter introduces the *Java Management Extensions (JMX)*, which were developed by Sun and other network-management industry leaders to define a component framework for building intelligent network-management applications. JMX defines a three-level management architecture—*instrumentation level, agent level and manager level*. The instrumentation level allows clients to interact with objects (called *managed resources*) by exposing public interfaces to those objects. The agent level contains *JMX agents*, which enable communication between remote clients and managed resources. The manager level contains applications (clients) that access and interact with managed resources via the JMX agents. JMX also provides support for existing management protocols—such as SNMP—so developers can integrate JMX solutions with existing management applications. This chapter discusses JMX architecture and presents a case study that uses JMX capabilities to manage a network printer simulator.

**Chapter 25—Jiro (on CD)**

This chapter serves as an introduction to Sun’s *Jiro* technology, a Java-based technology that provides infrastructure for developing management solutions for distributed resources on heterogeneous networks. Jiro is an implementation of the *Federated Management Architecture (FMA)* specification, which defines a standard protocol for communication between heterogeneous managed resources (such as devices, systems, applications). Jiro technology supports a three-tier architecture of management solutions. The top tier is the *client tier*. The client locates and communicates with the management services. The *middle tier* provides both static and dynamic management services. The *bottom tier* consists of the heterogeneous managed resources. Jiro is a complementary technology to JMX and can be used to build management solutions. The chapter concludes with a similar case study to the JMX case study presented in Chapter 24.

**Chapter 26—Common Object Request Broker Architecture (CORBA): Part 1 (on CD)**

In this chapter, we introduce the *Common Object Request Broker Architecture (CORBA)*. CORBA is an industry-standard, high-level distributed object framework for building powerful and flexible service-oriented applications. We investigate the essential details of CORBA as defined in the *Object Management Group (OMG)* specifications. We discuss the *Object Request Broker (ORB)*—the core of the CORBA infrastructure—and describe how it makes CORBA a powerful distributed object framework. We discuss the *Java Interface Definition Language (JavaIDL)*—the official mapping of Java to CORBA. Live-code examples demonstrate how to write CORBA-compliant distributed code using Java. Both client-side and server-side JavaIDL are demonstrated. A feature of the chapter is a case study that implements the Deitel Messenger application using CORBA.

**Chapter 27—Common Object Request Broker Architecture (CORBA): Part 2 (on CD)**

This chapter continues the discussion of CORBA. We introduce the Dynamic Invocation Interface as well as CORBA services, including the Naming, Security, Object Transaction and Persistent State services. The discussion continues with a comparison of RMI and CORBA; we also introduce RMI-IIOP, used to integrate RMI with CORBA. Finally, we present an alternate implementation of the Deitel Messenger application using RMI-IIOP.

### **Chapter 28—Peer-to-Peer Applications and JXTA**

Instant-messaging applications and document-sharing systems such as AOL Instant Messenger™ and Gnutella have exploded in popularity, transforming the way users interact with one another over networks. In a *peer-to-peer (P2P) application*, each node performs both client and server functions. Such applications distribute processing responsibilities and information to many computers, thus reclaiming otherwise wasted computing power and storage space, and eliminating central points of failure. In this chapter, we introduce the fundamental concepts of peer-to-peer applications. Using Jini (Chapter 22), RMI (Chapter 13) and multicast sockets, we present two peer-to-peer application case studies of instant-messaging systems. The first implementation uses Jini and RMI, and the second uses multicast sockets and RMI. Finally, we introduce JXTA (short for “juxtapose”—a new open-source technology from Sun Microsystems™ that defines common protocols for implementing peer-to-peer applications.

### **Chapter 29—Introduction to Web Services with SOAP**

*Interoperability*, or seamless communication and interaction between different software systems, is a primary goal of many businesses and organizations that rely heavily on computers and electronic networks. This chapter introduces *Web services* with *Simple Object Access Protocol (SOAP)*, a protocol designed to address this issue. Web services can be Web accessible applications, such as Web pages with dynamic content. More specifically, Web services expose public interfaces for Web-based applications to use. SOAP is a protocol that uses XML to make remote-procedure calls over HTTP to provide interoperability between disparate Web-based applications.

### **Appendix A—Creating Markup with XML (on CD)**

XML is enormously important in *Advanced Java 2 Platform How to Program* and is integrated into examples throughout the book. We have included a substantial introduction to XML in Appendices A–D. Appendix A introduces the fundamentals of XML. We discuss the properties of the XML character set, called *Unicode*—the standard aimed at providing a flexible character set for all the world’s languages. (Appendix I introduces Unicode.) We provide a brief overview of *parsers*—programs that process XML documents and their data. We also overview the requirements for a *well-formed document* (i.e., a document that is syntactically correct). We discuss *elements*, which hold data in XML documents. Several elements can have the same name (resulting in *naming collisions*); we introduce *namespaces*, which differentiate these elements to avoid these collisions.

### **Appendix B—XML Document Type Definitions (on CD)**

A *Document Type Definition (DTD)* is a structural definition for an XML document, specifying the type, order, number and attributes of the elements in an XML document as well as other information. By defining the structure of an XML document, a DTD reduces the validation and error-checking work of the application using the document. We discuss well-formed and valid documents (i.e., documents that conform to a DTD). This appendix shows how to specify different element and attribute types, values and defaults that describe the structure of the XML document.

**Appendix C—XML Document Object Model (DOM) (on CD)**

The W3C *Document Object Model (DOM)* is an API for XML that is platform and language independent. The DOM API provides a standard API (i.e., methods, objects, etc.) for manipulating XML-document contents. The *Java API for XML Processing (JAXP)* provides DOM support for Java programs. XML documents are hierarchically structured, so the DOM represents XML documents as tree structures. Using DOM, programs can modify the content, structure and formatting of documents dynamically. This appendix examines several important DOM capabilities, including the ability to retrieve data, insert data and replace data. We also demonstrate how to create and traverse documents using the DOM.

**Appendix D—XSLT: Extensible Stylesheet Language Transformations (on CD)**

XSL was designed to manipulate the rich and sophisticated data contained in an XML document. XSL has two major functions: formatting XML documents and transforming them into other data formats such as XHTML, Rich Text Format (RTF), etc. In this appendix, we discuss the subset of XSL called XSLT. XSLT uses XPath—a language of expressions for accessing portions of XML documents—to match nodes for transforming an XML document into another text document. We use JAXP—which includes XSLT support—in our examples. An XSL stylesheet contains *templates* with which elements and attributes can be matched. New elements and attributes can be created to facilitate a transformation.

**Appendix E—Downloading and Installing J2EE (on CD)**

We use the Java 2 Enterprise Edition extensively in this book to create substantial enterprise applications. This appendix provides instructions for downloading and installing Sun's reference implementation of the J2EE.

**Appendix F—Java Community Process (JCP) (on CD)**

This appendix provides an overview of the *Java Community Processes (JCP)*, which Sun Microsystems started in 1998. The JCP ([www.jcp.org](http://www.jcp.org)) allows Java individuals, organizations and corporations to participate in the development of new technologies and APIs for the Java Platform. Sun has integrated a number of technologies developed through the Java Community Process into the Java 2 Platform Software Development Kits, including the XML parsing specification.

**Appendix G—Java Native Interface (JNI) (on CD)**

The *Java Native Interface (JNI)* allows programmers to access pre-built applications and *libraries* written in other languages. JNI allows programmers to work in Java without requiring developers to rebuild existing libraries. JNI can be useful in time-critical applications—programmers may write a piece of the application in assembly code and link this program with Java to provide better performance. In this appendix, we explain how to integrate Java with C++ libraries. Included are the most common uses and functions of JNI. We show how Java programs can call *native* functions stored in compiled libraries, and how native code can access Java objects, methods and member variables from C++. Understanding these examples requires familiarity with C++.

**Appendix H—Career Opportunities (on CD)**

The Internet presents valuable resources and services for job seekers and employers. Automatic search features allow employees to scan the Web for open positions. Employers also

can find job candidates using the Internet. This greatly reduces the amount of time spent preparing and reviewing resumes, as well as travel expenses for distance recruiting and interviewing. In this chapter, we explore career services on the Web from the perspectives of job seekers and employers. We introduce comprehensive job sites, industry-specific sites (including site geared specifically for Java and wireless programmers) and contracting opportunities.

### **Appendix I—Unicode (on CD)**

This appendix introduces the *Unicode Standard*—a character-set-encoding standard that facilitates the production and distribution of software. As computer systems evolved worldwide, computer vendors developed numeric representations of character sets and special symbols for the local languages in different countries. In some cases, different representations were developed for the same languages. Such disparate character sets made communication between computer systems difficult. XML and XML-derived languages, such as WML, support the *Unicode Standard*, which defines a single character set with unique numeric values for characters and special symbols for most of the world's languages. In this appendix, we discuss the Unicode Standard and the *Unicode Consortium* ([www.unicode.org](http://www.unicode.org))—a non-profit organization that maintains the Unicode Standard.

## **1.4 Running Example Code**

Many example programs in *Advanced Java 2 Platform How to Program* are quite complex and require special software to execute. For example, Chapters 17–20 present a J2EE case study that requires an application server, which provides a runtime environment and services for an enterprise application. This case study also requires a database. For this and many other programs we provide installation, deployment and execution instructions in the text and at our Web site, [www.deitel.com](http://www.deitel.com).

At the time of this writing, Java 2 Enterprise Edition reference implementation version 1.2.1 was the current, released version of J2EE, and version 1.3 was in beta release. We will update installation instructions on our Web site when Sun releases version 1.3, which will include several enhancements and updates. For example, version 1.3 implements the Java messaging Service (JMS 1.0.2), J2EE Connector Technology and the Java API for XML Processing (JAXP 1.1). Java Servlets (version 2.3) implement filters, a lightweight transfer framework for requests and responses, monitoring application lifecycles and better internationalization support. The Java Server Pages implementation (version 1.2) features improved runtime support for tag libraries and translation time JSP page validation. The 1.3 Enterprise JavaBeans implementation (EJB 2.0) supports message-driven enterprise beans, interoperability between EJB containers and Container-Managed Persistence 2.0.

The examples in *Advanced Java 2 Platform How to Program* use Sun's standard naming convention for packages. We place each example in an appropriately named sub-package of package **com.deitel**. For example, the **WebBrowser** example in Chapter 2, Advanced Swing Graphical User Interfaces, contains the package declaration

```
package com.deitel.advjhtp1.gui.webbrowser;
```

The acronym **advjhtp1** in the package name indicates that this package is from *Advanced Java 2 Platform How to Program, First Edition*. This package structure requires that you compile the examples into the corresponding directory structure.

Managing packages with Java’s command-line compiler and tools can be cumbersome, so we recommend that readers use an integrated development environment to simplify the development and execution of the examples and exercises in this book. We used Sun’s Forte for Java Community Edition—which derives from the open-source NetBeans IDE ([www.netbeans.org](http://www.netbeans.org))—to develop the code examples for this book. We have included Forte for Java, Community Edition version 2.0 and the Java 2 Standard Edition SDK version 1.3.1 on the CD that accompanies this book. For tutorials on how to install Forte and how to develop applications with it, please refer to Forte’s help system or the documentation at:

**[www.sun.com/forte/ffj/documentation/index.html](http://www.sun.com/forte/ffj/documentation/index.html)**

Most Java development environments enable developers to load directory structures containing Java packages directly into those environments. To facilitate working with the code in this way, we have provided the complete directory structure, with source files in the appropriate locations, on the CD-ROM that accompanies this book. We recommend that you copy this directory structure from the CD-ROM that accompanies this book to your hard drive. Once you have copied the directory structure, you can load the examples according to the instructions for your development environment.

For readers who wish to use command-line tools for compiling and executing the programs in this book, we also provide separate folders with the examples for each chapter. To compile and execute the examples from the command line, copy the folder for the particular chapter or example onto your hard drive. For example, if you copy the **ch02** directory to the **C:\examples** directory on your hard drive, you can compile the **WebBrowser** example using the commands

```
cd C:\examples\ch02\fig02_01  
javac -d . WebBrowser.java WebBrowserPane.java WebToolBar.java
```

The command-line argument **-d .** specifies that the Java compiler should create the resulting **.class** files in the appropriate directory structure. To execute the example, you must provide the fully qualified package name for the class that defines method **main**. For example,

```
java com.deitel.advjhtp1.gui.webbrowser.WebBrowser
```

## 1.5 Design Patterns

Most code examples presented in introductory Java books—such as our *Java How to Program, Fourth edition*—contain fewer than 150 lines of code. These examples do not require an extensive design process, because they use only a few classes and illustrate rudimentary programming concepts. However, most of the programs in *Advanced Java How to Program*, such as the Java 2D case study (Chapter 5), the three-tier Wireless application (Chapter 12) and the Deitel Bookstore (Chapters 17–20), are much more complex. Such large applications can require thousands of lines of code, contain many interactions among objects and involve many user interactions. For such software, it is important to employ proven, effective design strategies. Systems such as automated-teller machines and air-traffic control systems can contain millions, or even hundreds of millions, of lines of code. Effective design is absolutely crucial to the proper construction of such complex systems.

Over the past decade, the software engineering industry has made significant progress in the field of *design patterns*—proven architectures for constructing flexible and maintainable object-oriented software.<sup>1</sup> Using design patterns can reduce the complexity of the design process substantially. Well-designed object-oriented software allows designers to reuse and integrate pre-existing components into future systems. Design patterns benefit system developers by

- helping to construct reliable software using proven architectures and accumulated industry expertise
- promoting design and code reuse in future systems
- helping to identify common mistakes and pitfalls that occur when building systems
- helping to design systems independently of the languages in which they will ultimately be implemented
- establishing a common design vocabulary among developers
- shortening the design phase in a software-development process

The notion of using design patterns to construct software systems originated in the field of architecture. Architects use established architectural design elements, such as arches and columns, when designing buildings. Designing with arches and columns is a proven strategy for constructing sound buildings—these elements may be viewed as architectural design patterns.

### 1.5.1 History of Object-Oriented Design Patterns

During 1991–1994, Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides—collectively known as the “gang of four”—combined their expertise in writing the book *Design Patterns, Elements of Reusable Object-Oriented Software* (Addison-Wesley: 1995). This book showed that design patterns evolved naturally through years of industry experience. John Vlissides states that “the single most important activity in pattern writing is reflection.”<sup>2</sup> This statement implies that to create patterns, developers must reflect on, and document, their successes (and failures) when designing and implementing software systems. Developers use design patterns to capture and use this collective experience, which ultimately helps them share similar successes with other developers.

The gang-of-four book described 23 design patterns, each providing a solution to a common software design problem. The book groups design patterns into three categories—*creational*, *structural* and *behavioral design patterns*. Figure 1.1 lists these design patterns.

Creational design patterns describe techniques for instantiating objects (or groups of objects). These design patterns address issues related to the creation of objects, such as preventing a system from creating more than one object of a class (e.g., Singleton) or deferring until execution time the decision as to what types of objects are created (e.g., Factory Method). For example, suppose we are designing a 3-D drawing program, in which the user can create several 3-D geometric objects, such as cylinders, spheres, cubes, tetrahedrons, etc. At compile time, the program does not know what types of shapes the user will choose to add to the drawing. Based on user input at runtime, this program should determine the class from which to instantiate an object. If the user chooses to create a cylinder, the program should “know” to instantiate an object of class **Cylinder** and add it to the drawing.

When the user decides what geometric object to draw, the program should determine the specific subclass from which to instantiate that object.

Structural design patterns describe common ways to organize classes and objects in a system. Developers often find two problems with poor organization. The first is that classes are assigned too many responsibilities. Such classes may damage information hiding and violate encapsulation, because each class may have access to information that belongs in a separate class. The second problem is that classes can overlap responsibilities. Burdening a design with unnecessary classes wastes time for designers because they will spend hours trying to extend or modify classes that should not even exist in the system. As we will see, structural design patterns help developers avoid these problems.

Behavioral design patterns assign responsibilities to objects. These patterns also provide proven strategies to model how objects collaborate with one another and offer special behaviors appropriate for a wide variety of applications. The Observer pattern is a classic example of collaborations between objects and of assigning responsibilities to objects. For example, GUI components use this patterns to communicate with their listeners, which respond to user interactions. A listener observes state changes in a particular component by registering to handle that component's events. When the user interacts with the component, that component notifies its listeners (also known as its *observers*) that the component's state has changed (e.g., a button has been pressed).

### 1.5.2 Design Patterns Discussion

Design patterns are implemented in code as sets of classes and objects. To use design patterns effectively, designers must familiarize themselves with the most popular and effective patterns used in the software-engineering industry. Throughout this book, we discuss fundamental object-oriented design patterns and architectures, as well as their importance in constructing well-engineered software. We discuss each design pattern as it is used in a particular code example or case study. Figure 1.2 lists those design patterns that we used and in which chapter we used them.

Creational	Structural	Behavioral
Abstract Factory	Adapter	Chain-of-Responsibility
Builder	Bridge	Command
Factory Method	Composite	Iterator
Prototype	Decorator	Interpreter
Singleton	Facade	Observer
	Flyweight	Mediator
	Proxy	Memento
		State
		Strategy
		Template Method
		Visitor

Fig. 1.1 Gang-of-four 23 design patterns.

Chapter	Creational design patterns	Structural design patterns	Behavioral design patterns
2			Command
3			Observer
5	Factory Method Singleton	Adapter	State Template Method
7		Decorator	
12	Factory Method		Command
24		Facade	Chain-of-Responsibility

**Fig. 1.2** Gang-of-four design patterns used in *Advanced Java 2 Platform How to Program*.

Note that Fig. 1.2 does not include every design pattern specified in Fig. 1.1. We used only those patterns that were appropriate for solving specific design problems that we encountered when writing the examples and case studies in this book. We now list other popular “gang-of-four” design patterns that are useful in building software, even though we did not use them when building the examples for this book.

### Prototype

Sometimes, a system must make a copy of an object but will not know that object’s class until run time. For example, consider a drawing program that contains several “shape” classes (e.g., classes **Line**, **Oval** and **Rectangle**, etc.) that extend an abstract super-class **Shape**. The user of this program should, at any time, be able to create, copy and paste new instances of **Shape** classes to add those shapes to drawings. The *Prototype design pattern* enables the user to accomplish this. This design pattern allows an object—called a *prototype*—to clone itself. The prototype is similar to a rubber stamp that can be used to create several identical “imprints.” In software, every prototype must belong to a class that implements a common interface that allows the prototype to clone itself. For example, the Java API provides method **clone** from interface **java.lang.Cloneable**—any object from a class that implements interface **Cloneable** uses method **clone** to make a copy of itself. Specifically, method **clone** creates a copy of an object, then returns a reference to that object. In the drawing program, if we designate class **Line** as the prototype, then it should implement interface **Cloneable**. To create a new line in our drawing, we clone the **Line** prototype—this prototype will return a reference to a different **Line** object. To copy a preexisting line, we clone that **Line** object. Developers often use method **clone** to prevent altering an object through its reference, because method **clone** returns a reference to an object’s copy, rather than return the object’s actual reference.

### Bridge

Suppose we are designing a **Button** class for both the Windows and Macintosh operating systems. Class **Button** contains specific button information such as an **ActionListener** and a **String** label. We design classes **Win32Button** and **MacButton** to extend class **Button**. Class **Win32Button** contains “look-and-feel” information on how to display a

**Button** on the Windows operating system, and class **MacButton** contains “look-and-feel” information on how to display a **Button** on the Macintosh operating system.

Two problems arise from this approach. First, if we create new **Button** subclasses, we must create corresponding **Win32Button** and **MacButton** subclasses. For example, if we create class **ImageButton** (a **Button** with an overlapping **Image**) that extends class **Button**, we must create additional subclasses **Win32ImageButton** and **MacImageButton**. In fact, we must create **Button** subclasses for every operating system we wish to support, which increases development time. The second problem is that when a new operating system enters the market, we must create additional **Button** subclasses specific to that operating system.

The *Bridge design pattern* avoids these problems by separating an abstraction (e.g., a **Button**) and its implementations (e.g., **Win32Button**, **MacButton**, etc.) into separate class hierarchies. For example, the Java AWT classes use the Bridge design pattern to enable designers to create AWT **Button** subclasses without needing to create corresponding subclasses specific to each operating system. Each AWT **Button** maintains a reference to a **ButtonPeer**, which is the superclass for platform-specific implementations, such as **Win32ButtonPeer**, **MacButtonPeer**, etc. When a programmer creates a **Button** object, class **Button** determines which platform-specific **ButtonPeer** object to create and stores a reference to that **ButtonPeer** object—this reference is the “bridge” in the Bridge design pattern. When the programmer invokes methods on the **Button** object, the **Button** object invokes the appropriate method on its **ButtonPeer** object to fulfill the request. If a designer creates **Button** subclass **ImageButton**, the designer does not need to create a corresponding **Win32ImageButton** or **MacImageButton** class. Class **ImageButton** “is a” **Button**, so when a programmer invokes an **ImageButton** method—such as **setImage**—on an **ImageButton** object, the **Button** superclass translates that method invocation into an appropriate **ButtonPeer** method invocation—such as **drawImage**.



### Portability Tip 1.1

Designers often use the Bridge design pattern to enhance the platform independence of their systems. We can design **Button** subclasses without worrying about how an operating system implements each subclass.

### Iterator

Designers use data structures such as arrays, linked lists and hash tables to organize data in a program. The *Iterator design pattern* allows objects to access individual objects from data structures without knowing that data structure’s implementation or how it stores object references. Instructions for traversing the data structure and accessing its elements are stored in a separate object called an *iterator*. Each data structure has an associated iterator implementation capable of traversing that data structure. Other objects can use this iterator, which implements a standard interface, regardless of the underlying data structure or implementation. Interface **Iterator** from package **java.util** uses the Iterator design pattern. Consider a system that contains **Sets**, **Vectors** and **Lists**. The algorithm for retrieving data from each structure differs among the classes. With the Iterator design pattern, each class contains a reference to an **Iterator** that stores traversal information specific to each data structure. For objects of these classes, we invoke an object’s **iterator** method to obtain a reference to an **Iterator** for that object. We invoke method **next** of the

**Iterator** to receive the next element in the structure without having to concern ourselves with the details of traversal implementation.

### Memento

Consider a drawing program that allows a user to draw graphics. Occasionally the user may position a graphic improperly in the drawing area. The program can offer an “undo” feature that allows the user to unwind such errors. Specifically, the program would restore the drawing area’s original state (before the user placed the graphic). More sophisticated drawing programs offer a *history*, which stores several states in a list, so the user can restore the program to any state in the history. The *Memento design pattern* allows an object to save its state, so that—if necessary—the user can restore the object to its former state.

The Memento design pattern requires three types of objects. The *originator object* occupies some *state*—the set of attribute values at a specific time in program execution. In our drawing-program example, the drawing area is the originator, because it occupies several states. The drawing area’s initial state is that the area contains no elements. The *memento object* stores a copy of all attributes associated with the originator’s state. The memento is stored as the first item in the history list, which acts as the *caretaker object*—the object that contains references to all memento objects associated with the originator.

Now, suppose the user draws a circle in the drawing area. The area now occupies a different state—the area contains a circle object centered at specified *x-y* coordinates. The drawing area then uses another memento to store this information. This memento is stored as the second item in the history list. The history list displays all mementos on screen, so the user can select which state to restore. Suppose the user wishes to remove the circle—if the user selects the first memento from the list, the drawing area uses the first memento to restore itself to a blank area.

### Strategy

Package `java.awt` offers several **LayoutManagers**, such classes **FlowLayout**, **BorderLayout** and **GridLayout**, with which developers build graphical user interfaces. Each **LayoutManager** arranges GUI components in a **Container** object—however, each **LayoutManager** implementation uses a different algorithm to arrange these components. A **FlowLayout** arranges components in a left-to-right sequence, a **BorderLayout** places components into five distinct regions and a **GridLayout** arranges components in row-column format. Interface **LayoutManager** plays the role of the *strategy design pattern*.

The Strategy design pattern allows developers to encapsulate a set of algorithms—called a strategy—that each have the same function (e.g., arrange GUI components) but different implementations. For example, interface **LayoutManager** (the strategy) is the set of algorithms that arranges GUI components. Each concrete **LayoutManager** subclass (e.g., the **FlowLayout**, **BorderLayout** and **GridLayout** objects) implements method **addLayoutComponent** to provide a specific component-arrangement algorithm.

## 1.5.3 Concurrency Patterns

Many additional design patterns have been created since the publication of the gang-of-four book, which introduced patterns involving object-oriented systems. Some of these new patterns involve specific types of object-oriented systems, such as concurrent, distributed or parallel systems. Multithreaded programming languages such as Java allow designers to

specify concurrent activities—that is, activities that operate in parallel with one another. Improper design of concurrent systems can introduce *concurrency problems*. For example, two objects attempting to alter shared data at the same time could corrupt that data. In addition, if two objects wait for one another to finish tasks, and if neither can complete their task, these objects could potentially wait forever—a situation called *deadlock*. Using Java, Doug Lea and Mark Grand created a set of *concurrency patterns* for multithreaded design architectures to prevent various problems associated with multithreading. We provide a partial list of these design patterns:

- The *Single-Threaded Execution design pattern* prevents several threads from invoking the same method of another object concurrently.<sup>3</sup> In Java, developers can use the **synchronized** keyword to apply this pattern.
- The *Balking design pattern* ensures that a method will *balk*—that is, return without performing any actions—if an object occupies a state that cannot execute that method.<sup>4</sup> A variation of this pattern is that the method throws an exception describing why that method is unable to execute—for example, a method throwing an exception when accessing a data structure that does not exist.
- The *Read/Write Lock design pattern* allows multiple threads to obtain concurrent read access on an object but prevents multiple threads from obtaining concurrent write access on that object. Only one thread at a time may obtain write access on an object—when that thread obtains write access, the object is *locked* to all other threads.<sup>5</sup>
- The *Two-Phase Termination design pattern* ensures that a thread frees resources—such as other spawned threads—in memory (phase one) before terminating (phase two).<sup>6</sup> In Java, a **Thread** object can use this pattern in method **run**. For instance, method **run** can contain an infinite loop that is terminated by some state change—upon termination, method **run** can invoke a **private** method responsible for stopping any other spawned threads (phase one). The thread then terminates after method **run** terminates (phase two). In Chapter 13, the **ChatServerAdministrator** and **ChatServer** classes of the RMI Deitel Messenger application use this design pattern, which we describe in greater detail.

#### 1.5.4 Architectural Patterns

Design patterns allow developers to design specific parts of systems, such as abstracting object instantiations, aggregating classes into larger structures or assigning responsibilities to objects. *Architectural patterns*, on the other hand, provide developers with proven strategies for designing subsystems and specifying how they interact with each other.<sup>7</sup>

For example, the Model-View-Controller architectural pattern separates application data (contained in the *model*) from graphical presentation components (the *view*) and input-processing logic (the *controller*). In the design for a simple text editor, the user inputs text from the keyboard and formats this text using the mouse. The program stores this text and format information into a series of data structures, then displays this information on screen for the user to read what has been inputted. The model, which contains the application data, might contain only the characters that make up the document. When a user provides some input, the controller modifies the model’s data with the given input. When the model

changes, it notifies the view of the change so the view can update its presentation with the changed data—e.g., the view might display characters using a particular font, with a particular size. Chapter 3 discusses Model-View-Controller architecture in detail, and our Java 2D drawing application in Chapter 5 and the Enterprise Java case study in Chapters 17–20 use this architecture extensively.

The Layers architectural pattern divides functionality into separate sets of system responsibilities called *layers*. For example, *three-tier applications*, in which each tier contains a unique system component, is an example of the Layers architectural pattern. This type of application contains three components that assume a unique responsibility. The *information tier* (also called the “bottom tier”) maintains data for the application, typically storing the data in a database. The *client tier* (also called the “top tier”) is the application’s user interface, such as a standard Web browser. The *middle tier* acts as an intermediary between the information tier and the client tier by processing client-tier requests, reading data from and writing data to the database. In this book, the three-tier architectures in the Deitel bookstore application (Chapter 11), the wireless application case study (Chapter 12) and the Enterprise Java case study (Chapters 17–20) all use the Layers architectural pattern. We discuss the nuances of each architecture in its respective chapter.

Using architectural patterns promotes extensibility when designing systems, because designers can modify a component without having to modify another. For example, a text editor that uses the Model-View-Controller architectural pattern is extensible; designers can modify the view that displays the document outline but would not have to modify the model, other views or controllers. A system designed with the Layers architectural pattern is also extensible; designers can modify the information tier to accommodate a particular database product, but they would not have to modify either the client tier or the middle tier extensively.

### 1.5.5 Further Study on Design Patterns

We hope that you will pursue further study of design patterns. We recommend that you visit the URLs and read the books we mention below as you study patterns throughout this book. We especially encourage you to read the gang-of-four book.

#### *Design Patterns*

##### **[www.hillside.net/patterns](http://www.hillside.net/patterns)**

This page has links to information on design patterns and languages.

##### **[www.hillside.net/patterns/books/](http://www.hillside.net/patterns/books/)**

This site lists books on design patterns.

##### **[www.netobjectives.com/design.htm](http://www.netobjectives.com/design.htm)**

This site overviews design patterns and motivates their importance.

##### **[umbc7.umbc.edu/~tarr/dp/dp.html](http://umbc7.umbc.edu/~tarr/dp/dp.html)**

This site links to design patterns Web sites, tutorials and papers.

##### **[www.links2go.com/topic/Design\\_Patterns](http://www.links2go.com/topic/Design_Patterns)**

This site links to sites and information on design patterns.

##### **[www.c2.com/ppr/](http://www.c2.com/ppr/)**

This site discusses recent advances in design patterns and ideas for future projects.

### **Design Patterns in Java**

**[www.research.umbc.edu/~tarr/cs491/fall00/cs491.html](http://www.research.umbc.edu/~tarr/cs491/fall00/cs491.html)**

This site is for a Java design patterns course at the University of Maryland. It contains numerous examples of how to apply design patterns in Java.

**[www.enteract.com/~bradapp/javapats.html](http://www.enteract.com/~bradapp/javapats.html)**

This site discusses Java design patterns and presents design patterns in distributed computing.

**[www.meurrens.org/ip-Links/java/designPatterns/](http://www.meurrens.org/ip-Links/java/designPatterns/)**

This site displays numerous links to resources and information on Java design patterns.

### **Architectural Patterns**

**[compsci.about.com/science/compsci/library/weekly/aa030600a.htm](http://compsci.about.com/science/compsci/library/weekly/aa030600a.htm)**

This site provides an overview the Model-View-Controller architecture.

**[www.javaworld.com/javaworld/jw-04-1998/jw-04-howto.html](http://www.javaworld.com/javaworld/jw-04-1998/jw-04-howto.html)**

This site contains an article discussing how Swing components use Model-View-Controller architecture.

**[www.ootips.org/mvc-pattern.html](http://www.ootips.org/mvc-pattern.html)**

This site provides information and tips on using MVC.

**[www.ftech.co.uk/~honeyg/articles/pda.htm](http://www.ftech.co.uk/~honeyg/articles/pda.htm)**

This site includes an article on the importance of architectural patterns in software.

**[www.tml.hut.fi/Opinnot/Tik-109.450/1998/niska/sld001.htm](http://www.tml.hut.fi/Opinnot/Tik-109.450/1998/niska/sld001.htm)**

This site provides information about architectural patterns, design patterns and idioms (patterns targeting a specific language).

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4. M. Grand, 417–420.
5. M. Grand, 431–439.
6. M. Grand, 449–453.
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# Advanced Swing Graphical User Interface Components

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## Objectives

- To be able to use Swing components to enhance application GUIs.
- To be able to use Swing text components to view styled documents.
- To understand the Command design pattern and its implementation in Swing.
- To be able to develop applications with multiple-document interfaces.
- To understand how to implement drag-and-drop support.
- To learn how to prepare internationalized applications.
- To understand how to use Swing to create accessible applications for people with disabilities.

*The best investment is in the tools of one's own trade.*

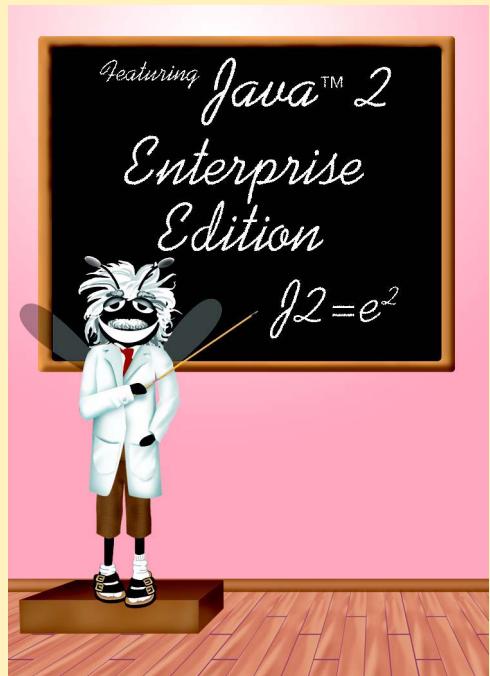
Benjamin Franklin

*Every action must be due to one or other of seven causes:  
chance, nature, compulsion, habit, reasoning, anger or  
appetite.*

Aristotle

*Happiness, like an old friend, is inclined to drop in  
unexpectedly—when you are working hard on something else.*

Ray Inman



## Outline

- 2.1 Introduction**
- 2.2 WebBrowser Using JEditorPane and JToolBar**
  - 2.2.1 Swing Text Components and HTML Rendering**
  - 2.2.2 Swing Toolbars**
- 2.3 Swing Actions**
- 2.4 JSplitPane and JTabbedPane**
- 2.5 Multiple-Document Interfaces**
- 2.6 Drag and Drop**
- 2.7 Internationalization**
- 2.8 Accessibility**
- 2.9 Internet and World Wide Web Resources**

[Summary](#) • [Terminology](#) • [Self-Review Exercises](#) • [Answers to Self-Review Exercises](#) • [Exercises](#)

## 2.1 Introduction

In this chapter, we introduce Swing components that enable developers to build functionally rich user interfaces. The Swing graphical user interface components were introduced with the Java Foundation Classes (JFC) as a downloadable extension to the Java 1.1 Platform, then became a standard extension in the Java 2 Platform. Swing provides a more complete set of GUI components than the Abstract Windowing Toolkit (AWT), including advanced features such as a pluggable look and feel, lightweight component rendering and drag-and-drop capabilities.

We introduce the **JEditorPane** class for rendering styled content, such as HTML pages, and build a simple Web browser. We continue our discussion of design patterns by introducing **Swing Actions**, which implement the Command design pattern. Swing **Actions** enable developers to build reusable, user-interface logic components. We also introduce **JSplitPane**, **JTabbedPane** and multiple-document-interface components for organizing GUI elements.

Java provides mechanisms for building applications for multiple languages and countries, and for disabled users. Building internationalized applications ensures that applications will be ready for use around the world in many languages and countries. Accessibility ensures that disabled users will be able to use applications through commonly available utilities, such as screen readers. We show how Swing components enable Java developers to build applications that are accessible to users with disabilities.

## 2.2 WebBrowser Using JEditorPane and JToolBar

In this section, we use Swing components to build a simple Web browser. We introduce Swing's advanced text-rendering capabilities and containers for grouping commonly used interface elements for convenient user access.

## 2.2.1 Swing Text Components and HTML Rendering

Many applications present text to the user for viewing and editing. This text may consist of plain, unformatted characters, or it may consist of richly styled characters that use multiple fonts and extensive formatting. Swing provides three basic types of text components for presenting and editing text. Class **JTextComponent** is the base class for all Swing text components, including **JTextField**, **JTextArea** and **JEditorPane**.

**JTextField** is a single-line text component suitable for obtaining simple user input or displaying information such as form field values, calculation results and so on. **JPasswordField** is a subclass of **JTextField** suitable for obtaining user passwords. These components do not perform any special text styling. Rather, they present all text in a single font and color. **JTextArea**, like **JTextField** and **JPasswordField**, also does not style its text. However, **JTextArea** does provide a larger visible area and supports larger plain-text documents.

**JEditorPane** provides enhanced text-rendering capabilities. **JEditorPane** supports styled documents that include formatting, font and color information. **JEditorPane** is capable of rendering HTML documents as well as Rich Text Format (RTF) documents. We use class **JEditorPane** to render HTML pages for a simple Web-browser application. **JTextPane** is a **JEditorPane** subclass that renders only styled documents, and not plain text. **JTextPane** provides developers with fine-grained control over the style of each character and paragraph in the rendered document.

**WebBrowserPane** (Fig. 2.1) extends class **JEditorPane** to create a Web-browsing component that maintains a history of visited URLs. Line 16 creates a **List** for keeping track of visited URLs. Line 23 invokes method **setEditable** of class **JEditorPane** to disable text editing in the **WebBrowserPane**. **JEditorPane** enables hyperlinks in HTML documents only if the **JEditorPane** is not editable.

```
1 // WebBrowserPane.java
2 // WebBrowserPane is a simple Web-browsing component that
3 // extends JEditorPane and maintains a history of visited URLs.
4 package com.deitel.advjhtp1.gui.webbrowser;
5
6 // Java core packages
7 import java.util.*;
8 import java.net.*;
9 import java.io.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class WebBrowserPane extends JEditorPane {
15
16     private List history = new ArrayList();
17     private int historyIndex;
```

Fig. 2.1 **WebBrowserPane** subclass of **JEditorPane** for viewing Web sites and maintaining URL history (part 1 of 3).

```
18
19 // WebBrowserPane constructor
20 public WebBrowserPane()
21 {
22     // disable editing to enable hyperlinks
23     setEditable( false );
24 }
25
26 // display given URL and add it to history
27 public void goToURL( URL url )
28 {
29     displayPage( url );
30     history.add( url );
31     historyIndex = history.size() - 1;
32 }
33
34 // display next history URL in editorPane
35 public URL forward()
36 {
37     historyIndex++;
38
39     // do not go past end of history
40     if ( historyIndex >= history.size() )
41         historyIndex = history.size() - 1;
42
43     URL url = ( URL ) history.get( historyIndex );
44     displayPage( url );
45
46     return url;
47 }
48
49 // display previous history URL in editorPane
50 public URL back()
51 {
52     historyIndex--;
53
54     // do not go past beginning of history
55     if ( historyIndex < 0 )
56         historyIndex = 0;
57
58     // display previous URL
59     URL url = ( URL ) history.get( historyIndex );
60     displayPage( url );
61
62     return url;
63 }
64
65 // display given URL in JEditorPane
66 private void displayPage( URL pageURL )
67 {
```

Fig. 2.1 **WebBrowserPane** subclass of **JEditorPane** for viewing Web sites and maintaining URL history (part 2 of 3).

```
68      // display URL
69      try {
70          setPage( pageURL );
71      }
72
73      // handle exception reading from URL
74      catch ( IOException ioException ) {
75          ioException.printStackTrace();
76      }
77  }
```

Fig. 2.1 **WebBrowserPane** subclass of **JEditorPane** for viewing Web sites and maintaining URL history (part 3 of 3).

Method **goToURL** (lines 27–32) navigates the **WebBrowserPane** to the given URL. Line 29 invokes method **displayPage** of class **WebBrowserPane** to display the given URL. Line 30 invokes method **add** of interface **List** to add the URL to the browser history. Line 31 updates the **historyIndex** to ensure that methods **back** and **forward** navigate to the appropriate URL.

Method **forward** (lines 35–47) navigates the **WebBrowserPane** to the next page in the URL history. Line 37 increments **historyIndex**, and lines 43–44 retrieve the URL from the **history List** and display the URL in **WebBrowserPane**. If the **historyIndex** is past the last page in the **history**, line 41 sets **historyIndex** to the last URL in **history**.

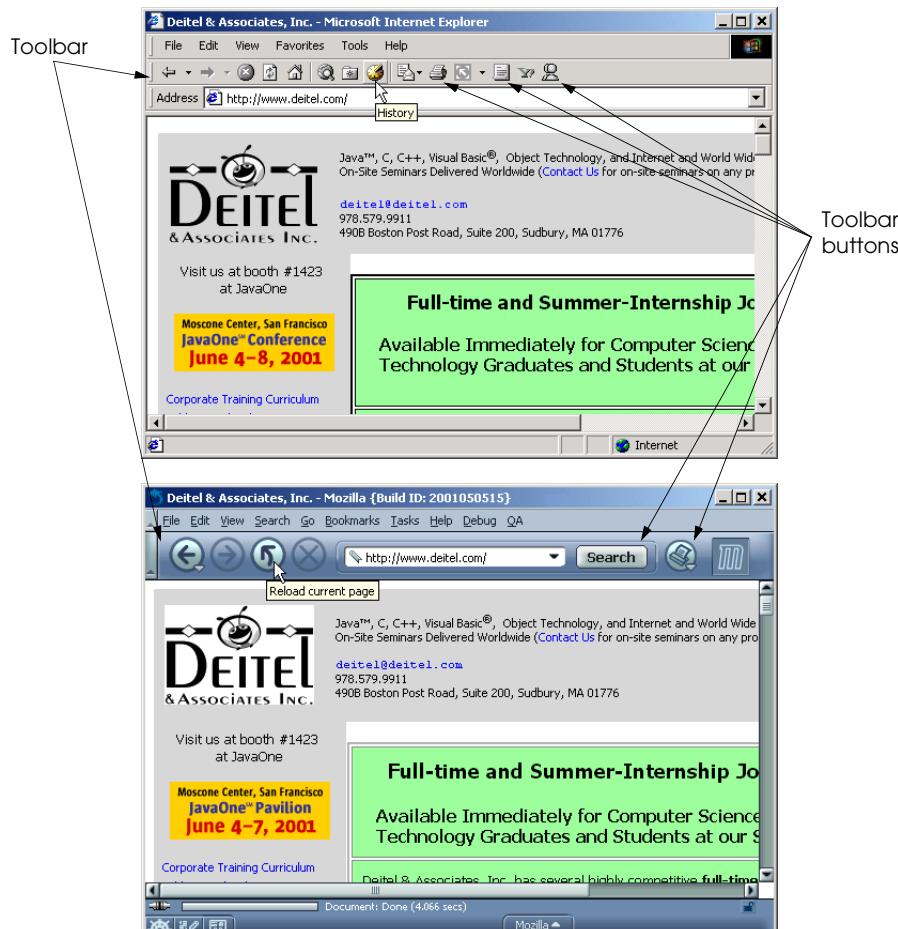
Method **back** (lines 50–63) navigates **WebBrowserPane** to the previous page in the URL history. Line 52 decrements **historyIndex**, and lines 55–56 ensure that **historyIndex** does not fall below **0**. Lines 59–60 retrieve the URL and display it in the **WebBrowserPane**.

Method **displayPage** takes as an argument a **URL** to display in the **WebBrowserPane**. Line 70 invokes method **setPage** of class **JEditorPane** to display the page that the URL references. Lines 74–76 catch an **IOException** if there is an error loading the page from the given **URL**.

## 2.2.2 Swing Toolbars

Toolbars are GUI containers typically located below an application's menus. Toolbars contain buttons and other GUI components for commonly used features, such as cut, copy and paste, or navigation buttons for a Web browser. Figure 2.2 shows toolbars in Internet Explorer and Mozilla.

Class **javax.swing.JToolBar** enables developers to add toolbars to Swing user interfaces. **JToolBar** also enables users to modify the appearance of the **JToolBar** in a running application. For example, the user can drag the **JToolBar** from the top of a window and "dock" the **JToolBar** on the side or bottom of the window. Users also can drag the **JToolBar** away from the application window (Fig. 2.4) to create a *floating JToolBar* (i.e., a **JToolBar** displayed in its own window). Developers can set **JToolBar** properties that enable or disable dragging and floating.



**Fig. 2.2** Toolbars for navigating the Web in Internet Explorer and Mozilla.

**WebToolBar** (Fig. 2.3) extends class **JToolBar** to provide commonly used navigation components for a **WebBrowserPane**. **WebToolBar** provides **backButton** (line 20) for navigating to the previous page, **forwardButton** (line 21) for navigating to the next page and **urlTextField** to allow the user to enter a URL (line 22).

The **WebToolBar** constructor (lines 25–96) takes as an argument a **WebBrowserPane** for displaying Web pages. Lines 34–53 create **urlTextField** and its associated **ActionListener**. When a user types a URL and hits the *Enter* key, line 44 invokes method **goToURL** of class **WebBrowserPane** to display the user-entered URL.

Lines 56–57 create **backButton**, which allows the user to navigate to the previously viewed Web site. Recall that class **WebBrowserPane** maintains a history of visited URLs. When the user selects **backButton**, line 65 invokes method **back** of class **Web-**

**BrowserPane** to navigate to the previous URL. Method **back** returns the destination URL, which line 68 displays in **urlTextField**. This ensures that **urlTextField** shows the proper URL for the Web site displayed in the **WebBrowserPane**.

Lines 74–75 create **forwardButton**, which allows the user to navigate forward through the **WebBrowserPane**'s history of visited URLs. When the user activates **forwardButton**, line 83 invokes method **forward** of class **WebBrowserPane** to navigate to the next URL in the **WebBrowserPane**'s URL history. Line 86 displays the URL in **urlTextField**.

```
1 // WebToolBar.java
2 // WebToolBar is a JToolBar subclass that contains components
3 // for navigating a WebBrowserPane. WebToolBar includes back
4 // and forward buttons and a text field for entering URLs.
5 package com.deitel.advjhtp1.gui.webbrowser;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.net.*;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.event.*;
15
16 public class WebToolBar extends JToolBar
17     implements HyperlinkListener {
18
19     private WebBrowserPane webBrowserPane;
20     private JButton backButton;
21     private JButton forwardButton;
22     private JTextField urlTextField;
23
24     // WebToolBar constructor
25     public WebToolBar( WebBrowserPane browser )
26     {
27         super( "Web Navigation" );
28
29         // register for HyperlinkEvents
30         webBrowserPane = browser;
31         webBrowserPane.addHyperlinkListener( this );
32
33         // create JTextField for entering URLs
34         urlTextField = new JTextField( 25 );
35         urlTextField.addActionListener(
36             new ActionListener() {
```

Fig. 2.3 **WebToolBar** **JToolBar** subclass for navigating URLs in a **WebBrowserPane** (part 1 of 3).

```
38         // navigate webBrowser to user-entered URL
39         public void actionPerformed( ActionEvent event )
40     {
41         // attempt to load URL in webBrowserPane
42         try {
43             URL url = new URL( urlTextField.getText() );
44             webBrowserPane.goToURL( url );
45         }
46
47         // handle invalid URL
48         catch ( MalformedURLException urlException ) {
49             urlException.printStackTrace();
50         }
51     }
52 }
53 ;
54
55 // create JButton for navigating to previous history URL
56 backButton = new JButton( new ImageIcon(
57     getClass().getResource( "images/back.gif" ) ) );
58
59 backButton.addActionListener(
60     new ActionListener() {
61
62         public void actionPerformed( ActionEvent event )
63     {
64         // navigate to previous URL
65         URL url = webBrowserPane.back();
66
67         // display URL in urlTextField
68         urlTextField.setText( url.toString() );
69     }
70 }
71 );
72
73 // create JButton for navigating to next history URL
74 forwardButton = new JButton( new ImageIcon(
75     getClass().getResource( "images/forward.gif" ) ) );
76
77 forwardButton.addActionListener(
78     new ActionListener() {
79
80         public void actionPerformed( ActionEvent event )
81     {
82         // navigate to next URL
83         URL url = webBrowserPane.forward();
84
85         // display new URL in urlTextField
86         urlTextField.setText( url.toString() );
87     }
88 }
89 );
```

Fig. 2.3 WebToolBar JToolBar subclass for navigating URLs in a WebBrowserPane (part 2 of 3).

```
90
91     // add JButtons and JTextField to WebToolBar
92     add( backButton );
93     add( forwardButton );
94     add( urlTextField );
95
96 } // end WebToolBar constructor
97
98 // listen for HyperlinkEvents in WebBrowserPane
99 public void hyperlinkUpdate( HyperlinkEvent event )
100 {
101     // if hyperlink was activated, go to hyperlink's URL
102     if ( event.getEventType() ==
103         HyperlinkEvent.EventType.ACTIVATED ) {
104
105         // get URL from HyperlinkEvent
106         URL url = event.getURL();
107
108         // navigate to URL and display URL in urlTextField
109         webBrowserPane.goToURL( url );
110         urlTextField.setText( url.toString() );
111     }
112 }
113 }
```

Fig. 2.3 **WebToolBar** **JToolBar** subclass for navigating URLs in a **WebBrowserPane** (part 3 of 3).

Based on class **JToolBar**'s inheritance hierarchy, each **JToolBar** also is a **java.awt.Container** and therefore can contain other GUI components. Lines 92–94 add **backButton**, **forwardButton** and **urlTextField** to the **WebToolBar** by invoking method **add** of class **JToolBar**. A **JToolBar** has property **orientation** that specifies how the **JToolBar** will arrange its child components. The default is horizontal orientation, so the **JToolBar** lays out these components next to one another, left to right.

Class **WebBrowserPane** renders HTML pages, which may contain hyperlinks to other Web pages. When a user activates a hyperlink in a **WebBrowserPane** (e.g., by clicking on the hyperlink), the **WebBrowserPane** issues a **HyperlinkEvent** of type **HyperlinkEvent.EventType.ACTIVATED**. Class **WebToolBar** implements interface **HyperlinkListener** to listen for **HyperlinkEvents**. There are several **HyperlinkEvent** types. Method **hyperlinkUpdate** (lines 99–112) invokes method **getEventType** of class **HyperlinkEvent** to check the event type (lines 102–103) and retrieves the **HyperlinkEvent**'s URL (line 106). This is the URL of the user-selected hyperlink. Line 109 invokes method **goToURL** of class **WebBrowserPane** to navigate to the selected URL, and line 110 updates **urlTextField** to display the selected URL.

Class **WebBrowser** (Fig. 2.4) uses a **WebBrowserPane** and **WebToolBar** to create a simple Web-browser application. Line 26 creates a **WebBrowserPane**, and line 27 creates a **WebToolBar** for this **WebBrowserPane**. Lines 31–33 add the **WebBrowserPane** and **WebToolBar** to the **WebBrowser**'s content pane.

```
1 // WebBrowser.java
2 // WebBrowser is an application for browsing Web sites using
3 // a WebToolBar and WebBrowserPane.
4 package com.deitel.advjhtp1.gui.webbrowser;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.net.*;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.swing.event.*;
14
15 public class WebBrowser extends JFrame {
16
17     private WebToolBar toolBar;
18     private WebBrowserPane browserPane;
19
20     // WebBrowser constructor
21     public WebBrowser()
22     {
23         super( "Deitel Web Browser" );
24
25         // create WebBrowserPane and WebToolBar for navigation
26         browserPane = new WebBrowserPane();
27         toolBar = new WebToolBar( browserPane );
28
29         // lay out WebBrowser components
30         Container contentPane = getContentPane();
31         contentPane.add( toolBar, BorderLayout.NORTH );
32         contentPane.add( new JScrollPane( browserPane ),
33                         BorderLayout.CENTER );
34     }
35
36     // execute application
37     public static void main( String args[] )
38     {
39         WebBrowser browser = new WebBrowser();
40         browser.setDefaultCloseOperation( EXIT_ON_CLOSE );
41         browser.setSize( 640, 480 );
42         browser.setVisible( true );
43     }
44 }
```

Fig. 2.4 **WebBrowser** application for browsing Web sites using **WebBrowserPane** and **WebToolBar** (part 1 of 2).

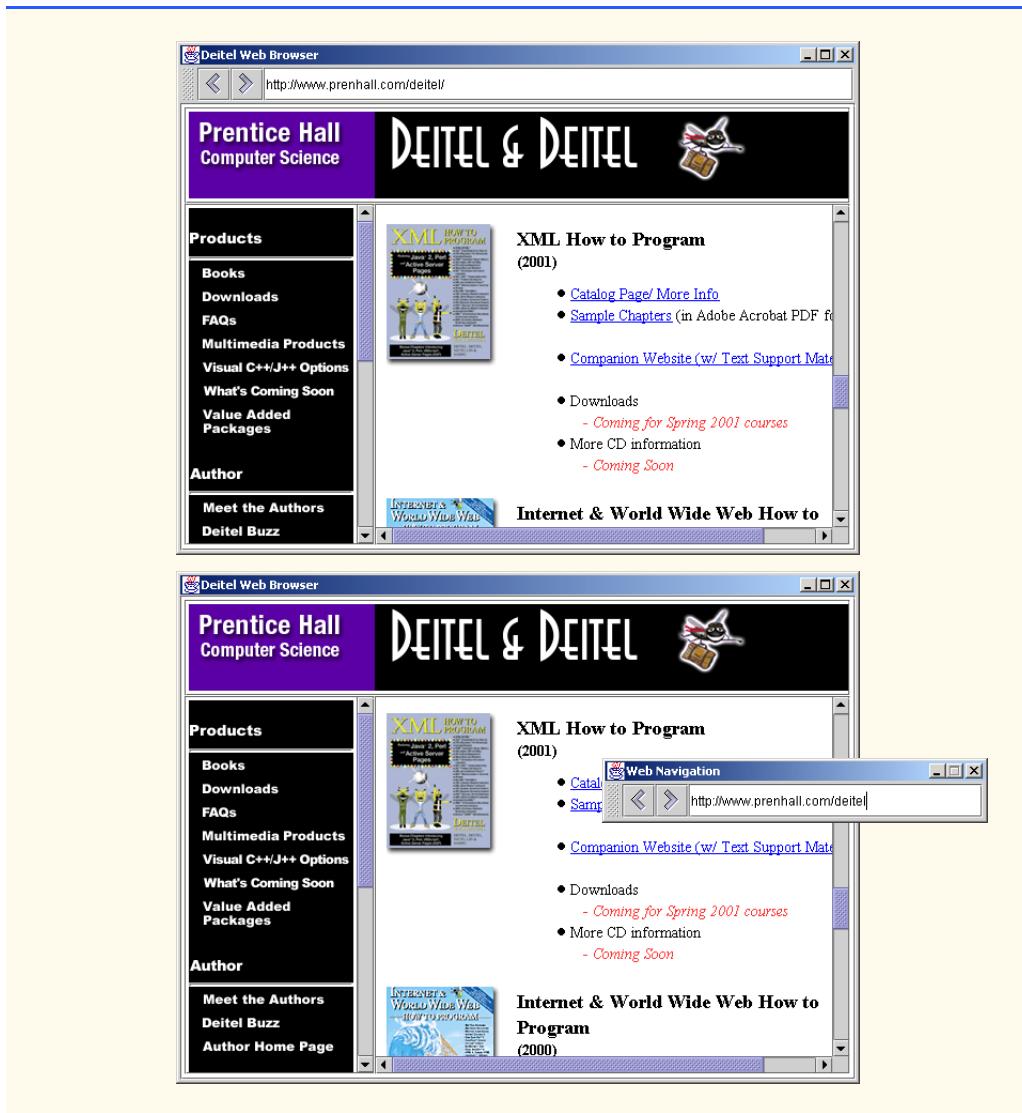


Fig. 2.4 **WebBrowser** application for browsing Web sites using **WebBrowserPane** and **WebToolBar** (part 2 of 2).

## 2.3 Swing Actions

Applications often provide users with several different ways to perform a given task. For example, in a word processor there might be an **Edit** menu with menu items for cutting, copying and pasting text. There also might be a toolbar that has buttons for cutting, copying and pasting text. There also might be a pop-up menu to allow users to right click on a document to cut, copy or paste text. The functionality the application provides is the same in each case—the developer provides the various interface components for the user's convenience. However, the same GUI component instance (e.g., a **JButton** for cutting text)

cannot be used for menus and toolbars and pop-up menus, so the developer must code the same functionality three times. If there were many such interface items, repeating this functionality would become tedious and error-prone.

The *Command design pattern* solves this problem by enabling developers to define the functionality (e.g., copying text) once in a reusable object that the developer then can add to a menu, toolbar or pop-up menu. This design pattern is called Command because it defines a user command or instruction. The **Action** interface defines required methods for the Java Swing implementation of the Command design pattern.

An **Action** represents user-interface logic and properties for GUI components that represent that logic, such as the label for a button, the text for a tool tip and the mnemonic key for keyboard access. The logic takes the form of an **actionPerformed** method that the event mechanism invokes in response to the user activating an interface component (e.g., the user clicking a **JButton**). Interface **Action** extends interface **ActionListener**, which enables **Actions** to process **ActionEvents** generated by GUI components. Once a developer defines an **Action**, the developer can add that **Action** to a **JMenu** or **JToolBar**, just as if the **Action** were a **JMenuItem** or **JButton**. For example, when a developer adds an **Action** to a **JMenu**, the **JMenu** creates a **JMenuItem** for the **Action** and uses the **Action** properties to configure the **JMenuItem**.

**Actions** provide an additional benefit in that the developer can enable or disable all GUI components associated with an **Action** by enabling or disabling the **Action** itself. For example, copying text from a document first requires that the user select the text to be copied. If there is no selected text, the program should not allow the user to perform a copy operation. If the application used a separate **JMenuItem** in a **JMenu** and **JButton** in a **JToolBar** for copying text, the developer would need to disable each of these GUI components individually. Using **Actions**, the developer could disable the **Action** for copying text, which also would disable all associated GUI components.

**ActionSample** (Fig. 2.5) demonstrates two **Actions**. Lines 15–16 declare **Action** references **sampleAction** and **exitAction**.

```
1 // ActionSample.java
2 // Demonstrating the Command design pattern with Swing Actions.
3 package com.deitel.advjhtp1.gui.actions;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.event.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class ActionSample extends JFrame {
13
14     // Swing Actions
15     private Action sampleAction;
16     private Action exitAction;
17 }
```

Fig. 2.5 **ActionSample** application demonstrating the Command design pattern with Swing **Actions** (part 1 of 4).

```
18 // ActionSample constructor
19 public ActionSample()
20 {
21     super( "Using Actions" );
22
23     // create AbstractAction subclass for sampleAction
24     sampleAction = new AbstractAction() {
25
26         public void actionPerformed( ActionEvent event )
27     {
28             // display message indicating sampleAction invoked
29             JOptionPane.showMessageDialog( ActionSample.this,
30                 "The sampleAction was invoked" );
31
32             // enable exitAction and associated GUI components
33             exitAction.setEnabled( true );
34         }
35     };
36
37     // set Action name
38     sampleAction.putValue( Action.NAME, "Sample Action" );
39
40     // set Action Icon
41     sampleAction.putValue( Action.SMALL_ICON, new ImageIcon(
42         getClass().getResource( "images/Help24.gif" ) ) );
43
44     // set Action short description (tooltip text)
45     sampleAction.putValue( Action.SHORT_DESCRIPTION,
46         "A Sample Action" );
47
48     // set Action mnemonic key
49     sampleAction.putValue( Action.MNEMONIC_KEY,
50         new Integer( 'S' ) );
51
52     // create AbstractAction subclass for exitAction
53     exitAction = new AbstractAction() {
54
55         public void actionPerformed( ActionEvent event )
56     {
57         // display message indicating exitAction invoked
58         JOptionPane.showMessageDialog( ActionSample.this,
59             "The exitAction was invoked" );
60         System.exit( 0 );
61     }
62 };
63
64     // set Action name
65     exitAction.putValue( Action.NAME, "Exit" );
66
67     // set Action icon
68     exitAction.putValue( Action.SMALL_ICON, new ImageIcon(
69         getClass().getResource( "images/EXIT.gif" ) ) );
```

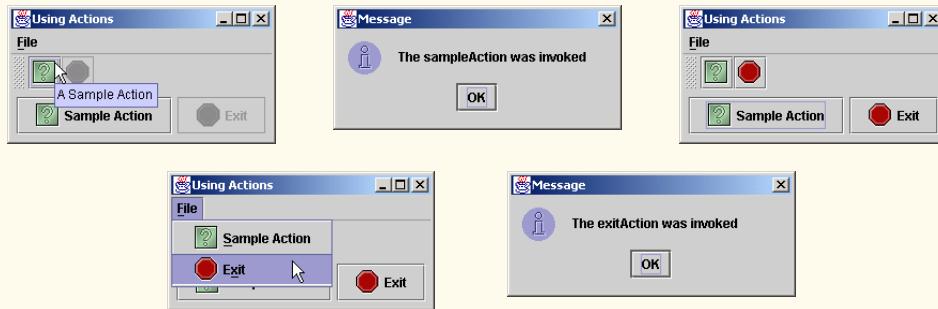
Fig. 2.5 **ActionSample** application demonstrating the Command design pattern with Swing **Actions** (part 2 of 4).

```
70
71     // set Action short description (tooltip text)
72     exitAction.putValue( Action.SHORT_DESCRIPTION,
73         "Exit Application" );
74
75     // set Action mnemonic key
76     exitAction.putValue( Action.MNEMONIC_KEY,
77         new Integer( 'x' ) );
78
79     // disable exitAction and associated GUI components
80     exitAction.setEnabled( false );
81
82     // create File menu
83     JMenu fileMenu = new JMenu( "File" );
84
85     // add sampleAction and exitAction to File menu to
86     // create a JMenuItem for each Action
87     fileMenu.add( sampleAction );
88     fileMenu.add( exitAction );
89
90     fileMenu.setMnemonic( 'F' );
91
92     // create JMenuBar and add File menu
93     JMenuBar menuBar = new JMenuBar();
94     menuBar.add( fileMenu );
95     setJMenuBar( menuBar );
96
97     // create JToolBar
98     JToolBar toolBar = new JToolBar();
99
100    // add sampleAction and exitAction to JToolBar to create
101    // JButtons for each Action
102    toolBar.add( sampleAction );
103    toolBar.add( exitAction );
104
105    // create JButton and set its Action to sampleAction
106    JButton sampleButton = new JButton();
107    sampleButton.setAction( sampleAction );
108
109    // create JButton and set its Action to exitAction
110    JButton exitButton = new JButton( exitAction );
111
112    // lay out JButtons in JPanel
113    JPanel buttonPanel = new JPanel();
114    buttonPanel.add( sampleButton );
115    buttonPanel.add( exitButton );
116
117    // add toolBar and buttonPanel to JFrame's content pane
118    Container container = getContentPane();
119    container.add( toolBar, BorderLayout.NORTH );
120    container.add( buttonPanel, BorderLayout.CENTER );
121 }
```

Fig. 2.5 **ActionSample** application demonstrating the Command design pattern with Swing **Actions** (part 3 of 4).

```

122
123     // execute application
124     public static void main( String args[] )
125     {
126         ActionSample sample = new ActionSample();
127         sample.setDefaultCloseOperation( EXIT_ON_CLOSE );
128         sample.pack();
129         sample.setVisible( true );
130     }
131 }
```



**Fig. 2.5** **ActionSample** application demonstrating the Command design pattern with Swing **Actions** (part 4 of 4).

Lines 24–35 create an anonymous inner class that extends class **AbstractAction** and assigns the instance to reference **sampleAction**. Class **AbstractAction** facilitates creating **Action** objects. Class **AbstractAction** implements interface **Action**, but is marked **abstract** because class **AbstractAction** does not provide an implementation for method **actionPerformed**. Lines 26–34 implement method **actionPerformed**. The Swing event mechanism invokes method **actionPerformed** when the user activates a GUI component associated with **sampleAction**. We show how to create these GUI components shortly. Lines 29–30 in method **actionPerformed** display a **JOptionPane** message dialog to inform the user that **sampleAction** was invoked. Line 33 then invokes method **setEnabled** of interface **Action** on the **exitAction** reference. This enables the **exitAction** and its associated GUI components. Note that **Actions** are enabled by default. We disabled the **exitAction** (line 80) to demonstrate that this disables the GUI components associated with that **Action**.

After instantiating an **AbstractAction** subclass to create **sampleAction**, lines 38–50 repeatedly invoke method **putValue** of interface **Action** to configure **sampleAction** properties. Each property has a key and a value. Interface **Action** defines the keys as **public** constants, which we list in Fig. 2.6. GUI components associated with **sampleAction** use the property values we assign for GUI component labels, icons, tool-tips and so on. Line 38 invokes method **putValue** of interface **Action** with arguments **Action.NAME** and "**Sample Action**". This assigns **sampleAction**'s name, which GUI components use as their label. Lines 41–42 invoke method **putValue** of interface **Action** with key **Action.SMALL\_ICON** and an **ImageIcon** value, which GUI components use as their **Icon**. Lines 45–46 set the **Action**'s tool tip using key

**Action.SHORT\_DESCRIPTION**. Lines 49–50 set the **Action**'s mnemonic key using key **Action.MNEMONIC\_KEY**. When the **Action** is placed in a **JMenu**, the mnemonic key provides keyboard access to the **Action**. Lines 53–80 create the **exitAction** in a similar way to **sampleAction**, with an appropriate name, icon, description and mnemonic key. Line 80 invokes method **setEnabled** of interface **Action** with argument **false** to disable the **exitAction**. We use this to demonstrate that disabling an **Action** also disables the **Action**'s associated GUI components.

Line 83 creates the **fileMenu JMenu**, which contains **JMenuItem**s corresponding to **sampleAction** and **exitAction**. Class **JMenu** overloads method **add** with a version that takes an **Action** argument. This overloaded **add** method returns a reference to the **JMenuItem** that it creates. Lines 87–88 invoke method **add** of class **JMenu** to add **sampleAction** and **exitAction** to the menu. We have no need for the **JMenuItem** references that method **add** returns, so we ignore them. Line 90 sets the **fileMenu** mnemonic key, and lines 93–95 add the **fileMenu** to a **JMenuBar** and invoke method **setJMenuBar** of class **JFrame** to add the **JMenuBar** to the application.

Line 98 creates a new **JToolBar**. Like **JMenu**, **JToolBar** also provides overloaded method **add** for adding **Actions** to **JToolBars**. Method **add** of class **JToolBar** returns a reference to the **JButton** created for the given **Action**. Lines 102–103 invoke method **add** of class **JToolBar** to add the **sampleAction** and **exitAction** to the **JToolBar**. We have no need for the **JButton** references that method **add** returns, so we ignore them.

Class **JButton** provides method **setAction** for configuring a **JButton** with properties of an **Action**. Line 106 creates **JButton sampleButton**. Line 107 invokes method **setAction** of class **JButton** with a **sampleAction** argument to configure **sampleButton**. Line 110 demonstrates an alternative way to configure a **JButton** with properties from an **Action**. The **JButton** constructor is overloaded to accept an **Action** argument. The constructor configures the **JButton** using properties from the given **Action**.

### Software Engineering Observation 2.1



According to the Java 2 SDK documentation, it is preferable to create **JButtons** and **JMenuItem**s, invoke method **setAction** then add the **JButton** or **JMenuItem** to its container, rather than adding the **Action** to the container directly. This is because most GUI-building tools do not support adding **Actions** to containers directly.

Lines 113–120 add the newly created **JButtons** to a **JPanel** and lay out the **JToolBar** and **JPanel** in the **JFrame**'s content pane. Note that in the first screen capture of Fig. 2.5, the **JButtons** for **exitAction** appear grayed-out. This is because the **exitAction** is disabled. After invoking the **sampleAction**, the **exitAction** is **enabled** and appears in full color. Note also the tool tips, icons and labels on each GUI component. Each of these items was configured using properties of the respective **Action** object.

Figure 2.6 summarizes **Action** properties. Each property name is a **static** constant in interface **Action** and acts as a key for setting or retrieving the property value.

In the following sections we demonstrate two alternative ways to create Swing **Action** instances. The first uses named inner classes. The second defines a generic **AbstractAction** subclass that provides a constructor for commonly used properties and *set* methods for each individual **Action** property.

Name	Description
<code>NAME</code>	Name to be used for GUI-component labels.
<code>SHORT_DESCRIPTION</code>	Descriptive text for use in tooltips.
<code>SMALL_ICON</code>	<code>Icon</code> for displaying in GUI-component labels.
<code>MNEMONIC_KEY</code>	Mnemonic key for keyboard access (e.g., for accessing menus and menu items using the keyboard).
<code>ACCELERATOR_KEY</code>	Accelerator key for keyboard access (e.g., using the <i>Ctrl</i> key).
<code>ACTION_COMMAND_KEY</code>	Key for retrieving command string to be used in <code>ActionEvents</code> .
<code>LONG_DESCRIPTION</code>	Descriptive text, e.g., for application help.

Fig. 2.6 `Action` class `static` keys for `Action` properties.

## 2.4 JSplitPane and JTabbedPane

**JSplitPane** and **JTabbedPane** are container components that enable developers to present large amounts of information in a small screen area. **JSplitPane** accomplishes this by dividing two components with a divider users can reposition to expand and contract the visible areas of the **JSplitPane**'s child components (Fig. 2.7). **JTabbedPane** uses a file-folder-style tab interface to arrange many components through which the user can browse.



### Look-and-Feel Observation 2.1

**JSplitPanes** can contain only two child components. However, each child component may contain nested components.

**FavoritesWebBrowser** (Fig. 2.7) is an application that uses a **JSplitPane** to show two **WebBrowserPane** components side-by-side in a single application window. On the left side, the **JSplitPane** contains a **WebBrowserPane** that displays a static HTML page containing links to the user's favorite Web sites. Activating the links in this favorites page displays the URL contents in the **WebBrowserPane** on the right side of the **JSplitPane**. This is a common user interface arrangement in Web browsers, such as Internet Explorer and Netscape Navigator.

```

1 // FavoritesWebBrowser.java
2 // FavoritesWebBrowser is an application for browsing Web sites
3 // using a WebToolBar and WebBrowserPane and displaying an HTML
4 // page containing links to favorite Web sites.
5 package com.deitel.advjhtp1.gui.splitpane;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.net.*;
11

```

Fig. 2.7 **FavoritesWebBrowser** application for displaying two Web pages side-by-side using **JSplitPane** (part 1 of 3).

```
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.event.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.gui.webbrowser.*;
18
19 public class FavoritesWebBrowser extends JFrame {
20
21     private WebToolBar toolBar;
22     private WebBrowserPane browserPane;
23     private WebBrowserPane favoritesBrowserPane;
24
25     // WebBrowser constructor
26     public FavoritesWebBrowser()
27     {
28         super( "Deitel Web Browser" );
29
30         // create WebBrowserPane and WebToolBar for navigation
31         browserPane = new WebBrowserPane();
32         toolBar = new WebToolBar( browserPane );
33
34         // create WebBrowserPane for displaying favorite sites
35         favoritesBrowserPane = new WebBrowserPane();
36
37         // add WebToolBar as listener for HyperlinkEvents
38         // in favoritesBrowserPane
39         favoritesBrowserPane.addHyperlinkListener( toolBar );
40
41         // display favorites.html in favoritesBrowserPane
42         favoritesBrowserPane goToURL(
43             getClass().getResource( "favorites.html" ) );
44
45         // create JSplitPane with horizontal split (side-by-side)
46         // and add WebBrowserPanes with JScrollPanes
47         JSplitPane splitPane = new JSplitPane(
48             JSplitPane.HORIZONTAL_SPLIT,
49             new JScrollPane( favoritesBrowserPane ),
50             new JScrollPane( browserPane ) );
51
52         // position divider between WebBrowserPanes
53         splitPane.setDividerLocation( 210 );
54
55         // add buttons for expanding/contracting divider
56         splitPane.setOneTouchExpandable( true );
57
58         // lay out WebBrowser components
59         Container contentPane = getContentPane();
60         contentPane.add( toolBar, BorderLayout.NORTH );
61         contentPane.add( splitPane, BorderLayout.CENTER );
62     }
63 }
```

Fig. 2.7 **FavoritesWebBrowser** application for displaying two Web pages side-by-side using **JSplitPane** (part 2 of 3).

```
64    // execute application
65    public static void main( String args[] )
66    {
67        FavoritesWebBrowser browser = new FavoritesWebBrowser();
68        browser.setDefaultCloseOperation( EXIT_ON_CLOSE );
69        browser.setSize( 640, 480 );
70        browser.setVisible( true );
71    }
72 }
```

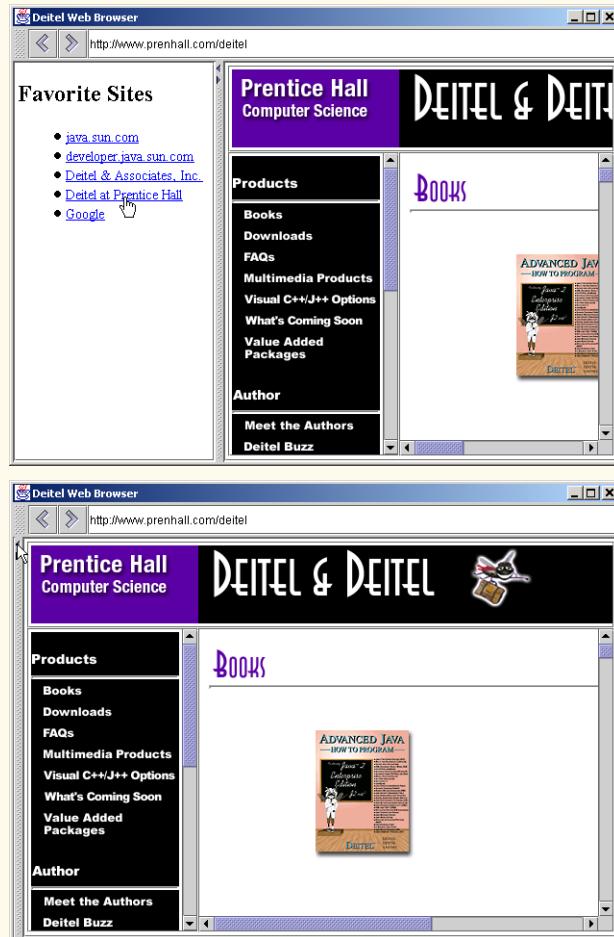


Fig. 2.7 **FavoritesWebBrowser** application for displaying two Web pages side-by-side using **JSplitPane** (part 3 of 3).

Lines 31–32 create a **WebBrowserPane** for displaying Web pages and a **WebToolBar** for navigating this **WebBrowserPane**. Line 35 creates an additional **WebBrowser** pane called **favoritesBrowserPane**, which the application will use to display **favorites.html**. This HTML document contains hyperlinks to some favorite Web sites. Line 39 invokes method **addHyperlinkListener** of class **WebBrowser-**

**Pane** to register the **toolBar** as a **HyperlinkListener** for **favoritesBrowserPane**. When a user activates a link in **favoritesBrowserPane**, **toolBar** will receive the **HyperlinkEvent** and display the activated URL in **browserPane**. This way the user can activate links in **favoritesBrowserPane** and display those links in **browserPane**. Lines 42–43 invoke method **goToURL** of class **WebBrowserPane** to load **favorites.html** in **favoritesBrowserPane**.

Lines 47–50 create a **JSplitPane**. This **JSplitPane** constructor takes as its first argument an integer that indicates the **JSplitPane** orientation. The constant **JSplitPane.HORIZONTAL\_SPLIT** specifies the **JSplitPane** should display its child components side-by-side. The constant **JSplitPane.VERTICAL\_SPLIT** would specify that the **JSplitPane** should display its child components one on top of the other. The second and third arguments to this **JSplitPane** constructor are the components to be divided in the **JSplitPane**. In this case, we add **favoritesBrowserPane** to the left side of the **JSplitPane** and **browserPane** to the right side of the **JSplitPane**. We place each **WebBrowserPane** in a **JScrollPane** to allow the user to scroll if the content exceeds the visible area.

Line 53 invokes method **setDividerLocation** of class **JSplitPane** to set the exact divider position between **favoritesBrowserPane** and **browserPane**. Line 56 invokes method **setOneTouchExpandable** of class **JSplitPane** to add two buttons to the divider that enable the user to expand or collapse the divider to one side or the other with a single click. Note the arrows on the divider in Fig. 2.7.

### Good Programming Practice 2.1



Place child components in **JScrollPanels** before adding the components to a **JSplitPane**. This ensures that the user will be able to view all the content in each child component by scrolling if necessary.

**JTabbedPane** presents multiple components in separate tabs, which the user can navigate using a mouse or keyboard. Dialog boxes often use components similar to **JTabbedPane**s. For example, Fig. 2.8 shows the **Display Properties** tabbed dialog in Windows 2000.

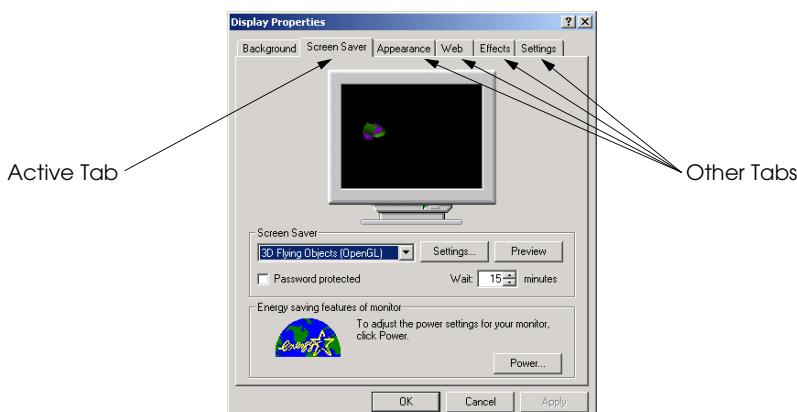


Fig. 2.8 Tabbed interface of **Display Properties** dialog box in Windows 2000.

**TabbedPaneWebBrowser** (Fig. 2.9) uses a **JTabbedPane** to enable users to browse multiple Web pages at once in a single application window. The user invokes an **Action** to add a new **WebBrowserPane** to the **JTabbedPane**. Each time the user adds a new **WebBrowserPane**, the **JTabbedPane** creates a new tab and places the **WebBrowserPane** in this new tab.

```
1 // TabbedPaneWebBrowser.java
2 // TabbedPaneWebBrowser is an application that uses a
3 // JTabbedPane to display multiple Web browsers.
4 package com.deitel.advjhttp1.gui.tabbedPane;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 // Deitel packages
14 import com.deitel.advjhttp1.gui.webbrowser.*;
15
16 public class TabbedPaneWebBrowser extends JFrame {
17
18     // JTabbedPane for displaying multiple browser tabs
19     private JTabbedPane tabbedPane = new JTabbedPane();
20
21     // TabbedPaneWebBrowser constructor
22     public TabbedPaneWebBrowser()
23     {
24         super( "JTabbedPane Web Browser" );
25
26         // create first browser tab
27         createNewTab();
28
29         // add JTabbedPane to contentPane
30         getContentPane().add( tabbedPane );
31
32         // create File JMenu for creating new browser tabs and
33         // exiting application
34         JMenu fileMenu = new JMenu( "File" );
35         fileMenu.add( new NewTabAction() );
36         fileMenu.addSeparator();
37         fileMenu.add( new ExitAction() );
38         fileMenu.setMnemonic( 'F' );
39
40         JMenuBar menuBar = new JMenuBar();
41         menuBar.add( fileMenu );
42         setJMenuBar( menuBar );
43
44     } // end TabbedPaneWebBrowser constructor
45
```

Fig. 2.9 **TabbedPaneWebBrowser** application using **JTabbedPane** to browse multiple Web sites concurrently (part 1 of 3).

```
46 // create new browser tab
47 private void createNewTab()
48 {
49     // create JPanel to contain WebBrowserPane and WebToolBar
50     JPanel panel = new JPanel( new BorderLayout() );
51
52     // create WebBrowserPane and WebToolBar
53     WebBrowserPane browserPane = new WebBrowserPane();
54     WebToolBar toolBar = new WebToolBar( browserPane );
55
56     // add WebBrowserPane and WebToolBar to JPanel
57     panel.add( toolBar, BorderLayout.NORTH );
58     panel.add( new JScrollPane( browserPane ),
59                 BorderLayout.CENTER );
60
61     // add JPanel to JTabbedPane
62     tabbedPane.addTab( "Browser " + tabbedPane.getTabCount(),
63                        panel );
64 }
65
66 // Action for creating new browser tabs
67 private class NewTabAction extends AbstractAction {
68
69     // NewTabAction constructor
70     public NewTabAction()
71     {
72         // set name, description and mnemonic key
73         putValue( Action.NAME, "New Browser Tab" );
74         putValue( Action.SHORT_DESCRIPTION,
75                   "Create New Web Browser Tab" );
76         putValue( Action.MNEMONIC_KEY, new Integer( 'N' ) );
77     }
78
79     // when Action invoked, create new browser tab
80     public void actionPerformed( ActionEvent event )
81     {
82         createNewTab();
83     }
84 }
85
86 // Action for exiting application
87 private class ExitAction extends AbstractAction {
88
89     // ExitAction constructor
90     public ExitAction()
91     {
92         // set name, description and mnemonic key
93         putValue( Action.NAME, "Exit" );
94         putValue( Action.SHORT_DESCRIPTION, "Exit Application" );
95         putValue( Action.MNEMONIC_KEY, new Integer( 'x' ) );
96     }
97 }
```

Fig. 2.9 **TabbedPaneWebBrowser** application using **JTabbedPane** to browse multiple Web sites concurrently (part 2 of 3).

```
98      // when Action invoked, exit application
99      public void actionPerformed( ActionEvent event )
100     {
101         System.exit( 0 );
102     }
103 }
104
105 // execute application
106 public static void main( String args[] )
107 {
108     TabbedPaneWebBrowser browser = new TabbedPaneWebBrowser();
109     browser.setDefaultCloseOperation( EXIT_ON_CLOSE );
110     browser.setSize( 640, 480 );
111     browser.setVisible( true );
112 }
113 }
```

Fig. 2.9 **TabbedPaneWebBrowser** application using **JTabbedPane** to browse multiple Web sites concurrently (part 3 of 3).

Line 19 creates a new **JTabbedPane**, to which the user will add **WebBrowserPanes**. Line 27 invokes method **createNewTab** of class **TabbedPaneWebBrowser** to create the first **WebBrowserPane** and place it in the **JTabbedPane**. Line 30 adds the **JTabbedPane** to the **TabbedPaneWebBrowser**'s content pane. Lines 34–42 create the **File** menu, which contains an **Action** for creating new **WebBrowserPanes** (line 35) and an **Action** for exiting the application (line 37). We discuss these actions in detail momentarily.

Method **createNewTab** (lines 46–64) creates a new **WebBrowserPane** and adds it to the **JTabbedPane**. Line 50 creates a **JPanel** for laying out the **WebBrowserPane** and its **WebToolBar**. Lines 53–59 create a **WebBrowserPane** and a **WebToolBar** and add them to the **JPanel**. Lines 62–63 invoke method **addTab** of class **JTabbedPane** to add the **JPanel** containing the **WebBrowserPane** and **WebToolBar** to the application's **JTabbedPane**. Method **addTab** of class **JTabbedPane** takes as a **String** argument the title for the new tab and as a **Component** argument the **Component** to display in the new tab. Although a developer may add any **Component** instance to a **JTabbedPane** to create a new tab, developers most commonly lay out components in a **JPanel** and add the **JPanel** to the **JTabbedPane**.

Figure 2.9 also demonstrates a second way to create **Action** instances. Lines 67–84 define inner class **NewTabAction**, which extends **AbstractAction**. The **NewTabAction** constructor (lines 70–77) configures the **Action** by invoking method **putValue** for the **Action** name, tool tip and mnemonic key. Lines 80–83 define method **actionPerformed** and invoke method **createNewTab** (line 82) to create a new tab in the **JTabbedPane** containing a **WebBrowserPane** and **WebToolBar**.

Lines 87–103 define inner class **ExitAction**, which also extends **AbstractAction**. The **ExitAction** constructor (lines 90–96) configures the **Action** name, tool tip and mnemonic key by invoking method **putValue**. Method **actionPerformed** (lines 99–102) invokes **static** method **exit** of class **System** to exit the application.

## 2.5 Multiple-Document Interfaces

Most applications provide a single-document interface—users can view and edit only one document at a time. For example, most Web browsers allow users to view only one Web page. To view multiple Web pages, users must launch additional Web browsers. *Multiple document interfaces* allow users to view multiple documents in a single application. Each document appears in a separate window in the application. The user can arrange, resize, iconify (i.e., minimize) and maximize these separate document windows like application windows on the desktop. For example, a digital photograph-editing application could use a multiple document interface to enable users to view and edit multiple photographs at once. The user could place the photograph windows side-by-side to compare the photographs or copy part of one photograph and paste it into the other.

Java Swing provides classes **JDesktopPane** and **JInternalFrame** for building multiple-document interfaces. These class names reinforce the idea that each document is a separate window (**JInternalFrame**) inside the application’s desktop (**JDesktopPane**), just as other applications are separate windows (e.g., **JFrames**) on the operating system’s desktop. **JInternalFrames** behave much like **JFrames**. Users can maximize, iconify, resize, open and close **JInternalFrames**. **JInternalFrames** have title bars with buttons for iconifying, maximizing and closing. Users also can move **JInternalFrames** within the **JDesktopPane**.

**MDIWebBrowser** (Fig. 2.10) uses **JInternalFrames** and a **JDesktopPane** to enable users to browse multiple Web sites within a single application window. Line 20 creates a **JDesktopPane**, which is a container for **JInternalFrames**. Line 32 adds the **JDesktopPane** to the **JFrame**’s content pane. Lines 36–44 construct the application menu. The **File** menu includes an **Action** for creating new browser windows (line 37) and an **Action** for exiting the application (line 39).

```
1 // MDIWebBrowser.java
2 // MDIWebBrowser is an application that uses JDesktopPane
3 // and JInternalFrames to create a multiple-document-interface
4 // application for Web browsing.
5 package com.deitel.advjhttp1.gui.mdi;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 // Deitel packages
15 import com.deitel.advjhttp1.gui.webbrowser.*;
16
17 public class MDIWebBrowser extends JFrame {
18
19     // JDesktopPane for multiple document interface
20     JDesktopPane desktopPane = new JDesktopPane();
```

Fig. 2.10 **MDIWebBrowser** application using **JDesktopPane** and **JInternalFrames** to browse multiple Web sites concurrently (part 1 of 4).

```
21
22     // MDIWebBrowser constructor
23     public MDIWebBrowser()
24     {
25         super( "MDI Web Browser" );
26
27         // create first browser window
28         createNewWindow();
29
30         // add JDesktopPane to contentPane
31         Container contentPane = getContentPane();
32         contentPane.add( desktopPane );
33
34         // create File JMenu for creating new windows and
35         // exiting application
36         JMenu fileMenu = new JMenu( "File" );
37         fileMenu.add( new NewWindowAction() );
38         fileMenu.addSeparator();
39         fileMenu.add( new ExitAction() );
40         fileMenu.setMnemonic( 'F' );
41
42         JMenuBar menuBar = new JMenuBar();
43         menuBar.add( fileMenu );
44         setJMenuBar( menuBar );
45     }
46
47     // create new browser window
48     private void createNewWindow()
49     {
50         // create new JInternalFrame that is resizable, closable,
51         // maximizable and iconifiable
52         JInternalFrame frame = new JInternalFrame(
53             "Browser", // title
54             true, // resizable
55             true, // closable
56             true, // maximizable
57             true ); // iconifiable
58
59         // create WebBrowserPane and WebToolBar
60         WebBrowserPane browserPane = new WebBrowserPane();
61         WebToolBar toolBar = new WebToolBar( browserPane );
62
63         // add WebBrowserPane and WebToolBar to JInternalFrame
64         Container contentPane = frame.getContentPane();
65         contentPane.add( toolBar, BorderLayout.NORTH );
66         contentPane.add( new JScrollPane( browserPane ),
67             BorderLayout.CENTER );
68
69         // make JInternalFrame opaque and set its size
70         frame.setSize( 320, 240 );
71     }
```

Fig. 2.10 **MDIWebBrowser** application using **JDesktopPane** and **JInternalFrames** to browse multiple Web sites concurrently (part 2 of 4).

```
72      // move JInternalFrame to prevent it from obscuring others
73      int offset = 30 * desktopPane.getAllFrames().length;
74      frame.setLocation( offset, offset );
75
76      // add JInternalFrame to JDesktopPane
77      desktopPane.add( frame );
78
79      // make JInternalFrame visible
80      frame.setVisible( true );
81  }
82
83  // Action for creating new browser windows
84  private class NewWindowAction extends AbstractAction {
85
86      // NewWindowAction constructor
87      public NewWindowAction()
88      {
89          // set name, description and mnemonic key
90          putValue( Action.NAME, "New Window" );
91          putValue( Action.SHORT_DESCRIPTION,
92                  "Create New Web Browser Window" );
93          putValue( Action.MNEMONIC_KEY, new Integer( 'N' ) );
94      }
95
96      // when Action invoked, create new browser window
97      public void actionPerformed( ActionEvent event )
98      {
99          createNewWindow();
100     }
101 }
102
103 // Action for exiting application
104 private class ExitAction extends AbstractAction {
105
106     // ExitAction constructor
107     public ExitAction()
108     {
109         // set name, description and mnemonic key
110         putValue( Action.NAME, "Exit" );
111         putValue( Action.SHORT_DESCRIPTION, "Exit Application" );
112         putValue( Action.MNEMONIC_KEY, new Integer( 'x' ) );
113     }
114
115     // when Action invoked, exit application
116     public void actionPerformed( ActionEvent event )
117     {
118         System.exit( 0 );
119     }
120 }
121
```

Fig. 2.10 **MDIWebBrowser** application using **JDesktopPane** and **JInternalFrames** to browse multiple Web sites concurrently (part 3 of 4).

```

122     // execute application
123     public static void main( String args[] )
124     {
125         MDIWebBrowser browser = new MDIWebBrowser();
126         browser.setDefaultCloseOperation( EXIT_ON_CLOSE );
127         browser.setSize( 640, 480 );
128         browser.setVisible( true );
129     }
130 }
```

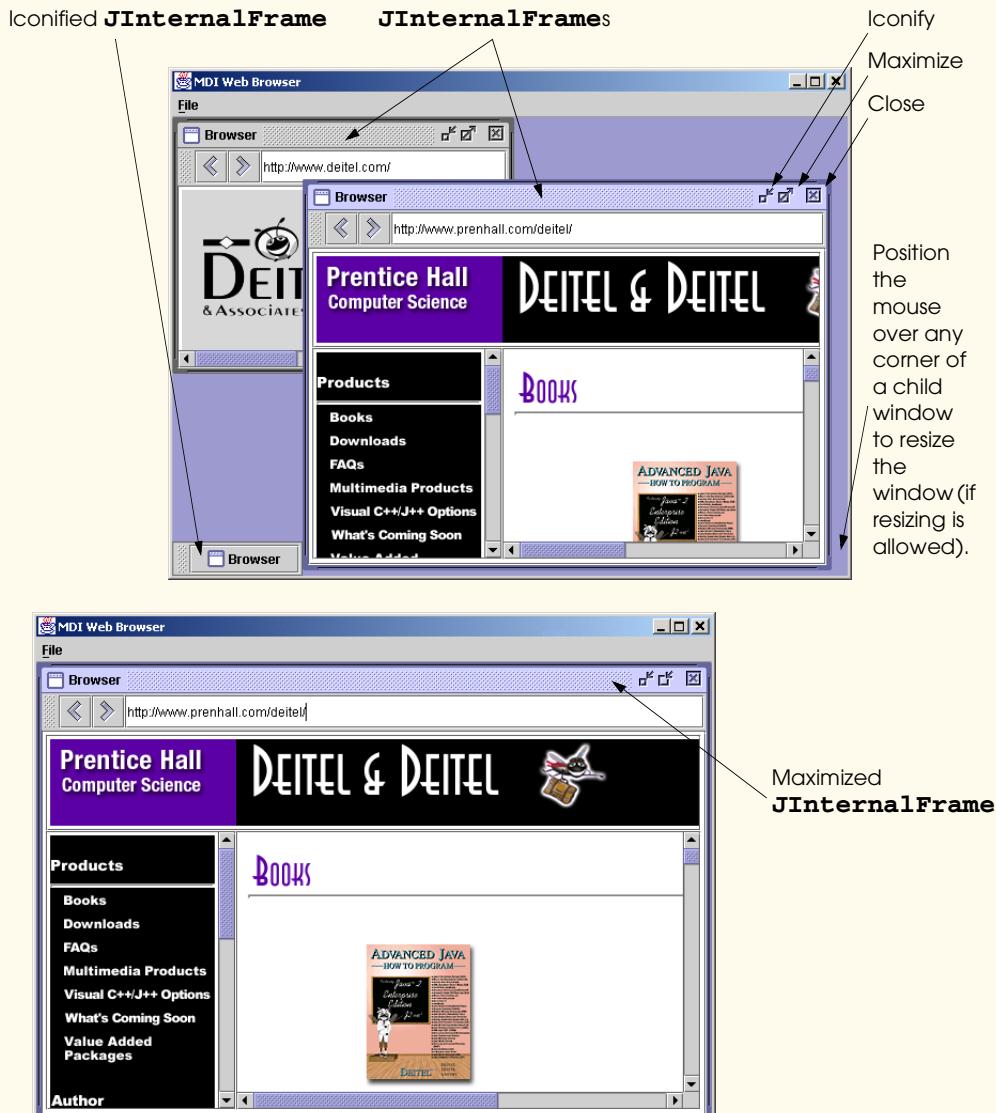


Fig. 2.10 MDIWebBrowser application using **JDesktopPane** and **JInternalFrames** to browse multiple Web sites concurrently (part 4 of 4).

Method `createNewWindow` (lines 48–81) creates a new `JInternalFrame` in response to the user invoking `NewWindowAction`. Lines 52–57 create a new `JInternalFrame` with the title "**Browser**". The four `boolean` arguments to the `JInternalFrame` constructor specify that the `JInternalFrame` is resizable, closable, maximizable and iconifiable. Lines 60–61 create a `WebBrowserPane` and `WebToolBar` for displaying and navigating Web pages. Like a `JFrame`, a `JInternalFrame` has a content pane. Line 64 invokes method `getContentPane` to get the `JInternalFrame`'s content pane, and lines 65–67 lay out the `WebToolBar` and `WebBrowserPane` in the content pane. A `JInternalFrame` has zero size when first created, so line 70 invokes method `setSize` of class `JInternalFrame` to size the `JInternalFrame` appropriately. To prevent new `JInternalFrames` from obscuring other `JInternalFrames` in the `JDesktopPane`, lines 73–74 invoke method `setLocation` of class `JInternalFrame` to position the new `JInternalFrame` at an offset from the previously created `JInternalFrame`. Line 77 invokes method `add` of class `JDesktopPane` to add the `JInternalFrame` to the display, and line 80 invokes method `setVisible` of class `JInternalFrame` to make the `JInternalFrame` visible.



### Look-and-Feel Observation 2.2

`JInternalFrames` have no size and are invisible by default. When creating a new `JInternalFrame`, be sure to invoke method `setSize` to size the `JInternalFrame` and `setVisible( true )` to make the `JInternalFrame` visible.

Class `MDIWebBrowser` uses two `Actions`—`NewWindowAction` for creating new Web browser windows and `ExitAction` for exiting the application. Lines 84–101 declare inner class `NewWindowAction`, which extends class `AbstractAction`. Lines 90–93 invoke method `putValue` of interface `Action` to configure `NewWindowAction` properties. Method `actionPerformed` (lines 97–100) invokes method `createNewWindow` to create a new Web browser window each time the user invokes `NewWindowAction`. Class `ExitAction` (lines 104–120) also invokes method `putValue` to configure the `Action` (lines 110–112) and implements method `actionPerformed` (lines 116–119) to exit the application (line 118) when invoked.

## 2.6 Drag and Drop

Drag and drop is a common way to manipulate data in a GUI. Most GUIs emulate real-world desktops, with icons that represent the objects on a virtual desk. Drag and drop enables users to move items around the desktop and to move and copy data among applications using mouse *gestures*. A gesture is a mouse movement that corresponds to a drag-and-drop *operation*, such as dragging a file from one folder and dropping the file into another folder.

Two Java APIs enable drag-and-drop data transfer between applications. The data transfer API—package `java.awt.datatransfer`—enables copying and moving data within a single application or among multiple applications. The drag-and-drop API enables Java applications to recognize drag-and-drop gestures and to respond to drag-and-drop operations. A drag-and-drop operation uses the data transfer API to transfer data from the *drag source* to the *drop target*. For example, a user could begin a drag gesture in a file-manager application (the drag source) to drag a file from a folder and drop the file on a Java application (the drop target). The Java application would use the drag-and-drop API to rec-

ognize that a drag-and-drop operation occurred and would use the data transfer API to retrieve the data transferred through the drag-and-drop operation.

**DnDWebBrowser** (Fig. 2.11) is a Web-browsing application that also allows users to drop a file onto the **WebBrowserPane** to view the file contents. For example, a user could drag an HTML file from the host operating system's file manager and drop the file on the **WebBrowserPane** to render the HTML. **DnDWebBrowser** uses the drag-and-drop API to recognize drag-and-drop operations and the data transfer API to retrieve the transferred data. Lines 32–33 create a **WebBrowserPane** component for viewing Web pages and a **WebToolBar** to provide navigation controls.

The **WebBrowserPane** in class **DnDWebBrowser** acts as a drop target (i.e., a user can drop a dragged object on the **WebBrowserPane**). Lines 37–38 invoke method **setDropTarget** of class **WebBrowserPane** and create a new **DropTarget** object. The first argument to the **DropTarget** constructor is the **java.awt.Component** that provides the GUI target onto which a user can drop objects. In this case, the **Component** is a **WebBrowserPane**. The second argument specifies the types of drag-and-drop operations that the **DropTarget** supports. Class **DnDConstants** specifies constant **ACTION\_COPY** for allowing a **DropTarget** to accept a drag-and-drop operation for copying a dragged object. Other operations include **ACTION\_MOVE** for moving an object and **ACTION\_LINK** for creating a link to an object (e.g., a symbolic link on a UNIX file-system). The third argument to the **DropTarget** constructor is the **DropTargetListener** to be notified of drag-and-drop operation events.

Class **DropTargetHandler** (lines 48–126) implements interface **DropTargetListener** to listen for drag-and-drop operation events related to a **DropTarget**. The drag-and-drop subsystem invokes method **drop** (lines 51–100) of interface **DropTargetListener** when the user drops an object on a **DropTarget**. Line 54 invokes method **getTransferable** of class **DropTargetDropEvent** to retrieve the **Transferable** object that the user dropped. Interface **java.awt.datatransfer.Transferable** declares methods that represent an object that can be transferred among applications. As part of the datatransfer API, interface **Transferable** represents objects that may be transferred through the system clipboard (e.g., via cut-and-paste operations) and objects that are transferred through drag and drop.

```
1 // DnDWebBrowser.java
2 // DnDWebBrowser is an application for viewing Web pages using
3 // drag and drop.
4 package com.deitel.advjhttp1.gui.dnd;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.dnd.*;
9 import java.awt.datatransfer.*;
10 import java.util.*;
11 import java.io.*;
12 import java.net.*;
13
```

Fig. 2.11 **DnDWebBrowser** application for browsing Web sites that also accepts drag-and-drop operations for viewing HTML pages (part 1 of 5).

```
14 // Java extension packages
15 import javax.swing.*;
16 import javax.swing.event.*;
17
18 // Deitel packages
19 import com.deitel.advjhttp1.gui.webbrowser.*;
20
21 public class DnDWebBrowser extends JFrame {
22
23     private WebToolBar toolBar;
24     private WebBrowserPane browserPane;
25
26     // DnDWebBrowser constructor
27     public DnDWebBrowser()
28     {
29         super( "Drag-and-Drop Web Browser" );
30
31         // create WebBrowserPane and WebToolBar for navigation
32         browserPane = new WebBrowserPane();
33         toolBar = new WebToolBar( browserPane );
34
35         // enable WebBrowserPane to accept drop operations, using
36         // DropTargetHandler as the DropTargetListener
37         browserPane.setDropTarget( new DropTarget( browserPane,
38             DnDConstants.ACTION_COPY, new DropTargetHandler() ) );
39
40         // lay out WebBrowser components
41         Container contentPane = getContentPane();
42         contentPane.add( toolBar, BorderLayout.NORTH );
43         contentPane.add( new JScrollPane( browserPane ),
44             BorderLayout.CENTER );
45     }
46
47     // inner class to handle DropTargetEvents
48     private class DropTargetHandler implements DropTargetListener {
49
50         // handle drop operation
51         public void drop( DropTargetDropEvent event )
52         {
53             // get dropped Transferable object
54             Transferable transferable = event.getTransferable();
55
56             // if Transferable is a List of Files, accept drop
57             if ( transferable.isDataFlavorSupported(
58                 DataFlavor.javaFileListFlavor ) ) {
59
60                 // accept the drop operation to copy the object
61                 event.acceptDrop( DnDConstants.ACTION_COPY );
62
63                 // process list of files and display each in browser
64                 try {
65
```

Fig. 2.11 **DnDWebBrowser** application for browsing Web sites that also accepts drag-and-drop operations for viewing HTML pages (part 2 of 5).

```
66          // get List of Files
67          java.util.List fileList =
68              ( java.util.List ) transferable.getTransferData(
69                  DataFlavor.javaFileListFlavor );
70
71          Iterator iterator = fileList.iterator();
72
73          while ( iterator.hasNext() ) {
74              File file = ( File ) iterator.next();
75
76              // display File in browser and complete drop
77              browserPane.goToURL( file.toURL() );
78          }
79
80          // indicate successful drop
81          event.dropComplete( true );
82      }
83
84      // handle exception if DataFlavor not supported
85      catch ( UnsupportedFlavorException flavorException ) {
86          flavorException.printStackTrace();
87          event.dropComplete( false );
88      }
89
90      // handle exception reading Transferable data
91      catch ( IOException ioException ) {
92          ioException.printStackTrace();
93          event.dropComplete( false );
94      }
95
96      // if dropped object is not file list, reject drop
97      else
98          event.rejectDrop();
99      }
100
101
102     // handle drag operation entering DropTarget
103     public void dragEnter( DropTargetDragEvent event )
104     {
105         // if data is javaFileListFlavor, accept drag for copy
106         if ( event.isDataFlavorSupported(
107             DataFlavor.javaFileListFlavor ) )
108
109             event.acceptDrag( DnDConstants.ACTION_COPY );
110
111         // reject all other DataFlavors
112         else
113             event.rejectDrag();
114     }
115
116     // invoked when drag operation exits DropTarget
117     public void dragExit( DropTargetEvent event ) {}
```

Fig. 2.11 **DnDWebBrowser** application for browsing Web sites that also accepts drag-and-drop operations for viewing HTML pages (part 3 of 5).

```
118 // invoked when drag operation occurs over DropTarget
119 public void dragOver( DropTargetDragEvent event ) {}
120
121 // invoked if dropAction changes (e.g., from COPY to LINK)
122 public void dropActionChanged( DropTargetDragEvent event )
123 {
124 }
125
126 } // end class DropTargetHandler
127
128 // execute application
129 public static void main( String args[] )
130 {
131     DnDWebBrowser browser = new DnDWebBrowser();
132     browser.setDefaultCloseOperation( EXIT_ON_CLOSE );
133     browser.setSize( 640, 480 );
134     browser.setVisible( true );
135 }
136 }
```

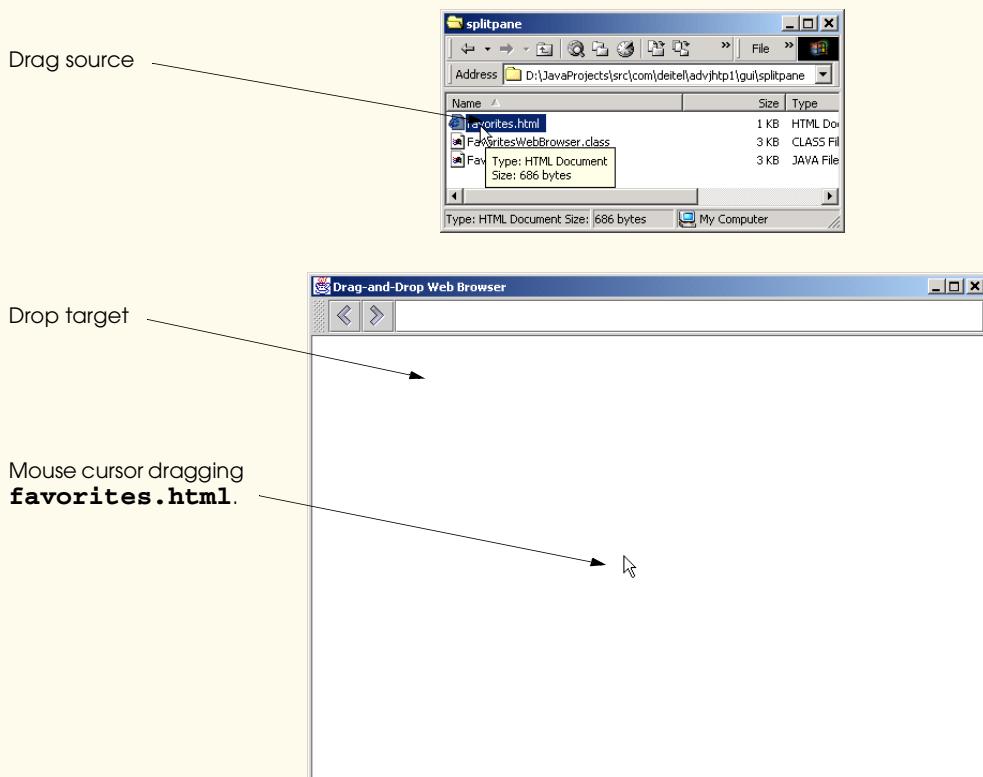


Fig. 2.11 **DnDWebBrowser** application for browsing Web sites that also accepts drag-and-drop operations for viewing HTML pages (part 4 of 5).

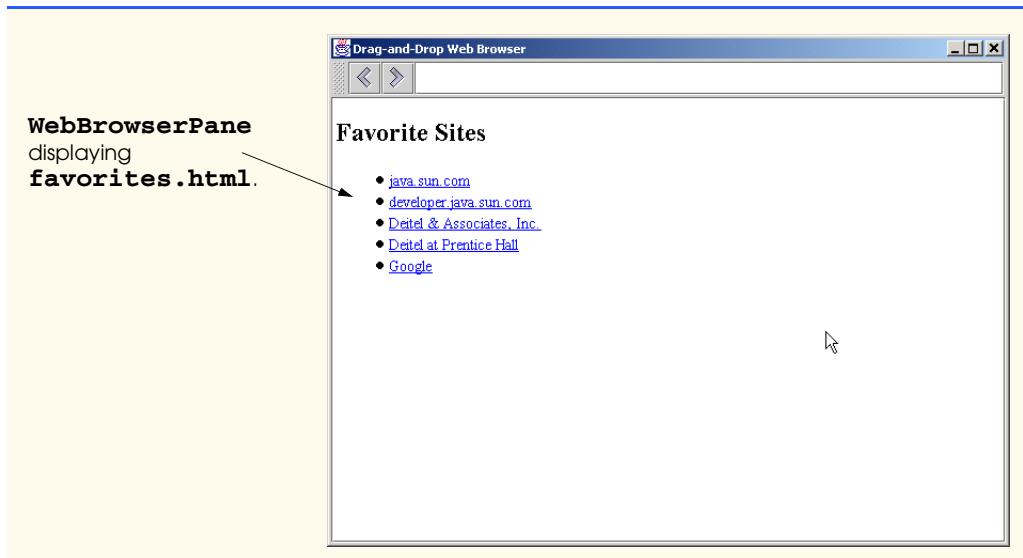


Fig. 2.11 **DnDWebBrowser** application for browsing Web sites that also accepts drag-and-drop operations for viewing HTML pages (part 5 of 5).

Lines 57–58 invoke method `isDataFlavorSupported` of interface `Transferable` to determine the type of data the `Transferable` object contains. The datatransfer API defines class `DataFlavor` to represent types of data contained in a `Transferable` object. Class `DataFlavor` provides several `static` constants that developers can use for comparison to common `DataFlavors`. Lines 57–58 determine if the `Transferable` object supports `DataFlavor.javaFileListFlavor`, which represents a `List` of `Files`. If a user drags one or more `Files` from the host operating system's file manager, the dropped `Transferable` object will support `DataFlavor.javaFileListFlavor`. If the `Transferable` object supports this `DataFlavor`, line 61 invokes method `acceptDrop` of class `DropTargetDropEvent` to indicate that the drop operation is allowed for this `DropTarget`.

Lines 67–69 retrieve the `List` of `Files` from the `Transferable` object by invoking method `getTransferData` of interface `Transferable`. Lines 73–78 iterate the `List` of `Files`, displaying each by invoking method `goToURL` of class `WebBrowserPane`. Line 80 invokes method `dropComplete` of class `DropTargetDropEvent` with a `true` argument to indicate that the drag-and-drop operation was successful. If the `DataFlavor` was not `DataFlavor.javaFileListFlavor`, line 99 invokes method `rejectDrop` of class `DropTargetDropEvent` to reject the drag-and-drop operation.

The drag-and-drop subsystem invokes method `dragEnter` of interface `DropTargetListener` (lines 103–114) when a drag-and-drop operation enters a `DropTarget` (e.g., the user drags the mouse into the `DropTarget`). Lines 106–107 check the `DataFlavors` that the `Transferable` object supports. If the `Transferable` object supports `DataFlavor.javaFileListFlavor`, line 109 invokes method `acceptDrag` of class `DropTargetDragEvent` to indicate that this

**DropTarget** allows the drag-and-drop operation. If the **Transferable** object does not support **DataFlavor.javaFileListFlavor**, line 113 invokes method **rejectDrag** of class **DropTargetDragEvent** to indicate that the **DropTarget** does not allow this drag-and-drop operation. The operating system may provide a visual cue to the user to indicate that the **DropTarget** does not allow the drag-and-drop operation, for example, by changing the mouse cursor.

The drag-and-drop subsystem invokes method **dragExit** (line 117) of interface **DropTargetListener** when the drag-and-drop operation leaves the **DropTarget** and method **dragOver** (line 120) when the drag-and-drop operation passes over the **DropTarget**. If the user changes the drop action (e.g., from **DndConstants.ACTION\_COPY** to **DndConstants.ACTION\_MOVE** by pressing the *Ctrl* key), the drag-and-drop subsystem invokes method **dropActionChanged** (line 123). We provide empty implementations of these methods because we do not require any special handling for these events.

## 2.7 Internationalization

Internationalization is the process of preparing an application for distribution in multiple *locales*. A locale identifies the language, currency, character set, date formats and other items most widely used for presenting information in a particular country or region. For example, in the U. S. locale, the language is English, the currency is the U. S. dollar and the date format is *month/day/year*. In the United Kingdom locale, the language also is English, but the currency is the British pound and the date format is *day/month/year*. Applications to be distributed in multiple locales must display information in the correct language and with appropriate date, currency and other formats.

To internationalize an application, a developer must replace hard-coded strings that the user might see, such as labels, tooltips and error messages, with strings contained in a **ResourceBundle**. A **ResourceBundle** is a Java properties file that maps keys to string values. For example, a **ResourceBundle** could contain the key **exitButtonLabel** with the string value **Exit**. Instead of hard coding the string **Exit** on a **JButton**'s label, the developer could retrieve the label from the **ResourceBundle**. The developer could then provide multiple versions of the **ResourceBundle** that use the same keys, but provide string values in different languages. For example, the developer could provide a **ResourceBundle** that contains French translations of each string value.

The developer also must use locale-sensitive classes to format data, such as dates, times and currencies, using locale-specific formats. There are several locale-sensitive classes that can perform this formatting, such as **NumberFormat** and **DateFormat**. A locale-sensitive class uses information about the appropriate locale to produce its output. For example, method **format** of class **DateFormat** takes as arguments a **Date** and a **Locale** and returns an appropriately formatted **String** for the given **Locale** (e.g., the string **3/8/2001** for the U. S. **Locale**).

Internationalized applications also must use *Unicode* characters. Unicode is a standard for encoding characters for most of the world's languages. Java uses Unicode to represent all characters, but it is possible that data generated by other applications may not use Unicode. Such data would need to be converted to Unicode before including it in an internationalized application. For more information about Unicode, please see Appendix I, Unicode.

Figure 2.12 presents an internationalized **WebToolBar** class. The **WebToolBar** constructor (lines 27–104) takes as an additional argument the **Locale** for which the **WebToolBar** should be localized. Lines 30–31 load the **ResourceBundle** named **StringsAndLabels** for the given **Locale** by invoking **static** method **getBundle** of class **ResourceBundle**. Line 33 invokes method **getString** of class  **ResourceBundle** to retrieve the **toolBarTitle** string from the  **ResourceBundle**. Line 33 also invokes method **setName** of class **JToolBar** to set the **JToolBar**'s name to the retrieved value.

```
1 // WebToolBar.java
2 // Internationalized WebToolBar with components for navigating
3 // a WebBrowserPane.
4 package com.deitel.advjhttp1.gui.i18n;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.net.*;
10 import java.util.*;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.event.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.gui.webbrowser.WebBrowserPane;
18 import com.deitel.advjhttp1.gui.actions.MyAbstractAction;
19
20 public class WebToolBar extends JToolBar
21     implements HyperlinkListener {
22
23     private WebBrowserPane webBrowserPane;
24     private JTextField urlTextField;
25
26     // WebToolBar constructor
27     public WebToolBar( WebBrowserPane browser, Locale locale )
28     {
29         // get resource bundle for internationalized strings
30         ResourceBundle resources = ResourceBundle.getBundle(
31             "StringsAndLabels", locale );
32
33         setName( resources.getString( "toolBarTitle" ) );
34
35         // register for HyperlinkEvents
36         webBrowserPane = browser;
37         webBrowserPane.addHyperlinkListener( this );
38
39         // create JTextField for entering URLs
40         urlTextField = new JTextField( 25 );
```

Fig. 2.12 **WebToolBar** that uses **ResourceBundles** for internationalization (part 1 of 3).

```
41     urlTextField.addActionListener(
42         new ActionListener() {
43
44             // navigate webBrowser to user-entered URL
45             public void actionPerformed( ActionEvent event ) {
46                 {
47                     // attempt to load URL in webBrowserPane
48                     try {
49                         URL url = new URL( urlTextField.getText() );
50                         webBrowserPane.goToURL( url );
51                     }
52
53                     // handle invalid URL
54                     catch ( MalformedURLException urlException ) {
55                         urlException.printStackTrace();
56                     }
57                 }
58             }
59         );
60
61         // create backAction and configure its properties
62         MyAbstractAction backAction = new MyAbstractAction() {
63
64             public void actionPerformed( ActionEvent event ) {
65                 {
66                     // navigate to previous URL
67                     URL url = webBrowserPane.back();
68
69                     // display URL in urlTextField
70                     urlTextField.setText( url.toString() );
71                 }
72             };
73
74             backAction.setSmallIcon( new ImageIcon(
75                 getClass().getResource( "images/back.gif" ) ) );
76
77             backAction.setShortDescription(
78                 resources.getString( "backToolTip" ) );
79
80             // create forwardAction and configure its properties
81             MyAbstractAction forwardAction = new MyAbstractAction() {
82
83                 public void actionPerformed( ActionEvent event ) {
84                     {
85                         // navigate to next URL
86                         URL url = webBrowserPane.forward();
87
88                         // display new URL in urlTextField
89                         urlTextField.setText( url.toString() );
90                     }
91                 };
92 }
```

Fig. 2.12 **WebToolBar** that uses **ResourceBundles** for internationalization (part 2 of 3).

```
93     forwardAction.setSmallIcon( new ImageIcon(
94         getClass().getResource( "images/forward.gif" ) ) );
95
96     forwardAction.setShortDescription(
97         resources.getString( "forwardToolTip" ) );
98
99     // add JButtons and JTextField to WebToolBar
100    add( backAction );
101    add( forwardAction );
102    add( urlTextField );
103
104 } // end WebToolBar constructor
105
106 // listen for HyperlinkEvents in WebBrowserPane
107 public void hyperlinkUpdate( HyperlinkEvent event )
108 {
109     // if hyperlink was activated, go to hyperlink's URL
110     if ( event.getEventType() ==
111         HyperlinkEvent.EventType.ACTIVATED ) {
112
113         // get URL from HyperlinkEvent
114         URL url = event.getURL();
115
116         // navigate to URL and display URL in urlTextField
117         webBrowserPane.goToURL( event.getURL() );
118         urlTextField.setText( url.toString() );
119     }
120 }
121 }
```

Fig. 2.12 **WebToolBar** that uses **ResourceBundles** for internationalization (part 3 of 3).

Lines 62–78 create an instance of class **MyAbstractAction** (Fig. 2.13) for the **WebToolBar**'s **backAction**. Lines 64–71 implement method **actionPerformed**. Lines 74–75 load the **Icon** for **backAction**, and lines 77–78 retrieve the internationalized tooltip text for **backAction** from the **ResourceBundle**. Lines 81–97 create the **forwardAction** in a similar manner.

The internationalized **WebToolBar** class also replaces the forward and back **JButtons** with **Actions**. Abstract class **MyAbstractAction** (Fig. 2.13) extends class **AbstractAction** to provide *set* methods for commonly used **Action** properties. The **MyAbstractAction** constructor (lines 19–27) takes as arguments the name, **Icon**, description and mnemonic key for the **Action**. Lines 23–26 invoke the appropriate *set* methods to configure the **Action** to the given values. Each *set* method invokes method **putValue** of interface **Action** with the appropriate key and the given value.

Figure 2.14 presents an internationalized **WebBrowser** class. Class **WebBrowser** has a single user-visible string, which is the application window title. The **WebBrowser** constructor (lines 26–42) takes as an argument the **Locale** for which the application should be localized. Lines 28–29 invoke **static** method **getBundle** of class **Resour-**

**ceBundle** to load the **ResourceBundle** containing the appropriate internationalized strings. Line 31 invokes method **getString** of class **ResourceBundle** to retrieve the **applicationTitle** string.

```
1 // MyAbstractAction.java
2 // MyAbstractAction is an AbstractAction subclass that provides
3 // set methods for Action properties (e.g., name, icon, etc.).
4 package com.deitel.advjhtp1.gui.actions;
5
6 // Java core packages
7 import java.awt.event.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public abstract class MyAbstractAction extends AbstractAction {
13
14     // no-argument constructor
15     public MyAbstractAction() {}
16
17     // construct MyAbstractAction with given name, icon
18     // description and mnemonic key
19     public MyAbstractAction( String name, Icon icon,
20         String description, Integer mnemonic )
21     {
22         // initialize properties
23         setName( name );
24         setSmallIcon( icon );
25         setShortDescription( description );
26         setMnemonic( mnemonic );
27     }
28
29     // set Action name
30     public void setName( String name )
31     {
32         putValue( Action.NAME, name );
33     }
34
35     // set Action Icon
36     public void setSmallIcon( Icon icon )
37     {
38         putValue( Action.SMALL_ICON, icon );
39     }
40
41     // set Action short description
42     public void setShortDescription( String description )
43     {
44         putValue( Action.SHORT_DESCRIPTION, description );
45     }
46
```

Fig. 2.13 MyAbstractAction AbstractAction subclass that provides set methods for Action properties (part 1 of 2).

```
47 // set Action mnemonic key
48 public void setMnemonic( Integer mnemonic )
49 {
50     putValue( Action.MNEMONIC_KEY, mnemonic );
51 }
52
53 // abstract actionPerformed method to be implemented
54 // by concrete subclasses
55 public abstract void actionPerformed( ActionEvent event );
56 }
```

Fig. 2.13 MyAbstractAction AbstractAction subclass that provides set methods for Action properties (part 2 of 2).

```
1 // WebBrowser.java
2 // WebBrowser is an application for browsing Web sites using
3 // a WebToolBar and WebBrowserPane.
4 package com.deitel.advjhttp1.gui.i18n;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.net.*;
10 import java.util.*;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.event.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.gui.webbrowser.WebBrowserPane;
18
19 public class WebBrowser extends JFrame {
20
21     private ResourceBundle resources;
22     private WebToolBar toolBar;
23     private WebBrowserPane browserPane;
24
25     // WebBrowser constructor
26     public WebBrowser( Locale locale )
27     {
28         resources = ResourceBundle.getBundle(
29             "StringsAndLabels", locale );
30
31         setTitle( resources.getString( "applicationTitle" ) );
32
33         // create WebBrowserPane and WebToolBar for navigation
34         browserPane = new WebBrowserPane();
35         toolBar = new WebToolBar( browserPane, locale );
36     }
```

Fig. 2.14 WebBrowser that uses ResourceBundles for internationalization (part 1 of 2).

```
37      // lay out WebBrowser components
38      Container contentPane = getContentPane();
39      contentPane.add( toolBar, BorderLayout.NORTH );
40      contentPane.add( new JScrollPane( browserPane ),
41                      BorderLayout.CENTER );
42  }
43 }
```

Fig. 2.14 **WebBrowser** that uses **ResourceBundles** for internationalization (part 2 of 2).

Class **BrowserLauncher** (Fig. 2.15) provides a **JComboBox** for selecting a **Locale** and launching an internationalized **WebBrowser**. Line 25 creates the **JComboBox** and lines 28–34 add sample **Locales** to the **JComboBox**. When the user selects a **Locale** from the **JComboBox**, lines 43–44 invoke method **launchBrowser** of class **BrowserLauncher** to launch a new **WebBrowser**. Method **launchBrowser** (lines 57–63) creates a new **WebBrowser** for the given **Locale**, sets its size and displays it.

The properties files of Fig. 2.16 and Fig. 2.17 contain internationalized strings for the default **Locale** (**Locale.US**) and the French Locale (**Locale.FRANCE**). In a properties file, the # character begins a single-line comment. Each property has a key, followed by an equals sign, followed by a value.

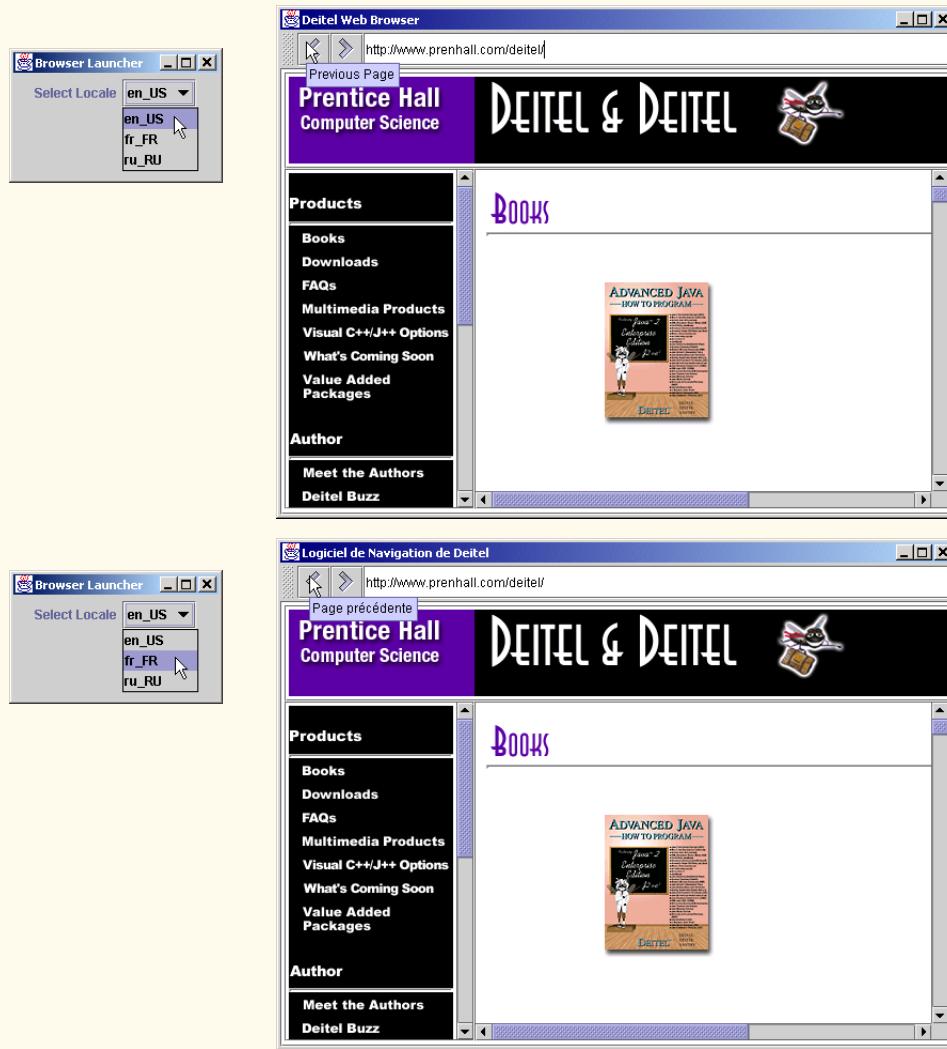
Note in Fig. 2.17 that the **backToolTip** value represents special characters (e.g., characters with accents) as *Unicode escape sequences* (line 3). Unicode can represent over 65,000 unique characters. A Unicode escape sequence begins with \u and contains four hexadecimal digits that represent the special character. Java uses Unicode characters by default and requires Unicode characters for proper internationalization.

```
1 // BrowserLauncher.java
2 // BrowserLauncher provides a list of Locales and launches a new
3 // Internationalized WebBrowser for the selected Locale.
4 package com.deitel.advjhtp1.gui.i18n;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.util.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class BrowserLauncher extends JFrame {
15
16     // JComboBox for selecting Locale
17     private JComboBox localeComboBox;
18
19     // BrowserLauncher constructor
20     public BrowserLauncher()
21     {
```

Fig. 2.15 **BrowserLauncher** application for selecting a **Locale** and launching an internationalized **WebBrowser** (part 1 of 3).

```
22     super( "Browser Launcher" );
23
24     // create JComboBox and add Locales
25     localeComboBox = new JComboBox();
26
27     // United States, English
28     localeComboBox.addItem( Locale.US );
29
30     // France, French
31     localeComboBox.addItem( Locale.FRANCE );
32
33     // Russia, Russian
34     localeComboBox.addItem( new Locale( "ru", "RU" ) );
35
36     // launch new WebBrowser when Locale selection changes
37     localeComboBox.addItemListener(
38         new ItemListener() {
39
40             public void itemStateChanged( ItemEvent event )
41             {
42                 if ( event.getStateChange() == ItemEvent.SELECTED )
43                     launchBrowser( ( Locale )
44                         localeComboBox.getSelectedItem() );
45             }
46         }
47     );
48
49     // lay out components
50     Container contentPane = getContentPane();
51     contentPane.setLayout( new FlowLayout() );
52     contentPane.add( new JLabel( "Select Locale" ) );
53     contentPane.add( localeComboBox );
54 }
55
56 // launch new WebBrowser for given Locale
57 private void launchBrowser( Locale locale )
58 {
59     WebBrowser browser = new WebBrowser( locale );
60     browser.setDefaultCloseOperation( DISPOSE_ON_CLOSE );
61     browser.setSize( 640, 480 );
62     browser.setVisible( true );
63 }
64
65 // execute application
66 public static void main( String args[] )
67 {
68     BrowserLauncher launcher = new BrowserLauncher();
69     launcher.setDefaultCloseOperation( EXIT_ON_CLOSE );
70     launcher.setSize( 200, 125 );
71     launcher.setVisible( true );
72 }
73 }
```

Fig. 2.15 **BrowserLauncher** application for selecting a **Locale** and launching an internationalized **WebBrowser** (part 2 of 3).



**Fig. 2.15** **BrowserLauncher** application for selecting a **Locale** and launching an internationalized **WebBrowser** (part 3 of 3).

```

1 # English language strings for internationalized WebBrowser
2 # application title
3 applicationTitle = Deitel Web Browser
4
5 # title for WebToolBar
6 toolBarTitle = Web Navigation
7

```

**Fig. 2.16** Properties file for default **Locale** (US English)—**StringsAndLabels.properties** (part 1 of 2).

```
8 # tooltip for forward toolbar button
9 forwardToolTip = Next Page
10
11 # tooltip for back button
12 backToolTip = Previous Page
```

Fig. 2.16 Properties file for default **Locale** (US English)—  
**StringsAndLabels.properties** (part 2 of 2).

```
1 # French language strings for internationalized WebBrowser
2 # tooltip for back button
3 backToolTip = Page pr\u00e9c\u00e9dente
4
5 # application title
6 applicationTitle = Logiciel de Navigation de Deitel
7
8 # title for WebToolBar
9 toolBarTitle = Navigation des Pages sur la Toile
10
11 # tooltip for forward toolbar button
12 forwardToolTip = Prochaine Page
```

Fig. 2.17 Properties file for French **Locale**—  
**StringsAndLabels\_fr\_FR.properties**.

The filenames for properties files enable internationalized applications to load the proper resources for the selected **Locale**. Note the names in the above figure captions for the properties files. The properties file for the default **Locale** (i.e., the **Locale** used if there is none specified) is named **StringsAndLabels.properties**. The properties file for **Locale.FRANCE** is named **StringsAndLabels\_fr\_FR.properties**. This name specifies that this is an internationalized version of the **StringsAndLabels** properties file for the French language (**fr**) in the country of France (**FR**). The lowercase language abbreviation is an *ISO Language Code* for the French language. The uppercase country abbreviation is an *ISO Country Code* for the country of France. Together, the ISO Language Code and ISO Country Code specify a locale. The list of ISO Language codes is available at [www.ics.uci.edu/pub/ietf/http/related/iso639.txt](http://www.ics.uci.edu/pub/ietf/http/related/iso639.txt). The list of ISO Country Codes is available at [www.chemie.fu-berlin.de/diverse/doc/ISO\\_3166.html](http://www.chemie.fu-berlin.de/diverse/doc/ISO_3166.html).

## 2.8 Accessibility

*Accessibility* refers to the level of an application’s usability for people with disabilities. To make an application accessible means to ensure that the application works for people with disabilities. Many software applications are inaccessible to people with visual, learning or mobility impairments. A high level of accessibility is difficult to achieve because there are many different disabilities, language barriers, hardware and software inconsistencies and so on. As greater numbers of people use computers, it is imperative that application designers increase the accessibility of their applications. Recent legislation in the United States has brought accessibility to the forefront of Web and application development.

The Swing API designers took advantage of the Java Accessibility API to build accessibility features into every Swing component to facilitate creating accessible Java applications. As a result, Java developers who use the Swing APIs to build application GUIs need only use the Swing APIs properly to enable most accessibility features. For example, when creating GUI elements such as **JButtons** and **JMenuItems**, developers should provide tooltip text that describes the component and mnemonic keys or accelerator keys for enabling keyboard access. These simple properties enable accessibility tools, such as screen readers, to convey important descriptive information to the user. Enabling keyboard access makes applications easier to navigate for all users, and also allows accessibility tools to navigate the application more easily.

When it is not appropriate for a GUI component to have a tooltip or label, developers can use methods **setAccessibleName** and **setAccessibleDescription** of class **AccessibilityContext** to provide descriptive text. Each Swing component contains an **AccessibilityContext** for enabling the component's accessibility features. Assistive technologies (e.g., screen readers, input devices) then use the Java Access Bridge to interact with the Java application to take advantage of the developer-provided descriptive text.

Class **ActionSample2** (Fig. 2.18) modifies class **ActionSample** (Fig. 2.5) to demonstrate adding accessible component names and descriptions to Swing components.

**Action actionSample** (lines 26–50) now contains accessible text in the dialog box that opens when **actionSample** is fired. Lines 36–37 declare an **AccessibleContext** object for the **JOptionPane** **action** by calling method **getAccessibleContext** on **action**. Line 38 calls method **setAccessibleName** to set **action**'s name in **AccessibleContext actionContext**. Lines 39–41 call method **setAccessibleDescription** of class **AccessibleContext** to set **actionSample**'s description. Line 53 specify a name for **actionSample** and lines 60–61 specify a short description. Lines 64–65 assign a mnemonic key to **actionSample**.

**Action exitAction** (lines 68–92) now contains accessible text in the dialog box that opens when **exitSample** is fired. Lines 78–79 obtain an **AccessibleContext** for the **JOptionPane** by invoking method **getAccessibleContext**. Line 80 calls method **setAccessibleName** to specify a name for the **JOptionPane**'s **AccessibleContext**. Lines 81–83 call method **setAccessibleContext**. Line 96 specifies a name for **exitAction** by invoking method **putValue** of interface **Action**. Lines 102–103 associate a short description with **exitAction**. Lines 106–107 assign a mnemonic key to **exitAction**.

```
1 // ActionSample2.java
2 // ActionSample2 demonstrates the Accessibility features of
3 // Swing components.
4 package com.deitel.advjhtp1.gui.actions;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
```

Fig. 2.18 **ActionSample2** demonstrates **Accessibility** package (part 1 of 5).

```
10 // Java extension packages
11 import javax.accessibility.*;
12 import javax.swing.*;
13
14 public class ActionSample2 extends JFrame {
15
16     // Swing Actions
17     private Action sampleAction;
18     private Action exitAction;
19
20     // ActionSample2 constructor
21     public ActionSample2()
22     {
23         super( "Using Actions" );
24
25         // create AbstractAction subclass for sampleAction
26         sampleAction = new AbstractAction() {
27
28             public void actionPerformed( ActionEvent event )
29             {
30                 // display message indicating sampleAction invoked
31                 JOptionPane action = new JOptionPane(
32                     "The sampleAction was invoked." );
33
34                 // get AccessibleContext for action and set name
35                 // and description
36                 AccessibleContext actionContext =
37                     action.getAccessibleContext();
38                 actionContext.setAccessibleName( "sampleAction" );
39                 actionContext.setAccessibleDescription(
40                     "SampleAction opens a dialog box to demonstrate"
41                     + " the Action class." );
42
43                 // create and display dialog box
44                 action.createDialog( ActionSample2.this,
45                     "sampleAction" ).setVisible( true );
46
47                 // enable exitAction and associated GUI components
48                 exitAction.setEnabled( true );
49             }
50         };
51
52         // set Action name
53         sampleAction.putValue( Action.NAME, "Sample Action" );
54
55         // set Action Icon
56         sampleAction.putValue( Action.SMALL_ICON, new ImageIcon(
57             getClass().getResource( "images/Help24.gif" ) ) );
58
59         // set Action short description (tooltip text)
60         sampleAction.putValue( Action.SHORT_DESCRIPTION,
61             "A Sample Action" );
```

Fig. 2.18 ActionSample2 demonstrates **Accessibility** package (part 2 of 5).

```
62
63     // set Action mnemonic key
64     sampleAction.putValue( Action.MNEMONIC_KEY,
65         new Integer( 'S' ) );
66
67     // create AbstractAction subclass for exitAction
68     exitAction = new AbstractAction() {
69
70         public void actionPerformed( ActionEvent event )
71     {
72             // display message indicating sampleAction invoked
73             JOptionPane exit = new JOptionPane(
74                 "The exitAction was invoked." );
75
76             // get AccessibleContext for exit and set name and
77             // description
78             AccessibleContext exitContext =
79                 exit.getAccessibleContext();
80             exitContext.setAccessibleName( "exitAction" );
81             exitContext.setAccessibleDescription( "ExitAction"
82                 + " opens a dialog box to demonstrate the"
83                 + " Action class and then exits the program." );
84
85             // create and display dialog box
86             exit.createDialog( ActionSample2.this,
87                 "exitAction" ).setVisible( true );
88
89             // exit program
90             System.exit( 0 );
91         }
92     };
93
94     // set Action name
95     exitAction.putValue( Action.NAME, "Exit" );
96
97     // set Action icon
98     exitAction.putValue( Action.SMALL_ICON, new ImageIcon(
99         getClass().getResource( "images/EXIT.gif" ) ) );
100
101    // set Action short description (tooltip text)
102    exitAction.putValue( Action.SHORT_DESCRIPTION,
103        "Exit Application" );
104
105    // set Action mnemonic key
106    exitAction.putValue( Action.MNEMONIC_KEY,
107        new Integer( 'x' ) );
108
109    // disable exitAction and associated GUI components
110    exitAction.setEnabled( false );
111
112    // create File menu
113    JMenu fileMenu = new JMenu( "File" );
```

Fig. 2.18 ActionSample2 demonstrates **Accessibility** package (part 3 of 5).

```
114 // add sampleAction and exitAction to File menu to
115 // create a JMenuItem for each Action
116 fileMenu.add( sampleAction );
117 fileMenu.add( exitAction );
118
119 fileMenu.setMnemonic( 'F' );
120
121
122 // create JMenuBar and add File menu
123 JMenuBar menuBar = new JMenuBar();
124 menuBar.add( fileMenu );
125 setJMenuBar( menuBar );
126
127 // create JToolBar
128 JToolBar toolBar = new JToolBar();
129
130 // add sampleAction and exitAction to JToolBar to create
131 // JButtons for each Action
132 toolBar.add( sampleAction );
133 toolBar.add( exitAction );
134
135 // get AccessibleContext for toolBar and set name and
136 // description
137 AccessibleContext toolContext =
138     toolBar.getAccessibleContext();
139 toolContext.setAccessibleName( "ToolBar" );
140 toolContext.setAccessibleDescription( "ToolBar contains"
141     + " sampleAction button and exitAction button." );
142
143 // create JButton and set its Action to sampleAction
144 JButton sampleButton = new JButton();
145 sampleButton.setAction( sampleAction );
146
147 // get AccessibleContext for sampleButton and set name
148 // and description
149 AccessibleContext sampleContext =
150     sampleButton.getAccessibleContext();
151 sampleContext.setAccessibleName( "SampleButton" );
152 sampleContext.setAccessibleDescription( "SampleButton"
153     + " produces a sampleAction event." );
154
155 // create JButton and set its Action to exitAction
156 JButton exitButton = new JButton( exitAction );
157
158 // get AccessibleContext for exitButton and set name and
159 // description
160 AccessibleContext exitContext =
161     exitButton.getAccessibleContext();
162 exitContext.setAccessibleName( "ExitButton" );
163 exitContext.setAccessibleDescription( "ExitButton"
164     + " produces an exitAction event." );
165
```

Fig. 2.18 ActionSample2 demonstrates **Accessibility** package (part 4 of 5).

```
166     // lay out JButtons in JPanel
167     JPanel buttonPanel = new JPanel();
168     buttonPanel.add( sampleButton );
169     buttonPanel.add( exitButton );
170
171     // add toolBar and buttonPanel to JFrame's content pane
172     Container container = getContentPane();
173     container.add( toolBar, BorderLayout.NORTH );
174     container.add( buttonPanel, BorderLayout.CENTER );
175
176 }
177
178 // execute application
179 public static void main( String args[] )
180 {
181     ActionSample2 sample = new ActionSample2();
182     sample.setDefaultCloseOperation( EXIT_ON_CLOSE );
183     sample.pack();
184     sample.setVisible( true );
185 }
186 }
```

Fig. 2.18 `ActionSample2` demonstrates **Accessibility** package (part 5 of 5).

Line 120 adds a mnemonic key for the **File** menu to enable keyboard access to this menu. Lines 137–138 obtain the **AccessibleContext** for **toolBar**. Line 139 sets a name for **toolBar** by invoking method **setAccessibleName**. Lines 140–141 set a description for **toolBar** by invoking method **setAccessibleDescription**. Lines 149–150 obtain an **AccessibleContext** for **JButton sampleButton**. Line 151 sets a name for **sampleButton** by invoking method **setAccessibleName**. Lines 152–153 set a description for **sampleButton** by invoking method **setAccessibleDescription**. Lines 160–161 obtain an **AccessibleContext** for **JButton exitButton**. Line 162 sets a name for **exitButton** by invoking method **setAccessibleName**. Lines 163–164 set a description for **exitButton** by invoking method **setAccessibleDescription**.

We will download the *Java Access Bridge* and a demonstration of *JAWS for Windows 3.7* to demonstrate the accessibility features of **ActionSample2**. The Java Access Bridge allows assistive programs in Windows to use the accessibility information of a Java program. The Java Access Bridge can be downloaded at

**java.sun.com/products/accessbridge**

JAWS for Windows is a screen reader from Henter-Joyce ([www.hj.com](http://www.hj.com)). A demonstration version of JAWS can be downloaded at

[www.hj.com/JAWS/JAWS37DemoOp.htm](http://www.hj.com/JAWS/JAWS37DemoOp.htm)

Download and install both programs to try the rest of the example in this section.

With the Access Bridge installed and JAWS running in the background, execute **ActionSample2**. JAWS reads the name of the new window that opens. The GUI of **ActionSample2** (Fig. 2.19) is identical to the original **ActionSample** (Fig. 2.5).

Switch between the buttons by pressing *Tab* to move forward or *Shift + Tab* to move backward. JAWS reads the name of the new button whenever the focus changes. To press the button that holds the focus, press the space bar. The **sampleAction** dialog opens and JAWS reads its name. Pressing the space bar or the *Enter* key closes the dialog. The **Exit** button is now available in the GUI. Switch the focus to the larger button labeled **Sample Action** (not the one in the tool bar) and press *Insert + F1*. This JAWS command reads the description attached to the button's **AccessibleContext** (Fig. 2.20). Do the same command on the **Exit** button to hear its description (Fig. 2.21). **ActionSample2**'s **Actions** are also available through the **File** menu. The **File** menu's mnemonic key is the underlined letter **F**. Pressing *Alt + F* opens the **File** menu and causes JAWS to read the menu name (Fig. 2.22). The arrow keys move the cursor within the menu. JAWS reads the name of each menu item as it is selected (Fig. 2.23). Pressing the space bar, *Enter* key, or a mnemonic key activates one of the **Actions**.

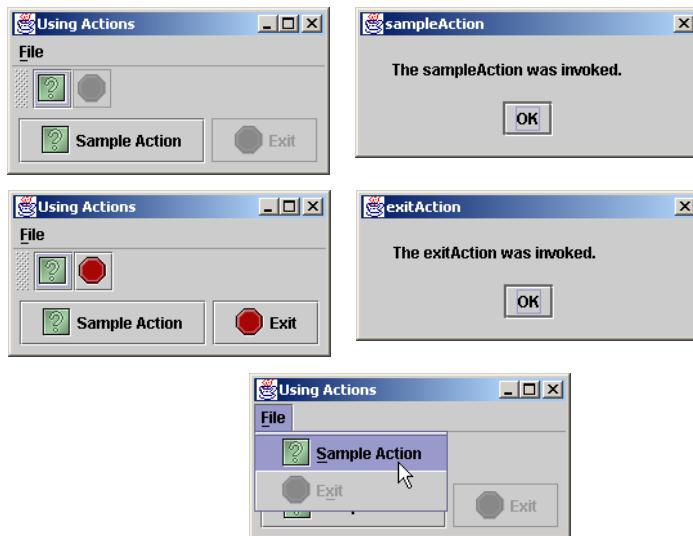


Fig. 2.19 **Actions** `sampleAction` and `exitAction` of **ActionSample2**.

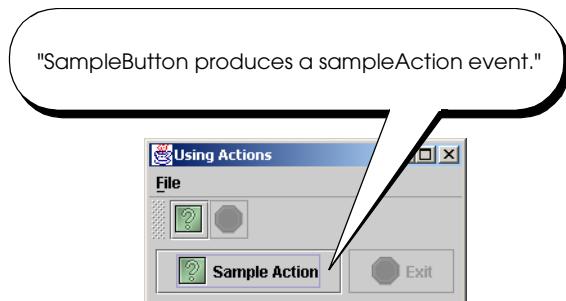


Fig. 2.20 **AccessibleDescription** of `sampleButton`.

"ExitButton produces an exitAction event."

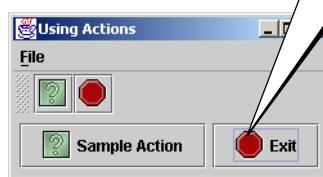


Fig. 2.21 AccessibleDescription of `exitButton`.

"Sample Action."

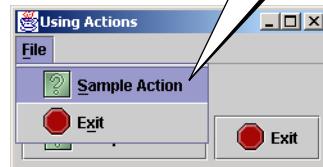


Fig. 2.22 Sample Action menu item description.

"ExitT."

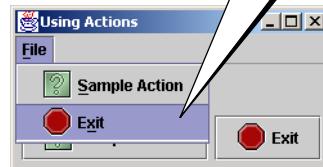


Fig. 2.23 Exit menu item description.

## 2.9 Internet and World Wide Web Resources

### *Swing*

[java.sun.com/products/jfc/tsc](http://java.sun.com/products/jfc/tsc)

The Swing Connection contains technical articles and documentation for Swing components.

[www.javaworld.com/javaworld/topicalindex/jw-ti-foundation.html](http://www.javaworld.com/javaworld/topicalindex/jw-ti-foundation.html)

JavaWorld collection of Swing-related articles.

## ***Internationalization***

**[www.ibm.com/developerworks/theme/international-index.html](http://www.ibm.com/developerworks/theme/international-index.html)**

IBM offers links to internationalization resources including multilingual software and international calendars.

**[developer.java.sun.com/developer/technicalArticles/Intl/index.html](http://developer.java.sun.com/developer/technicalArticles/Intl/index.html)**

This site provides numerous articles on learning how to localize and internationalize various Java programs.

**[www.onjava.com/pub/a/onjava/2001/04/12/internationalization.html](http://www.onjava.com/pub/a/onjava/2001/04/12/internationalization.html)**

This article, *Java Internationalization and Localization*, by Jaric Sng describes the steps for accessing, installing, and determining fonts, focusing on Japanese, Chinese, and Korean.

**[java.sun.com/j2se/1.3/docs/guide/intl](http://java.sun.com/j2se/1.3/docs/guide/intl)**

This site supplies a guide to Java internationalization. It includes a detailed section on formatting currencies, time zones, dates, texts, messages and other international dissimilarities.

## ***Accessibility***

**[java.sun.com/products/jfc/jaccess-1.3/doc/guide.html](http://java.sun.com/products/jfc/jaccess-1.3/doc/guide.html)**

Sun Microsystems has improved Java accessibility through Java Accessibility API and Java Accessibility Utilities. Check out a detailed description of these packages at this site.

**[developer.java.sun.com/developer/earlyAccess/jaccesshelper](http://developer.java.sun.com/developer/earlyAccess/jaccesshelper)**

The Java Accessibility Helper examines Java programs for accessibility issues and provides a report that details changes needed to be made. This is an early-access download and requires a free registration with the Java Developer Connection Web site.

**[www.ibm.com/able/snsjavag.html](http://www.ibm.com/able/snsjavag.html)**

"IBM Guidelines for Writing Accessible Applications Using 100% Pure Java," by Richard S. Schwerdtfeger, states the necessary features that should be provided to create full accessibility. In addition, this online guidebook discusses the various programs to achieve accessibility.

**[www.sun.com/access/developers/access.quick.ref.html](http://www.sun.com/access/developers/access.quick.ref.html)**

This site simply emphasizes the importance of accessibility and gives tips on making applications accessible.

**[www.w3.org/WAI](http://www.w3.org/WAI)**

The World Wide Web Consortium's *Web Accessibility Initiative (WAI)* site promotes design of universally accessible Web sites. This site will help you keep up-to-date with current guidelines and forthcoming recommendations for Web accessibility.

**[www.sun.com/access/gnome](http://www.sun.com/access/gnome)**

GNOME Developer's Site provides information on various assistive technologies, such as screen magnifiers and screen keyboards for Linux and Unix platforms that use the GNOME user interface.

**[www.voice-assistant.com](http://www.voice-assistant.com)**

The Voice Mate V4 assists the blind with using a computer. It speaks the menu options and characters as they are typed.

**[www.magnifiers.org](http://www.magnifiers.org)**

On this site, you can find information and downloads for screen magnifiers.

**[www.voicerecognition.com](http://www.voicerecognition.com)**

This site contains information on various voice-recognition products.

**[trace.wisc.edu/world/web](http://trace.wisc.edu/world/web)**

This site explains how to make Web sites more accessible to disabled users. It also gives multiple references to other sites on Web accessibility.

**[www.access-board.gov/508.htm](http://www.access-board.gov/508.htm)**

Electronic version of Section 508 of the Rehabilitation Act, which mandates that government agencies provide accessible electronic access to information from federal agencies.

## SUMMARY

- Swing provides three basic types of text components for presenting and editing text. Class **JTextComponent** is the base class for all Swing text components, including **JTextField**, **JTextArea** and **JEditorPane**.
- **JTextField** is a single-line text component suitable for obtaining simple user input or displaying information such as form field values, calculation results and so on. **JPasswordField** is a subclass of **JTextField** suitable for obtaining user passwords.
- **JEditorPane** provides enhanced text-rendering capabilities. **JEditorPane** supports styled documents that include formatting, font and color information. **JEditorPane** is capable of rendering HTML documents as well as Rich Text Format (RTF) documents.
- Toolbars are GUI containers typically located below an application's menus. Toolbars contain buttons and other GUI components for commonly used features, such as cut, copy and paste, or navigation buttons for a Web browser.
- Class **javax.swing.JToolBar** enables developers to add toolbars to Swing user interfaces. **JToolBar** also enables users to modify the appearance of the **JToolBar** in a running application.
- Users can drag a **JToolBar** from the top of a windows and "dock" the **JToolBars** on the side or bottom. Users also can drag the **JToolBar** away from the application window to create a floating **JToolBar**.
- Based on **JToolBar**'s inheritance hierarchy, each **JToolBar** also is a **java.awt.Container** and therefore can contain other GUI components.
- A **JToolBar** has property **orientation** that specifies how the **JToolBar** will arrange its child components. The default is horizontal orientation, which indicates that the **JToolBar** lays out its child components next to one another.
- The Command design pattern enables developers to define requests (e.g., a user request to copy text) once in a reusable object that the developer then can add to a menu, toolbar or pop-up menu. This design pattern is called Command because it defines a user command or instruction.
- An **Action**, which implements the Command design pattern, represents user-interface logic and properties for GUI components that represent that logic, such as the label for a button, the text for a tool tip and the mnemonic key for keyboard access.
- The logic for an **Action** takes the form of an **actionPerformed** method that the event mechanism invokes in response to the user activating an interface component (e.g., the user clicking a **JButton**).
- Interface **Action** extends interface **ActionListener**, which enables **Actions** to process **ActionEvents** generated by GUI components. **Actions** provide an additional benefit in that the developer can enable or disable all GUI components associated with an **Action** by enabling or disabling the **Action** itself.
- that **sampleAction** was invoked. Line 33 then invokes method **setEnabled** of interface **Action** on the **exitAction** reference. This enables the **exitAction** and its associated GUI components. Note that **Actions** are enabled by default. We disabled the **exitAction** (line 80) to demonstrate that this disables the GUI components associated with that **Action**.
- **JSplitPane** and **JTabbedPane** are container components that enable developers to present large amounts of information in a small screen area.

- **JSplitPane** divides two components with a divider that users can reposition to expand and contract the visible areas of the **JSplitPane**'s child components. **JSplitPanes** can contain only two child components, although each child component may contain nested components.
- The constant **JSplitPane.HORIZONTAL\_SPLIT** specifies the **JSplitPane** should display its child components side-by-side. The constant **JSplitPane.VERTICAL\_SPLIT** specifies that the **JSplitPane** should display its child components one on top of the other.
- Adding child components to **JScrollPanes** before adding those components to a **JSplitPane** ensures that the user will be able to view all the content in each child component by scrolling if necessary.
- **JTabbedPane** presents multiple components in separate tabs, which the user can navigate using a mouse or keyboard. Dialog boxes often use components similar to **JTabbedPanes**.
- Multiple document interfaces allow users to view multiple documents in a single application. Each document appears in a separate window in the application. The user can arrange, resize, iconify (i.e., minimize) and maximize these separate document windows like application windows on the desktop.
- **JInternalFrames** behave much like **JFrames**. Users can maximize, iconify, resize, open and close **JInternalFrames**. **JInternalFrames** have title bars with buttons for iconifying, maximizing and closing. Users also can move **JInternalFrames** within the **JDesktopPane**.
- **JInternalFrames** have no size and are invisible by default. When creating a new **JInternalFrame**, be sure to invoke method **setSize** to size the **JInternalFrame** and **setVisible(true)** to make the **JInternalFrame** visible.
- Drag and drop enables users to move items around the desktop and to move and copy data among applications using mouse gestures. A gesture is a mouse movement that corresponds to a drag-and-drop operation, such as dragging a file from one folder and dropping the file into another folder.
- The data transfer API—package **java.awt.datatransfer**—enables copying and moving data within a single application or among multiple applications. The drag-and-drop API enables Java applications to recognize drag-and-drop gestures and to respond to drag-and-drop operations.
- A drag-and-drop operation uses the data transfer API to transfer data from the drag source to the drop target. Applications can use the drag-and-drop API to recognize drag-and-drop operations and use the data transfer API to retrieve the data transferred through those drag-and-drop operations.
- The drag-and-drop subsystem invokes method **drop** of interface **DropTargetListener** when the user drops an object on a **DropTarget**.
- Interface **java.awt.datatransfer.Transferable** declares methods that represent an object that can be transferred among applications. As part of the datatransfer API, interface **Transferable** represents objects that may be transferred through the system clipboard (e.g., via cut-and-paste operations) and objects that are transferred through drag and drop.
- Internationalization is the process of preparing an application for distribution in multiple locales. A locale identifies the language, currency, character set, date formats and other items most widely used for presenting information in a particular country or region.
- Applications to be distributed in multiple locales must display information in the correct language and with appropriate date, currency and other formats.
- A **ResourceBundle** is a Java properties file that maps keys to string values. For example, a **ResourceBundle** could contain the key **exitButtonLabel** with the string value **Exit**. Instead of hard coding the string **Exit** on a **JButton**'s label, the developer could retrieve the label from the **ResourceBundle**. The developer could then provide multiple versions of the **ResourceBundle** that use the same keys, but provide string values in different languages.

- The developer also must use locale-sensitive classes to format data, such as dates, times and currencies, using locale-specific formats. There are several locale-sensitive classes that can perform this formatting, such as **NumberFormat** and **DateFormat**.
- Internationalized applications also must use Unicode characters. Unicode is a standard for encoding characters for most of the world's languages. Java uses Unicode to represent all characters.
- The filenames for properties files enable internationalized applications to load the proper resources for the selected **Locale**. These filenames must use a lowercase language abbreviation—called an ISO Language Code—and an uppercase country abbreviation—called an ISO Country Code.
- *Accessibility* refers to the level of an application's usability for people with disabilities. To make an application accessible means to ensure that the application works for people with disabilities.
- Many software applications are inaccessible to people with visual, learning or mobility impairments. A high level of accessibility is difficult to achieve because there are many different disabilities, language barriers, hardware and software inconsistencies and so on.
- Recent legislation in the United States has brought accessibility to the forefront of Web and application development.
- The Swing API designers took advantage of the Java Accessibility API to build accessibility features into every Swing component to facilitate creating accessible Java applications. As a result, Java developers who use the Swing APIs to build application GUIs need only use the Swing APIs properly to enable most accessibility features.
- Developers should provide tooltip text that describes each component and mnemonic keys or accelerator keys for enabling keyboard access. These simple properties enable accessibility tools, such as screen readers, to convey important descriptive information to the user. Enabling keyboard access makes applications easier to navigate for all users, and also allows accessibility tools to navigate the application more easily.
- Methods **setAccessibleName** and **setAccessibleDescription** of class **AccessibleContext** enable developers to provide descriptive text for components. Each Swing component contains an **AccessibleContext** for enabling the component's accessibility features.
- Assistive technologies (e.g., screen readers, input devices) can use the Java Access Bridge to interact with Java applications to take advantage of the developer-provided descriptive text.

## TERMINOLOGY

<b>AbstractAction</b> class	drag and drop
accessibility	drag-and-drop gesture
<b>AccessibleContext</b> class	drag-and-drop operation
<b>Action</b> interface	<b>DropTarget</b> class
<b>Action.ACCELERATOR_KEY</b> constant	<b>DropTargetDragEvent</b> class
<b>Action.ACTION_COMMAND_KEY</b> constant	<b>DropTargetDropEvent</b> class
<b>Action.MNEMONIC_KEY</b> constant	<b>DropTargetListener</b> interface
<b>Action.NAME</b> constant	<b>HyperlinkEvent</b> class
<b>Action.SHORT_DESCRIPTION</b> constant	<b>HyperlinkEvent.EventType</b> .
<b>Action.SMALL_ICON</b> constant	<b>ACTIVATED</b> constant
<b>addHyperlinkListener</b> method of class <b>JEditorPane</b>	<b>HyperlinkListener</b> interface
Command design pattern	iconify
<b>DataFlavor.javaFileListFlavor</b> constant	internationalization
<b>DnDConstants</b> class	Java Access Bridge
	<b>JDesktopPane</b> class
	<b>JEditorPane</b> class

<b>JInternalFrame</b> class	<b>putValue</b> method of interface <b>Action</b>
<b>JPasswordField</b> class	<b>ResourceBundle</b> class
<b>JSplitPane</b> class	screen reader
<b>JSplitPane.HORIZONTAL_SPLIT</b> constant	<b>setAccessibleDescription</b> method of class <b>AccessibleContext</b>
<b>JSplitPane.VERTICAL_SPLIT</b> constant	<b>setAccessibleName</b> method of class <b>AccessibleContext</b>
<b>JTabbedPane</b> class	<b>setEditable</b> method of class <b>JEditorPane</b>
<b>JTextArea</b> class	<b>setEnabled</b> method of interface <b>Action</b>
<b>JTextComponent</b> class	tab
<b>JTextField</b> class	toolbar
<b>JToolBar</b> class	tooltip
<b>Locale</b> class	<b>Transferable</b> interface
maximize	
multiple-document interface	
<b>orientation</b> property of class <b>JToolBar</b>	

### SELF-REVIEW EXERCISES

**2.1** State which of the following are *true* and which are *false*. If *false*, explain why.

- The Abstract Windowing Toolkit provides a richer set of components than the Swing component set.
- Swing provides a pluggable look and feel that enables components to change their appearance.
- JEditorPane** is capable of rendering only plain text, not richly styled text.
- Toolbars—implemented by class **JToolBar**—enable developers to provide users with quick access to commonly used user-interface elements, such as cut, copy and paste.
- Interface **Action** provides set and get methods for each **Action** property.
- JSplitPanes** can contain any number of child components.

**2.2** Fill in the blanks in each of the following:

- The drag-and-drop API uses the \_\_\_\_\_ API to transfer data through drag-and-drop operations.
- A multiple document interface uses instances of class \_\_\_\_\_ for individual windows, which are contained in a \_\_\_\_\_.
- The **JInternalFrame** constructor takes four boolean arguments that indicate whether the window is \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- A \_\_\_\_\_ identifies the language, currency, character set, date formats and other items most widely used for presenting information in a particular country or region.
- \_\_\_\_\_ refers to the level of an application's usability for people with disabilities.

### ANSWERS TO SELF-REVIEW EXERCISES

**2.1** a) False. Swing provides a richer set of components than the older AWT. b) True. c) False. **JEditorPane** can render HTML and RTF documents, which can contain rich styling information. d) True. e) False. Interface **Action** provides method **putValue**, which enables programmers to specify the property name and value as a key/value pair. f) False. Each **JSplitPane** may contain exactly two child components, but each child component may contain its own child components.

**2.2** a) data transfer API. b) **JInternalFrame**, **JDesktopPane**. c) resizable, closable, maximizable, iconifiable. d) **Locale**. e) Accessibility.

### EXERCISES

**2.3** Modify class **WebToolBar** (Fig. 2.3) to include a **JComboBox** from which the user can select URLs from the history.

**2.4** Create an image-viewing application that supports drag-and-drop loading of images. When the user drags and drops a image file onto the application window, load that image in an **ImageIcon** and display the **ImageIcon** in a **JPanel**.

**2.5** Modify class **ActionSample2** (Fig. 2.18) to use **ResourceBundles** for all user-visible **Strings** in the application. If you know a language other than English, provide a **ResourceBundle** that contains Strings in that language.

**2.6** Making an application accessible requires that the application provides keyboard navigation for all the application's functionality. Unplug your mouse from your computer and try using various programs, such as word processors, Web browsers and the Java programs in this chapter. What about these applications makes it difficult to navigate without a mouse? Is there functionality that you cannot access using a keyboard?

# 3

## Model-View-Controller

### Objectives

- To understand the model-view-controller (MVC) architecture for separating data, presentation and user input logic.
- To understand the Observer design pattern.
- To understand MVC's use in Java's Swing GUI components.
- To understand the default model implementations for Swing components.
- To understand the use of **TableModels** to represent tabular data for **JTables**.
- To understand tree data structures and their use as **TreeModels** for **JTrees**.

*The universe is wider than our views of it.*

Henry David Thoreau

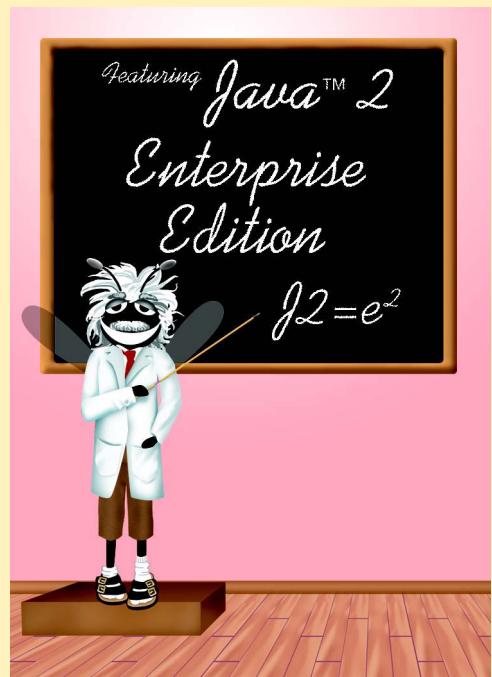
*Let all your views in life be directed to a solid, however moderate, independence; ...*

Junius

*I think that I shall never see*

*A poem as lovely as a tree.*

Joyce Kilmer



## Outline

- 3.1 Introduction
- 3.2 Model-View-Controller Architecture
- 3.3 Observable Class and Observer Interface
- 3.4 JList
- 3.5 JTable
- 3.6 JTree
  - 3.6.1 Using DefaultTreeModel
  - 3.6.2 Custom TreeModel Implementation

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 3.1 Introduction

In this chapter, we introduce the *model-view-controller architecture* (MVC) and its particular application in Java’s Swing classes. The MVC architecture uses object-oriented design principles to modularize applications into data components, presentation components and input-processing components. Data components maintain the raw application data, such as the text of a document in a word processor or the locations of the pieces in a game of chess. The presentation components most commonly provide a visual representation of application data—for example a 3D graphic showing the chessboard and the arrangement of pieces. The input-processing components handle input from the user, such as dragging the mouse to move a piece on the chess board.

MVC has many uses in desktop applications, enterprise applications, simulations and other types of programs. In this chapter, we discuss MVC in general and its variant, the *delegate-model architecture*. We also introduce the Observer design pattern, which is a design pattern built into the MVC architecture. After reading this chapter, you will be able to design your own programs using MVC. You also will be able to take advantage of advanced Swing components that use the delegate-model architecture, such as **JList**, **JTable** and **JTree**.

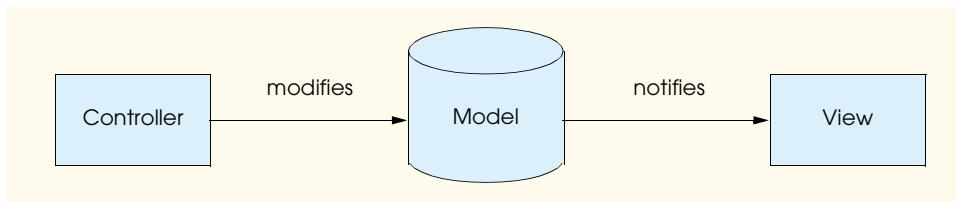
### 3.2 Model-View-Controller Architecture

The *model-view-controller* architecture (MVC) separates application data (contained in the *model*) from graphical presentation components (the *view*) and input-processing logic (the *controller*). MVC originally appeared in Smalltalk-80 as a method for separating user interfaces from underlying application data.<sup>1</sup> Figure 3.1 shows the relationships between components in MVC. In our Enterprise Java case study (Chapters 17–20), we will show that MVC is applicable across a wide range of problems and can make applications easier to maintain and extend.

The controller implements logic for processing user input. The model contains application data, and the view generates a presentation of the data stored in the model. When a

---

1. E. Gamma et al., *Design Patterns* (New York: Addison-Wesley Publishing Company, 1995), 4.

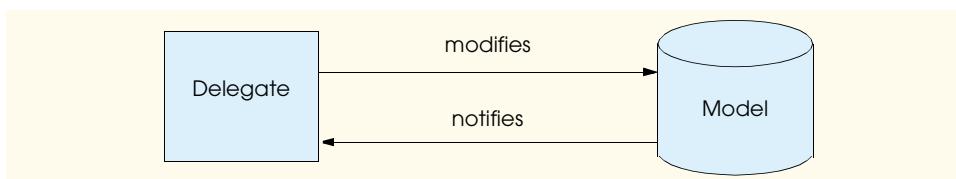


**Fig. 3.1** Model-view-controller architecture.

user provides some input (e.g., by typing text in a word processor,) the controller modifies the model with the given input. It is important to note that the model contains only the raw application data. In a simple text editor, the model might contain only the characters that make up the document. When the model changes, it notifies the view of the change, so that the view can update its presentation with the changed data. The view in a word processor might display the characters on the screen in a particular font, with a particular size, etc.

MVC does not restrict an application to a single view and controller. In a word processor, for example, there might be two views of a single document model. One view might display the document as an outline, and the other might display the document in a print-preview window. The word processor also may implement multiple controllers, such as a controller for handling keyboard input and a controller for handling mouse selections. If either controller makes a change in the model, both the outline view and the print-preview window show the change immediately, because the model notifies all views of any changes. A developer can provide additional views and controllers for the model without changing the existing components.

Java's Swing components implement a variation of MVC that combines the view and controller into a single object, called a *delegate* (Fig. 3.2). The delegate provides both a graphical presentation of the model and an interface for modifying the model. For example, every **JButton** has an associated **ButtonModel** for which the **JButton** is a delegate. The **ButtonModel** maintains state information, such as whether the **JButton** is pressed and whether the **JButton** is enabled, as well as a list of **ActionListeners**. The **JButton** provides a graphical presentation (e.g., a rectangle on the screen with a label and a border) and modifies the **ButtonModel**'s state (e.g., when the user presses the **JButton**). We discuss several Swing components that implement the delegate-model architecture throughout this chapter.



**Fig. 3.2** Delegate-model architecture in Java Swing components.

### 3.3 Observable Class and Observer Interface

The *Observer design pattern* enables loose coupling between an object and its dependent objects.<sup>2</sup> Loosely coupled objects interact by invoking methods declared in well-known interfaces, instead of invoking methods declared in particular classes. Using interface methods prevents each object from relying on the other objects' concrete class type. For example, Java's event-handling mechanism uses loose coupling to notify objects of events. If an object needs to handle certain events, it implements the appropriate listener interface (e.g., **ActionListener**). Objects that generate events invoke listener interface methods to notify listening objects of events. This loose coupling enables a **JButton**, for example, to send an **ActionEvent** to a **JFrame** subclass that implements **ActionListener**. The **JButton** interacts with the **JFrame** subclass only through method **actionPerformed** of interface **ActionListener**, and not through any method that is specific to the **JFrame** subclass. The **JButton** can send **ActionEvents** to other objects that also implement interface **ActionListener** (e.g., a programmer-defined class or an inner class).

Class **java.util.Observable** represents a model in MVC, or the *subject* in the Observer design pattern. Class **Observable** provides method **addObserver**, which takes a **java.util.Observer** argument. Interface **Observer** represents the view in MVC and enables loose coupling between an **Observable** object and its **Observers**. When the **Observable** object changes, it notifies each registered **Observer** of the change. The **Observer** can be an instance of any class that implements interface **Observer**; because the **Observable** object invokes methods defined in interface **Observer**, the objects remain loosely coupled. We discuss the details of this interaction in the example that follows.

The example in Fig. 3.4–Fig. 3.10. uses the MVC architecture, class **Observable** and interface **Observer** to implement an **AccountManager** application for managing bank account information. Figure 3.3 illustrates the application's MVC architecture. The **AccountController** accepts user input in the form of dollar amounts entered in a **JTextField**. The user then selects a **JButton**, either to withdraw or deposit the given amount, and the **AccountController** modifies the **Account** to execute the transaction. Class **Account** is an **Observable** object that acts as the application's model. When the **AccountController** performs the withdrawal or deposit, the **Account** notifies each view (**AccountTextView**, **AccountBarGraphView** and **AccountPieChartView**) that the **Account** information has changed. Each view updates its display with the modified **Account** information.

Class **Account** (Fig. 3.4) represents a bank account in the **AccountManager** application (Fig. 3.10). Class **Account** extends class **Observable** (line 9) and acts as a model in the application. Class **Account** has **balance** and **name** properties that represent the amount of money in the **Account** and a short description of the **Account**. The **Account** constructor (lines 18–22) initializes the **name** and **balance** properties.

Method **setBalance** (lines 25–35) changes the model by updating the account **balance**. The MVC architecture requires the model to notify its views when the model changes. Line 31 invokes method **setChanged** of class **Observable** to set the model's **changed** flag. Line 34 invokes method **notifyObservers** of class **Observable** to notify all **Account** **Observers** (i.e., views) of the change. An **Observable** object

2. E. Gamma et al., *Design Patterns* (New York: Addison-Wesley Publishing Company, 1995), 293.

must invoke method `setChanged` before invoking method `notifyObservers`. Method `notifyObservers` invokes method `update` of interface `Observer` for each registered `Observer`. Method `getBalance` (lines 38–41) simply returns the current `Account` balance. Method `getBalance` does not modify the model, so method `getBalance` does not invoke `setChanged` or `notifyObservers`.



### Common Programming Error 3.1

*Failing to invoke method `setChanged` before invoking method `notifyObservers` is a logic error. If method `setChanged` has not been invoked, method `notifyObservers` considers the `Observable` object unchanged and will not invoke each `Observer`'s `update` method.*

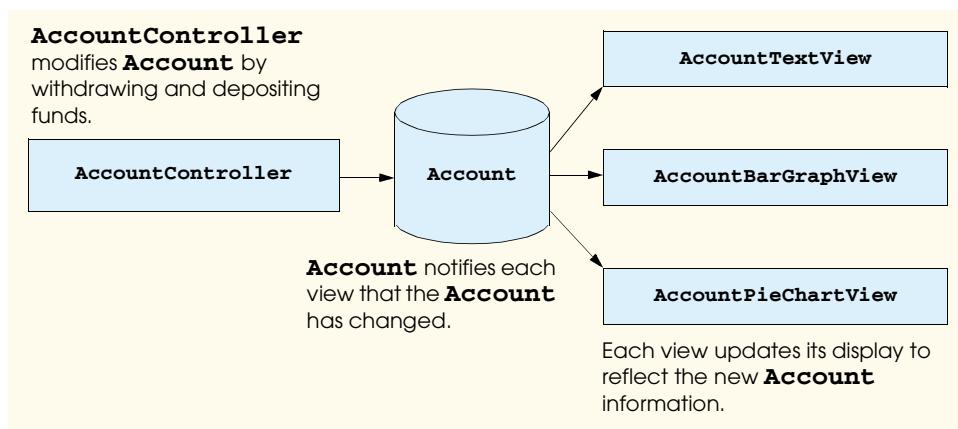


Fig. 3.3 **AccountManager** application MVC architecture.

```

1 // Account.java
2 // Account is an Observable class that represents a bank
3 // account in which funds may be deposited or withdrawn.
4 package com.deitel.advjhtp1.mvc.account;
5
6 // Java core packages
7 import java.util.Observable;
8
9 public class Account extends Observable {
10
11     // Account balance
12     private double balance;
13
14     // readonly Account name
15     private String name;
16
17     // Account constructor
18     public Account( String accountName, double openingDeposit )
19     {

```

Fig. 3.4 **Account Observable** class that represents a bank account (part 1 of 2).

```
20     name = accountName;
21     setBalance( openingDeposit );
22 }
23
24 // set Account balance and notify observers of change
25 private void setBalance( double accountBalance )
26 {
27     balance = accountBalance;
28
29     // must call setChanged before notifyObservers to
30     // indicate model has changed
31     setChanged();
32
33     // notify Observers that model has changed
34     notifyObservers();
35 }
36
37 // get Account balance
38 public double getBalance()
39 {
40     return balance;
41 }
42
43 // withdraw funds from Account
44 public void withdraw( double amount )
45     throws IllegalArgumentException
46 {
47     if ( amount < 0 )
48         throw new IllegalArgumentException(
49             "Cannot withdraw negative amount" );
50
51     // update Account balance
52     setBalance( getBalance() - amount );
53 }
54
55 // deposit funds in account
56 public void deposit( double amount )
57     throws IllegalArgumentException
58 {
59     if ( amount < 0 )
60         throw new IllegalArgumentException(
61             "Cannot deposit negative amount" );
62
63     // update Account balance
64     setBalance( getBalance() + amount );
65 }
66
67 // get Account name (readonly)
68 public String getName()
69 {
70     return name;
71 }
72 }
```

Fig. 3.4 **Account Observable** class that represents a bank account (part 2 of 2).



### Software Engineering Observation 3.1

Method **notifyObservers** does not guarantee the order in which it notifies **Observers**. Method **notifyObservers** as implemented in class **Observable** notifies **Observers** in the order the **Observers** were registered, but this behavior may be different in **Observable** subclasses or in different Java implementations.



### Software Engineering Observation 3.2

Method **notifyObservers** has no relation to methods **notify** and **notifyAll** of class **Object**. Multithreaded programs use methods **notify** and **notifyAll** to wake up **Threads** waiting to obtain an **Object**'s monitor.

Method **withdraw** (lines 44–53) subtracts the given **amount** from the **Account balance**. If the given **amount** is negative, lines 48–49 **throw** an **IllegalArgumentException**. Line 52 subtracts the withdrawn **amount** from the current **balance** and invokes method **setBalance** to update the **Account**. Method **setBalance** will notify **Observers** that the model was changed, so that the **Observers** can update their displays.

Method **deposit** (lines 56–65) adds the **amount** input to the **Account balance**. If the **amount** is negative, lines 60–61 **throw** an **IllegalArgumentException**. Line 64 adds the deposit **amount** to the current **balance** and invokes method **setBalance** to update the **Account**. Method **getName** (lines 68–71) returns the **Account name**.

Application **AccountManager** presents **Account** information to the user through three views: **AccountTextView**, **AccountBarGraphView** and **AccountPieChartView**. Each view presents a different visual representation of the **Account** information. **AbstractAccountView** (Fig. 3.5) is an **abstract** base class for these **Account** views that provides common functionality, such as registering as an **Account** observer. Class **AbstractAccountView** implements interface **Observer**, which allows each **AbstractAccountView** subclass to register as an **Observer** of an **Account**..

```
1 // AbstractAccountView.java
2 // AbstractAccountView is an abstract class that represents
3 // a view of an Account.
4 package com.deitel.advjhtp1.mvc.account;
5
6 // Java core packages
7 import java.util.*;
8 import java.awt.*;
9
10 // Java extension packages
11 import javax.swing.JPanel;
12 import javax.swing.border.*;
13
14 public abstract class AbstractAccountView extends JPanel
15     implements Observer {
16
17     // Account to observe
18     private Account account;
19 }
```

Fig. 3.5 **AbstractAccountView** abstract base class for observing **Accounts** (part 1 of 2).

```
20 // AbstractAccountView constructor
21 public AbstractAccountView( Account observableAccount )
22     throws NullPointerException
23 {
24     // do not allow null Accounts
25     if ( observableAccount == null )
26         throw new NullPointerException();
27
28     // update account data member to new Account
29     account = observableAccount;
30
31     // register as an Observer to receive account updates
32     account.addObserver( this );
33
34     // set display properties
35     setBackground( Color.white );
36     setBorder( new MatteBorder( 1, 1, 1, 1, Color.black ) );
37 }
38
39 // get Account for which this view is an Observer
40 public Account getAccount()
41 {
42     return account;
43 }
44
45 // update display with Account balance
46 protected abstract void updateDisplay();
47
48 // receive updates from Observable Account
49 public void update( Observable observable, Object object )
50 {
51     updateDisplay();
52 }
53 }
```

Fig. 3.5 **AbstractAccountView** abstract base class for observing **Accounts** (part 2 of 2).

Class **AbstractAccountView** extends **JPanel** because **AbstractAccountView** implementations provide graphical presentations of **Account** data. Line 18 declares a **private** member variable for the **Account** that the **AbstractAccountView** will observe. The constructor (lines 21–37) sets the **account** member variable to the new **Account** (line 29). Line 32 invokes method **addObserver** of class **Observable** to register the newly created **AbstractAccountView** instance as an **Observer** of the new **Account**. The **Account** will now notify this **AbstractAccountView** of any modifications to the **Account**. Lines 35–36 set the **AbstractAccountView**'s background color and border.

Method **getAccount** (lines 40–43) returns the **AbstractAccountView**'s **account**. Method **updateDisplay** (line 46) is marked **abstract**, requiring each **AbstractAccountView** subclass to provide an appropriate implementation for displaying the **Account** information. For example, **AbstractAccountView** subclass **AccountTextView** provides an **updateDisplay** implementation that shows the

**Account** balance in a **JTextField**. Method **update** (lines 49–52) invokes method **updateDisplay** each time an **Account** notifies the **AbstractAccountView** of a change. Interface **Observer** defines method **update**, which takes as an **Observable** argument a reference to the **Observable** instance that issued the **update**. An **Observable** object issues an **update** by invoking method **notifyObservers** of class **Observable**. Method **notifyObservers** invokes method **update** for each registered **Observer**. An **Observer** that listens for updates from multiple **Observable** objects can use the **Observable** argument to determine which **Observable** object issued the **update**. The **Object** argument (line 50) contains optional data the **Observable** object may pass to an overloaded version of method **notifyObservers**. This **Object** could contain information about the specific data that changed in the model.

**AccountTextView** (Fig. 3.6) extends **AbstractAccountView** to provide a text-based view of **Account** data. Line 16 creates a **JTextField** in which **AccountTextView** displays the **Account** balance. Lines 19–20 create a **NumberFormat** field to format the **Account** balance as U. S. dollars. The **AccountTextView** constructor (lines 23–35) invokes the **AbstractAccountView** constructor with the given **Account** to perform required initialization (line 25). Line 28 makes the **balanceTextField** uneditable to prevent users from modifying the balance directly. Lines 31–32 add a **JLabel** and the **balanceTextField** to the **AccountTextView**. Line 34 invokes method **updateDisplay** to display the current **Account** balance.

```
1 // AccountTextView.java
2 // AccountTextView is an AbstractAccountView subclass
3 // that displays an Account balance in a JTextField.
4 package com.deitel.advjhtp1.mvc.account;
5
6 // Java core packages
7 import java.util.*;
8 import java.text.NumberFormat;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class AccountTextView extends AbstractAccountView {
14
15     // JTextField for displaying Account balance
16     private JTextField balanceTextField = new JTextField( 10 );
17
18     // NumberFormat for US dollars
19     private NumberFormat moneyFormat =
20         NumberFormat.getCurrencyInstance( Locale.US );
21
22     // AccountTextView constructor
23     public AccountTextView( Account account )
24     {
25         super( account );
26     }
27
28     // Set the balance in the JTextField
29     protected void updateDisplay()
30     {
31         JLabel label = new JLabel( "Balance: " );
32         label.setHorizontalAlignment( SwingConstants.RIGHT );
33         label.setHorizontalTextPosition( SwingConstants.RIGHT );
34         balanceTextField.setEditable( false );
35         balanceTextField.setText( moneyFormat.format( account.getBalance() ) );
36     }
37
38     // Get the balance from the JTextField
39     protected void update( Object arg )
40     {
41         if ( arg instanceof Observable )
42             updateDisplay();
43     }
44 }
```

Fig. 3.6 **AccountTextView** for displaying observed **Account** information in a **JTextField** (part 1 of 2).

```
27     // make balanceTextField readonly
28     balanceTextField.setEditable( false );
29
30     // lay out components
31     add( new JLabel( "Balance: " ) );
32     add( balanceTextField );
33
34     updateDisplay();
35 }
36
37 // update display with Account balance
38 public void updateDisplay()
39 {
40     // set text in balanceTextField to formatted balance
41     balanceTextField.setText( moneyFormat.format(
42         getAccount().getBalance() ) );
43 }
44 }
```

Fig. 3.6 **AccountTextView** for displaying observed **Account** information in a **JTextField** (part 2 of 2).

Method **updateDisplay** (lines 38–43) implements abstract method **updateDisplay** of class **AbstractAccountView**. Lines 41–42 set the **balanceTextField**'s text to the formatted **Account** balance. Recall that method **update** of class **AbstractAccountView** invokes method **updateDisplay** each time method **update** receives a notification from the **Account** model.

**AccountBarGraphView** (Fig. 3.7) extends **AbstractAccountView** to provide a bar-graph view of **Account** data. Method **paintComponent** (lines 21–57) draws a bar graph for the current **Account** balance. Line 24 invokes method **paintComponent** of the superclass to follow the proper painting sequence. Line 27 gets the current **Account** balance. Line 32 calculates the length in pixels of the **Account**'s bar graph. The entire graph is 200 pixels wide and represents -\$5,000 to +\$5,000, so we divide the **Account** balance by \$10,000 and multiply by 200 pixels to calculate the length of the the bar. If the **Account** balance is positive, lines 36–37 draw the bar graph in black. If the **Account** balance is negative, lines 42–43 draw the bar graph in red.

```
1 // AccountBarGraphView.java
2 // AccountBarGraphView is an AbstractAccountView subclass
3 // that displays an Account balance as a bar graph.
4 package com.deitel.advjhtp1.mvc.account;
5
6 // Java core packages
7 import java.awt.*;
8
9 // Java extension packages
10 import javax.swing.*;
```

Fig. 3.7 **AccountBarGraphView** for rendering observed **Account** information as a bar graph (part 1 of 3).

```
12 public class AccountBarGraphView extends AbstractAccountView {
13
14     // AccountBarGraphView constructor
15     public AccountBarGraphView( Account account )
16     {
17         super( account );
18     }
19
20     // draw Account balance as a bar graph
21     public void paintComponent( Graphics g )
22     {
23         // ensure proper painting sequence
24         super.paintComponent( g );
25
26         // get Account balance
27         double balance = getAccount().getBalance();
28
29         // calculate integer height for bar graph (graph
30         // is 200 pixels wide and represents Account balances
31         // from -$5,000.00to +$5,000.00)
32         int barLength = ( int ) ( ( balance / 10000.0 ) * 200 );
33
34         // if balance is positive, draw graph in black
35         if ( balance >= 0.0 ) {
36             g.setColor( Color.black );
37             g.fillRect( 105, 15, barLength, 20 );
38         }
39
40         // if balance is negative, draw graph in red
41         else {
42             g.setColor( Color.red );
43             g.fillRect( 105 + barLength, 15, -barLength, 20 );
44         }
45
46         // draw vertical and horizontal axes
47         g.setColor( Color.black );
48         g.drawLine( 5, 25, 205, 25 );
49         g.drawLine( 105, 5, 105, 45 );
50
51         // draw graph labels
52         g.setFont( new Font( "SansSerif", Font.PLAIN, 10 ) );
53         g.drawString( "-$5,000", 5, 10 );
54         g.drawString( "$0", 110, 10 );
55         g.drawString( "+$5,000", 166, 10 );
56
57     } // end method paintComponent
58
59     // repaint graph when display is updated
60     public void updateDisplay()
61     {
62         repaint();
63     }
```

Fig. 3.7 **AccountBarGraphView** for rendering observed **Account** information as a bar graph (part 2 of 3).

```

64      // get AccountBarGraphView's preferred size
65      public Dimension getPreferredSize()
66      {
67          return new Dimension( 210, 50 );
68      }
69
70
71      // get AccountBarGraphView's minimum size
72      public Dimension getMinimumSize()
73      {
74          return getPreferredSize();
75      }
76
77      // get AccountBarGraphView's maximum size
78      public Dimension getMaximumSize()
79      {
80          return getPreferredSize();
81      }
82  }

```

**Fig. 3.7 AccountBarGraphView** for rendering observed **Account** information as a bar graph (part 3 of 3).

Method **updateDisplay** (lines 60–63) invokes method **repaint** (line 62) to update the bar graph’s display. **AbstractAccountView** method **update** invokes method **updateDisplay** each time the **Account** model notifies the view of a change in the model. Method **getPreferredSize** (lines 66–69) overrides method **getPreferredSize** of class **JPanel**. Line 68 returns a new **Dimension** object that specifies the **AccountBarGraphView**’s preferred size as 210 pixels wide by 50 pixels tall. Most **LayoutManagers** use method **getPreferredSize** to determine how much space to allocate for each component. Lines 72–81 override methods **getMinimumSize** and **getMaximumSize** to return the **AccountBarGraphView**’s preferred size.

**AssetPieChartView** (Fig. 3.8) provides a pie-chart view of multiple asset **Accounts**. **AssetPieChartView** shows the percentage of total assets held in each **Account** as wedges in the pie chart. **AssetPieChartView** defines method **addAccount** (line 25–42), which adds an **Account** to the **List** of **Accounts** shown in the pie chart. If the given **Account** reference is **null**, line 29 throws a **NullPointerException**. Otherwise, line 32 adds the **Account** to **accounts**. Line 35 invokes method **getRandomColor** and adds the random **Color** to the **colors Map**. **AssetPieChartView** uses this color to draw the **Account**’s wedge in the pie chart. The **Account** object itself is the **Color**’s key in the **Map**. Line 38 invokes method **addObserver** of class **Account** to register the **AssetPieChartView** for **Account** updates. Line 41 invokes method **repaint** to display the pie chart with the new **Account**’s information.

Method **removeAccount** (lines 45–58) removes an **Account** from the pie chart. Line 48 invokes method **deleteObserver** of class **Account** to unregister the **AssetPieChartView** as an **Observer** of the **Account**. Line 51 removes the **Account** from **List accounts**, and line 54 removes the **Account**’s color from **HashMap colors**. Line 57 invokes method **repaint** to update the pie-chart display.

```
1 // AssetPieChartView.java
2 // AssetPieChartView is an AbstractAccountView subclass that
3 // displays multiple asset Account balances as a pie chart.
4 package com.deitel.advjhttp1.mvc.account;
5
6 // Java core packages
7 import java.awt.*;
8 import java.util.*;
9 import java.util.List;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.swing.border.*;
14
15 public class AssetPieChartView extends JPanel
16     implements Observer {
17
18     // Set of observed Accounts
19     private List accounts = new ArrayList();
20
21     // Map of Colors for drawing pie chart wedges
22     private Map colors = new HashMap();
23
24     // add Account to pie chart view
25     public void addAccount( Account account )
26     {
27         // do not add null Accounts
28         if ( account == null )
29             throw new NullPointerException();
30
31         // add Account to accounts Vector
32         accounts.add( account );
33
34         // add Color to Hashtable for drawing Account's wedge
35         colors.put( account, getRandomColor() );
36
37         // register as Observer to receive Account updates
38         account.addObserver( this );
39
40         // update display with new Account information
41         repaint();
42     }
43
44     // remove Account from pie chart view
45     public void removeAccount( Account account )
46     {
47         // stop receiving updates from given Account
48         account.deleteObserver( this );
49
50         // remove Account from accounts Vector
51         accounts.remove( account );
52     }
```

Fig. 3.8 AssetPieChartView for rendering multiple observed asset Accounts as a pie chart (part 1 of 5).

```
53     // remove Account's Color from Hashtable
54     colors.remove( account );
55
56     // update display to remove Account information
57     repaint();
58 }
59
60 // draw Account balances in a pie chart
61 public void paintComponent( Graphics g )
62 {
63     // ensure proper painting sequence
64     super.paintComponent( g );
65
66     // draw pie chart
67     drawPieChart( g );
68
69     // draw legend to describe pie chart wedges
70     drawLegend( g );
71 }
72
73 // draw pie chart on given Graphics context
74 private void drawPieChart( Graphics g )
75 {
76     // get combined Account balance
77     double totalBalance = getTotalBalance();
78
79     // create temporary variables for pie chart calculations
80     double percentage = 0.0;
81     int startAngle = 0;
82     int arcAngle = 0;
83
84     Iterator accountIterator = accounts.iterator();
85     Account account = null;
86
87     // draw pie wedge for each Account
88     while ( accountIterator.hasNext() ) {
89
90         // get next Account from Iterator
91         account = ( Account ) accountIterator.next();
92
93         // draw wedges only for included Accounts
94         if ( !includeAccountInChart( account ) )
95             continue;
96
97         // get percentage of total balance held in Account
98         percentage = account.getBalance() / totalBalance;
99
100        // calculate arc angle for percentage
101        arcAngle = ( int ) Math.round( percentage * 360 );
102
103        // set drawing Color for Account pie wedge
104        g.setColor( ( Color ) colors.get( account ) );
```

Fig. 3.8 **AssetPieChartView** for rendering multiple observed asset **Accounts** as a pie chart (part 2 of 5).

```
105      // draw Account pie wedge
106      g.fillArc( 5, 5, 100, 100, startAngle, arcAngle );
107
108      // calculate startAngle for next pie wedge
109      startAngle += arcAngle;
110  }
111 } // end method drawPieChart
112
113 // draw pie chart legend on given Graphics context
114 private void drawLegend( Graphics g )
115 {
116     Iterator accountIterator = accounts.iterator();
117     Account account = null;
118
119     // create Font for Account name
120     Font font = new Font( "SansSerif", Font.BOLD, 12 );
121     g.setFont( font );
122
123     // get FontMetrics for calculating offsets and
124     // positioning descriptions
125     FontMetrics metrics = getFontMetrics( font );
126     int ascent = metrics.getMaxAscent();
127     int offsetY = ascent + 2;
128
129     // draw description for each Account
130     for ( int i = 1; accountIterator.hasNext(); i++ ) {
131
132         // get next Account from Iterator
133         account = ( Account ) accountIterator.next();
134
135         // draw Account color swatch at next offset
136         g.setColor( ( Color ) colors.get( account ) );
137         g.fillRect( 125, offsetY * i, ascent, ascent );
138
139         // draw Account name next to color swatch
140         g.setColor( Color.black );
141         g.drawString( account.getName(), 140,
142                     offsetY * i + ascent );
143     }
144 } // end method drawLegend
145
146 // get combined balance of all observed Accounts
147 private double getTotalBalance()
148 {
149     double sum = 0.0;
150
151     Iterator accountIterator = accounts.iterator();
152     Account account = null;
153
154 }
```

Fig. 3.8 **AssetPieChartView** for rendering multiple observed asset **Accounts** as a pie chart (part 3 of 5).

```
155     // calculate total balance
156     while ( accountIterator.hasNext() ) {
157         account = ( Account ) accountIterator.next();
158
159         // add only included Accounts to sum
160         if ( includeAccountInChart( account ) )
161             sum += account.getBalance();
162     }
163
164     return sum;
165 }
166
167 // return true if given Account should be included in
168 // pie chart
169 protected boolean includeAccountInChart( Account account )
170 {
171     // include only Asset accounts (Accounts with positive
172     // balances)
173     return account.getBalance() > 0.0;
174 }
175
176 // get a random Color for drawing pie wedges
177 private Color getRandomColor()
178 {
179     // calculate random red, green and blue values
180     int red = ( int ) ( Math.random() * 256 );
181     int green = ( int ) ( Math.random() * 256 );
182     int blue = ( int ) ( Math.random() * 256 );
183
184     // return newly created Color
185     return new Color( red, green, blue );
186 }
187
188 // receive updates from Observable Account
189 public void update( Observable observable, Object object )
190 {
191     repaint();
192 }
193
194 // get AccountBarGraphView's preferred size
195 public Dimension getPreferredSize()
196 {
197     return new Dimension( 210, 110 );
198 }
199
200 // get AccountBarGraphView's preferred size
201 public Dimension getMinimumSize()
202 {
203     return getPreferredSize();
204 }
205
```

Fig. 3.8 **AssetPieChartView** for rendering multiple observed asset **Accounts** as a pie chart (part 4 of 5).

```
206     // get AccountBarGraphView's preferred size
207     public Dimension getMaximumSize()
208     {
209         return getPreferredSize();
210     }
211 }
```

Fig. 3.8 **AssetPieChartView** for rendering multiple observed asset **Accounts** as a pie chart (part 5 of 5).

Method **paintComponent** (lines 61–71) invokes methods **drawPieChart** (line 67) and **drawLegend** (line 70) to draw the pie chart and chart legend, respectively. Method **drawPieChart** (lines 74–112) draws a pie-chart wedge for each **Account**. Line 77 invokes method **getTotalBalance** to get the total balance for all **Accounts**. Lines 80–111 calculate the percentage of the total balance held in each **Account** and draw the wedges. Line 91 gets the next **Account** from **accountIterator**. Line 94 invokes method **includeAccountInChart** to determine if the pie chart should include the current **Account**. If the chart should not include the **Account**, line 95 **continues** the **while** loop to the next iteration. Line 98 calculates the percentage of the total assets held in the current **Account**. Line 101 calculates the size of the **Account**'s pie wedge. Line 104 gets the **Account**'s color from **Map colors** and invokes method **setColor** of class **Graphics**. Line 107 invokes method **fillArc** of class **Graphics** to draw the **Account**'s pie wedge. The first four arguments to method **fillArc** specify the position and diameter of the arc, respectively. The third argument—**startAngle**—specifies the angle at which the arc should begin. The fourth argument—**arcAngle**—specifies the degrees of arc sweep. Line 101 sets the **startAngle** for the next pie wedge.

Method **drawLegend** (lines 115–145) draws a legend (shown in Fig. 3.10) to show which color represents each **Account**. The legend shows each color square and **Account** name in a list along the right side of the pie chart. Lines 137–138 set the **Font** in which to draw the **Account**. Lines 121–128 use a **FontMetrics** object to calculate the heights of characters in the current **Font**. Line 127 invokes method **getMaxAscent** of class **FontMetrics** to get the *maximum ascent* (i.e., maximum height above the baseline) of characters in the current **Font**. Line 128 calculates **offsetY** by adding 2 to the **Font**'s maximum ascent. We use **offsetY** to determine the position at which to draw each **Account**'s color square and name. Lines 131–144 draw the legend item for each **Account**. Line 134 gets the next **Account** from **accountIterator**. Lines 137–138 draw the color square, and lines 141–143 draw the **Account** name.

Method **getTotalBalance** (lines 148–165) calculates the total balance for all included **Accounts**. Line 160 invokes method **includeAccountInChart** to determine whether the calculation should include the current **Account**. If the calculation should include the **Account**, line 161 adds the **Account**'s balance to variable **sum**.

Method **includeAccountInChart** (lines 169–174) returns a **boolean** indicating whether the **Account** should be included in the pie chart. **AssetPieChartView** shows only asset **Accounts** (i.e., **Accounts** with positive balances). Line 173 returns **true** only if the **Account** balance is greater than zero. Subclasses can override this method to include and exclude **Accounts** based on other criteria.

Method `getRandomColor` (lines 177–186) generates a random `Color`. `AssetPieChartView` uses this method to generate a different `Color` for each `Account` in the pie chart. Lines 180–182 calculate random values for the `red`, `green` and `blue` `Color` components. Line 185 creates a new `Color` object using the random `red`, `green` and `blue` values and returns the new `Color` to the caller.

Method `update` (lines 189–192) invokes method `repaint` to update the pie-chart display. Method `getPreferredSize` (lines 195–198) returns the `AssetPieChartView`'s preferred size, which provides enough space to draw the pie chart and legend.

`AccountController` (Fig. 3.9) implements the controller in the MVC architecture. `AccountController` provides a user interface for modifying `Account` data. `AccountController` extends `JPanel` (line 14), because it provides a set of GUI components for depositing and withdrawing `Account` funds.

Line 28 sets the `account` member variable to the `Account` that `AccountController` will control. Line 31 creates a `JTextField` into which users can enter an amount to withdraw from, or deposit in, the controlled `Account`. Line 34 creates a `JButton` for depositing the given amount into the `Account`. The `depositButton`'s `ActionListener` (lines 37–55) invokes method `deposit` of class `Account` to deposit the amount entered in `amountTextField` (lines 44–45). If method `parseDouble` (line 44) throws a `NumberFormatException` because the text entered was not a valid number, lines 48–53 `catch` the exception and display an error message to the user.

```
1 // AccountController.java
2 // AccountController is a controller for Accounts. It provides
3 // a JTextField for inputting a deposit or withdrawal amount
4 // and JButtons for depositing or withdrawing funds.
5 package com.deitel.advjhttp1.mvc.account;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class AccountController extends JPanel {
15
16     // Account to control
17     private Account account;
18
19     // JTextField for deposit or withdrawal amount
20     private JTextField amountTextField;
21
22     // AccountController constructor
23     public AccountController( Account controlledAccount )
24     {
25         super();
26     }
```

Fig. 3.9 `AccountController` for obtaining user input to modify `Account` information (part 1 of 3).

```
27     // account to control
28     account = controlledAccount;
29
30     // create JTextField for entering amount
31     amountTextField = new JTextField( 10 );
32
33     // create JButton for deposits
34     JButton depositButton = new JButton( "Deposit" );
35
36     depositButton.addActionListener(
37         new ActionListener() {
38
39             public void actionPerformed( ActionEvent event )
40             {
41                 try {
42
43                     // deposit amount entered in amountTextField
44                     account.deposit( Double.parseDouble(
45                         amountTextField.getText() ) );
46                 }
47
48                 catch ( NumberFormatException exception ) {
49                     JOptionPane.showMessageDialog (
50                         AccountController.this,
51                         "Please enter a valid amount", "Error",
52                         JOptionPane.ERROR_MESSAGE );
53                 }
54             } // end method actionPerformed
55         }
56     );
57
58     // create JButton for withdrawals
59     JButton withdrawButton = new JButton( "Withdraw" );
60
61     withdrawButton.addActionListener(
62         new ActionListener() {
63
64             public void actionPerformed( ActionEvent event )
65             {
66                 try {
67
68                     // withdraw amount entered in amountTextField
69                     account.withdraw( Double.parseDouble(
70                         amountTextField.getText() ) );
71                 }
72
73                 catch ( NumberFormatException exception ) {
74                     JOptionPane.showMessageDialog (
75                         AccountController.this,
76                         "Please enter a valid amount", "Error",
77                         JOptionPane.ERROR_MESSAGE );
78                 }
79             }
80         }
81     );
82
83     // add components to frame
84     frame.add( depositButton, "Center" );
85     frame.add( withdrawButton, "Center" );
86     frame.add( amountTextField, "Center" );
87
88     // set frame properties
89     frame.setTitle( "Account Controller" );
90     frame.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
91     frame.pack();
92     frame.setVisible( true );
93 }
```

Fig. 3.9 **AccountController** for obtaining user input to modify **Account** information (part 2 of 3).

```

79             } // end method actionPerformed
80         }
81     );
82
83     // lay out controller components
84     setLayout( new FlowLayout() );
85     add( new JLabel( "Amount: " ) );
86     add( amountTextField );
87     add( depositButton );
88     add( withdrawButton );
89 }
90 }
```

**Fig. 3.9 AccountController** for obtaining user input to modify **Account** information (part 3 of 3).

Line 59 creates a **JButton** for withdrawing the given amount from the **Account**. The **withdrawButton**'s **ActionListener** (lines 62–80) invokes method **withdraw** of class **Account** to withdraw the amount entered in **amountTextField** (lines 69–70). If method **parseDouble** (line 69) throws a **NumberFormatException**, because the text entered was not a valid number, lines 73–78 **catch** the exception and display an error message to the user. Lines 84–88 lay out **amountTextField**, a **JLabel**, **depositButton** and **withdrawButton**.

**AccountManager** (Fig. 3.10) is an application that uses MVC to manage **Account** information. Lines 22 creates a new **Account** with the name **Account 1** and a \$1,000.00 balance. Line 25 invokes method **getAccountPanel** of class **AccountManager** to create a **JPanel** containing view and controller components for **account1**. Line 28 creates a new **Account** with the name **Account 2** and a \$3,000.00 balance. Line 31 invokes method **createAccountPanel** to create a **JPanel** containing view and controller components for **account2**. Lines 34–35 create an **AssetPieChartView** for displaying **account1** and **account2** information in a pie chart. Lines 38–39 invoke method **addAccount** of class **AssetPieChartView** to add **account1** and **account2** to the pie chart. Lines 42–47 create a **JPanel** with a **TitledBorder** for the **AssetPieChartView**. Lines 50–54 lay out the **JPanels** for each account and **AssetPieChartView**.

Method **createAccountPanel** creates a **JPanel** containing an **AccountController**, **AccountTextView** and **AccountBarGraphView** for the given **Account**. Lines 64–68 create a **JPanel** with a **TitledBorder** to contain the **Account**'s GUI components. Lines 71–72 create an **AccountTextView** for the **Account**. Lines 75–76 create an **AccountBarGraphView** for the **Account**. Lines 79–80 create an **AccountController** for the **Account**. Lines 83–85 lay out the **AccountTextView**, **AccountBarGraphView** and **AccountController** components on **accountPanel**.

Figure 3.10 shows sample **AccountManager** output. Notice as you run the program that the views reflect each withdrawal or deposit immediately. For example, depositing **1500.00** in **Account 1** causes the **AccountTextView** for **Account 1** to display **\$2,500.00**, the **AccountBarGraphView** for **Account 1** to display a larger bar graph and **AssetPieChartView** to display a larger wedge for **Account 1**. Withdrawing **4623.12** from Account 2 causes a new balance of **(\$1,623.12)** (parentheses

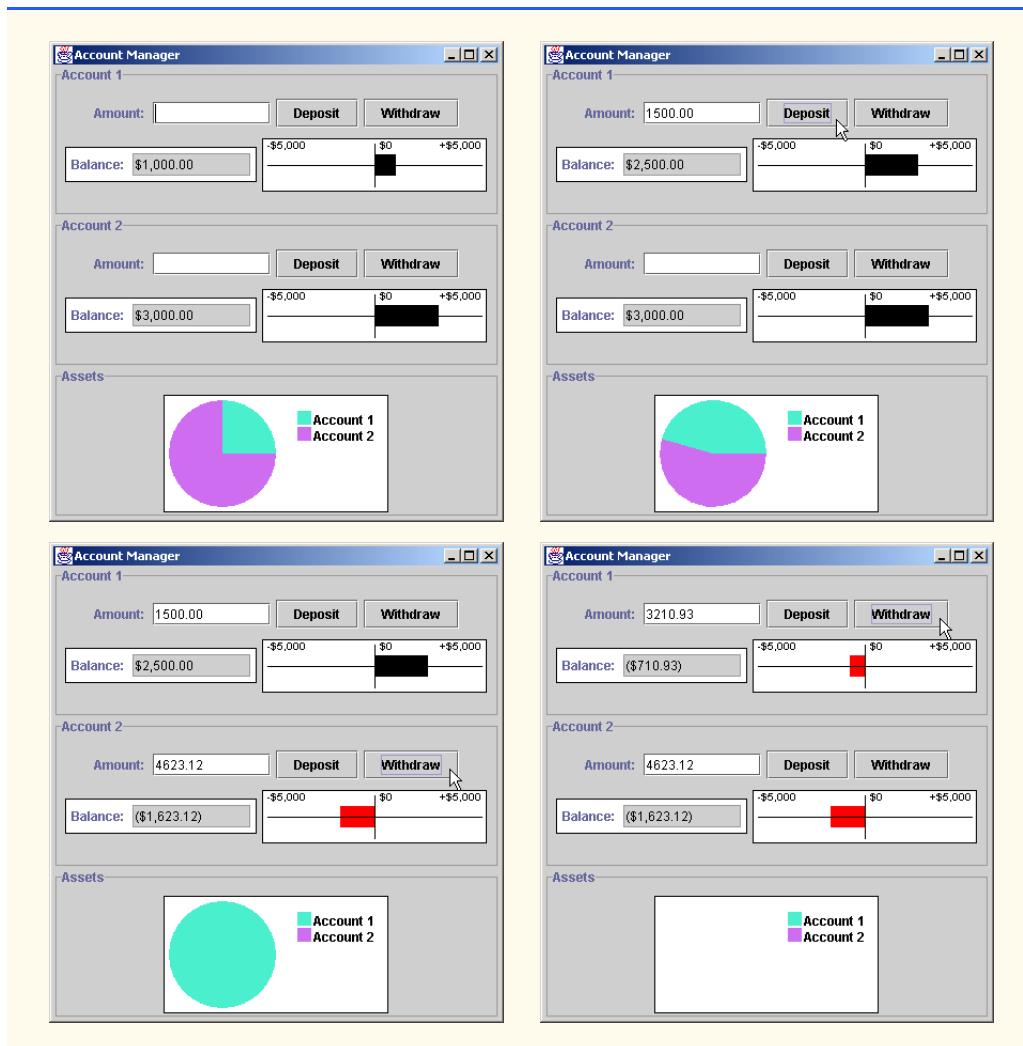
indicate a negative balance) to be shown, a red bar graph to be displayed and the **Account 2** wedge from **AssetPieChartView** to be removed. If both **Accounts** have negative balances, **AssetPieChartView** removes both **Accounts** from the pie chart.

```
1 // AccountManager.java
2 // AccountManager is an application that uses the MVC design
3 // pattern to manage bank Account information.
4 package com.deitel.advjhtp1.mvc.account;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12 import javax.swing.border.*;
13
14 public class AccountManager extends JFrame {
15
16     // AccountManager no-argument constructor
17     public AccountManager()
18     {
19         super( "Account Manager" );
20
21         // create account1 with initial balance
22         Account account1 = new Account( "Account 1", 1000.00 );
23
24         // create GUI for account1
25         JPanel account1Panel = createAccountPanel( account1 );
26
27         // create account2 with initial balance
28         Account account2 = new Account( "Account 2", 3000.00 );
29
30         // create GUI for account2
31         JPanel account2Panel = createAccountPanel( account2 );
32
33         // create AccountPieChartView to show Account pie chart
34         AssetPieChartView pieChartView =
35             new AssetPieChartView();
36
37         // add both Accounts to AccountPieChartView
38         pieChartView.addAccount( account1 );
39         pieChartView.addAccount( account2 );
40
41         // create JPanel for AccountPieChartView
42         JPanel pieChartPanel = new JPanel();
43
44         pieChartPanel.setBorder(
45             new TitledBorder( "Assets" ) );
```

Fig. 3.10 **AccountManager** application for displaying and modifying **Account** information using the model-view-controller architecture (part 1 of 3).

```
47     pieChartPanel.add( pieChartView );
48
49     // lay out account1, account2 and pie chart components
50     Container contentPane = getContentPane();
51     contentPane.setLayout( new GridLayout( 3, 1 ) );
52     contentPane.add( account1Panel );
53     contentPane.add( account2Panel );
54     contentPane.add( pieChartPanel );
55
56     setSize( 425, 450 );
57
58 } // end AccountManager constructor
59
60 // create GUI components for given Account
61 private JPanel createAccountPanel( Account account )
62 {
63     // create JPanel for Account GUI
64     JPanel accountPanel = new JPanel();
65
66     // set JPanel's border to show Account name
67     accountPanel.setBorder(
68         new TitledBorder( account.getName() ) );
69
70     // create AccountTextView for Account
71     AccountTextView accountTextView =
72         new AccountTextView( account );
73
74     // create AccountBarGraphView for Account
75     AccountBarGraphView accountBarGraphView =
76         new AccountBarGraphView( account );
77
78     // create AccountController for Account
79     AccountController accountController =
80         new AccountController( account );
81
82     // lay out Account's components
83     accountPanel.add( accountController );
84     accountPanel.add( accountTextView );
85     accountPanel.add( accountBarGraphView );
86
87     return accountPanel;
88
89 } // end method getAccountPanel
90
91 // execute application
92 public static void main( String args[] )
93 {
94     AccountManager manager = new AccountManager();
95     manager.setDefaultCloseOperation( EXIT_ON_CLOSE );
96     manager.setVisible( true );
97 }
98 }
```

Fig. 3.10 **AccountManager** application for displaying and modifying **Account** information using the model-view-controller architecture (part 2 of 3).



**Fig. 3.10** **AccountManager** application for displaying and modifying **Account** information using the model-view-controller architecture (part 3 of 3).

### 3.4 JList

**JList** is a Swing component that implements the delegate-model architecture. **JList** acts as a delegate for an underlying **ListModel** (Fig. 3.11). Interface **ListModel** defines methods for getting list elements, getting the size of the list and registering and unregistering **ListDataListeners**. A **ListModel** notifies each registered **ListDataListener** of each change in the **ListModel**.

Class **PhilosophersJList** (Fig. 3.12) uses a **JList** and **DefaultListModel** to display a list of philosophers. Class **DefaultListModel** provides a basic **ListModel** implementation. Line 23 creates a new **DefaultListModel**, and lines 24–31 add several philosophers to the **DefaultListModel**. Line 34 creates a new **JList** and

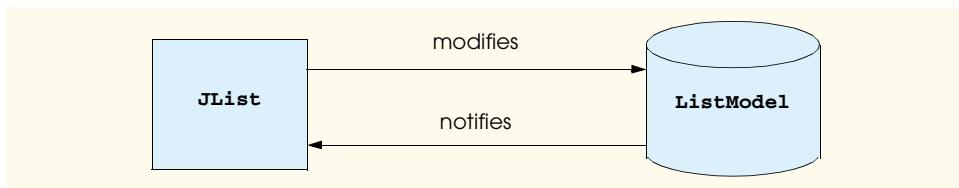


Fig. 3.11 **JList** and **ListModel** delegate-model architecture.

passes the **philosophers DefaultListModel** to the **JList** constructor. The **JList** constructor registers the **JList** as a **ListDataListener** of the **DefaultListModel**, so that updates to the **DefaultListModel** will be reflected in the **JList**. Lines 37–38 set the **JList**'s selection mode to allow the user to select only one philosopher at a time. The selection modes are constant integer values defined in interface **ListSelectionMode**. For example, **MULTIPLE\_INTERVAL\_SELECTION** allows the user to select multiple, separate intervals in the **JList**.

```

1 // PhilosophersJList.java
2 // MVC architecture using JList with a DefaultListModel
3 package com.deitel.advjhtp1.mvc.list;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.event.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class PhilosophersJList extends JFrame {
13
14     private DefaultListModel philosophers;
15     private JList list;
16
17     // PhilosophersJList constructor
18     public PhilosophersJList()
19     {
20         super( "Favorite Philosophers" );
21
22         // create a DefaultListModel to store philosophers
23         philosophers = new DefaultListModel();
24         philosophers.addElement( "Socrates" );
25         philosophers.addElement( "Plato" );
26         philosophers.addElement( "Aristotle" );
27         philosophers.addElement( "St. Thomas Aquinas" );
28         philosophers.addElement( "Soren Kierkegaard" );
29         philosophers.addElement( "Immanuel Kant" );
30         philosophers.addElement( "Friedrich Nietzsche" );
31         philosophers.addElement( "Hannah Arendt" );
32
  
```

Fig. 3.12 **PhilosophersJList** application demonstrating **JList** and **DefaultListModel** (part 1 of 3).

```
33     // create a JList for philosophers DefaultListModel
34     list = new JList( philosophers );
35
36     // allow user to select only one philosopher at a time
37     list.setSelectionMode(
38         ListSelectionModel.SINGLE_SELECTION );
39
40     // create JButton for adding philosophers
41     JButton addButton = new JButton( "Add Philosopher" );
42     addButton.addActionListener(
43         new ActionListener() {
44
45             public void actionPerformed( ActionEvent event )
46             {
47                 // prompt user for new philosopher's name
48                 String name = JOptionPane.showInputDialog(
49                     PhilosophersJList.this, "Enter Name" );
50
51                 // add new philosopher to model
52                 philosophers.addElement( name );
53             }
54         }
55     );
56
57     // create JButton for removing selected philosopher
58     JButton removeButton =
59         new JButton( "Remove Selected Philosopher" );
60
61     removeButton.addActionListener(
62         new ActionListener() {
63
64             public void actionPerformed( ActionEvent event )
65             {
66                 // remove selected philosopher from model
67                 philosophers.removeElement(
68                     list.getSelectedValue() );
69             }
70         }
71     );
72
73     // lay out GUI components
74     JPanel inputPanel = new JPanel();
75     inputPanel.add( addButton );
76     inputPanel.add( removeButton );
77
78     Container container = getContentPane();
79     container.add( list, BorderLayout.CENTER );
80     container.add( inputPanel, BorderLayout.NORTH );
81
82     setDefaultCloseOperation( EXIT_ON_CLOSE );
83     setSize( 400, 300 );
84     setVisible( true );
```

Fig. 3.12 **PhilosophersJList** application demonstrating **JList** and **DefaultListModel** (part 2 of 3).

```

85
86     } // end PhilosophersJList constructor
87
88     // execute application
89     public static void main( String args[] )
90     {
91         new PhilosophersJList();
92     }
93 }
```

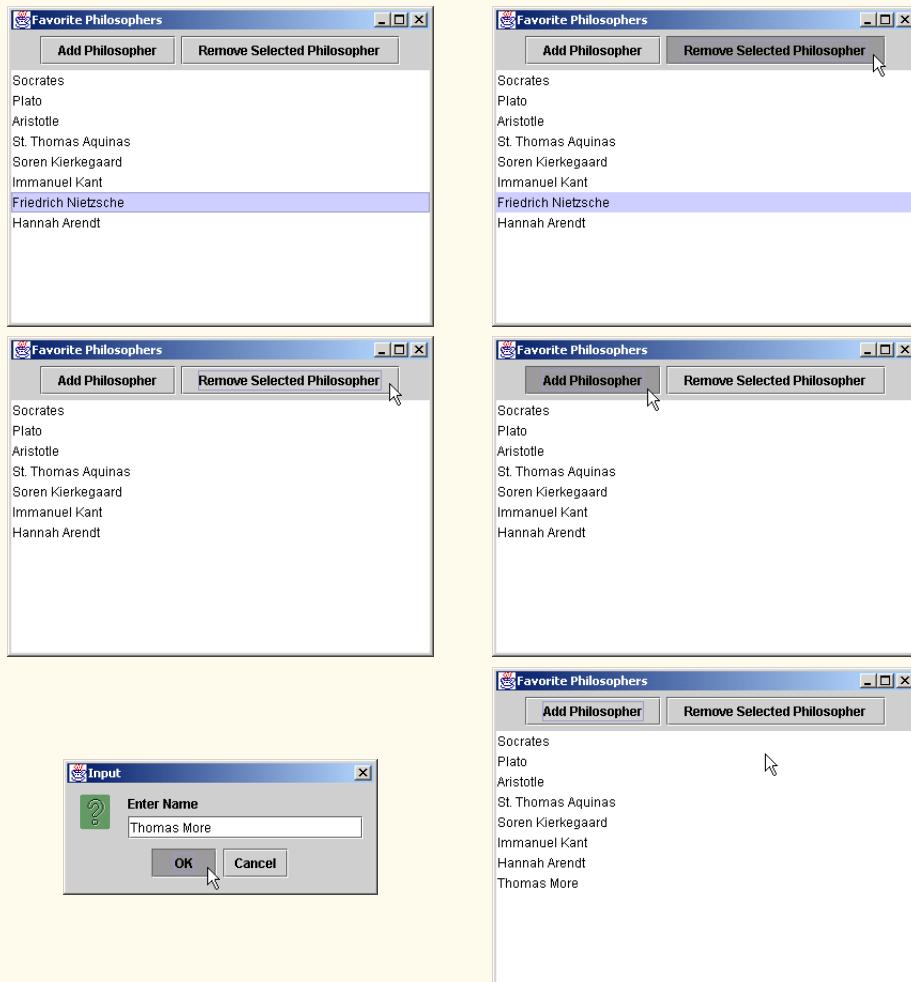


Fig. 3.12 **PhilosophersJList** application demonstrating **JList** and **DefaultListModel** (part 3 of 3).

Lines 41–55 create a **JButton** for adding new philosophers to the **DefaultListModel**. Lines 48–49 in method **actionPerformed** invoke **static** method **showInputDialog** of class **JOptionPane** to prompt the user for the philosopher's name.

Line 52 invokes method `addElement` of class `DefaultListModel` to add the new philosopher to the list. The `DefaultListModel` will notify the `JList` that the model changed, and the `JList` will update the display to include the new list item.

Lines 58–71 create a `JButton` for deleting a philosopher from the `DefaultListModel`. Lines 67–68 in method `actionPerformed` invoke method `getSelectedValue` of class `JList` to get the currently selected philosopher and invoke method `removeElement` of class `DefaultListModel` to remove the philosopher. The `DefaultListModel` will notify the `JList` that the model changed, and the `JList` will update the display to remove the deleted philosopher. Lines 74–84 lay out the GUI components and set `JFrame` properties for the application window.

### 3.5 JTable

`JTable` is another `Swing` component that implements the delegate-model architecture. `JTables` are delegates for tabular data stored in `TableModel` implementations. Interface `TableModel` declares methods for retrieving and modifying data (e.g., the value in a certain table cell) and for retrieving and modifying metadata (e.g., the number of columns and rows). The `JTable` delegate invokes `TableModel` methods to build its view of the `TableModel` and to modify the `TableModel` based on user input.

Figure 3.13 describes the methods defined in interface `TableModel`. Custom implementations of interface `TableModel` can use arbitrary internal representations of the tabular data. For example, the `DefaultTableModel` implementation uses `Vectors` to store the rows and columns of data. In Chapter 8, JDBC, we implement interface `TableModel` to create a `TableModel` that represents data stored in a JDBC `ResultSet`. Figure 3.14 illustrates the delegate-model relationship between `JTable` and `TableModel`.

Method	Description
<code>void addTableModelListener( TableModelListener listener )</code>	Add a <code>TableModelListener</code> to the <code>TableModel</code> . The <code>TableModel</code> will notify the <code>TableModelListener</code> of changes in the <code>TableModel</code> .
<code>void removeTableModelListener( TableModelListener listener )</code>	Remove a previously added <code>TableModelListener</code> from the <code>TableModel</code> .
<code>Class getColumnClass( int columnIndex )</code>	Get the <code>Class</code> object for values in the column with specified <code>columnIndex</code> .
<code>int getColumnCount()</code>	Get the number of columns in the <code>TableModel</code> .
<code>String getColumnName( int columnIndex )</code>	Get the name of the column with the given <code>columnIndex</code> .
<code>int getRowCount()</code>	Get the number of rows in the <code>TableModel</code> .

Fig. 3.13 `TableModel` interface methods and descriptions (part 1 of 2).

Method	Description
<code>Object getValueAt( int rowIndex, int columnIndex )</code>	Get an <code>Object</code> reference to the value stored in the <code>TableModel</code> at the given row and column indices.
<code>void setValueAt( Object value, int rowIndex, int columnIndex )</code>	Set the value stored in the <code>TableModel</code> at the given row and column indices.
<code>boolean isCellEditable( int rowIndex, int columnIndex )</code>	Return <code>true</code> if the cell at the given row and column indices is editable.

Fig. 3.13 `TableModel` interface methods and descriptions (part 2 of 2).

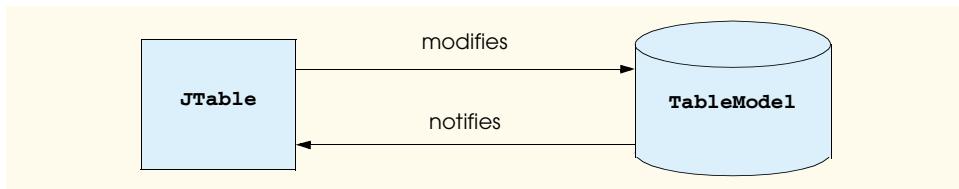


Fig. 3.14 `JTable` and `TableModel` delegate-model architecture.

**PhilosophersJTable** (Fig. 3.15) displays philosopher information in a `JTable` using a `DefaultTableModel`. Class `DefaultTableModel` implements interface `TableModel` and uses `Vectors` to represent the rows and columns of data. Line 24 creates the `philosophers DefaultTableModel`. Lines 27–29 add columns to the `DefaultTableModel` for the philosophers' first names, last names and years in which they lived. Lines 32–53 create rows for seven philosophers. Each row is a `String` array whose elements are the philosopher's first name, last name and the year in which the philosopher lived, respectively. Method `addRow` of class `DefaultTableModel` adds each philosopher to the `DefaultTableModel`. Line 56 creates the `JTable` that will act as a delegate for the `philosophers DefaultTableModel`.

Lines 59–72 create a `JButton` and `ActionListener` for adding a new philosopher to the `DefaultTableModel`. Line 66 in method `actionPerformed` creates a `String` array of three empty elements. Line 69 adds the empty `String` array to the `DefaultTableModel`. This causes the `JTable` to display a blank row at the bottom of the `JTable`. The user can then type the philosopher's information directly into the `JTable` cells. This demonstrates the `JTable` delegate acting as a controller, because it modifies the `DefaultTableModel` based on user input.

```

1 // PhilosophersJTable.java
2 // MVC architecture using JTable with a DefaultTableModel
3 package com.deitel.advjhtp1.mvc.table;
  
```

Fig. 3.15 `PhilosophersJTable` application demonstrating `JTable` and `DefaultTableModel` (part 1 of 4).

```
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.event.*;
8
9 // Java extension packages
10 import javax.swing.*;
11 import javax.swing.table.*;
12
13 public class PhilosophersJTable extends JFrame {
14
15     private DefaultTableModel philosophers;
16     private JTable table;
17
18     // PhilosophersJTable constructor
19     public PhilosophersJTable()
20     {
21         super( "Favorite Philosophers" );
22
23         // create a DefaultTableModel to store philosophers
24         philosophers = new DefaultTableModel();
25
26         // add Columns to DefaultTableModel
27         philosophers.addColumn( "First Name" );
28         philosophers.addColumn( "Last Name" );
29         philosophers.addColumn( "Years" );
30
31         // add philosopher names and dates to DefaultTableModel
32         String[] socrates = { "Socrates", "", "469-399 B.C." };
33         philosophers.addRow( socrates );
34
35         String[] plato = { "Plato", "", "428-347 B.C." };
36         philosophers.addRow( plato );
37
38         String[] aquinas = { "Thomas", "Aquinas", "1225-1274" };
39         philosophers.addRow( aquinas );
40
41         String[] kierkegaard = { "Soren", "Kierkegaard",
42             "1813-1855" };
43         philosophers.addRow( kierkegaard );
44
45         String[] kant = { "Immanuel", "Kant", "1724-1804" };
46         philosophers.addRow( kant );
47
48         String[] nietzsche = { "Friedrich", "Nietzsche",
49             "1844-1900" };
50         philosophers.addRow( nietzsche );
51
52         String[] arendt = { "Hannah", "Arendt", "1906-1975" };
53         philosophers.addRow( arendt );
54
```

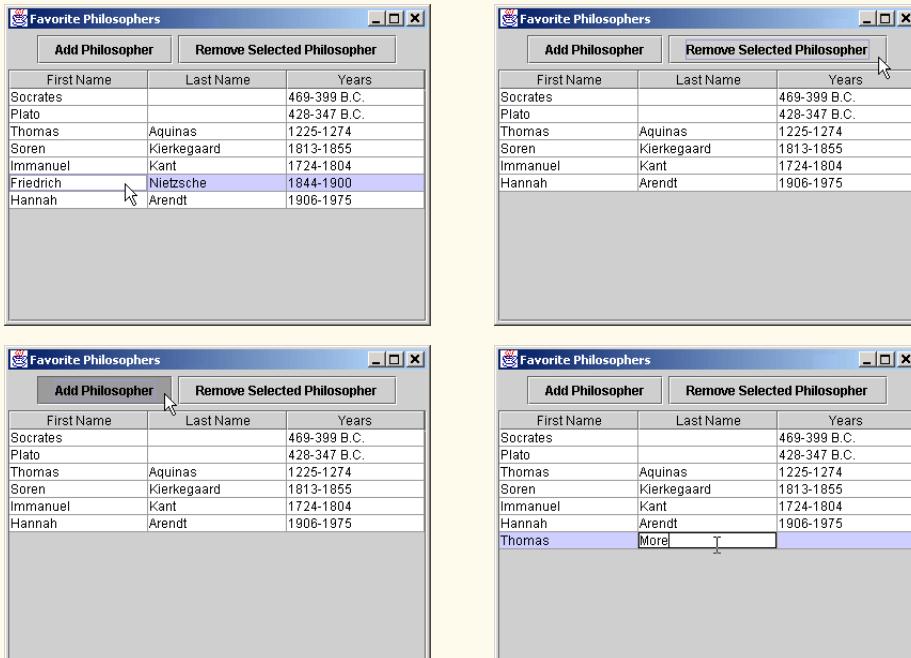
Fig. 3.15 PhilosophersJTable application demonstrating **JTable** and **DefaultTableModel** (part 2 of 4).

```
55     // create a JTable for philosophers DefaultTableModel
56     table = new JTable( philosophers );
57
58     // create JButton for adding philosophers
59     JButton addButton = new JButton( "Add Philosopher" );
60     addButton.addActionListener(
61         new ActionListener() {
62
63             public void actionPerformed( ActionEvent event )
64             {
65                 // create empty array for new philosopher row
66                 String[] philosopher = { "", "", "" };
67
68                 // add empty philosopher row to model
69                 philosophers.addRow( philosopher );
70             }
71         }
72     );
73
74     // create JButton for removing selected philosopher
75     JButton removeButton =
76         new JButton( "Remove Selected Philosopher" );
77
78     removeButton.addActionListener(
79         new ActionListener() {
80
81             public void actionPerformed( ActionEvent event )
82             {
83                 // remove selected philosopher from model
84                 philosophers.removeRow(
85                     table.getSelectedRow() );
86             }
87         }
88     );
89
90     // lay out GUI components
91     JPanel inputPanel = new JPanel();
92     inputPanel.add( addButton );
93     inputPanel.add( removeButton );
94
95     Container container = getContentPane();
96     container.add( new JScrollPane( table ),
97         BorderLayout.CENTER );
98     container.add( inputPanel, BorderLayout.NORTH );
99
100    setDefaultCloseOperation( EXIT_ON_CLOSE );
101    setSize( 400, 300 );
102    setVisible( true );
103
104 } // end PhilosophersJTable constructor
105
```

Fig. 3.15 PhilosophersJTable application demonstrating **JTable** and **DefaultTableModel** (part 3 of 4).

```

106     // execute application
107     public static void main( String args[] )
108     {
109         new PhilosophersJTable();
110     }
111 }
```



**Fig. 3.15** **PhilosophersJTable** application demonstrating **JTable** and **DefaultTableModel** (part 4 of 4).

Lines 75–88 create a **JButton** and **ActionListener** for removing a philosopher from the **DefaultTableModel**. Lines 84–85 in method **actionPerformed** retrieve the currently selected row in the **JTable** delegate and invoke method **removeRow** of class **DefaultTableModel** to remove the selected row. The **DefaultTableModel** notifies the **JTable** that the **DefaultTableModel** has changed, and the **JTable** removes the appropriate row from the display. Lines 96–97 add the **JTable** to a **JScrollPane**. **JTables** will not display their column headings unless placed within a **JScrollPane**.

## 3.6 JTTree

**JTtree** is one of the more complex Swing components that implements the delegate-model architecture. **TreeModels** represent hierarchical data, such as family trees, certain types of file systems, company management structures and document outlines. **JTrees** act as delegates (i.e., combined view and controller) for **TreeModels**.

To describe tree data structures, it is common to use terms that more commonly describe family trees.<sup>3</sup> A tree data structure consists of a set of nodes (i.e., members or elements of the tree) that are related as *parents*, *children*, *siblings*, *ancestors* and *descendents*. A parent is a node that has other nodes as its children. A child is a node that has a parent. Sibling nodes are two or more nodes that share the same parent. An ancestor is a node that has children that also have children. A descendent is a node whose parent also has a parent. A tree must have one node—called the *root node*—that is the parent or ancestor of all other nodes in the tree. [Note: Unlike in a family tree, in a tree data structure a child node can have only one parent.]

Figure 3.16 shows the relationships among nodes in a tree. The **JTree** contains a hierarchy of philosophers whose root is node **Philosophers**. Node **Philosophers** has seven child nodes, representing the major eras of philosophy—**Ancient**, **Medieval**, **Renaissance**, **Early Modern**, **Enlightenment**, **19th Century** and **20th Century**. Each philosopher (e.g., **Socrates**, **St. Thomas Aquinas** and **Immanuel Kant**) is a child of the philosopher’s era and is a descendent of node **Philosophers**. Nodes **Socrates**, **Plato** and **Aristotle** are sibling nodes, because they share the same parent node (**Ancient**).

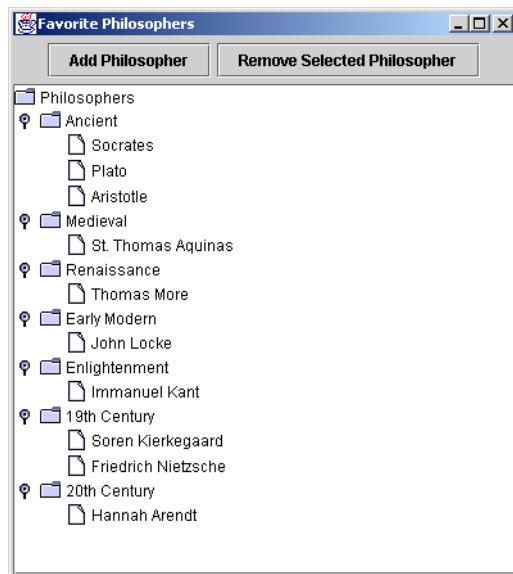


Fig. 3.16 **JTree** showing a hierarchy of philosophers.

3. Note that nodes in the tree data structures we discuss in this section each have only a single parent, unlike a family tree.

### 3.6.1 Using DefaultTreeModel

Interface **TreeModel** declares methods for representing a tree data structure in a **JTree**. Objects of any class can represent nodes in a **TreeModel**. For example, a **Person** class could represent a node in a family tree **TreeModel**. Class **DefaultTreeModel** provides a default **TreeModel** implementation. Interface **TreeNode** defines common operations for nodes in a **DefaultTreeModel**, such as **getParent** and **getAllowsChildren**. Interface **MutableTreeNode** extends interface **TreeNode** to represent a node that can change, either by adding or removing child nodes or by changing the **Object** associated with the node. Class **DefaultMutableTreeNode** provides a **MutableTreeNode** implementation suitable for use in a **DefaultTreeModel**.



#### Software Engineering Observation 3.3

Although a **TreeModel** implementation can use objects of any class to represent the **TreeModel**'s nodes, the **TreeModel** implementation must be able to determine the hierarchical relationships among those objects. For example, a **Person** class would have to provide methods such as **getParent** and **getChildren** for use in a family tree **TreeModel**.

**JTree** employs two interfaces to implement the **JTree**'s delegate functionality. Interface **TreeCellRenderer** represents an object that creates a view for each node in the **JTree**. Class **DefaultTreeCellRenderer** implements interface **TreeCellRenderer** and extends class **JLabel** to provide a **TreeCellRenderer** default implementation. Interface **TreeCellEditor** represents an object for controlling (i.e., editing) each node in the **JTree**. Class **DefaultTreeCellEditor** implements interface **TreeCellEditor** and uses a **JTextField** for the **TreeCellEditor** default implementation.

**PhilosophersJTree** (Fig. 3.17) uses a **DefaultTreeModel** to represent a set of philosophers. The **DefaultTreeModel** organizes the philosophers hierarchically according to their associated eras in the history of philosophy. Lines 26–27 invoke method **createPhilosopherTree** to get the root, **DefaultMutableTreeNode**, which contains all the philosopher nodes. Line 30 creates a **DefaultTreeModel** and passes the **philosophersNode DefaultMutableTreeNode** to the **DefaultTreeModel** constructor. Line 33 creates a **JTree** and passes **DefaultTreeModel philosophers** to the **JTree** constructor.

```
1 // PhilosophersJTree.java
2 // MVC architecture using JTree with a DefaultTreeModel
3 package com.deitel.advjhtp1.mvc.tree;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.event.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.swing.*;
12 import javax.swing.tree.*;
```

Fig. 3.17 **PhilosophersJTree** application demonstrating **JTree** and **DefaultTreeModel** (part 1 of 6).

```
13
14 public class PhilosophersJTree extends JFrame {
15
16     private JTree tree;
17     private DefaultTreeModel philosophers;
18     private DefaultMutableTreeNode rootNode;
19
20     // PhilosophersJTree constructor
21     public PhilosophersJTree()
22     {
23         super( "Favorite Philosophers" );
24
25         // get tree of philosopher DefaultMutableTreeNodes
26         DefaultMutableTreeNode philosophersNode =
27             createPhilosopherTree();
28
29         // create philosophers DefaultTreeModel
30         philosophers = new DefaultTreeModel( philosophersNode );
31
32         // create JTree for philosophers DefaultTreeModel
33         tree = new JTree( philosophers );
34
35         // create JButton for adding philosophers
36         JButton addButton = new JButton( "Add" );
37         addButton.addActionListener(
38             new ActionListener() {
39
40                 public void actionPerformed( ActionEvent event )
41                 {
42                     addElement();
43                 }
44             }
45         );
46
47         // create JButton for removing selected philosopher
48         JButton removeButton =
49             new JButton( "Remove" );
50
51         removeButton.addActionListener(
52             new ActionListener() {
53
54                 public void actionPerformed( ActionEvent event )
55                 {
56                     removeElement();
57                 }
58             }
59         );
60
61         // lay out GUI components
62         JPanel inputPanel = new JPanel();
63         inputPanel.add( addButton );
64         inputPanel.add( removeButton );
```

Fig. 3.17 **PhilosophersJTree** application demonstrating **JTree** and **DefaultTreeModel** (part 2 of 6).

```
65     Container container = getContentPane();
66
67     container.add( new JScrollPane( tree ),
68                     BorderLayout.CENTER );
69
70     container.add( inputPanel, BorderLayout.NORTH );
71
72     setDefaultCloseOperation( EXIT_ON_CLOSE );
73     setSize( 400, 300 );
74     setVisible( true );
75
76 } // end PhilosophersJTree constructor
77
78 // add new philosopher to selected era
79 private void addElement()
80 {
81     // get selected era
82     DefaultMutableTreeNode parent = getSelectedNode();
83
84     // ensure user selected era first
85     if ( parent == null ) {
86         JOptionPane.showMessageDialog(
87             PhilosophersJTree.this, "Select an era.",
88             "Error", JOptionPane.ERROR_MESSAGE );
89
90         return;
91     }
92
93
94     // prompt user for philosopher's name
95     String name = JOptionPane.showInputDialog(
96         PhilosophersJTree.this, "Enter Name:" );
97
98     // add new philosopher to selected era
99     philosophers.insertNodeInto(
100         new DefaultMutableTreeNode( name ),
101         parent, parent.getChildCount() );
102
103 } // end method addElement
104
105 // remove currently selected philosopher
106 private void removeElement()
107 {
108     // get selected node
109     DefaultMutableTreeNode selectedNode = getSelectedNode();
110
111     // remove selectedNode from model
112     if ( selectedNode != null )
113         philosophers.removeNodeFromParent( selectedNode );
114
115 }
```

Fig. 3.17 PhilosophersJTree application demonstrating JTTree and DefaultTreeModel (part 3 of 6).

```
116 // get currently selected node
117 private DefaultMutableTreeNode getSelectedNode()
118 {
119     // get selected DefaultMutableTreeNode
120     return ( DefaultMutableTreeNode )
121         tree.getLastSelectedPathComponent();
122 }
123
124 // get tree of philosopher DefaultMutableTreeNodes
125 private DefaultMutableTreeNode createPhilosopherTree()
126 {
127     // create rootNode
128     DefaultMutableTreeNode rootNode =
129         new DefaultMutableTreeNode( "Philosophers" );
130
131     // Ancient philosophers
132     DefaultMutableTreeNode ancient =
133         new DefaultMutableTreeNode( "Ancient" );
134     rootNode.add( ancient );
135
136     ancient.add( new DefaultMutableTreeNode( "Socrates" ) );
137     ancient.add( new DefaultMutableTreeNode( "Plato" ) );
138     ancient.add( new DefaultMutableTreeNode( "Aristotle" ) );
139
140     // Medieval philosophers
141     DefaultMutableTreeNode medieval =
142         new DefaultMutableTreeNode( "Medieval" );
143     rootNode.add( medieval );
144
145     medieval.add( new DefaultMutableTreeNode(
146         "St. Thomas Aquinas" ) );
147
148     // Renaissance philosophers
149     DefaultMutableTreeNode renaissance =
150         new DefaultMutableTreeNode( "Renaissance" );
151     rootNode.add( renaissance );
152
153     renaissance.add( new DefaultMutableTreeNode(
154         "Thomas More" ) );
155
156     // Early Modern philosophers
157     DefaultMutableTreeNode earlyModern =
158         new DefaultMutableTreeNode( "Early Modern" );
159     rootNode.add( earlyModern );
160
161     earlyModern.add( new DefaultMutableTreeNode(
162         "John Locke" ) );
163
164     // Enlightenment Philosophers
165     DefaultMutableTreeNode enlightenment =
166         new DefaultMutableTreeNode( "Enlightenment" );
167     rootNode.add( enlightenment );
```

Fig. 3.17 **PhilosophersJTree** application demonstrating **JTree** and **DefaultTreeModel** (part 4 of 6).

```
168     enlightenment.add( new DefaultMutableTreeNode(
169         "Immanuel Kant" ) );
170
171     // 19th Century Philosophers
172     DefaultMutableTreeNode nineteenth =
173         new DefaultMutableTreeNode( "19th Century" );
174     rootNode.add( nineteenth );
175
176     nineteenth.add( new DefaultMutableTreeNode(
177         "Soren Kierkegaard" ) );
178
179     nineteenth.add( new DefaultMutableTreeNode(
180         "Friedrich Nietzsche" ) );
181
182     // 20th Century Philosophers
183     DefaultMutableTreeNode twentieth =
184         new DefaultMutableTreeNode( "20th Century" );
185     rootNode.add( twentieth );
186
187     twentieth.add( new DefaultMutableTreeNode(
188         "Hannah Arendt" ) );
189
190     return rootNode;
191
192 } // end method createPhilosopherTree
193
194 // execute application
195 public static void main( String args[] )
196 {
197     new PhilosophersJTree();
198 }
199 }
```

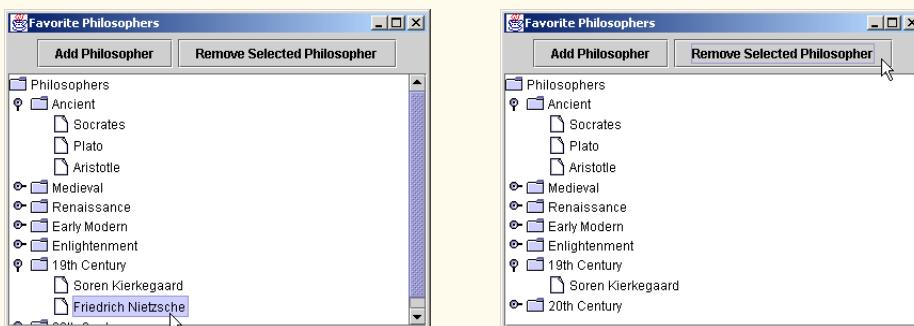
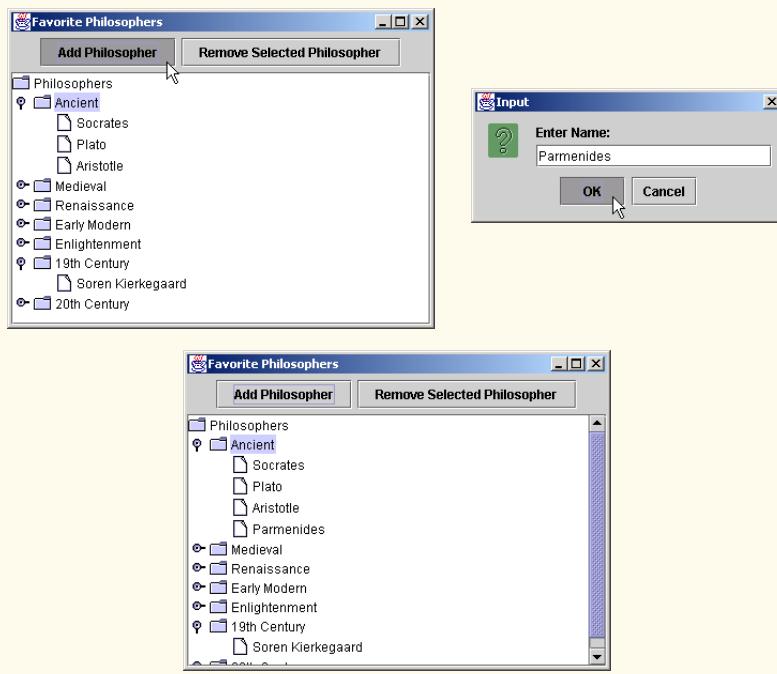


Fig. 3.17 **PhilosophersJTree** application demonstrating **JTree** and **DefaultTreeModel** (part 5 of 6).



**Fig. 3.17** **PhilosophersJTree** application demonstrating **JTree** and **DefaultTreeModel** (part 6 of 6).

Lines 36–45 create a **JButton** and an **ActionListener** for adding a philosopher to the **philosophers DefaultTreeModel**. Line 42 in method **actionPerformed** invokes method **addElement** to add a new philosopher. Lines 48–59 create a **JButton** and an **ActionListener** for removing a philosopher from the **philosophers DefaultTreeModel**. Line 56 invokes method **removeElement** to remove the currently selected philosopher from the model.

Method **addElement** (lines 80–103) gets the currently selected node in the **JTree** by invoking method **getSelectedNode** (line 83). Method **addElement** inserts the new philosopher node as a child of the currently selected node. If there is no node currently selected, line 91 returns from method **addElement** without adding a new node. Lines 95–96 invoke **static** method **showInputDialog** of class **JOptionPane** to prompt the user for the new philosopher's name. Lines 99–101 invoke method **insertNodeInto** of class **DefaultTreeModel** to insert the new philosopher in the model. Line 100 creates a new **DefaultMutableTreeNode** for the given philosopher. Line 101 specifies the parent node to which the new philosopher should be added. The final argument to method **insertNodeInto** specifies the index at which the new node should be inserted. Line 101 invokes method **getChildCount** of class **DefaultMutableTreeNode** to get the total number of children in node **parent**, which will cause the new node to be added as the last child of **parent**.

Method `removeElement` (lines 106–114) invokes method `getSelectedNode` (line 109) to get the currently selected node in the `JTree`. If `selectedNode` is not `null`, line 113 invokes method `removeNodeFromParent` of class `DefaultTreeModel` to remove `selectedNode` from the model. Method `getSelectedNode` (lines 117–122) invokes method `getLastSelectedPathComponent` of class `JTree` to get a reference to the currently selected node (line 121). Line 120 casts the selected node to `DefaultMutableTreeNode` and returns the reference to the caller.

Method `createPhilosopherTree` (lines 125–192) creates `DefaultMutableTreeNodes` for several philosophers and for the eras in which the philosophers lived. Lines 128–129 create a `DefaultMutableTreeNode` for the tree's root. Class `DefaultMutableTreeNode` has property `userObject` that stores an `Object` that contains the node's data. The `String` passed to the `DefaultMutableTreeNode` constructor (line 129) is the `userObject` for `rootNode`. The `JTree`'s `TreeCellRenderer` will invoke method `toString` of class `DefaultMutableTreeNode` to get a `String` to display for this node in the `JTree`.



#### Software Engineering Observation 3.4

Method `toString` of class `DefaultMutableTreeNode` returns the value returned by its `userObject`'s `toString` method.

Lines 132–134 create a `DefaultMutableTreeNode` for the `ancient` era of philosophy and add node `ancient` as a child of `rootNode` (line 134). Lines 136–138 create `DefaultMutableTreeNodes` for three ancient philosophers and add each `DefaultMutableTreeNode` as a child of `DefaultMutableTreeNode` `ancient`. Lines 141–189 create several additional `DefaultMutableTreeNodes` for other eras in the history of philosophy and for philosophers in those eras. Line 191 returns `rootNode`, which now contains the era and philosopher `DefaultMutableTreeNodes` as its children and descendants, respectively.

### 3.6.2 Custom TreeModel Implementation

If the `DefaultTreeModel` implementation is not sufficient for an application, developers also can provide custom implementations of interface `TreeModel`. `FileSystemModel` (Fig. 3.18) implements interface `TreeModel` to provide a model of a computer's file system. A file system consists of directories and files arranged in a hierarchy. Line 17 declares a `File` reference `root` that serves as the root node in the hierarchy. This `File` is a directory that contains files and other directories. The `FileSystemModel` constructor (lines 23–26) takes a `File` argument for the `FileSystemModel` root. Method `getRoot` (lines 29–32) returns the `FileSystemModel`'s root node.

```
1 // FileSystemModel.java
2 // TreeModel implementation using File objects as tree nodes.
3 package com.deitel.advjhtp1.mvc.tree.filesystem;
4
5 // Java core packages
6 import java.io.*;
```

Fig. 3.18 `FileSystemModel` implementation of interface `TreeModel` to represent a file system (part 1 of 5).

```
7 import java.util.*;
8
9 // Java extension packages
10 import javax.swing.*;
11 import javax.swing.tree.*;
12 import javax.swing.event.*;
13
14 public class FileSystemModel implements TreeModel {
15
16     // hierarchy root
17     private File root;
18
19     // TreeModelListeners
20     private Vector listeners = new Vector();
21
22     // FileSystemModel constructor
23     public FileSystemModel( File rootDirectory )
24     {
25         root = rootDirectory;
26     }
27
28     // get hierarchy root (root directory)
29     public Object getRoot()
30     {
31         return root;
32     }
33
34     // get parent's child at given index
35     public Object getChild( Object parent, int index )
36     {
37         // get parent File object
38         File directory = ( File ) parent;
39
40         // get list of files in parent directory
41         String[] children = directory.list();
42
43         // return File at given index and override toString
44         // method to return only the File's name
45         return new TreeFile( directory, children[ index ] );
46     }
47
48     // get parent's number of children
49     public int getChildCount( Object parent )
50     {
51         // get parent File object
52         File file = ( File ) parent;
53
54         // get number of files in directory
55         if ( file.isDirectory() ) {
56
57             String[] fileList = file.list();
```

Fig. 3.18 **FileSystemModel** implementation of interface **TreeModel** to represent a file system (part 2 of 5).

```
59         if ( fileList != null )
60             return file.list().length;
61     }
62
63     return 0; // childCount is 0 for files
64 }
65
66 // return true if node is a file, false if it is a directory
67 public boolean isLeaf( Object node )
68 {
69     File file = ( File ) node;
70     return file.isFile();
71 }
72
73 // get numeric index of given child node
74 public int getIndexOfChild( Object parent, Object child )
75 {
76     // get parent File object
77     File directory = ( File ) parent;
78
79     // get child File object
80     File file = ( File ) child;
81
82     // get File list in directory
83     String[] children = directory.list();
84
85     // search File list for given child
86     for ( int i = 0; i < children.length; i++ ) {
87
88         if ( file.getName().equals( children[ i ] ) ) {
89
90             // return matching File's index
91             return i;
92         }
93     }
94
95     return -1; // indicate child index not found
96
97 } // end method getIndexOfChild
98
99 // invoked by delegate if value of Object at given
100 // TreePath changes
101 public void valueForPathChanged( TreePath path,
102     Object value )
103 {
104     // get File object that was changed
105     File oldFile = ( File ) path.getLastPathComponent();
106
107     // get parent directory of changed File
108     String fileParentPath = oldFile.getParent();
109 }
```

Fig. 3.18 **FileSystemModel** implementation of interface **TreeModel** to represent a file system (part 3 of 5).

```
110     // get value of newFileName entered by user
111     String newFileName = ( String ) value;
112
113     // create File object with newFileName for
114     // renaming oldFile
115     File targetFile = new File(
116         fileParentPath, newFileName );
117
118     // rename oldFile to targetFile
119     oldFile.renameTo( targetFile );
120
121     // get File object for parent directory
122     File parent = new File( fileParentPath );
123
124     // create int array for renamed File's index
125     int[] changedChildrenIndices =
126         { getIndexOfChild( parent, targetFile ) };
127
128     // create Object array containing only renamed File
129     Object[] changedChildren = { targetFile };
130
131     // notify TreeModelListeners of node change
132     fireTreeNodesChanged( path.getParentPath(),
133                         changedChildrenIndices, changedChildren );
134
135 } // end method valueForPathChanged
136
137 // notify TreeModelListeners that children of parent at
138 // given TreePath with given indices were changed
139 private void fireTreeNodesChanged( TreePath parentPath,
140     int[] indices, Object[] children )
141 {
142     // create TreeModelEvent to indicate node change
143     TreeModelEvent event = new TreeModelEvent( this,
144         parentPath, indices, children );
145
146     Iterator iterator = listeners.iterator();
147     TreeModelListener listener = null;
148
149     // send TreeModelEvent to each listener
150     while ( iterator.hasNext() ) {
151         listener = ( TreeModelListener ) iterator.next();
152         listener.treeNodesChanged( event );
153     }
154 } // end method fireTreeNodesChanged
155
156 // add given TreeModelListener
157 public void addTreeModelListener(
158     TreeModelListener listener )
159 {
160     listeners.add( listener );
161 }
```

Fig. 3.18 **FileSystemModel** implementation of interface **TreeModel** to represent a file system (part 4 of 5).

```
162     // remove given TreeModelListener
163     public void removeTreeModelListener(
164         TreeModelListener listener )
165     {
166         listeners.remove( listener );
167     }
168
169
170     // TreeFile is a File subclass that overrides method
171     // toString to return only the File name.
172     private class TreeFile extends File {
173
174         // TreeFile constructor
175         public TreeFile( File parent, String child )
176         {
177             super( parent, child );
178         }
179
180         // override method toString to return only the File name
181         // and not the full path
182         public String toString()
183         {
184             return getName();
185         }
186     } // end inner class TreeFile
187 }
```

Fig. 3.18 **FileSystemModel** implementation of interface **TreeModel** to represent a file system (part 5 of 5).

When building its view of a **TreeModel**, a **JTree** repeatedly invokes method **getChild** (lines 35–46) to traverse the **TreeModel**'s nodes. Method **getChild** returns argument **parent**'s child node at the given **index**. The nodes in a **TreeModel** need not implement interface **TreeNode** or interface **MutableTreeNode**; any **Object** can be a node in a **TreeModel**. In class **FileSystemModel**, each node is a **File**. Line 38 casts **Object** reference **parent** to a **File** reference. Line 41 invokes method **list** of class **File** to get a list of file names in **directory**. Line 45 returns a new **TreeFile** object for the **File** at the given **index**. **JTree** invokes method **toString** of class **TreeFile** to get a label for the node in the **JTree**.

Method **getChildCount** (lines 49–64) returns the number of children contained in argument **parent**. Line 52 casts **Object** reference **parent** to a **File** reference named **file**. If **file** is a directory (line 55), lines 57–60 get a list of file names in the directory and return the **length** of the list. If **file** is not a directory, line 63 returns **0**, to indicate that **file** has no children.

A **JTree** invokes method **isLeaf** of class **FileSystemModel** (lines 67–71) to determine if **Object** argument **node** is a *leaf node*—a node that does not contain children.<sup>4</sup> In a file system, only directories can contain children, so line 70 returns **true** only if argument **node** is a file (not a directory).

4. Leaf node controls the initial screen display of the expand handle.

Method `getIndexOfChild` (lines 74–98) returns argument `child`'s index in the given `parent` node. For example, if `child` were the third node in `parent`, method `getIndexOfChild` would return zero-based index 2. Lines 77 and 80 get `File` references for the `parent` and `child` nodes, respectively. Line 83 gets a list of files, and lines 86–93 search through the list for the given `child`. If the filename in the list matches the given child (line 88), line 91 returns the index `i`. Otherwise, line 95 returns `-1`, to indicate that `parent` did not contain `child`.

The `JTree` delegate invokes method `valueForPathChanged` (lines 101–135) when the user edits a node in the tree. A user can click on a node in the `JTree` and edit the node's name, which corresponds to the associated `File` object's file name. When a user edits a node, `JTree` invokes method `valueForPathChanged` and passes a `TreePath` argument that represents the changed node's location in the tree, and an `Object` that contains the node's new value. In this example, the new value is a new file name `String` for the associated `File` object. Line 105 invokes method `getLastPathComponent` of class `TreePath` to obtain the `File` object to rename. Line 108 gets `oldFile`'s parent directory. Line 111 casts argument `value`, which contains the new file name, to a `String`. Lines 115–116 create `File` object `targetFile` using the new file name. Line 119 invokes method `renameTo` of class `File` to rename `oldFile` to `targetFile`.

After renaming the file, the `FileSystemModel` must notify its `TreeModelListeners` of the change by issuing a `TreeModelEvent`. A `TreeModelEvent` that indicates a node change includes a reference to the `TreeModel` that generated the event, the `TreePath` of the changed nodes' parent node, an integer array containing the changed nodes' indices and an `Object` array containing references to the changed nodes themselves. Line 122 creates a `File` object for the renamed file's parent directory. Lines 125–126 create an integer array for the indices of changed nodes. Line 128 creates an `Object` array of changed nodes. The integer and `Object` arrays have only one element each because only one node changed. If multiple nodes were changed, these arrays would need to include elements for each changed node. Lines 132–133 invoke method `fireTreeNodeChanged` to issue the `TreeModelEvent`.



### Performance Tip 3.1

*JTree uses the index and Object arrays in a TreeModelEvent to determine which nodes in the JTree need to be updated. This method improves performance by updating only the nodes that have changed, and not the entire JTree.*

Method `fireTreeNodeChanged` (lines 139–154) issues a `TreeModelEvent` to all registered `TreeModelListeners`, indicating that nodes in the `TreeModel` have changed. `TreePath` argument `parentPath` is the path to the parent whose child nodes changed. The integer and `Object` array arguments contain the indices of the changed nodes and references to the changed nodes, respectively. Lines 143–144 create the `TreeModel` event with the given event data. Lines 150–153 iterate through the list of `TreeModelListeners`, sending the `TreeModelEvent` to each. Methods `addTreeModelListener` (lines 157–161) and `removeTreeModelListener` (lines 164–168) allow `TreeModelListeners` to register and unregister for `TreeModelEvents`.

Inner-class `TreeFile` (lines 172–186) overrides method `toString` of superclass `File`. Method `toString` of class `File` returns a `String` containing the `File`'s full path name (e.g., `D:\Temp\README.TXT`). Method `toString` of class `TreeFile` (lines 182–185) overrides this method to return only the `File`'s name (e.g.,

**README.TXT**). Class **JTree** uses a **DefaultTreeCellRenderer** to display each node in its **TreeModel**. The **DefaultTreeCellRenderer** invokes the node's **toString** method to get the text for the **DefaultTreeCellRenderer**'s label. Class **TreeFile** overrides method **toString** of class **File** so the **DefaultTreeCellRenderer** will show only the **File**'s name in the **JTree**, instead of the full path.

**FileTreeFrame** (Fig. 3.19) uses a **JTree** and a **FileSystemModel** to allow the user to view and modify a file system. The user interface consists of a **JTree** that shows the file system and a **JTextArea** that shows information about the currently selected file. Lines 33–34 create the uneditable **JTextArea** for displaying file information. Lines 37–38 create a **FileSystemModel** whose root is **directory**. Line 41 creates a **JTree** for the **FileSystemModel**. Line 44 sets the **JTree**'s editable property to **true**, to allow users to rename files displayed in the **JTree**.

```
1 // FileTreeFrame.java
2 // JFrame for displaying file system contents in a JTree
3 // using a custom TreeModel.
4 package com.deitel.advjhtp1.mvc.tree.filesystem;
5
6 // Java core packages
7 import java.io.*;
8 import java.awt.*;
9 import java.awt.event.*;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.swing.tree.*;
14 import javax.swing.event.*;
15
16 public class FileTreeFrame extends JFrame {
17
18     // JTree for displaying file system
19     private JTree fileTree;
20
21     // FileSystemModel TreeModel implementation
22     private FileSystemModel fileSystemModel;
23
24     // JTextArea for displaying selected file's details
25     private JTextArea fileDetailsTextArea;
26
27     // FileTreeFrame constructor
28     public FileTreeFrame( String directory )
29     {
30         super( "JTree FileSystem Viewer" );
31
32         // create JTextArea for displaying File information
33         fileDetailsTextArea = new JTextArea();
34         fileDetailsTextArea.setEditable( false );
35     }
```

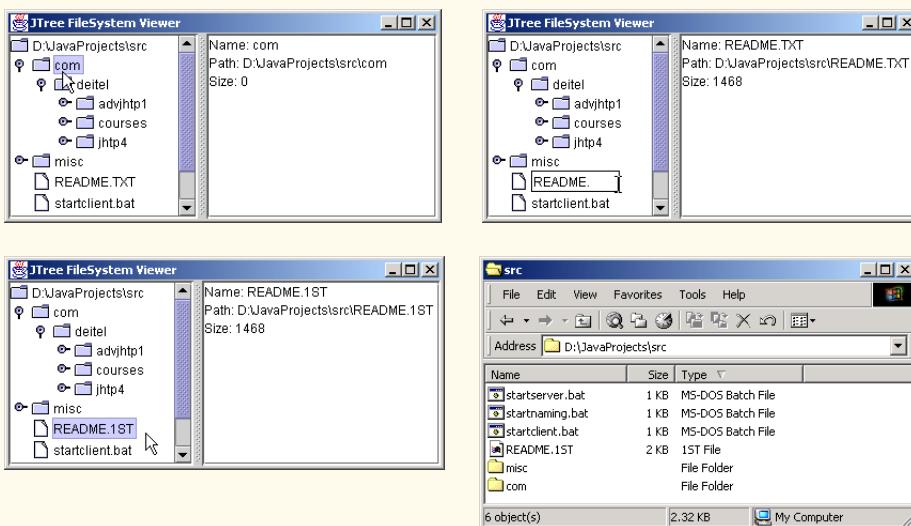
Fig. 3.19 **FileTreeFrame** application for browsing and editing a file system using **JTree** and **FileSystemModel** (part 1 of 3).

```
36     // create FileSystemModel for given directory
37     fileSystemModel = new FileSystemModel(
38         new File( directory ) );
39
40     // create JTree for FileSystemModel
41     fileTree = new JTree( fileSystemModel );
42
43     // make JTree editable for renaming Files
44     fileTree.setEditable( true );
45
46     // add a TreeSelectionListener
47     fileTree.addTreeSelectionListener(
48         new TreeSelectionListener() {
49
50             // display details of newly selected File when
51             // selection changes
52             public void valueChanged(
53                 TreeSelectionEvent event )
54             {
55                 File file = ( File )
56                     fileTree.getLastSelectedPathComponent();
57
58                 fileDetailsTextArea.setText(
59                     getFileDetails( file ) );
60             }
61         }
62     ); // end addTreeSelectionListener
63
64     // put fileTree and fileDetailsTextArea in a JSplitPane
65     JSplitPane splitPane = new JSplitPane(
66         JSplitPane.HORIZONTAL_SPLIT, true,
67         new JScrollPane( fileTree ),
68         new JScrollPane( fileDetailsTextArea ) );
69
70     getContentPane().add( splitPane );
71
72     setDefaultCloseOperation( EXIT_ON_CLOSE );
73     setSize( 640, 480 );
74     setVisible( true );
75 }
76
77 // build a String to display file details
78 private String getFileDetails( File file )
79 {
80     // do not return details for null Files
81     if ( file == null )
82         return "";
83
84     // put File information in a StringBuffer
85     StringBuffer buffer = new StringBuffer();
86     buffer.append( "Name: " + file.getName() + "\n" );
87     buffer.append( "Path: " + file.getPath() + "\n" );
```

Fig. 3.19 **FileTreeFrame** application for browsing and editing a file system using **JTree** and **FileSystemModel** (part 2 of 3).

```

88         buffer.append( "Size: " + file.length() + "\n" );
89
90     return buffer.toString();
91 }
92
93 // execute application
94 public static void main( String args[] )
95 {
96     // ensure that user provided directory name
97     if ( args.length != 1 )
98         System.err.println(
99             "Usage: java FileTreeFrame <path>" );
100
101    // start application using provided directory name
102    else
103        new FileTreeFrame( args[ 0 ] );
104 }
105 }
```



**Fig. 3.19** **FileTreeFrame** application for browsing and editing a file system using **JTree** and **FileSystemModel** (part 3 of 3).

Lines 47–62 create a **TreeSelectionListener** to listen for **TreeSelectionEvents** in the **JTree**. Lines 55–56 of method **valueChanged** get the selected **File** object from the **JTree**. Lines 58–59 invoke method **getFileDetails** to retrieve information about the selected **File** and to display the details in **fileDetailsTextArea**. Lines 65–69 create a **JSplitPane** to separate the **JTree** and **JTextArea**. Lines 67 and 68 place the **JTree** and **JTextArea** in **JScrollPanes**. Line 70 adds the **JSplitPane** to the **JFrame**.

Method **getFileDetails** (lines 78–91) takes a **File** argument and returns a **String** containing the **File**'s name, path and length. If the **File** argument is **null**, line 81 returns an empty **String**. Line 85 creates a **StringBuffer**, and lines 86–88 append

the **File**'s name, path and length. Line 90 invokes method **toString** of class **StringBuffer** and returns the result to the caller.

Method **main** (lines 94–104) executes the **FileTreeFrame** application. Lines 97–99 check the command-line arguments to ensure that the user provided a path for the **FileTreeModel**'s root. If the user did not provide a command-line argument, lines 98–99 display the program's usage instructions. Otherwise, line 103 creates a new **FileTreeFrame** and passes the command-line argument to the constructor.

In this chapter, we introduced the model-view-controller architecture, the Observer design pattern and the delegate-model architecture used by several Swing components. In later chapters, we use MVC to build a Java2D paint program (Chapter 6), database-aware programs (Chapter 8, JDBC) and an Enterprise Java case study (Chapters 16–19).

## SUMMARY

- The model-view-controller (MVC) architecture separates application data (contained in the model) from graphical presentation components (the view) and input-processing logic (the controller).
- The Java Foundation Classes (more commonly referred to as Swing components) implement a variation of MVC that combines the view and the controller into a single object, called a *delegate*. The delegate provides both a graphical presentation of the model and an interface for modifying the model.
- Every **JButton** has an associated **ButtonModel** for which the **JButton** is a delegate. The **ButtonModel** maintains the state information, such as whether the **JButton** is clicked, whether the **JButton** is enabled as well as a list of **ActionListeners**. The **JButton** provides a graphical presentation (e.g., a rectangle on the screen, with a label and a border) and modifies the **ButtonModel**'s state (e.g., when the user clicks the **JButton**).
- The *Observer design pattern* is a more general application of MVC that provides loose coupling between an object and its dependent objects.
- Class **java.util.Observable** represents a model in MVC, or the subject in the Observer design pattern. Class **Observable** provides method **addObserver**, which takes a **java.util.Observer** argument.
- Interface **Observer** represents the view in MVC, or the observer in the Observer design pattern. When the **Observable** object changes, it notifies each registered **Observer** of the change.
- The model-view-controller architecture requires the model to notify its views when the model changes. Method **setChanged** of class **Observable** sets the model's **changed** flag. Method **notifyObservers** of class **Observable** notifies all **Observers** (i.e., views) of the change.
- An **Observable** object must invoke method **setChanged** before invoking method **notifyObservers**. Method **notifyObservers** invokes method **update** of interface **Observer** for each registered **Observer**.
- **JList** is a Swing component that implements the delegate-model architecture. **JList** acts as a delegate for an underlying **ListModel**.
- Interface **ListModel** defines methods for getting list elements, getting the size of the list and registering and unregistering **ListDataListeners**. A **ListModel** notifies each registered **ListDataListener** of each change in the **ListModel**.
- **JTable** is another **Swing** component that implements the delegate-model architecture. **JTables** are delegates for tabular data stored in **TableModel** implementations.
- **JTree** is one of the more complex Swing components that implements the delegate-model architecture. **TreeModels** represent hierarchical data, such as family trees, file systems, company

management structures and document outlines. **JTrees** act as delegates (i.e., combined view and controller) for **TreeModels**.

- To describe tree data structures, it is common to use family-tree terminology. A tree data structure consists of a set of nodes (i.e., members or elements of the tree) that are related as parents, children, siblings, ancestors and descendants.
- Interface **TreeModel** defines methods that describe a tree data structure suitable for representation in a **JTree**. Objects of any class can represent nodes in a **TreeModel**. For example, a **Person** class could represent a node in a family tree **TreeModel**.
- Class **DefaultTreeModel** provides a default **TreeModel** implementation. Interface **TreeNode** defines common operations for nodes in a **DefaultTreeModel**, such as **getParent** and **getAllowsChildren**.
- Interface **MutableTreeNode** extends interface **TreeNode** to represent a node that can change, either by addition or removal of child nodes or by change of the **Object** associated with the node. Class **DefaultMutableTreeNode** provides a **MutableTreeNode** implementation suitable for use in a **DefaultTreeModel**.
- Interface **TreeCellRenderer** represents an object that creates a view for each node in the **JTree**. Class **DefaultTreeCellRenderer** implements interface **TreeCellRenderer** and extends class **JLabel** to provide a **TreeCellRenderer** default implementation.
- Interface **TreeCellEditor** represents an object for controlling (i.e., editing) each node in the **JTree**. Class **DefaultTreeCellEditor** implements interface **TreeCellEditor** and uses a **JTextField** to provide a **TreeCellEditor** default implementation.
- If the **DefaultTreeModel** implementation is not sufficient for an application, developers can also provide custom implementations of interface **TreeModel**.

## TERMINOLOGY

ancestor	<b>ListModel</b> interface
child	<b>ListSelectionModel</b> interface
controller	model
<b>DefaultListModel</b> class	model-view-controller architecture
<b>DefaultMutableTreeNode</b> class	<b>MutableTreeNode</b> interface
<b>DefaultTableModel</b> class	<b>notifyObservers</b> method of class <b>Observable</b>
<b>DefaultTreeCellEditor</b> class	<b>Observable</b> class
<b>DefaultTreeCellRenderer</b> class	Observer design pattern
<b>DefaultTreeModel</b> class	<b>Observer</b> interface
delegate	parent
delegate-model architecture	<b>setChanged</b> method of class <b>Observable</b>
descendent	sibling
<b>getChild</b> method of interface <b>TreeModel</b>	<b>TableModel</b> interface
<b>getChildAtIndex</b> method of interface <b>TreeModel</b>	<b>TreeCellEditor</b> interface
<b>getChildCount</b> method of interface <b>TreeModel</b>	<b>TreeCellRenderer</b> interface
<b>getIndexOfChild</b> method of interface <b>TreeModel</b>	<b>TreeModel</b> interface
<b>isLeaf</b> method of interface <b>TreeModel</b>	<b>TreeNode</b> interface
<b>JList</b> class	<b>update</b> method of interface <b>Observer</b>
<b>JTable</b> class	<b>valueForPathChanged</b> method of interface <b>TreeModel</b>
<b>JTree</b> class	view

## SELF-REVIEW EXERCISES

- 3.1 What more general design pattern does the model-view-controller (MVC) architecture use?
- 3.2 How does the variation of MVC implemented in the Swing packages differ from regular MVC?
- 3.3 List the Swing classes that use MVC.
- 3.4 What type of data does a **TableModel** contain, and what Swing class is a **TableModel** delegate?
- 3.5 What interfaces does a **JTree** employ to provide its delegate functionality for a **TreeModel**?

## ANSWERS TO SELF-REVIEW EXERCISES

- 3.1 The model-view-controller architecture uses the more general Observer design pattern to separate a model (i.e., a subject) from its views (i.e., its observers).
- 3.2 The Swing packages use a version of MVC known as the delegate-model architecture, in which the view and controller are combined into a single object to form a delegate.
- 3.3 Most Swing classes use MVC, including **JButton**, **JList**, **JTable** and **JTree**.
- 3.4 A **TableModel** contains tabular data, such as data from a database table or spreadsheet. **JTable** is a delegate for **TableModels**.
- 3.5 A **JTree** uses a **TreeCellRenderer** to provide a view of its nodes and a **TreeCellEditor** to provide a controller for its nodes.

## EXERCISES

- 3.1 Create class **LiabilityPieChartView** as a subclass of class **AssetPieChartView** (Fig. 3.8) that includes only liability **Accounts** (i.e., **Accounts** with negative balances). Modify class **AccountManager** (Fig. 3.10) to include a **LiabilityPieChartView**, in addition to the **AssetPieChartView**.
- 3.2 Create a new version of class **AccountBarGraphView** (Fig. 3.7) that shows multiple **Accounts** in a single bar graph. [Hint: Try modeling your class after **AssetPieChartView** to include multiple **Accounts**.]
- 3.3 Enhance your solution to Exercise 3.2 to allow transfers between accounts. Modify class **AccountController** (Fig. 3.9) to include a **JComboBox** to select the destination account and a **JButton** to perform the transfer.
- 3.4 Create a **TreeModel** implementation named **XMLTreeModel** that provides a read-only model of an XML document. Create a program that uses a **JTree** to display the XML document. If you are not familiar with XML, please see Appendices A–D.

# 4

# Graphics Programming with Java 2D and Java 3D

## Objectives

- To be able to use the Java 2D API to draw various shapes and general paths.
- To be able to specify **Paint** and **Stroke** characteristics of shapes displayed with **Graphics2D**.
- To be able to manipulate images using Java 2D image processing.
- To use the Java 3D API and Java 3D Utility classes to create three-dimensional graphics scenes.
- To manipulate the texture and lighting of three-dimensional objects with Java 3D.

*Sit in reverie and watch the changing color of the waves that break upon the idle seashore of the mind.*

Henry Wadsworth Longfellow

*Art is not a mirror to reflect the world, but a hammer with which to shape it.*

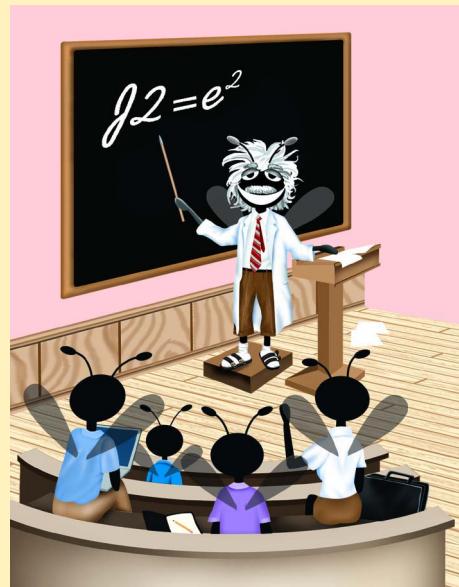
Vladimir Mayakovsky

*... work transforms talent into genius.*

Anna Povlova

*A work that aspires, however humbly, to the condition of art should carry its justification in every line.*

Joseph Conrad



## Outline

- 4.1    **Introduction**
- 4.2    **Coordinates, Graphics Contexts and Graphics Objects**
- 4.3    **Java 2D API**
  - 4.3.1    **Java 2D Shapes**
  - 4.3.2    **Java 2D Image Processing**
- 4.4    **Java 3D API**
  - 4.4.1    **Obtaining and Installing the Java 3D API**
  - 4.4.2    **Java 3D Scenes**
  - 4.4.3    **A Java 3D Example**
- 4.5    **A Java 3D Case Study: A 3D Game with Custom Behaviors**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

## 4.1 Introduction

Over the past few years, developers have strived to integrate cutting-edge graphics and animation in their applets and applications. However, the original Java AWT graphics packages have provided a limited means to achieve such goals. Now, with the *Java 2D™ API* and *Java 3D™ API*, developers can implement more sophisticated graphics applications—such as games, screen savers, splash screens and 3D GUI's.

This chapter overviews several of Java's 2D and 3D graphics capabilities. We begin with a brief introduction to fundamental graphics topics, such as coordinate systems and graphics contexts. Next, we discuss several Java 2D capabilities, such as controlling how to fill shapes with colors and patterns. We also introduce how to blur, invert, sharpen and change the color of an image using Java 2D's image processing capabilities. In the second half of our graphics discussion, we present the Java 3D API. Using the Java 3D utility classes, we build an application that allows the user to manipulate (rotate, scale and translate) 3D objects with a mouse. The application has a control panel that allows the user both to apply textures to 3D objects using texture mapping and to vary the lighting effects on 3D objects by changing the color of a light source.

## 4.2 Coordinates, Graphics Contexts and Graphics Objects

Java's 2D *coordinate system* (Fig. 4.1) is a scheme for identifying every point on the screen. By default, the upper left corner of a GUI component has the coordinates (0, 0). The y-coordinate is the vertical distance moving down from the upper left corner. The x-coordinate is the horizontal distance moving right from the upper left corner.

A Java *graphics context* enables drawing on the screen. A **Graphics** object manages a graphics context by controlling how information is drawn. **Graphics** objects contain methods for drawing, font manipulation, color manipulation and the like. Every application that performs drawing on the screen uses **Graphics** object to manage the application's graphics context.

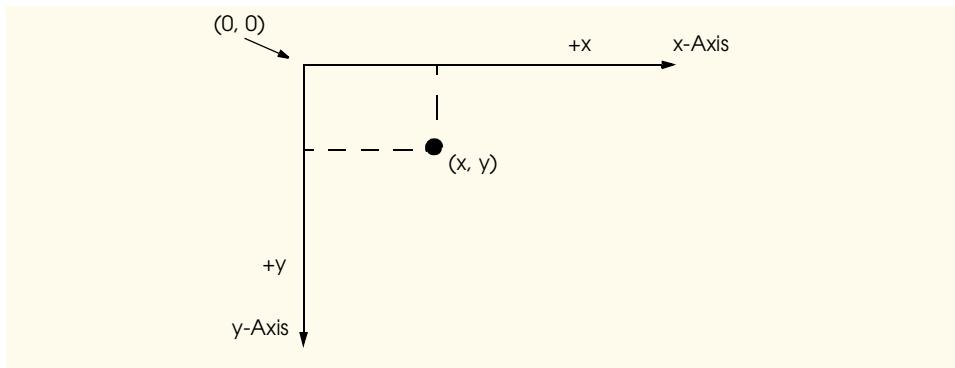


Fig. 4.1 Java coordinate system. Units are measured in pixels.

Class **Graphics** is an **abstract** class (i.e., a **Graphics** object cannot be instantiated). This contributes to Java's portability. Drawing is performed differently on each platform that supports Java so there cannot be one class that implements drawing capabilities on all systems. For example, the graphics capabilities that enable a PC running Microsoft Windows to draw a rectangle are different from the graphics capabilities that enable a UNIX workstation to draw a rectangle—and those are both different from the graphics capabilities that enable a Macintosh to draw a rectangle. For each platform, a **Graphics** subclass implements all the drawing capabilities. This implementation is hidden by the **Graphics** class, which supplies the interface that enables us to write programs that use graphics in a platform-independent manner.

Class **Component** is the superclass for many of the classes in the **java.awt** package. Method **paint** of class **Component** is called when the contents of the **Component** should be painted—either in response to the **Component** first being shown or damage needing repair—such as resizing the **Component** window. Method **paint** takes a **Graphics** reference as an argument. When a **Component** needs to be painted, the system passes a **Graphics** reference to method **paint**. This **Graphics** reference is a reference to the platform-specific **Graphics** subclass. The developer should not call method **paint** directly, because drawing graphics is an *event driven process*. To request the system to call **paint**, a developer can invoke method **repaint** of class **Component**. Method **repaint** requests a call to method **update** of class **Component** as soon as possible, to clear the **Component**'s background of any previous drawing. Method **update** then calls **paint** directly.

Class **JComponent**—a **Component** subclass—is the superclass for many of the classes in the **javax.swing** package. The Swing painting mechanism calls method **paintComponent** of class **JComponent** when the contents of the **JComponent** should be painted. Method **paintComponent**—which takes as an argument a **Graphics** object—helps the Swing components paint properly. The **Graphics** object is passed to the **paintComponent** method by the system when a **paintComponent** operation is required for a **JComponent**. The developer should not call method **paintComponent** directly. If the developer needs to call **paintComponent**, a call is made to method **repaint** of class **Component**—exactly as discussed earlier for method **repaint** of class **Component**.

### 4.3 Java 2D API

The *Java 2D™ API* provides advanced 2D graphics capabilities for developers who require detailed and complex graphical manipulations in their programs. The Java 2D API is part of the Java 2 Platform, Standard Edition. The Java 2D API includes features for processing line art, text and images in packages **`java.awt.image`**, **`java.awt.color`**, **`java.awt.font`**, **`java.awt.geom`**, **`java.awt.print`** and **`java.awt.image.renderable`**. Figure 4.2 describes several of the Java 2D classes and interfaces covered in this chapter.

Class/Interface	Description
<i>Classes and interfaces from package <code>java.awt</code></i>	
<b><code>Graphics2D</code></b>	<b><code>Graphics</code></b> subclass for rendering 2D shapes, text and images.
<b><code>BasicStroke</code></b>	Defines a basic set of rendering attributes for the outlines of graphics primitives.
<b><code>GradientPaint</code></b>	Provides a way to fill and outline 2D shapes with a linear color gradient.
<b><code>TexturePaint</code></b>	Provides a way to fill and outline shapes with texture images.
<b><code>Paint</code></b>	Defines how color patterns can be generated for rendering operations.
<b><code>Shape</code></b>	Provides definitions for geometrical objects.
<b><code>Stroke</code></b>	Provides methods for obtaining the outline of a geometrical shape.
<i>Classes and interfaces from package <code>java.awt.geom</code></i>	
<b><code>GeneralPath</code></b>	Represents a path constructed from straight lines, quadratic curves and cubic curves.
<b><code>Line2D</code></b>	Represents a line in coordinate space.
<b><code>RectangularShape</code></b>	Base class for geometrical shapes with rectangular frames. Subclasses include <b><code>Arc2D</code></b> , <b><code>Ellipse2D</code></b> , <b><code>Rectangle2D</code></b> and <b><code>RoundRectangle2D</code></b> .
<b><code>BufferedImage</code></b>	Describes an <b><code>Image</code></b> with a buffer of colored pixel data composed of a <b><code>ColorModel</code></b> and a <b><code>Raster</code></b> .
<b><code>ColorModel</code></b>	Defines methods for translating a numerical pixel value to a color.
<i>Classes and interfaces from package <code>java.awt.image</code></i>	
<b><code>Raster</code></b>	Is part of a <b><code>BufferedImage</code></b> that describes sample values in a rectangular array of pixels.
<b><code>Kernel</code></b>	Describes a 2D array used for filtering <b><code>BufferedImages</code></b> .

Fig. 4.2 Some Java 2D classes and interfaces (part 1 of 2).

Class/Interface	Description
<b>BufferedImageOp</b>	Defines methods that perform operations on <b>BufferedImages</b> (e.g. blurring a <b>BufferedImage</b> )
<b>RasterOp</b>	Describes single-input/single-output processes performed on <b>Rasters</b> .

Fig. 4.2 Some Java 2D classes and interfaces (part 2 of 2).

Class **java.awt.Graphics2D** enables drawing with the Java 2D API. Class **Graphics2D** is a subclass of class **Graphics**, so it has all the capabilities for managing the application’s graphics context discussed earlier in this chapter. To access the **Graphics2D** capabilities, we cast the **Graphics** reference passed to **paint** to a **Graphics2D** reference.

Java 2D can render three types of built-in graphics objects—termed *graphics primitives*—images, text and geometrical shapes. There are seven **Graphics2D** state attributes that determine how graphics primitives are rendered—*clipping, compositing, font, paint, rendering hints, stroke* and *transforms*. Figure 4.3 describes each of these seven attributes. The attributes form a pipeline that processes the graphics primitives to produce the final image. The first stage in the pipeline determines which of the primitives to render. A *draw method* then draws the primitive—method **draw** for shapes, method **drawString** for text and method **drawImage** for images. The pipeline applies any transformations, fills and strokes during the drawing process. The next stage is to *rasterize* the drawn shape—convert the shape to a two-dimensional array of numerical pixel values called a *raster*. At this stage, the pipeline invokes any image-processing operations on the raster. The raster is then clipped, colored and combined with the current drawing—known as *compositing*. Finally, the image is *rendered*—drawn—on an output device, such as a screen or printer.

Attribute	Description
Clipping	Defines the area in which rendering operations take effect. Any geometrical shape, including text, can be used as a clipping region.
Compositing	Is a Set of <i>blending rules</i> that control how the pixels in a source image mix with the pixels in a destination image.
Font	Fonts are created from shapes that represent the characters to be drawn—called <i>glyphs</i> . Text is rendered by drawing and filling the glyphs.
Paint	Determines the colors, patterns and gradients for filling and outlining a shape.
Rendering Hints	Specify techniques and methods that help to optimize drawing.

Fig. 4.3 The seven state attributes of a Java 2D graphics context (part 1 of 2).

Attribute	Description
Stroke	Determines the outline of the shape to be drawn.
Transform	Defines ways to perform linear transformations—an operation that changes the shape of an image.

**Fig. 4.3** The seven state attributes of a Java 2D graphics context (part 2 of 2).

The Java 2D API provides hints and rules that instruct the graphics engine how to perform these operations. The following sections present several features of image and geometrical shape-rendering processes.

### 4.3.1 Java 2D Shapes

In this section, we present several Java 2D shape classes from package `java.awt.geom`, including `Ellipse2D.Double`, `Line2D.Double`, `Rectangle2D.Double`, `RoundRectangle2D.Double` and `Arc2D.Double`. Each class represents a shape with dimensions specified as double-precision floating-point values. Each class can also be represented with single-precision floating-point values (e.g., `Ellipse2D.Float`). In each case, class `Double` is a `static` inner class contained in the class to the left of the dot operator (e.g., `Ellipse2D`).

Class `Shapes` (Fig. 4.4) demonstrates several Java 2D shapes and rendering attributes (such as thick lines), filling shapes with patterns and drawing dashed lines. These are just a few of the many capabilities Java 2D provides.

```
1 // Shapes.java
2 // Shapes demonstrates some Java 2D shapes.
3
4 // Java core packages
5 import java.awt.*;
6 import java.awt.event.*;
7 import java.awt.geom.*;
8 import java.awt.image.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class Shapes extends JFrame {
14
15     // constructor method
16     public Shapes()
17     {
18         super( "Drawing 2D shapes" );
19     }
20 }
```

**Fig. 4.4** Demonstrating some Java 2D shapes (part 1 of 3).

```
21 // draw shapes using Java 2D API
22 public void paint( Graphics g )
23 {
24     // call superclass' paint method
25     super.paint( g );
26
27     // get Graphics 2D by casting g to Graphics2D
28     Graphics2D graphics2D = ( Graphics2D ) g;
29
30     // draw 2D ellipse filled with blue-yellow gradient
31     graphics2D.setPaint( new GradientPaint
32         ( 5, 30, Color.blue, 35, 100, Color.yellow, true ) );
33     graphics2D.fill( new Ellipse2D.Double( 5, 30, 65, 100 ) );
34
35     // draw 2D rectangle in red
36     graphics2D.setPaint( Color.red );
37     graphics2D.setStroke( new BasicStroke( 10.0f ) );
38     graphics2D.draw(
39         new Rectangle2D.Double( 80, 30, 65, 100 ) );
40
41     // draw 2D rounded rectangle with BufferedImage background
42     BufferedImage bufferedImage = new BufferedImage(
43         10, 10, BufferedImage.TYPE_INT_RGB );
44
45     Graphics2D graphics = bufferedImage.createGraphics();
46     graphics.setColor( Color.yellow ); // draw in yellow
47     graphics.fillRect( 0, 0, 10, 10 ); // draw filled rectangle
48     graphics.setColor( Color.black ); // draw in black
49     graphics.drawRect( 1, 1, 6, 6 ); // draw rectangle
50     graphics.setColor( Color.blue ); // draw in blue
51     graphics.fillRect( 1, 1, 3, 3 ); // draw filled rectangle
52     graphics.setColor( Color.red ); // draw in red
53     graphics.fillRect( 4, 4, 3, 3 ); // draw filled rectangle
54
55     // paint buffImage into graphics context of JFrame
56     graphics2D.setPaint( new TexturePaint(
57         bufferedImage, new Rectangle( 10, 10 ) ) );
58     graphics2D.fill( new RoundRectangle2D.Double(
59         155, 30, 75, 100, 50, 50 ) );
60
61     // draw 2D pie-shaped arc in white
62     graphics2D.setPaint( Color.white );
63     graphics2D.setStroke( new BasicStroke( 6.0f ) );
64     graphics2D.draw( new Arc2D.Double(
65         240, 30, 75, 100, 0, 270, Arc2D.PIE ) );
66
67     // draw 2D lines in green and yellow
68     graphics2D.setPaint( Color.green );
69     graphics2D.draw( new Line2D.Double( 395, 30, 320, 150 ) );
70
71     float dashes[] = { 10, 2 };
72
73     graphics2D.setPaint( Color.yellow );
```

Fig. 4.4 Demonstrating some Java 2D shapes (part 2 of 3).

```
74     graphics2D.setStroke( new BasicStroke(
75         4, BasicStroke.CAP_ROUND, BasicStroke.JOIN_ROUND,
76         10, dashes, 0 ) );
77     graphics2D.draw( new Line2D.Double( 320, 30, 395, 150 ) );
78
79 } // end method paint
80
81 // start application
82 public static void main( String args[] )
83 {
84     Shapes application = new Shapes();
85     application.setDefaultCloseOperation(
86         JFrame.EXIT_ON_CLOSE );
87
88     application.setSize( 425, 160 );
89     application.setVisible( true );
90 }
91 }
```

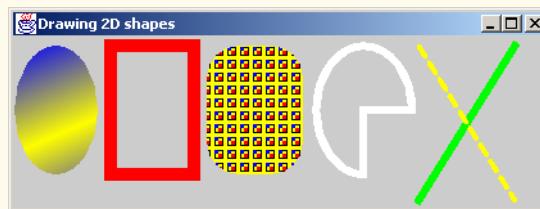


Fig. 4.4 Demonstrating some Java 2D shapes (part 3 of 3).

Line 28 casts the **Graphics** reference received by **paint** to a **Graphics2D** reference to allow access to Java 2D features. The first shape we draw is an oval filled with gradually changing colors. Lines 31–32 invoke method **setPaint** of class **Graphics2D** to set the **Paint** object that determines the color for the shape to display. A **Paint** object is an object of any class that implements interface **java.awt.Paint**. The **Paint** object can be something as simple as one of the predefined **Color** objects (class **Color** implements **Paint**), or the **Paint** object can be an instance of the Java 2D API's **GradientPaint**, **SystemColor** or **TexturePaint** classes. In this case, we use a **GradientPaint** object.

Class **GradientPaint** paints a shape in gradually changing colors—a *gradient*. The **GradientPaint** constructor used here requires seven arguments. The first two arguments specify the starting coordinate for the gradient. The third argument specifies the starting **Color** for the gradient. The fourth and fifth arguments specify the ending coordinate for the gradient. The sixth argument specifies the ending **Color** for the gradient. The last argument specifies whether the gradient is *cyclic* (**true**) or *acyclic* (**false**). The two coordinates determine the direction of the gradient. The second coordinate (*35, 100*) is down and to the right of the first coordinate (*5, 30*); therefore, the gradient goes down and to the right at an angle. Since this gradient is cyclic (**true**), the color starts with blue, gradually becomes yellow, then gradually returns to blue. If the gradient is acyclic, the color transitions from the first color specified (e.g., blue) to the second color (e.g., yellow).

Line 33 uses method `fill` of class `Graphics2D` to draw a filled `Shape` object. The `Shape` object is an instance of any class that implements interface `Shape` (package `java.awt`)—in this case, an instance of class `Ellipse2D.Double`. The `Ellipse2D.Double` constructor receives four arguments that specify the bounding rectangle for the ellipse to display.

Next we draw a red rectangle with a thick border. Line 36 uses method `setPaint` to set the `Paint` object to `Color.red`. Line 37 uses method `setStroke` of class `Graphics2D` to set the characteristics of the rectangle's border. Method `setStroke` requires a `Stroke` object as its argument. The `Stroke` object is an instance of any class that implements interface `Stroke` (package `java.awt`)—in this case, an instance of class `BasicStroke`. Class `BasicStroke` provides a variety of constructors to specify the line width, how the line ends (called the *end caps*), how lines join together (called *line joins*) and the dash attributes of the line (if it is a dashed line). The constructor here specifies that the line should be 10 pixels wide.

Lines 38–39 invoke method `draw` of `Graphics2D` to draw a `Shape` object—in this case, an instance of class `Rectangle2D.Double`. The `Rectangle2D.Double` constructor receives four arguments specifying the upper left *x*-coordinate, upper left *y*-coordinate, width and height of the rectangle measured in pixels.

Next we draw a rounded rectangle filled with a pattern created in a `BufferedImage` (package `java.awt.image`) object. Lines 42–43 create the `BufferedImage` object. Class `BufferedImage` can produce images in color and gray scale. This particular `BufferedImage` is 10 pixels wide and 10 pixels tall. The third constructor argument `BufferedImage.TYPE_INT_RGB` specifies that the image is stored in color using the Red Green Blue (RGB) color scheme.

To create the fill pattern for the rounded rectangle, we must first draw into the `BufferedImage`. Line 45 creates a `Graphics2D` object for drawing on the `BufferedImage`. Lines 46–53 use methods `setColor`, `fillRect` and `drawRect` (discussed earlier in this chapter) to create the pattern.

Lines 56–57 set the `Paint` object to a new `TexturePaint` (package `java.awt`) object. A `TexturePaint` object uses the image stored in its associated `BufferedImage` as the fill texture for a filled-in shape. The second argument specifies the `Rectangle` area from the `BufferedImage` that will be replicated through the texture. In this case, the `Rectangle` is the same size as the `BufferedImage`. However, a smaller portion of the `BufferedImage` can be used.

Lines 58–59 invoke method `fill` of `Graphics2D` to draw a filled `Shape` object—`RoundRectangle2D.Double`. The `RoundRectangle2D.Double` constructor receives six arguments specifying the rectangle dimensions and the arc width and arc height—measured in pixels—used to determine the rounding of the corners.

Next we draw a oblong arc with a thick white line. Line 62 sets the `Paint` object to `Color.white`. Line 63 sets the `Stroke` object to a new `BasicStroke` for a line 6 pixels wide. Lines 64–65 use method `draw` of class `Graphics2D` to draw a `Shape` object—in this case, an `Arc2D.Double`. The `Arc2D.Double` constructor's first four arguments specifying the upper left *x*-coordinate, upper left *y*-coordinate, width and height of the bounding rectangle for the arc. The fifth argument specifies the start angle measured in degrees. The sixth argument specifies the arc angle. The start angle and arc angles are measured relative to the shape's bounding rectangle. The last argument specifies how the

arc is closed. Constant **Arc2D.PIE** indicates that the arc is closed by drawing two lines. One line from the arc's starting point to the center of the bounding rectangle and one line from the center of the bounding rectangle to the ending point. Class **Arc2D** provides two other **static** constants for specifying how the arc is closed. Constant **Arc2D.CHORD** draws a line from the starting point to the ending point. Constant **Arc2D.OPEN** specifies that the arc is not closed.

Finally, we draw two lines using **Line2D** objects—one solid and one dashed. Line 68 sets the **Paint** object to **Color.green**. Line 69 uses method **draw** of class **Graphics2D** to draw a **Shape** object—in this case, an instance of class **Line2D.Double**. The **Line2D.Double** constructor's arguments specify starting coordinates and ending coordinates of the line.

Line 71 defines a two-element **float** array. This array describes the length—in pixels—of the dashes and spaces in the dashed line. In this case, each dash will be 10 pixels long and each space will be two pixels long. To create dashes of different lengths in a pattern, simply provide the lengths of each dash as an element in the array. Line 73 sets the **Paint** object to **Color.yellow**. Lines 74–76 set the **Stroke** object to a new **BasicStroke**. The line will be 4 pixels wide and will have rounded ends (**BasicStroke.CAP\_ROUND**). If lines join together (as in a rectangle at the corners), the joining of the lines will be rounded (**BasicStroke.JOIN\_ROUND**). The **dashes** argument specifies the dash lengths for the line. The last argument indicates the starting subscript in the **dashes** array for the first dash in the pattern. Line 77 then draws a line with the current **Stroke**.

Next we present a general path—a shape constructed from lines and complex curves. A general path is represented with an object of class **GeneralPath** (package **java.awt.geom**). Class **Shapes2** (Fig. 4.5) demonstrates drawing a general path in the shape of a five-pointed star.

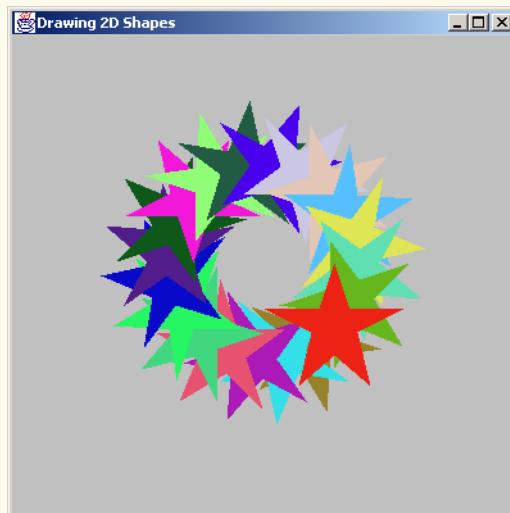
```
1 // Shapes2.java
2 // Shapes2 demonstrates a general path.
3
4 // Java core packages
5 import java.awt.*;
6 import java.awt.event.*;
7 import java.awt.geom.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class Shapes2 extends JFrame {
13
14     // set window's title bar String and background color
15
16     public Shapes2()
17     {
18         super( "Drawing 2D Shapes" );
19
20         getContentPane().setBackground( Color.gray );
21     }
22 }
```

Fig. 4.5 Demonstrating Java 2D paths (part 1 of 3).

```
23 // draw general paths
24 public void paint( Graphics g )
25 {
26     // call superclass' paint method
27     super.paint( g );
28
29     int xPoints[] =
30     { 55, 67, 109, 73, 83, 55, 27, 37, 1, 43 };
31     int yPoints[] =
32     { 0, 36, 36, 54, 96, 72, 96, 54, 36, 36 };
33
34     Graphics2D graphics2D = ( Graphics2D ) g;
35
36     // create a star from a series of points
37     GeneralPath star = new GeneralPath();
38
39     // set the initial coordinate of the General Path
40     star.moveTo( xPoints[ 0 ], yPoints[ 0 ] );
41
42     // create the star--this does not draw the star
43     for ( int count = 1; count < xPoints.length; count++ )
44         star.lineTo( xPoints[ count ], yPoints[ count ] );
45
46     // close the shape
47     star.closePath();
48
49     // translate the origin to (200, 200)
50     graphics2D.translate( 200, 200 );
51
52     // rotate around origin and draw stars in random colors
53     for ( int count = 1; count <= 20; count++ ) {
54
55         // rotate coordinate system
56         graphics2D.rotate( Math.PI / 10.0 );
57
58         // set random drawing color
59         graphics2D.setColor( new Color(
60             ( int )( Math.random() * 256 ),
61             ( int )( Math.random() * 256 ),
62             ( int )( Math.random() * 256 ) ) );
63
64         // draw filled star
65         graphics2D.fill( star );
66     }
67
68 } // end method paint
69
70 // execute application
71 public static void main( String args[] )
72 {
73     Shapes2 application = new Shapes2();
74     application.setDefaultCloseOperation(
75         JFrame.EXIT_ON_CLOSE );
```

Fig. 4.5 Demonstrating Java 2D paths (part 2 of 3).

```
76     application.setSize( 400, 400 );
77     application.setVisible( true );
78   }
79 }
```



**Fig. 4.5** Demonstrating Java 2D paths (part 3 of 3).

Lines 29–32 define two **int** arrays representing the *x*- and *y*-coordinates of the points in the star. Line 37 defines **GeneralPath** object **star**. Line 40 uses method **moveTo** of class **GeneralPath** to specify the first point in the **star**. The **for** structure at lines 43–44 uses method **lineTo** of class **GeneralPath** to draw a line to the next point in the **star**. Each new call to **lineTo** draws a line from the previous point to the current point. Line 47 uses method **closePath** of class **GeneralPath** to draw a line from the last point to the point specified in the last call to **moveTo**. This completes the general path.

Line 50 uses method **translate** of class **Graphics2D** to move the drawing origin to location (200, 200). All drawing operations now use location (200, 200) as (0, 0). The **for** structure at lines 53–65 draws the **star** 20 times by rotating it around the new origin point. Line 56 uses method **rotate** of class **Graphics2D** to rotate the next displayed shape. The argument specifies the rotation angle in radians ( $360^\circ = 2\pi$  radians). Line 65 uses **Graphics2D** method **fill** to draw a filled version of the **star**.

### 4.3.2 Java 2D Image Processing

*Image processing* is the manipulation of digital images by applying *filters*—mathematical operations that change images. Java 2D provides an image-processing API to shield developers from the mathematics behind filters. *Compression filters*, *measurement filters* and *enhancement filters* constitute the three major image-processing categories. Compression filters reduce a digital image's memory usage, resulting in reduced storage size and faster transmission of complex digital images. Some common applications of compression filters include high-definition television (HDTV), video phones and virtual reality. Measurement

filters collect data from digital images. Measurement filters play a crucial role in the field of image recognition and *machine vision* (e.g., for printed circuit board inspection and assembly-line welding robots). Enhancement filters—filters that alter certain physical aspects of an image—often restore corrupted images to their original form. Sometimes, the processes of creating, storing or transmitting a digital image introduces data corruption such as noise, motion blurring and color loss. Enhancement filters can remove noise, sharpen edges and brighten colors to recover the original image. For example, satellite images use enhancement filters to remove noise created from capturing images at such lengthy distances.

Java 2D image-processing filters operate on objects of class **BufferedImage**, which separates image data into two components—a **Raster** and a **ColorModel**. A **Raster**—composed of a **DataBuffer** and a **SampleModel**—organizes and stores the data that determine a pixel’s color. Each pixel is composed of *samples*—number values that represent the pixel’s color components. The **DataBuffer** stores the raw sample data for an image. The **SampleModel** accesses the sample values in the **DataBuffer** for any given pixel. The **ColorModel** is an interpreter for the **Raster**, taking the sample values for each pixel in the **Raster** and converting them to the appropriate color. The **ColorModel** converts the sample data to different colors depending on the *color scale* of the image. Two common color scales are *grayscale* and *RGB*. In grayscale, every pixel is represented by one sample interpreted as a color between black and white. In *RGB*, each pixel is represented by three samples that correspond to the red, green and blue color components of the pixel.

This section presents an application that demonstrates how to create and filter **BufferedImages**. We build filters that blur, sharpen, invert and change the color scale of a **BufferedImage**. These are “fundamental” filters found in mass graphics programs, such as Paint Shop Pro. Our application allows the user to apply a series of filters to a **BufferedImage** to demonstrate the effects of multiple filters. Sample filter results appear in the screen captures of Fig. 4.13. The application consists of three distinct parts:

1. **ImagePanel**—a **JPanel** extended to provide image-processing capabilities.
2. **Java2DImageFilter**—an interface for image-processing filters that will alter the image in an **ImagePanel**. The classes that implement interface **Java2DImageFilter** include **BlurFilter**, **SharpenFilter**, **InvertFilter** and **ColorChangeFilter**.
3. **Java2DExample**—a GUI that displays the filtered image and presents the user with a menu for selecting image filters.

Class **ImagePanel** (Fig. 4.6) allows a user to experiment with applying various filters to an image. **ImagePanel** contains an image and methods for filtering that image. Lines 18–19 declare two **BufferedImage** references—**displayImage** and **originalImage**. The image filters manipulate **displayImage**, and **originalImage** stores a copy of the original image so the user can view the original image.

```
1 // ImagePanel.java
2 // ImagePanel contains an image for display. The image is
3 // converted to a BufferedImage for filtering purposes.
4 package com.deitel.advjhtp1.java2d;
```

Fig. 4.6 Class **ImagePanel** allows for displaying and filtering **BufferedImages** (part 1 of 3).

```
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.awt.image.*;
10 import java.net.*;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.event.*;
15
16 public class ImagePanel extends JPanel {
17
18     private BufferedImage displayImage; // filtered image
19     private BufferedImage originalImage; // original image
20     private Image image; // image to load
21
22     // ImagePanel constructor
23     public ImagePanel( URL imageURL )
24     {
25         image =
26             Toolkit.getDefaultToolkit().createImage( imageURL );
27
28         // create MediaTracker for image
29         MediaTracker mediaTracker = new MediaTracker( this );
30         mediaTracker.addImage( image, 0 );
31
32         // wait for Image to load
33         try {
34             mediaTracker.waitForAll();
35         }
36
37         // exit program on error
38         catch ( InterruptedException interruptedException ) {
39             interruptedException.printStackTrace();
40         }
41
42         // create BufferedImages from Image
43         originalImage = new BufferedImage( image.getWidth( null ),
44             image.getHeight( null ), BufferedImage.TYPE_INT_RGB );
45
46         displayImage = originalImage;
47
48         // get BufferedImage's graphics context
49         Graphics2D graphics = displayImage.createGraphics();
50         graphics.drawImage( image, null, null );
51
52     } // end ImagePanel constructor
53
54     // apply Java2DImageFilter to Image
55     public void applyFilter( Java2DImageFilter filter )
56     {
```

Fig. 4.6 Class **ImagePanel** allows for displaying and filtering **BufferedImages** (part 2 of 3).

```
57     // process Image using Java2DImageFilter
58     displayImage = filter.processImage( displayImage );
59     repaint();
60 }
61
62 // set Image to originalImage
63 public void displayOriginalImage()
64 {
65     displayImage = new BufferedImage( image.getWidth( null ),
66         image.getHeight( null ), BufferedImage.TYPE_INT_RGB );
67
68     Graphics2D graphics = displayImage.createGraphics();
69     graphics.drawImage( originalImage, null, null );
70     repaint();
71 }
72
73 // draw ImagePanel
74 public void paintComponent( Graphics g )
75 {
76     super.paintComponent( g );
77     Graphics2D graphics = ( Graphics2D ) g;
78     graphics.drawImage( displayImage, 0, 0, null );
79 }
80
81 // get preferred ImagePanel size
82 public Dimension getPreferredSize()
83 {
84     return new Dimension( displayImage.getWidth(),
85         displayImage.getHeight() );
86 }
87
88 // get minimum ImagePanel size
89 public Dimension getMinimumSize()
90 {
91     return getPreferredSize();
92 }
93 }
```

Fig. 4.6 Class **ImagePanel** allows for displaying and filtering **BufferedImages** (part 3 of 3).

The **ImagePanel** constructor (lines 23–52) accepts as an argument a **URL** that specifies the file containing the image to filter. Lines 25–26 create an **Image** object—**image**—from this file. Lines 29–30 instantiate a **MediaTracker** for **image** loading. Method **waitForAll** (line 34) of class **MediaTracker** ensures that **image** is loaded into memory before we filter this image.

Lines 43–46 create **BufferedImages** **displayImage** and **originalImage**. The **BufferedImage** constructor accepts three arguments—the image's width, height and type. We use predefined type **TYPE\_INT\_RGB**, which defines three 8-bit segments each representing a red, green and blue color components. Line 49 creates a **Graphics2D** object for rendering **displayImage**. Line 50 renders the loaded **image** on **ImagePanel** using method **drawImage** of class **Graphics2D**.

Method `applyFilter` (lines 55–60) applies an `Java2DImageFilter` to `displayImage`. Line 58 invokes method `processImage` of class `Java2DImageFilter`, which passes `displayImage` as a parameter. Method `processImage` applies an image filter to `displayImage`. Line 59 calls method `repaint`, which indicates that `ImagePanel1` needs to be redrawn. In turn, a system call is made to method `paintComponent` of class `ImagePanel1`. Method `paintComponent` (lines 74–79) draws `displayImage` onto `ImagePanel1`. Line 77 casts the `Graphics` object to a `Graphics2D` object to access `Graphics2D` methods. The `Graphics2D`'s method `drawImage` (line 78) renders `displayImage` in the `ImagePanel1`.

We provide a means to reconstruct the original image after the program applies filters to `displayImage`. Method `displayOriginal` (lines 63–71) creates a new `BufferedImage` that contains a copy of `originalImage` so the user can apply a new set of filters to `displayImage`. Lines 65–66 recreate `displayImage` as a new `BufferedImage`. Line 68 creates a `Graphics2D` for `displayImage`. Line 69 calls method `drawImage` of class `Graphics2D`, which draws `originalImage` into `displayImage`.

We now implement our image-processing filters—`BlurFilter`, `SharpenFilter`, `InvertFilter` and `ColorFilter`. Our filters implement interface `Java2DImageFilter` (Fig. 4.7). Classes that implement `Java2DImageFilter` must implement method `processImage` (line 13). Method `processImage` accepts a `BufferedImage` to filter and returns the filtered `BufferedImage`.

The `Java2DImageFilters` in this application use well-known Java 2D image-processing operations. Java 2D has several image filters that operate on `BufferedImages`. Interfaces `BufferedImageOp` and `RasterOp` serve as the base classes for Java 2D image filters. Method `filter` of interfaces `BufferedImageOp` and `RasterOp` takes as arguments two images—the *source* image and the *destination* image. All classes that implement `BufferedImageOp` and `RasterOp` apply a filter to the source image to produce the destination image. A `BufferedImageOp` processes a `BufferedImage`, while a `RasterOp` processes only the `Raster` associated with a `BufferedImage`. Several Java 2D image filters implement `BufferedImageOp` and/or `RasterOp` (Fig. 4.8).

```
1 // Java2DImageFilter.java
2 // Java2DImageFilter is an interface that defines method
3 // processImage for applying a filter to an Image.
4 package com.deitel.advjhtp1.java2d;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.image.*;
9
10 public interface ImageFilter {
11
12     // apply filter to Image
13     public BufferedImage processImage( BufferedImage image );
14 }
```

Fig. 4.7    `Java2DImageFilter` interface for creating Java 2D image filters.

Class	Implements Interfaces	Description
<b>AffineTransformOp</b>	<b>BufferedImageOp</b> <b>RasterOp</b>	Performs linear mapping from 2D coordinates in the source image to 2D coordinates in the destination image. (Example: Rotate an image about a point in the image.)
<b>BandCombineOp</b>	<b>RasterOp</b>	Performs a linear combination of the bands in a <b>Raster</b> . (Example: Change the color palette in an image.)
<b>ColorConvertOp</b>	<b>BufferedImageOp</b> <b>RasterOp</b>	Performs color conversion on each pixel in the source image. (Example: Convert from RGB color to gray scale.)
<b>ConvolveOp</b>	<b>BufferedImageOp</b> <b>RasterOp</b>	Combines source pixel values with surrounding pixel values to derive destination pixel values. (Example: Sharpen edges in an image.)
<b>LookupOp</b>	<b>BufferedImageOp</b> <b>RasterOp</b>	Performs a lookup operation on the source image to create the destination image. (Example: Invert the RGB colors in an image.)
<b>RescaleOp</b>	<b>BufferedImageOp</b> <b>RescaleOp</b>	Rescale the data in the source image by a scalar plus offset. (Example: Darken the coloring of an image.)

Fig. 4.8 Classes that implement **BufferedImageOp** and **RasterOp**.

We now present each **Java2DImageFilter** in our application. Class **InvertFilter** (Fig. 4.9), which implements interface **Java2DImageFilter**, inverts the color of the pixels in a **BufferedImage**. Each pixel consists of three samples—8-bit R, G and B integers. An 8-bit color sample takes on an integer in the range 0–255. By inverting the numerical value of the pixel sample, we can invert the color of the pixel. Line 15 creates an array to hold the inverted integers. Lines 17–18 invert the array values.

**InvertFilter** uses a **LookupOp**—a subclass of **BufferedImageOp**—to invert the colors. Class **BufferedImageOp**—the base class for most Java 2D filters—operates on two images (the source image and the destination image). All classes that implement **BufferedImageOp** filter the source image to produce the destination image. A **LookupOp** is an array indexed by source pixel color values and contains destination pixel color values. Lines 21–22 create a new **LookupOp**—**invertFilter**. The **LookupOp** constructor takes as arguments a **ByteLookUpTable** that contains the lookup array table—**invertArray**—and a **RenderingHints**. The **RenderingHints** object describes optimizations for the rendering engine. In this application, no optimizations are needed, so **RenderingHints** is **null**. Line 25 invokes method **filter** of class **LookupOp**, which processes **image** with **invertFilter** and returns the filtered image.

```
1 // InvertFilter.java
2 // InvertFilter, which implements Java2DImageFilter, inverts a
3 // BufferedImage's RGB color values.
4 package com.deitel.advjhtp1.java2d;
5
6 // Java core packages
7 import java.awt.image.*;
8
9 public class InvertFilter implements Java2DImageFilter {
10
11     // apply color inversion filter to BufferedImage
12     public BufferedImage processImage( BufferedImage image )
13     {
14         // create 256 color array and invert colors
15         byte[] invertArray = new byte[ 256 ];
16
17         for ( int counter = 0; counter < 256; counter++ )
18             invertArray[ counter ] = ( byte )( 255 - counter );
19
20         // create filter to invert colors
21         BufferedImageOp invertFilter = new LookupOp(
22             new ByteLookupTable( 0, invertArray ), null );
23
24         // apply filter to displayImage
25         return invertFilter.filter( image, null );
26
27     } // end method processImage
28 }
```

Fig. 4.9 InvertFilter inverts colors in a BufferedImage.

Class **SharpenFilter** (Fig. 4.10) is a filter that detects and enhances *edges*—differences in the sample values of neighboring pixels—in an image. A sharpening filter first detects edges by determining differences in neighboring pixel sample values, then enhances the edge by increasing the difference between the sample values. **SharpenFilter** uses a **ConvolveOp**—another subclass of **BufferedImageOp**—to create the sharpening filter. A **ConvolveOp** combines the colors of a source pixel and its surrounding neighbors to determine the color of the corresponding destination pixel. Lines 15–18 create **sharpenMatrix**—the values used in the **ConvolveOp**. Lines 21–23 create the **ConvolveOp**—**sharpenFilter**—passing three parameters (a **Kernel**, an integer edge hint and a **RenderingHints** object). The **Kernel**—a 2D array—specifies how a **ConvolveOp** filter should combine neighboring pixel values. Every **ConvolveOp** is built from a **Kernel**. The **Kernel** constructor takes as arguments a width, height and an array of values. Using these arguments, a two-dimensional array is constructed from the array values. Edge hints instruct the filter how to alter pixels at the perimeter of the image. **EDGE\_NO\_OP** (line 23) instructs **sharpenFilter** to copy the source pixels at the perimeter of **image** directly to the destination image without modification. Line 26 invokes method **filter** of class **ConvolveOp**, which takes as an argument a **BufferedImage**. Method **filter** returns the filtered image.

```
1 // SharpenFilter.java
2 // SharpenFilter, which implements Java2DImageFilter, sharpens
3 // the edges in a BufferedImage.
4 package com.deitel.advjhtp1.java2d;
5
6 // Java core packages
7 import java.awt.image.*;
8
9 public class SharpenFilter implements Java2DImageFilter {
10
11     // apply edge-sharpening filter to BufferedImage
12     public BufferedImage processImage( BufferedImage image )
13     {
14         // array used to detect edges in image
15         float[] sharpenMatrix = {
16             0.0f, -1.0f, 0.0f,
17             -1.0f, 5.0f, -1.0f,
18             0.0f, -1.0f, 0.0f };
19
20         // create filter to sharpen edges
21         BufferedImageOp sharpenFilter =
22             new ConvolveOp( new Kernel( 3, 3, sharpenMatrix ),
23                 ConvolveOp.EDGE_NO_OP, null );
24
25         // apply sharpenFilter to displayImage
26         return sharpenFilter.filter( image, null );
27
28     } // end method processImage
29 }
```

Fig. 4.10 SharpenFilter sharpens edges in a **BufferedImage**.

Class **BlurFilter** (Fig. 4.11) uses a **ConvolveOp** to blur a **BufferedImage**. A blurring filter smooths distinct edges by averaging each pixel value with that of its eight neighboring pixels. Lines 14–17 create **blurMatrix**—an array of values for constructing the **Kernel**. Lines 20–21 create **ConvolveOp blurFilter** using the default constructor, which takes as an argument a **Kernel** constructed from **blurMatrix**. The default constructor uses **EDGE\_ZERO\_FILL** for the edge hint and a **null RenderingHints**. **EDGE\_ZERO\_FILL** specifies that pixels at the outer edge of the destination **BufferedImage** be set to 0—this is the default. Line 24 invokes **blurFilter**'s method **filter** on **image**.

```
1 // BlurFilter.java
2 // Blurfilter blurs a BufferedImage.
3 package com.deitel.advjhtp1.java2d;
4
5 // Java core packages
6 import java.awt.image.*;
7
8 public class BlurFilter implements Java2DImageFilter {
```

Fig. 4.11 BlurFilter blurs the colors in a **BufferedImage** (part 1 of 2).

```
9
10    // apply blurring filter to BufferedImage
11    public BufferedImage processImage( BufferedImage image )
12    {
13        // array used to blur BufferedImage
14        float[] blurMatrix = {
15            1.0f / 9.0f, 1.0f / 9.0f, 1.0f / 9.0f,
16            1.0f / 9.0f, 1.0f / 9.0f, 1.0f / 9.0f,
17            1.0f / 9.0f, 1.0f / 9.0f, 1.0f / 9.0f };
18
19        // create ConvolveOp for blurring BufferedImage
20        BufferedImageOp blurFilter = new ConvolveOp(
21            new Kernel( 3, 3, blurMatrix ) );
22
23        // apply blurFilter to BufferedImage
24        return blurFilter.filter( image, null );
25
26    } // end method processImage
27 }
```

Fig. 4.11 **BlurFilter** blurs the colors in a **BufferedImage** (part 2 of 2).

Class **ColorFilter** (Fig. 4.12) alters the *color bands* in a **BufferedImage**. There are three color bands in a **TYPE\_INT\_RGB BufferedImage**—red, green and blue. Each color band is defined by three coefficients that represent the R, G and B components in the band. The standard red color band consists of **1.0f** R, **0.0f** G and **0.0f** B color components—i.e. the standard red band consists entirely of red. Likewise, the standard green color band consists of **0.0f** R, **1.0f** G and **0.0f** B, while the standard blue color band consists of **0.0f** R, **0.0f** G and **1.0f** B. We can change image colors by altering the values of the R, G and B coefficients in a color band.

```
1 // ColorFilter.java
2 // ColorFilter is an Java2DImageFilter that alters the RGB
3 // color bands in a BufferedImage.
4 package com.deitel.advjhtp1.java2d;
5
6 // Java core packages
7 import java.awt.image.*;
8
9 public class ColorFilter implements Java2DImageFilter {
10
11    // apply color-change filter to BufferedImage
12    public BufferedImage processImage( BufferedImage image )
13    {
14        // create array used to change RGB color bands
15        float[][] colorMatrix = {
16            { 1.0f, 0.0f, 0.0f },
17            { 0.5f, 1.0f, 0.5f },
18            { 0.2f, 0.4f, 0.6f } };
19    }
```

Fig. 4.12 **ColorFilter** changes the colors in a **BufferedImage** (part 1 of 2).

```
20     // create filter to change colors
21     BandCombineOp changeColors =
22         new BandCombineOp( colorMatrix, null );
23
24     // create source and display Rasters
25     Raster sourceRaster = image.getRaster();
26
27     WritableRaster displayRaster =
28         sourceRaster.createCompatibleWritableRaster();
29
30     // filter Rasters with changeColors filter
31     changeColors.filter( sourceRaster, displayRaster );
32
33     // create new BufferedImage from display Raster
34     return new BufferedImage( image.getColorModel(),
35         displayRaster, true, null );
36
37 } // end method processImage
38 }
```

Fig. 4.12 **ColorFilter** changes the colors in a **BufferedImage** (part 2 of 2).

Lines 15–18 create **colorMatrix**—a 2D array that represents a nonstandard *color space*—the aggregation of red, green and blue color bands. The red band (line 16) is the same as in the standard space. The green and blue bands (lines 17–18) assume color values from all three color components—green and blue will contain elements of R, G and B. Lines 21–22 create a **BandCombineOp**—a subclass of **RasterOp**. Class **RasterOp** is the base class for filters that operate on **Rasters**. A **BandCombineOp** operates on the color bands of a **Raster**. Every **BufferedImage** contains a **Raster**. The **Raster** organizes and stores the samples that determine the pixel colors in the **BufferedImage**.

Line 25 calls method **getRaster** of class **BufferedImage**, which returns the **Raster** associated with **image**—**sourceRaster**. Lines 27–28 call method **createCompatibleWritableRaster** of class **Raster**, which returns **displayRaster**—a **WritableRaster** compatible with **sourceRaster**. Compatible **Rasters** contain the same number of bands. A **WritableRaster** allows sample data to be written while a **Raster** is read-only. Line 31 invokes method **filter** of class **BandCombineOp**, which takes as arguments a source **Raster** and a destination **WritableRaster**. The source **Raster** is filtered and written into the destination **WritableRaster**.

Lines 34–35 construct a **BufferedImage**. This **BufferedImage** constructor takes four arguments—a **ColorModel**, a **Raster**, a **boolean** and a **Hashtable**. We use the **ColorModel** of the original image, accessed through method **getColorModel** of class **Image** (line 34). Class **ColorModel** converts **Raster** data to colors depending on the *color scale* of the image. The **Raster** argument to the **BufferedImage** constructor is our **displayRaster**. The **boolean** value indicates whether the **Raster** has been premultiplied with *alpha values*. Each pixel is a small square. A curve in an image may require that only a portion of a pixel be colored—the alpha values tell the **Raster** how much of the pixel to cover. The **Hashtable** contains **String**/object properties and is **null** in this case. **BufferedImage**'s constructor will throw a **RasterFormatException**.

**ception** if the number and types of bands in the **Raster** do not match the number and types of bands required by the **ColorModel**.

Class **Java2DEExample** (Fig. 4.13) provides a user interface for applying **Java2DImageFilters** to **ImagePanels**. Lines 23–26 declare the **Java2DImageFilters**. Lines 34–37 initialize the **Java2DImageFilters**. Lines 40–41 create **imagePanel**—the **ImagePanel** to be filtered. Lines 44–45 create **filterMenu**—the menu of **Java2DImageFilters**. Lines 52–54 create the first **JMenuItem** for **filterMenu**—**originalMenuItem**. An **ItemListener** invokes **imagePanel**'s **displayOriginal** method when **originalMenuItem** is selected (lines 56–66). Lines 69–76 call method **createMenuItem** (lines 93–116) for each of the four **Java2DImageFilters**. This method creates a **JMenuItem** for the filter with the appropriate title and mnemonic. **ImagePanel** invokes method **applyFilter** when the **JMenuItem** is selected (line 108). **Java2DEExample** contains method **main** (lines 119–125), for starting the application.

```
1 // Java2DEExample.java
2 // Java2DEExample is an application that applies filters to an
3 // image using Java 2D.
4 package com.deitel.advjhtp1.java2d;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.awt.image.*;
10 import java.lang.*;
11 import java.net.*;
12
13 // Java extension packages
14 import javax.swing.*;
15 import javax.swing.event.*;
16
17 public class Java2DEExample extends JFrame {
18
19     private JMenu filterMenu;
20     private ImagePanel imagePanel;
21
22     // image filters
23     private Java2DImageFilter invertFilter;
24     private Java2DImageFilter sharpenFilter;
25     private Java2DImageFilter blurFilter;
26     private Java2DImageFilter colorFilter;
27
28     // initialize JMenuItems
29     public Java2DEExample()
30     {
31         super( "Java 2D Image Processing Demo" );
32
33         // create Java2DImageFilters
34         blurFilter = new BlurFilter();
```

Fig. 4.13 Java 2D image-processing application GUI (part 1 of 4).

```
35     sharpenFilter = new SharpenFilter();
36     invertFilter = new InvertFilter();
37     colorFilter = new ColorFilter();
38
39     // initialize JPanel
40     imagePanel = new JPanel(
41         Java2DEExample.class.getResource( "images/ajhttp.png" ) );
42
43     // create JMenuBar
44     JMenuBar menuBar = new JMenuBar();
45     setJMenuBar( menuBar );
46
47     // create JMenu
48     filterMenu = new JMenu( "Image Filters" );
49     filterMenu.setMnemonic( 'I' );
50
51     // create JMenuItem for displaying original Image
52     JMenuItem originalMenuItem =
53         new JMenuItem( "Display Original" );
54     originalMenuItem.setMnemonic( 'O' );
55
56     originalMenuItem.addActionListener(
57         new ActionListener() {
58
59             // show original Image
60             public void actionPerformed( ActionEvent action )
61             {
62                 imagePanel.displayOriginalImage();
63             }
64
65         } // end anonymous inner class
66     );
67
68     // create JMenuItems for Java2DImageFilters
69     JMenuItem invertMenuItem = createMenuItem(
70         "Invert", 'I', invertFilter );
71     JMenuItem sharpenMenuItem = createMenuItem(
72         "Sharpen", 'S', sharpenFilter );
73     JMenuItem blurMenuItem = createMenuItem(
74         "Blur", 'B', blurFilter );
75     JMenuItem changeColorsMenuItem = createMenuItem(
76         "Change Colors", 'C', colorFilter );
77
78     // add JMenuItems to JMenu
79     filterMenu.add( originalMenuItem );
80     filterMenu.add( invertMenuItem );
81     filterMenu.add( sharpenMenuItem );
82     filterMenu.add( blurMenuItem );
83     filterMenu.add( changeColorsMenuItem );
84
85     // add JMenu to JMenuBar
86     menuBar.add( filterMenu );
```

Fig. 4.13 Java 2D image-processing application GUI (part 2 of 4).

```

88         getContentPane().add( imagePanel, BorderLayout.CENTER );
89
90     } // end Java2DExample constructor
91
92     // create JMenuItem and ActionListener for given filter
93     public JMenuItem createMenuItem( String menuItemName,
94         char mnemonic, final Java2DImageFilter filter )
95     {
96         // create JMenuItem
97         JMenuItem menuItem = new JMenuItem( menuItemName );
98
99         // set Mnemonic
100        menuItem.setMnemonic( mnemonic );
101
102        menuItem.addActionListener(
103            new ActionListener()
104            {
105
106                // apply Java2DImageFilter when MenuItem accessed
107                public void actionPerformed( ActionEvent action )
108                {
109                    imagePanel.applyFilter( filter );
110
111                } // end anonymous inner class
112            });
113
114        return menuItem;
115
116    } // end method createMenuItem
117
118    // start program
119    public static void main( String args[] )
120    {
121        Java2DExample application = new Java2DExample();
122        application.setDefaultCloseOperation( EXIT_ON_CLOSE );
123        application.pack();
124        application.setVisible( true );
125    }
126 }

```

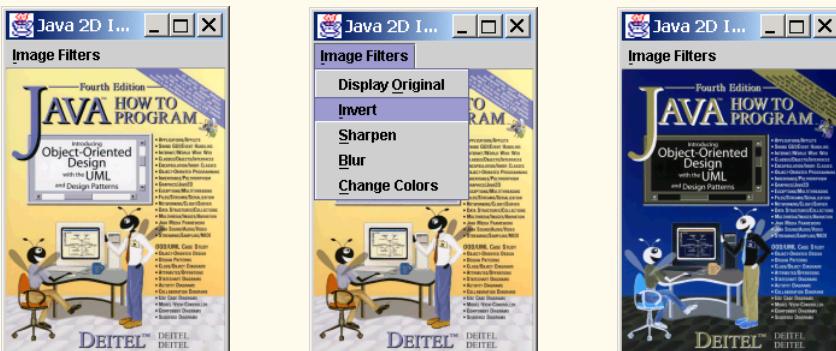


Fig. 4.13 Java 2D image-processing application GUI (part 3 of 4).



Fig. 4.13 Java 2D image-processing application GUI (part 4 of 4).

This concludes our discussion of the Java 2D API. This section has presented several of the features that make Java 2D a powerful 2D graphics API. We discussed geometrical shape-rendering processes, including how to create and fill shapes with different colors and patterns, how to draw a **GeneralPath** and how to apply transforms to Java 2D shapes. We also introduced and discussed Java 2D image processing, including how to create and apply filters to **BufferedImages**.

## 4.4 Java 3D API

We live in a 3D world. Our vision enables us to see in three dimensions—*x*, *y*, and *z* coordinates. Many of the surfaces onto which graphics are displayed—for example, monitors and printed pages—are flat. 3D-graphics programming enables us to render realistic models of our 3D world onto a 2D-viewing surface. 3D graphics have advanced to the point that nearly anything you can see around you can be *modeled*—represented numerically by shape and size—and *rendered*—drawn on your computer screen.

There now exists an increasing number of 3D-computer-graphics applications—from flight simulators and medical-imaging equipment to 3D games and screen savers. Rapid advances in computer hardware have resulted in tremendous growth in the 3D-graphics industry. Developments in high-performance hardware led to developments in high-performance 3D graphics APIs—beginning in the 1970s with Siggraph’s CORE API, continuing in the 1980s with SGI’s *OpenGL* and on through today with Microsoft’s *Direct3D* and *Java 3D*<sup>TM,1</sup>.

Sophisticated 3D graphics require sophisticated graphics algorithms that often involve complex math. However, the *Java 3D API* provides robust and advanced 3D-graphics capabilities to Java developers while hiding the mathematics behind graphics algorithms. Java 3D is a high-level graphics-programming API. Java 3D handles all the necessary low-level graphics calls, so developers can create high-performance 3D-graphics scenes without having to understand any underlying hardware. Like Java, Java 3D is *write once run anywhere*<sup>TM</sup>. Java 3D applications will run in the same way across different 3D graphics platforms.

Sun Microsystems designed the Java 3D API with four major goals in mind—application portability, hardware independence, performance scalability and the ability to produce 3D graphics over a network.<sup>2</sup> Simplifying of complex graphics operations played a key role in developing the Java 3D API. Some of the markets and applications for the Java 3D API include<sup>3</sup>

- 3D-data visualization
- collaborative applications
- gaming (especially network-based multiplayer systems)
- business graphics
- interactive educational systems
- molecular modeling and viewing (MCAD)
- 3D-Web development
- 3D-GUI development

- 
1. Sun Microsystems, Inc., “The Fourth Generation of 3D Graphics API’s has arrived!” 25 January 2000. <[java.sun.com/products/java-media/3D/collateral/wp\\_mktg/j3d\\_wp.pdf](http://java.sun.com/products/java-media/3D/collateral/wp_mktg/j3d_wp.pdf)>.
  2. Sun Microsystems, Inc., “The Java 3D API: For Developers and End Users,” 1 December 1998. <<http://java.sun.com/products/java-media/3D/collateral/presentation/sld004.html>>.
  3. Sun Microsystems, Inc., “The Java 3D API: For Developers and End Users,” 1 December 1998. <<http://java.sun.com/products/java-media/3D/collateral/presentation/sld015.html>>.

Java 3D offers several features that these markets use to develop their 3D-applications:

- *Behavior*—Java 3D supports multiple types of behavior including animation and motion, *collision detection* (detecting when two objects collide) and *morphing* (transforming an image into another *image*).
- *Fog*—Java 3D supports fog content that restricts viewers ability to see certain objects in the scene. For example, fog helps to create a realistic model of a rainstorm in a 3D game.
- *Geometry*—Java 3D has built-in 3D-geometric primitives for creating geometric shapes. Java 3D can render scenes generated by existing 3D authoring tools, such as 3DStudioMax, VRML and Lightwave3D.
- *Light*—Lights allow you to illuminate objects in a 3D scene. Java 3D supports different forms of light and control over color, direction and intensity.
- *Sound*—A unique feature of Java 3D is support for 3D sound.
- *Texture*—Java 3D supports *texture mapping* for attaching images over 3D-geometric models.

Next, we present an overview of the Java 3D API—we examine the structure of a Java 3D scene by presenting an application that incorporates 3D geometry, lights and interactive animation. In the next section, we explain how to obtain and install the Java 3D API so you can run the examples in this chapter and create your own 3D content.

#### 4.4.1 Obtaining and Installing the Java 3D API

The Java 3D API requires that you have the *Java 2 Platform, Standard Edition* and either OpenGL or Direct3D installed on your computer—Java 3D uses OpenGL or Direct3D graphics libraries to render 3D scenes. You can obtain OpenGL from [www.opengl.org](http://www.opengl.org). You can obtain Direct3D—part of Microsoft’s *DirectX API*—from [www.microsoft.com/directx/](http://www.microsoft.com/directx/).

The Java 3D API is not integrated in the core Java 2 Platform. To use the Java 3D API, you must install the appropriate Java extension and utility packages. The Java 3D API packages differ slightly depending on which low-level graphics libraries are installed on your computer. The version of Java 3D used in this chapter requires the OpenGL graphics library and *Windows 2000* Operating System. The version of Java 3D packages you install depends on your operating system and graphics API. You can obtain the Java 3D packages and installation instructions from [java.sun.com/products/java-media/3D/download.html](http://java.sun.com/products/java-media/3D/download.html).

#### 4.4.2 Java 3D Scenes

Pictures rendered with Java3D are called *scenes*. A scene—also called a *virtual universe*—is 3D space that contains a set of shapes. The root of the Java 3D scene is a **VirtualUniverse** object. The **VirtualUniverse** has a *coordinate system* for describing the location of *scene graphs* it contains. Each Java 3D scene is described by a number of scene graphs—hierarchical structures that specify attributes of a 3D environment. Each scene

graph attaches to the **VirtualUniverse** at a specified point in the **VirtualUniverse**'s coordinate system. A scene graph is composed of an internal coordinate system and a number of *branch graphs*. Each scene graph has an internal coordinate system, so developers can attach scene graphs with different coordinate systems in the same **VirtualUniverse**. Class **Locale** is the root node in a scene graph, which contains the attachment coordinate for the **VirtualUniverse** and a number of branch graphs. There are two types of branch graphs in Java 3D—*content-branch graphs* and *view-branch graphs*. Content-branch graphs specify content in 3D scenes, such as geometry, lighting, textures, fog and behaviors. View-branch graphs contain *viewing platforms*—collections of objects that specify the perspective, position, orientation and scale in 3D scenes. The viewing platform is also called the *viewpoint*.

The Java 3D class **SceneGraphObject** is the base class for all objects in a branch graph. A **SceneGraphObject** may contain a **Group**, which represents a node that contains multiple children. The children of a **Group** may be other **Groups**, **Leafs** or **NodeComponents**. **Leafs** specify geometry, lights and sound in content-branch graphs and the viewing-platform components in the view-branch graph. **NodeComponent** objects specify the various *components* of **Groups** and **Leafs** such as texture and coloring attributes. Figure 4.14 lists some Java 3D **Group**, **Leaf** and **NodeComponent** subclasses.

Class	Description
<i>Partial list of Java3D Group classes</i>	
<b>BranchGroup</b>	A scene-graph's root <b>Node</b> that attaches to a <b>Locale</b> .
<b>Switch</b>	Can render either a single child or a mask of children.
<b>TransformGroup</b>	Contains a single transformation (e.g., translation, rotation or scaling).
<i>Partial list of Java3D Leaf classes</i>	
<b>Behavior</b>	Contains methods for gathering user input (e.g., key presses and mouse clicks) and describing objects' behavior upon certain events (e.g., collisions).
<b>Light</b>	Describes a set of parameters for Java 3D light sources.
<b>Shape3D</b>	Describes 3D-geometric objects.
<b>ViewPlatform</b>	Controls the viewpoint for a 3D scene.
<i>Partial list of Java3D NodeComponent classes</i>	
<b>Appearance</b>	Specifies <b>Shape3D</b> attributes, such as <i>coloring</i> and <i>texture</i> .
<b>Material</b>	Describes an illuminated object's properties (e.g., <i>reflective color</i> and <i>shininess</i> ).
<b>Texture</b>	Specifies properties for <i>texture mapping</i> —a technique for drawing 2D images over 3D geometric models.

Fig. 4.14 Java 3D **Group**, **Leaf** and **NodeComponent** subclasses.

#### 4.4.3 A Java 3D Example

This section creates an interactive Java 3D scene. The application demonstrates how to create and use Java 3D **Geometry** and **Lights**. A Java Swing GUI enables the user to change the properties of the shapes and lights in the 3D scene. The application demonstrates *mouse behaviors*—i.e., using the mouse to rotate, scale and translate the 3D-shapes. The application consists of three classes—**Java3DWorld** (Fig. 4.15), **ControlPanel** (Fig. 4.21) and **Java3DExample** (Fig. 4.22). Figure 4.16–Fig. 4.20 show sample screen captures demonstrating the features of this application.

Class **Java3DWorld** (Fig. 4.15) creates the Java 3D environment using geometry, transforms and lighting. Lines 19–22 import the Java 3D utility packages which simplify the scene-content creation. Class **Java3DWorld** extends class **Canvas3D** (line 24), a **java.awt.Canvas** subclass for 3D rendering. We use a **Canvas3D** as the drawing surface for our 3D graphics application. Lines 26–38 declare the Java 3D objects we use in the application. We discuss each object's function momentarily.

```
1 // Java3DWorld.java
2 // Java3DWorld is a Java 3D Graphics display environment
3 // that creates a SimpleUniverse and provides capabilities for
4 // allowing a user to control lighting, motion, and texture
5 // of the 3D scene.
6 package com.deitel.advjhtp1.java3d;
7
8 // Java core packages
9 import java.awt.event.*;
10 import java.awt.*;
11 import java.net.*;
12
13 // Java extension packages
14 import javax.swing.event.*;
15 import javax.media.j3d.*;
16 import javax.vecmath.*;
17
18 // Java 3D utility packages
19 import com.sun.j3d.utils.universe.*;
20 import com.sun.j3d.utils.image.*;
21 import com.sun.j3d.utils.geometry.*;
22 import com.sun.j3d.utils.behaviors.mouse.*;
23
24 public class Java3DWorld extends Canvas3D {
25
26     private Appearance appearance; // 3D object's appearance
27     private Box shape; // 3D object to manipulate
28     private Color3f lightColor; // Light color
29     private Light ambientLight; // ambient scene lighting
30     private Light directionalLight; //directional light
31     private Material material; // 3D objects color object
32     private SimpleUniverse simpleUniverse; // 3D scene environment
33     private TextureLoader textureLoader; // 3D object's texture
34 }
```

Fig. 4.15 Creating a Java 3D **SimpleUniverse** with content (part 1 of 5).

```
35     // holds 3D transformation information
36     private TransformGroup transformGroup;
37
38     private String imageName; // texture image file name
39
40     // Java3DWorld constructor
41     public Java3DWorld( String imageFileName )
42     {
43         super( SimpleUniverse.getPreferredConfiguration() );
44
45         imageName = imageFileName;
46
47         // create SimpleUniverse (3D Graphics environment)
48         simpleUniverse = new SimpleUniverse( this );
49
50         // set default view point and direction
51         ViewingPlatform viewPlatform =
52             simpleUniverse.getViewingPlatform();
53
54         viewPlatform.setNominalViewingTransform();
55
56         // create 3D scene
57         BranchGroup branchGroup = createScene();
58
59         // attach BranchGroup to SimpleUniverse
60         simpleUniverse.addBranchGraph( branchGroup );
61
62     } // end Java3DWorld constructor
63
64     // create 3D scene
65     public BranchGroup createScene()
66     {
67         BranchGroup scene = new BranchGroup();
68
69         // initialize TransformGroup
70         transformGroup = new TransformGroup();
71
72         // set TransformGroup's READ and WRITE permission
73         transformGroup.setCapability(
74             TransformGroup.ALLOW_TRANSFORM_READ );
75
76         transformGroup.setCapability(
77             TransformGroup.ALLOW_TRANSFORM_WRITE );
78
79         // add TransformGroup to BranchGroup
80         scene.addChild( transformGroup );
81
82         // create BoundingSphere
83         BoundingSphere bounds = new BoundingSphere(
84             new Point3d( 0.0f, 0.0f, 0.0f ), 100.0 );
85
86         appearance = new Appearance(); // create object appearance
87         material = new Material(); // create texture material
```

Fig. 4.15 Creating a Java 3D `SimpleUniverse` with content (part 2 of 5).

```
88     appearance.setMaterial( material );
89
90     String rgb = new String( "RGB" );
91
92     // load texture for scene object
93     textureLoader = new TextureLoader(
94         Java3DWorld.class.getResource( imageName ), rgb, this );
95
96     // set capability bits for enabling texture
97     textureLoader.getTexture().setCapability(
98         Texture.ALLOW_ENABLE_WRITE );
99
100    // initial texture will not show
101    textureLoader.getTexture().setEnabled( false );
102
103    // set object's texture
104    appearance.setTexture( textureLoader.getTexture() );
105
106    // create object geometry
107    Box shape = new Box( 0.3f, 0.3f, 0.3f,
108        Box.GENERATE_NORMALS | Box.GENERATE_TEXTURE_COORDS,
109        appearance );
110
111    // add geometry to TransformGroup
112    transformGroup.addChild( shape );
113
114    // initialize Ambient lighting
115    ambientLight = new AmbientLight();
116    ambientLight.setInfluencingBounds( bounds );
117
118    // initialize directionalLight
119    directionalLight = new DirectionalLight();
120
121    lightColor = new Color3f(); // initialize light color
122
123    // set initial DirectionalLight color
124    directionalLight.setColor( lightColor );
125
126    // set capability bits to allow DirectionalLight's
127    // Color and Direction to be changed
128    directionalLight.setCapability(
129        DirectionalLight.ALLOW_DIRECTION_WRITE );
130
131    directionalLight.setCapability(
132        DirectionalLight.ALLOW_DIRECTION_READ );
133
134    directionalLight.setCapability(
135        DirectionalLight.ALLOW_COLOR_WRITE );
136
137    directionalLight.setCapability(
138        DirectionalLight.ALLOW_COLOR_READ );
139
140    directionalLight.setInfluencingBounds( bounds );
```

Fig. 4.15 Creating a Java 3D **SimpleUniverse** with content (part 3 of 5).

```
141
142     // add light nodes to BranchGroup
143     scene.addChild( ambientLight );
144     scene.addChild( directionalLight );
145
146     // initialize rotation behavior
147     MouseRotate rotateBehavior = new MouseRotate();
148     rotateBehavior.setTransformGroup( transformGroup );
149     rotateBehavior.setSchedulingBounds( bounds );
150
151     // initialize translation behavior
152     MouseTranslate translateBehavior = new MouseTranslate();
153     translateBehavior.setTransformGroup( transformGroup );
154     translateBehavior.setSchedulingBounds(
155         new BoundingBox( new Point3d( -1.0f, -1.0f, -1.0f ),
156         new Point3d( 1.0f, 1.0f, 1.0f ) ) );
157
158     // initialize scaling behavior
159     MouseZoom scaleBehavior = new MouseZoom();
160     scaleBehavior.setTransformGroup( transformGroup );
161     scaleBehavior.setSchedulingBounds( bounds );
162
163     // add behaviors to BranchGroup
164     scene.addChild( scaleBehavior );
165     scene.addChild( rotateBehavior );
166     scene.addChild( translateBehavior );
167
168     scene.compile();
169
170     return scene;
171
172 } // end method createScene
173
174 // change DirectionLight color
175 public void changeColor( Color color )
176 {
177     lightColor.set( color );
178     directionalLight.setColor( lightColor );
179 }
180
181 // change geometry surface to textured image or material color
182 public void updateTexture( boolean textureValue )
183 {
184     textureLoader.getTexture().setEnable( textureValue );
185 }
186
187 // change image used for texture
188 public void setImageName( String imageFileName )
189 {
190     imageName = imageFileName;
191 }
192
```

Fig. 4.15 Creating a Java 3D **SimpleUniverse** with content (part 4 of 5).

```
193 // get image file name
194 public String getImageName()
195 {
196     return imageName;
197 }
198
199 // return preferred dimensions of Container
200 public Dimension getPreferredSize()
201 {
202     return new Dimension( 500, 500 );
203 }
204
205 // return minimum size of Container
206 public Dimension getMinimumSize()
207 {
208     return getPreferredSize();
209 }
210 }
```

Fig. 4.15 Creating a Java 3D **SimpleUniverse** with content (part 5 of 5).

The **Java3DWorld** constructor (lines 41–62) accepts as a **String** argument the image file for texture mapping. Class **SimpleUniverse**, which creates a Java 3D scene, encapsulates all the objects in the virtual universe and viewing platform. By using a **SimpleUniverse**, developers create and attach content-branch graphs—the **SimpleUniverse** uses this information to construct the 3D scene.

The first step in creating a Java 3D scene is to initialize the **Canvas3D** (line 43). The **Canvas3D** constructor takes as an argument a **java.awt.GraphicsConfiguration** (line 43). Method **getPreferredConfiguration** of class **SimpleUniverse** returns the system's **java.awt.GraphicsConfiguration**, which specifies a graphics device, such as a computer monitor. Line 48 invokes the **SimpleUniverse** constructor, passing the **Canvas3D** as an argument. This constructor creates a Java 3D **SimpleUniverse** with the **Canvas3D** as the drawing surface. Class **SimpleUniverse** creates and configures the objects in the view branch graph. Lines 51–54 configure the *viewing distance*—the length between the viewer and the canvas—for our 3D scene. All objects in the view branch graph are members of class **ViewingPlatform**. Method **getViewingPlatform** of class **SimpleUniverse** returns a reference to the **ViewingPlatform** created inside the **SimpleUniverse** (lines 51–52). Method **setNominalViewingTransform** of class **ViewPlatform** sets the viewing distance for our 3D scene to the *nominal* (i.e., default) distance of **PI/4.0**. We now create content for our Java 3D scene.

In this application, we add one content branch-graph to the **SimpleUniverse**. Line 57 calls method **createScene** (lines 65–172), which returns a content **BranchGroup**. Class **BranchGroup** is the root node of a scene graph in a Java 3D scene. The **BranchGroup** contains the children **Groups**, **Leafs** and **NodeComponents** that describe the Java 3D scene. Line 60 attaches the content **BranchGroup** to the **SimpleUniverse** using method **addBranchGraph** of class **SimpleUniverse**.

Method **createScene** creates, constructs and compiles the **BranchGroup** content. Line 67 creates an instance of class **BranchGroup**. Line 70 creates a **TransformGroup**.

Class **TransformGroup**—a subclass of **Group**—specifies *transformational behavior* such as rotation, scaling and translation. Lines 73–77 set the **READ** and **WRITE** capability bits for the **TransformGroup** using method **setCapabilityBits** of the **TransformGroup**. Capability bits are integer flags that specify whether a given object should allow its properties to be read or written during execution. Line 80 calls method **addChild** of class **BranchGroup**, which adds the **TransformGroup** to the **BranchGroup**.



### Performance Tip 4.1

By default, Java 3D sets an object's properties so they cannot be changed during run-time. Java 3D does this to increase run-time performance.

Lines 83–84 create a **BoundingSphere**. Class **BoundingSphere** creates a spherical *bounding volume*, which specifies the volume of space in which **Lights** and **Behaviors** affect geometry in the scene. Outside the bounding volume, the **Lights** and **Behaviors** have no impact on the scene's geometry. Lines 83–84 create a **BoundingSphere** that is centered at the origin and has a **100** meter radius.

Line 86 creates the **Appearance** that describes the visual attributes of shapes. Lines 87 creates a default **Material** object. Class **Material** specifies the properties of an *illuminated* object—any object defined within the bounds of a **Light**. The default **Material** constructor specifies that objects in ambient white light will appear grey. The default **Material** constructor also enables any objects with the associated **Material** to be illuminated in the 3D scene. Line 88 calls method **setMaterial** of class **Appearance** to set the **Material** to the default material, although we could have created a **Material** object that would make the shape's surface reflect like a mirror or shine like metal.

Lines 93–104 create and load the image for texture mapping. Class **com.sun.j3d.utils.image.TextureLoader** loads an **Image** for texturing. The **TextureLoader** constructor takes as arguments the image file (**imageName**), the image format (**rgb**) and an **ImageObserver**. Lines 97–98 invoke method **setCapability** of class **TextureLoader** with argument **ALLOW\_ENABLE\_WRITE** so the user can apply textures to the **Texture** object during execution. Every **TextureLoader** has an associated **Texture** object that contains the texturing attributes. Line 101 disables texture mapping using method **setEnabled** of class **Texture**, although the user can enable it in runtime. Method **setTexture** of class **Appearance** sets the **Texture** object in **Appearance** to our **Texture** (line 104).

Lines 107–109 create a 3D **Box**—the shape that appears in our scene. The **Box** constructor takes as arguments three **floats** for the length, width and height, a set of integer flags that indicate the *position information* to generate and an **Appearance** object. Position information is generated when geometry is created—by default only spatial coordinates are generated. To ensure proper lighting and texture mapping for geometry, line 108 instructs the compiler to generate additional position information. Line 112 uses method **addChild** of class **TransformGroup** to add the **Box** to the **TransformGroup** so the user can perform transformations on the **Box**.

Line 115 creates an **AmbientLight** for the scene. Class **AmbientLight** is a uniform light source that illuminates all objects within its boundary. **AmbientLight** will not illuminate those objects outside its boundary. Line 116 calls method **setInfluencingBounds** to set the **AmbientLight** boundary using the **BoundingSphere** we created in line 86. Lines 119–140 create a **DirectionalLight** for the scene. Class **Dir**

**tionalLight** describes a light source that travels between two points—the *source* and *destination*. Line 119 creates a **DirectionalLight** using the default constructor. Line 121 creates a **Color3f** object—a color defined by three **floats** that represent the RGB color components. Line 124 calls method **setColor** of **DirectionalLight** to set the light source color. Lines 128–138 set the capability bits to allow the user to alter the color and direction of the **DirectionalLight**. Lines 143–144 add the two light sources to the **BranchGroup**. All objects in the **BranchGroup** will be illuminated—as long as these objects are enabled for illumination.

Lines 147–161 create different behaviors for the **Box**. We use **MouseBehavior** class in utility package **com.sun.j3d.utils.behavior.mouse**. Lines 147–149 create an instance of class **MouseRotate**, which stores a rotational transformation for an object controlled with the left mouse button. By moving the mouse while pressing the left mouse button, the user controls the rotation of the **Box**. Line 148 calls method **setTransformGroup** of class **MouseRotate** to gather the rotation information from the **TransformGroup**. Line 149 calls method **setSchedulingBounds** of **MouseRotate** to set **MouseRotate**'s bounding volume. Figure 4.16 shows the output when the user rotates the **Box**.

Class **MouseTranslate**—another subclass of **MouseBehavior** creates a behavior that controls the *translation* (i.e., the displacement) of shapes when the user presses the right mouse button, then drags the mouse. Line 152 creates an instance of **MouseTranslate**. Line 153 calls method **setTransformGroup** of class **MouseTranslate** to gather the translational information from the **TransformGroup**. Lines 154–156 call method **setSchedulingBounds**, passing as an argument a **BoundingBox**. Class **BoundingBox** creates a cubic boundary. **BoundingBox**'s constructors takes as arguments two **Point3d** objects, which represent the upper-right and lower-left vertices of the cube. Outside this **BoundingBox**, the **MouseTranslate** behavior does not work. Figure 4.17 shows the output when the user translates the **Box**.

Class **MouseZoom**—another subclass of **MouseBehavior**—controls the shape's size when the user presses either the middle mouse button (on a three-button mouse) or the Alt key and left button (on a two-button mouse), then drags the mouse. Line 159 creates an instance of class **mouseZoom**. Line 160 calls method **setTransformGroup** of class **MouseZoom** to gather the scaling information from the **TransformGroup**. Line 161 calls method **setSchedulingBounds**, passing the **BoundingSphere** we created earlier in method **createScene**. Figure 4.18 demonstrates the output when the user scales the **Box**.

Lines 164–166 add the three **MouseBehaviors** to the **BranchGroup**. Line 168 calls method **compile** of class **BranchGroup**. Compiling a **BranchGroup** informs the Java 3D engine to optimize rendering the scene using the capability bits set by the developer.

To toggle texture mapping and lighting during execution, we implement methods that update the **Appearance** and **DirectionalLight**. Method **changeColor** (lines 175–179) uses a **Color** object to set the **DirectionalLight** color. Line 177 creates a **Color3D** object from the **Color** argument and passes it to method **setColor** of the **DirectionalLight**. Figure 4.19 shows the output as the user alters the color for **DirectionalLight**.

Method **updateTexture** (lines 182–185) toggles texture mapping of the shapes in the scene. This method takes a **boolean** argument that specifies whether to enable texture mapping for the 3D shape. Figure 4.20 shows the output when the user enables texture mapping.

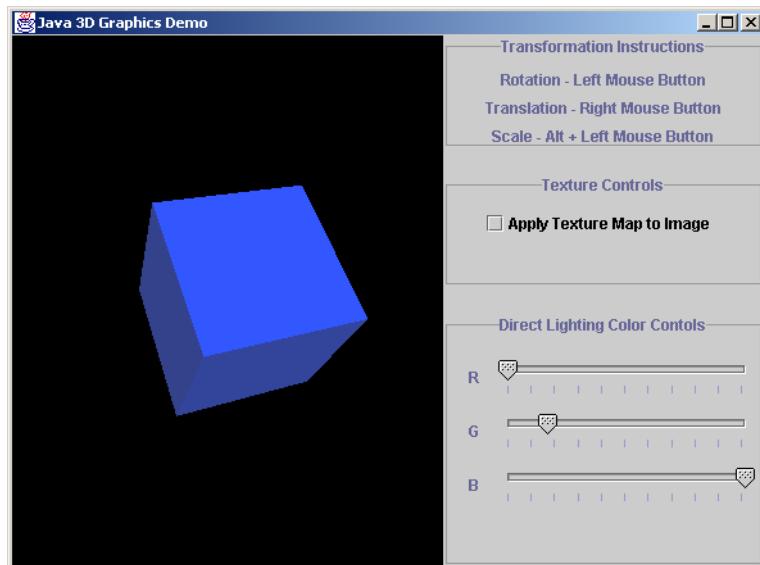
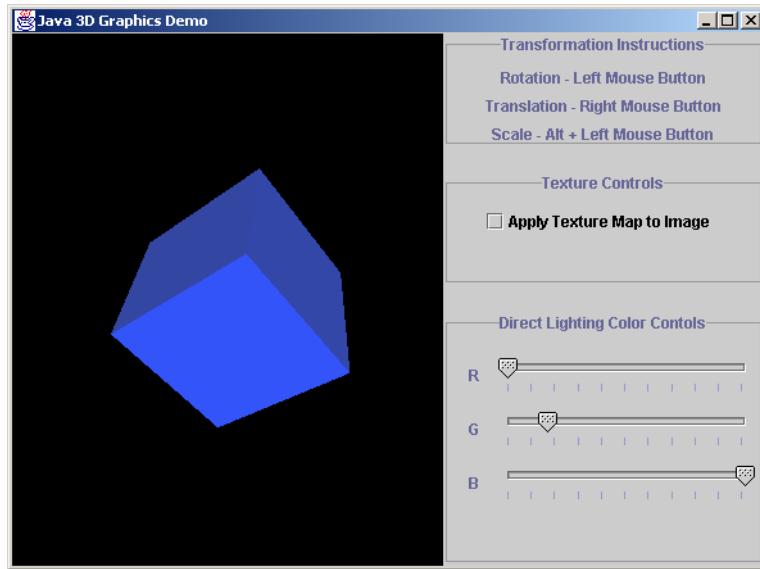


Fig. 4.16 Demonstrating **MouseRotate** behavior.

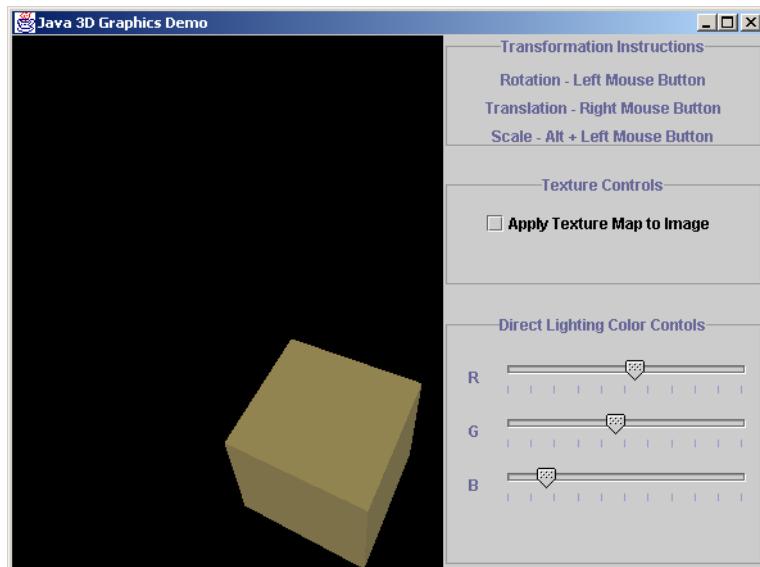
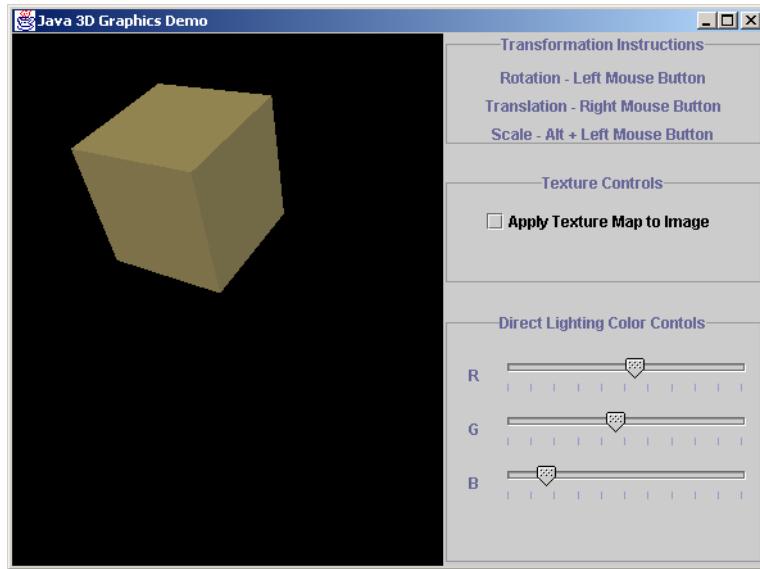


Fig. 4.17 Demonstrating `MouseTranslate` behavior.

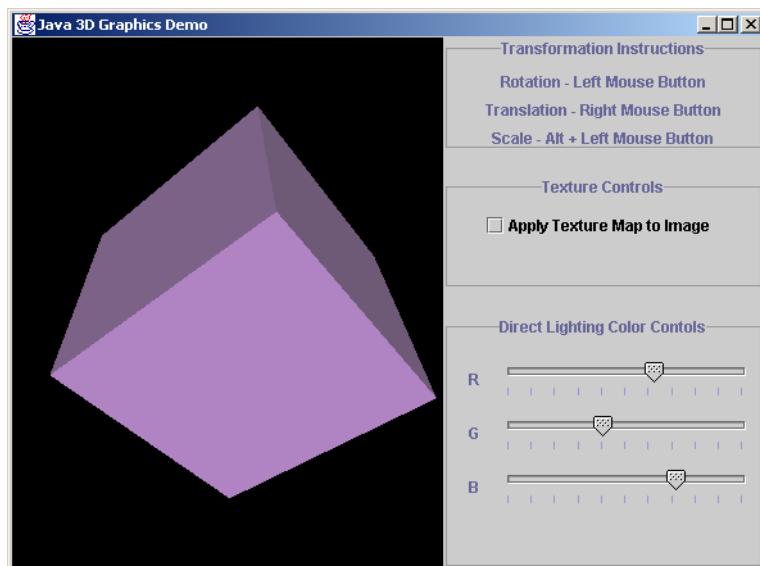
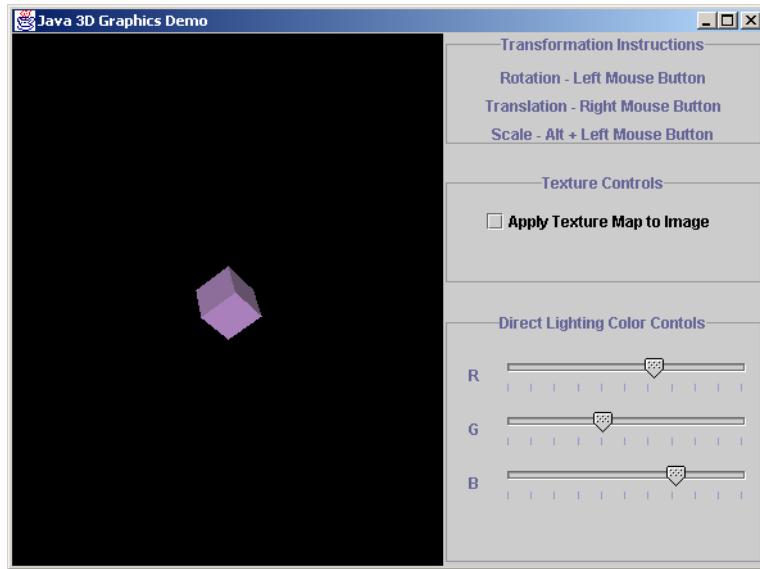


Fig. 4.18 Demonstrating **MouseZoom** behavior.

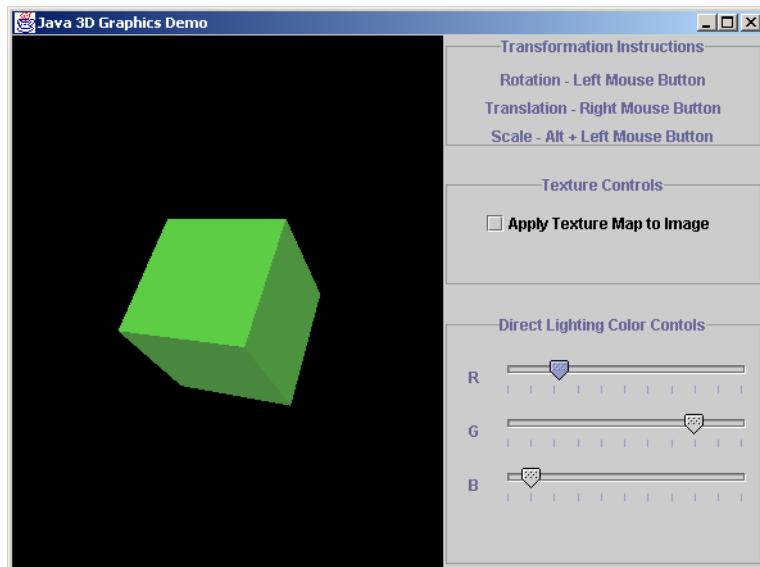
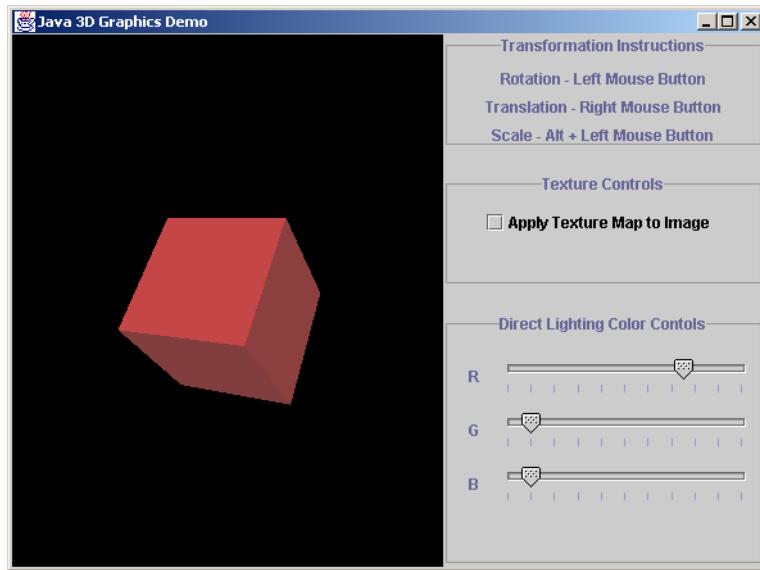


Fig. 4.19 Demonstrating changing color in Java 3D.

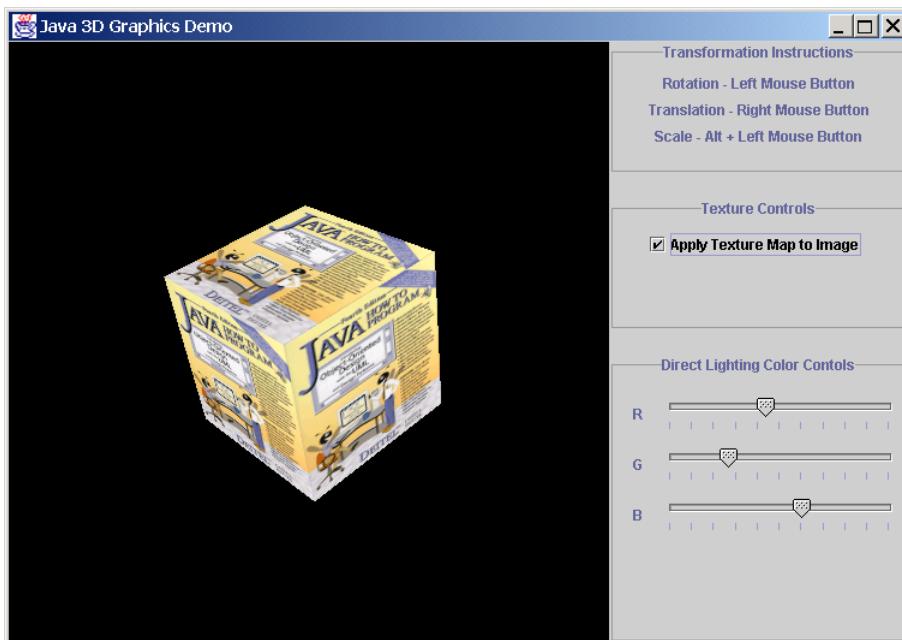
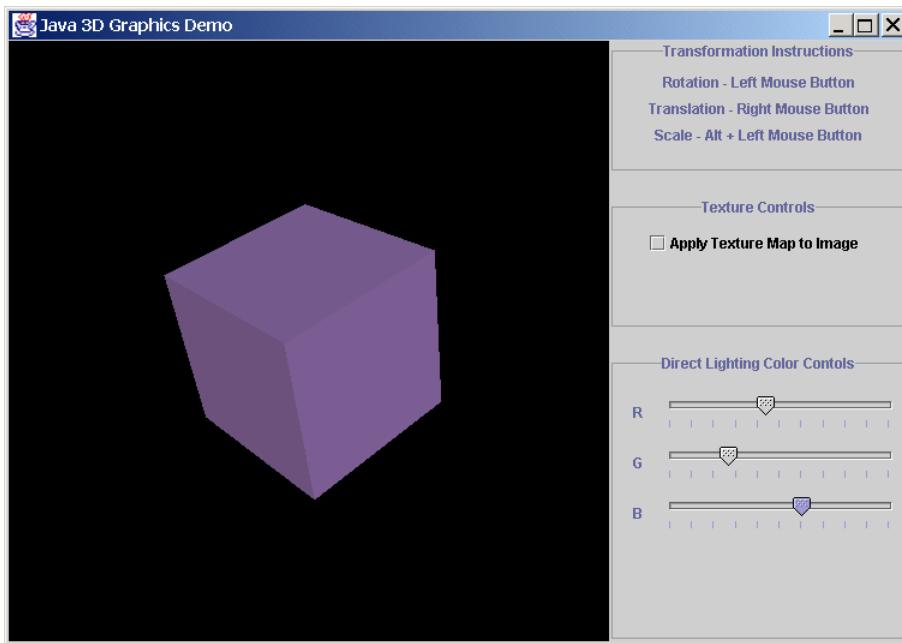


Fig. 4.20 Demonstrating texture mapping in Java 3D.

The user controls the **DirectionalLight** properties and texture mapping in the **Java3DWorld** using class **ControlPanel** (Fig. 4.21). Lines 18–21 declare three **JSliders** and one **JCheckbox** for the user to interact with the 3D application. Line 24 declares a reference to a **Java3DWorld** object to access its **updateTexture** and **changeColor** methods.

```
1 // ControlPanel.java
2 // ControlPanel is a JPanel that contains Swing controls
3 // for manipulating a Java3DWorld.
4 package com.deitel.advjhtp1.java3d;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12 import javax.swing.border.*;
13 import javax.swing.event.*;
14
15 public class ControlPanel extends JPanel {
16
17     // JSliders control lighting color
18     private JSlider redSlider, greenSlider, blueSlider;
19
20     // JCheckbox turns on texture mapping
21     private JCheckBox textureCheckBox;
22
23     // graphics display environment
24     private Java3DWorld java3DWorld;
25
26     // ControlPanel constructor
27     public ControlPanel( Java3DWorld tempJ3DWorld )
28     {
29         java3DWorld = tempJ3DWorld;
30
31         // assemble instruction panel
32         JPanel instructionPanel = new JPanel();
33
34         TitledBorder titledBorder =
35             new TitledBorder( "Transformation Instructions" );
36
37         titledBorder.setTitleJustification( TitledBorder.CENTER );
38         instructionPanel.setBorder( titledBorder );
39
40         JLabel rotationInstructions =
41             new JLabel( "Rotation - Left Mouse Button",
42                         SwingConstants.CENTER );
43
44         JLabel translationInstructions =
45             new JLabel( "Translation - Right Mouse Button",
46                         SwingConstants.CENTER );
```

Fig. 4.21 **ControlPanel** provides Swing controls for **Java3DWorld** (part 1 of 4).

```
47     JLabel scalingInstructions =
48         new JLabel( "Scale - Alt + Left Mouse Button",
49             SwingConstants.CENTER );
50
51     // add instruction JLabels to JPanel
52     instructionPanel.add( rotationInstructions );
53     instructionPanel.add( translationInstructions );
54     instructionPanel.add( scalingInstructions );
55
56     // assemble texture mapping control panel
57     JPanel texturePanel = new JPanel();
58
59     TitledBorder textureBorder =
60         new TitledBorder( "Texture Controls" );
61
62     textureBorder.setTitleJustification( TitledBorder.CENTER );
63     texturePanel.setBorder( textureBorder );
64
65     textureCheckBox = new JCheckBox(
66         "Apply Texture Map to Image" );
67
68     texturePanel.add( textureCheckBox );
69
70     // create ItemListener for JCheckBox
71     textureCheckBox.addItemListener(
72         new ItemListener() {
73
74             // invoked when checkbox selected/deselected
75             public void itemStateChanged( ItemEvent event )
76             {
77                 if( event.getStateChange() == ItemEvent.SELECTED )
78                     Java3DWorld.updateTexture( true );
79                 else
80                     Java3DWorld.updateTexture( false );
81             }
82
83         } // end anonymous inner class
84     );
85
86
87     // create JPanel with instructionPanel and texturePanel
88     JPanel topPanel = new JPanel(
89         new GridLayout( 2, 1, 0, 20 ) );
90
91     topPanel.add( instructionPanel );
92     topPanel.add( texturePanel );
93
94     // assemble lighting color control panel
95     JPanel colorPanel = new JPanel(
96         new FlowLayout( FlowLayout.LEFT, 15, 15 ) );
97
98     TitledBorder colorBorder =
99         new TitledBorder( "Direct Lighting Color Controls" );
```

Fig. 4.21 **ControlPanel** provides Swing controls for **Java3DWorld** (part 2 of 4).

```
100
101     colorBorder.setTitleJustification( TitledBorder.CENTER );
102     colorPanel.setBorder( colorBorder );
103
104     JLabel redLabel = new JLabel( "R" );
105     JLabel greenLabel = new JLabel( "G" );
106     JLabel blueLabel = new JLabel( "B" );
107
108     // create JSlider for adjusting red light component
109     redSlider = new JSlider(
110         SwingConstants.HORIZONTAL, 0, 255, 25 );
111
112     redSlider.setMajorTickSpacing( 25 );
113     redSlider.setPaintTicks( true );
114
115     // create JSlider for adjusting green light component
116     greenSlider = new JSlider(
117         SwingConstants.HORIZONTAL, 0, 255, 25 );
118
119     greenSlider.setMajorTickSpacing( 25 );
120     greenSlider.setPaintTicks( true );
121
122     // create JSlider for adjusting blue light component
123     blueSlider = new JSlider(
124         SwingConstants.HORIZONTAL, 0, 255, 25 );
125
126     blueSlider.setMajorTickSpacing( 25 );
127     blueSlider.setPaintTicks( true );
128
129     // create ChangeListener for JSliders
130     ChangeListener slideListener = new ChangeListener() {
131
132         // invoked when slider has been accessed
133         public void stateChanged(ChangeEvent event)
134         {
135             Color color = new Color(
136                 redSlider.getValue(), greenSlider.getValue(),
137                 blueSlider.getValue() );
138
139             Java3DWorld.changeColor( color );
140         }
141
142     }; // end anonymous inner class
143
144     // add listener to sliders
145     redSlider.addChangeListener( slideListener );
146     greenSlider.addChangeListener( slideListener );
147     blueSlider.addChangeListener( slideListener );
148
149     // add lighting color control components to colorPanel
150     colorPanel.add( redLabel );
151     colorPanel.add( redSlider );
152     colorPanel.add( greenLabel );
```

Fig. 4.21 **ControlPanel** provides Swing controls for **Java3DWorld** (part 3 of 4).

```
153     colorPanel.add( greenSlider );
154     colorPanel.add( blueLabel );
155     colorPanel.add( blueSlider );
156
157     // set Java3DWorld object default RGB slider values
158     Java3DWorld.changeColor(
159         new Color( redSlider.getValue(),
160             greenSlider.getValue(), blueSlider.getValue() ) );
161
162     // set GridLayout
163     setLayout( new GridLayout( 2, 1, 0, 20 ) );
164
165     // add JPanels to ControlPanel
166     add( topPanel );
167     add( colorPanel );
168
169 } // end ControlPanel constructor method
170
171 // return preferred dimensions of container
172 public Dimension getPreferredSize()
173 {
174     return new Dimension( 250, 150 );
175 }
176
177 // return minimum size of container
178 public Dimension getMinimumSize()
179 {
180     return getPreferredSize();
181 }
182 }
```

Fig. 4.21 **ControlPanel** provides Swing controls for **Java3DWorld** (part 4 of 4).

There are three sets of controls for the **Java3DWorld**—transformation, texture mapping and lighting controls. The translations are controlled using **MouseTranslate**, **MouseRotate** and **MouseZoom**—no Swing components are needed to control the **Java3DWorld** transforms. Lines 32–55 create a **JPanel** that contains **JLabels** with instructions for applying transforms to the scene using the mouse.

Lines 58–69 create a **JPanel** with texture-mapping controls. The **JCheckBox** regulates the texture mapping in the application. Lines 72–85 attach an **ItemListener** to **textureCheckBox**. When the user selects this **JCheckBox**, line 79 calls method **updateTexture** of **Java3DWorld** to enable texture mapping. If the user deselects the **JCheckBox**, line 81 disables texture mapping.

Lines 104–127 create three **JSliders** that can assume an integer 0–255, inclusive. Lines 130–142 create a **ChangeListener** for the **JSliders**. When the user accesses a **JSlider**, line 139 calls method **changeColor** of **Java3DWorld** to change the shape's color in the 3D scene.

Class **Java3DExample** (Fig. 4.22) contains the **Java3DWorld** and **ControlPanel**. The **Java3DExample** constructor (lines 21–32) creates the **Java3DWorld** object by passing a **String** argument that specifies the image used for texture mapping (line 25). Line 26 creates **controlPanel**, passing the **Java3DWorld** as an argument. Method **main** (lines 35–41) executes the application.

```
1 // Java3DEExample.java
2 // Java3DEExample is an application that demonstrates Java 3D
3 // and provides an interface for a user to control the
4 // transformation, lighting color, and texture of a 3D scene.
5 package com.deitel.advjhtp1.java3d;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.swing.event.*;
14
15 public class Java3DEExample extends JFrame {
16
17     private Java3DWorld java3DWorld; // 3D scene panel
18     private JPanel controlPanel; // 3D scene control panel
19
20     // initialize Java3DWorld and ControlPanel
21     public Java3DEExample()
22     {
23         super( "Java 3D Graphics Demo" );
24
25         java3DWorld = new Java3DWorld( "images/ajhttp.png" );
26         controlPanel = new ControlPanel( java3DWorld );
27
28         // add Components to JFrame
29         getContentPane().add( java3DWorld, BorderLayout.CENTER );
30         getContentPane().add( controlPanel, BorderLayout.EAST );
31
32     } // end Java3DEExample constructor
33
34     // start program
35     public static void main( String args[] )
36     {
37         Java3DEExample application = new Java3DEExample();
38         application.setDefaultCloseOperation( EXIT_ON_CLOSE );
39         application.pack();
40         application.setVisible( true );
41     }
42 }
```

Fig. 4.22 GUI for `Java3DWorld` and `ControlPanel`.

## 4.5 A Java 3D Case Study: A 3D Game with Custom Behaviors

In Section 4.4.3, we demonstrated how the Java 3D `MouseBehavior` utility classes add interactive behavior to a 3D scene. The *utility behavior classes* provide a simple and convenient way to add interaction to our 3D applications. However, some applications—such as computer games—require custom behaviors (e.g., *collision detection*, *navigation* and *position checking*). In this section, we demonstrate how to implement custom behaviors using the `javax.media.j3d.Behavior` class. We demonstrate collision detection

among scene obstacles, navigation through a 3D scene and position checking of a user-navigated shape to determine when it has reached its target. We also introduce how to animate shapes using **Interpolators**. We examine how to use additional **Node** and **Group** subclasses, such as **Switches** and **Text3Ds**. The final product is a 3D game in which the user navigates a shape through a 3D scene full of “flying” obstacles. The goal of the game is to move this shape to a specific target point without having the shape collide with any of the moving obstacles.

Class **Java3DWorld1** (Fig. 4.23) creates the 3D game’s objects, behaviors and animation. Class **Java3DWorld1** extends class **Canvas3D** (line 22). Lines 25–54 declare constants for setting various parameters in our 3D scene. Line 56 declares the **Switch** that contains the flying shapes. Class **Switch** extends Java 3D class **Group**. A **Switch** object specifies which of its children to render. Line 57 declares the **BoundingSphere** for scheduling bounds for the scene graph. Line 59 declares the **SimpleUniverse** that contains the **Locale** and view branch graph for our application. Line 61 declares the **String** that describes the image file for texturing shapes.

The **Java3DWorld1** constructor (lines 64–85) accepts as an argument a **String** that represents the image file for texturing the target shape. Line 66 initializes the **Canvas3D** by invoking the superclass constructor with a **GraphicsConfiguration** argument. Method **getPreferredConfiguration** of class **SimpleUniverse** returns the system’s **java.awt.GraphicsConfiguration**, which specifies a graphics-output device. Line 71 creates a **SimpleUniverse** with the **Canvas3D** as the drawing surface. Class **SimpleUniverse** creates the Java 3D scene that encapsulates all the shapes in the virtual universe and viewing platform. Lines 74–77 configure the scene’s viewing distance to the default value (**PI/4.0**). Line 80 calls method **createScene** (lines 65–248) to create a **BranchGroup** that line 60 attaches to the **SimpleUniverse**.

Method **createScene** constructs the **BranchGroup** content. Line 93 creates the **Switch** object that contains the scenes in our 3D game by calling method **initializeSwitch** (lines 285–297). This method takes an **int** argument (**DEFAULT\_SCENE**) that specifies the default scene to display upon creation. Lines 288–294 set the **Switch** group’s capability bits to allow the **Switch** (and its children) to be read and written at run time. In this application, we implement collision detection—lines 293–294 set the capability bit that allows collision reporting. Upon collision—i.e., when two shapes intersect—the Java 3D engine compiles the scene-graph path to the object that triggered the collision. When method **initializeSwitch** returns the **Switch** to method **createScene**, line 96 calls method **initializeSwitch** again to create a **Switch** that contains various shapes in the scene. Line 100 creates a **BranchGroup** that aggregates the shapes in **Switch** (line 103). Line 106 attaches the **BranchGroup** to the **Switch** of scenes. Line 109 attaches the **Switch** of scenes to the root **sceneBranchGraph**. Lines 112–113 create the **BoundingSphere** for setting the bounds for the **sceneBranchGraph**.

The 3D game features a scene with several 3D obstacles that “fly” across the screen. These obstacles rotate and translate at random. Rotation and translation are types of transformations. We discussed in the previous section that a **TransformGroup** holds the information about a spatial transformation and applies transformations to its children. The rotation and translation transformations animate the 3D shapes in our scene. Each shape needs two **TransformGroups**—one for rotation information and one for translation information. Lines 116–121 call method **createTransformGroupArray** (lines 294–

322) to create **TransformGroup** arrays **spinTransform** and **pathTransform**, which store the rotational and translation information, respectively. Method **createTransformGroupArray** takes an **int** argument (**NUMBER\_OF\_SHAPES**) that specifies the array size. Line 305 initializes each **TransformGroup** in the array, and lines 308–317 set the capability bits of each **TransformGroup** to enable collision reporting and allow reading and writing during run time.

```
1 // Class Java3DWorld1 is a Java 3D game.
2 // The goal is to navigate the small red ball in the bottom right
3 // corner to the screen's top-left corner without colliding with
4 // any of the flying objects. The user can specify the number of
5 // flying objects to make the game more difficult.
6 package com.deitel.advjhtp1.java3dgame;
7
8 // Java core packages
9 import java.awt.*;
10 import java.net.*;
11 import java.util.BitSet;
12
13 // Java extension packages
14 import javax.media.j3d.*;
15 import javax.vecmath.*;
16
17 // Java3D utility packages
18 import com.sun.j3d.utils.geometry.*;
19 import com.sun.j3d.utils.image.*;
20 import com.sun.j3d.utils.universe.*;
21
22 public class Java3DWorld1 extends Canvas3D {
23
24     // container dimensions
25     private static final int CONTAINER_WIDTH = 600;
26     private static final int CONTAINER_HEIGHT = 600;
27
28     // constants that specify number of shapes
29     private static final int NUMBER_OF_SHAPES = 20;
30     private static final int NUMBER_OF_PRIMITIVES = 4;
31
32     // initial scene to display in Switch
33     private static final int DEFAULT_SCENE = 0;
34
35     // constants for animating rotation
36     private static final int MAX_ROTATION_SPEED = 25000;
37     private static final int MIN_ROTATION_SPEED = 20000;
38     private static final float MIN_ROTATION_ANGLE = 0.0f;
39     private static final float MAX_ROTATION_ANGLE =
40         ( float ) Math.PI * 8.0f;
41
42     // constants for animating translation
43     private static final int MAX_TRANSLATION_SPEED = 7500;
44     private static final int MIN_TRANSLATION_SPEED = 2500;
45
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 1 of 13).

```
46     // maximum time until animations begins
47     public static final int MAX_PHASE_DELAY = 20000;
48
49     // 3D shape information
50     private static final float MAX_RADIUS = 0.15f;
51     private static final float MAX_LENGTH = 0.2f;
52     private static final float MAX_SHININESS = 128.0f;
53     private static final float SPHERE_RADIUS = 0.15f;
54     private static final float BOUNDING_RADIUS = 100.0f;
55
56     private Switch shapeSwitch; // contains flying shapes
57     private BoundingSphere bounds; // bounds for nodes and groups
58
59     private SimpleUniverse simpleUniverse; // 3D environment
60
61     private String imageName; // texture image file name
62
63     // Java3DWorld1 constructor
64     public Java3DWorld1( String imageFileName ) {
65
66         super( SimpleUniverse.getPreferredConfiguration() );
67
68         imageName = imageFileName;
69
70         // create SimpleUniverse ( 3D Graphics environment )
71         simpleUniverse = new SimpleUniverse( this );
72
73         // set viewing distance for 3D scene
74         ViewingPlatform viewPlatform =
75             simpleUniverse.getViewingPlatform();
76
77         viewPlatform.setNominalViewingTransform();
78
79         // create 3D scene
80         BranchGroup branchGroup = createScene();
81
82         // attach BranchGroup to SimpleUniverse
83         simpleUniverse.addBranchGraph( branchGroup );
84
85     } // end Java3DWorld1 constructor
86
87     // create 3D scene
88     public BranchGroup createScene()
89     {
90         BranchGroup sceneBranchGroup = new BranchGroup();
91
92         // create scene Switch group
93         Switch sceneSwitch = initializeSwitch( DEFAULT_SCENE );
94
95         // create Switch group containing shapes
96         shapeSwitch = initializeSwitch( DEFAULT_SCENE );
97     }
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 2 of 13).

```
98     // initialize BranchGroup that contains only elements
99     // in game scene
100    BranchGroup gameBranchGroup = new BranchGroup();
101
102    // add shapeSwitch to gameBranchGroup
103    gameBranchGroup.addChild( shapeSwitch );
104
105    // add gameBranchGroup to sceneSwitch
106    sceneSwitch.addChild( gameBranchGroup );
107
108    // add sceneSwitch to sceneBranchGroup
109    sceneBranchGroup.addChild( sceneSwitch );
110
111    // create BoundingSphere for 3D objects and behaviors
112    bounds = new BoundingSphere(
113        new Point3d( 0.0f, 0.0f, 0.0f ), BOUNDING_RADIUS );
114
115    // create rotation TransformGroup array
116    TransformGroup[] spinTransform =
117        createTransformGroupArray( NUMBER_OF_SHAPES );
118
119    // create translation TransformGroup array
120    TransformGroup[] pathTransform =
121        createTransformGroupArray( NUMBER_OF_SHAPES );
122
123    // create RotationInterpolators
124    createRotationInterpolators( spinTransform,
125        NUMBER_OF_SHAPES );
126
127    // create PositonInterpolators
128    createPositionInterpolators( pathTransform,
129        NUMBER_OF_SHAPES );
130
131    // create Appearance objects for Primitives
132    Appearance[] shapeAppearance =
133        createAppearance( NUMBER_OF_SHAPES );
134
135    // create shapes
136    Primitive[] shapes =
137        createShapes( shapeAppearance, NUMBER_OF_SHAPES );
138
139    // add shapes to scene structure
140    for ( int x = 0; x < NUMBER_OF_SHAPES; x++ ) {
141
142        // add primitive to spinTransform group
143        spinTransform[ x ].addChild( shapes[ x ] );
144
145        // add spinTransform group to pathTransform group
146        pathTransform[ x ].addChild( spinTransform[ x ] );
147
148        // add pathTransform group to shapeSwitch group
149        shapeSwitch.addChild( pathTransform[ x ] );
150    }
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 3 of 13).

```
151
152     // create and set scene lighting
153     setLighting( sceneBranchGroup, bounds );
154
155     // create scene to display if user loses
156     TransformGroup loserTransformGroup =
157         createEndScene( "You Lose!" );
158
159     // add loser scene to sceneSwitch
160     sceneSwitch.addChild( loserTransformGroup );
161
162     // create scene to display if user wins
163     TransformGroup winnerTransformGroup =
164         createEndScene( "You Win!" );
165
166     // add winner scene to sceneSwitch
167     sceneSwitch.addChild( winnerTransformGroup );
168
169     // create shiny red Appearance for navigating shape
170     Appearance flyingAppearance = createAppearance(
171         new Color3f( 1.0f, 0.0f, 0.0f ) );
172
173     // initialize navigable sphere
174     Primitive flyingBall = new Sphere(
175         0.03f, Sphere.GENERATE_NORMALS, flyingAppearance );
176
177     // set capability bits to enable collision detection and
178     // allow for read/write of bounds
179     flyingBall.setCollidable( true );
180     flyingBall.setCapability( Node.ENABLE_COLLISION_REPORTING );
181     flyingBall.setCapability( Node.ALLOW_BOUNDS_READ );
182     flyingBall.setCapability( Node.ALLOW_BOUNDS_WRITE );
183
184     // create TransformGroup to translate shape position
185     TransformGroup startTransform = createTransform(
186         new Vector3f( 0.9f, -0.9f, 0.0f ) );
187
188     startTransform.addChild( flyingBall );
189     gameBranchGroup.addChild( startTransform );
190
191     // create Material for Appearance for target sphere
192     Appearance targetAppearance = createAppearance(
193         new Color3f( 0.0f, 1.0f, 0.0f ) );
194
195     // obtain textured image for target sphere
196     String rgb = new String( "RGB" );
197     TextureLoader textureLoader = new TextureLoader(
198         Java3DWorld1.class.getResource( imageName ), rgb, this );
199     textureLoader.getTexture().setEnable( true );
200     targetAppearance.setTexture( textureLoader.getTexture() );
201
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 4 of 13).

```
202     // initialize target sphere
203     Primitive targetSphere = new Sphere( SPHERE_RADIUS,
204         Sphere.GENERATE_TEXTURE_COORDS | Sphere.GENERATE_NORMALS,
205         targetAppearance );
206
207     // disable collision detection for sphere
208     targetSphere.setCollidable( false );
209
210     // create vector to target point
211     Vector3f target = new Vector3f( -1.0f, 1.0f, -1.0f );
212
213     // create TransformGroup that translates sphere position
214     TransformGroup targetTransform = createTransform( target );
215     targetTransform.addChild( targetSphere );
216     gameBranchGroup.addChild( targetTransform );
217
218     // create Navigator behavior
219     Navigator navigator = new Navigator( startTransform );
220     navigator.setSchedulingBounds( bounds );
221
222     // create Collide behavior
223     Collide collider = new Collide(
224         simpleUniverse, flyingBall, sceneSwitch );
225     collider.setSchedulingBounds( bounds );
226
227     // create GoalDetector behavior
228     GoalDetector goalDetector = new GoalDetector(
229         simpleUniverse, startTransform, sceneSwitch,
230         target, SPHERE_RADIUS );
231     goalDetector.setSchedulingBounds( bounds );
232
233     // add Behaviors to scene
234     sceneBranchGroup.addChild( goalDetector );
235     sceneBranchGroup.addChild( collider );
236     sceneBranchGroup.addChild( navigator );
237
238     // create Background for scene
239     Background background = new Background();
240     background.setColor( 0.4f, 0.4f, 1.0f );
241     background.setApplicationBounds( bounds );
242     sceneBranchGroup.addChild( background );
243
244     sceneBranchGroup.compile();
245
246     return sceneBranchGroup;
247
248 } // end method createScene
249
250 // create Appearance object for Primitive in scene
251 private Appearance createAppearance( Color3f diffuseColor )
252 {
253     Appearance appearance = new Appearance();
254     Material material = new Material();
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 5 of 13).

```
255     material.setShininess( MAX_SHININESS );
256     material.setDiffuseColor( diffuseColor );
257     material.setAmbientColor( 0.0f, 0.0f, 0.0f );
258     appearance.setMaterial( material );
259     return appearance;
260 }
261 } // end method createAppearance
262
263
264 // create TransformGroup for placing an object in scene
265 private TransformGroup createTransform(
266     Vector3f positionVector )
267 {
268     // initialize a TransformGroup and set capability bits
269     TransformGroup transformGroup = new TransformGroup();
270     transformGroup.setCapability(
271         TransformGroup.ALLOW_TRANSFORM_READ );
272     transformGroup.setCapability(
273         TransformGroup.ALLOW_TRANSFORM_WRITE );
274
275     // translate starting position to bottom right of scene
276     Transform3D location = new Transform3D();
277     location.setTranslation( positionVector );
278     transformGroup.setTransform( location );
279
280     return transformGroup;
281 }
282 } // end method createTransform
283
284 // initialize Switch group and set capability bits
285 private Switch initializeSwitch( int sceneNumber )
286 {
287     Switch switchGroup = new Switch( sceneNumber );
288     switchGroup.setCollidable( true );
289     switchGroup.setCapability( Switch.ALLOW_SWITCH_WRITE );
290     switchGroup.setCapability( Switch.ALLOW_SWITCH_READ );
291     switchGroup.setCapability( Group.ALLOW_CHILDREN_WRITE );
292     switchGroup.setCapability( Group.ALLOW_CHILDREN_READ );
293     switchGroup.setCapability(
294         Group.ENABLE_COLLISION_REPORTING );
295     return switchGroup;
296 }
297 } // end method initializeSwitch
298
299 private TransformGroup[] createTransformGroupArray(
300     int size )
301 {
302     TransformGroup[] transformGroup =
303         new TransformGroup[ size ];
304
305     // set TransformGroup's WRITE and READ permissions
306     // and enable collision reporting
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 6 of 13).

```
307     for ( int i = 0; i < size; i++ ) {
308
309         // create TransformGroups
310         transformGroup[ i ] = new TransformGroup();
311
312         // enable collision reporting
313         transformGroup[ i ].setCapability(
314             Group.ENABLE_COLLISION_REPORTING );
315
316         // enable WRITE permission
317         transformGroup[ i ].setCapability(
318             TransformGroup.ALLOW_TRANSFORM_WRITE );
319
320         // enable READ permission
321         transformGroup[ i ].setCapability(
322             TransformGroup.ALLOW_TRANSFORM_READ );
323     }
324
325     return transformGroup;
326
327 } // end method createTransformGroupArray
328
329 // create RotationInterpolators for scene
330 private void createRotationInterpolators(
331     TransformGroup[] transformGroup, int size )
332 {
333     // declare structures for creating RotationInterpolators
334     Alpha[] alphaSpin = new Alpha[ size ];
335
336     Transform3D[] spinAxis =
337         new Transform3D[ size ];
338
339     RotationInterpolator[] spinner =
340         new RotationInterpolator[ size ];
341
342     // create RotationInterpolator for each shape
343     for ( int x = 0; x < size; x++ ) {
344
345         // initialize Alpha
346         alphaSpin[ x ] = new Alpha();
347
348         // set increasing time for Alpha to random number
349         alphaSpin[ x ].setIncreasingAlphaDuration(
350             MIN_ROTATION_SPEED + ( ( int ) ( Math.random() *
351                 MAX_ROTATION_SPEED ) ) );
352
353         // initialize RotationInterpolator using appropriate
354         // Alpha and TransformGroup
355         spinner[ x ] = new RotationInterpolator(
356             alphaSpin[ x ], transformGroup[ x ] );
357
358         spinAxis[ x ] = new Transform3D();
359 }
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 7 of 13).

```
360         // set random X-axis rotation
361         spinAxis[ x ].rotX(
362             ( float ) ( Math.PI * ( Math.random() * 2 ) ) );
363         spinner[ x ].setAxisOfRotation( spinAxis[ x ] );
364
365         // set minimum and maximum rotation angles
366         spinner[ x ].setMinimumAngle( MIN_ROTATION_ANGLE );
367         spinner[ x ].setMaximumAngle( MAX_ROTATION_ANGLE );
368
369         spinner[ x ].setSchedulingBounds( bounds );
370
371         // add RotationInterpolator to appropriate TransformGroup
372         transformGroup[ x ].addChild( spinner[ x ] );
373     }
374
375 } // end method createRotationInterpolators
376
377 // create PositionInterpolators
378 private void createPositionInterpolators(
379     TransformGroup[] transformGroup, int size )
380 {
381     // create structures for PositionInterpolators
382     Alpha[] alphaPath = new Alpha[ size ];
383
384     PositionInterpolator[] mover =
385         new PositionInterpolator[ size ];
386
387     Transform3D[] pathAxis =
388         new Transform3D[ size ];
389
390     // create PositionInterpolator for each shape
391     for ( int x = 0; x < size; x++ ) {
392
393         // initialize Alpha
394         alphaPath[ x ] = new Alpha();
395
396         // set mode to increase and decrease interpolation
397         alphaPath[ x ].setMode(
398             Alpha.INCREASING_ENABLE | Alpha.DECREASING_ENABLE );
399
400         // set random phase delay
401         alphaPath[ x ].setPhaseDelayDuration(
402             ( ( int ) ( Math.random() * MAX_PHASE_DELAY ) ) );
403
404         // randomize translation speed
405         int speed = MIN_TRANSLATION_SPEED +
406             ( int ) ( Math.random() * MAX_TRANSLATION_SPEED );
407
408         // set increasing and decreasing durations
409         alphaPath[ x ].setIncreasingAlphaDuration( speed );
410         alphaPath[ x ].setDecreasingAlphaDuration( speed );
411 }
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 8 of 13).

```
412     // randomize translation axis
413     pathAxis[ x ] = new Transform3D();
414     pathAxis[ x ].rotX(
415         ( float ) ( Math.PI * ( Math.random() * 2 ) ) );
416     pathAxis[ x ].rotY(
417         ( float ) ( Math.PI * ( Math.random() * 2 ) ) );
418     pathAxis[ x ].rotZ(
419         ( float ) ( Math.PI * ( Math.random() * 2 ) ) );
420
421     // initialize PositionInterpolator
422     mover[ x ] = new PositionInterpolator( alphaPath[ x ],
423                                         transformGroup[ x ], pathAxis[ x ], 1.0f, -1.0f );
424
425     mover[ x ].setSchedulingBounds( bounds );
426
427     // add PostionInterpolator to appropriate TransformGroup
428     transformGroup[ x ].addChild( mover[ x ] );
429 }
430
431 } // end method createPositionInterpolators
432
433 // create appearance and material arrays for Primitives
434 private Appearance[] createAppearance( int size )
435 {
436     // create Appearance objects for each shape
437     Appearance[] appearance =
438         new Appearance[ size ];
439
440     Material[] material = new Material[ size ];
441
442     // set material and appearance properties for each shape
443     for( int i = 0; i < size; i++ ) {
444         appearance[ i ] = new Appearance();
445         material[ i ] = new Material();
446
447         // set material ambient color
448         material[ i ].setAmbientColor(
449             new Color3f( 0.0f, 0.0f, 0.0f ) );
450
451         // set material Diffuse color
452         material[ i ].setDiffuseColor( new Color3f(
453             ( float ) Math.random(), ( float ) Math.random(),
454             ( float ) Math.random() ) );
455
456         // set Material for appropriate Appearance object
457         appearance[ i ].setMaterial( material[ i ] );
458     }
459     return appearance;
460
461 } // end method createAppearance
462
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 9 of 13).

```
463 // create Primitives shapes
464 private Primitive[] createShapes( Appearance[] appearance,
465     int size )
466 {
467     Primitive[] shapes = new Primitive[ size ];
468
469     // random loop to get index
470     for ( int x = 0; x < size; x++ ) {
471
472         // generate random shape index
473         int index = ( int ) ( Math.random() * NUMBER_OF_PRIMITIVES );
474
475         // create shape based on random index
476         switch( index ) {
477
478             case 0: // create Box
479                 shapes[ x ] = new Box(
480                     ( ( float ) Math.random() * MAX_LENGTH ),
481                     ( ( float ) Math.random() * MAX_LENGTH ),
482                     ( ( float ) Math.random() * MAX_LENGTH ),
483                     Box.GENERATE_NORMALS, appearance[ x ] );
484             break;
485
486             case 1: // create Cone
487                 shapes[ x ] = new Cone(
488                     ( ( float ) Math.random() * MAX_RADIUS ),
489                     ( ( float ) Math.random() * MAX_LENGTH ),
490                     Cone.GENERATE_NORMALS, appearance[ x ] );
491             break;
492
493             case 2: // create Cylinder
494                 shapes[ x ] = new Cylinder(
495                     ( ( float ) Math.random() * MAX_RADIUS ),
496                     ( ( float ) Math.random() * MAX_LENGTH ),
497                     Cylinder.GENERATE_NORMALS, appearance[ x ] );
498             break;
499
500             case 3: // create Sphere
501                 shapes[ x ] = new Sphere(
502                     ( ( float ) Math.random() * MAX_RADIUS ),
503                     Sphere.GENERATE_NORMALS, appearance[ x ] );
504             break;
505
506         } // end switch statement
507
508         // set capability bits to enable collisions and to set
509         // read/write permissions of bounds
510         shapes[ x ].setCapability(
511             Node.ENABLE_COLLISION_REPORTING );
512         shapes[ x ].setCapability(
513             Node.ALLOW_BOUNDS_READ );
514         shapes[ x ].setCapability(
515             Node.ALLOW_BOUNDS_WRITE );
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 10 of 13).

```
516         shapes[ x ].setCollidable( true );
517     }
518
519     return shapes;
520 } // end method createShapes
521
522 // initialize ambient and directional lighting
523 private void setLighting( BranchGroup scene,
524     BoundingSphere bounds )
525 {
526     // initialize ambient lighting
527     AmbientLight ambientLight = new AmbientLight();
528     ambientLight.setInfluencingBounds( bounds );
529
530     // initialize directional lighting
531     DirectionalLight directionalLight = new DirectionalLight();
532     directionalLight.setColor(
533         new Color3f( 1.0f, 1.0f, 1.0f ) );
534     directionalLight.setInfluencingBounds( bounds );
535
536     // add lights to scene
537     scene.addChild( ambientLight );
538     scene.addChild( directionalLight );
539
540 } // end method setLighting
541
542 // update scene by rendering different shapes in shapeSwitch
543 public void switchScene( int numberChildren, int size )
544 {
545     // create a new BitSet of size NUMBER_OF_SHAPES
546     BitSet bitSet = new BitSet( size );
547
548     // set BitSet values
549     for ( int i = 0; i < numberChildren; i++ )
550         bitSet.set( i );
551
552     // instruct switchShape to render Mask of objects
553     shapeSwitch.setWhichChild( Switch.CHILD_MASK );
554     shapeSwitch.setChildMask( bitSet );
555
556 } // end method switchScene
557
558 // create end scene when user wins or loses
559 private TransformGroup createEndScene( String text )
560 {
561     TransformGroup transformGroup = new TransformGroup();
562     transformGroup.setCapability(
563         TransformGroup.ALLOW_TRANSFORM_WRITE );
564
565     // disable scene collision detection
566     transformGroup.setCollidable( false );
567 }
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 11 of 13).

```
569      // create Alpha object
570      Alpha alpha = new Alpha();
571      alpha.setIncreasingAlphaDuration( MAX_ROTATION_SPEED );
572
573      // create RotationInterpolator for scene
574      RotationInterpolator rotation =
575      new RotationInterpolator( alpha, transformGroup );
576
577      // set axis of rotation
578      Transform3D axis = new Transform3D();
579      axis.rotY( ( float ) ( Math.PI / 2.0 ) );
580      rotation.setAxisOfRotation( axis );
581
582      // set minimum and maximum rotation angles
583      rotation.setMinimumAngle( 0.0f );
584      rotation.setMaximumAngle( ( float ) ( Math.PI * 8.0 ) );
585
586      rotation.setSchedulingBounds( bounds );
587      transformGroup.addChild( rotation );
588
589      // create scene geometry
590      Appearance appearance = new Appearance();
591      Material material = new Material();
592      appearance.setMaterial( material );
593
594      // set diffuse color of material
595      material.setDiffuseColor(
596          new Color3f( 0.0f, 0.8f, 1.0f ) );
597
598      // create Font3D object
599      Font3D font3d = new Font3D(
600          new Font( "Helvetica", Font.ITALIC, 1 ),
601          new FontExtrusion() );
602
603
604      // create Text3D object from Font3D object
605      Text3D text3d = new Text3D( font3d, text,
606          new Point3f( -2.0f, 0.0f, 0.0f ) );
607
608      // create Shape3D object from Text3D object
609      Shape3D textShape = new Shape3D( text3d );
610
611      textShape.setAppearance( appearance );
612
613      // disable collision detection
614      textShape.setCollidable( false );
615
616      transformGroup.addChild( textShape );
617
618      return transformGroup;
619
620  } // end method createEndScene
621
```

Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 12 of 13).

```
622
623     // return preferred dimensions of Container
624     public Dimension getPreferredSize()
625     {
626         return new Dimension( CONTAINER_WIDTH, CONTAINER_HEIGHT );
627     }
628
629     // return minimum size of Container
630     public Dimension getMinimumSize()
631     {
632         return getPreferredSize();
633     }
634 }
```

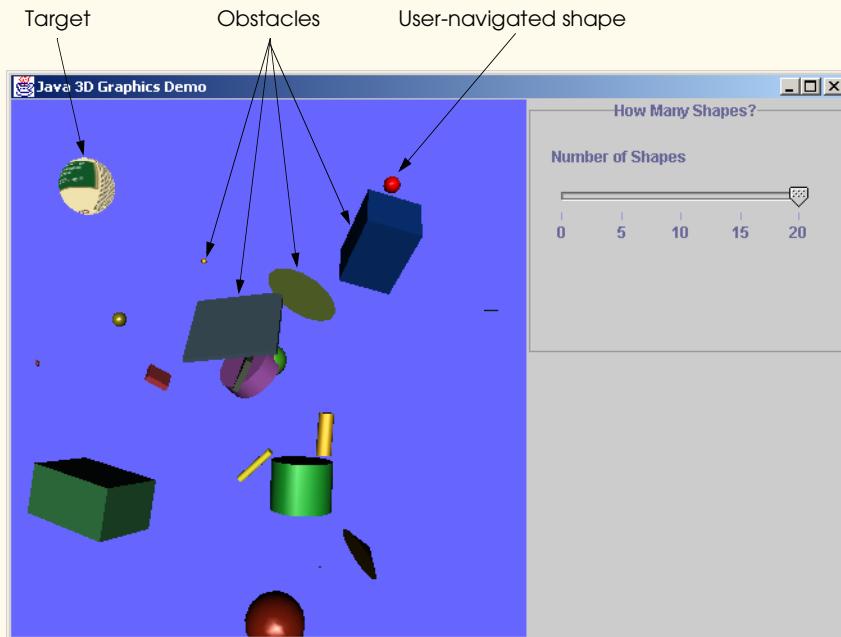


Fig. 4.23 Class **Java3DWorld1** creates the 3D-game environment (part 13 of 13).

When method **createTransformGroupArray** returns the array, method **createScene** creates the **Interpolators**, which help animate the transformations. Class **Interpolator** is a subclass of **Behavior**—later, we discuss how to implement custom behaviors. Now, we discuss how to use some well-known **Behavior** subclasses provided by Java 3D. To animate shapes smoothly in a scene, Java 3D provides **Interpolators** and **Alphas**. **Interpolators** use **Alphas** to specify certain characteristics of animation, such as the speed of transformations (e.g., rotation speed), or how fast a shape changes color (e.g., lighting effects). **Interpolator** objects convert time values to transformations of 3D shapes—**Alpha** objects generate these time values. For example, when a shape “flies” across the screen in one second, the **Interpolator** converts **Alpha**-generated time values (from 0 to 1) to translation operations that move the shape in the one-second period. An **Interpolator** operates in conjunction with a **Trans-**

**formGroup**—each **TransformGroup** has an associated **Interpolator**. The **Interpolator** describes how to animate shapes in the **TransformGroup**. Java 3D provides several **Interpolator** subclasses. In this game, we use **RotationInterpolator** for rotating objects and **PositionInterpolator** for translating objects.

Lines 124–125 pass the **spinTransform** array of **TransformGroups** to method **createRotationInterpolators** (lines 330–375), which initializes the **RotationInterpolators** for **spinTransform**. An **Alpha** object and a **Transform3D** object compose a **RotationInterpolator** object. **Alpha** objects contain a series of phases that either *increase* or *decrease*. Increasing **Alpha** objects generate values in a sequence from 0 to 1, whereas decreasing **Alpha** objects generate values in a sequence from 1 to 0. An **Alpha** object’s default constructor sets that **Alpha** to generate increasing values, which result in a shape spinning in one specific direction (decreasing values enable the shape to spin in the opposite direction). For each **Alpha** object, lines 349–351 call method **setIncreasingAlphaDuration**, which specifies the time (in milliseconds) for that **Alpha** object to increase from 0 to 1. A random-number generation sets the time value between **MIN\_ROTATION\_SPEED** and **MAX\_ROTATION\_SPEED**. Lines 355–356 create the **RotationInterpolator** array that use the **Alpha** array and the **spinTransform** array. The **Alpha** object controls the **Interpolator**, which in turn transforms the 3D shapes in the **TransformGroup**. The **RotationInterpolator** constructor creates a default **Transform3D** for the rotation. Class **Transform3D** is a two-dimensional array that represents a general transform—in this case, a rotation. Each **Transform3D** has an associated integer type that determines the transformation to represent. Lines 358–369 create the **Transform3D** for the **RotationInterpolator**. Lines 361–363 assign the **Transform3D** a random axis of rotation. Lines 366–367 assign the minimum and maximum rotation angles (i.e., the starting and stopping angles for a complete rotational period). Line 372 adds the **RotationInterpolators** to the **TransformGroup** **spinTransform**.

When method **createRotationInterpolators** returns, lines 128–129 pass **pathTransform** as an argument to method **createPositionInterpolators** (lines 378–431). This method creates a set of **PositionInterpolators** that translate the shapes in the scene—specifically, the method creates **PositionInterpolators** for each **TransformGroup** in **pathTransform**. **PositionInterpolators** operate similarly to **RotationInterpolators**, except **PositionInterpolators** translate a 3D shape’s position on a given axis, whereas **RotationInterpolators** rotate a 3D shape on a given axis. Line 382 creates the **Alpha** objects associated with the **PositionInterpolators**—these values provide the time values that help to determine the shapes’ position. Lines 397–398 set the **Alpha** object as increasing and decreasing to ensure that the 3D shapes move back and forth across the screen. If the **Alpha** object was only decreasing or increasing, the shapes would move in only one direction. We chose to delay the initial movement of each shape to ensure that the 3D obstacle will not collide with the user-navigated shape immediately after the player starts the game. Lines 401–402 accomplish this by setting a randomized *phase delay* on each **Alpha** object. To make the game more interesting, we chose to set the increasing and decreasing durations to random speeds. Lines 413–419 assign random translation axes to the **Transform3D** objects that hold translation information to give obstacles different directions. Lines 422–423 pass five arguments to the **PositionInterpolator** constructor. The first three

arguments are the array of **Alpha** values, the array of **TransformGroup** values (**pathTransform**) and the array of **Transform3D** values. The last two arguments specify the starting and ending positions in the 3D scene for the **PositionInterpolator** translation. Line 428 adds each **PositionInterpolator** to each **TransformGroup** in **pathTransform**.

At this point, **Java3DWorld1** has created the **TransformGroups** and **Interpolators** for each 3D shape. Now **Java3DWorld1** must create the actual shapes. Lines 132–133 invoke method **createAppearance** (lines 434–461), which creates an array of randomly colored **Appearance** objects. Line 440 creates an array of **Material** objects, because every **Appearance** object has an associated **Material** object. Lines 448–449 sets each **Material**'s *ambient color*—the **Material**'s color when illuminated by reflected light. Lines 452–454 randomly set each **Material**'s *diffuse color*—the **Material**'s color when illuminated by some light source. Line 457 sets each **Material** in the **Material** array to an associated **Appearance** in the **Appearance** array. Line 459 then returns the **Appearance** array.

Lines 136–137 pass the **Appearance** array to method **createShapes** (lines 464–522) to create an array of **Primitives** that represent the shapes of the obstacles. The Java 3D **com.sun.j3d.utils.geometry** package provides four types of 3D-geometric **Primitive** types: **Box**, **Cone**, **Cylinder** and **Sphere**. Line 473 randomly generates a number between 0 and 3—each number is associated with one of these **Primitive** object. Lines 476–506 implement a **switch** statement—each case creates a unique type. The constructor of each **Primitive** subclass specifies that **Primitive**'s dimensions, lighting and appearance. Consider the **Box** constructor—lines 479–483 pass the **Box**'s length, width and height, the **GENERATE\_NORMALS** constant (for the direction of the lighting), and an **Appearance** object. Lines 510–515 set the capability bits for each **Primitive** to enable collision reporting and read/write access during execution. Line 516 invokes method **setCollidable** of each **Primitive**'s **Node** superclass, so each **Primitive** can collide with other “collidable” **Primitives**. Line 520 returns the array of 3D shapes.

Lines 140–150 set up the **sceneBranchGraph**. Line 143 adds each 3D shape to each **TransformGroup** in **spinTransform**, line 146 adds each **TransformGroup** in **spinTransform** to each **TransformGroup** in **pathTransform**. Line 149 adds each **TransformGroup** in **pathTransform** to **shapeSwitch**. Line 153 calls method **setLighting** (lines 525–542) to create the **AmbientLight** and **DirectionalLight** that illuminate the shapes in the scene. Lines 156–157 call method **createEndScene** (lines 561–620) to create a **TransformGroup** associated with the player losing the game. Method **createEndScene** uses its **String** argument to create a rotating object of class **Text3D**—a **Geometry** subclass for representing 3D text. Lines 563–568 create the **TransformGroup** to hold the **Text3D**. Lines 571–587 create the **RotationInterpolator** for rotating the **Text3D**. Lines 591–594 create an **Appearance** object for the **Text3D**. Lines 600–602 create a **Font3D** object, which uses both a **java.awt.Font** object and a Java 3D **FontExtrusion** object. A **FontExtrusion** describes the adding of a third dimension to the **Font**'s 2D text. Using the **Font3D** object, the **String** argument that holds the text and a **Point3f** object—*x-y-z* coordinates that specify a location in a **SimpleUniverse**, lines 605–606 create the **Text3D** object. Line 609 creates a **Shape3D**—a **Node** that describes a 3D shape—from the **Text3D**. Line 611

sets the **Shape3D**'s **Appearance**. Line 614 specifies that the **Shape3D** objects in this scene should not collide with other **Shape3D** objects. Line 616 adds each **Shape3D** to the **TransformGroup**, and line 619 returns the **TransformGroup**. Line 160 adds this **TransformGroup** (for the losing scene) to the **Switch** group. When the user-navigated shape collides with an obstacle, the application displays a scene with the rotating 3D text “**You Lose.**” Lines 163–164 call method **createEndScene** to create the scene that displays “**You Win**” when the player navigates the shape to the destination without collision. Line 167 adds this scene (**TransformGroup**) to the **Switch**.

The two missing pieces in our game are the navigable shape and the target (destination) shape. Lines 170–189 create a shiny red **Sphere** as the shape that the user navigates to the target shape. Lines 192–193 call method **createAppearance** (lines 251–261) to set this shape's **Appearance**. This method takes as an argument a **Color3f** object and initializes an **Appearance** object based on a **Material** object that uses the **Color3f** object. Lines 174–175 instantiate the navigable shape as a **Sphere**. Lines 179–182 enable this **Sphere** to collide with the other **Primitives** in the scene. Lines 185–186 call method **createTransform** to create a **TransformGroup** to translate the **Sphere**'s starting position to the bottom-right corner of the scene. Lines 188–189 add the **Sphere** to this **TransformGroup**, then add the **TransformGroup** to the **gameBranchGroup**. Lines 192–216 create the game's target shape: a **Sphere** that contains an image texture. Lines 196–200 load an image in a **Texture** object, then create an **Appearance** object with this **Texture** object. Lines 203–205 instantiate the target **Sphere**, and line 208 ensures that the **Sphere** cannot collide with the other **Primitives** in the game. We discuss later how the user-navigated shape interacts with the target **Sphere** (i.e., how the user-navigated shape determines that it has reached its goal). Line 214 calls method **createTransform** to create a **TransformGroup** that places the target **Sphere** in the upper-right corner of the scene. Line 215 adds the **Sphere** to this **TransformGroup**, and line 216 adds the **TransformGroup** to the **gameBranchGroup**.

We designed the game so the user can control the game difficulty. Using a **JSlider** in class **ControlPanel**, the user can specify the number of obstacles in the game. Method **switchScene** (lines 545–558) accepts an **int** argument that represents the number of shapes to display. Lines 548–552 create a **BitMask** from the **int** argument, then lines 555–556 renders each shape associated with the **BitMask**.

The last step in creating **Java3DWorld1** involves implementing a set of custom behaviors—that is, collision detection, navigation and goal detection. Lines 219–231 create these three behaviors. Class **Collide** enables shapes to detect collision, class **Navigator** enables the user (using the keyboard) to navigate the shiny red **Sphere** through the scene and class **GoalDetector** helps determine when this **Sphere** has reached the target **Sphere**. We discuss each class in detail momentarily. We add these behaviors to the **sceneBranchGraph**. Line 244 compiles **sceneBranchGraph** to create the displayable 3D scene.

### Custom Behaviors

The previous section demonstrated **Interpolators**—a set of **Behavior** subclasses that specify certain animation characteristics. Developers often need more specialized behaviors for 3D applications (e.g., collision detection, navigation and position checking). The Java 3D API provides the abstract **Behavior** class to create these custom behaviors. A **Behavior** object has an associated *behavior scheduler* responsible for registering

*wake-up conditions*—criteria that determines when the behavior scheduler should trigger a behavior. The behavior scheduler is a Java 3D subsystem that shields developers from implementation details. The behavior scheduler registers the wake-up conditions and handles the logic for when these conditions are satisfied. All classes that extend **Behavior** must implement methods **initialize** and **processStimulus**. Method **initialize** registers a set of wake-up conditions with the behavior scheduler. Method **processStimulus** handles the logic when the wake-up conditions are satisfied. The developer must implement method **processStimulus**, although typically, **processStimulus** determines the wake-up conditions that caused the event, handle the event (e.g., modify the scene-graph, etc.) and then reregister the wake-up conditions with the behavior scheduler.

The application in this section demonstrates three types of custom behavior: *collision detection*, *navigation* and *position checking*. We begin with the collision-detection behavior.

Collision detection determines when a shape's bounding volume—the volume enclosing either a shape or the bounds of a shape—intersects another. Class **Collide** (Fig. 4.24), which extends superclass **Behavior**, implements collision-detection behavior for our Java 3D application. In Java 3D, shapes are either *armed nodes* or *triggering nodes*. A collision occurs when an armed node's bounding volume intersects a triggering node's bounding volume. Line 21 declares the armed node for collision detection. Line 24 declares the **WakeUpCondition** object for our **Behavior** class. A Java 3D **Behavior** object passes the **WakeUpCondition** to the behavior scheduler. When the **WakeUpCondition** is satisfied (i.e., upon collision), the behavior scheduler returns an enumeration of the **WakeUpCriterion** that triggered the behavior. Line 26 declares the **Switch** that contains scenes for the **SimpleUniverse** to display. Line 27 declares a reference to the Java 3D **SimpleUniverse** for displaying scenes in the **Switch**.

The **Collide** constructor (lines 33–52) takes a **SimpleUniverse**, a **Node** and a **Switch** as arguments. The reference to the **SimpleUniverse** adjusts the **ViewPlatform** when displaying different scenes in the **Switch**. The **Node** is the arming node for the collision-detection behavior. Lines 41–43 initialize **WakeUpOnCollisionEntry**—the specific **WakeUpCriterion** for our **Behavior** class. Class **WakeUpOnCollisionEntry** takes as arguments an arming **Node** and integer **USE\_GEOMETRY**, which specifies the **Node**'s geometric volume as the bounding surface for collision detection. Line 46 initializes the array of **WakeUpCriterion** for our behavior class. This array contains only one element—**WakeUpOnCollisionEntry**. Line 50 initializes the **WakeUpCondition** as a **WakeUpOr** that contains the **WakeUpCriterion**. The objects in **WakeUpOr** generate events when a **WakeUpCriterion** is satisfied (when a collision occurs). Method **initialize** (lines 55–59) registers the **WakeUpCondition** with the behavior scheduler by calling method **wakeUpOn** of superclass **Behavior**. Method **wakeUpOn** takes as an argument the **WakeUpCondition** object, which registers with the behavior scheduler.

Upon collision, the behavior scheduler calls method **processStimulus** (lines 62–81), passing as an argument an **Enumeration** of the **WakeUpCriteria**s that triggered the event. Lines 65–79 handle each **WakeUpCriterion** in the **Enumeration**. Line 72 handles only those **WakeUpCriteria**s that are **WakeUpOnCollisionEntry** events. Line 73 invokes method **processCollision** (lines 85–106) for those **WakeUpCriteria**s that satisfy this condition. Line 77 reregisters the **WakeUpCriterion** with the behavior scheduler.

Method **processCollision** handles the logic in response to the collision. In this application, a collision implies that the armed node (i.e., the user-navigated shape) has collided with an obstacle—the user then loses the game. Lines 87–100 set the translation component of the **ViewPlatform**'s **Transform3D**—the camera shifts back to expand the view. Line 104 switches to the scene associated with a collision—rotating 3D text that reads “**You Lose.**” Figure 4.24 demonstrates the 3D application display after the user-navigated shape collides with an obstacle.

```
1 // Class Collide implements collision-detection behavior
2 // for a Java 3D application. Collide switches scenes
3 // when the armed object collides with another object.
4 package com.deitel.advjhtp1.java3dgame;
5
6 // Core Java packages
7 import java.lang.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.media.j3d.*;
12 import javax.vecmath.*;
13
14 // Java 3D utility packages
15 import com.sun.j3d.utils.geometry.*;
16 import com.sun.j3d.utils.universe.*;
17
18 public class Collide extends Behavior {
19
20     // armed node generates WakeupOnCollisionEntry upon collision
21     private Node armingNode;
22
23     // specifies to what WakeupEvents to react
24     private WakeupCondition wakeupCondition;
25
26     private Switch switchScene; // Switch group contains 3D scenes
27     private SimpleUniverse simpleUniverse;
28
29     // index of scene to switch to upon collision
30     private static final int LOSER_SCENE = 1;
31
32     // constructor method initializes members
33     public Collide( SimpleUniverse universe, Node node,
34                     Switch tempSwitch )
35     {
36         armingNode = node;
37         switchScene = tempSwitch;
38         simpleUniverse = universe;
39
40         // create WakeupOnCollisionEntry
41         WakeupOnCollisionEntry wakeupEvent =
42             new WakeupOnCollisionEntry( armingNode,
43                                         WakeupOnCollisionEntry.USE_GEOMETRY );
```

Fig. 4.24 Implementing collision detection in a Java 3D application (part 1 of 3).

```
44      // set of WakeupEvents to which Behavior responds
45      WakeupCriterion[] wakeupCriteria = { wakeupEvent };
46
47      // Behavior responds when any WakeupEvent in
48      // WakeupCriterion occurs
49      wakeupCondition = new WakeupOr( wakeupCriteria );
50
51  } // end constructor
52
53
54  // initialize Behavior's wakeup conditions
55  public void initialize()
56  {
57      // register WakeupCriterion to respond to collision events
58      wakeupOn( wakeupCondition );
59  }
60
61  // handle WakeupEvents
62  public void processStimulus( Enumeration detected )
63  {
64      // loop to handle events
65      while( detected.hasMoreElements() ) {
66
66          // get next sequential element
67          WakeupCriterion criterion =
68              ( WakeupCriterion ) detected.nextElement();
69
70          // process event if WakeupOnCollisionEntry
71          if ( criterion instanceof WakeupOnCollisionEntry ) {
72              processCollision();
73
74                  // re-register WakeupCriterion to respond to new
75                  // WakeonOnCollisionEntry event
76                  wakeupOn( wakeupCondition );
77
78          }
79      }
80
81  } // end method processStimulus
82
83  // process collision by moving camera view back and
84  // switching scenes in Switch group
85  private void processCollision()
86  {
87      Transform3D shiftViewBack = new Transform3D();
88
89      // set Transform3D's Translation
90      shiftViewBack.setTranslation(
91          new Vector3f( 0.0f, 0.0f, 8.0f ) );
92
93      // set Transform3D that determines View
94      ViewingPlatform viewPlatform =
95          simpleUniverse.getViewingPlatform();
96
```

Fig. 4.24 Implementing collision detection in a Java 3D application (part 2 of 3).

```

97     TransformGroup platformTransform =
98         viewPlatform.getViewPlatformTransform();
99
100    platformTransform.setTransform( shiftViewBack );
101
102
103    // render scene in Switch group
104    switchScene.setWhichChild( LOSER_SCENE );
105
106 } // end method processCollision
107 }
```



**Fig. 4.24** Implementing collision detection in a Java 3D application (part 3 of 3).

We provide class **Navigator** (Fig. 4.25) so the user can navigate the shape in our 3D scene. Class **Navigator** responds to certain key presses by translating a **Node** in a 3D scene. **Navigator** moves the **Node** by updating that **Node**'s **TransformGroup**. Line 22 declares the **TransformGroup**. Lines 25–30 declare **float** constants that represent the amount by which **Navigator** translates the shape upon each keypress. Line 33 declares the **WakeupCondition** for activating the navigational behavior.

```

1 // Class Navigator is a subclass of Behavior that implements a
2 // keyboard translation navigator. Navigator responds to certain
3 // key presses by translating an object in a 3D scene.
4 package com.deitel.advjhtp1.java3dgame;
5
6 // Core Java packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.util.*;
```

**Fig. 4.25** Behavior that enables the user to navigate a 3D shape (part 1 of 4).

```
10 // Java extension packages
11 import javax.media.j3d.*;
12 import javax.vecmath.*;
13
14 // Java 3D utility packages
15 import com.sun.j3d.utils.universe.*;
16
17 public class Navigator extends Behavior {
18
19     // TransformGroup associated with object controlled
20     // by keyboard navigator
21     private TransformGroup objectTransform;
22
23     // translation amounts
24     private static final float LEFT = -0.02f;
25     private static final float RIGHT = 0.02f;
26     private static final float UP = 0.02f;
27     private static final float DOWN = -0.02f;
28     private static final float FORWARD = 0.02f;
29     private static final float BACKWARD = -0.02f;
30
31     // waking conditions for Behavior
32     private WakeupCondition wakeupCondition;
33
34     // constructor method
35     public Navigator( TransformGroup transform )
36     {
37         objectTransform = transform;
38
39         // initialize WakeupOnAWTEvent to respond to
40         // AWT KeyEvent.KEY_PRESSED events
41         WakeupOnAWTEvent wakeupEvent =
42             new WakeupOnAWTEvent( KeyEvent.KEY_PRESSED );
43
44         // set of WakeupEvents to which Behavior responds
45         WakeupCriterion[] wakeupCriteria = { wakeupEvent };
46
47         // Behavior responds when WakeupEvent in the
48         // WakeupCriterion occurs
49         wakeupCondition = new WakeupOr( wakeupCriteria );
50
51     } // end constructor
52
53     // initialize Behavior's wakeup conditions
54     public void initialize()
55     {
56         // register WakeupCriterion to generate WakeupEvents
57         // when AWT events occur
58         wakeupOn( wakeupCondition );
59     }
60 }
61
```

Fig. 4.25 Behavior that enables the user to navigate a 3D shape (part 2 of 4).

```
62 // handle WakeupEvents
63 public void processStimulus( Enumeration detected )
64 {
65     // loop to handle events
66     while ( detected.hasMoreElements() ) {
67
68         // get next WakeupCriterion
69         WakeupCriterion wakeupCriterion =
70             ( WakeupCriterion ) detected.nextElement();
71
72         // handle WakeupCriterion if WakeupOnAWTEvent
73         if ( wakeupCriterion instanceof WakeupOnAWTEvent ) {
74             WakeupOnAWTEvent awtEvent =
75                 (WakeupOnAWTEvent) wakeupCriterion;
76             AWTEvent[] events = awtEvent.getAWTEvent();
77
78             // invoke method moveObject with AWTEvent
79             moveShape( events );
80         }
81     }
82
83     // re-register wakeupCondition to respond to next key press
84     wakeupOn( wakeupCondition );
85
86 } // end method processStimulus
87
88 // handle AWT KeyEvents by translating an object in 3D scene
89 private void moveShape( AWTEvent[] awtEvents )
90 {
91     // handle all events in AWTEvent array
92     for ( int x = 0; x < awtEvents.length; x++ )
93     {
94         // handle if AWTEvent is KeyEvent
95         if ( awtEvents[ x ] instanceof KeyEvent ) {
96
97             // get cooresponding KeyEvent
98             KeyEvent keyEvent = ( KeyEvent ) awtEvents[ x ];
99
100            // respond only if KeyEvent is of type KEY_PRESSED
101            if ( keyEvent.getID() == KeyEvent.KEY_PRESSED ) {
102
103                // get KeyCode associated with KeyEvent
104                int keyCode = keyEvent.getKeyCode();
105
106                Transform3D transform3D = new Transform3D();
107
108                // get Transform3D from TransformGroup of
109                // navigable object
110                objectTransform.getTransform( transform3D );
111
112                Vector3f translateVector = new Vector3f();
113
```

**Fig. 4.25** Behavior that enables the user to navigate a 3D shape (part 3 of 4).

```
114         // retrieve translation vector associated with
115         // Transform3D
116         transform3D.get( translateVector );
117
118         // update x, y, or z component of translation
119         // vector based on keypress
120         switch ( keyCode ) {
121
122             case KeyEvent.VK_A: // move left
123                 translateVector.x += LEFT;
124                 break;
125
126             case KeyEvent.VK_D: // move right
127                 translateVector.x += RIGHT;
128                 break;
129
130             case KeyEvent.VK_W: // move up
131                 translateVector.y += UP;
132                 break;
133
134             case KeyEvent.VK_S: // move down
135                 translateVector.y += DOWN;
136                 break;
137
138             case KeyEvent.VK_UP: // move backwards
139                 translateVector.z += BACKWARD;
140                 break;
141
142             case KeyEvent.VK_DOWN: // move forwards
143                 translateVector.z += FORWARD;
144                 break;
145
146         } // end switch
147
148         // set translational component of Transform3D
149         // with updated translation Vector3f
150         transform3D.setTranslation( translateVector );
151
152         // set TransformGroup's Transform3D
153         objectTransform.setTransform( transform3D );
154
155     } // end if KeyEvent.KEY_PRESSED
156 }
157
158 } // end for loop that handles key presses
159
160 } // end method moveShape
161 }
```

Fig. 4.25 Behavior that enables the user to navigate a 3D shape (part 4 of 4).

The **Navigator** constructor (lines 36–52) accepts as an argument a **TransformGroup** that contains the navigable 3D shape. Lines 42–43 initialize a **WakeupOnAWTEvent** that triggers a **Behavior** upon an **AWTEvent** (such as a keypress). The

**WakeupOnAWTEvent** constructor takes as an argument the specific **AWTEvent** satisfies the wake-up conditions. In this case, **KeyEvent.KEY\_PRESSED** events activate **Behavior**. Line 46 creates the **WakeupCriterions** from the **WakeupOnAWTEvent**. Line 50 creates the **WakeupOr** that contains the **WakeupCriterions**.

Method **initialize** (lines 55–60) registers the **WakeupOr** with the behavior scheduler by passing the **WakeupOr** to method **wakeupOn** of superclass **Behavior**. Method **processStimulus** (lines 63–86) handles the logic for the triggered **Behavior** (i.e., a keypress). This method takes as an argument an **Enumeration** of the **WakeupCriterion** objects associated with the **Behavior**. Lines 69–70 retrieve each **WakeupCriterion** from the **Enumeration**. If the **WakeupCriterion** is a **WakeupOnAWTEvent**, line 76 invokes method **getAWTEvent** of class **WakeupOnAWTEvent**, which returns the array of **AWTEvents** that triggered the **Behavior**. Line 79 passes this array to method **moveShape** (lines 89–160), which translates the user-navigated shape, depending on which key the user pressed. Lines 95–101 test if each **AWTEvent** in the array is associated with a key press—line 104 determines the specific key pressed. Lines 106–116 declare a **Transform3D** and a **Vector3f** for updating the 3D shape's position. The **Vector3f** holds the coordinates that represent the *translational component* of the 3D shape's **Transform3D**. The translational component of a 3D shape specifies the shape's position on the *x*, *y* and *z*-axis. Lines 120–146 use a **switch** statement to update the 3D shape's position according to the key the user pressed. Figure 4.26 lists the keys and corresponding translations that are valid for **Navigator**. The **Vector3f**'s *x*-component corresponds to the left and right position (*X*-axis) of a shape. The **Vector3f**'s *y*-component corresponds to the up and down position (*Y*-axis) of a shape. The **Vector3f**'s *z*-component corresponds to the back and forward position (*Z*-axis) of a shape. The **switch** statement modifies the appropriate component of the **Vector3f**. Lines 150–153 call method **setTranslation** of class **Transform3D** and method **setTransform** of class **TransformGroup** to make the translation. The Java 3D engine then updates the 3D scene with the modified **TransformGroup** information.

We have implemented **Behavior** for detecting **Node** collision (which causes the user to lose the game) and the **Behavior** for enabling the user to navigate the scene. We now implement class **GoalDetector** (Fig. 4.27)—the **Behavior** for checking the position of a 3D shape (which allows the user to win the game). Line 25 declares the **TransformGroup** for the 3D-shape's position to check. Line 27 declares a **Switch** of scenes to display in the **SimpleUniverse**. The **SimpleUniverse** reference (line 28) adjusts the **ViewPlatform** when displaying different scenes in the **Switch**. We implement the target shape as a sphere with coordinates **goalX**, **goalY** and **goalZ** (line 30) and radius **sphereRadius** (line 33). The user wins the game when the user-navigated shape reaches the target sphere. Line 36 declares the **WakeupCondition** for the position-checking behavior.

Key	Translation
A	move left
D	move right

Fig. 4.26 Keys for navigating the 3D scene in **Navigator** (part 1 of 2).

Key	Translation
W	move up
S	move down
Up Arrow	move forward
Down Arrow	move backward

Fig. 4.26 Keys for navigating the 3D scene in **Navigator** (part 2 of 2).

```
1 // Class GoalDetector defines a position-checking behavior that
2 // checks to see if the position of a Node is equal to the target
3 // position. If the positions are equal, the game is over and
4 // a Java 3D Switch displays a different scene.
5 package com.deitel.advjhtp1.java3dgame;
6
7 // Core Java packages
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.util.*;
11
12 // Java extension packages
13 import javax.media.j3d.*;
14 import javax.vecmath.*;
15
16 // Java 3D utility packages
17 import com.sun.j3d.utils.universe.*;
18
19 public class GoalDetector extends Behavior {
20
21     // index of scene to display if goal detected
22     private static final int WINNER_SCENE = 2;
23
24     // TransformGroup associated with object
25     private TransformGroup objectTransform;
26
27     private Switch switchScene; // Switch group that contains scenes
28     private SimpleUniverse simpleUniverse;
29
30     private float goalX, goalY, goalZ; // goal coordinates
31
32     // radius of sphere at goal coordinates
33     private float sphereRadius;
34
35     // Behavior's waking conditions
36     private WakeupCondition wakeupCondition;
37 }
```

Fig. 4.27 Implementing a position-checking **Behavior** (part 1 of 5).

```
38     // constructor method initializes members
39     // and creates WakeupCriterion
40     public GoalDetector( SimpleUniverse universe,
41         TransformGroup transform, Switch switchGroup,
42         Vector3f goalVector, float radius )
43     {
44         objectTransform = transform;
45         switchScene = switchGroup;
46         simpleUniverse = universe;
47
48         // set goal coordinates to goalVector coordinates
49         goalX = goalVector.x;
50         goalY = goalVector.y;
51         goalZ = goalVector.z;
52
53         // set radius of sphere at goal coordinates
54         sphereRadius = radius;
55
56         // initialize WakeupOnAWTEvent to respond to
57         // AWT KeyEvent.KEY_PRESSED events
58         WakeupOnAWTEvent wakeupEvent =
59             new WakeupOnAWTEvent( KeyEvent.KEY_PRESSED );
60
61         // set of WakeupEvents to which Behavior responds
62         WakeupCriterion[] wakeupArray = { wakeupEvent };
63
64         // Behavior responds when WakeupEvent in
65         // WakeupCriterion occurs
66         wakeupCondition = new WakeupOr( wakeupArray );
67
68     } // end constructor method
69
70     // register Behavior's wakeup conditions
71     public void initialize()
72     {
73         // register WakeupCriterion to respond to AWTEvents
74         wakeupOn( wakeupCondition );
75     }
76
77     // handle WakeupEvents
78     public void processStimulus( Enumeration detected )
79     {
80         // loop to handle events
81         while ( detected.hasMoreElements() ) {
82
83             // get next sequential WakeupCriterion
84             WakeupCriterion wakeupCriterion =
85                 ( WakeupCriterion ) detected.nextElement();
86
87             // handle if WakeupOnAWTEvent
88             if ( wakeupCriterion instanceof WakeupOnAWTEvent ) {
89
```

Fig. 4.27 Implementing a position-checking **Behavior** (part 2 of 5).

```
90         // ensure WakeupOnAWTEvent is KeyEvent.KEY_PRESSED
91         WakeupOnAWTEvent awtEvent =
92             ( WakeupOnAWTEvent ) wakeupCriterion;
93         AWTEvent[] event = awtEvent.getAWTEvent();
94
95         // check object position
96         checkPosition( event );
97
98         // re-register WakeupCriterion to respond to next
99         // key press
100        wakeupOn( wakeupCondition );
101    }
102  }
103
104 } // end method processStimulus
105
106 // check position of object in objectTransform TransformGroup
107 private void checkPosition( AWTEvent[] awtEvents )
108 {
109     Vector3f translate = new Vector3f();
110     Transform3D transform3d = new Transform3D();
111
112     // get Transform3D associated with objectTransform
113     objectTransform.getTransform( transform3d );
114
115     // get Transform3D's translation vector
116     transform3d.get( translate );
117
118     // handle all key presses in awtEvents
119     for ( int x = 0; x < awtEvents.length; x++ ) {
120
121         // handle if AWTEvent is KeyEvent
122         if ( awtEvents[ x ] instanceof KeyEvent ) {
123             KeyEvent keyEvent = (KeyEvent) awtEvents[ x ];
124
125             // handle if KeyEvent.KEY_PRESSED
126             if ( keyEvent.getID() == KeyEvent.KEY_PRESSED ) {
127
128                 // if object position == goal coordinates
129                 if ( atGoal( translate ) ) {
130                     Transform3D shiftBack = new Transform3D();
131
132                     // set translation to 8.0 on +z-axis
133                     shiftBack.setTranslation(
134                         new Vector3f( 0.0f, 0.0f, 8.0f ) );
135
136                     // set Transform3D that determines view
137                     // in SimpleUniverse
138                     ViewingPlatform viewPlatform =
139                         simpleUniverse.getViewingPlatform();
140
141                     TransformGroup platformTransform =
142                         viewPlatform.getViewPlatformTransform();
```

Fig. 4.27 Implementing a position-checking **Behavior** (part 3 of 5).

```
143         platformTransform.setTransform( shiftBack );
144
145         // render winner scene in SimpleUniverse
146         switchScene.setWhichChild( WINNER_SCENE );
147     }
148 }
149 }
150 }
151 } // end if KeyEvent
152
153 } // end for loop that handles key presses
154
155 } // end method checkPosition
156
157 // helper method returns true if current position is within
158 // goal boundary
159 private boolean atGoal( Vector3f currentPosition )
160 {
161     // calculate difference between current location and goal
162     float x = Math.abs( currentPosition.x - goalX );
163     float y = Math.abs( currentPosition.y - goalY );
164     float z = Math.abs( currentPosition.z - goalZ );
165
166     // return true if current position within sphereRadius of
167     // goal coordinates
168     return ( ( x < sphereRadius ) && ( y < sphereRadius ) &&
169             ( z < sphereRadius ) );
170 }
171 }
```

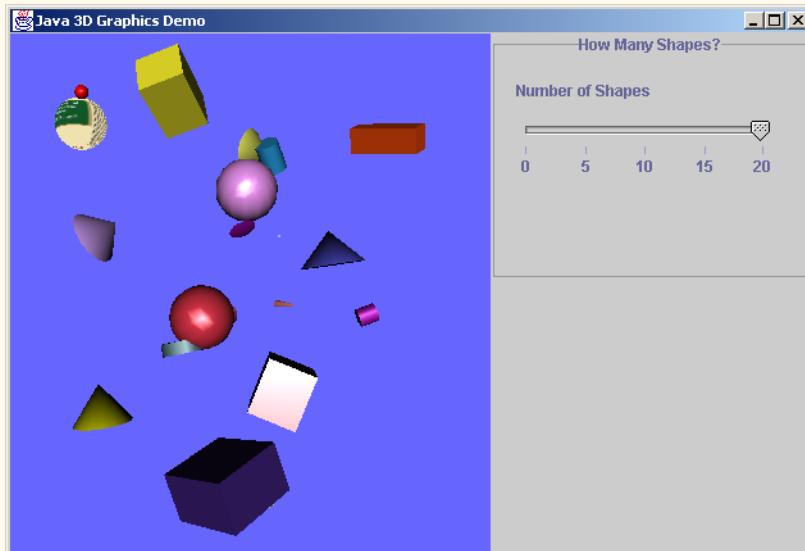


Fig. 4.27 Implementing a position-checking **Behavior** (part 4 of 5).



Fig. 4.27 Implementing a position-checking **Behavior** (part 5 of 5).

The constructor method (lines 40–68) takes five arguments. The first three arguments are the **SimpleUniverse**, **TransformGroup** and **Switch**. The fourth argument is a **Vector3f** that contains the target shape's location. Lines 49–51 set the target-point coordinates by extracting the *x*, *y* and *z* coordinates from the **Vector3f**. The final argument is the target-sphere radius. Lines 58–59 create a **WakeUpOnAWTEvent** that responds when the user presses a key. **GoalDetector** then checks the user-navigated shape's position to see if that shape has reached the target sphere. Line 62 creates a **WakeUpCriterion** from the **WakeUpOnAWTEvent**, and line 66 creates a **WakeupOr** from the **Wake-upCriterion**. Method **initialize** (lines 71–75) registers the **WakeupOr** with the behavior scheduler by calling method **wakeupOn** of superclass **Behavior**.

Method **processStimulus** (lines 78–104) handles the logic for the triggered **Behavior**. This method takes as an argument an **Enumeration** of the **WakeupCriteria**s that generated the behavioral event. Lines 84–85 retrieve each **WakeupCriterion** from the **Enumeration**. If the **WakeupCriterion** is a **Wake-upOnAWTEvent**, line 93 invokes method **getAWTEvent** of class **WakeupOnAWTEvent**, which returns the array of the **AWTEvents** that triggered the **Behavior**. Line 96 passes this array to method **checkPosition** (lines 107–155), which implements the position-checking algorithm.

Method **checkPosition** (lines 107–155) checks the position of the 3D shape. This method determines the 3D shape's position by checking the **Vector3f**, which represents that shape's translational component. Line 113 calls method **getTransform** of class **TransformGroup** to retrieve the **Transform3D** associated with the **TransformGroup**. Line 116 calls method **get** of class **Transform3D**, which retrieves the **Vector3f** that represents the translational component of the 3D shape. Lines 119–126 check if each **AWTEvent** in the array is a **KeyEvent.KEY\_PRESSED** event—line 129 then calls method **atGoal**, which returns a **boolean** variable that represents whether the

user-navigated shape has reached the target shape. Method **atGoal** (lines 159–170) takes as an argument the **Vector3f** that contains the coordinates of the user-navigated shape's current position. Lines 162–164 determine the absolute difference between the target shape's coordinates (**goalX**, **goalY** and **goalZ**) and the user-navigated shape's current coordinates. Lines 168–169 return **true** if the absolute difference for each coordinate is within the **sphereRadius**, indicating that the shape has reached the target sphere. If method **atGoal** returns **true**, the user has won the game. Lines 130–144 set the translation component of the **ViewPlatform**'s **Transform3D**; the camera shifts back to expand the view. Line 147 switches to the winning scene: rotating 3D text that reads “**You Win.**” Line 147 invokes method **setWhichChild** of class **Switch** passing as an argument the index of the winning scene. Figure 4.27 illustrates the game both immediately before and after the navigable object has reached the target shape.

### User Interface

Using the **ControlPanel1** (Fig. 4.21), the user can specify the number of flying obstacles to control the game difficulty. Line 23 declares the **JSlider** that the player uses to specify the number of obstacles. Line 24 declares a **Java3DWorld1** reference through which **ControlPanel1** can set the user-specified number. The **ControlPanel1** constructor (lines 27–75) accepts as an argument a **Java3DWorld1**—line 29 sets this argument as **ControlPanel1**'s **Java3DWorld1** reference. Lines 44–50 create a **JSlider** that assumes any integer value from 1 to 20, inclusive. Lines 53–62 create a **ChangeListener** for the **JSlider**. When the player uses this **JSlider**, method **stateChanged** (lines 56–60) passes the number of obstacles to method **switchScene** of **Java3DWorld1**. The display then reveals a new scene with the specified number of obstacles.

```
1 // ControlPanel1.java
2 // ControlPanel1 is a JPanel that contains Swing controls
3 // for manipulating a Java3DWorld1.
4 package com.deitel.advjhtp1.java3dgame;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12 import javax.swing.border.*;
13 import javax.swing.event.*;
14
15 public class ControlPanel1 extends JPanel {
16
17     private static final int CONTAINER_WIDTH = 250;
18     private static final int CONTAINER_HEIGHT = 150;
19
20     private static final int NUMBER_OF_SHAPES = 20;
21
22     // JSliders control lighting color
23     private JSlider numberSlider;
```

Fig. 4.28 Implementing Swing controls for the **Java3DWorld1** (part 1 of 3).

```
24     private Java3DWorld1 java3DWorld1;
25
26     // ControlPanel constructor
27     public ControlPanel1( Java3DWorld1 tempJ3DWorld )
28     {
29         java3DWorld1 = tempJ3DWorld;
30
31         // assemble lighting color control panel
32         JPanel colorPanel = new JPanel(
33             new FlowLayout( FlowLayout.LEFT, 15, 15 ) );
34
35         TitledBorder colorBorder =
36             new TitledBorder( "How Many Shapes?" );
37
38         colorBorder.setTitleJustification( TitledBorder.CENTER );
39         colorPanel.setBorder( colorBorder );
40
41         JLabel numberLabel = new JLabel( "Number of Shapes" );
42
43         // create JSlider for adjusting number of flying shapes
44         numberSlider = new JSlider(
45             SwingConstants.HORIZONTAL, 1, NUMBER_OF_SHAPES, 1 );
46
47         numberSlider.setMajorTickSpacing( 4 );
48         numberSlider.setPaintTicks( true );
49         numberSlider.setPaintTrack( true );
50         numberSlider.setPaintLabels( true );
51
52         // create ChangeListener for JSliders
53         ChangeListener slideListener = new ChangeListener() {
54
55             // invoked when slider has been accessed
56             public void stateChanged(ChangeEvent event )
57             {
58                 java3DWorld1.switchScene( numberSlider.getValue(),
59                     NUMBER_OF_SHAPES );
60             }
61
62         }; // end anonymous inner class
63
64         // add listener to sliders
65         numberSlider.addChangeListener( slideListener );
66
67         // add lighting color control components to colorPanel
68         colorPanel.add( numberLabel );
69         colorPanel.add( numberSlider );
70         add( colorPanel );
71
72         // set GridLayout
73         setLayout( new GridLayout( 2, 1, 0, 20 ) );
74
75     } // end ControlPanel1 constructor method
76 }
```

Fig. 4.28 Implementing Swing controls for the **Java3DWorld1** (part 2 of 3).

```
77     // return preferred dimensions of container
78     public Dimension getPreferredSize()
79     {
80         return new Dimension( CONTAINER_WIDTH, CONTAINER_HEIGHT );
81     }
82
83     // return minimum size of container
84     public Dimension getMinimumSize()
85     {
86         return getPreferredSize();
87     }
88 }
```

Fig. 4.28 Implementing Swing controls for the **Java3DWorld1** (part 3 of 3).

This concludes our discussion of the Java 3D API. In this section, we presented a brief overview of Java 3D graphics programming. We have explained how the performance, scalability and simplicity of Java 3D make it an excellent choice for developers to incorporate 3D graphics into applications. We presented two applications that demonstrated Java 3D geometry, textures, lighting and behaviors.

We have discussed several of Java’s graphics capabilities. We began with a brief introduction to fundamental graphics topics, including coordinate systems and graphics contexts. We then discussed several Java 2D capabilities, such as controlling how to fill shapes with colors and patterns. We also introduced how to blur, invert, sharpen and change the color of an image using Java 2D’s image-processing capabilities. The second half of our graphics discussion presented the Java 3D API. Using the Java 3D utility classes, we built an application that allows the user to change properties of a Java 3D scene, including manipulating (rotate, scale and translate) 3D objects with a mouse and changing a scene’s lighting. In Chapter 5, we use Java 2D in the Deitel drawing application. We also introduce design patterns—proven strategies for creating reusable and extensible software—and use them to build this program.

## SUMMARY

- A coordinate system is a scheme for identifying every point on the screen.
- The upper-left corner of a GUI component has the coordinates (0, 0).
- A graphics context enables drawing on the screen. A **Graphics** object manages a graphics context by controlling how information is drawn.
- **Graphics** objects contain methods for drawing, font manipulation, color manipulation, etc.
- Method **paint** is called in response to an event such as uncovering a window.
- Method **repaint** requests a call to method **update** of class **Component** as soon as possible to clear the **Component**’s background of any previous drawing. Method **update** then calls **paint** directly.
- The Swing painting mechanism calls method **paintComponent** of class **JComponent** when the contents of the **JComponent** should be painted.
- The Java 2D provides advanced two-dimensional graphics capabilities for processing line art, text and images.
- Class **java.awt.Graphics2D** enables drawing with the Java 2D API.

- To access the **Graphics2D** capabilities, we cast the **Graphics** reference passed to **paint** to a **Graphics2D** reference.
- There are seven **Graphics2D** attributes that determine how graphics primitives are rendered—clipping, compositing, font, paint, rendering hints, stroke and transforms.
- Method **setPaint** of class **Graphics2D** sets the **Paint** object that determines the color for the shape to display. A **Paint** object is an object of any class that implements interface **java.awt.Paint**. The **Paint** object can be a **Color** or an instance of the Java 2D API's **GradientPaint**, **SystemColor** or **TexturePaint** classes.
- Class **GradientPaint** paints a shape in gradually changing colors—known as a gradient.
- Method **fill** of class **Graphics2D** draws a filled **Shape** object. The **Shape** object is an instance of any class that implements interface **Shape**.
- A general path is a shape constructed from lines and complex curves represented with an object of class **GeneralPath** (package **java.awt.geom**).
- Method **moveTo** of class **GeneralPath** specifies the first point in a general path. Method **lineTo** of class **GeneralPath** draws a line to the next point in the general path. Each new call to **lineTo** draws a line from the previous point to the current point. Method **closePath** of class **GeneralPath** draws a line from the last point to the point specified in the last call to **moveTo**.
- Method **translate** of class **Graphics2D** moves the drawing to a new location. All drawing operations now use that location as (0, 0).
- Image processing is the manipulation of digital images by applying filters.
- There are three main types of image-processing filters. Compression filters reduce a digital image's memory usage. Measurement filters collect data from digital images. Enhancement filters appropriate and interpolate missing parts of corrupted images from the existing information.
- A **BufferedImage** separates image data into a **Raster** and a **ColorModel**. A **Raster** organizes and stores the numerical data that determine a pixel's color. The **ColorModel** is an interpreter that takes the sample values in the **Raster** and converts them to different colors depending on color scale the image.
- Java 2D image-processing filters operate on objects of class **BufferedImage**.
- Interfaces **BufferedImageOp** and **RasterOp** serve as the base classes for Java 2D image filters. A **BufferedImageOp** processes a **BufferedImage**, while a **RasterOp** only processes the **Raster** associated with a **BufferedImage**.
- Method **filter** takes as arguments a source image and a destination image. The source image is filtered to produce the destination image.
- A **LookupOp** is an array indexed by source pixel color values that contains destination pixel color values.
- A sharpening filter detects edges by looking for differences in neighboring pixel sample values and enhances the edge by enlarging the difference between the sample values and is created with a **ConvolveOp**.
- A **ConvolveOp** combines the colors of a source pixel and its surrounding neighbors to determine the color of the corresponding destination pixel.
- A **Kernel** is a 2D array that specifies how a **ConvolveOp** filter should combine neighboring pixel values.
- Edge hints instruct the filter on how to alter pixels at the perimeter of the image. **EDGE\_NO\_OP** instructs the filter to copy the pixels at the source perimeter directly to the destination image without modification. **EDGE\_ZERO\_FILL** instructs the filter to fill the pixels at the perimeter of the destination with the value 0.

- A blurring filter averages each pixel value with that of its eight neighboring pixels, smoothing distinct edges and is created using a **ConvolveOp**.
- Each color band in a **TYPE\_INT\_RGB BufferedImage** is defined by three coefficients that represent the R, G and B components in the band.
- We can change the colors in an image by altering the values of the R, G and B coefficients in a color band using a **BandCombineOp**. A **BandCombineOp** operates on the color bands of a **Raster**.
- The Java 3D API requires that you have either OpenGL or Direct3D installed on your computer. The Java 3D API also requires you to install the appropriate Java extension and utility packages found at [java.sun.com/products/java-media/3D/download.html](http://java.sun.com/products/java-media/3D/download.html).
- The root node of the Java 3D scene is a **VirtualUniverse** that has a coordinate-system, which describes the location of scene graphs.
- A scene graph is a tree-like structure that contains nodes, which describe all attributes of the 3D environment. Each scene graph attaches to the **VirtualUniverse** at a specified point in the **VirtualUniverse's** coordinate-system.
- Class **Locale** is the root node in a scene graph, which contains the attachment coordinate for the **VirtualUniverse** and a number of branch graphs.
- There are two types of branch graphs—content-branch graphs and view-branch graphs. View-branch graphs contain collections of objects that specify the perspective, position, orientation and scale of 3D scenes. Content-branch graphs describe the geometry, lighting, textures, fog, sound and behaviors in the 3D scenes.
- Class **SceneGraphObject** is the base class for all objects in a Java 3D branch graph. **SceneGraphObject** has two subclasses—**Node** and **NodeComponent**.
- Class **Group** serves as the general-purpose grouping **Node**.
- **Leaf** subclasses include **Behavior**, **Light** and **Shape3D**.
- **NodeComponent** objects describe the attributes of **Groups** and **Leafs**.
- **Canvas3D** is a **Canvas** subclass that supports 3D rendering.
- Class **SimpleUniverse** encapsulates all objects in the virtual universe and viewing platform.
- Class **BranchGroup** is the root node of a scene graph.
- Class **TransformGroup** specifies transformations including rotation, scaling and translation.
- To modify an object in a scene in run time, the developer must set that object's capability bits using method **setCapability**.
- All content **Leafs** in Java 3D are bounded by a volume that defines the space in which the **Leafs** are rendered.
- Class **Appearance** describes the attributes of the 3D geometry and has associated attribute objects, such as **Material** and **Texture**.
- Class **Material** defines the properties of any object that falls under illumination.
- Class **com.sun.j3d.utils.image.TextureLoader** loads an **Image** for texturing geometry.
- Class **AmbientLight** is a light source that illuminates all shapes evenly within its bounds.
- Class **DirectionalLight** is a light source that travels from a source point to a destination point.
- When a **Light** source is added to a **Group**, all objects in that **Group** are illuminated.
- The **MouseBehavior** classes in utility package **com.sun.j3d.utils.behavior.mouse** help developers integrate mouse interaction into applications.
- Classes **MouseRotate**, **MouseTranslate** and **MouseZoom** allow the user to use a mouse to rotate, translate and scale a 3D shape, respectively.

- Method **compile** of class **BranchGroup** causes the **BranchGroup** and all its children to be compiled.
- A **Switch** group specifies which of its children to render. A **Switch** can render either one child at a time or several children at once.
- **Interpolators** use **Alphas** to specify certain characteristics of animation, such as the speed of transformations (e.g., rotation speed), or how fast a shape changes color (e.g., lighting effects).
- **Interpolators** operates in conjunction with a **TransformGroup**: each **TransformGroup** has an associated **Interpolator**. The **Interpolator** describes how to animate shapes in the **TransformGroup**.
- An **Alpha** object generates the time values to the **Interpolator**. **Alpha** objects consist of a series of phases that can be either increasing or decreasing.
- Class **Transform3D** is a two-dimensional array that represents a general transform. Each **Transform3D** has an associated integer type that determines the transformation to represent.
- A **Material**'s ambient color is the **Material**'s color when illuminated by reflected light. A **Material**'s diffuse color is the **Material**'s color when illuminated by some light source.
- The Java 3D **com.sun.j3d.utils.geometry** package provides four types of 3D geometric **Primitive** objects: **Box**, **Cone**, **Cylinder** and **Sphere**.
- Class **Text3D** is a **Geometry** subclass for representing three-dimensional text.
- A **Font3D** object is constructed from a **java.awt.Font** object and a Java 3D **FontExtrusion** object. A **FontExtrusion** describes process of adding a third dimension to the **Font**'s 2D text.
- A **Point3f** specifies x-y-z coordinates in a 3D **SimpleUniverse**.
- The Java 3D API provides the abstract **Behavior** class to create a variety of custom behaviors.
- A **Behavior** object has an associated behavior scheduler responsible for registering wake-up conditions.
- All classes that extend **Behavior** must implement methods **initialize** and **processStimulus**.
- Collision detection determines when a shape's bounding volume—the volume enclosing either a shape or the bounds of a shape—intersects another.
- A collision occurs when an armed node's bounding volume intersects a triggering node's bounding volume.
- When a **WakeupCondition** is satisfied, the behavior scheduler calls method **processStimulus**, passing as an argument an **Enumeration** of the **WakeupCriterions** that triggered the event.

## TERMINOLOGY

<b>addChild</b> method	bounding volume
alpha values	<b>BoundingBox</b> class
<b>AmbientLight</b> class	<b>BoundingSphere</b> class
<b>Appearance</b> class	<b>Box</b> class
arc angle	branch graph
<b>Arc2D.Double</b> class	<b>BranchGroup</b> class
<b>BandCombineOp</b> class	<b>BufferedImage</b> class
<b>BasicStroke</b> class	<b>BufferedImageOp</b> interface
<b>Behavior</b> class	<b>ByteLookUpTable</b> class
bounding rectangle	<b>Canvas3D</b> class

capability bits  
clipping  
**closePath** method  
**Color3f** class  
**compile** method  
collision detection  
**Color** class  
color bands  
color scale  
**ColorModel** class  
compositing  
compression filters  
**ConvolveOp** class  
coordinate system  
**Component** class  
**DataBuffer** class  
Direct3D  
**DirectionalLight** class  
**draw** method  
**drawImage** method  
**drawRect** method  
**drawString** method  
edges  
**Ellipse2D.Double** class  
enhancement filter  
event-driven process  
**fill** method  
**fillRect** method  
**filter** method  
fog  
**Font** class  
**GeneralPath** class  
geometry  
**getColorModel** method  
**getPreferredConfiguration** method  
**getRaster** method  
**getViewingPlatform** method  
gradient  
**GradientPaint** class  
**Graphics** class  
graphics context  
graphics primitives  
**Graphics2D** class  
grayscale  
**Group** class  
image processing  
Java 2D API  
Java 3D API  
**JComponent** class  
**Kernel** class  
**Leaf** class  
**Light** class  
line joins  
**Line2D.Double** class  
**lineTo** method  
**Locale** class  
**LookupOp** class  
machine vision  
**Material** class  
measurement filters  
modeled  
morphing  
**MouseBehavior** class  
**MouseRotate** class  
**MouseZoom** class  
**MouseTranslate** class  
**moveTo** method  
**Node** class  
**NodeComponent** class  
OpenGL  
optimization  
**Paint** interface  
**paint** method  
**paintComponent** method  
pixel  
polygon  
**Raster** class  
**RasterFormatException** class  
rasterize  
**RasterOp** interface  
**Rectangle2D.Double** class  
render  
rendering engine  
rendering hints  
rendering pipeline  
**RenderingHints** class  
**repaint** method  
RGB value  
rotate  
**RoundRectangle2D.Double** class  
sample  
**SampleModel** class  
scene  
scene graph  
**SceneGraphObject** class  
**setColor** method  
**setCapability** method  
**setEnabled** method  
**setInfluencingBounds** method  
**setMaterial** method

<b>setNominalViewingTransform</b> method	<b>TextureLoader</b> class
<b>setPaint</b> method	<b>TexturePaint</b> class
<b>setStroke</b> method	<b>TransformGroup</b> class
<b>setTransformGroup</b> method	transforms
<b>Shape</b> interface	translate
<b>SimpleUniverse</b> class	<b>update</b> method
<b>Stroke</b> interface	viewing distance
<b>SystemColor</b> class	<b>ViewingPlatform</b> class
<b>Texture</b> class	<b>VirtualUniverse</b> class
texture mapping	<b>WriteableRaster</b> class

## SELF-REVIEW EXERCISES

- 4.1** Fill in the blanks in each of the following statements:
- In Java 2D, class \_\_\_\_\_ defines the fill for a shape such that the fill gradually changes from one color to another.
  - In Java 2D, an image-processing filter that operates on both a pixel and its neighboring pixels is implemented using class \_\_\_\_\_.
  - Class \_\_\_\_\_ stores pixel sample data in a **BufferedImage**, while class \_\_\_\_\_ contains instructions for translating the pixel sample to a color.
  - Rotation, scaling and translation are all examples of \_\_\_\_\_.
  - Method \_\_\_\_\_ of class **DirectionalLight** sets a flag that alerts the compiler that the **DirectionalLight**'s attributes should be writable during execution.
  - In Java 3D, class \_\_\_\_\_ contains **NodeComponents** that describe the attributes of a shape, including **Material** and **Texture**.
- 4.2** State whether each of the following is *true* or *false*. If *false*, explain why.
- The **LookupOp** constructor takes as arguments a **Kernel** and a **RenderingHints** object.
  - Method **closePath** of class **GeneralPath** to draw a line from the last point to the point specified in the first call to **moveTo**.
  - The source and destination **Raster** arguments to the **BandCombineOp** constructor can be the same **Rasters**.
  - In Java 3D, **Behaviors** do not affect objects outside the **Behavior**'s bounding volume.
  - Class **SimpleUniverse** creates a Java 3D scene that contains a **VirtualUniverse**, **Locale** and view branch graph.
  - All children in a **BranchGroup** will be affected behaviors defined in **TransformGroup** objects that are part of that **BranchGroup**.

## ANSWERS TO SELF-REVIEW EXERCISES

- 4.1** a) **GradientPaint**. b) **ConvolveOp**. c) **DataBuffer**, **ColorModel**. d) transformations. e) **setCapability**. f) **Appearance**.
- 4.2** a) False. The arguments to the **LookupOp** constructor are a **LookupTable** that contains the color sample lookup array and a **RenderingHints** object. b) False. Method **closePath** draws a line from the last point to the point specified in the *last* call to **moveTo**. c) True. d) True. e) True. f) False. Only those **Nodes** that are children of the **TransformGroup** will be affected by the **TransformGroup**'s behavior. Any **Nodes** outside the **TransformGroup** are not affected by the **TransformGroup**'s behavior.

## EXERCISES

- 4.3** Write a program that draws a pyramid. Use class **GeneralPath** and method **draw** of class **Graphics2D**.
- 4.4** Write a program that draws a series of eight concentric circles that are separated by 10 pixels using class **Ellipse2D.Double**. The outer seven circles should be filled with randomly generated solid colors. The innermost circle should be filled with a gradient. Use method **draw** of class **Graphics2D**.
- 4.5** Modify the image-processing program presented in this chapter to include an **Java2DImageFilter** that removes the green color band from a **BufferedImage**. Add this option to the menu created in Fig. 4.13.
- 4.6** Modify the program of Fig. 4.15 and Fig. 4.21 so that the set of **JSlider** controls affect the direction of the **DirectionalLight** source as opposed to the color. Use method **setDirection** of class **DirectionalLight**.
- 4.7** For the program of Fig. 4.23, create a **Behavior** that temporarily “shields” the user-navigated sphere from a collision with an obstacle. When the user presses the space-bar, the user-navigated sphere turns blue to indicate that it is “shielded”—the sphere is “invincible” and should not collide with any obstacles for three seconds (i.e., during this time, the sphere can pass through obstacles without the “**You Lose**” screen appearing). The user can use the “shield” feature three times per game—after that, pressing the space-bar has no effect. When the shield “wears off,” the user-navigated shape should turn red to indicate that it can collide with obstacles.

# 5

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# Case Study: Java 2D GUI Application with Design Patterns

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## Objectives

- To understand the model-view-controller architecture in a GUI application.
- To understand drag-and-drop techniques for transferring data in and among applications
- To understand the Factory Method design pattern for creating objects based on runtime criteria.
- To understand the integration of multiple Java technologies to build applications.
- To understand the use of multiple design patterns in a single application.
- To understand the implementation of multiple-document-interface applications.

*All my life I have struggled to make one authentic gesture.*

Isadora Duncan

*Whatever is in any way beautiful has its source of beauty in itself, and is complete in itself; praise forms no part of it.*

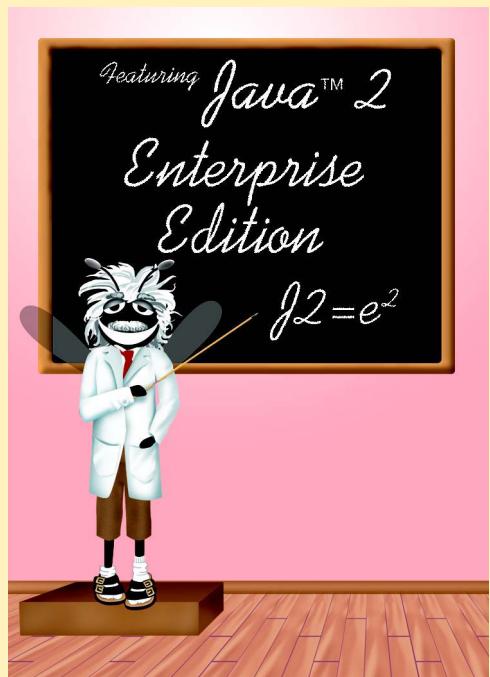
Marcus Aurelius Antoninus

*The source of genius is imagination alone, ...the refinement of the senses that sees what others do not see, or sees them differently.*

Eugene Delacroix

*That is a transformation in which imagination collaborates with memory.*

Edgar Degas



## Outline

- 5.1 Introduction**
- 5.2 Application Overview**
- 5.3 MyShape Class Hierarchy**
- 5.4 Deitel DrawingModel**
- 5.5 Deitel Drawing Views**
- 5.6 Deitel Drawing Controller Logic**
  - 5.6.1 MyShapeControllers for Processing User Input**
  - 5.6.2 MyShapeControllers and Factory Method Design Pattern**
  - 5.6.3 Drag-and-Drop Controller**
- 5.7 DrawingInternalFrame Component**
- 5.8 ZoomDialog, Action and Icon Components**
- 5.9 DeitelDrawing Application**

*Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

## 5.1 Introduction

In this chapter, we implement a Java application case study as a capstone for the many Java features and techniques presented in previous chapters, including Swing GUI components and Java 2D graphics. This case study is a substantial application with almost 4,000 lines of code, so we use several design patterns to facilitate proper object-oriented design and extensibility. These design patterns include some we introduced in previous chapters (e.g., the Command design pattern and the MVC architecture), and some that we introduce in this case study.

## 5.2 Application Overview

The Deitel Drawing application is a painting program that enables users to create drawings that contain lines, shapes, text and images. Deitel Drawing includes the following features:

1. Colors, filled shapes and gradients
2. Multiple-document interface
3. Drag-and-drop support for moving shapes between drawings
4. Drag-and-drop support for JPEG images
5. Saving drawings as XML documents
6. Scaling drawings to different sizes and aspect ratios
7. Multiple drawing tools (controllers)
8. Modifying shape properties such as line width, fill and gradient

Deitel Drawing uses the model-view-controller architecture to make the application modular and extensible. The model consists of a collection of objects that extend abstract

base class **MyShape**. Using polymorphism, views create graphical presentations of the **MyShape** collections. Multiple controllers handle input for drawing **MyShape** subclasses and for processing drag-and-drop operations.

Deitel Drawing uses the Java2D graphics APIs to create high-quality graphical presentations of drawing models. Lines, shapes and fonts are drawn using anti-aliasing to smooth jagged edges. Deitel Drawing takes advantage of Java 2D's **GradientPaint** class to draw shapes using multicolor gradients. Java 2D also provides transformation capabilities that enable the application to display scaled views of drawings. Using Java's event-handling mechanism, Deitel Drawing allows users to scale drawings dynamically by resizing a **ZoomDialog** window. The model-view-controller architecture ensures that each view is consistent with the drawing stored in the model. As a user draws new shapes, those shapes are immediately shown in each view.

Enabling drag-and-drop functionality in applications is nontrivial. The Deitel Drawing application uses Java's sophisticated drag-and-drop API to implement drag-and-drop functionality that allows users to move objects between drawings easily. Users also can drag and drop JPEG images from other applications (such as the host operating system's file manager) into drawings. Once the JPEG image is part of the drawing, the user can drag and drop the image between drawings just as with other shapes.

Figure 5.1 shows the Deitel Drawing application with a sample drawing. The shapes in this drawing were generated randomly by the solution to Exercise 5.8. Figure 5.2 shows the same drawing scaled to approximately twice the original size in a **ZoomDialog**.

### 5.3 MyShape Class Hierarchy

Deitel Drawing represents each shape in a drawing as a separate object that extends class **MyShape**. **MyShape** is an **abstract** base class that defines the basic interface for shapes and default implementations for methods common to all shapes.

Class **MyShape** (Fig. 5.3) is the root of the shape-class hierarchy. Implementing interface **Serializable** enables the Deitel Drawing application to serialize **MyShape** objects to disk, so drawings can be saved.

Lines 17–24 define several properties common to all **MyShapes**, such as the *x*- and *y*-coordinates and the **MyShape**'s colors. Some **MyShapes** can be **filled** (e.g., a filled square) or drawn with a gradient (lines 20–21). Line 22 declares property **strokeSize**, which specifies the thickness of the shape's lines. Methods **getLeftX** (lines 26–29) and **getLeftY** (lines 32–35) return the *x*- and *y*-coordinates of the **MyShape**'s left-most point. Methods **getRightX** (lines 38–41) and **getRightY** (lines 44–47) return the *x*- and *y*-coordinates of the **MyShape**'s right-most point. Methods **getWidth** (lines 50–53) and **getHeight** (lines 56–59) return the **MyShape**'s width and height as calculated from the shape's coordinates. Methods **setPoint1** (lines 62–66) and **setPoint2** (lines 69–73) modify the shape's *x*- and *y*-coordinates. Methods **setStartPoint** (lines 76–80) and **setEndPoint** (lines 83–87) set the points at which drawing began and drawing ended. The **MyShape** uses the start and end points to determine how to draw its gradient. Lines 90–136 provide *get* methods for each individual *x*- and *y*-coordinate. Method **moveByOffset** (lines 139–145) moves the **MyShape** by the given *x* and *y* offset values.

Lines 148–181 provide *set* and *get* methods for each of the **MyShape**'s colors. **MyShapes** can be drawn either in their primary color (**startColor**) or with a gradient that starts with **startColor** and ends with **endColor**. Lines 184–193 provide *set* and *get* methods for the **useGradient** property, which, if **true**, draws the shape using a color gradient.

Lines 196–206 provide *set* and *get* methods for property **strokeSize**. The Java2D API uses strokes to draw objects on a graphics context. The **strokeSize** property determines the thickness of the line that strokes the shape. Lines 209–218 provide *set* and *get* methods for property **filled**, which specifies whether the shape should be filled or drawn as an outline.

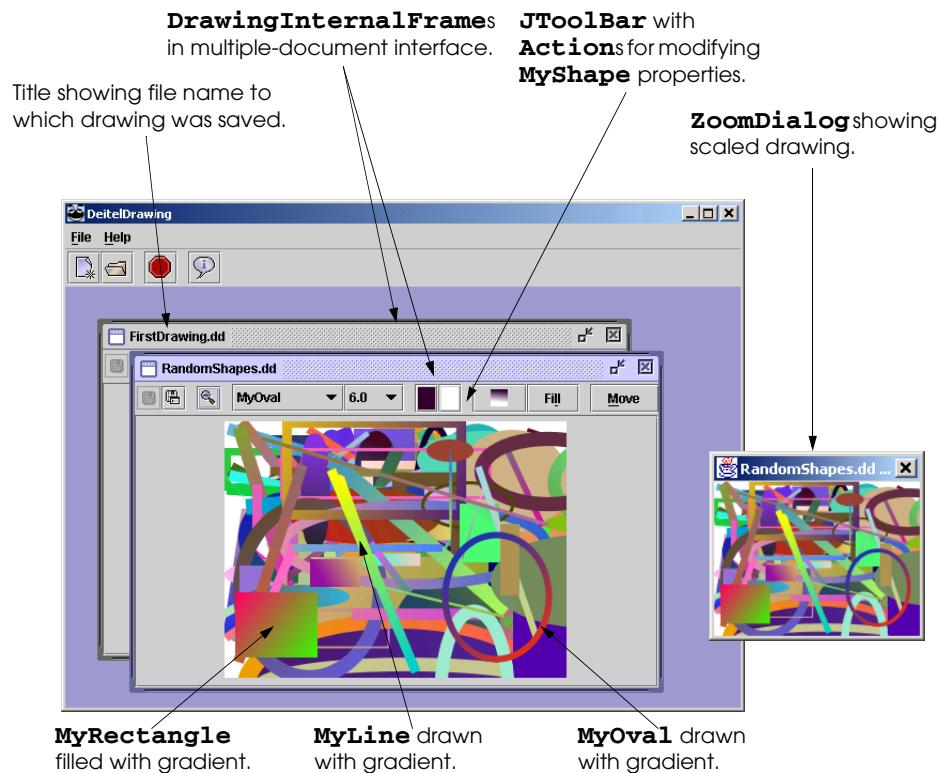
Line 222 declares **abstract** method **draw**, which takes as a **Graphics2D** argument the graphics context on which to draw the shape. Method **draw** is **abstract** because a generic **MyShape** object cannot be drawn; only specific subclasses of class **MyShape** (e.g., **MyOval**) can be drawn. Method **contains** (line 225) returns **true** if the given **Point2D** falls within the **MyShape**'s area. Method **contains** also is declared **abstract** to require each subclass to define an appropriate implementation. The drag-and-drop implementation in this example uses method **contains** when beginning a drag operation.

Method **configureGraphicsContext** (lines 228–247) configures the given **Graphics2D** object for drawing this **MyShape**. If there does not exist a **Stroke** for drawing the shape, line 233 creates a **BasicStroke** object using **MyShape**'s **strokeSize** property. Line 234 sets the **Graphics2D** object's **stroke** property. If the **gradient** property is **true**, lines 239–242 create a **GradientPaint** object that begins with **startColor** and ends with **endColor**. The gradient extends from the point (**startX**, **startY**) to the point (**endX**, **endY**). If the **gradient** property is **false**, line 246 invokes method **setPaint** of class **Graphics2D** to use the **MyShape**'s default **Color**.

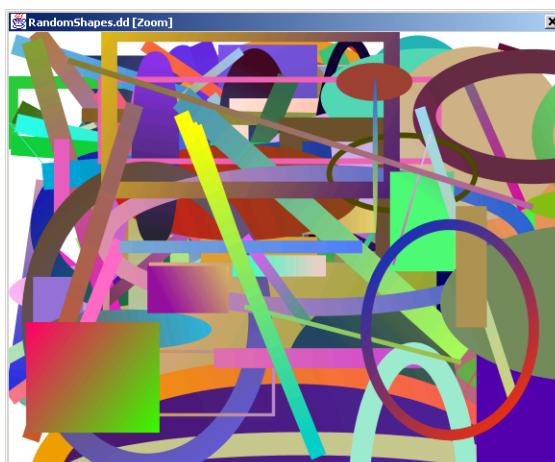
Method **getXML** (lines 250–337) produces an XML representation of a **MyShape** object. Method **getXML** uses the **Document** argument only to create **Elements**—method **getXML** does not modify this **Document**. Line 252 creates a **shape Element**. Lines 255–293 create **Elements** for the *x*- and *y*-coordinates and add them as children of **Element shape**. Lines 296–299 create a **useGradient Element**, and lines 302–321 create **Elements** for each **MyShape** color. Lines 324–327 create **Element strokeSize** and lines 330–333 create **Element fill**. Line 336 returns the newly created **shape Element** to the caller.

Class **MyLine** (Fig. 5.4) is a **MyShape** subclass that represents a line in the drawing. Lines 15–26 implement method **draw**, which was declared **abstract** in class **MyShape**. Line 18 invokes method **configureGraphicsContext** to configure the given **Graphics2D** object with the **MyLine** object's color, **strokeSize** and other properties. Lines 21–22 create a Java2D **Line2D.Float** object for the **MyLine** object's *x*- and *y*-coordinates. Class **Line2D.Float** represents a line using **floats** for its *x*- and *y*-coordinates. Line 25 invokes method **draw** of class **Graphics2D** to draw the line on the **Graphics2D** context.

Method **contains** (lines 29–32) calculates the line's slope to determine if the given **Point2D** is on the line. Method **getXML** (lines 49–55) invokes method **getXML** of class **MyShape** (line 37) to get the default **shape Element**. Line 38 sets **Attribute type** of **Element shape** to the value **MyLine** to indicate that this **MyShape** object is an instance of class **MyLine**.



**Fig. 5.1** Deitel Drawing application showing randomly drawn shapes (Exercise 5.8) and a **ZoomDrawingView** (Fig. 5.13).



**Fig. 5.2** Large-scale view of drawing from Fig. 5.1.

```
1 // MyShape.java
2 // MyShape is an abstract base class that represents a shape
3 // to be drawn in the DeitelDrawing application.
4 package com.deitel.advjhtp1.drawing.model.shapes;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.geom.Point2D;
9
10 // third-party packages
11 import org.w3c.dom.*;
12
13 public abstract class MyShape {
14
15     // MyShape properties (coordinates, colors, etc.)
16     private int x1, y1, x2, y2;
17     private int startX, startY, endX, endY;
18     private Color startColor = Color.black;
19     private Color endColor = Color.white;
20     private boolean filled = false;
21     private boolean gradient = false;
22     private float strokeSize = 1.0f;
23     private Stroke currentStroke;
24
25     // get x coordinate of left corner
26     public int getLeftX()
27     {
28         return x1;
29     }
30
31     // get y coordinate of left corner
32     public int getLeftY()
33     {
34         return y1;
35     }
36
37     // get x coordinate of right corner
38     public int getRightX()
39     {
40         return x2;
41     }
42
43     // get y coordinate of right corner
44     public int getRightY()
45     {
46         return y2;
47     }
48
49     // get MyShape width
50     public int getWidth()
51     {
52         return Math.abs( getX1() - getX2() );
53     }
```

Fig. 5.3 MyShape abstract base class for drawing objects (part 1 of 7).

```
54
55     // get MyShape height
56     public int getHeight()
57     {
58         return Math.abs( getY1() - getY2() );
59     }
60
61     // set Point1's x and y coordinates
62     public void setPoint1( int x, int y )
63     {
64         x1 = x;
65         y1 = y;
66     }
67
68     // set Point2's x and y coordinates
69     public final void setPoint2( int x, int y )
70     {
71         x2 = x;
72         y2 = y;
73     }
74
75     // set start Point's x and y coordinates
76     public final void setStartPoint( int x, int y )
77     {
78         startX = x;
79         startY = y;
80     }
81
82     // set end Point's x and y coordinates
83     public final void setEndPoint( int x, int y )
84     {
85         endX = x;
86         endY = y;
87     }
88
89     // get x1 coordinate
90     public final int getX1()
91     {
92         return x1;
93     }
94
95     // get x2 coordinate
96     public final int getX2()
97     {
98         return x2;
99     }
100
101    // get y1 coordinate
102    public final int getY1()
103    {
104        return y1;
105    }
106
```

Fig. 5.3 **MyShape abstract** base class for drawing objects (part 2 of 7).

```
107     // get y2 coordinate
108     public final int getY2()
109     {
110         return y2;
111     }
112
113
114     // get startX coordinate
115     public final int getStartX()
116     {
117         return startX;
118     }
119
120     // get startY coordinate
121     public final int getStartY()
122     {
123         return startY;
124     }
125
126     // get endX coordinate
127     public final int getEndX()
128     {
129         return endX;
130     }
131
132     // get endY coordinate
133     public final int getEndY()
134     {
135         return endY;
136     }
137
138     // move MyShape by given offset
139     public void moveByOffset( int x, int y )
140     {
141         setPoint1( getX1() + x, getY1() + y );
142         setPoint2( getX2() + x, getY2() + y );
143         setStartPoint( getStartX() + x, getStartY() + y );
144         setEndPoint( getEndX() + x, getEndY() + y );
145     }
146
147     // set default drawing color
148     public void setColor( Color color )
149     {
150         setStartColor( color );
151     }
152
153     // get default drawing color
154     public Color getColor()
155     {
156         return getStartColor();
157     }
158
159     // set primary drawing color
```

Fig. 5.3 **MyShape** abstract base class for drawing objects (part 3 of 7).

```
160     public void setStartColor( Color color )
161     {
162         startColor = color;
163     }
164
165     // get primary drawing color
166     public Color getStartColor()
167     {
168         return startColor;
169     }
170
171     // set secondary drawing color (for gradients)
172     public void setEndColor( Color color )
173     {
174         endColor = color;
175     }
176
177     // get secondary drawing color
178     public Color getEndColor()
179     {
180         return endColor;
181     }
182
183     // enable/disable gradient drawing
184     public void setUseGradient( boolean useGradient )
185     {
186         gradient = useGradient;
187     }
188
189     // get gradient enabled/disabled property
190     public boolean useGradient()
191     {
192         return gradient;
193     }
194
195     // set stroke size
196     public void setStrokeSize( float size )
197     {
198         strokeSize = size;
199         currentStroke = new BasicStroke( strokeSize );
200     }
201
202     // get stroke size
203     public float getStrokeSize()
204     {
205         return strokeSize;
206     }
207
208     // set filled property
209     public void setFilled ( boolean fill )
210     {
211         filled = fill;
212     }
```

Fig. 5.3 MyShape abstract base class for drawing objects (part 4 of 7).

```
213
214     // get filled property
215     public boolean isFilled()
216     {
217         return filled;
218     }
219
220     // abstract draw method to be implemented by subclasses
221     // to draw actual shapes
222     public abstract void draw( Graphics2D g2D );
223
224     // return true if the Point2D falls within this shape
225     public abstract boolean contains( Point2D point );
226
227     // configure Graphics2D context for known drawing properties
228     protected void configureGraphicsContext( Graphics2D g2D )
229     {
230         // set Stroke for drawing shape
231         if ( currentStroke == null )
232             currentStroke = new BasicStroke( getStrokeSize() );
233
234         g2D.setStroke( currentStroke );
235
236         // if gradient selected, create new GradientPaint starting
237         // at x1, y1 with color1 and ending at x2, y2 with color2
238         if ( useGradient() )
239             g2D.setPaint ( new GradientPaint(
240                 ( int ) getStartX(), ( int ) getStartY(),
241                 getStartColor(), ( int ) getEndX(), ( int ) getEndY(),
242                 getEndColor() ) );
243
244         // if no gradient selected, use primary color
245         else
246             g2D.setPaint( getColor() );
247     }
248
249     // get MyShape XML representation
250     public Element getXML( Document document )
251     {
252         Element shapeElement = document.createElement( "shape" );
253
254         // create Elements for x and y coordinates
255         Element temp = document.createElement( "x1" );
256         temp.appendChild( document.createTextNode(
257             String.valueOf( getX1() ) ) );
258         shapeElement.appendChild( temp );
259
260         temp = document.createElement( "y1" );
261         temp.appendChild( document.createTextNode(
262             String.valueOf( getY1() ) ) );
263         shapeElement.appendChild( temp );
264
265         temp = document.createElement( "x2" );
```

Fig. 5.3 **MyShape** abstract base class for drawing objects (part 5 of 7).

```
266     temp.appendChild( document.createTextNode(
267         String.valueOf( getX2() ) ) );
268     shapeElement.appendChild( temp );
269
270     temp = document.createElement( "y2" );
271     temp.appendChild( document.createTextNode(
272         String.valueOf( getY2() ) ) );
273     shapeElement.appendChild( temp );
274
275     temp = document.createElement( "startX" );
276     temp.appendChild( document.createTextNode(
277         String.valueOf( getStartX() ) ) );
278     shapeElement.appendChild( temp );
279
280     temp = document.createElement( "startY" );
281     temp.appendChild( document.createTextNode(
282         String.valueOf( getStartY() ) ) );
283     shapeElement.appendChild( temp );
284
285     temp = document.createElement( "endX" );
286     temp.appendChild( document.createTextNode(
287         String.valueOf( getEndX() ) ) );
288     shapeElement.appendChild( temp );
289
290     temp = document.createElement( "endY" );
291     temp.appendChild( document.createTextNode(
292         String.valueOf( getEndY() ) ) );
293     shapeElement.appendChild( temp );
294
295     // create Element for gradient property
296     temp = document.createElement( "useGradient" );
297     temp.appendChild( document.createTextNode(
298         String.valueOf( useGradient() ) ) );
299     shapeElement.appendChild( temp );
300
301     // create XML element for startColor
302     Color color = getStartColor();
303     temp = document.createElement( "startColor" );
304     temp.setAttribute( "red",
305         String.valueOf( color.getRed() ) );
306     temp.setAttribute( "green",
307         String.valueOf( color.getGreen() ) );
308     temp.setAttribute( "blue",
309         String.valueOf( color.getBlue() ) );
310     shapeElement.appendChild( temp );
311
312     // create XML element for endColor
313     color = getEndColor();
314     temp = document.createElement( "endColor" );
315     temp.setAttribute( "red",
316         String.valueOf( color.getRed() ) );
317     temp.setAttribute( "green",
318         String.valueOf( color.getGreen() ) );
```

Fig. 5.3 MyShape abstract base class for drawing objects (part 6 of 7).

```
319     temp.setAttribute( "blue",
320         String.valueOf( color.getBlue() ) );
321     shapeElement.appendChild( temp );
322
323     // add strokeSize element
324     temp = document.createElement( "strokeSize" );
325     temp.appendChild( document.createTextNode(
326         String.valueOf( getStrokeSize() ) ) );
327     shapeElement.appendChild( temp );
328
329     // add fill element
330     temp = document.createElement( "fill" );
331     temp.appendChild( document.createTextNode(
332         String.valueOf( isFilled() ) ) );
333     shapeElement.appendChild( temp );
334
335     return shapeElement;
336
337 } // end method getXML
338 }
```

Fig. 5.3 **MyShape** abstract base class for drawing objects (part 7 of 7).

```
1 // MyLine.java
2 // MyLine is a MyShape subclass that represents a line.
3 package com.deitel.advjhtp1.drawing.model.shapes;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.geom.*;
8
9 // third-party packages
10 import org.w3c.dom.*;
11
12 public class MyLine extends MyShape {
13
14     // draw MyLine object on given Graphics2D context
15     public void draw( Graphics2D g2D )
16     {
17         // configure Graphics2D (gradient, color, etc.)
18         configureGraphicsContext( g2D );
19
20         // create new Line2D.Float
21         Shape line = new Line2D.Float( getX1(), getY1(), getX2(),
22             getY2() );
23
24         // draw shape
25         g2D.draw( line );
26     }
27 }
```

Fig. 5.4 **MyLine** subclass of class **MyShape** that represents a line (part 1 of 2).

```
28     // determine if MyLine contains given Point2D
29     public boolean contains( Point2D point )
30     {
31         // get Point1 and Point2 coordinates
32         float x1 = getX1();
33         float x2 = getX2();
34         float y1 = getY1();
35         float y2 = getY2();
36
37         // determines slope of line
38         float slope = ( y2 - y1 ) / ( x2 - x1 );
39
40         // determines slope from point argument and Point1
41         float realSlope = ( float )
42             ( ( point.getY() - y1 ) / ( point.getX() - x1 ) );
43
44         // return true if slope and realSlope are close in value
45         return Math.abs( realSlope - slope ) < 0.1;
46     }
47
48     // get MyLine XML representation
49     public Element getXML( Document document )
50     {
51         Element shapeElement = super.getXML( document );
52         shapeElement.setAttribute( "type", "MyLine" );
53
54         return shapeElement;
55     }
56 }
```

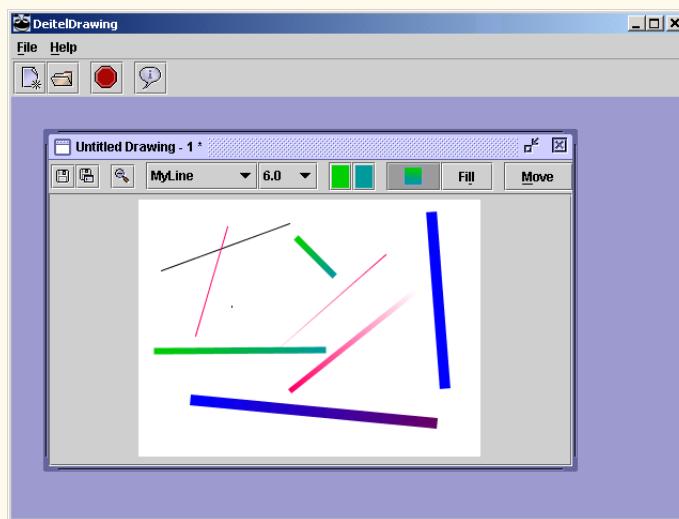


Fig. 5.4 **MyLine** subclass of class **MyShape** that represents a line (part 2 of 2).

Class **MyRectangle** (Fig. 5.5) is a **MyShape** subclass that represents a rectangle. Lines 17–31 implement method **draw**, which takes as a **Graphics2D** argument the

graphics context on which to draw the **MyRectangle**. Line 20 invokes method **configureGraphicsContext** to set the appropriate **strokeSize**, color and other drawing properties. Lines 23–24 create a new **Rectangle2D.Float** instance. The **Rectangle2D.Float** constructor takes as arguments the *x*- and *y*-coordinates of the rectangle's upper left hand corner and the rectangle's width and height. If **MyRectangle**'s **filled** property is set, line 28 draws a filled rectangle by invoking method **fill** of class **Graphics2D**. If **MyRectangle**'s **filled** property is false, line 30 invokes method **draw** of class **Graphics2D** to draw the rectangle's outline.

```
1 // MyRectangle.java
2 // MyRectangle is a MyShape subclass that represents a
3 // rectangle, including an implementation of the draw method
4 // for drawing the rectangle on a Graphics2D context.
5 package com.deitel.advjhtp1.drawing.model.shapes;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.geom.*;
10
11 // third-party packages
12 import org.w3c.dom.*;
13
14 public class MyRectangle extends MyShape {
15
16     // draw MyRectangle on given Graphics2D context
17     public void draw( Graphics2D g2D )
18     {
19         // configure Graphics2D (gradient, color, etc.)
20         configureGraphicsContext( g2D );
21
22         // create Rectangle2D for drawing MyRectangle
23         Shape shape = new Rectangle2D.Float( getLeftX(),
24             getLeftY(), getWidth(), getHeight() );
25
26         // if shape is filled, draw filled shape
27         if ( isFilled() )
28             g2D.fill( shape );
29         else
30             g2D.draw( shape );
31     }
32
33     // return true if point falls within MyRectangle
34     public boolean contains( Point2D point )
35     {
36         Rectangle2D.Float rectangle = new Rectangle2D.Float(
37             getLeftX(), getLeftY(), getWidth(), getHeight() );
38
39         return rectangle.contains( point );
40     }
41 }
```

Fig. 5.5 **MyRectangle** subclass of class **MyShape** that represents a rectangle (part 1 of 2).

```
42     // get XML representation of MyRectangle
43     public Element getXML( Document document )
44     {
45         Element shapeElement = super.getXML( document );
46         shapeElement.setAttribute( "type", "MyRectangle" );
47
48         return shapeElement;
49     }
50 }
```

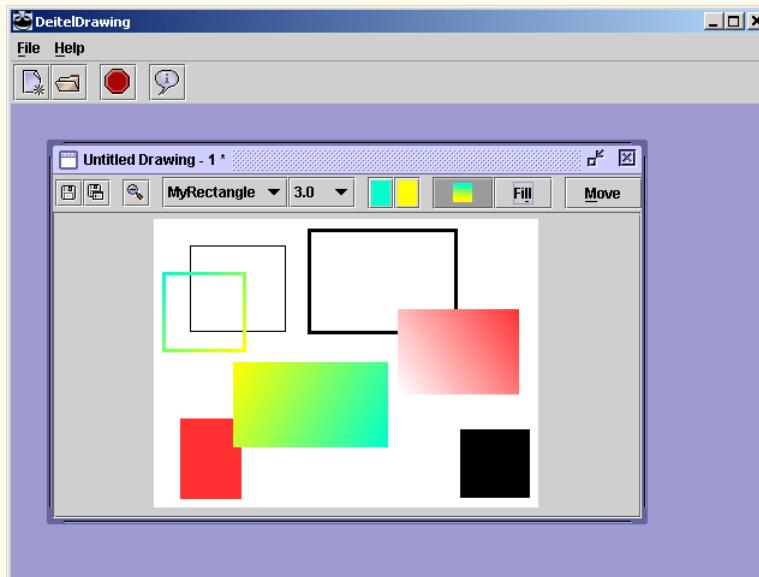


Fig. 5.5 **MyRectangle** subclass of class **MyShape** that represents a rectangle (part 2 of 2).

Method **contains** (lines 34–40) creates a **Rectangle2D.Float** object (line 36–37) and invokes method **contains** of class **Rectangle2D.Float** to determine whether the given **Point2D** falls within the **MyRectangle**. Method **getXML** (lines 43–49) creates an XML **Element** to represent the **MyRectangle** object. Line 45 invokes method **getXML** of class **MyShape** to get the default **shape Element**. Line 46 invokes method **setAttribute** of interface **Element** to add **Attribute type** with the value **MyRectangle** to **Element shape**.

Class **MyOval** (Fig. 5.6) is a **MyShape** subclass that represents an oval. Lines 15–29 implement method **draw** for drawing the **MyOval** object on the given **Graphics2D** context. Line 18 invokes method **configureGraphicsContext** to set the color, **strokeSize** and other properties for drawing the **MyOval**. Lines 21–22 create an **Ellipse2D.Float** instance for drawing the **MyOval**. The **Ellipse2D.Float** constructor takes as arguments the *x*- and *y*-coordinates and the width and height of the oval's bounding rectangle. If the **MyOval** is **filled**, line 26 invokes method **fill** of class **Graphics2D** to draw a filled oval. If the **MyOval** is not **filled**, line 28 invokes method **draw** of class **Graphics2D** to draw the oval's outline.

Method **contains** (lines 32–38) creates an **Ellipse2D.Float** object and invokes method **contains** of class **Ellipse2D.Float** to determine whether the given **Point2D** falls within the oval. Method **getXML** (lines 41–47) creates an XML **Element** to represent the **MyOval** object. Line 43 invokes method **getXML** of class **MyShape** to get the default **shape Element**. Line 44 invokes method **setAttribute** of interface **Element** to add **Attribute type** with value **MyOval** to **Element shape**.

Class **MyText** (Fig. 5.7) is a **MyShape** subclass that represents styled text in a drawing. A **MyText** object contains a **String** of text (line 18), in a particular font (line 20), of a particular size (line 21) that optionally may be bold, underlined and/or italic (lines 22–24). Method **draw** (lines 27–66) draws the **MyText** object using a **java.text.AttributedString**. An **AttributedString** contains text and attributes of that text, such as its font, size, bold, italic, etc. Line 30 invokes method **configureGraphicsContext** to initialize the **Graphics2D** object for drawing the **MyText** object. Line 33 creates an **AttributedString**, and lines 36–58 set that **AttributedString**'s attributes, including the font, size, bold, italic, etc. Line 65 invokes method **drawString** of class **Graphics2D** to draw the **AttributedString** on the graphics context. Method **contains** (lines 69–72) always returns **false**, which disallows dragging of **MyText** objects.

```
1 // MyOval.java
2 // MyOval is a MyShape subclass that represents an oval.
3 package com.deitel.advjhtp1.drawing.model.shapes;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.geom.*;
8
9 // third-party packages
10 import org.w3c.dom.*;
11
12 public class MyOval extends MyShape {
13
14     // draw MyOval on given Graphics2D context
15     public void draw( Graphics2D g2D )
16     {
17         // configure Graphics2D (gradient, color, etc.)
18         configureGraphicsContext( g2D );
19
20         // create Ellipse2D for drawing oval
21         Shape shape = new Ellipse2D.Float( getLeftX(),
22             getLeftY(), getWidth(), getHeight() );
23
24         // if shape is filled, draw filled shape
25         if ( isFilled() )
26             g2D.fill( shape );
27         else
28             g2D.draw( shape );
29     }
30 }
```

Fig. 5.6 **MyOval** subclass of class **MyShape** that represents an oval (part 1 of 2).

```
31     // return true if point falls inside MyOval
32     public boolean contains( Point2D point )
33     {
34         Ellipse2D.Float ellipse = new Ellipse2D.Float(
35             getLeftX(), getLeftY(), getWidth(), getHeight() );
36
37         return ellipse.contains( point );
38     }
39
40     // get MyOval XML representation
41     public Element getXML( Document document )
42     {
43         Element shapeElement = super.getXML( document );
44         shapeElement.setAttribute( "type", "MyOval" );
45
46         return shapeElement;
47     }
48 }
```

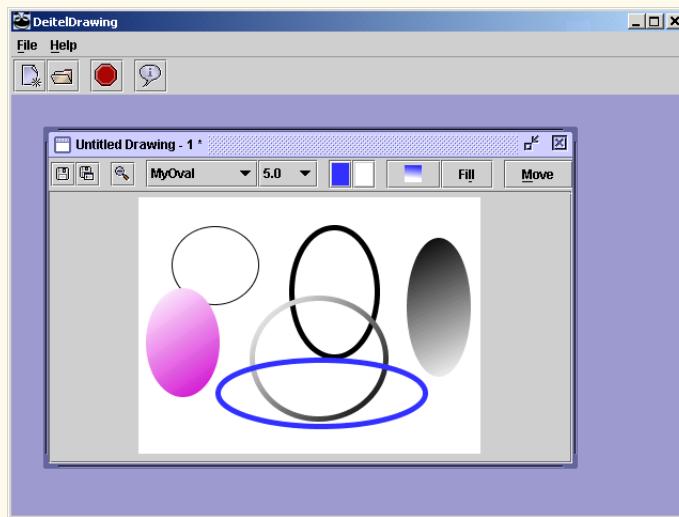


Fig. 5.6 **MyOval** subclass of class **MyShape** that represents an oval (part 2 of 2).

```
1  // MyText.java
2  // MyText is a MyShape subclass that represents styled text
3  // in a drawing.
4  package com.deitel.advjhtp1.drawing.model.shapes;
5
6  // Java core packages
7  import java.awt.*;
8  import java.text.*;
```

Fig. 5.7 **MyText** subclass of class **MyShape** that represents a string of text (part 1 of 5).

```
9 import java.awt.font.*;
10 import java.awt.geom.*;
11
12 // third-party packages
13 import org.w3c.dom.*;
14
15 public class MyText extends MyShape {
16
17     // MyText properties (font, font size, text, etc.)
18     private String text;
19     private AttributedString attributedString;
20     private String fontName = "Serif";
21     private int fontSize = 12;
22     private boolean underlined = false;
23     private boolean boldSelected = false;
24     private boolean italicSelected = false;
25
26     // draw MyText on given Graphics2D context
27     public void draw( Graphics2D g2D )
28     {
29         // configure Graphics2D (gradient, color, etc.)
30         configureGraphicsContext( g2D );
31
32         // create AttributedString for drawing text
33         attributedString = new AttributedString( text );
34
35         // set AttributedString Font
36         attributedString.addAttribute( TextAttribute.FAMILY,
37             fontName );
38
39         // set AttributedString Font size
40         attributedString.addAttribute( TextAttribute.SIZE,
41             new Float( fontSize ) );
42
43         // if selected, set bold, italic and underlined
44         if ( boldSelected )
45             attributedString.addAttribute( TextAttribute.WEIGHT,
46                 TextAttribute.WEIGHT_BOLD );
47
48         if ( italicSelected )
49             attributedString.addAttribute( TextAttribute.POSTURE,
50                 TextAttribute.POSTURE_OBLIQUE );
51
52         if ( underlined )
53             attributedString.addAttribute( TextAttribute.UNDERLINE,
54                 TextAttribute.UNDERLINE_ON );
55
56         // set AttributedString Color
57         attributedString.addAttribute( TextAttribute.FOREGROUND,
58             getColor() );
59
60         // create AttributedCharacterIterator for AttributedString
```

Fig. 5.7 MyText subclass of class MyShape that represents a string of text (part 2 of 5).

```
61     AttributedCharacterIterator characterIterator =
62         attributedString.getIterator();
63
64     // draw string using AttributedCharacterIterator
65     g2D.drawString( characterIterator, getX1(), getY1() );
66 }
67
68 // return false because MyText objects contain no area
69 public boolean contains( Point2D point )
70 {
71     return false;
72 }
73
74 // set MyText text
75 public void setText( String myText )
76 {
77     text = myText;
78 }
79
80 // get text contained in MyText
81 public String getText()
82 {
83     return text;
84 }
85
86 // set MyText Font size
87 public void setFontSize( int size )
88 {
89     fontSize = size;
90 }
91
92 // get MyText Font size
93 public int getFontSize()
94 {
95     return fontSize;
96 }
97
98 // set MyText Font name
99 public void setFontName( String name )
100 {
101     fontName = name;
102 }
103
104 // get MyText Font name
105 public String getFontName()
106 {
107     return fontName;
108 }
109
110 // set MyText underlined property
111 public void setUnderlineSelected( boolean textUnderlined )
112 {
```

Fig. 5.7 MyText subclass of class MyShape that represents a string of text (part 3 of 5).

```
113     underlined = textUnderlined;
114 }
115
116 // get MyText underlined property
117 public boolean isUnderlineSelected()
118 {
119     return underlined;
120 }
121
122 // set MyText bold property
123 public void setBoldSelected( boolean textBold )
124 {
125     boldSelected = textBold;
126 }
127
128 // get MyText bold property
129 public boolean isBoldSelected()
130 {
131     return boldSelected;
132 }
133
134 // set MyText italic property
135 public void setItalicSelected( boolean textItalic )
136 {
137     italicSelected = textItalic;
138 }
139
140 // get MyText italic property
141 public boolean isItalicSelected()
142 {
143     return italicSelected;
144 }
145
146 // get MyText XML representation
147 public Element getXML( Document document )
148 {
149     Element shapeElement = super.getXML( document );
150     shapeElement.setAttribute( "type", "MyText" );
151
152     // create text Element
153     Element temp = document.createElement( "text" );
154     temp.appendChild( document.createTextNode( getText() ) );
155     shapeElement.appendChild( temp );
156
157     // create fontSize Element
158     temp = document.createElement( "fontSize" );
159     temp.appendChild( document.createTextNode(
160         String.valueOf( fontSize ) ) );
161     shapeElement.appendChild( temp );
162
163     // create fontName Element
164     temp = document.createElement( "fontName" );
```

Fig. 5.7 **MyText** subclass of class **MyShape** that represents a string of text (part 4 of 5).

```
165     temp.appendChild( document.createTextNode(
166         String.valueOf( fontName ) ) );
167     shapeElement.appendChild( temp );
168
169     // create underlined Element
170     temp = document.createElement( "underlined" );
171     temp.appendChild( document.createTextNode(
172         String.valueOf( underlined ) ) );
173     shapeElement.appendChild( temp );
174
175     // create bold Element
176     temp = document.createElement( "bold" );
177     temp.appendChild( document.createTextNode(
178         String.valueOf( boldSelected ) ) );
179     shapeElement.appendChild( temp );
180
181     // create italic Element
182     temp = document.createElement( "italic" );
183     temp.appendChild( document.createTextNode(
184         String.valueOf( italicSelected ) ) );
185     shapeElement.appendChild( temp );
186
187     return shapeElement;
188
189 } // end method getXML
190 }
```

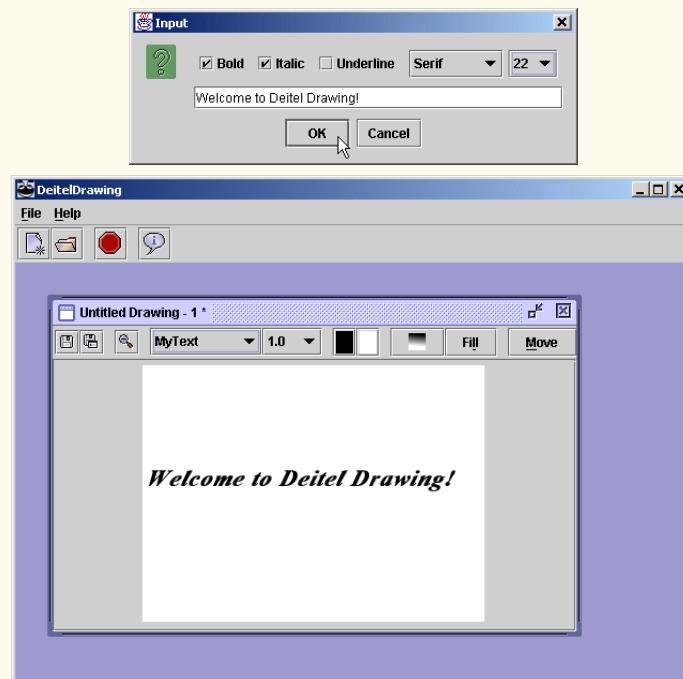


Fig. 5.7 **MyText** subclass of class **MyShape** that represents a string of text (part 5 of 5).

Lines 75–144 provide *set* and *get* methods for **MyText** properties, including its text, font, size, bold, italic and underline properties. Method **getXML** (lines 147–189) creates an XML representation of a **MyText** object. Lines 149–150 obtain the default **shapeElement** and set its **type** attribute to the value "**MyText**". Lines 153–185 create **Elements** that represent each **MyText**-specific property.

Class **MyImage** (Fig. 5.8) is a **MyShape** subclass that represents a JPEG image in a drawing. As we will see in Section 5.6.3, Deitel Drawing enables users to add JPEG images to a drawing using drag and drop. Line 17 declares **BufferedImage** member variable **image** for storing the **MyImage** object's image.

```
1 // MyImage.java
2 // MyImage is a MyShape subclass that contains a JPEG image.
3 package com.deitel.advjhtp1.drawing.model.shapes;
4
5 // Java core packages
6 import java.io.*;
7 import java.awt.*;
8 import java.awt.image.*;
9 import java.awt.geom.*;
10
11 // third-party packages
12 import org.w3c.dom.*;
13 import com.sun.image.codec.jpeg.*;
14
15 public class MyImage extends MyShape {
16
17     private BufferedImage image;
18     private String fileName;
19
20     // draw image on given Graphics2D context
21     public void draw( Graphics2D g2D )
22     {
23         // draw image on Graphics2D context
24         g2D.drawImage( getImage(), getX1(), getY1(), null );
25     }
26
27     // return true if Point falls within MyImage
28     public boolean contains( Point2D point )
29     {
30         Rectangle2D.Float rectangle = new Rectangle2D.Float(
31             getX1(), getY1(), getWidth(), getHeight() );
32
33         return rectangle.contains( point );
34     }
35
36     // get MyImage image
37     public BufferedImage getImage()
38     {
39         return image;
40     }
```

Fig. 5.8 **MyImage** subclass of class **MyShape** that represents a JPEG image in a drawing (part 1 of 3).

```
41 // set filename for loading image
42 public void setFileName( String name )
43 {
44     // load image from file
45     try {
46         File file = new File( name );
47
48         FileInputStream inputStream =
49             new FileInputStream( file );
50
51         // decode JPEG image
52         JPEGImageDecoder decoder =
53             JPEGCodec.createJPEGDecoder( inputStream );
54
55         image = decoder.decodeAsBufferedImage();
56
57         setPoint2( getX1() + image.getWidth(),
58                 getY1() + image.getHeight() );
59     }
60
61     // handle exception reading image from file
62     catch ( IOException ioException ) {
63         ioException.printStackTrace();
64     }
65
66     // set fileName if try is successful
67     fileName = name;
68 }
69
70
71 // get image filename
72 public String getFileName()
73 {
74     return fileName;
75 }
76
77 // get MyImage XML Element
78 public Element getXML( Document document )
79 {
80     Element shapeElement = super.getXML( document );
81     shapeElement.setAttribute( "type", "MyImage" );
82
83     // create filename Element
84     Element temp = document.createElement( "fileName" );
85     temp.appendChild( document.createTextNode(
86         getFileName() ) );
87     shapeElement.appendChild( temp );
88
89     return shapeElement;
90 }
91 } // end method getXML
92 }
```

Fig. 5.8 **MyImage** subclass of class **MyShape** that represents a JPEG image in a drawing (part 2 of 3).

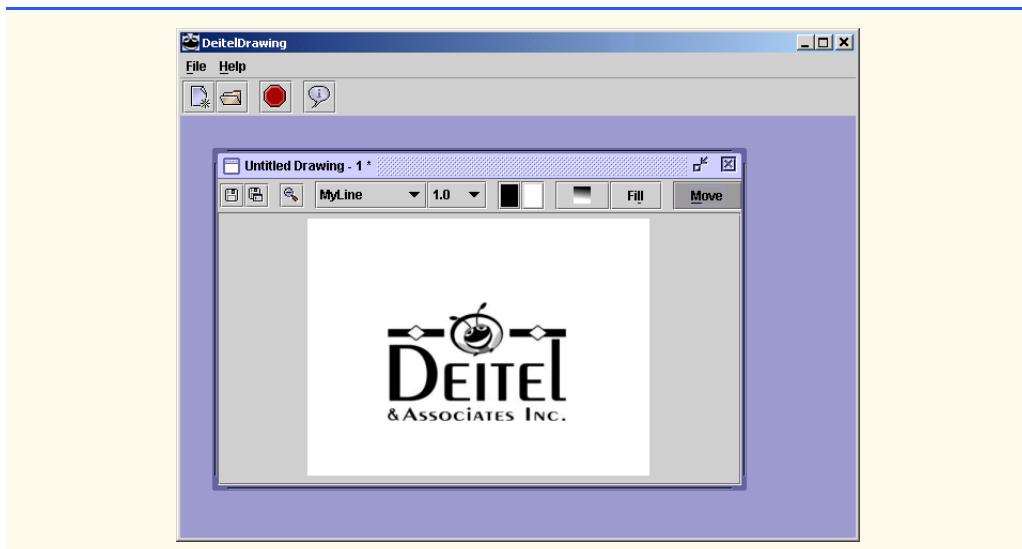


Fig. 5.8 **MyImage** subclass of class **MyShape** that represents a JPEG image in a drawing (part 3 of 3).

Lines 21–25 implement method **draw** to draw the **MyImage** object. Line 24 invokes method **drawImage** of class **Graphics2D** to draw the **MyImage** object's **BufferedImage**. Method **contains** (lines 28–34) creates a **Rectangle2D.Float** object of the same dimensions as the **MyImage** object. Line 33 invokes method **contains** of class **Rectangle2D.Float** to determine whether the given **Point2D** object falls within the **MyImage** object's area.

Method **getImage** (lines 46–49) gets the **BufferedImage** for the **MyImage** object. Method **setFileName** (lines 43–69) takes as a **String** argument the name of the **File** that contains the **MyImage** object's image. Lines 49–56 open a **FileInputStream** for the **File** and decode the **File** as a JPEG image using method **decodeAs BufferedImage** of class **JPEGImageDecoder**. Line 56 invokes method **setImage** of class **MyImage** to set the **image** property to the newly loaded **BufferedImage**. Method **getFileName** (lines 72–75) returns a **String** that contains the name of the **File** from which the JPEG image was loaded.

Method **getXML** (lines 78–91) creates an XML representation of a **MyImage** object. Line 80 invokes method **getXML** of class **MyShape** to retrieve the default **shape Element**. Line 81 adds **Attribute type** with the value **MyImage** to **Element shape**. Lines 84–87 create a **fileName Element** that contains the name of the **File** from which the JPEG image was loaded, and appends this **Element** as a child of **Element shape**.

## 5.4 Deitel DrawingModel

The Deitel Drawing application employs the model-view-controller architecture to enhance the application's modularity and extensibility. Deitel Drawing represents each drawing as a **Collection** of **MyShape** objects stored in a **DrawingModel** (Fig. 5.9). Class

**DrawingModel** extends **Observable** (line 13) to allow **Observers** to register as listeners for changes in the **DrawingModel**.

```
1 // DrawingModel.java
2 // DrawingModel is the model for a DeitelDrawing painting. It
3 // provides methods for adding and removing shapes from a
4 // drawing.
5 package com.deitel.advjhtp1.drawing.model;
6
7 // Java core packages
8 import java.util.*;
9
10 // Deitel packages
11 import com.deitel.advjhtp1.drawing.model.shapes.*;
12
13 public class DrawingModel extends Observable {
14
15     // shapes contained in model
16     private Collection shapes;
17
18     // no-argument constructor
19     public DrawingModel()
20     {
21         shapes = new ArrayList();
22     }
23
24     // add shape to model
25     public void addShape( MyShape shape )
26     {
27         // add new shape to list of shapes
28         shapes.add( shape );
29
30         // send model changed notification
31         fireModelChanged();
32     }
33
34     // remove shape from model
35     public void removeShape( MyShape shape )
36     {
37         // remove shape from list
38         shapes.remove( shape );
39
40         // send model changed notification
41         fireModelChanged();
42     }
43
44     // get Collection of shapes in model
45     public Collection getShapes()
46     {
47         return Collections.unmodifiableCollection( shapes );
48     }
```

Fig. 5.9 **DrawingModel Observable** class that represents a drawing containing multiple **MyShapes** (part 1 of 2).

```

49
50     // set Collection of shapes in model
51     public void setShapes( Collection newShapes )
52     {
53         // copy Collection into new ArrayList
54         shapes = new ArrayList( newShapes );
55
56         // send model changed notification
57         fireModelChanged();
58     }
59
60     // empty the current ArrayList of shapes
61     public void clear()
62     {
63         shapes = new ArrayList();
64
65         // send model changed notification
66         fireModelChanged();
67     }
68
69     // send model changed notification
70     private void fireModelChanged()
71     {
72         // set model changed flag
73         setChanged();
74
75         // notify Observers that model changed
76         notifyObservers();
77     }
78 }
```

**Fig. 5.9** **DrawingModel Observable** class that represents a drawing containing multiple **MyShapes** (part 2 of 2).

The **DrawingModel** consists of a **Collection** of **MyShape** objects and methods for adding and removing shapes. Lines 31 and 41 invoke **private** method **fireModelChanged** to notify **Observers** of additions to, and deletions from, the **DrawingModel**. Method **fireModelChanged** (lines 72–79) invokes method **setChanged** of class **Observable** to mark the **DrawingModel** as changed (line 75). Line 78 invokes method **notifyObservers** to send a notification to each registered **Observer** that the **DrawingModel** has changed.

Method **getShapes** (lines 51–54) invokes **static** method **unmodifiableCollection** of class **Collections** to obtain an unmodifiable reference to the **shapes Collection**. Returning an unmodifiable **Collection** prevents the caller from changing the model through that **Collection** reference.

Class **DrawingFileReaderWriter** (Fig. 5.10) provides methods **writeFile** and **readFile** for saving and loading drawings. Class **DrawingFileReaderWriter** enables the application to save and load drawings as XML documents. Static method **writeFile** (lines 28–89) takes as arguments a **DrawingModel** and the file name to which the **DrawingModel** should be saved. Lines 34–40 create a new XML DOM object in memory. Lines 43–44 create the **shapes Element**, which is the root of the XML doc-

ument. Lines 47–55 iterate through the **DrawingModel**'s shapes, and invoke method **getXML** on each **MyShape** to obtain its XML **Element** representation. Line 54 adds each **shape Element** to the XML document. Lines 58–70 use a **Transformer** to output the XML document to the given **fileName**. [Note: If you are not familiar with XML and the Java API for XML Processing, please see Appendices A–D.]

```
1 // DrawingFileReaderWriter.java
2 // DrawingFileReaderWriter defines static methods for reading
3 // and writing DeitelDrawing files on disk.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.awt.Color;
10
11 // Java extension packages
12 import javax.xml.parsers.*;
13 import javax.xml.transform.*;
14 import javax.xml.transform.dom.*;
15 import javax.xml.transform.stream.*;
16
17 // third-party packages
18 import org.w3c.dom.*;
19 import org.xml.sax.*;
20
21 // Deitel packages
22 import com.deitel.advjhtp1.drawing.model.*;
23 import com.deitel.advjhtp1.drawing.model.shapes.*;
24
25 public class DrawingFileReaderWriter {
26
27     // write drawing to file with given fileName
28     public static void writeFile( DrawingModel drawingModel,
29         String fileName )
30     {
31         // open file for writing and save drawing data
32         try {
33
34             DocumentBuilderFactory builderFactory =
35                 DocumentBuilderFactory.newInstance();
36
37             DocumentBuilder builder =
38                 builderFactory.newDocumentBuilder();
39
40             Document document = builder.newDocument();
41
42             // create shapes element to contain all MyShapes
43             Element shapesElement =
44                 document.createElement( "shapes" );
45             document.appendChild( shapesElement );
```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 1 of 8).

```
46         Iterator iterator = drawingModel.getShapes().iterator();
47
48         // populate shapes element with shape element for each
49         // MyShape in DrawingModel
50         while ( iterator.hasNext() ) {
51             MyShape shape = ( MyShape ) iterator.next();
52
53             shapesElement.appendChild( shape.getXML( document ) );
54         }
55
56
57         // use Transformer to write shapes XML document to a file
58         TransformerFactory transformerFactory =
59             TransformerFactory.newInstance();
60
61         Transformer transformer =
62             transformerFactory.newTransformer();
63
64         // specify the shapes.dtd Document Type Definition
65         transformer.setOutputProperty(
66             OutputKeys.DOCTYPE_SYSTEM, "shapes.dtd" );
67
68         transformer.transform( new DOMSource( document ),
69             new StreamResult( new FileOutputStream(
70                 fileName ) ) );
71
72     } // end try
73
74     // handle exception building XML Document
75     catch ( ParserConfigurationException parserException ) {
76         parserException.printStackTrace();
77     }
78
79     // handle exception transforming XML Document
80     catch ( TransformerException transformerException ) {
81         transformerException.printStackTrace();
82     }
83
84     // handle exception opening FileOutputStream
85     catch ( FileNotFoundException fileException ) {
86         fileException.printStackTrace();
87     }
88
89 } // end method writeFile
90
91 // open existing drawing from file
92 public static Collection readFile( String fileName )
93 {
94     // load shapes from file
95     try {
96
97         // Collection of MyShapes read from XML Document
```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 2 of 8).

```
98         Collection shapes = new ArrayList();
99
100        DocumentBuilderFactory builderFactory =
101            DocumentBuilderFactory.newInstance();
102
103        builderFactory.setValidating( true );
104
105        DocumentBuilder builder =
106            builderFactory.newDocumentBuilder();
107
108        Document document = builder.parse(
109            new File( fileName ) );
110
111        // get all shape elements in XML Document
112        NodeList list = document.getElementsByTagName( "shape" );
113
114        // get MyShape from each shape element in XML Document
115        for ( int i = 0; i < list.getLength(); i++ ) {
116            Element element = ( Element ) list.item( i );
117            MyShape shape = getShapeFromElement( element );
118            shapes.add( shape );
119        }
120
121        return shapes;
122
123    } // end try
124
125    // handle exception creating DocumentBuilder
126    catch ( ParserConfigurationException parserException ) {
127        parserException.printStackTrace();
128    }
129
130    // handle exception parsing Document
131    catch ( SAXException saxException ) {
132        saxException.printStackTrace();
133    }
134
135    // handle exception reading Document from file
136    catch ( IOException ioException ) {
137        ioException.printStackTrace();
138    }
139
140    return null;
141
142} // end method readFile
143
144// create MyShape using properties specified in given Element
145private static MyShape getShapeFromElement( Element element )
146{
147    MyShape shape = null;
148
149    // get MyShape type (e.g., MyLine, MyRectangle, etc.)
```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 3 of 8).

```
150     String type = element.getAttribute( "type" );
151
152     // create appropriate MyShape subclass instance
153     if ( type.equals( "MyLine" ) ) {
154         shape = new MyLine();
155     }
156
157     else if ( type.equals( "MyRectangle" ) ) {
158         shape = new MyRectangle();
159     }
160
161     else if ( type.equals( "MyOval" ) ) {
162         shape = new MyOval();
163     }
164
165     else if ( type.equals( "MyText" ) ) {
166         shape = new MyText();
167
168         // create MyText reference for setting MyText-specific
169         // properties, including fontSize, text, etc.
170         MyText textShape = ( MyText ) shape;
171
172         // set text property
173         String text =
174             getStringValueFromChildElement( element, "text" );
175
176         textShape.setText( text );
177
178         // set fontSize property
179         int fontSize =
180             getIntValueFromChildElement( element, "fontSize" );
181
182         textShape.setFontSize( fontSize );
183
184         // set fontName property
185         String fontName =
186             getStringValueFromChildElement( element, "fontName" );
187
188         textShape.setFontName( fontName );
189
190         // set underlined property
191         boolean underlined = getBooleanValueFromChildElement(
192             element, "underlined" );
193
194         textShape.setUnderlineSelected( underlined );
195
196         // set bold property
197         boolean bold =
198             getBooleanValueFromChildElement( element, "bold" );
199
200         textShape.setBoldSelected( bold );
201
```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 4 of 8).

```
202         // set italic property
203         boolean italic =
204             getBooleanValueFromChildElement( element, "italic" );
205
206         textShape.setItalicSelected( italic );
207     }
208
209     else if ( type.equals( "MyImage" ) ) {
210         shape = new MyImage();
211
212         // create MyImage reference for setting MyImage-specific
213         // fileName property
214         MyImage imageShape = ( MyImage ) shape;
215
216         String fileName = getStringValueFromChildElement(
217             element, "fileName" );
218
219         imageShape.setFileName( fileName );
220     }
221
222     // set properties common to all MyShapes, including x1, y1,
223     // x2, y2, startColor, endColor, etc.
224
225     // set x1 and y1 properties
226     int x1 = getIntValueFromChildElement( element, "x1" );
227     int y1 = getIntValueFromChildElement( element, "y1" );
228
229     shape.setPoint1( x1, y1 );
230
231     // set x2 and y2 properties
232     int x2 = getIntValueFromChildElement( element, "x2" );
233     int y2 = getIntValueFromChildElement( element, "y2" );
234
235     shape.setPoint2( x2, y2 );
236
237     // set startX and startY properties
238     int startX =
239         getIntValueFromChildElement( element, "startX" );
240     int startY =
241         getIntValueFromChildElement( element, "startY" );
242
243     shape.setStartPoint( startX, startY );
244
245     // set endX and endY properties
246     int endX = getIntValueFromChildElement( element, "endX" );
247     int endY = getIntValueFromChildElement( element, "endY" );
248
249     shape.setEndPoint( endX, endY );
250
251     // set startColor and endColor properties
252     Color startColor =
253         getColorValueFromChildElement( element, "startColor" );
```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 5 of 8).

```
254     shape.setStartColor( startColor );
255
256     Color endColor =
257         getColorValueFromChildElement( element, "endColor" );
258
259     shape.setEndColor( endColor );
260
261     // set useGradient property
262     boolean useGradient = getBooleanValueFromChildElement(
263         element, "useGradient" );
264
265     shape.setUseGradient( useGradient );
266
267     // set strokeSize property
268     float strokeSize = getFloatValueFromChildElement(
269         element, "strokeSize" );
270
271     shape.setStrokeSize( strokeSize );
272
273     // set filled property
274     boolean fill =
275         getBooleanValueFromChildElement( element, "fill" );
276
277     shape.setFilled( fill );
278
279     return shape;
280
281 } // end method getShapeFromElement
282
283
284 // get int value from child element with given name
285 private static int getIntValueFromChildElement( Element parent,
286     String childElementName )
287 {
288     // get NodeList for Elements of given childElementName
289     NodeList childNodes = parent.getElementsByTagName(
290         childElementName );
291
292     // get Text Node from zeroth child Element
293     Node childTextNode = childNodes.item( 0 ).getFirstChild();
294
295     // parse int value from Text Node
296     return Integer.parseInt( childTextNode.getNodeValue() );
297
298 } // end method getIntValueFromChildElement
299
300
301 // get float value from child element with given name
302 private static float getFloatValueFromChildElement(
303     Element parent, String childElementName )
304 {
305     // get NodeList for Elements of given childElementName
306     NodeList childNodes = parent.getElementsByTagName(
```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 6 of 8).

```

306         childElementName );
307
308     // get Text Node from zeroth child Element
309     Node childTextNode = childNodes.item( 0 ).getFirstChild();
310
311     // parse float value from Text Node
312     return Float.parseFloat( childTextNode.getNodeValue() );
313
314 } // end method getFloatValueFromChildElement
315
316 // get boolean value from child element with given name
317 private static boolean getBooleanValueFromChildElement(
318     Element parent, String childElementName )
319 {
320     // get NodeList for Elements of given childElementName
321     NodeList childNodes = parent.getElementsByTagName(
322         childElementName );
323
324     Node childTextNode = childNodes.item( 0 ).getFirstChild();
325
326     // parse boolean value from Text Node
327     return Boolean.valueOf(
328         childTextNode.getNodeValue() ).booleanValue();
329
330 } // end method getBooleanValueFromChildElement
331
332 // get String value from child element with given name
333 private static String getStringValueFromChildElement(
334     Element parent, String childElementName )
335 {
336     // get NodeList for Elements of given childElementName
337     NodeList childNodes = parent.getElementsByTagName(
338         childElementName );
339
340     // get Text Node from zeroth child Element
341     Node childTextNode = childNodes.item( 0 ).getFirstChild();
342
343     // return String value of Text Node
344     return childTextNode.getNodeValue();
345
346 } // end method getStringValueFromChildElement
347
348 // get Color value from child element with given name
349 private static Color getColorValueFromChildElement(
350     Element parent, String childElementName )
351 {
352     // get NodeList for Elements of given childElementName
353     NodeList childNodes = parent.getElementsByTagName(
354         childElementName );
355
356     // get zeroth child Element
357     Element childElement = ( Element ) childNodes.item( 0 );

```

Fig. 5.10 **DrawingFileReaderWriter** utility class for saving drawings to files and loading drawings from files (part 7 of 8).

```

358
359     // get red, green and blue attribute values
360     int red = Integer.parseInt(
361         childElement.getAttribute( "red" ) );
362
363     int green = Integer.parseInt(
364         childElement.getAttribute( "green" ) );
365
366     int blue = Integer.parseInt(
367         childElement.getAttribute( "blue" ) );
368
369     // return Color for given red, green and blue values
370     return new Color( red, green, blue );
371
372 } // end method getColorValueFromChildElement
373 }
```

**Fig. 5.10** `DrawingFileReaderWriter` utility class for saving drawings to files and loading drawings from files (part 8 of 8).

Method `readFile` (lines 92–142) loads a drawing from an XML document. Lines 100–109 create a `DocumentBuilder` and parse the XML document with the given `fileName`. Line 112 invokes method `getElementsByTagName` of interface `Document` to retrieve all `shape Elements` in the document. Lines 115–119 process each `shape Element` by invoking method `getShapeFromElement` (line 117), which returns a `MyShape` object for each `Element`. Line 120 adds each `MyShape` to the `shapes Collection`.

Method `getShapeFromElement` (lines 145–282) builds an appropriate `MyShape` subclass instance for the given `shape Element`. Line 150 retrieves the value of the `type Attribute` to determine the appropriate `MyShape` subclass to instantiate. Lines 170–206 obtain values specific to `MyText` objects. Lines 216–219 obtain values specific to `MyImage` objects. Lines 226–278 obtain values that apply to all `MyShapes`.

Method `getIntValueFromChildElement` (lines 285–298) is a utility method for obtaining an `int` value from a particular child `Element`. Lines 289–290 obtain a `NodeList` of `Elements` with the given `childElementName`. Line 293 obtains the `Text Node` child of the `Element` and line 298 parses the `Text Node` to produce an `int` value. Methods `.getFloatValueFromChildElement` (lines 301–314), `getBooleanValueFromChildElement` (lines 317–330), `getStringValueFromChildElement` (lines 333–346) and `getColorValueFromChildElement` perform similar processing to retrieve values of other data types.

Figure 5.11 shows a sample XML document produced by `DrawingFileReaderWriter`. Note that the `MyText shape` element (lines 49–69) has child elements `text`, `fontSize`, `fontName`, `underline`, `bold` and `italic`, whereas the other shape elements have only the basic `MyShape`-related elements.

```

1 <?xml version="1.0" encoding="UTF-8"?>
2 <!DOCTYPE shapes SYSTEM "shapes.dtd">
```

**Fig. 5.11** Sample XML document generated by `DrawingFileReaderWriter` (part 1 of 3).

```
3  <shapes>
4      <shape type="MyLine">
5          <x1>122</x1>
6          <y1>36</y1>
7          <x2>43</x2>
8          <y2>120</y2>
9          <startX>43</startX>
10         <startY>120</startY>
11         <endX>122</endX>
12         <endY>36</endY>
13         <useGradient>false</useGradient>
14         <startColor red="0" green="0" blue="0"/>
15         <endColor red="255" green="255" blue="255"/>
16         <strokeSize>1.0</strokeSize>
17         <fill>false</fill>
18     </shape>
19     <shape type="MyRectangle">
20         <x1>62</x1>
21         <y1>71</y1>
22         <x2>124</x2>
23         <y2>132</y2>
24         <startX>62</startX>
25         <startY>71</startY>
26         <endX>124</endX>
27         <endY>132</endY>
28         <useGradient>false</useGradient>
29         <startColor red="0" green="0" blue="0"/>
30         <endColor red="255" green="255" blue="255"/>
31         <strokeSize>1.0</strokeSize>
32         <fill>false</fill>
33     </shape>
34     <shape type="MyOval">
35         <x1>18</x1>
36         <y1>11</y1>
37         <x2>107</x2>
38         <y2>123</y2>
39         <startX>18</startX>
40         <startY>11</startY>
41         <endX>107</endX>
42         <endY>123</endY>
43         <useGradient>false</useGradient>
44         <startColor red="0" green="0" blue="0"/>
45         <endColor red="255" green="255" blue="255"/>
46         <strokeSize>1.0</strokeSize>
47         <fill>false</fill>
48     </shape>
49     <shape type="MyText">
50         <x1>38</x1>
51         <y1>167</y1>
52         <x2>0</x2>
53         <y2>0</y2>
54         <startX>0</startX>
```

Fig. 5.11 Sample XML document generated by **DrawingFileReaderWriter** (part 2 of 3).

```

55      <startY>0</startY>
56      <endX>0</endX>
57      <endY>0</endY>
58      <useGradient>false</useGradient>
59      <startColor red="0" green="0" blue="0"/>
60      <endColor red="255" green="255" blue="255"/>
61      <strokeSize>1.0</strokeSize>
62      <fill>false</fill>
63      <text>Welcome to Deitel Drawing!</text>
64      <fontSize>10</fontSize>
65      <fontName>SansSerif</fontName>
66      <underlined>false</underlined>
67      <bold>true</bold>
68      <italic>false</italic>
69    </shape>
70    <shape type="MyOval">
71      <x1>84</x1>
72      <y1>63</y1>
73      <x2>169</x2>
74      <y2>148</y2>
75      <startX>169</startX>
76      <startY>63</startY>
77      <endX>84</endX>
78      <endY>148</endY>
79      <useGradient>true</useGradient>
80      <startColor red="51" green="51" blue="255"/>
81      <endColor red="255" green="255" blue="255"/>
82      <strokeSize>1.0</strokeSize>
83      <fill>true</fill>
84    </shape>
85  </shapes>

```

**Fig. 5.11** Sample XML document generated by **DrawingFileReaderWriter** (part 3 of 3).

## 5.5 Deitel Drawing Views

The Deitel Drawing application provides two views of user drawings. Class **DrawingView** (Fig. 5.12) is the primary view and extends **JPanel** to provide a surface onto which the user can draw **MyShapes**. Class **DrawingView** also implements interface **Observer** (line 20), so it can listen for **DrawingModel** changes.

```

1 // DrawingView.java
2 // DrawingView is a view of a DrawingModel that draws shapes using
3 // the Java2D API.
4 package com.deitel.advjhtp1.drawing.view;
5
6 // Java core packages
7 import java.awt.*;

```

**Fig. 5.12** **DrawingView** class for displaying **MyShapes** in a **DrawingModel** (part 1 of 4).

```
8 import java.awt.geom.*;
9 import java.awt.event.*;
10 import java.util.*;
11 import java.util.List;
12
13 // Java extension packages
14 import javax.swing.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.drawing.model.*;
18 import com.deitel.advjhttp1.drawing.model.shapes.*;
19
20 public class DrawingView extends JPanel implements Observer {
21
22     // model for which this is a view
23     private DrawingModel drawingModel;
24
25     // construct DrawingView for given model
26     public DrawingView( DrawingModel model )
27     {
28         // set DrawingModel
29         drawingModel = model;
30
31         // set background color
32         setBackground( Color.white );
33
34         // enable double buffering to reduce screen flicker
35         setDoubleBuffered( true );
36     }
37
38     // set DrawingModel for view to given model
39     public void setModel( DrawingModel model )
40     {
41         if ( drawingModel != null )
42             drawingModel.deleteObserver( this );
43
44         drawingModel = model;
45
46         // register view as observer of model
47         if ( model != null ) {
48             model.addObserver( this );
49             repaint();
50         }
51     }
52
53     // get DrawingModel associated with this view
54     public DrawingModel getModel()
55     {
56         return drawingModel;
57     }
58
59     // repaint view when update received from model
```

Fig. 5.12 DrawingView class for displaying MyShapes in a DrawingModel (part 2 of 4).

```
60    public void update( Observable observable, Object object )
61    {
62        repaint();
63    }
64
65    // overridden paintComponent method for drawing shapes
66    public void paintComponent( Graphics g )
67    {
68        // call superclass paintComponent
69        super.paintComponent( g );
70
71        // create Graphics2D object for given Graphics object
72        Graphics2D g2D = ( Graphics2D ) g;
73
74        // enable anti-aliasing to smooth jagged lines
75        g2D.setRenderingHint( RenderingHints.KEY_ANTIALIASING,
76            RenderingHints.VALUE_ANTIALIAS_ON );
77
78        // enable high-quality rendering in Graphics2D object
79        g2D.setRenderingHint( RenderingHints.KEY_RENDERING,
80            RenderingHints.VALUE_RENDER_QUALITY );
81
82        // draw all shapes in model
83        drawShapes( g2D );
84    }
85
86    // draw shapes in model
87    public void drawShapes( Graphics2D g2D )
88    {
89        // get Iterator for shapes in model
90        Iterator iterator = drawingModel.getShapes().iterator();
91
92        // draw each MyShape in DrawingModel
93        while ( iterator.hasNext() ) {
94            MyShape shape = ( MyShape ) iterator.next();
95            shape.draw( g2D );
96        }
97    }
98
99    // get preferred size for this component
100   public Dimension getPreferredSize()
101   {
102       return new Dimension( 320, 240 );
103   }
104
105   // insist on preferred size for this component
106   public Dimension getMinimumSize()
107   {
108       return getPreferredSize();
109   }
110
111   // insist on preferred size for this component
```

Fig. 5.12 DrawingView class for displaying MyShapes in a DrawingModel (part 3 of 4).

```
112     public Dimension getMaximumSize()
113     {
114         return getPreferredSize();
115     }
116
117     // add DrawingView as Observer of DrawingModel when
118     // DrawingView obtains screen resources
119     public void addNotify()
120     {
121         super.addNotify();
122         drawingModel.addObserver( this );
123     }
124
125     // remove DrawingView as Observer of DrawingModel when
126     // DrawingView loses screen resources
127     public void removeNotify()
128     {
129         super.removeNotify();
130         drawingModel.deleteObserver( this );
131     }
132 }
```

Fig. 5.12 **DrawingView** class for displaying **MyShapes** in a **DrawingModel** (part 4 of 4).

Method **setModel** (lines 39–51) first removes the **DrawingView** as an **Observer** of the existing **DrawingModel** (line 42), then registers the **DrawingView** as an **Observer** for the new **DrawingModel** (line 48). The **Observable DrawingModel** invokes method **update** of class **DrawingView** (lines 60–63) each time the **DrawingModel** changes. Method **update** invokes method **repaint** of class **JPanel** (line 62) each time the **DrawingView** receives an update from the **DrawingModel**. Methods **addNotify** (lines 119–123) and **removeNotify** (lines 127–131) add and delete the **DrawingView** as an **Observer** of the **DrawingModel** when the **DrawingView** obtains and discards its screen resources, respectively.

Method **paintComponent** (lines 66–84) configures the **Graphics2D** context for high-quality, anti-aliased drawing (lines 75–80) and invokes method **drawShapes** (line 83) to draw the **DrawingModel**'s shapes. Method **drawShapes** (lines 87–101) gets an **Iterator** for the **Collection** of **MyShapes** obtained from the **DrawingModel** (line 90). Lines 93–96 draw each **MyShape** on the given **Graphics2D** context.

Class **ZoomDrawingView** (Fig. 5.13) extends class **DrawingView** to provide a scaled view of a **DrawingModel**. Line 21 declares an **AffineTransform** reference that **ZoomDrawingView** uses to scale its rendering of the **DrawingModel**. The primary **ZoomDrawingView** constructor (lines 38–67) takes as arguments a **DrawingModel** and the factors by which the **AffineTransform** should scale points along the *x*- and *y*-axes.

Lines 48–65 add a **ComponentListener** anonymous inner class for the **ZoomDrawingView**. This **ComponentListener** adjusts the scale factors when the **ZoomDrawingView** component changes size. This allows the user to resize a window that contains a **ZoomDrawingView** to change its scale. For example, if the user resizes the window to **640x480**—twice the size of a default **DrawingView**—the **AffineTransform** magnifies the drawing view by a scale factor of **2**. If the user resizes the window to

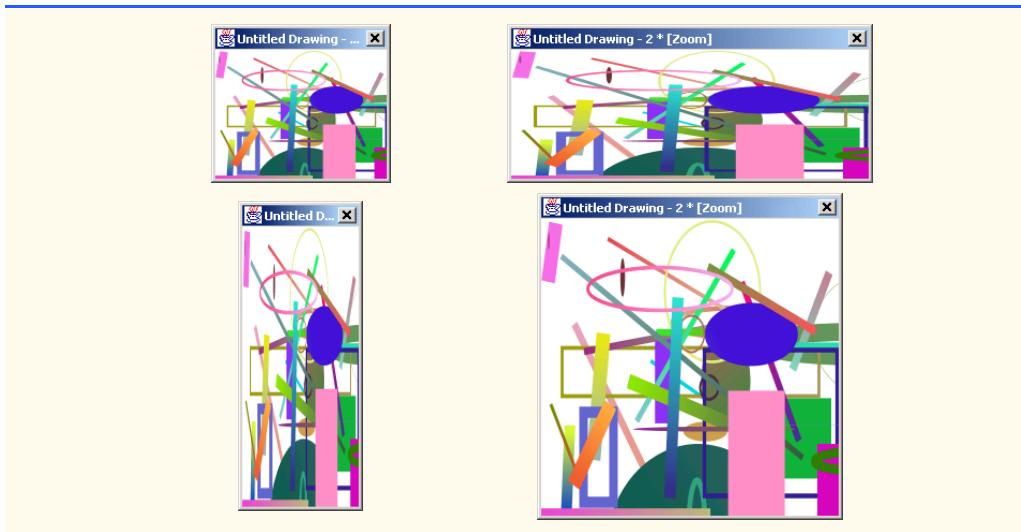
**160x120**—half the size of a default **DrawingView**—the **AffineTransform** shrinks the drawing view by a scale factor of **0.5**. The *x*- and *y*-axes also scale independently. The user can stretch the window horizontally to produce a short, wide drawing view or vertically to produce a tall, narrow drawing view.

```
1 // ZoomDrawingView.java
2 // ZoomDrawingView is a subclass of DrawingView that scales
3 // the view of the drawing using the given scale factor.
4 package com.deitel.advjhtp1.drawing.view;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.geom.*;
9 import java.awt.event.*;
10
11 // Deitel packages
12 import com.deitel.advjhtp1.drawing.model.*;
13
14 public class ZoomDrawingView extends DrawingView {
15
16     // factor for scaling view
17     private double scaleFactorX;
18     private double scaleFactorY;
19
20     // transform for scaling view
21     private AffineTransform scaleTransform;
22
23     // construct ZoomDrawingView with given model and default
24     // scale factor
25     public ZoomDrawingView( DrawingModel model )
26     {
27         this( model, 1.0 );
28     }
29
30     // construct ZoomDrawingView with given model and scale factor
31     public ZoomDrawingView( DrawingModel model, double scale )
32     {
33         this( model, scale, scale );
34     }
35
36     // construct ZoomDrawingView with given model and separate
37     // x and y scale factors
38     public ZoomDrawingView( DrawingModel model, double scaleX,
39                           double scaleY )
40     {
41         // call DrawingView constructor
42         super( model );
43
44         // set scale factor for this view
45         setScaleFactors( scaleX, scaleY );
46     }
```

Fig. 5.13 **ZoomDrawingView** subclass of **DrawingView** for displaying scaled **MyShapes** (part 1 of 3).

```
47     // listen for component resize events to adjust scale
48     addComponentListener(
49         new ComponentAdapter() {
50
51             // when view is resized, update scale factors
52             public void componentResized( ComponentEvent event )
53             {
54                 double width = ( double ) getSize().width;
55                 double height = ( double ) getSize().height;
56
57                 // calculate new scale factors
58                 double factorX = width / 320.0;
59
60                 double factorY = height / 240.0;
61
62                 setScaleFactors( factorX, factorY );
63             }
64         );
65     );
66
67 } // end ZoomDrawingView constructor
68
69 // draw shapes using scaled Graphics2D object
70 public void drawShapes( Graphics2D g2D )
71 {
72     // set Graphics2D object transform
73     g2D.setTransform( scaleTransform );
74
75     // draw shapes on scaled Graphics2D object
76     super.drawShapes( g2D );
77 }
78
79 // set scale factors for view
80 public void setScaleFactors( double scaleX, double scaleY )
81 {
82     // set scale factors
83     scaleFactorX = scaleX;
84     scaleFactorY = scaleY;
85
86     // create AffineTransform with given scale factors
87     scaleTransform = AffineTransform.getScaleInstance(
88         scaleFactorX, scaleFactorY );
89 }
90
91 // get preferred size for this component
92 public Dimension getPreferredSize()
93 {
94     // default size is 320 x 240; scale using scaleFactors
95     return new Dimension( ( int )( 320 * scaleFactorX ),
96         ( int )( 240 * scaleFactorY ) );
97 }
98 }
```

Fig. 5.13 ZoomDrawingView subclass of DrawingView for displaying scaled MyShapes (part 2 of 3).



**Fig. 5.13** `ZoomDrawingView` subclass of `DrawingView` for displaying scaled `MyShapes` (part 3 of 3).

Method `drawShapes` (lines 70–77) overrides method `drawShapes` from class `DrawingView`. Line 73 invokes method `setTransform` of class `Graphics2D` to cause the `Graphics2D` object to use the provided `AffineTransform` to scale the drawing. Method `setScaleFactors` (lines 80–89) takes as `double` arguments the scale factors to use for the *x*- and *y*-axes. Lines 87–88 create the `AffineTransform` that method `drawShapes` uses to scale the drawing. Static method `getScaleInstance` of class `AffineTransform` returns an `AffineTransform` object that scales drawings based on the provided *x*- and *y*-axis scale factors. For example, scale factors of `0.5` and `0.5` would produce a view that is one quarter the original size.

## 5.6 Deitel Drawing Controller Logic

The model-view-controller architecture separates logic for processing user input into objects that are separate from the views and the model. The Deitel Drawing application uses two types of controllers to handle user input—`MyShapeControllers` and a `DragAndDropController`.

### 5.6.1 MyShapeControllers for Processing User Input

The primary user-input device for creating drawings is the mouse. A user can create and manipulate new shapes in a drawing by pressing the mouse button, dragging the mouse then releasing the mouse button. For each type of `MyShape`, however, there are different requirements for handling mouse events. For example, drawing a `MyText` shape requires the application to obtain from the user the text to be drawn and that text's properties, such as its font size. Class `MyShapeController` (Fig. 5.14) is an abstract base class that defines the basic functionality required by all `MyShapeControllers`. Subclasses of `MyShapeController` provide the implementation details for adding instances of each particular `MyShape` subclass to a drawing.

```
1 // MyShapeController.java
2 // MyShapeController is an abstract base class that represents
3 // a controller for painting shapes.
4 package com.deitel.advjhtp1.drawing.controller;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Deitel packages
11 import com.deitel.advjhtp1.drawing.model.*;
12 import com.deitel.advjhtp1.drawing.model.shapes.*;
13
14 public abstract class MyShapeController {
15
16     private DrawingModel drawingModel;
17
18     // primary and secondary Colors for drawing and gradients
19     private Color primaryColor = Color.black;
20     private Color secondaryColor = Color.white;
21
22     // Class object for creating new MyShape-subclass instances
23     private Class shapeClass;
24
25     // common MyShape properties
26     private boolean fillShape = false;
27     private boolean useGradient = false;
28     private float strokeSize = 1.0f;
29
30     // indicates whether the user has specified drag mode; if
31     // true, MyShapeController should ignore mouse events
32     private boolean dragMode = false;
33
34     private MouseListener mouseListener;
35     private MouseMotionListener mouseMotionListener;
36
37     // MyShapeController constructor
38     public MyShapeController( DrawingModel model, Class
39         myShapeClass )
40     {
41         // set DrawingModel to control
42         drawingModel = model;
43
44         // set MyShape subclass
45         shapeClass = myShapeClass;
46
47         // listen for mouse events
48         mouseListener = new MouseAdapter() {
49
50             // when mouse button pressed, create new shape
51             public void mousePressed( MouseEvent event )
52             {
```

Fig. 5.14 **MyShapeController** abstract base class for controllers that handle mouse input (part 1 of 5).

```
53             // if not in dragMode, start new shape at
54             // given coordinates
55         if ( !dragMode )
56             startShape( event.getX(), event.getY() );
57     }
58
59     // when mouse button released, set shape's final
60     // coordinates
61     public void mouseReleased( MouseEvent event )
62     {
63         // if not in dragMode, finish drawing current shape
64         if ( !dragMode )
65             endShape( event.getX(), event.getY() );
66     }
67 }
68
69     // listen for mouse motion events
70     mouseMotionListener = new MouseMotionAdapter() {
71
72         // when mouse is dragged, set coordinates for current
73         // shape's Point2
74         public void mouseDragged( MouseEvent event )
75         {
76             // if not in dragMode, modify current shape
77             if ( !dragMode )
78                 modifyShape( event.getX(), event.getY() );
79         }
80     };
81
82 } // end MyShapeController constructor
83
84     // set primary color (start color for gradient)
85     public void setPrimaryColor( Color color )
86     {
87         primaryColor = color;
88     }
89
90     // get primary color
91     public Color getPrimaryColor()
92     {
93         return primaryColor;
94     }
95
96     // set secondary color (end color for gradients)
97     public void setSecondaryColor( Color color )
98     {
99         secondaryColor = color;
100    }
101
102    // get secondary color
103    public Color getSecondaryColor()
104    {
```

Fig. 5.14 **MyShapeController** abstract base class for controllers that handle mouse input (part 2 of 5).

```
105     return secondaryColor;
106 }
107
108 // fill shape
109 public void setShapeFilled( boolean fill )
110 {
111     fillShape = fill;
112 }
113
114 // get shape filled
115 public boolean getShapeFilled()
116 {
117     return fillShape;
118 }
119
120 // use gradient when painting shape
121 public void setUseGradient( boolean gradient )
122 {
123     useGradient = gradient;
124 }
125
126 // get use gradient
127 public boolean getUseGradient()
128 {
129     return useGradient;
130 }
131
132 // set dragMode
133 public void setDragMode( boolean drag )
134 {
135     dragMode = drag;
136 }
137
138 // set stroke size for lines
139 public void setStrokeSize( float stroke )
140 {
141     strokeSize = stroke;
142 }
143
144 // get stroke size
145 public float getStrokeSize()
146 {
147     return strokeSize;
148 }
149
150 // create new instance of current MyShape subclass
151 protected MyShape createNewShape()
152 {
153     // create new instance of current MyShape subclass
154     try {
155         MyShape shape = ( MyShape ) shapeClass.newInstance();
156     }
```

Fig. 5.14 **MyShapeController** abstract base class for controllers that handle mouse input (part 3 of 5).

```
157         // set MyShape properties
158         shape.setFilled( fillShape );
159         shape.setUseGradient( useGradient );
160         shape.setStrokeSize( getStrokeSize() );
161         shape.setStartColor( getPrimaryColor() );
162         shape.setEndColor( getSecondaryColor() );
163
164         // return reference to newly created shape
165         return shape;
166     }
167
168     // handle exception instantiating shape
169     catch ( InstantiationException instanceException ) {
170         instanceException.printStackTrace();
171         return null;
172     }
173
174     // handle access exception instantiating shape
175     catch ( IllegalAccessException accessException ) {
176         accessException.printStackTrace();
177         return null;
178     }
179 }
180 // end method createNewShape
181
182 // get MyShapeController's MouseListener
183 public MouseListener getMouseListener()
184 {
185     return mouseListener;
186 }
187
188 // get MyShapeController's MouseMotionListener
189 public MouseMotionListener getMouseMotionListener()
190 {
191     return mouseMotionListener;
192 }
193
194 // add given shape to DrawingModel
195 protected void addShapeToModel( MyShape shape )
196 {
197     drawingModel.addShape( shape );
198 }
199
200 // remove given shape from DrawingModel
201 protected void removeShapeFromModel( MyShape shape )
202 {
203     drawingModel.removeShape( shape );
204 }
205
206 // start new shape
207 public abstract void startShape( int x, int y );
208 }
```

Fig. 5.14 **MyShapeController** abstract base class for controllers that handle mouse input (part 4 of 5).

```
209     // modify current shape  
210     public abstract void modifyShape( int x, int y );  
211  
212     // finish shape  
213     public abstract void endShape( int x, int y );  
214 }
```

Fig. 5.14 **MyShapeController** abstract base class for controllers that handle mouse input (part 5 of 5).

Each **MyShapeController** is responsible for responding to mouse events to allow users to add shapes to drawings. Lines 48–67 create a **MouseListener** that listens for **mousePressed** and **mouseReleased** events. When the user presses the mouse button, line 56 starts drawing a new shape at the location where the mouse press occurred by invoking method **startShape**. When the user releases the mouse button, line 65 invokes method **endShape** to complete the currently drawn shape. As the user drags the mouse, the **MouseMotionListener** on lines 70–80 invokes method **modifyShape** to modify the shape currently being drawn.

Note that class **MyShapeController** uses instances of **MouseAdapter** and **MouseMotionAdapter** to respond to **MouseEvents**. Objects of the classes **MouseAdapter** and **MouseMotionAdapter** act as adapters between objects that generate **MouseEvents** and those objects that handle these events. In this case study, **MyShapeController**'s **MouseAdapter** (lines 46–65) and **MouseMotionAdapter** (lines 68–79) adapts a **MyShapeController** to a **MouseListener** and **MouseMotionListener**, respectively. These adapter classes are examples of the *Adapter design pattern*, which provides an object with a new interface that *adapts* to another object's interface, allowing both objects to collaborate with one another. The adapter in this pattern is similar to an adapter for a plug on an electrical device—electrical sockets in Europe are different from those in the United States, so an adapter is needed to plug an American device into a European electrical socket and vice versa.

Methods **startShape**, **endShape** and **modifyShape** are abstract methods that each **MyShapeController** subclass must implement. This enables the developer to provide custom controllers for different shape types. The developer simply overrides these methods to perform the necessary input processing logic.

Method **createNewShape** (lines 151–180) uses Java's *reflection mechanism* to create new instances of **MyShape** subclasses as the user adds new shapes to a drawing. Reflection enables Java programs to determine information about classes and objects at runtime. In this example, we use reflection to enable our application to create instances of arbitrary **MyShape** subclasses dynamically. Each **MyShapeController** maintains a **Class** reference to the **Class** object for the **MyShape** subclass that the **MyShapeController** controls. For example, when the application creates a **MyShapeController** for drawing **MyLines**, the **MyShapeController** stores a reference to the **Class** object for class **MyLine**. Line 155 invokes method **newInstance** of class **Class** to create a new instance of the specified **MyShape** subclass. Lines 158–162 initialize this new instance with the currently selected fill, gradient, stroke size and color properties.

Class **BoundedShapeController** (Fig. 5.15) provides a basic implementation of abstract base class **MyShapeController** for drawing rectangle-bounded shapes (in this

application, **MyRectangles** and **MyOvals**). Method **startShape** (lines 22–37) creates a new instance of the appropriate **MyShape** subclass (line 25), sets the **MyShape**'s position on the drawing (lines 30–32) and adds the **MyShape** to the **DrawingModel** (line 35). The **MouseListener** in class **MyShapeController** invokes method **startShape** when the user presses the mouse button to begin drawing a shape.

```

1 // BoundedShapeController.java
2 // BoundedShapeController is a MyShapeController subclass for
3 // rectangle-bounded shapes, such as MyOvals and MyRectangles.
4 package com.deitel.advjhtp1.drawing.controller;
5
6 // Deitel packages
7 import com.deitel.advjhtp1.drawing.model.*;
8 import com.deitel.advjhtp1.drawing.model.shapes.*;
9
10 public class BoundedShapeController extends MyShapeController {
11
12     private MyShape currentShape;
13
14     // BoundedShapeController constructor
15     public BoundedShapeController(
16         DrawingModel model, Class shapeClass )
17     {
18         super( model, shapeClass );
19     }
20
21     // start drawing shape
22     public void startShape( int x, int y )
23     {
24         // get new shape
25         currentShape = createNewShape();
26
27         if ( currentShape != null ) {
28
29             // set location of shape in drawing
30             currentShape.setPoint1( x, y );
31             currentShape.setPoint2( x, y );
32             currentShape.setStartPoint( x, y );
33
34             // add newly created shape to DrawingModel
35             addShapeToModel( currentShape );
36         }
37     }
38
39     // modify shape currently being drawn
40     public void modifyShape( int x, int y )
41     {
42         // remove shape from DrawingModel
43         removeShapeFromModel( currentShape );
44         currentShape.setEndPoint( x, y );
45

```

Fig. 5.15 **BoundedShapeController** **MyShapeController** subclass for controlling **MyLines**, **MyOvals** and **MyRectangles** (part 1 of 2).

```
46     int startX = currentShape.getStartX();
47     int startY = currentShape.getStartY();
48
49     // set Point1 to upper-left coordinates of shape
50     currentShape.setPoint1(
51         Math.min( x, startX ), Math.min( y, startY ) );
52
53     // set Point2 to lower right coordinates of shape
54     currentShape.setPoint2(
55         Math.max( x, startX ), Math.max( y, startY ) );
56
57     // add shape back into model
58     addShapeToModel( currentShape );
59 }
60
61 // finish drawing shape
62 public void endShape( int x, int y )
63 {
64     modifyShape( x, y );
65 }
66 }
```

Fig. 5.15 **BoundedShapeController** **MyShapeController** subclass for controlling **MyLines**, **MyOvals** and **MyRectangles** (part 2 of 2).

When the user drags the mouse, the **MouseMotionListener** inherited from class **MyShapeController** invokes method **modifyShape** (lines 40–59) and passes the *x*- and *y*-coordinates of the **MouseEvent**. Method **modifyShape** removes **currentShape** from the **DrawingModel** (line 43), updates the **currentShape**'s various point properties with new coordinates (lines 46–55) and adds **currentShape** to the **DrawingModel**.

When the user releases the mouse button, the mouse handler invokes method **endShape** to complete the addition of the **MyShape** to the drawing. Method **endShape** invokes method **modifyShape** (line 52) to set the final values for **currentShape**'s coordinates.

Class **MyLineController** (Fig. 5.16) is a **MyShapeController** subclass for drawing **MyLine** objects. Method **startShape** (lines 20–36) is similar to method **startShape** in class **BoundedShapeController**. Method **modifyShape** (lines 39–56) removes the **MyLine** from the **DrawingModel** (line 42) and sets the **MyLine**'s **endPoint** to the current *x*, *y* coordinate. Lines 49–52 update the **MyLine**'s **Point1** and **Point2** coordinates.

```
1 // MyLineController.java
2 // MyLineController is a MyShapeController subclass for MyLines.
3 package com.deitel.advjhtp1.drawing.controller;
4
5 // Deitel packages
6 import com.deitel.advjhtp1.drawing.model.*;
```

Fig. 5.16 **MyLineController** **MyShapeController** subclass for drawing **MyLines** (part 1 of 3).

```
7 import com.deitel.advjhtp1.drawing.model.shapes.*;
8
9 public class MyLineController extends MyShapeController {
10
11     private MyShape currentShape;
12
13     // MyLineController constructor
14     public MyLineController( DrawingModel model, Class shapeClass )
15     {
16         super( model, shapeClass );
17     }
18
19     // start drawing new shape
20     public void startShape( int x, int y )
21     {
22         // create new shape
23         currentShape = createNewShape();
24
25         if ( currentShape != null ) {
26
27             // set location of shape in drawing
28             currentShape.setPoint1( x, y );
29             currentShape.setPoint2( x, y );
30             currentShape.setStartPoint( x, y );
31
32             // add newly created shape to DrawingModel
33             addShapeToModel( currentShape );
34         }
35
36     } // end method startShape
37
38     // modify shape currently being drawn
39     public void modifyShape( int x, int y )
40     {
41         // remove shape from DrawingModel
42         removeShapeFromModel( currentShape );
43         currentShape.setEndPoint( x, y );
44
45         int startX = currentShape.getStartTime();
46         int startY = currentShape.getStartTime();
47
48         // set current ( x, y ) to Point1
49         currentShape.setPoint1( x, y );
50
51         // set Point2 to StartPoint
52         currentShape.setPoint2( startX, startY );
53
54         // add shape back into model
55         addShapeToModel( currentShape );
56     }
57
58     // finish drawing shape
```

Fig. 5.16 MyLineController MyShapeController subclass for drawing MyLines (part 2 of 3).

```
59     public void endShape( int x, int y )
60     {
61         modifyShape( x, y );
62     }
63 }
```

Fig. 5.16 **MyLineController** **MyShapeController** subclass for drawing **MyLines** (part 3 of 3).

Instances of class **MyText** are drawn quite differently from instances of classes **MyLine**, **MyOval** and **MyRectangle** and therefore require a custom implementation of class **MyShapeController**. Class **MyTextController** (Fig. 5.17) presents a dialog box that prompts the user for the text to be drawn as well as **MyText** properties (e.g., bold, italic, font, etc.).

```
1 // MyTextController.java
2 // MyTextController is a MyShapeController subclass for drawing
3 // MyText objects.
4 package com.deitel.advjhtp1.drawing.controller;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 // Deitel packages
14 import com.deitel.advjhtp1.drawing.model.*;
15 import com.deitel.advjhtp1.drawing.model.shapes.*;
16
17 public class MyTextController extends MyShapeController {
18
19     // MyTextController constructor
20     public MyTextController( DrawingModel model, Class shapeClass )
21     {
22         // invoke superclass constructor; always use MyText class
23         super( model, MyText.class );
24     }
25
26     // start drawing MyText object
27     public void startShape( int x, int y ) {
28
29         // create MyText shape
30         MyText currentText = new MyText();
31
32         // set MyText's Point1
33         currentText.setPoint1( x, y );
34     }
35 }
```

Fig. 5.17 **MyTextController** **MyShapeController** subclass for adding **MyText** instances to a drawing (part 1 of 4).

```
5      // create TextInputPanel to get text and properties
6      TextInputPanel inputPanel = new TextInputPanel();
7
8      // display TextInputPanel in JOptionPane
9      String text = JOptionPane.showInputDialog( null,
10          inputPanel );
11
12     // ensure provided text is not null or empty
13     if ( text == null || text.equals( "" ) )
14         return;
15
16     // set MyText properties (bold, italic, etc.)
17     currentText.setBoldSelected(
18         inputPanel.boldSelected() );
19
20     currentText.setItalicSelected(
21         inputPanel.italicSelected() );
22
23     currentText.setUnderlineSelected(
24         inputPanel.underlineSelected() );
25
26     currentText.setFontName(
27         inputPanel.getSelectedFontName() );
28
29     currentText.setFontSize(
30         inputPanel.getSelectedFontSize() );
31
32     currentText.setColor( getPrimaryColor() );
33
34     // set MyText's text
35     currentText.setText( text );
36
37     // add MyText object to model
38     addShapeToModel( currentText );
39 }
40
41 // modify shape currently being drawn
42 public void modifyShape( int x, int y ) {}
43
44 // finish drawing shape
45 public void endShape( int x, int y ) {}
46
47 // JPanel with components for inputting MyText properties
48 private static class TextInputPanel extends JPanel {
49
50     private JCheckBox boldCheckBox;
51     private JCheckBox italicCheckBox;
52     private JCheckBox underlineCheckBox;
53     private JComboBox fontComboBox;
54     private JComboBox fontComboBox;
55
56     // TextInputPanel constructor
```

Fig. 5.17 **MyTextController** **MyShapeController** subclass for adding **MyText** instances to a drawing (part 2 of 4).

```
87     public TextInputPanel()
88     {
89         boldCheckBox = new JCheckBox( "Bold" );
90         italicCheckBox = new JCheckBox( "Italic" );
91         underlineCheckBox = new JCheckBox( "Underline" );
92
93         // create JComboBox for selecting Font
94         fontComboBox = new JComboBox();
95         fontComboBox.addItem( "SansSerif" );
96         fontComboBox.addItem( "Serif" );
97
98         // create JComboBox for selecting Font size
99         fontFontSizeComboBox = new JComboBox();
100        fontFontSizeComboBox.addItem( "10" );
101        fontFontSizeComboBox.addItem( "12" );
102        fontFontSizeComboBox.addItem( "14" );
103        fontFontSizeComboBox.addItem( "18" );
104        fontFontSizeComboBox.addItem( "22" );
105        fontFontSizeComboBox.addItem( "36" );
106        fontFontSizeComboBox.addItem( "48" );
107        fontFontSizeComboBox.addItem( "72" );
108
109        setLayout( new FlowLayout() );
110
111        add( boldCheckBox );
112        add( italicCheckBox );
113        add( underlineCheckBox );
114        add( fontComboBox );
115        add( fontFontSizeComboBox );
116    }
117
118    // get bold property
119    public boolean boldSelected()
120    {
121        return boldCheckBox.isSelected();
122    }
123
124    // get italic property
125    public boolean italicSelected()
126    {
127        return italicCheckBox.isSelected();
128    }
129
130    // get underline property
131    public boolean underlineSelected()
132    {
133        return underlineCheckBox.isSelected();
134    }
135
136    // get font name property
137    public String getSelectedFontName()
138    {
```

Fig. 5.17 **MyTextController** **MyShapeController** subclass for adding **MyText** instances to a drawing (part 3 of 4).

```

139         return fontComboBox.getSelectedItem().toString();
140     }
141
142     // get font size property
143     public int getSelectedFontSize()
144     {
145         return Integer.parseInt(
146             fontSizeComboBox.getSelectedItem().toString() );
147     }
148 }
149 }
```

Fig. 5.17 **MyTextController** **MyShapeController** subclass for adding **MyText** instances to a drawing (part 4 of 4).

Method **startShape** (lines 27–69) creates a new **MyText** object (line 30) and sets its coordinates to the given *x*, *y* coordinate. Line 36 creates a new **TextInputPanel** and lines 39–40 display the **TextInputPanel** in a **JOptionPane**. After the user enters the text and its properties, lines 47–68 set the **MyText** object’s properties and add the **MyText** object to the **DrawingModel**. **MyTextController** uses static class **TextInputPanel** (lines 78–148) to present a GUI for setting **MyText** object properties. Class **TextInputPanel** includes **JCheckboxes** for selecting bold, italic and underline, and **JComboboxes** for selecting the font and font size.

Class **MyShapeController** uses the *Template Method design pattern* to ensure that all **MyShapeControllers** follow the same three-step algorithm for creating shapes—the user clicks on the drawing area to specify a shape’s position, drags the mouse cursor across the area to specify its size, then releases the mouse button to create the shape. These steps correspond to the abstract methods **startShape**, **modifyShape** and **endShape**, respectively. Each **MyShapeController** subclass uses this algorithm but implements each step differently from the other implementations. For example, method **startShape** of class **MyTextController** presents a dialog box that obtains font information and text from the user. However, neither class **MyLineController** nor class **BoundedShapeController** needs to set fonts, so their implementations of method **startShape** differ from that of class **MyTextController**. Because the Template Method design pattern encapsulates a step-by-step algorithm that several objects can use, this pattern becomes beneficial when we add new **MyShapeController** subclasses (e.g., **RandomShapeController** in Exercise 5.8) to our system—we need implement only those methods that comprise the algorithm.

## 5.6.2 MyShapeControllers and Factory Method Design Pattern

The model-view-controller architecture makes the Deitel Drawing application easily extensible through the addition of new **MyShape** subclasses and new views. Creating a new **MyShape** subclass also could require a new **MyShapeController** subclass (as class **MyText** does). To eliminate the need to change existing code when adding a new **MyShapeController** to the application, Deitel Drawing uses a combination of two popular design patterns—the Factory Method design pattern and the Singleton design pattern.

The Deitel Drawing application uses the *Factory Method design pattern* to enable the user to select an appropriate **MyShapeController** at runtime. As its name implies, a Factory method creates objects. Factory methods can create objects based on criteria that are known only at runtime. These criteria could be in the form of user input, system properties, etc. In the Deitel Drawing application, the criterion is the user-selected **MyShape** type. The particular **MyShape** subclass the user selects is known only at run time, so at compile time we cannot determine what type of **MyShapeController** to use for controlling user input. We use a Factory Method in class **MyShapeControllerFactory** (Fig. 5.18) to construct the appropriate **MyShapeController** for the user-selected **MyShape**.

Method **newMyShapeController** (lines 75–106) is a Factory Method that takes as a **DrawingModel** argument the model to be controlled and as a **String** argument the name of the **MyShape** subclass for which to create a **MyShapeController** instance. Lines 83–85 invoke **static** method **forName** of class **Class** to get the **Class** object for the given **MyShape** subclass. If the given **MyShape** subclass is **MyLine**, line 89 returns a **MyLineController**. If the given **MyShape** subclass is **MyText**, line 92 returns a new instance of class **MyTextController**. Otherwise, lines 95–96 return a new instance of class **BoundedShapeController**.

```
1 // MyShapeControllerFactory.java
2 // MyShapeControllerFactory uses the Factory Method design
3 // pattern to create an appropriate instance of MyShapeController
4 // for the given MyShape subclass.
5 package com.deitel.advjhtp1.drawing.controller;
6
7 // Deitel packages
8 import com.deitel.advjhtp1.drawing.model.*;
9 import com.deitel.advjhtp1.drawing.model.shapes.*;
10
11 public class MyShapeControllerFactory {
12
13     private static final String FACTORY_PROPERTY_KEY =
14         "MyShapeControllerFactory";
15
16     private static final String[] supportedShapes =
17         { "MyLine", "MyRectangle", "MyOval", "MyText" };
18
19     // reference to Singleton MyShapeControllerFactory
20     private static MyShapeControllerFactory factory;
21
22     // MyShapeControllerFactory constructor
23     protected MyShapeControllerFactory() {}
24
25     // return Singleton instance of MyShapeControllerFactory
26     public static final MyShapeControllerFactory getInstance()
27     {
28         // if factory is null, create new MyShapeControllerFactory
29         if ( factory == null ) {
```

Fig. 5.18 **MyShapeControllerFactory** class for creating appropriate **MyShapeController** for given **MyShape** type (part 1 of 3).

```
30      // get System property that contains the factory
31      // class name
32      String factoryClassName =
33          System.getProperty( FACTORY_PROPERTY_KEY );
34
35      // if the System property is not set, create a new
36      // instance of the default MyShapeControllerFactory
37      if ( factoryClassName == null )
38          factory = new MyShapeControllerFactory();
39
40      // create a new MyShapeControllerFactory using the
41      // class name provided in the System property
42      else {
43
44          // create MyShapeControllerFactory subclass instance
45          try {
46              factory = ( MyShapeControllerFactory )
47                  Class.forName( factoryClassName ).newInstance();
48          }
49
50
51          // handle exception loading instantiating
52          catch ( ClassNotFoundException classException ) {
53              classException.printStackTrace();
54          }
55
56          // handle exception instantiating factory
57          catch ( InstantiationException exception ) {
58              exception.printStackTrace();
59          }
60
61          // handle exception if no access to specified Class
62          catch ( IllegalAccessException accessException ) {
63              accessException.printStackTrace();
64          }
65      }
66
67  } // end if
68
69  return factory;
70
71 } // end method getInstance
72
73 // create new MyShapeController subclass instance for given
74 // suitable for controlling given MyShape subclass type
75 public MyShapeController newMyShapeController(
76     DrawingModel model, String shapeClassName )
77 {
78     // create Class instance for given class name and
79     // construct appropriate MyShapeController
80     try {
81
```

Fig. 5.18 **MyShapeControllerFactory** class for creating appropriate **MyShapeController** for given **MyShape** type (part 2 of 3).

```
82         // get Class object for selected MyShape subclass
83         Class shapeClass = Class.forName(
84             MyShape.class.getPackage().getName() + "." +
85             shapeClassName );
86
87         // return appropriate controller for MyShape subclass
88         if ( shapeClassName.equals( "MyLine" ) )
89             return new MyLineController( model, shapeClass );
90
91         else if ( shapeClassName.equals( "MyText" ) )
92             return new MyTextController( model, shapeClass );
93
94         else
95             return new BoundedShapeController( model,
96                 shapeClass );
97     }
98
99     // handle exception if MyShape derived class not found
100    catch ( ClassNotFoundException classException ) {
101        classException.printStackTrace();
102    }
103
104    return null;
105}
106 // end method newMyShapeController
107
108 // get String array of MyShape subclass names for which this
109 // factory can create MyShapeControllers
110 public String[] getSupportedShapes()
111 {
112     return supportedShapes;
113 }
114 }
```

Fig. 5.18 **MyShapeControllerFactory** class for creating appropriate **MyShapeController** for given **MyShape** type (part 3 of 3).

Class **MyShapeControllerFactory** also uses the *Singleton design pattern* to control how other objects obtain instances of **MyShapeControllerFactory**. Specifically, the Singleton design pattern ensures that only one instance of a particular object can exist in a particular application. Class **MyShapeControllerFactory** declares a **protected**, no-argument constructor to prevent other objects from instantiating **MyShapeControllerFactory** objects directly. Other objects that require an instance of class **MyShapeControllerFactory** can invoke method **getInstance** (lines 26–71) to obtain the Singleton instance. If a **MyShapeControllerFactory** has not been created yet, lines 29–65 create a **MyShapeControllerFactory**. Line 69 returns the Singleton **MyShapeControllerFactory** instance to the caller.

In this example, our implementation provides the benefit of allowing the **MyShapeControllerFactory** to determine at runtime the particular subclass of **MyShapeControllerFactory** to instantiate. Lines 33–34 read a system property whose value specifies from which particular **MyShapeControllerFactory** subclass method **getInstance** should instantiate a new **MyShapeControllerFactory**. By speci-

fying a value for this system property at the command line, a user can “install” a new **MyShapeControllerFactory** subclass without requiring changes to existing application code. For example, Exercise 5.8 asks you to create a **RandomMyShapeController** that draws random shapes in the drawing. To add this new **MyShapeController** to the application, you also must create a **MyShapeControllerFactory** subclass (e.g., **RandomMyShapeControllerFactory**) that creates **RandomMyShapeControllers**. From the command line, the user can specify that the program should use this new factory by specifying the system property as follows

```
java -DMyShapeControllerFactory=RandomMyShapeControllerFactory com.deitel.advjhtp1.drawing.DeitelDrawing
```

If the user does not specify a class name in the **MyShapeControllerFactory** system property, the application uses the default **MyShapeControllerFactory** (line 39).

### 5.6.3 Drag-and-Drop Controller

The Deitel Drawing application supports two types of drag-and-drop operations. First, users can drag and drop certain **MyShapes** within drawings and between drawings in the multiple-document interface. Second, users can drag JPEG images from the host operating system’s file manager and drop them on drawings to add those images to drawings.

There are several objects required to enable drag and drop in a Java application. A drag-and-drop operation begins in a **DragSource**. Static method **getDefaulDragSource** of class **DragSource** returns the **DragSource** for the host platform. A **DragGestureRecognizer** recognizes user gestures that begin drag-and-drop operations, such as pressing the mouse button over an object and dragging that object. When a user makes a drag gesture, the **DragGestureRecognizer** notifies its registered **DragGestureListeners**. The **DragGestureListener** then begins the drag-and-drop operation. The user continues the drag gesture until reaching the **DropTarget**, which is the destination for the drag-and-drop operation. When the user makes a gesture to complete the drag-and-drop operation (e.g., by releasing the mouse button), both the **DropTarget** and **DragSource** are notified that the drag-and-drop operation has completed. The event associated with the drag-and-drop operation’s completion includes information about the success or failure of the drag-and-drop operation and a **Transferable** object containing the data that was transferred.

In the Deitel Drawing application, an instance of class **DragAndDropController** (Fig. 5.19) controls each drag-and-drop operation. Class **DragAndDropController** implements three interfaces to handle drag-and-drop operations—**DragGestureListener**, **DragSourceListener** and **DropTargetListener**. These interfaces enable **DragAndDropController** to recognize drag gestures, **DragSource** events and **DropTarget** events.

---

```
1 // DragAndDropController.java
2 // DragAndDropController is a controller for handling drag and
3 // drop in DeitelDrawing. DragAndDropController implements
```

---

**Fig. 5.19** **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 1 of 8).

```
4 // DragGestureListener and DragSourceListener to handle drag
5 // events and DropTargetListener to handle drop events.
6 package com.deitel.advjhtp1.drawing.controller;
7
8 // Java core packages
9 import java.util.*;
10 import java.io.*;
11 import java.awt.Point;
12 import java.awt.dnd.*;
13 import java.awt.datatransfer.*;
14
15 // Deitel packages
16 import com.deitel.advjhtp1.drawing.model.*;
17 import com.deitel.advjhtp1.drawing.model.shapes.*;
18
19 public class DragAndDropController implements DragGestureListener,
20 DragSourceListener, DropTargetListener {
21
22     // model to control
23     private DrawingModel drawingModel;
24
25     private boolean dragMode = false;
26
27     // DragAndDropController constructor
28     public DragAndDropController( DrawingModel model )
29     {
30         drawingModel = model;
31     }
32
33     // set drag mode
34     public void setDragMode( boolean drag )
35     {
36         dragMode = drag;
37     }
38
39     // recognize drag operation beginning (method of interface
40     // DragGestureListener)
41     public void dragGestureRecognized( DragGestureEvent event )
42     {
43         // if not in dragMode, ignore drag gesture
44         if ( !dragMode )
45             return;
46
47         // get Point at which drag began
48         Point origin = event.getDragOrigin();
49
50         // get MyShapes from DrawingModel
51         List shapes = new ArrayList( drawingModel.getShapes() );
52
53         // find top-most shape that contains drag origin (i.e.,
54         // start at end of ListIterator and work backwards)
```

Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 2 of 8).

```
55     ListIterator shapeIterator =
56         shapes.listIterator( shapes.size() );
57
58     while ( shapeIterator.hasPrevious() ) {
59
60         MyShape shape = ( MyShape ) shapeIterator.previous();
61
62         if ( shape.contains( origin ) ) {
63
64             // create TransferableShape for dragging shape
65             // from Point origin
66             TransferableShape transfer =
67                 new TransferableShape( shape, origin );
68
69             // start drag operation
70             event.startDrag( null, transfer, this );
71
72             break;
73         }
74
75     } // end while
76
77 } // end method dragGestureRecognized
78
79 // handle drop events (method of interface DropTargetListener)
80 public void drop( DropTargetDropEvent event )
81 {
82     // get dropped object
83     Transferable transferable = event.getTransferable();
84
85     // get dropped object's DataFlavors
86     DataFlavor[] dataFlavors =
87         transferable.getTransferDataFlavors();
88
89     // get DropTargetDropEvent location
90     Point location = event.getLocation();
91
92     // process drops for supported types
93     for ( int i = 0; i < dataFlavors.length; i++ ) {
94         DataFlavor dataFlavor = dataFlavors[ i ];
95
96         // handle drop of JPEG images
97         if ( dataFlavor.equals(
98             DataFlavor.javaFileListFlavor ) ) {
99
100            // accept the drop operation
101            event.acceptDrop( DnDConstants.ACTION_COPY );
102
103            // attempt to drop the images and indicate whether
104            // drop is complete
105            event.dropComplete(
106                dropImages( transferable, location ) );
```

Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 3 of 8).

```
107         }
108
109     // handle drop of TransferableShape objects
110     else if ( dataFlavor.isMimeTypeEqual(
111             TransferableShape.MIME_TYPE ) ) {
112
113         // accept drop of TransferableShape
114         event.acceptDrop( DnDConstants.ACTION_MOVE );
115
116         // drop TransferableShape into drawing
117         dropShape( transferable, location );
118
119         // complete drop operation
120         event.dropComplete( true );
121     }
122
123     // reject all other DataFlavors
124     else
125         event.rejectDrop();
126
127 } // end for
128
129 } // end method drop
130
131 // drop JPEG images onto drawing
132 private boolean dropImages( Transferable transferable,
133     Point location )
134 {
135     // boolean indicating successful drop
136     boolean success = true;
137
138     // attempt to drop images onto drawing
139     try {
140
141         // get list of dropped files
142         List fileList =
143             ( List ) transferable.getTransferData(
144                 DataFlavor.javaFileListFlavor );
145
146         Iterator iterator = fileList.iterator();
147
148         // search for JPEG images
149         for ( int i = 1; iterator.hasNext(); i++ ) {
150             File file = ( File ) iterator.next();
151
152             // if dropped file is a JPEG image, decode and
153             // add MyImage to drawingModel
154             if ( fileIsJPEG( file ) ) {
155
156                 // create MyImage for given JPEG file
157                 MyImage image = new MyImage();
158                 image.setFileName( file.getPath() );
```

Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 4 of 8).

```
159         image.setPoint1( location.x, location.y );
160
161         // add to DrawingModel
162         drawingModel.addShape( image );
163     }
164
165     else
166     success = false;
167
168 } // end for
169
170 } // end try
171
172 // handle exception if DataFlavor not supported
173 catch ( UnsupportedFlavorException flavorException ) {
174     success = false;
175     flavorException.printStackTrace();
176 }
177
178 // handle exception reading File
179 catch ( IOException ioException ) {
180     success = false;
181     ioException.printStackTrace();
182 }
183
184 return success;
185
186 } // end method dropImages
187
188 // return true if File has .jpg or .jpeg extension
189 private boolean fileIsJPEG( File file )
190 {
191     String fileName = file.getName().toLowerCase();
192
193     return fileName.endsWith( ".jpg" ) ||
194         fileName.endsWith( ".jpeg" );
195 }
196
197 // drop MyShape object onto drawing
198 private void dropShape( Transferable transferable,
199     Point location )
200 {
201     try {
202
203         DataFlavor flavor = new DataFlavor(
204             TransferableShape.MIME_TYPE, "Shape" );
205
206         // get TransferableShape object
207         TransferableShape transferableShape =
208             ( TransferableShape ) transferable.getTransferData(
209                 flavor );
210 }
```

Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 5 of 8).

```
211      // get MyShape and origin Point from TransferableShape
212      MyShape shape = transferableShape.getShape();
213      Point origin = transferableShape.getOrigin();
214
215      // calculate offset for dropping MyShape
216      int xOffSet = location.x - origin.x;
217      int yOffSet = location.y - origin.y;
218
219      shape.moveByOffset( xOffSet, yOffSet );
220
221      // add MyShape to target DrawingModel
222      drawingModel.addShape( shape );
223
224  } // end try
225
226  // handle exception if DataFlavor not supported
227  catch ( UnsupportedFlavorException flavorException ) {
228      flavorException.printStackTrace();
229  }
230
231  // handle exception getting Transferable data
232  catch ( IOException ioException ) {
233      ioException.printStackTrace();
234  }
235
236 } // end method dropShape
237
238 // check for success when drag-and-drop operation ends
239 // (method of interface DragSourceListener)
240 public void dragDropEnd( DragSourceDropEvent event )
241 {
242     // if drop successful, remove MyShape from source
243     // DrawingModel
244     if ( event.getDropSuccess() ) {
245
246         // get Transferable object from DragSourceContext
247         Transferable transferable =
248             event.getDragSourceContext().getTransferable();
249
250         // get TransferableShape object from Transferable
251         try {
252
253             // get TransferableShape object
254             TransferableShape transferableShape =
255                 ( TransferableShape ) transferable.getTransferData(
256                     new DataFlavor( TransferableShape.MIME_TYPE,
257                     "Shape" ) );
258
259             // get MyShape from TransferableShape object
260             // and remove from source DrawingModel
261             drawingModel.removeShape(
262                 transferableShape.getShape() );
```

Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 6 of 8).

```
263         }
264
265         // handle exception if DataFlavor not supported
266         catch ( UnsupportedFlavorException flavorException ) {
267             flavorException.printStackTrace();
268         }
269
270         // handle exception getting transfer data
271         catch ( IOException ioException ) {
272             ioException.printStackTrace();
273         }
274
275     } // end if
276
277 } // end method dragDropEnd
278
279 // required methods of interface DropTargetListener
280 public void dragEnter( DropTargetDragEvent event ) {}
281 public void dragExit( DropTargetEvent event ) {}
282 public void dragOver( DropTargetDragEvent event ) {}
283 public void dropActionChanged( DropTargetDragEvent event ) {}
284
285 // required methods of interface DragSourceListener
286 public void dragEnter( DragSourceDragEvent event ) {}
287 public void dragExit( DragSourceEvent event ) {}
288 public void dragOver( DragSourceDragEvent event ) {}
289 public void dropActionChanged( DragSourceDragEvent event ) {}
290 }
```

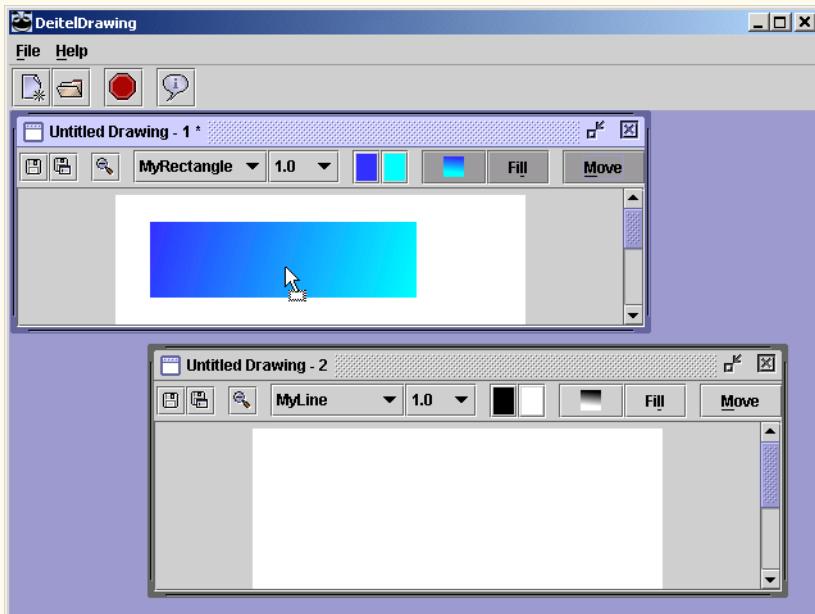


Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 7 of 8).

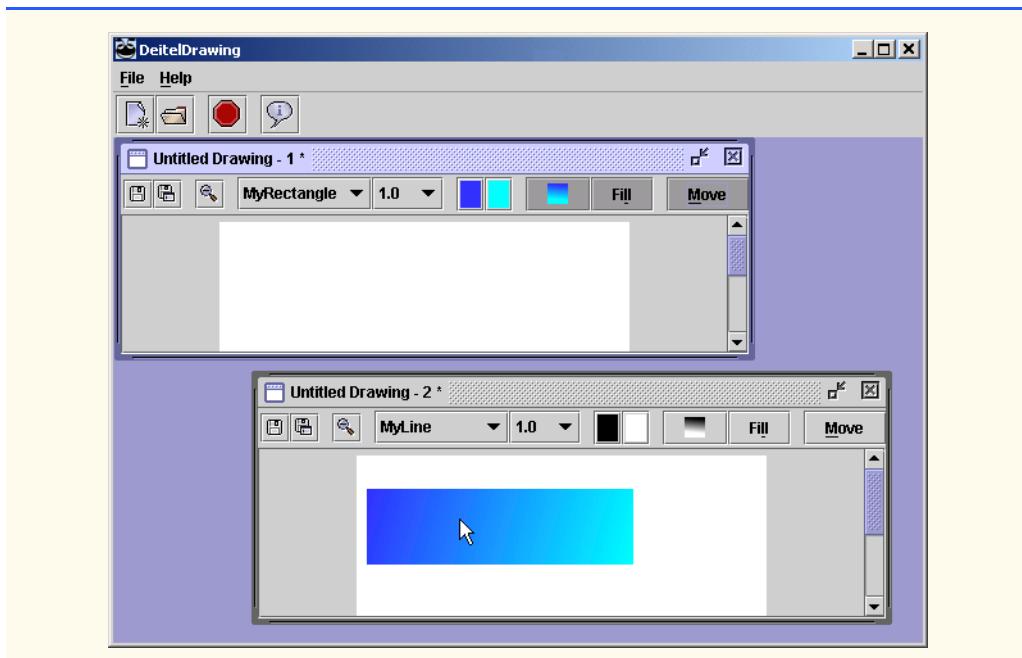


Fig. 5.19 **DragAndDropController** for moving **MyShapes** between drawings and adding JPEG images to drawings using drag and drop (part 8 of 8).

The drag-and-drop subsystem invokes method **dragGestureRecognized** (lines 41–77) when the user makes a drag gesture, such as pressing the mouse button and dragging the mouse on a draggable object. If the user has not selected drag mode in the Deitel Drawing application, line 45 returns to ignore the drag gesture. Lines 58–75 search through the **Collection** of **MyShapes** in the **DrawingModel** for the topmost shape that intersects **Point origin**, which is where the drag gesture occurred. Note that lines 58–75 go through the **Collection** in reverse order, since the topmost shape is at the end of the **Collection**. Lines 66–67 create a **TransferableShape** (Fig. 5.22) that contains the **MyShape** to be dragged and the **Point** at which the drag began. Line 70 invokes method **startDrag** of class **DragGestureEvent** to begin the drag-and-drop operation.

When the user drops a dragged object, the **DropTarget** notifies its **DropTargetListener**s by invoking method **drop** (lines 80–129). Line 83 gets the **Transferable** object from the **DropTargetEvent**. Each **Transferable** object contains an array of **DataFlavors** that describe the type of data contained in the **Transferable** object. Lines 93–127 process the array of **DataFlavors** to determine the type of object that the user dropped. If the **DataFlavor** is **DataFlavor.javaFileListFlavor** (lines 97–98), the user dropped a **List** of **Files** from the host operating system's file manager. Line 101 accepts the drop, and line 106 invokes method **dropImages** to process the **File List**. The Deitel Drawing application allows the user to drop only JPEG images, not other file types. If method **dropImages** returns **true**, the files were all JPEG images and the drag-and-drop operation completes successfully. If the **DataFlavor**'s MIME type matches class **TransferableShape**'s MIME type (lines 110–111), line 114 invokes method **acceptDrop** of class **DropTargetDropEvent** to accept the

drop and line 117 invokes method `dropShape` to process the `MyShape` that the user dropped. Line 120 invokes method `dropComplete` of class `DropTargetDropEvent` to indicate that the drop completed successfully. If the `DataFlavor` was neither a file list from the file manager nor a `TransferableShape`, line 125 rejects the drop by invoking method `rejectDrop` of class `DropTargetDropEvent`.

Method `dropImages` (lines 132–186) takes as arguments a `Transferable` object containing a `File List` and the `Point` at which the drop occurred. Lines 142–144 get the `File List`, and line 146 obtains an `Iterator` to process the `List`. Lines 149–168 check each `File` to determine whether it contains a JPEG image. If the `File` does contain a JPEG image (line 154), lines 157–162 create a new `MyImage` object for the JPEG image and add it to the `DrawingModel`. Method `fileIsJPEG` (lines 189–195) returns `true` if the given `File`'s name ends with the `.jpg` or `.jpeg` extension.

Method `dropShape` (lines 198–253) takes as a `Transferable` argument the object that the user dropped and a `Point` argument for the drop location. Lines 207–209 get the `TransferableShape` object by invoking method `getTransferData` of interface `Transferable`. If the `Transferable` object does not support the `DataFlavor` passed on line 209, method `getTransferData` throws an `UnsupportedFlavorException`. If there is an error reading the data, method `getTransferData` could throw an `IOException`. Line 212 gets the `MyShape` object from the `TransferableShape`, and line 213 gets the `Point` from which the `MyShape` was dragged. Lines 216–219 calculate the offset from the dragged point to the drop point and invoke `MyShape` method `moveByOffset` to position the `MyShape`. Line 222 adds the `MyShape` to the `DropTarget`'s `DrawingModel`.

The drag-and-drop subsystem invokes method `dragDropEnd` (lines 240–277) when the drag-and-drop operation completes. If the drag-and-drop operation succeeded (line 244), lines 261–262 remove the dragged `MyShape` object from the source `DrawingModel`. The remaining empty methods (lines 280–289) satisfy interfaces `DropTargetListener` and `DragSourceListener`. Figure 5.20 and Fig. 5.21 describe the methods of interfaces `DragSourceListener` and `DropTargetListener`.

Method	Description
<code>public void dragEnter( DragSourceDragEvent event )</code>	Invoked when drag-and-drop operation enters the <code>DragSource</code> .
<code>public void dragExit( DragSourceDragEvent event )</code>	Invoked when drag-and-drop operation exits the <code>DragSource</code> .
<code>public void dragOver( DragSourceDragEvent event )</code>	Invoked when drag-and-drop operation moves over <code>DragSource</code> .
<code>public void dragDropEnd( DragSourceDragEvent event )</code>	Invoked when drag-and-drop operation ends.
<code>public void dragDropActionChanged( DragSourceDragEvent event )</code>	Invoked if user changes drag-and-drop operation (e.g., from copy to move).

Fig. 5.20 `DragSourceListener` interface methods and their descriptions.

Method	Description
<code>public void dragEnter( DropTargetDragEvent event )</code>	Invoked when drag-and-drop operation enters the <code>DropTarget</code> .
<code>public void dragExit( DropTargetEvent event )</code>	Invoked when drag-and-drop operation exits the <code>DropTarget</code> .
<code>public void dragOver( DropTargetDragEvent event )</code>	Invoked when drag-and-drop operation moves over <code>DropTarget</code> .
<code>public void drop( DragTargetDropEvent event )</code>	Invoked when user drops dragged object on <code>DropTarget</code> .
<code>public void dragDropActionChanged( DragSourceDragEvent event )</code>	Invoked if user changes drag-and-drop operation (e.g., from copy to move).

Fig. 5.21 `DropTargetListener` interface methods and their descriptions.

Class `TransferableShape` (Fig. 5.22) implements interface `Transferable` to provide a means by which to transfer `MyShapes` using drag and drop. Interface `Transferable` is part of Java's data transfer API, which enables clipboard and drag-and-drop functionality in Java applications. Deitel Drawing enables users to drag and drop `TransferableShape` objects between drawings in the multiple-document interface. Lines 24–25 define `static String` variable `MIME_TYPE`, which the data transfer API uses to determine the type of data being transferred. *MIME types (Multipurpose Internet Mail Extension types)* are text strings that were originally created to describe data contained in e-mail attachments sent over the Internet. Many applications and operating systems now use MIME types for the more general purpose of describing objects that contain data, such as files, items on the system clipboard and drag-and-drop objects. Lines 28–29 declare an array of `DataFlavor` objects that class `TransferableShape` supports.

```

1 // TransferableShape.java
2 // TransferableShape is a Transferable object that contains a
3 // MyShape and the point from which the user dragged that MyShape.
4 package com.deitel.advjhtp1.drawing.controller;
5
6 // Java core packages
7 import java.util.*;
8 import java.io.*;
9 import java.awt.Point;
10 import java.awt.dnd.*;
11 import java.awt.datatransfer.*;
12
13 // Deitel packages
14 import com.deitel.advjhtp1.drawing.model.*;
15 import com.deitel.advjhtp1.drawing.model.shapes.*;
16

```

Fig. 5.22 `TransferableShape` enables `DragAndDropController` to transfer `MyShape` objects through drag-and-drop operations (part 1 of 3).

```
17 public class TransferableShape implements Transferable {
18
19     // the MyShape to transfer from Point origin
20     private MyShape shape;
21     private Point origin;
22
23     // MIME type that identifies dragged MyShapes
24     public static final String MIME_TYPE =
25         "application/x-deitel-shape";
26
27     // DataFlavors that MyShape supports for drag and drop
28     private static final DataFlavor[] flavors = new DataFlavor[] {
29         new DataFlavor( MIME_TYPE, "Shape" ) };
30
31     // TransferableShape constructor
32     public TransferableShape( MyShape myShape, Point originPoint )
33     {
34         shape = myShape;
35         origin = originPoint;
36
37     } // end TransferableShape constructor
38
39     // get Point from which user dragged MyShape
40     public Point getOrigin()
41     {
42         return origin;
43     }
44
45     // get MyShape
46     public MyShape getShape()
47     {
48         return shape;
49     }
50
51     // get data flavors MyShape supports
52     public DataFlavor[] getTransferDataFlavors()
53     {
54         return flavors;
55     }
56
57     // determine if MyShape supports given data flavor
58     public boolean isDataFlavorSupported( DataFlavor flavor )
59     {
60         // search for given DataFlavor in flavors array
61         for ( int i = 0; i < flavors.length; i++ )
62
63             if ( flavor.equals( flavors[ i ] ) )
64                 return true;
65
66         return false;
67     }
68 }
```

Fig. 5.22 **TransferableShape** enables **DragAndDropController** to transfer MyShape objects through drag-and-drop operations (part 2 of 3).

```
69     // get data to be transferred for given DataFlavor
70     public Object getTransferData( DataFlavor flavor )
71         throws UnsupportedFlavorException, IOException
72     {
73         if ( !isDataFlavorSupported( flavor ) )
74             throw new UnsupportedFlavorException( flavor );
75
76         // return TransferableShape object for transfer
77         return this;
78     }
79 }
```

Fig. 5.22 **TransferableShape** enables **DragAndDropController** to transfer **MyShape** objects through drag-and-drop operations (part 3 of 3).

Method **getTransferDataFlavors** (lines 52–55) returns the **TransferableShape**'s array of **DataFlavor**s. Method **getTransferDataFlavors** returns a **DataFlavor** array because it is possible that some objects support many **DataFlavor**s. Method **isDataFlavorSupported** (lines 58–67) takes a **DataFlavor** argument that lines 61–64 compare to each **DataFlavor** that class **TransferableShape** supports. If the given **DataFlavor** matches a supported **DataFlavor**, line 64 returns **true**.

Method **getTransferData** (lines 70–78) returns an **Object** containing the data to be transferred by the drag-and-drop operation. The **DataFlavor** argument specifies the particular type of data to be transferred. If the **DataFlavor** argument specifies an invalid **DataFlavor** for class **TransferableShape**, line 74 throws an **UnsupportedFlavorException**. If the **DataFlavor** matches a supported **DataFlavor** for class **MyShape**, line 77 returns a reference to the current **TransferableShape** instance to be transferred.

## 5.7 DrawingInternalFrame Component

**DrawingInternalFrame** (Fig. 5.23) is a **JInternalFrame** subclass that provides a user interface for viewing and modifying drawings. The Deitel Drawing application uses a multiple-document interface to allow the user to view and modify several drawings in a single application window. When the user creates a new drawing or opens a saved drawing, the drawing is displayed in a **DrawingInternalFrame**.

```
1 // DrawingInternalFrame.java
2 // DrawingInternalFrame is a JInternalFrame subclass for
3 // DeitelDrawing drawings.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 1 of 15).

```
9 import java.awt.dnd.*;
10 import java.io.*;
11 import java.util.*;
12 import java.util.List;
13
14 // Java extension packages
15 import javax.swing.*;
16 import javax.swing.event.*;
17 import javax.swing.border.*;
18
19 // Deitel packages
20 import com.deitel.advjhtp1.drawing.model.*;
21 import com.deitel.advjhtp1.drawing.model.shapes.*;
22 import com.deitel.advjhtp1.drawing.view.*;
23 import com.deitel.advjhtp1.drawing.controller.*;
24
25 public class DrawingInternalFrame extends JInternalFrame
26     implements Observer {
27
28     // offsets to stagger new windows
29     private static final int xOffset = 30;
30     private static final int yOffset = 30;
31     private static int openFrameCount = 0;
32
33     // MVC components
34     private DrawingModel drawingModel;
35     private DrawingView drawingView;
36     private MyShapeController myShapeController;
37     private DragAndDropController dragAndDropController;
38     private MyShapeControllerFactory shapeControllerFactory;
39
40     // file management properties
41     private JFileChooser fileChooser;
42     private String fileName;
43     private String absoluteFilePath;
44     private boolean saved = true;
45
46     private DrawingToolBar toolBar;
47     private ZoomDialog zoomDialog;
48
49     // Actions for save, zoom, move, etc.
50     private Action saveAction, saveAsAction, zoomAction,
51         moveAction, fillAction, gradientAction;
52
53     // DrawingInternalFrame constructor
54     public DrawingInternalFrame( String title )
55     {
56         super( title + " - " + ( ++openFrameCount ), true, true,
57               false, true );
58
59         setDefaultCloseOperation(
60             WindowConstants.DO_NOTHING_ON_CLOSE );
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 2 of 15).

```
61      // create new DrawingModel
62      drawingModel = new DrawingModel();
63
64
65      // create new DrawingView for DrawingModel
66      drawingView = new DrawingView( drawingModel );
67
68      // register DrawingInternalFrame as a DrawingModel Observer
69      drawingModel.addObserver( this );
70
71      // MyShapeControllerFactory for creating MyShapeControllers
72      shapeControllerFactory =
73          MyShapeControllerFactory.getInstance();
74
75      // create DragAndDropController for drag and drop operations
76      dragAndDropController =
77          new DragAndDropController( drawingModel );
78
79      // get default DragSource for current platform
80      DragSource dragSource = DragSource.getDefaultDragSource();
81
82      // create DragGestureRecognizer to register
83      // DragAndDropController as DragGestureListener
84      dragSource.createDefaultDragGestureRecognizer( drawingView,
85          DnDConstants.ACTION_COPY_OR_MOVE,
86          dragAndDropController );
87
88      // enable drawingView to accept drop operations, using
89      // dragAndDropController as DropTargetListener
90      drawingView.setDropTarget( new DropTarget( drawingView,
91          DnDConstants.ACTION_COPY_OR_MOVE,
92          dragAndDropController ) );
93
94      // add drawingView to viewPanel, put viewPanel in
95      // JScrollPane and add JScrollPane to DrawingInternalFrame
96      JPanel viewPanel = new JPanel();
97      viewPanel.add( drawingView );
98      getContentPane().add( new JScrollPane( viewPanel ),
99          BorderLayout.CENTER );
100
101     // create fileChooser and set its FileFilter
102     fileChooser = new JFileChooser();
103     fileChooser.setFileFilter( new DrawingFileFilter() );
104
105     // show/hide ZoomDialog when frame activated/deactivated
106     addInternalFrameListener(
107         new InternalFrameAdapter() {
108
109             // when DrawingInternalFrame activated, make
110             // associated zoomDialog visible
111             public void internalFrameActivated(
112                 InternalFrameEvent event )
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 3 of 15).

```
113         {
114             if ( zoomDialog != null )
115                 zoomDialog.setVisible( true );
116         }
117
118         // when DrawingInternalFrame is deactivated, make
119         // associated zoomDialog invisible
120         public void internalFrameDeactivated(
121             InternalFrameEvent event )
122         {
123             if ( zoomDialog != null )
124                 zoomDialog.setVisible( false );
125         }
126     }
127
128 ); // end call to addInternalFrameListener
129
130 // stagger each DrawingInternalFrame to prevent it from
131 // obscuring other InternalFrames
132 setLocation( xOffset * openFrameCount,
133               yOffset * openFrameCount );
134
135 // add new DrawingToolBar to NORTH area
136 toolBar = new DrawingToolBar();
137 getContentPane().add( toolBar, BorderLayout.NORTH );
138
139 // get name of first MyShape that shapeControllerFactory
140 // supports and create MyShapeController
141 String shapeName =
142     shapeControllerFactory.getSupportedShapes()[ 0 ];
143
144 setMyShapeController(
145     shapeControllerFactory.newMyShapeController(
146         drawingModel, shapeName ) );
147
148 // set DrawingInternalFrame size
149 setSize( 500, 320 );
150
151 } // end DrawingInternalFrame constructor
152
153 // get DrawingInternalFrame Save Action
154 public Action getSaveAction()
155 {
156     return saveAction;
157 }
158
159 // get DrawingInternalFrame Save As Action
160 public Action getSaveAsAction()
161 {
162     return saveAsAction;
163 }
164
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 4 of 15).

```
165     // set Saved flag for current drawing and update frame
166     // title to indicate saved state to user
167     public void setSaved( boolean drawingSaved )
168     {
169         // set Saved property
170         saved = drawingSaved;
171
172         // get current DrawingInternalFrame title
173         String title = getTitle();
174
175         // if drawing is not saved and title does not end with
176         // an asterisk, add asterisk to title
177         if ( !title.endsWith( " *" ) && !isSaved() )
178             setTitle( title + " *" );
179
180         // if title ends with * and drawing has been saved,
181         // remove * from title
182         else
183
184             if ( title.endsWith( " *" ) && isSaved() )
185                 setTitle( title.substring( 0,
186                     title.length() - 2 ) );
187
188         // enable save actions if drawing not saved
189         getSaveAction().setEnabled( !isSaved() );
190     }
191
192     // return value of saved property
193     public boolean isSaved()
194     {
195         return saved;
196     }
197
198     // handle updates from DrawingModel
199     public void update( Observable observable, Object object )
200     {
201         // set saved property to false to indicate that
202         // DrawingModel has changed
203         setSaved( false );
204     }
205
206     // set fileName for current drawing
207     public void setFileName( String file )
208     {
209         fileName = file;
210
211         // update DrawingInternalFrame title
212         setTitle( fileName );
213     }
214
215     // get fileName for current drawing
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 5 of 15).

```
216     public String getFileName()
217     {
218         return fileName;
219     }
220
221     // get full path (absoluteFilePath) for current drawing
222     public String getAbsoluteFilePath()
223     {
224         return absoluteFilePath;
225     }
226
227     // set full path (absoluteFilePath) for current drawing
228     public void setAbsoluteFilePath( String path )
229     {
230         absoluteFilePath = path;
231     }
232
233     // get DrawingModel for current drawing
234     public DrawingModel getModel()
235     {
236         return drawingModel;
237     }
238
239     // set JInternalFrame and ZoomDialog titles
240     public void setTitle( String title )
241     {
242         super.setTitle( title );
243
244         if ( zoomDialog != null )
245             zoomDialog.setTitle( title );
246     }
247
248     // set MyShapeController for handling user input
249     public void setMyShapeController(
250         MyShapeController controller )
251     {
252         // remove old MyShapeController
253         if ( myShapeController != null ) {
254
255             // remove mouse listeners
256             drawingView.removeMouseListener(
257                 myShapeController.getMouseListener() );
258
259             drawingView.removeMouseMotionListener(
260                 myShapeController.getMouseMotionListener() );
261         }
262
263         // set MyShapeController property
264         myShapeController = controller;
265
266         // register MyShapeController to handle mouse events
267         drawingView.addMouseListener(
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 6 of 15).

```
268         myShapeController.getMouseListener() );
269
270     drawingView.addMouseListener(
271         myShapeController.getMouseMotionListener() );
272
273     // update new MyShapeController with currently selected
274     // drawing properties (stroke size, color, fill, etc.)
275     myShapeController.setStrokeSize( toolBar.getStrokeSize() );
276
277     myShapeController.setPrimaryColor(
278         toolBar.getPrimaryColor() );
279
280     myShapeController.setSecondaryColor(
281         toolBar.getSecondaryColor() );
282
283     myShapeController.setDragMode( toolBar.getDragMode() );
284
285     myShapeController.setShapeFilled(
286         toolBar.getShapeFilled() );
287
288     myShapeController.setUseGradient(
289         toolBar.getUseGradient() );
290
291 } // end method setMyShapeController
292
293 // close DrawingInternalFrame; return false if drawing
294 // was not saved and user canceled the close operation
295 public boolean close()
296 {
297     // if drawing not saved, prompt user to save
298     if ( !isSaved() ) {
299
300         // display JOptionPane confirmation dialog to allow
301         // user to save drawing
302         int response = JOptionPane.showInternalConfirmDialog(
303             this, "The drawing in this window has been " +
304             "modified. Would you like to save changes?", "Save Changes",
305             JOptionPane.YES_NO_CANCEL_OPTION,
306             JOptionPane.QUESTION_MESSAGE );
307
308         // if user selects Yes, save drawing and close
309         if ( response == JOptionPane.YES_OPTION ) {
310             saveDrawing();
311             dispose();
312
313             // return true to indicate frame closed
314             return true;
315         }
316
317         // if user selects No, close frame without saving
318         else if ( response == JOptionPane.NO_OPTION ) {
319             dispose();
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 7 of 15).

```
320         return true;
321     }
322
323     // if user selects Cancel, do not save or close
324     else
325         return false; // indicate frame was not closed
326     }
327
328     // if drawing has been saved, close frame
329     else {
330         dispose();
331         return true;
332     }
333
334 } // end method close
335
336 // open existing drawing from file
337 public boolean openDrawing()
338 {
339     // open JFileChooser Open dialog
340     int response = fileChooser.showOpenDialog( this );
341
342     // if user selected valid file, open an InputStream
343     // and retrieve the saved shapes
344     if ( response == fileChooser.APPROVE_OPTION ) {
345
346         // get selecte file name
347         String fileName =
348             fileChooser.getSelectedFile().getAbsolutePath();
349
350         // get shapes List from file
351         Collection shapes =
352             DrawingFileReaderWriter.readFile( fileName );
353
354         // set shapes in DrawingModel
355         drawingModel.setShapes( shapes );
356
357         // set fileName property
358         setFileName( fileChooser.getSelectedFile().getName() );
359
360         // set absoluteFilePath property
361         setAbsoluteFilePath( fileName );
362
363         // set saved property
364         setSaved( true );
365
366         // return true to indicate successful file open
367         return true;
368     }
369
370     // return false to indicate file open failed
371     else
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 8 of 15).

```
372         return false;
373     } // end method openDrawing
375
376     // save current drawing to file
377     public void saveDrawing()
378     {
379         // get absolute path to which file should be saved
380         String fileName = getAbsolutePath();
381
382         // if fileName is null or empty, call saveDrawingAs
383         if ( fileName == null || fileName.equals( "" ) )
384             saveDrawingAs();
385
386         // write drawing to given fileName
387         else {
388             DrawingFileReaderWriter.writeFile( drawingModel,
389                 fileName );
390
391             // update saved property
392             setSaved( true );
393         }
394
395     } // end method saveDrawing
396
397     // prompt user for file name and save drawing
398     public void saveDrawingAs()
399     {
400         // display JFileChooser Save dialog
401         int response = fileChooser.showSaveDialog( this );
402
403         // if user selected a file, save drawing
404         if ( response == fileChooser.APPROVE_OPTION )
405         {
406             // set absoluteFilePath property
407             setAbsolutePath(
408                 fileChooser.getSelectedFile().getAbsolutePath() );
409
410             // set fileName property
411             setFileName( fileChooser.getSelectedFile().getName() );
412
413             // write drawing to file
414             DrawingFileReaderWriter.writeFile( drawingModel,
415                 getAbsolutePath() );
416
417             // update saved property
418             setSaved( true );
419         }
420
421     } // end method saveDrawingAs
422
423     // display zoomDialog
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 9 of 15).

```
424     public void showZoomDialog()
425     {
426         // if zoomDialog is null, create one
427         if ( zoomDialog == null )
428             zoomDialog = new ZoomDialog( getModel(), getTitle() );
429
430         // make extant zoomDialog visible
431         else
432             zoomDialog.setVisible( true );
433     }
434
435     // dispose DrawingInternalFrame
436     public void dispose()
437     {
438         // dispose associated zoomDialog
439         if ( zoomDialog != null )
440             zoomDialog.dispose();
441
442         super.dispose();
443     }
444
445     // JToolBar subclass for DrawingInternalFrame
446     private class DrawingToolBar extends JToolBar {
447
448         // user interface components
449         private GradientIcon gradientIcon;
450         private JPanel primaryColorPanel, secondaryColorPanel;
451         private JButton primaryColorButton;
452         private JButton secondaryColorButton;
453         private JComboBox shapeChoice, strokeSizeChoice;
454         private JToggleButton gradientButton, fillButton;
455         private JToggleButton moveButton;
456
457         // DrawingToolBar constructor
458         public DrawingToolBar()
459         {
460             // create JComboBox for choosing current shape type
461             shapeChoice = new JComboBox(
462                 shapeControllerFactory.getSupportedShapes() );
463             shapeChoice.setToolTipText( "Choose Shape" );
464
465             // when shapeChoice changes, get new MyShapeController
466             // from MyShapeControllerFactory
467             shapeChoice.addActionListener(
468                 new ActionListener() {
469
470                     public void actionPerformed( ActionEvent event )
471                     {
472                         // get selected shape type
473                         String className =
474                             shapeChoice.getSelectedItem().toString();
475
476                     }
477                 }
478             );
479         }
480
481         // ...
482     }
483 }
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 10 of 15).

```
476             setMyShapeController(
477                 shapeControllerFactory.newMyShapeController(
478                     drawingModel, className ) );
479         }
480     }
481 }
482 ); // end call to addActionListener
483
484 // create JComboBox for selecting stroke size
485 strokeSizeChoice = new JComboBox(
486     new String[] { "1.0", "2.0", "3.0", "4.0", "5.0",
487         "6.0", "7.0", "8.0", "9.0", "10.0" } );
488
489 strokeSizeChoice.setToolTipText( "Choose Line Width" );
490
491 // set stroke size property to selected value
492 strokeSizeChoice.addActionListener(
493     new ActionListener() {
494
495         public void actionPerformed( ActionEvent event )
496         {
497             myShapeController.setStrokeSize(
498                 getStrokeSize() );
499         }
500     }
501 );
502
503 // create JToggleButton for filling shapes
504 fillButton = new JToggleButton( "Fill" );
505
506 fillAction = new AbstractDrawingAction( "Fill", null,
507     "Fill Shape", new Integer( 'L' ) ) {
508
509     public void actionPerformed( ActionEvent event )
510     {
511         myShapeController.setShapeFilled(
512             getShapeFilled() );
513     }
514 };
515
516 fillButton.setAction( fillAction );
517
518 // create GradientIcon to display gradient settings
519 gradientIcon = new GradientIcon( Color.black,
520     Color.white );
521
522 // create JToggleButton to enable/disable gradients
523 gradientButton = new JToggleButton( gradientIcon );
524
525 gradientAction = new AbstractDrawingAction( "",
526     gradientIcon, "Use Gradient", new Integer( 'G' ) ) {
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 11 of 15).

```
528         public void actionPerformed( ActionEvent event )
529     {
530         myShapeController.setUseGradient(
531             getUseGradient() );
532     }
533 };
534
535 gradientButton.setAction( gradientAction );
536
537 // create JPanel to display primary drawing color
538 primaryColorPanel = new JPanel();
539 primaryColorPanel.setPreferredSize(
540     new Dimension( 16, 16 ) );
541 primaryColorPanel.setOpaque( true );
542 primaryColorPanel.setBackground( Color.black );
543
544 // create JButton for changing color1
545 primaryColorButton = new JButton();
546 primaryColorButton.add( primaryColorPanel );
547
548 // display JColorChooser for selecting startColor value
549 primaryColorButton.addActionListener(
550     new ActionListener() {
551
552         public void actionPerformed( ActionEvent event )
553     {
554         Color color = JColorChooser.showDialog(
555             DrawingInternalFrame.this, "Select Color",
556             primaryColorPanel.getBackground() );
557
558         if ( color != null ) {
559             primaryColorPanel.setBackground( color );
560             gradientIcon.setStartColor( color );
561             myShapeController.setPrimaryColor( color );
562         }
563     }
564
565     } // end ActionListener inner class
566
567 ); // end call to addActionListener
568
569 // create JPanel to display secondary drawing color
570 secondaryColorPanel = new JPanel();
571 secondaryColorPanel.setPreferredSize(
572     new Dimension( 16, 16 ) );
573 secondaryColorPanel.setOpaque( true );
574 secondaryColorPanel.setBackground( Color.white );
575
576 // create JButton for changing secondary color
577 secondaryColorButton = new JButton();
578 secondaryColorButton.add( secondaryColorPanel );
579
```

Fig. 5.23 `DrawingInternalFrame` class that provides a user interface for creating drawings (part 12 of 15).

```
580 // display JColorChooser for selecting endColor value
581 secondaryColorButton.addActionListener(
582     new ActionListener() {
583
584         public void actionPerformed( ActionEvent event )
585         {
586             Color color = JColorChooser.showDialog(
587                 DrawingInternalFrame.this, "Select Color",
588                 secondaryColorPanel.getBackground() );
589
590             if ( color != null ) {
591                 secondaryColorPanel.setBackground( color );
592                 gradientIcon.setEndColor( color );
593                 myShapeController.setSecondaryColor(
594                     color );
595             }
596         }
597     }
598 } // end ActionListener inner class
599
600 ); // end call to addActionListener
601
602 // create Action for saving drawings
603 Icon saveIcon = new ImageIcon(
604     DrawingInternalFrame.class.getResource(
605         "images/save.gif" ) );
606
607 saveAction = new AbstractDrawingAction( "Save", saveIcon,
608     "Save Drawing", new Integer( 'S' ) ) {
609
610     public void actionPerformed( ActionEvent event )
611     {
612         saveDrawing();
613     }
614 };
615
616 // create action for saving drawings as given file name
617 Icon saveAsIcon = new ImageIcon(
618     DrawingInternalFrame.class.getResource(
619         "images/saveAs.gif" ) );
620
621 saveAsAction = new AbstractDrawingAction( "Save As",
622     saveAsIcon, "Save Drawing As", new Integer( 'A' ) ) {
623
624     public void actionPerformed( ActionEvent event )
625     {
626         saveDrawingAs();
627     }
628 };
629
630 // create action for displaying zoomDialog
631 Icon zoomIcon = new ImageIcon(
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 13 of 15).

```
632         DrawingInternalFrame.class.getResource(
633             "images/zoom.gif" ) );
634
635     zoomAction = new AbstractDrawingAction( "Zoom", zoomIcon,
636             "Show Zoom Window", new Integer( 'Z' ) ) {
637
638         public void actionPerformed( ActionEvent event )
639         {
640             showZoomDialog();
641         }
642     };
643
644     // create JToggleButton for setting drag and drop mode
645     moveButton = new JToggleButton();
646
647     Icon moveIcon = new ImageIcon(
648         DrawingInternalFrame.class.getResource(
649             "images/move.gif" ) );
650
651     moveAction = new AbstractDrawingAction( "Move", null,
652             "Move Shape", new Integer( 'M' ) ) {
653
654         public void actionPerformed( ActionEvent event )
655         {
656             myShapeController.setDragMode(
657                 getDragMode() );
658
659             dragAndDropController.setDragMode(
660                 getDragMode() );
661         }
662     };
663
664     moveButton.setAction( moveAction );
665
666     // add Actions, buttons, etc. to JToolBar
667     add( saveAction );
668     add( saveAsAction );
669     addSeparator();
670     add( zoomAction );
671     addSeparator();
672     add( shapeChoice );
673     add( strokeSizeChoice );
674     addSeparator();
675     add( primaryColorButton );
676     add( secondaryColorButton );
677     addSeparator();
678     add( gradientButton );
679     add( fillButton );
680     addSeparator();
681     add( moveButton );
682
683     // disable floating
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 14 of 15).

```
684         setFloatable( false );
685
686     } // end DrawingToolBar constructor
687
688     // get currently selected stroke size
689     public float getStrokeSize()
690     {
691         Object selectedItem = strokeSizeChoice.getSelectedItem();
692
693         return Float.parseFloat( selectedItem.toString() );
694     }
695
696     // get current shape filled value
697     public boolean getShapeFilled()
698     {
699         return fillButton.isSelected();
700     }
701
702     // get current use gradient property
703     public boolean getUseGradient()
704     {
705         return gradientButton.isSelected();
706     }
707
708     // get primary drawing Color
709     public Color getPrimaryColor()
710     {
711         return primaryColorPanel.getBackground();
712     }
713
714     // get secondary drawing Color
715     public Color getSecondaryColor()
716     {
717         return secondaryColorPanel.getBackground();
718     }
719
720     // get current drag mode
721     public boolean getDragMode()
722     {
723         return moveButton.isSelected();
724     }
725
726 } // end DrawingToolBar inner class
727 }
```

Fig. 5.23 **DrawingInternalFrame** class that provides a user interface for creating drawings (part 15 of 15).

Each **DrawingInternalFrame** has a **DrawingModel**, **DrawingView**, **MyShapeController** and **DragAndDropController** (lines 36–39). These objects implement the model-view-controller architecture in the Deitel Drawing application. The **DrawingInternalFrame**'s **DrawingView** displays the drawing contained in the associated **DrawingModel**.

Lines 76–92 enable drag and drop in the **DrawingInternalFrame**. Lines 76–77 create a **DragAndDropController**, which controls drag-and-drop operations. Line 80 invokes static method **getDefaultValue** of class **DragSource** to get the host platform's default **DragSource** object. Lines 84–86 invoke method **createDefaultDragGestureRecognizer** of class **DragSource** to register the **DragAndDropController** as the listener for drag gestures that occur inside the **DrawingView**. This enables the **DragAndDropController** to recognize user gestures to drag **MyShapes** in a drawing. Lines 90–92 invoke method **setDropTarget** of class **DrawingView** to enable the **DrawingView** to accept dropped objects, such as **TransferableShapes** from other drawings or JPEG images from the host operating system's file manager.

Each **DrawingInternalFrame** has an associated **ZoomDialog** that displays a scaled view of the **DrawingModel**. Lines 106–128 create an **InternalFrameListener** that makes the **ZoomDialog** visible when the **DrawingInternalFrame** is activated (lines 111–116) and hides the **ZoomDialog** when the **DrawingInternalFrame** is deactivated (lines 120–125). This ensures that the proper **ZoomDialog** will be displayed when the user switches between **DrawingInternalFrames** in the multiple-document interface.

Recall that the Deitel Drawing application uses a **MyShapeControllerFactory** to create **MyShapeControllers** that handle user input. Lines 141–146 set a **MyShapeController** for the **DrawingInternalFrame**. Line 142 invokes method **getSupportedShapes** of class **MyShapeControllerFactory** to determine for which types of shapes the **MyShapeControllerFactory** can provide **MyShapeControllers**. Lines 141–142 assign the zeroth supported shape to reference **shapeName**. Lines 144–146 invoke **MyShapeControllerFactory** method **newMyShapeController** to obtain an appropriate **MyShapeController** for **shapeName**, and set the **DrawingInternalFrame**'s **MyShapeController**.

Class **DrawingInternalFrame** implements interface **Observer**, so the **DrawingModel** can notify the **DrawingInternalFrame** of changes. When **DrawingInternalFrame** receives an update indicating the **DrawingModel** has changed, method **update** (lines 199–204) invokes method **setSaved** (lines 167–190) with argument **false**. If property **saved** is **false**, method **setSaved** adds an asterisk to the **DrawingInternalFrame**'s title to give the user a visual cue that indicates that the drawing has been modified. If property **saved** is **true**—which indicates that the drawing has not been modified since it was last saved—lines 185–186 remove the asterisk from the **DrawingInternalFrame**'s title. If the drawing has been saved, line 189 disables the **saveAction**. When the drawing is modified, line 189 enables the **saveAction**, which allows the user to save the drawing.

Method **setMyShapeController** (lines 249–291) sets the **MyShapeController** object for controlling mouse input. Lines 253–261 remove the previous **MouseListener** and **MouseMotionListener** from the **DrawingView**. Lines 264–289 register the new **MyShapeController**'s **MouseListener** and **MouseMotionListener** and configure the **MyShapeController** with the currently selected stroke size, colors, drag mode, fill and gradient.

Method **close** (lines 295–334) closes the **DrawingInternalFrame** and prompts the user to save the drawing if the **DrawingModel** has been modified since the last save. Lines 302–306 prompt the user to save an unsaved drawing. If the user selects **Yes**, lines

310–314 save the drawing, invoke method **dispose** to close the **DrawingInternalFrame** and return **true** to indicate that the frame closed successfully. If the user selects **No**, line 319 invokes method **dispose** without saving the drawing, and returns **true** to indicate that the frame closed successfully. If the user selects **Cancel**, the drawing is not saved and line 325 returns **false** to indicate that the **DrawingInternalFrame** was not closed. If the drawing has not been modified since the last save, lines 330–331 invoke method **dispose** and return **true**.

Method **openDrawing** (lines 337–374) opens an existing drawing from the file system. Line 340 displays a **JFileChooser** open dialog. Lines 347–352 get the selected file name and invoke static method **readFile** of class **DrawingFileReaderWriter** to read the **Collection** of shapes from the file.

Method **saveDrawing** (lines 377–395) saves the current drawing. If the drawing does not have an associated file name, line 384 invokes method **saveDrawingAs**. If the drawing does have an associated file name, lines 388–389 invoke static method **writeFile** of class **DrawingFileReaderWriter** to save the drawing. Method **saveDrawingAs** (lines 398–421) displays a **JFileChooser** save dialog to prompt the user for a file in which to save the drawing. Lines 414–415 invoke static method **writeFile** of class **DrawingFileReaderWriter** to save the drawing.

Inner class **DrawingToolBar** (lines 446–726) provides GUI components for saving drawings, selecting the **MyShape** type to draw, and modifying the current **MyShapeController**'s properties, including the stroke size, colors, drag mode, fill mode and gradient. Lines 461–462 populate the **shapeChoice JComboBox** with the array of shape types that the **MyShapeControllerFactory** supports. When the user selects a shape type from **shapeChoice**, lines 477–478 invoke **MyShapeControllerFactory** method **newMyShapeController** to obtain an appropriate **MyShapeController** for the specified shape type. Lines 476–478 invoke method **setMyShapeController** to specify the **MyShapeController** with which the **DrawingInternalFrame** should process user input.

When the user changes the **DrawingInternalFrame**'s state by selecting a new type of shape to draw, that change in state also causes a change in the **DrawingInternalFrame**'s behavior. For example, if the user changes the **MyShapeController** reference from an instance of class **MyTextController** to an instance of class **MyLineController**, the **DrawingInternalFrame** no longer behaves in the same way. Now when the user presses the mouse button and drags the mouse, the **DrawingInternalFrame** draws lines instead of text. This is an example of the *State design pattern*, which enables an object to change its behavior when that object's state changes. Using the State design pattern becomes beneficial when we add new states (i.e., **MyShapeController** subclasses) to our system—we create an additional **MyShapeController** subclass (e.g., **RandomMyShapeController** in Exercise 5.8) that encapsulates **DrawingInternalFrame**'s behavior when occupying that state.

Lines 485–501 create a **JComboBox** for selecting the stroke size for shapes. Lines 504–516 create a **JToggleButton** and **Action** for creating filled shapes. Lines 519–535 create a **JToggleButton** and **Action** for creating shapes that use gradients. Lines 538–600 create **JButtons** for selecting the **startColor** and **endColor** for shapes. Each **JButton** contains a **JPanel** that displays the currently selected color. When clicked, the **ActionListener** for each **JButton** displays a **JColorChooser** dialog

that enables the user to select a new color. Lines 603–642 create **Actions** for saving drawings and displaying a **DrawingInternalFrame**'s associated **ZoomDialog** (Fig. 5.25). Lines 645–662 create a **JToggleButton** and **Action** for enabling drag mode, which allows users to drag shapes from this **DrawingInternalFrame**'s **DrawingView**.

Class **DrawingFileFilter** (Fig. 5.24) is a **FileFilter** implementation that enables a **JFileChooser** dialog to show only those files appropriate for our application. Line 15 specifies a description for Deitel Drawing files. Line 8 specifies the filename extension for Deitel Drawing files. Method **accept** (lines 27–31) returns true only if the given **File** matches the filename extension for Deitel Drawing files.

## 5.8 ZoomDialog, Action and Icon Components

Class **ZoomDialog** (Fig. 5.25) is a **JDialog** subclass that uses class **ZoomDrawingView** (Fig. 5.13) to present a scalable **DrawingModel** view. As the user resizes the **ZoomDialog**, the **ZoomDrawingView** adjusts its scale factors to scale to the appropriate size. Note that **ZoomDialog** is a *non-modal dialog* (i.e., the user does not need to close the dialog to continue working with the main portion of the application).

```
1 // DrawingFileFilter.java
2 // DrawingFileFilter is a FileFilter subclass for selecting
3 // DeitelDrawing files in a JFileChooser dialog.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.io.File;
8
9 // Java extension packages
10 import javax.swing.filechooser.*;
11
12 public class DrawingFileFilter extends FileFilter {
13
14     // String to use in JFileChooser description
15     private String DESCRIPTION = "DeitelDrawing Files (*.dd)";
16
17     // file extensions for DeitelDrawing files
18     private String EXTENSION = ".dd";
19
20     // get description for DeitelDrawing files
21     public String getDescription()
22     {
23         return DESCRIPTION;
24     }
25
26     // return true if given File has proper extension
27     public boolean accept( File file )
28     {
29         return ( file.getName().toLowerCase().endsWith(
30             EXTENSION ) );
```

Fig. 5.24 **DrawingFileFilter** is a **FileFilter** subclass that enables users to select Deitel Drawing files from **JFileChooser** dialogs (part 1 of 2).

```
31     }
32 }
```

Fig. 5.24 **DrawingFileFilter** is a **FileFilter** subclass that enables users to select Deitel Drawing files from **JFileChooser** dialogs (part 2 of 2).

```
1 // ZoomDialog.java
2 // ZoomDialog is a JDialog subclass that shows a zoomed view
3 // of a DrawingModel.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 // Deitel packages
14 import com.deitel.advjhtp1.drawing.model.*;
15 import com.deitel.advjhtp1.drawing.view.*;
16
17 public class ZoomDialog extends JDialog {
18
19     private ZoomDrawingView drawingView;
20     private double zoomFactor = 0.5;
21
22     // ZoomDialog constructor
23     public ZoomDialog( DrawingModel model, String title )
24     {
25         // set ZoomDialog title
26         setTitle( title );
27
28         // create ZoomDrawingView for using default zoomFactor
29         drawingView = new ZoomDrawingView( model, zoomFactor );
30
31         // add ZoomDrawingView to ContentPane
32         getContentPane().add( drawingView );
33
34         // size ZoomDialog to fit ZoomDrawingView's preferred size
35         pack();
36
37         // make ZoomDialog visible
38         setVisible( true );
39     }
40
41     // set JDialog title
42     public void setTitle( String title )
43     {
44         super.setTitle( title + " [Zoom]" );
45     }
46 }
```

Fig. 5.25 **ZoomDialog** for displaying **DrawingModel**s in a scalable view.

Class **AbstractDrawingAction** is an abstract base class that extends class **AbstractAction** to provide a more convenient way to create Swing **Actions**. The **AbstractDrawingAction** constructor (lines 16–24) takes as arguments the name, **Icon**, description and mnemonic for the **Action**. Lines 27–48 define *set* methods for each **Action** property. Method **actionPerformed** (line 52) is marked **abstract** to require an implementation in each subclass.

```
1 // AbstractDrawingAction.java
2 // AbstractDrawingAction is an Action implementation that
3 // provides set and get methods for common Action properties.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.awt.event.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public abstract class AbstractDrawingAction
13     extends AbstractAction {
14
15     // construct AbstractDrawingAction with given name, icon
16     // description and mnemonic key
17     public AbstractDrawingAction( String name, Icon icon,
18         String description, Integer mnemonic )
19     {
20         setName( name );
21         setSmallIcon( icon );
22         setShortDescription( description );
23         setMnemonic( mnemonic );
24     }
25
26     // set Action name
27     public void setName( String name )
28     {
29         putValue( Action.NAME, name );
30     }
31
32     // set Action Icon
33     public void setSmallIcon( Icon icon )
34     {
35         putValue( Action.SMALL_ICON, icon );
36     }
37
38     // set Action short description
39     public void setShortDescription( String description )
40     {
41         putValue( Action.SHORT_DESCRIPTION, description );
42     }
43
```

Fig. 5.26 **AbstractDrawingAction** abstract base class for **Actions** (part 1 of 2).

```
44     // set Action mnemonic key
45     public void setMnemonic( Integer mnemonic )
46     {
47         putValue( Action.MNEMONIC_KEY, mnemonic );
48     }
49
50     // abstract actionPerformed method to be implemented
51     // by concrete subclasses
52     public abstract void actionPerformed( ActionEvent event );
53 }
```

Fig. 5.26 **AbstractDrawingAction** abstract base class for **Actions** (part 2 of 2).

Class **GradientIcon** implements interface **Icon** and draws a gradient from **startColor** (line 15) to **endColor** (line 16). The Deitel Drawing application uses a **GradientIcon** to show a preview of the currently selected colors drawn as a gradient. Method **paintIcon** (lines 62–75) draws a filled rectangle, using a Java2D **GradientPaint** and the **GradientIcon**'s **startColor** and **endColor**.

```
1 // GradientIcon.java
2 // GradientIcon is an Icon implementation that draws a 16 x 16
3 // gradient from startColor to endColor.
4 package com.deitel.advjhtp1.painting;
5
6 // Java core packages
7 import java.awt.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class GradientIcon implements Icon {
13
14     // Colors to use for gradient
15     private Color startColor;
16     private Color endColor;
17
18     // GradientIcon constructor
19     public GradientIcon( Color start, Color end )
20     {
21         setStartColor( start );
22         setEndColor( end );
23     }
24
25     // set gradient start color
26     public void setStartColor( Color start )
27     {
28         startColor = start;
29     }
30 }
```

Fig. 5.27 **GradientIcon** implementation of interface **Icon** that draws a gradient (part 1 of 2).

```
31     // get gradient start color
32     public Color getStartColor()
33     {
34         return startColor;
35     }
36
37     // set gradient end color
38     public void setEndColor( Color end )
39     {
40         endColor = end;
41     }
42
43     // get gradient end color
44     public Color getEndColor()
45     {
46         return endColor;
47     }
48
49     // get icon width
50     public int getIconWidth()
51     {
52         return 16;
53     }
54
55     // get icon height
56     public int getIconHeight()
57     {
58         return 16;
59     }
60
61     // draw icon at given location on given component
62     public void paintIcon( Component component, Graphics g,
63                           int x, int y )
64     {
65         // get Graphics2D object
66         Graphics2D g2D = ( Graphics2D ) g;
67
68         // set GradientPaint
69         g2D.setPaint ( new GradientPaint( x, y,
70                                         getStartColor(), 16, 16,
71                                         getEndColor() ) );
72
73         // fill rectangle with gradient
74         g2D.fillRect( x, y, 16, 16 );
75     }
76 }
```

GradientIcon in a  
JToggleButton.

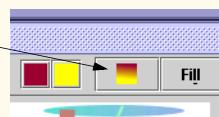


Fig. 5.27 **GradientIcon** implementation of interface **Icon** that draws a gradient (part 2 of 2).

## 5.9 DeitelDrawing Application

Class **DeitelDrawing** (Fig. 5.28) integrates the components we have discussed in this chapter into a multiple-document-interface application. The Deitel Drawing application displays the Deitel logo in a **SplashScreen** (Fig. 5.29) while the application loads (line 44). Lines 60–111 create **AbstractDrawingActions** for creating new drawings, opening existing drawings, exiting the application and displaying information about the Deitel Drawing application.

```
1 // DeitelDrawing.java
2 // DeitelDrawing is a drawing program that uses, MVC, a
3 // multiple-document interface and Java2D.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.awt.*;
10 import java.awt.event.*;
11 import java.beans.*;
12
13 // Java extension packages
14 import javax.swing.*;
15 import javax.swing.event.*;
16 import javax.swing.border.*;
17
18 public class DeitelDrawing extends JFrame {
19
20     private JMenuBar menuBar;
21     private JMenu fileMenu, helpMenu;
22
23     private Action newAction, openAction,
24         exitAction, aboutAction;
25
26     private JMenuItem saveMenuItem, saveAsMenuItem;
27
28     private JToolBar toolBar;
29     private JPanel toolBarPanel, frameToolBarPanel;
30     private JDesktopPane desktopPane;
31
32     private SplashScreen splashScreen;
33
34     // DeitelDrawing constructor
35     public DeitelDrawing()
36     {
37         super( "DeitelDrawing" );
38
39         // set icon for JFrame's upper-left-hand corner
40         ImageIcon icon = new ImageIcon(
41             DeitelDrawing.class.getResource( "images/icon.png" ) );
42         setIconImage( icon.getImage() );
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 1 of 8).

```
43     showSplashScreen();
44
45     // do not hide window when close button clicked
46     setDefaultCloseOperation(
47         WindowConstants.DO_NOTHING_ON_CLOSE );
48
49
50     // create JDesktopPane for MDI
51     desktopPane = new JDesktopPane();
52
53     // show contents when dragging JInternalFrames
54     desktopPane.setDragMode( JDesktopPane.LIVE_DRAG_MODE );
55
56     // create Action for creating new drawings
57     Icon newIcon = new ImageIcon(
58         DeitelDrawing.class.getResource( "images/new.gif" ) );
59
60     newAction = new AbstractDrawingAction( "New", newIcon,
61         "Create New Drawing", new Integer( 'N' ) ) {
62
63         public void actionPerformed( ActionEvent event )
64         {
65             createNewWindow();
66         }
67     };
68
69     // create Action for opening existing drawings
70     Icon openIcon = new ImageIcon(
71         DeitelDrawing.class.getResource( "images/open.gif" ) );
72
73     openAction = new AbstractDrawingAction( "Open", openIcon,
74         "Open Existing Drawing", new Integer( 'O' ) ) {
75
76         public void actionPerformed( ActionEvent event )
77         {
78             DrawingInternalFrame frame = createNewWindow();
79
80             if ( !frame.openDrawing() )
81                 frame.close();
82         }
83     };
84
85     // create Action for exiting application
86     Icon exitIcon = new ImageIcon(
87         DeitelDrawing.class.getResource( "images/exit.gif" ) );
88
89     exitAction = new AbstractDrawingAction( "Exit", exitIcon,
90         "Exit Application", new Integer( 'X' ) ) {
91
92         public void actionPerformed( ActionEvent event )
93         {
94             exitApplication();
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 2 of 8).

```
95         }
96     };
97
98     // create Action for opening About dialog
99     Icon aboutIcon = new ImageIcon(
100         DeitelDrawing.class.getResource( "images/about.gif" ) );
101
102    aboutAction = new AbstractDrawingAction( "About",
103        aboutIcon, "About Application", new Integer( 'b' ) ) {
104
105        public void actionPerformed( ActionEvent event )
106        {
107            JOptionPane.showMessageDialog( DeitelDrawing.this,
108                "DeitelDrawing v1.0.\nCopyright " +
109                "2002. Deitel & Associates, Inc." );
110        }
111    };
112
113    // create File menu and set its mnemonic
114    fileMenu = new JMenu( "File" );
115    fileMenu.setMnemonic( 'F' );
116
117    // create Help menu and set its mnemonic
118    helpMenu = new JMenu( "Help" );
119    helpMenu.setMnemonic( 'H' );
120
121    menuBar = new JMenuBar();
122
123    // add New Drawing and Open Drawing actions to
124    // File menu and remove their icons
125    fileMenu.addAction().setIcon( null );
126    fileMenu.add( openAction ).setIcon( null );
127
128    // create JMenuItems for saving drawings; these
129    // JMenuItems will invoke the save Actions for the
130    // current DrawingInternalFrame
131    saveMenuItem = new JMenuItem( "Save" );
132    saveAsMenuItem = new JMenuItem( "Save As" );
133
134    // add Save, Save As and Close JMenuItems to File menu
135    fileMenu.add( saveMenuItem );
136    fileMenu.add( saveAsMenuItem );
137
138    fileMenu.addSeparator();
139
140    // add Exit action to File menu and remove its icon
141    fileMenu.add( exitAction ).setIcon( null );
142
143    // add About action to Help menu and remove its icon
144    helpMenu.add( aboutAction ).setIcon( null );
145
146    // add File and Help menus to JMenuBar
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 3 of 8).

```
147     menuBar.add( fileMenu );
148     menuBar.add( helpMenu );
149
150     // set Frame's JMenuBar
151     setJMenuBar( menuBar );
152
153     // create application JToolBar
154     toolBar = new JToolBar();
155
156     // disable JToolBar floating
157     toolBar.setFloatable( false );
158
159     // add New Drawing and Open Drawing actions to JToolBar
160     toolBar.addAction( newAction );
161     toolBar.addAction( openAction );
162
163     toolBar.addSeparator();
164
165     // add Exit action to JToolBar
166     toolBar.addAction( exitAction );
167
168     toolBar.addSeparator();
169
170     // add About action to JToolBar
171     toolBar.addAction( aboutAction );
172
173     // add toolBar and desktopPane to ContentPane
174     getContentPane().add( toolBar, BorderLayout.NORTH );
175     getContentPane().add( desktopPane, BorderLayout.CENTER );
176
177     // add WindowListener for windowClosing event
178     addWindowListener(
179         new WindowAdapter() {
180
181             public void windowClosing( WindowEvent event )
182             {
183                 exitApplication();
184             }
185         });
186
187
188     // wait for SplashScreen to go away
189     while ( splashScreen.isVisible() ) {
190
191         try {
192             Thread.sleep( 10 );
193         }
194
195         // handle exception
196         catch ( InterruptedException interruptedException ) {
197             interruptedException.printStackTrace();
198         }
199     }
200 }
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 4 of 8).

```
199      }
200
201      // set initial JFrame size
202      setSize( 640, 480 );
203
204      // position application window
205      centerWindowOnScreen();
206
207      // make application visible
208      setVisible( true );
209
210      // create new, empty drawing window
211      createNewWindow();
212
213 } // end DeitelDrawing constructor
214
215 // create new DrawingInternalFrame
216 private DrawingInternalFrame createNewWindow()
217 {
218     // create new DrawingInternalFrame
219     DrawingInternalFrame frame =
220         new DrawingInternalFrame( "Untitled Drawing" );
221
222     // add listener for InternalFrame events
223     frame.addInternalFrameListener(
224         new DrawingInternalFrameListener() );
225
226     // make DrawingInternalFrame opaque
227     frame.setOpaque( true );
228
229     // add DrawingInternalFrame to desktopPane
230     desktopPane.add( frame );
231
232     // make DrawingInternalFrame visible
233     frame.setVisible( true );
234
235     // select new DrawingInternalFrame
236     try {
237         frame.setSelected( true );
238     }
239
240     // handle exception selecting DrawingInternalFrame
241     catch ( PropertyVetoException vetoException ) {
242         vetoException.printStackTrace();
243     }
244
245     // return reference to newly created DrawingInternalFrame
246     return frame;
247 }
248
249 // InternalFrameAdapter to listen for InternalFrame events
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 5 of 8).

```
250    private class DrawingInternalFrameListener
251        extends InternalFrameAdapter {
252
253            // when DrawingInternalFrame is closing disable
254            // appropriate Actions
255            public void internalFrameClosing(
256                InternalFrameEvent event )
257            {
258                DrawingInternalFrame frame =
259                    ( DrawingInternalFrame ) event.getSource();
260
261                // frame closes successfully, disable Save menu items
262                if ( frame.close() ) {
263                    saveMenuItem.setAction( null );
264                    saveAsMenuItem.setAction( null );
265                }
266            }
267
268            // when DrawingInternalFrame is activated, make its JToolBar
269            // visible and set JMenuItems to DrawingInternalFrame Actions
270            public void internalFrameActivated(
271                InternalFrameEvent event )
272            {
273                DrawingInternalFrame frame =
274                    ( DrawingInternalFrame ) event.getSource();
275
276                // set saveMenuItem to DrawingInternalFrame's saveAction
277                saveMenuItem.setAction( frame.getSaveAction() );
278                saveMenuItem.setIcon( null );
279
280                // set saveAsMenuItem to DrawingInternalFrame's
281                // saveAsAction
282                saveAsMenuItem.setAction( frame.getSaveAsAction() );
283                saveAsMenuItem.setIcon( null );
284            }
285        }
286
287        // close each DrawingInternalFrame to let user save drawings
288        // then exit application
289        private void exitApplication()
290        {
291            // get array of JInternalFrames from desktopPane
292            JInternalFrame frames[] = desktopPane.getAllFrames();
293
294            // keep track of DrawingInternalFrames that do not close
295            boolean allFramesClosed = true;
296
297            // select and close each DrawingInternalFrame
298            for ( int i = 0; i < frames.length; i++ ) {
299                DrawingInternalFrame nextFrame =
300                    ( DrawingInternalFrame ) frames[ i ];
301
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 6 of 8).

```
302         // select current DrawingInternalFrame
303         try {
304             nextFrame.setSelected( true );
305         }
306
307         // handle exception when selecting DrawingInternalFrame
308         catch ( PropertyVetoException vetoException ) {
309             vetoException.printStackTrace();
310         }
311
312         // close DrawingInternalFrame and update allFramesClosed
313         allFramesClosed = allFramesClosed && nextFrame.close();
314     }
315
316         // exit application only if all frames were closed
317         if ( allFramesClosed )
318             System.exit( 0 );
319
320     } // end method exitApplication
321
322     // display application's splash screen
323     public void showSplashScreen()
324     {
325         // create ImageIcon for logo
326         Icon logoIcon = new ImageIcon(
327             getClass().getResource( "images/deitellogo.png" ) );
328
329         // create new JLabel for logo
330         JLabel logoLabel = new JLabel( logoIcon );
331
332         // set JLabel background color
333         logoLabel.setBackground( Color.white );
334
335         // set splash screen border
336         logoLabel.setBorder(
337             new MatteBorder( 5, 5, 5, 5, Color.black ) );
338
339         // make logoLabel opaque
340         logoLabel.setOpaque( true );
341
342         // create SplashScreen for logo
343         splashScreen = new SplashScreen( logoLabel );
344
345         // show SplashScreen for 3 seconds
346         splashScreen.showSplash( 3000 );
347
348     } // end method showSplashScreen
349
350     // center application window on user's screen
351     private void centerWindowOnScreen()
352     {
353         // get Dimension of user's screen
```

Fig. 5.28 **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 7 of 8).

```

354     Dimension screenDimension =
355         Toolkit.getDefaultToolkit().getScreenSize();
356
357     // use screen width and height and application width
358     // and height to center application on user's screen
359     int width = getSize().width;
360     int height = getSize().height;
361     int x = ( screenDimension.width - width ) / 2 ;
362     int y = ( screenDimension.height - height ) / 2 ;
363
364     // place application window at screen's center
365     setBounds( x, y, width, height );
366 }
367
368 // execute application
369 public static void main( String args[] )
370 {
371     new DeitelDrawing();
372 }
373 }
```

**Fig. 5.28** **DeitelDrawing** application that uses a multiple-document interface for displaying and modifying **DeitelDrawing** drawings (part 8 of 8).

Method **createNewWindow** (lines 216–247) creates a new **DrawingInternalFrame**. Inner class **DrawingInternalFrameListener** (lines 250–285) listens for **internalFrameClosing** and **internalFrameActivated** messages. The Deitel Drawing application’s **File** menu contains **JMenuItem**s for saving the currently active drawing. When a **DrawingInternalFrame** closes, lines 263–264 remove that **DrawingInternalFrame**’s **saveAction** and **saveAsAction** from **saveMenuItem** and **saveAsMenuItem**. When a **DrawingInternalFrame** is activated, lines 277–283 invoke method **setAction** of class **JMenuItem** to set the **Actions** for **saveMenuItem** and **saveAsMenuItem**.

Method **exitApplication** (lines 289–320) prompts the user to save any unsaved drawings before the application exits. Line 292 invokes method **getAllFrames** of class **JDesktopPane** to retrieve an array of **JInternalFrames** in the application. Line 313 invokes method **close** of class **DrawingInternalFrame** to attempt to close each **DrawingInternalFrame** in the array. Method **close** returns **true** if the **DrawingInternalFrame** closed successfully, **false** otherwise. Line 313 accumulates the results of closing each **DrawingInternalFrame** in **boolean allFramesClosed**. If all **DrawingInternalFrames** close successfully, line 318 exits the application. If any **DrawingInternalFrame** did not close, the application assumes that the user cancelled the request to close the application.

The Deitel Drawing application displays the Deitel logo in a **SplashScreen** (Fig. 5.29) while the application loads. The **SplashScreen** constructor (lines 19–58) takes as an argument the **Component** to display. Line 22 creates **JWindow** (a borderless window) in which to display the given component. Lines 46–56 center the **SplashScreen**’s **JWindow** on the user’s screen.

```
1 // SplashScreen.java
2 // SplashScreen implements static method showSplash for
3 // displaying a splash screen.
4 package com.deitel.advjhtp1.drawing;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class SplashScreen {
14
15     private JWindow window;
16     private Timer timer;
17
18     // SplashScreen constructor
19     public SplashScreen( Component component )
20     {
21         // create new JWindow for splash screen
22         window = new JWindow();
23
24         // add provided component to JWindow
25         window.getContentPane().add( component );
26
27         // allow user to dismiss SplashScreen by clicking mouse
28         window.addMouseListener(
29
30             new MouseAdapter() {
31
32                 // when user presses mouse in SplashScreen,
33                 // hide and dispose JWindow
34                 public void mousePressed( MouseEvent event ) {
35                     window.setVisible( false );
36                     window.dispose();
37                 }
38             }
39
40         ); // end call to addMouseListener
41
42         // size JWindow for given Component
43         window.pack();
44
45         // get user's screen size
46         Dimension screenDimension =
47             Toolkit.getDefaultToolkit().getScreenSize();
48
49         // calculate x and y coordinates to center splash screen
50         int width = window.getSize().width;
51         int height = window.getSize().height;
52         int x = ( screenDimension.width - width ) / 2 ;
```

Fig. 5.29 **SplashScreen** class for displaying a logo while the application loads (part 1 of 2).

```
53     int y = ( screenDimension.height - height ) / 2 ;
54
55     // set the bounds of the window to center it on screen
56     window.setBounds( x, y, width, height );
57
58 } // end SplashScreen constructor
59
60 // show splash screen for given delay
61 public void showSplash( int delay ) {
62
63     // display the window
64     window.setVisible( true );
65
66     // create and start a new Timer to remove SplashScreen
67     // after specified delay
68     timer = new Timer( delay,
69         new ActionListener() {
70
71             public void actionPerformed( ActionEvent event )
72             {
73                 // hide and dispose of window
74                 window.setVisible( false );
75                 window.dispose();
76                 timer.stop();
77             }
78         }
79     );
80
81     timer.start();
82
83 } // end method showSplash
84
85 // return true if SplashScreen window is visible
86 public boolean isVisible()
87 {
88     return window.isVisible();
89 }
90 }
```



Fig. 5.29 **SplashScreen** class for displaying a logo while the application loads (part 2 of 2).

Method **showSplash** (lines 61–83) takes as an integer argument the number of milliseconds for which to display the **SplashScreen**. Line 64 makes the **JWindow** visible, and line 51 causes the current **Thread** to sleep for the given **delay**. After the **delay** expires, lines 60–61 hide and **dispose** of the **JWindow**.

In this chapter, we presented a substantial application that used the MVC architecture and many popular design patterns, including Observer, Factory Method, Template Method, State and Command. We also demonstrated how applications can store and retrieve information in XML documents. Our drawing application takes advantage of the rich set of GUI components offered by Swing and the powerful drawing capabilities offered by Java 2D. Drag-and-drop functionality enables users to transfer shapes between drawings and add their own images.

Throughout the rest of the book, we use design patterns and the MVC architecture to build substantial examples and case studies. For example, the Enterprise Java case study of Chapters 17–20 presents an online bookstore that uses the MVC architecture.

### SELF-REVIEW EXERCISES

- 5.1 Which part of the model-view-controller architecture processes user input? Which Deitel Drawing classes implement this part of MVC?
- 5.2 What interface must a class implement to enable data transfer using drag and drop for instances of that class?
- 5.3 In general, how does a user begin a drag-and-drop operation? Give an example.
- 5.4 What type of object notifies a **DragGestureListener** that the user made a drag gesture?
- 5.5 How can a **DropTargetListener** or **DragSourceListener** determine what type of data a **Transferable** object contains?

### ANSWERS TO SELF-REVIEW EXERCISES

- 5.1 The controller in MVC processes user input. In the Deitel Drawing application, **MyShapeController** subclasses process user input via the mouse. Class **DragAndDropController** processes user input via drag-and-drop operations.
- 5.2 A class that supports drag and drop must implement interface **Transferable**.
- 5.3 A user begins a drag-and-drop operation by making a drag gesture. For example, on the Windows platform, a user makes a drag gesture by pressing the mouse button on a draggable object and dragging the mouse.
- 5.4 A **DragGestureRecognizer** issues a **DragGestureEvent** to notify a **DragGestureListener** that the user made a drag gesture.
- 5.5 Method **getTransferDataFlavors** of interface **Transferable** returns an array of **DataFlavor** objects. Each **DataFlavor** has a MIME type that describes the type of data the **Transferable** object supports.

### EXERCISES

- 5.6 Create class **RotatingDrawingView** that extends class **DrawingView** and uses Java 2D transformations (Chapter 4) to display the drawing rotated by ninety degrees.
- 5.7 Modify your solution to Exercise 5.6 to use a and a **java.awt.Timer** to continually rotate the drawing in five-degree increments.

**5.8** Create class **RandomMyShapeController** that extends class **MyShapeController** and adds random **MyShape** subclasses with random sizes, colors and other properties to the **DrawingModel**. In method **startShape**, class **RandomMyShapeController** should prompt the user for the number of random shapes to add to the drawing. Create a new **MyShapeControllerFactory** subclass (Fig. 5.18) named **RandomMyShapeControllerFactory** that constructs a **RandomMyShapeController** when the **String "Random"** is passed to method **newMyShapeController**. [Hint: Be sure to override method **getSupportedShapes** of class **MyShapeControllerFactory** to return a **String** array that includes the **String "Random"**.]

# 6

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# JavaBeans Component Model

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## Objectives

- To understand JavaBeans and how they facilitate component-oriented software construction.
- To be able to use Forte for Java Community Edition to build JavaBeans-based applications.
- To be able to wrap class definitions as JAR files for use as JavaBeans and stand-alone applications.
- To be able to define JavaBean properties and events.

*Mirrors should reflect a little before throwing back images.*  
Jean Cocteau

*Television is like the invention of indoor plumbing. It didn't change people's habits. It just kept them inside the house.*  
Alfred Hitchcock

*The power of the visible is the invisible.*

Marianne Moore

*The sun has a right to "set" where it wants to, and so, I may add, has a hen.*

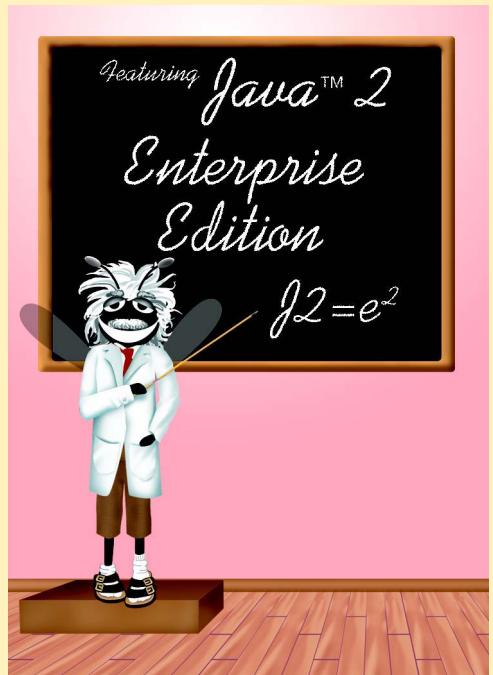
Charles Farrar Browne

*The causes of events are ever more interesting than the events themselves.*

Marcus Tullius Cicero

*...the mechanic that would perfect his work must first sharpen his tools.*

Confucius



## Outline

- 
- 6.1 Introduction**
  - 6.2 Using Beans in Forte for Java Community Edition**
  - 6.3 Preparing a Class to be a JavaBean**
  - 6.4 Creating a JavaBean: Java Archive Files**
  - 6.5 JavaBean Properties**
  - 6.6 Bound Properties**
  - 6.7 Indexed Properties and Custom Events**
  - 6.8 Customizing JavaBeans for Builder Tools**
    - 6.8.1 PropertyEditors**
    - 6.8.2 Customizers**
  - 6.9 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 6.1 Introduction

This chapter presents Java’s reusable software component model: *JavaBeans*. JavaBeans (often called *beans*) allow developers to reap the benefits of rapid application development in Java by assembling predefined software components to create powerful applications and applets. *Graphical programming and design environments* (often called *builder tools*, *IDEs* or *integrated development environments*) that support beans provide programmers with tremendous flexibility by allowing programmers to reuse and integrate existing disparate components that, in many cases, were never intended to be used together. These components can be linked together to create applets, applications or even new beans for reuse by others.

JavaBeans and other component-based technologies have led to a new type of programmer, the *component assembler*, who uses well-defined components to create more robust functionality. Component assemblers do not need to know the implementation details of components. Rather, they need to know what services the components provide, so they can have other components interact with them.

As an example of the concept of beans, assume that a component assembler has an animation bean that has methods to **startAnimation** and **stopAnimation**. The component assembler may want to provide two buttons, one that will start the animation and one that will stop the animation (an example you will see later in this chapter). With beans, we can simply “connect” one button to the animation’s **startAnimation** method and connect another button to the animation’s **stopAnimation** method, such that when the user clicks a button, the appropriate method of the animation bean is called. The builder tool does all the work of associating the button-click event with the appropriate method to call on the animation bean. All the programmer needs to do is tell the builder tool which two components to “connect.”

The benefit of beans in this example is that the animation bean and the button beans do not need to know about each other before they are assembled in a builder tool. Someone else can be responsible for defining the concept of a button in a reusable manner (e.g.,

**javax.swing.JButton**). A button is not specific to our example. Rather, it is a component used in many applications and applets. When the user of a program clicks a button, the user expects an action specific to that program to occur. (Some buttons, such as **OK** buttons, typically have the same meaning in all programs.) However, the basic concept of a button—how it is displayed, how it works and how it notifies other components that it was clicked—is the same in every application (although we typically customize the button’s label). The component assembler’s job is not to create the concept of a button, but rather to use the preexisting button component to provide functionality to the user of the program.

Component assemblers can make beans communicate through the beans’ well-defined services (i.e., methods), typically without writing any code (the builder tool often generates the code, which is sometimes hidden from the component assembler—depending on the tool). Indeed, a component assembler often can create complex applications literally by “connecting the dots.”

In this chapter, we show you how to use existing beans and how to create your own basic beans. After studying this chapter, you will have a foundation in JavaBeans programming that will enable you to develop applications and applets rapidly using the more advanced features of integrated development environments that support beans. You will also have a solid foundation for further study of JavaBeans.

For more JavaBeans information, visit the Sun Microsystems Web site for JavaBeans:

**[java.sun.com/beans/](http://java.sun.com/beans/)**

This site provides a complete set of resources for learning about and using JavaBeans.

## 6.2 Using Beans in Forte for Java Community Edition

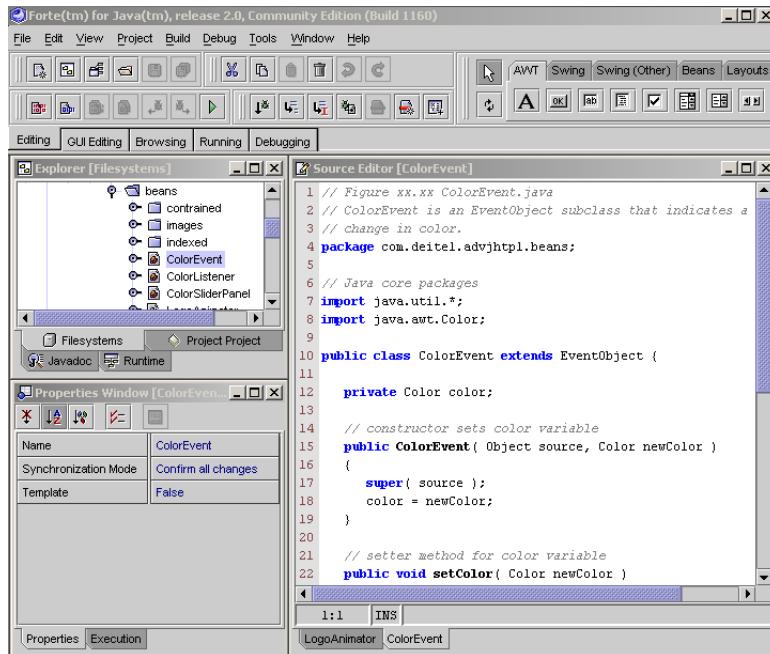
Sun Microsystem’s *Forte for Java Community Edition* (Fig. 6.1) is an integrated development environment that provides a builder tool for assembling JavaBeans. Forte provides visual access to a variety of JavaBeans and allows you to install and manipulate additional beans. In this section, we demonstrate how to use existing beans in Forte. Later in the chapter, we rely on your knowledge of this section to use the beans created in this chapter. We assume you are already familiar with the basic operation of *Forte*. For details on getting started with *Forte*, visit the resources for this book on our Web site, **[www.deitel.com](http://www.deitel.com)**. There, we have a “Getting Started with *Forte for Java Community Edition 2.0*” tutorial.

### Software Engineering Observation 6.1

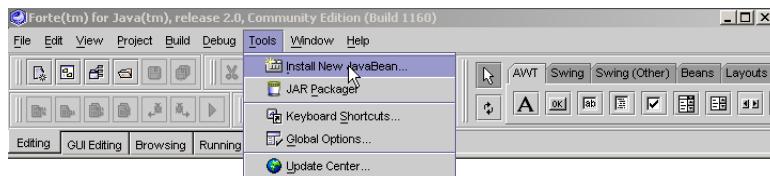


A benefit of working in a bean-ready development environment is that the environment visually presents the properties of the bean to the programmer for easy modification and customization of the bean at design time.

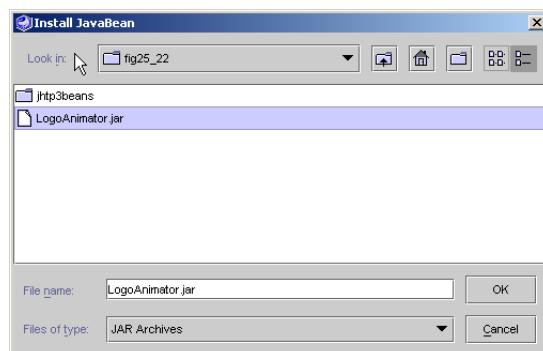
A bean must be installed before it is manipulated in Forte. Click the **Tools** menu and select **Install New JavaBean...** (Fig. 6.2). A file dialog box labelled **Install JavaBean** appears (Fig. 6.3). Copy **LogoAnimator.jar** from the CD-ROM that accompanies this book. The next dialog box lists the JavaBeans within the selected JAR file (Fig. 6.4). Select **LogoAnimator** and click the **OK** button (Fig. 6.4). Select **Beans** in the **Palette Category** dialog box that appears next and click **OK** (Fig. 6.4). Clicking the **Beans** tab in the **Component Palette** shows a question mark icon (Fig. 6.5). Moving the mouse over the icon in the **Component Palette** displays a tool tips showing that the icon represents the **LogoAnimator** JavaBean (Fig. 6.5).



**Fig. 6.1** Forte for Java Community Edition 2.0.



**Fig. 6.2** Install New JavaBean... menu item.



**Fig. 6.3** Install JavaBean dialog.

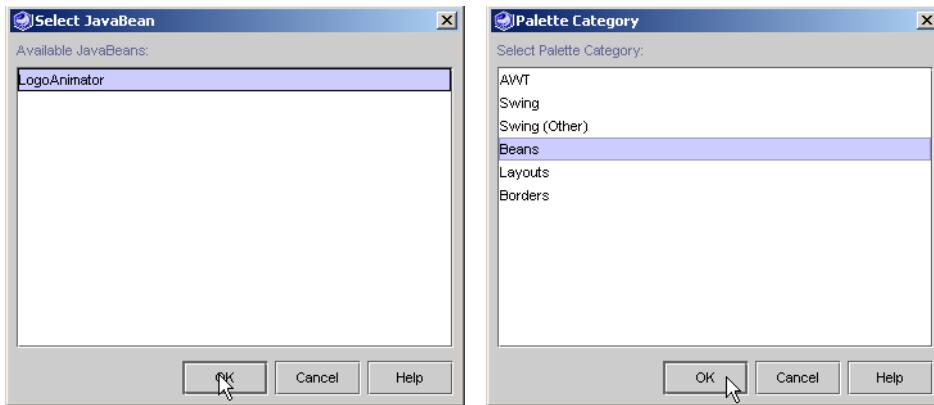


Fig. 6.4 Select JavaBean and Palette Category dialogs.

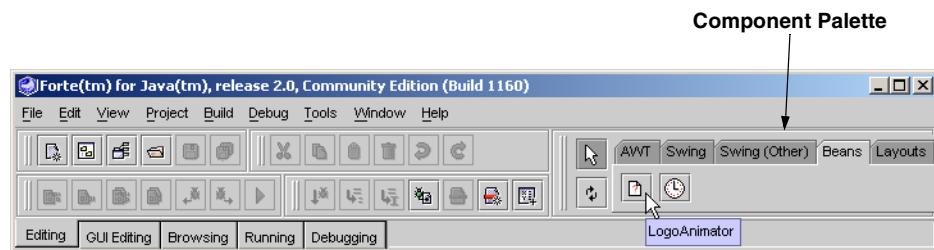


Fig. 6.5 Beans tab in the Component Palette and tooltip for LogoAnimator JavaBean.

GUI JavaBeans must be added to a Java **Container** to be able to use the builder tool to edit the bean properties or to link the beans to other components. To demonstrate adding and manipulating JavaBeans, we open a **JFrame**. Select the **Filesystems** tab in the **Explorer** window (Fig. 6.6). Select the **Development** directory (Fig. 6.7). Select **New...** from the **File** menu (Fig. 6.8). In the **Template Chooser** (Fig. 6.9), expand the **Swing Forms** option and select **JFrame**. Enter “**AnimationWindow**” in the **Name:** field (Fig. 6.9). Click **Finish** to create the new **JFrame**.



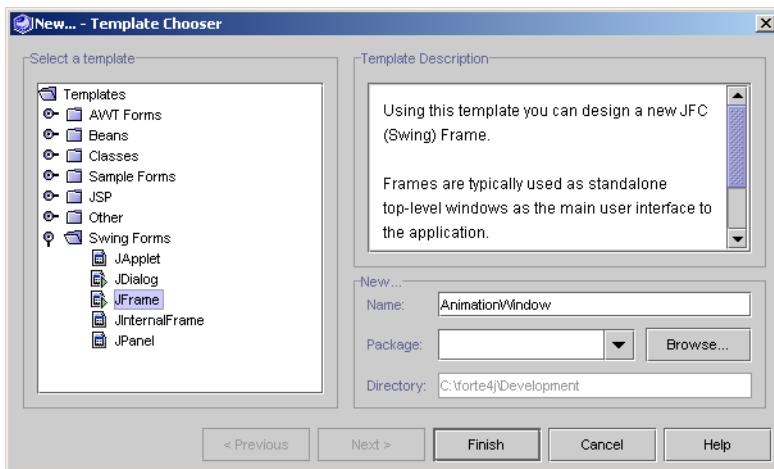
Fig. 6.6 Filesystems tab in the Explorer window.



**Fig. 6.7** Development directory selected in **Explorer** window.



**Fig. 6.8** New... menu item.



**Fig. 6.9** New... - Template Chooser dialog.

The new **AnimationWindow** class appears inside the **Filesystems** field of the **Explorer**. The **Component Inspector**, **Form** and **Source Editor** windows should all appear (Fig. 6.10). The **Component Inspector** (Fig. 6.11) lists all the visual and nonvisual components within **AnimationWindow** and also shows the property sheet for selected components (we will discuss the property sheet later). The **Form** window (Fig. 6.11) shows the **JFrame** with its current layout and components. The **Source**

**Editor** (Fig. 6.12) shows the Java source code Forte generates. Forte updates this code as components and events are added, deleted and changed.

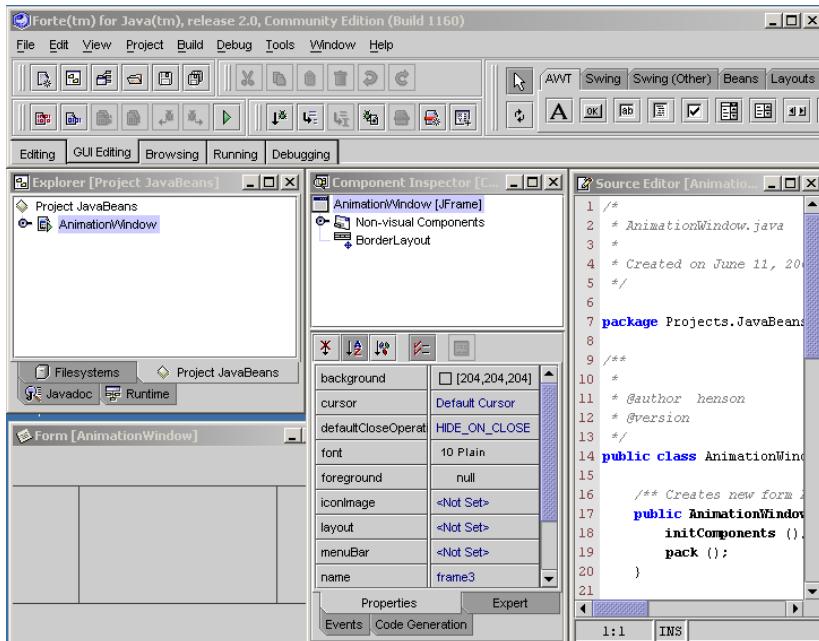


Fig. 6.10 GUI Editing tab of Forte.

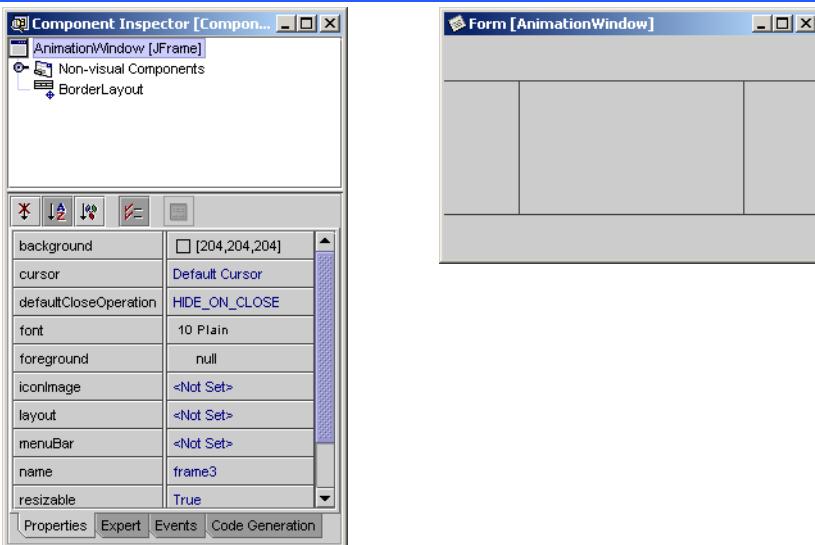
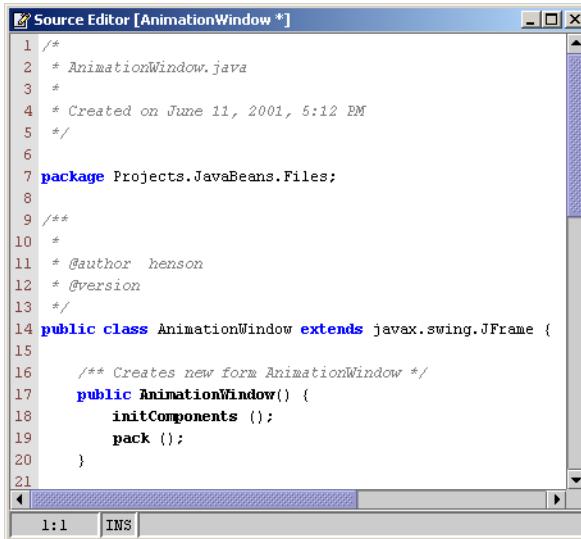


Fig. 6.11 Component Inspector and Form windows.



**Fig. 6.12** Source Editor window.

We now begin building the application by placing the **LogoAnimator** JavaBean we just imported into the **AnimationWindow**. Click the **Beans** tab of the **Component Palette** (Fig. 6.13). Next, click the **LogoAnimator** icon (Fig. 6.14). Then, click in the **Form** window in the center of the **JFrame**. A spinning animation of the Deitel and Associates, Inc., logo will appear in the window (Fig. 6.15).



**Fig. 6.13** Beans tab of the Component Palette.



**Fig. 6.14** LogoAnimator icon.



Fig. 6.15 **LogoAnimator** animation in the **Form** window.

The property sheet in the **Component Inspector** displays a component's properties and allows them to be edited. Click the **LogoAnimator** in the **Form** window. Blue squares appear at the corners of the animation to show it is selected (Fig. 6.15). The **Component Inspector** shows all the **LogoAnimator** properties (Fig. 6.16). Many of the properties are inherited from **JPanel**, the superclass of **LogoAnimator**. The **background** property shows a swatch of color and a name indicating the **LogoAnimator** background color. Click the color, and a drop-down menu appears (Fig. 6.17). It lists some of the predefined colors in Java. Select the first color listed in the drop-down menu to change the **LogoAnimator**'s background to white (Fig. 6.18). Try selecting other colors to get used to changing JavaBean properties.

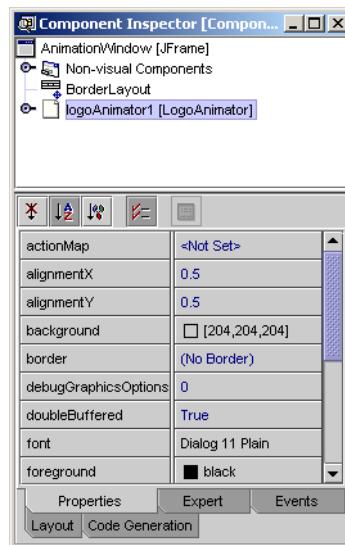


Fig. 6.16 **Component Inspector** with **LogoAnimator** Properties sheet.

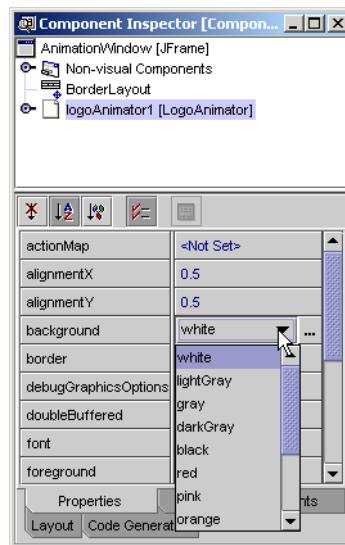


Fig. 6.17 Component Inspector drop down-menu for the **background** property.

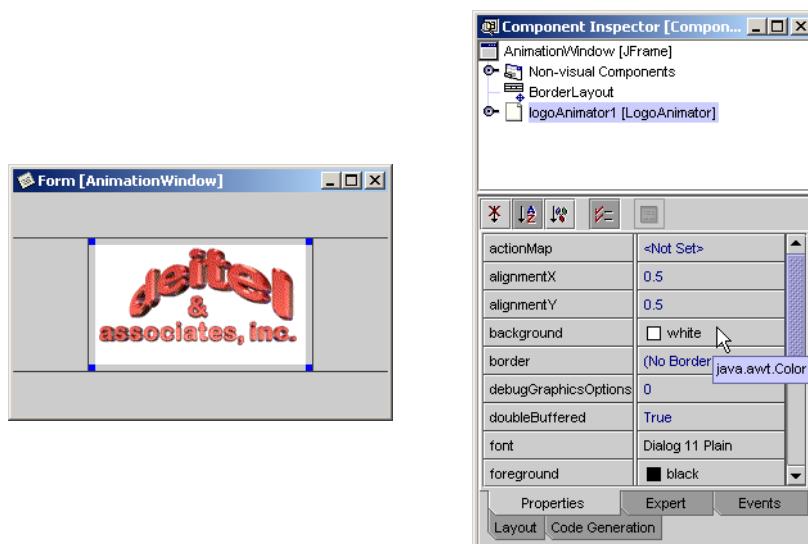


Fig. 6.18 Changing **background** color of **LogoAnimator**.

In addition to changing JavaBean properties with the builder tool, component assemblers can connect JavaBeans with events. For instance, a button can control the function of another component. We demonstrate this with buttons that start and stop the **LogoAnimator**'s animation.

Before adding other components to our example, we change the window's layout to a **FlowLayout**. In the **Explorer** window, expand the **AnimationWindow** node (Fig. 6.19). Right click the **JFrame** node, select **Set Layout** and click **FlowLayout** (Fig. 6.20).

Select the **Swing** tab in the **Component Palette** (Fig. 6.21). This tab contains the most common Swing components. The second component in the list is the **JButton** (Fig. 6.22). Click the **JButton** icon, then click an empty spot in the **Form** that contains the **LogoAnimator**. A new **JButton** appears in the window next to the **LogoAnimator** (Fig. 6.23). Select the **JButton** and locate the **text** property in the **Component Inspector**. Click the text field, type **Start Animation** (Fig. 6.24), then press **Enter**. The button text in the **Form** will change to the new value (Fig. 6.24). Repeat this procedure to add another **JButton** with the text **Stop Animation**.

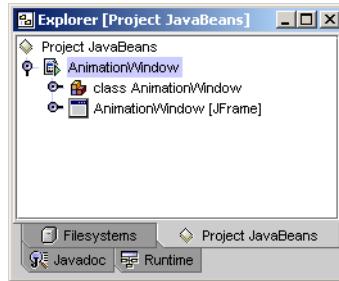


Fig. 6.19 **AnimationWindow** selected in **Explorer**.

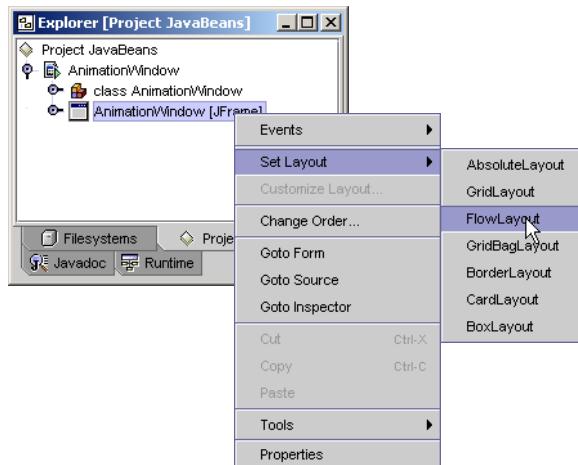


Fig. 6.20 Selecting **FlowLayout** in the **Explorer** menu.



Fig. 6.21 Swing tab of the Component Palette.



Fig. 6.22 JButton icon in the Component Palette.



Fig. 6.23 Adding a JButton to AnimationWindow.

This figure consists of two screenshots of the Forte IDE. On the left, the "Component Inspector" window is open, showing the component tree for "AnimationWindow [JFrame]". It lists "Non-visual Components" (FlowLayout), "logoAnimator1 [LogoAnimator]", and "jButton1 [JButton]". The "jButton1" node is expanded. On the right, the main workspace shows the "Form [AnimationWindow]" window with the JButton. The JButton's text property has been changed to "Start Animation" via the Component Inspector. The "Properties" tab of the Component Inspector is active, displaying the JButton's properties: rolloverSelectedIcon (null), selected (False), selectedIcon (null), text ("Start Animation"), toolTipText (null), UI (&lt;Not Set&gt;), verifyInputWhenFocus (True), verticalAlignment (CENTER), and verticalTextPosition (CENTER). The "Events" tab is also visible at the bottom.

Fig. 6.24 Editing text property of JButton.

Next, we connect the **Start Animation** and **Stop Animation** buttons to the **Logo-Animator** so the user can start and stop the animation. The button with the mouse pointer icon to the left of the **Component Palette** enables **Selection Mode** (Fig. 6.25). This mode enables Forte users to select components in a **Form** window. The button with the double-arrows icon below the **Selection Mode** icon enables **Connection Mode** (Fig. 6.26), which allows Forte users to connect components with a wizard that generates code in the **Source Editor**. Click the **Connection Mode** icon to enter **Connection Mode** (Fig. 6.27). Click the **Start Animation JButton** (Fig. 6.28), which will be the source of the event (i.e., the source component) that starts the animation. Red squares appear at the corners of the **JButton**. Next, click the **LogoAnimator**. Red squares also appear at the corners of **LogoAnimator** and the **Connection Wizard** dialog appears (Fig. 6.29). Step 1 of the **Connection Wizard** lists all the events that the source component supports. In this application, we want the button click event to call the animator's **startAnimation** method, so we need to connect the button's action event to **LogoAnimator**'s **start-Animation** method. Expand the **action** node, highlight **actionPerformed** and click the **Next** button at the bottom of the **Connection Wizard** (Fig. 6.30). Step 2 (Fig. 6.31) lists the methods or properties that can be set on the target component (**LogoAnimator**). Click the **Method Call** radio button to show a list of **LogoAnimator**'s methods. Many of the methods that appear in the list are inherited from **LogoAnimator**'s superclass—**JPanel**. Select method **startAnimation** from the list and click the **Finish** button at the bottom of the **Connection Wizard** (Fig. 6.31). Repeat the above procedure for the **Stop Animation** button, but select method **stopAnimation** in Step 2 of the **Connection Wizard**.

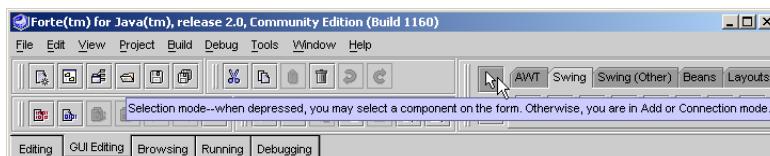


Fig. 6.25 Component Palette Selection mode.



Fig. 6.26 Component Palette Connection mode.



Fig. 6.27 Select Connection mode.



Fig. 6.28 Connecting JButton and LogoAnimator.

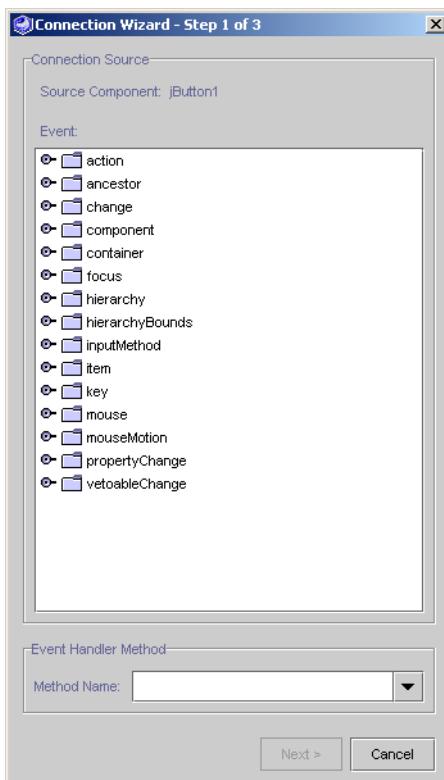


Fig. 6.29 Connection Wizard dialog.

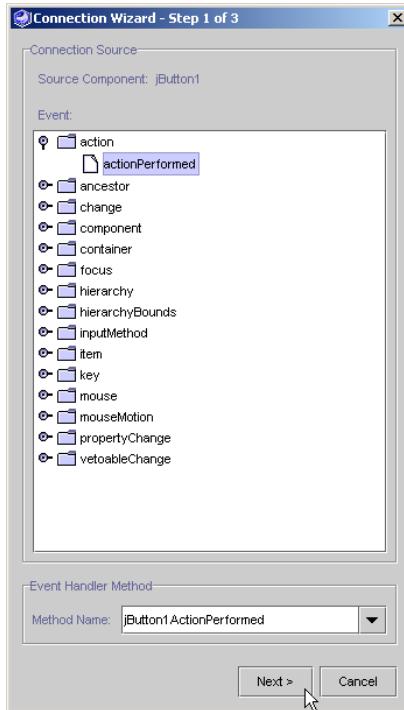


Fig. 6.30 Select **actionPerformed** event.

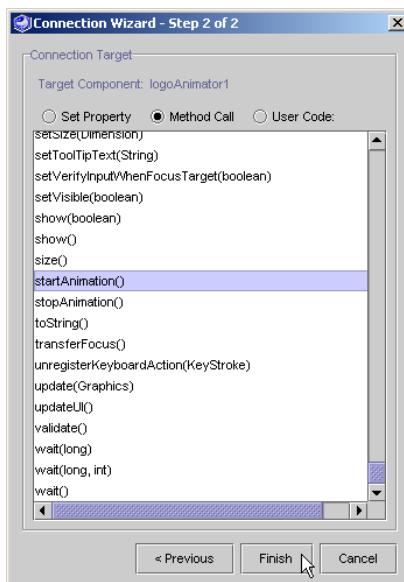


Fig. 6.31 Selecting method **startAnimation** for the target component.

To test that the connections between the buttons and the LogoAnimator work correctly, execute the **AnimationWindow** application by right clicking **AnimationWindow** in the **Explorer** window and selecting **Execute** from the menu (Fig. 6.32). Forte switches to the **Running** tab and displays **AnimationWindow** (Fig. 6.33). **AnimationWindow** contains the **LogoAnimator** and the two **JButtons**. Click the **Stop Animation** button. The Deitel logo in **LogoAnimator** stops. Clicking the **Start Animation** button starts the animation from the point it stopped.



### Testing and Debugging Tip 6.1

*A benefit of working in a bean-ready development environment is that the beans typically execute live in the development environment. This allows you to view your program immediately in the design environment, rather than using the standard edit, compile and execute cycle.*

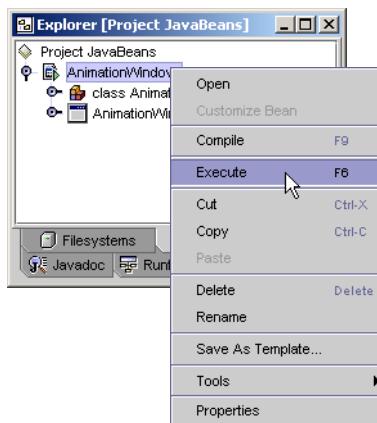


Fig. 6.32 Select **Execute** from **Explorer** menu.

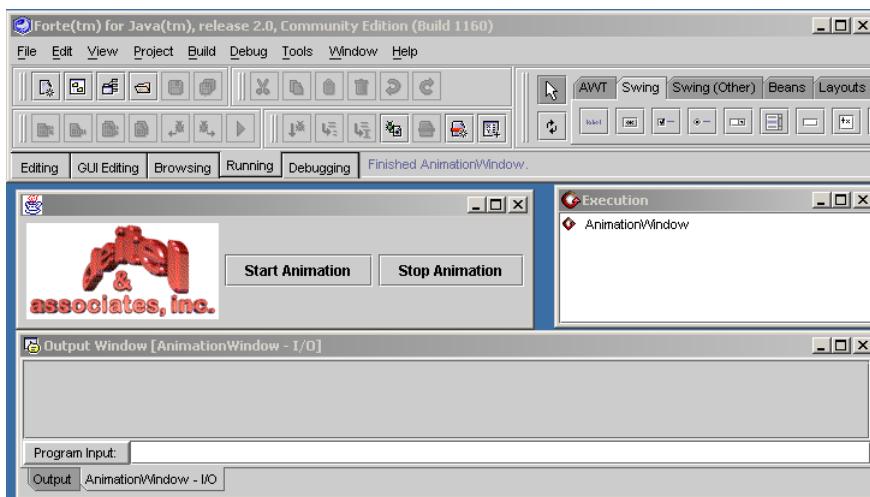


Fig. 6.33 **AnimationWindow** running in **Forte**.

### 6.3 Preparing a Class to be a JavaBean

In the previous section, we introduced the **LogoAnimator** JavaBean to demonstrate the basics of using JavaBeans within the Forte integrated development environment. This section presents the Java code for **LogoAnimator** (Fig. 6.34).

```
1 // Fig. 6.34: LogoAnimator.java
2 // LogoAnimator is a JavaBean containing an animated logo.
3 package com.deitel.advjhtp1.beans;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.event.*;
8 import java.io.*;
9 import java.net.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class LogoAnimator extends JPanel
15     implements ActionListener, Serializable {
16
17     protected ImageIcon images[];
18     protected int totalImages = 30, currentImage;
19     protected Timer animationTimer;
20
21     // load images and start animation
22     public LogoAnimator()
23     {
24         images = new ImageIcon[ totalImages ];
25
26         URL url;
27
28         // load animation frames
29         for ( int i = 0; i < images.length; ++i ) {
30             url = LogAnimator.class.getResource(
31                 "images/deitel" + i + ".png" );
32             images[ i ] = new ImageIcon( url );
33         }
34
35         startAnimation();
36     }
37
38     // render one frame of the animation
39     public void paintComponent( Graphics g )
40     {
41         super.paintComponent( g );
42
43         // draw current animation frame
44         images[ currentImage ].paintIcon( this, g, 0, 0 );
45         currentImage = ( currentImage + 1 ) % totalImages;
46     }
```

Fig. 6.34 Definition of class **LogoAnimator** (part 1 of 3).

```
47
48     // start Timer that drives animation
49     public void startAnimation()
50     {
51         // if animationTimer is null, restart animation
52         if ( animationTimer == null ) {
53             currentImage = 0;
54             animationTimer = new Timer( 50, this );
55             animationTimer.start();
56         }
57     }
58     else // continue from last image displayed
59
60         if ( !animationTimer.isRunning() )
61             animationTimer.restart();
62     }
63
64     // repaint when Timer event occurs
65     public void actionPerformed( ActionEvent actionEvent )
66     {
67         repaint();
68     }
69
70     // stop Timer that drives animation
71     public void stopAnimation()
72     {
73         animationTimer.stop();
74     }
75
76     // get animation preferred width and height
77     public Dimension getPreferredSize()
78     {
79         return new Dimension( 160, 80 );
80     }
81
82     // get animation minimum width and height
83     public Dimension getMinimumSize()
84     {
85         return getPreferredSize();
86     }
87
88     // execute bean as standalone application
89     public static void main( String args[] )
90     {
91         // create new LogoAnimator
92         LogoAnimator animation = new LogoAnimator();
93
94         // create new JFrame with title "Animation test"
95         JFrame application = new JFrame( "Animator test" );
96         application.setDefaultCloseOperation(
97             JFrame.EXIT_ON_CLOSE );
98     }
```

Fig. 6.34 Definition of class **LogoAnimator** (part 2 of 3).

```

99      // add LogoAnimator to JFrame
100     application.getContentPane().add( animation,
101         BorderLayout.CENTER );
102
103     // set the window size and validate layout
104     application.pack();
105     application.setVisible( true );
106   }
107
108 } // end class LogoAnimator

```

Fig. 6.34 Definition of class **LogoAnimator** (part 3 of 3).

Class **LogoAnimator** (Fig. 6.34) implements the **LogoAnimator** JavaBean. **LogoAnimator** extends **JPanel** (line 14), making it a GUI component. Many JavaBeans are GUI components intended to be manipulated visually in a builder tool, such as Forte. In fact, most Java **Swing** components are JavaBeans, such as the **JButtons** we manipulated visually in Forte in the previous section. GUIs using **Swing** components can be developed quickly in Forte and other JavaBean-enabled builder tools.

Class **LogoAnimator** implements interface **Serializable** (line 15). The **Serializable** interface allows an instance of **LogoAnimator** to be saved as a file. By implementing **Serializable**, a customized JavaBean can be saved and reloaded in a builder tool or in a Java application. Forte can save an instance of **LogoAnimator** with the **Serialize As...** option in the **Customize Bean** dialog. **Serializable** objects can be serialized in Java programs with the  **ObjectOutputStream** and **ObjectInputStream** classes.



### Software Engineering Observation 6.2

*JavaBeans must all implement interface **Serializable** to support persistence using standard Java serialization.*

Line 17 declares **ImageIcon** array **images**, which contains the 30 PNG images that comprise the animated logo in **LogoAnimator**. Line 18 declares two integer variables, **totalImages** and **currentImage**. Line 19 declares **animationTimer**, a **Timer** object that controls the animation speed.

Lines 22–36 define **LogoAnimator**'s no-argument constructor. Line 24 initializes array **images** with length **totalImages**. Lines 29–33 load the PNG images into the array. Line 35 invokes method **startAnimation** to start the **LogoAnimator** animation.

**LogoAnimator** overrides method **paintComponent** (lines 39–46), inherited from class **JPanel**. Method **paintComponent** draws **LogoAnimator** whenever it is called. Line 44 calls method **paintIcon** on an **ImageIcon** in array **images**. The **ImageIcon** is at index **currentImage**. This paints one of the animation frames. Line 45 advances the variable **currentImage** to the next animation frame.

Method **startAnimation** (lines 49–62) initializes **animationTimer**, the **Timer** object that controls the delay between animation frames. If **animationTimer** is null, lines 52–56 create a new **Timer** object with a delay of 50 milliseconds. Otherwise, **startAnimation** restarts **animationTimer** on lines 58–61.

**LogoAnimator** implements method **actionPerformed** of interface **ActionListener** on lines 65–68. The **animationTimer** generates an **ActionEvent** at a

rate specified in its constructor argument. When **animationTimer** generates an **ActionEvent**, line 67 calls method **repaint**. Method **repaint**, in turn, calls **paintComponent**, which draws the next animation frame.

Method **stopAnimation** (lines 71–74) calls method **stop** on **animationTimer** (line 73). This stops **animationTimer** from generating **ActionEvents**, which stops the animation.

Method **getPreferredSize** (lines 77–80) returns a **Dimension** object with the preferred size of **LogoAnimator**. Method **getMinimumSize** (line 83–86) simply calls **getPreferredSize**. The **LayoutManager** calls these two methods to determine how to size **LogoAnimator** within the runtime environment.

Method **main** (lines 89–106) allows **LogoAnimator** to be executed as an application. Method **main** creates a new **JFrame** and adds an instance of **LogoAnimator** to the **JFrame**. JavaBeans do not need a **main** method, but the **main** method is needed to execute a JavaBean independently.

**LogoAnimator** can be compiled either from the command line or in Forte. **LogoAnimator** declares a package, so use the **-d** option of the Java compiler to create the proper directory structure. The command line

```
javac -d . LogoAnimator.java
```

compiles **LogoAnimator** and places the package directory in the current directory. The full directory structure for the package is **com\deitel\advjhttp1\beans\** (substitute forward slashes, /, in UNIX/Linux). For **LogoAnimator** to execute properly, the directory **images** with the PNG files used by **LogoAnimator** must be placed in the same directory as class **LogoAnimator** (e.g. **com\deitel\advjhttp1\beans\**). The **images** directory and the **PNG** files for **LogoAnimator** are on the CD-ROM that accompanies this book.

To compile in Forte, open the **LogoAnimator.java** file in Forte, right click in the **Source Editor** window and select **Compile** (Fig. 6.35). Forte compiles the source code and reports any errors in a separate window. Be sure to place the **images** directory in the same directory as **LogoAnimator.class**. **LogoAnimator** will not execute properly without the images.

## 6.4 Creating a JavaBean: Java Archive Files

JavaBeans normally are stored and distributed in a *Java Archive files (JAR files)*. A JAR file for a JavaBean must contain a *manifest file*, which describes the JAR file contents. Manifest files contain attributes (called *headers*) that describe the individual components in the JAR. This is important for integrated development environments that support JavaBeans. When a JAR file containing a JavaBean (or a set of JavaBeans) is loaded into an IDE, the IDE reads at the manifest file to determine which of the classes in the JAR represent JavaBeans. IDEs typically make these classes available to the programmer in a visual manner, as shown in the Forte overview earlier in this chapter. We create file **manifest.tmp**, which the **jar** utility uses to create the file as **MANIFEST.MF** and places in the **META-INF** directory of the JAR file. [Note: The file **manifest.tmp** can have any name—**jar** simply uses the file's contents to create **MANIFEST.MF** in the JAR file.] All JavaBean-aware development environments know to read the **MANIFEST.MF**

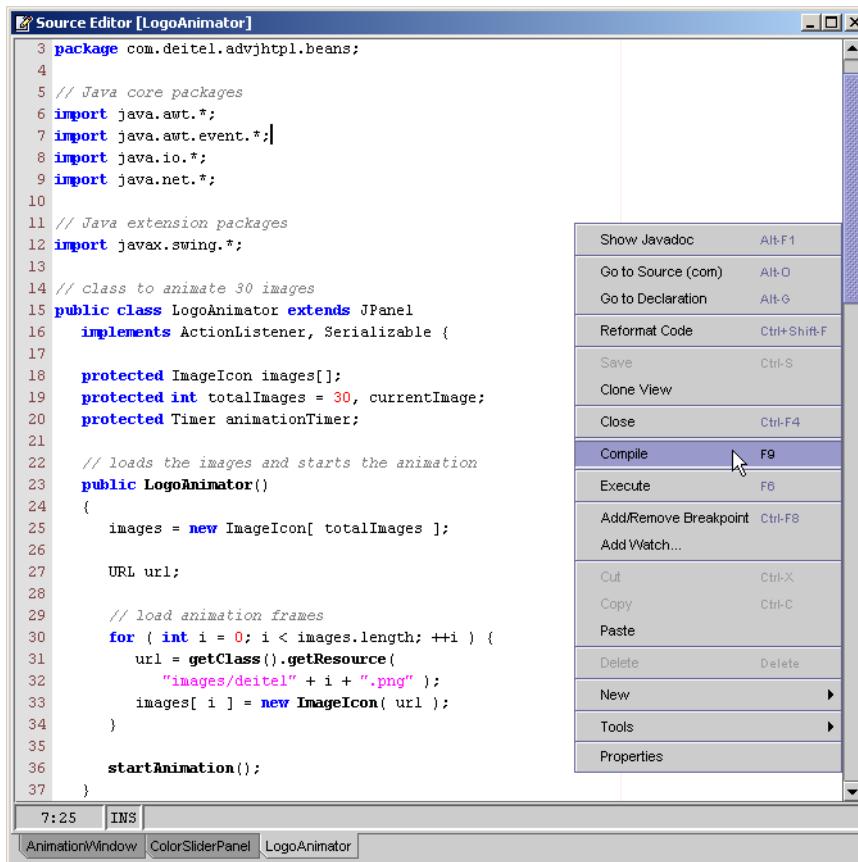


Fig. 6.35 Compile option in the Source Editor menu.

file in the **META-INF** directory of the JAR file. The Java interpreter can execute an application directly from a JAR file if the manifest file specifies which class in the JAR contains method **main**. Figure 6.36 shows the manifest file (**manifest.tmp**) for the **LogoAnimator** JavaBean.



### Software Engineering Observation 6.3

*You must define a manifest file that describes the contents of a JAR file if you intend either to use the bean in a bean-aware integrated development environment or execute an application directly from a JAR file.*

---

```

1 Main-Class: com.deitel.advjhtpl.beans.LogoAnimator
2
3 Name: com/deitel/advjhtpl/beans/LogoAnimator.class
4 Java-Bean: True

```

---

Fig. 6.36 Method file **manifest.tmp** for the **LogoAnimator** bean.

Class **com.deitel.advjhttp1.beans.LogoAnimator** contains method **main**. This is specified by the **Main-Class** header (line 1). This header enables the virtual machine to execute the application in the JAR file directly. To execute **LogoAnimator** from its JAR file, launch the Java virtual machine with the **-jar** command-line option as follows:

```
java -jar LogoAnimator.jar
```

The interpreter looks at the manifest file to determine which class to execute. On many platforms, you can execute an application in a JAR file by double clicking the JAR file in your system's file manager. This executes the **jar** command with the **-jar** option for the JAR file the user clicks. The application can also be executed from a JAR file that does not contain a manifest with the command

```
java -classpath LogoAnimator.jar  
com.deitel.advjhttp1.beans.LogoAnimator
```

where **-classpath** indicates the *class path* (i.e., the directories and JAR files in which the interpreter should search for classes). The **-classpath** option is followed by the JAR file containing the application class. The last command-line argument is the full class name (including the package name) for the application class.

Line 3 of the manifest file specifies the **Name** header of the file containing the bean class (including the **.class** file name extension), using its package and class name. Notice that the dots (.) typically used in package names are replaced with forward slashes (/) for the **Name** header in the manifest file. Line 4 use the **Java-Bean** header to specify that the class named on line 3 is a JavaBean. It is possible to have classes that are not JavaBeans in a JAR file. Such classes typically support the JavaBeans in the archive. For example, a linked-list bean might have a supporting linked-list-node class, objects of which represent each node in the list. Each class listed in the manifest file should be separated from other classes by a blank line. If the class is a bean, its **Name** header should be followed immediately by its **Java-Bean** header.

In the manifest file, a bean's name is specified with the **Name** header followed by the fully qualified name of the bean (i.e., the complete package name and class name). The dots (.) normally used to separate package names and class names are replaced with forward slash (/) in this line of the manifest file.



### Common Programming Error 6.1

If a class represents a bean, the **Java-Bean** header must follow the **Name** header immediately with a value of **True**. Otherwise, IDEs will not recognize the class as a bean.



### Software Engineering Observation 6.4

If a class containing **main** is included in a JAR file, that class can be used by the interpreter to execute the application directly from the JAR file by specifying the **Main-Class** header at the beginning of the manifest file. The full package name and class name of the class should be specified with periods (.) separating the package components and class name.



### Common Programming Error 6.2

Not specifying a manifest file or specifying a manifest file with incorrect syntax when creating a JAR file is an error—builder tools will not recognize the beans in the JAR file.



### Common Programming Error 6.3

If a JAR file manifest does not specify the **Main-Class** header, there must be a blank line at the top of the manifest file before listing any **Name** headers. Some JAR utilities will report an error and not create a JAR without a blank line at the top of the manifest.

Next, we create the JAR file for the **LogoAnimator** bean. This is accomplished with the **jar** utility at the command line (such as the MS-DOS prompt or UNIX shell). The command

```
jar cfm LogoAnimator.jar manifest.tmp  
com\deitel\advjhttp1\beans\*.*
```

creates the JAR file. [Note: This command uses the backslash (\) as the directory separator from the Windows Command Prompt. UNIX would use the forward slash (/) as the directory separator.] In the preceding command, **jar** is the Java archive utility used to create JAR files. The options for the **jar** utility—**c fm** are provided next. The letter **c** indicates that we are creating a JAR file. The letter **f** indicates that the next argument in the command line (**LogoAnimator.jar**) is the name of the JAR file to create. The letter **m** indicates that the next argument in the command line (**manifest.tmp**) is the manifest file that **jar** uses to create the file **META-INF/MANIFEST.MF** in the JAR. Following the options, the JAR file name and the manifest file name are the actual files to include in the JAR file. We specified **com\deitel\advjhttp1\beans\\*.\***, indicating that all the files in the **beans** directory should be included in the JAR file. The **com.deitel.advjhttp1.beans** package directory contains the **.class** files for the **LogoAnimator** and its supporting classes, as well as the images used in the animation. [Note: You can include particular files by specifying the path and file name for each individual file.] It is important that the directory structure in the JAR file match the class' package structure. Therefore, we executed the **jar** command from the directory on our system in which the **com** directory that begins the package name reside.

To confirm that the files were archived correctly, issue the command

```
jar tvf LogoAnimator.jar
```

In this command, the letter **t** indicates that **jar** should list the table of contents for the JAR file. The letter **v** indicates that the output should be verbose (the *verbose output* includes the file size in bytes and the date and time each file was created, in addition to the directory structure and file name). The letter **f** specifies that the next argument on the command line is the JAR file for which **jar** should display information.

Try executing the **LogoAnimator** application with the command

```
java -jar LogoAnimator.jar
```

You will see that the animation appears in its own window on your screen.

JAR files also can be created inside Forte's integrated development environment. Right click **LogoAnimator** in the **Explorer** window and select **Add to JAR** from the **Tools** menu, as described in Section 6.2. This displays the **JAR Packager** dialog. Our class **LogoAnimator** already is selected to be included in the JAR file. At the top of the dialog, type **LogoAnimator.jar** in the JAR Archive textfield and specify the directory in which the JAR will appear. Add the **images** directory to the JAR (Fig. 6.37). Next, click the **Manifest** tab and select the **Generate File List** check box. This creates a list of

all files in the JAR, including **LogoAnimator.class** and the PNG files. The **Java-Bean** and **Main-Class** headers are not generated by Forte and must be typed into the manifest (Fig. 6.38). Click **Create JAR** to create **LogoAnimator.jar**. Now the Logo-Animator can be loaded into the **Component Palette** as described in Section 6.2.

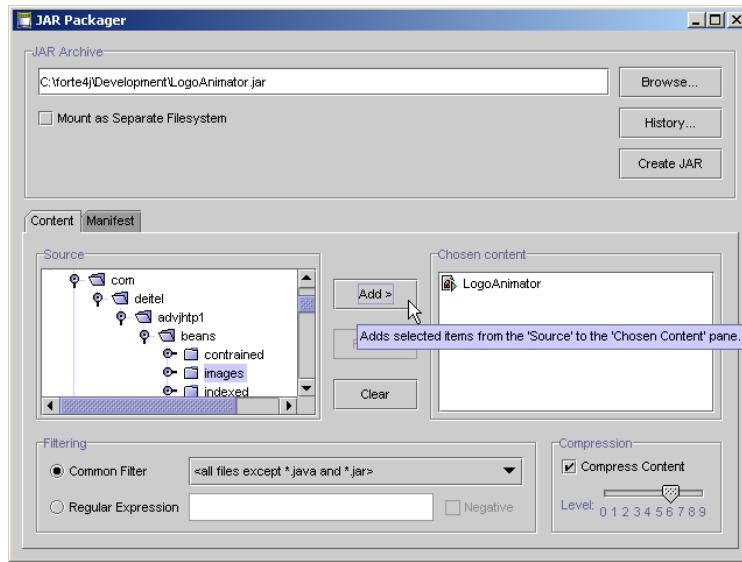


Fig. 6.37 Add **images** directory to **LogoAnimator.jar**.

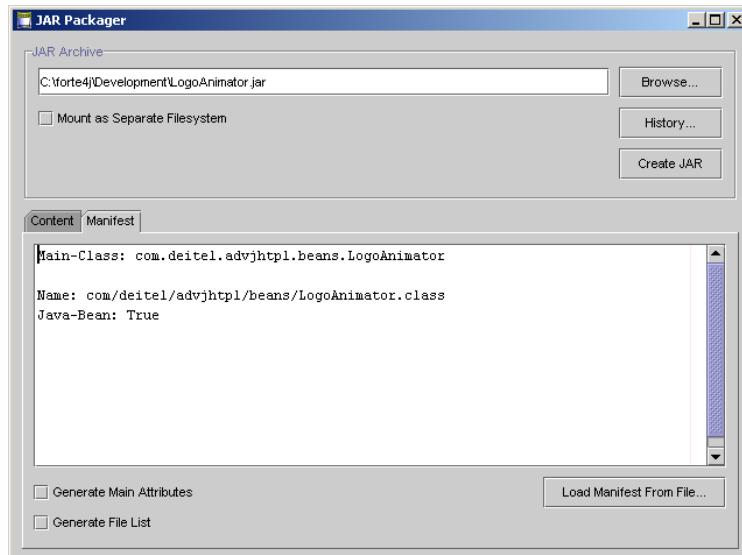


Fig. 6.38 Manifest tab of JAR Packager dialog.

## 6.5 JavaBean Properties

In this section, we demonstrate adding an **animationDelay** property to **LogoAnimator**, to control the animation's speed. For this purpose, we extend class **LogoAnimator** to create class **LogoAnimator2**. The new code for our property is defined by methods **setAnimationDelay** (lines 16–19) and **getAnimationDelay** (lines 22–25) in Fig. 6.39.

```
1 // Fig. 6.39: LogoAnimator2.java
2 // LogoAnimator2 extends LogoAnimator to include
3 // animationDelay property and implements ColorListener
4 package com.deitel.advjhtp1.beans;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class LogoAnimator2 extends LogoAnimator {
14
15     // set animationDelay property
16     public void setAnimationDelay( int delay )
17     {
18         animationTimer.setDelay( delay );
19     }
20
21     // get animationDelay property
22     public int getAnimationDelay()
23     {
24         return animationTimer.getDelay();
25     }
26
27     // launch LogoAnimator in JFrame for testing
28     public static void main( String args[] )
29     {
30         // create new LogoAnimator2
31         LogoAnimator2 animation = new LogoAnimator2();
32
33         // create new JFrame and add LogoAnimator2 to it
34         JFrame application = new JFrame( "Animator test" );
35         application.getContentPane().add( animation,
36             BorderLayout.CENTER );
37
38         application.setDefaultCloseOperation(
39             JFrame.EXIT_ON_CLOSE );
40         application.pack();
41         application.setVisible( true );
42     }
43 }
44 } // end class LogoAnimator2
```

Fig. 6.39 LogoAnimator2 with property **animationDelay**.

To create the **animationDelay** property, we defined methods **setAnimationDelay** and **getAnimationDelay**. A *read/write* property of a bean is defined as a *set/get* method pair of the form

```
public void setPropertyName( DataType value )
public DataType getPropertyName()
```

where **PropertyName** is replaced in each case by the actual property name. These methods often are referred to as a “property *set* method” and “property *get* method,” respectively.



#### Software Engineering Observation 6.5

A JavaBean *read/write* property is defined by a *set/get* method pair in which the *set* method returns **void** and takes one argument and the *get* method returns the same type as the corresponding *set* method’s argument and takes no arguments. It is also possible to have *read-only* properties (defined with only a *get* method) and *write-only* properties (defined with only a *set* method).



#### Software Engineering Observation 6.6

For a property with the name **propertyName**, the corresponding *set/get* method pair would be **setPropertyName/getPropertyName** by default. Note that the first letter of **propertyName** is capitalized in the *set/get* method names.

If the property is a **boolean** data type, the *set/get* method pair is sometimes defined as

```
public void setPropertyName( boolean value )
public boolean isPropertyName()
```

where the *get* method name begins with the word **is** rather than **get**.

When a builder tool examines a bean, it inspects the bean methods for pairs of *set/get* methods that represent properties (some builder tools also expose *read-only* and *write-only* properties). This process is known as *introspection*. If the builder tool finds an appropriate *set/get* method pair during the introspection process, the builder tool exposes that pair of methods as a property in the builder tool’s user interface. In the first **LogoAnimator**, the pair of methods

```
public void setBackground( Color c )
public Color getBackground()
```

that were inherited from class **JPanel** allowed Forte to expose the **background** property in the **Component Inspector** for customization. Notice that the naming convention for the *set/get* method pair used a capital letter for the first letter of the property name, but the exposed property in the **Component Inspector** is shown with a lowercase first letter.



#### Software Engineering Observation 6.7

When a builder tool examines a bean, if it locates a *set/get* method pair that matches the JavaBean’s property pattern, it exposes that pair of methods as a property in the bean.

Remember that class **LogoAnimator2** must be wrapped as a JavaBean to load it into Forte and other builder tools. Compile **LogoAnimator2**, and then place it in a JAR file as described in the previous section. Now import **LogoAnimator2** into the **Component Palette**, and drop an instance of **LogoAnimator2** into a **JFrame** as in Section 6.2. Select **LogoAnimator2** in the **Form** window or **Component Inspector**. The **animationDelay** property is now exposed in the **Component Inspector** (Fig. 6.40). Try

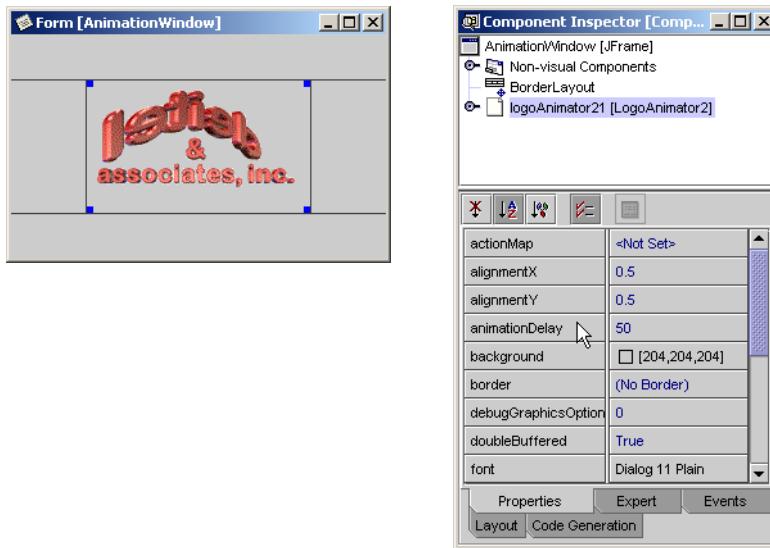


Fig. 6.40 LogoAnimator2 bean with property **animationDelay** exposed in Forte's Component Inspector.

changing the value of the property to see its effect on the speed of the animation (you must press *Enter* after changing the value to effect the change). Smaller values cause the animation to spin faster, larger values cause it to spin slower. Try typing **1000** to see one frame of the animation per second.

## 6.6 Bound Properties

A *bound property* causes the JavaBean that owns the property to notify other objects when the bound property's value changes. This notification is accomplished with standard Java event-handling features—the bean notifies its registered **PropertyChangeListeners** when the bound property's value changes. To support this feature, the **java.beans** package provides interface **PropertyChangeListener** so listeners can be configured to receive property-change notifications, class **PropertyChangeEvent** to provide information to a **PropertyChangeListener** about the change in a property's value and class **PropertyChangeSupport** to provide the listener registration and notification services (i.e., to maintain the list of listeners and notify them when an event occurs).



### Software Engineering Observation 6.8

A bound property causes the object that owns the property to notify other objects that there has been a change in the value of that property.

The next example creates a new GUI component (**SliderFieldPanel**) that extends **JPanel** and includes one **JSlider** object and one **JTextField** object. When the **JSlider** value changes, our new GUI component automatically updates the **JTextField** with the new value. Also, when a new value is entered in the **JTextField** and the user presses the *Enter* key, the **JSlider** is automatically repositioned to the appro-

priate location. Our purpose in defining this new component is to link one of these to the **LogoAnimator2** animation to control the speed of the animation. When the **SliderFieldPanel** value changes, we want the animation speed to change. Figure 6.41 presents the code for class **SliderFieldPanel**.

```
1 // Fig. 6.41: SliderFieldPanel.java
2 // SliderFieldPanel provides a slider to adjust the animation
3 // speed of LogoAnimator2.
4 package com.deitel.advjhtp1.beans;
5
6 // Java core packages
7 import java.io.*;
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.beans.*;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.event.*;
15
16 public class SliderFieldPanel extends JPanel
17     implements Serializable {
18
19     private JSlider slider;
20     private JTextField field;
21     private Box boxContainer;
22     private int currentValue;
23
24     // object to support bound property changes
25     private PropertyChangeSupport changeSupport;
26
27     // SliderFieldPanel constructor
28     public SliderFieldPanel()
29     {
30         // create PropertyChangeSupport for bound properties
31         changeSupport = new PropertyChangeSupport( this );
32
33         // initialize slider and text field
34         slider = new JSlider(
35             SwingConstants.HORIZONTAL, 1, 100, 1 );
36         field = new JTextField(
37             String.valueOf( slider.getValue() ), 5 );
38
39         // set box layout and add slider and text field
40         boxContainer = new Box( BoxLayout.X_AXIS );
41         boxContainer.add( slider );
42         boxContainer.add( Box.createHorizontalStrut( 5 ) );
43         boxContainer.add( field );
44
45         setLayout( new BorderLayout() );
46         add( boxContainer );
47     }
```

Fig. 6.41 Definition for class **SliderFieldPanel** (part 1 of 4).

```
48     // add ChangeListener for JSlider
49     slider.addChangeListener(
50
51         new ChangeListener() {
52
53             // handle state change for JSlider
54             public void stateChanged(ChangeEvent changeEvent)
55             {
56                 setCurrentValue( slider.getValue() );
57             }
58
59         } // end anonymous inner class
60
61     ); // end call to addChangeListener
62
63     // add ActionListener for JTextField
64     field.addActionListener(
65
66         new ActionListener() {
67
68             // handle action for JTextField
69             public void actionPerformed(ActionEvent
70                 actionEvent)
71             {
72                 setCurrentValue(
73                     Integer.parseInt( field.getText() ) );
74             }
75
76         } // end anonymous inner class
77
78     ); // end call to addActionListener
79
80 } // end SliderFieldPanel constructor
81
82 // add PropertyChangeListener
83 public void addPropertyChangeListener(
84     PropertyChangeListener listener)
85 {
86     changeSupport.addPropertyChangeListener( listener );
87 }
88
89 // remove PropertyChangeListener
90 public void removePropertyChangeListener(
91     PropertyChangeListener listener)
92 {
93     changeSupport.removePropertyChangeListener( listener );
94 }
95
96 // set minValue property
97 public void setMinimumValue( int minimum )
98 {
99     slider.setMinimum( minimum );
```

Fig. 6.41 Definition for class **SliderFieldPanel** (part 2 of 4).

```
100
101     if ( slider.getValue() < slider.getMinimum() ) {
102         slider.setValue( slider.getMinimum() );
103         field.setText( String.valueOf( slider.getValue() ) );
104     }
105 }
106
107 // get minimumValue property
108 public int getMinimumValue()
109 {
110     return slider.getMinimum();
111 }
112
113 // set maximumValue property
114 public void setMaximumValue( int maximum )
115 {
116     slider.setMaximum( maximum );
117
118     if ( slider.getValue() > slider.getMaximum() ) {
119         slider.setValue( slider.getMaximum() );
120         field.setText( String.valueOf( slider.getValue() ) );
121     }
122 }
123
124 // get maximumValue property
125 public int getMaximumValue()
126 {
127     return slider.getMaximum();
128 }
129
130 // set currentValue property
131 public void setCurrentValue( int current )
132     throws IllegalArgumentException
133 {
134     if ( current < 0 )
135         throw new IllegalArgumentException();
136
137     int oldValue = currentValue;
138
139     // set currentValue property
140     currentValue = current;
141
142     // change slider and textfield values
143     slider.setValue( currentValue );
144     field.setText( String.valueOf( currentValue ) );
145
146     // fire PropertyChange
147     changeSupport.firePropertyChange(
148         "currentValue", new Integer( oldValue ),
149         new Integer( currentValue ) );
150 }
151
```

Fig. 6.41 Definition for class **SliderFieldPanel** (part 3 of 4).

```
152 // get currentValue property
153 public int getCurrentValue()
154 {
155     return slider.getValue();
156 }
157
158 // set fieldWidth property
159 public void setFieldWidth( int columns )
160 {
161     field.setColumns( columns );
162     boxContainer.validate();
163 }
164
165 // get fieldWidth property
166 public int getFieldWidth()
167 {
168     return field.getColumns();
169 }
170
171 // get minimum panel size
172 public Dimension getMinimumSize()
173 {
174     return boxContainer.getMinimumSize();
175 }
176
177 // get preferred panel size
178 public Dimension getPreferredSize()
179 {
180     return boxContainer.getPreferredSize();
181 }
182
183 } // end class SliderFieldPanel
```

Fig. 6.41 Definition for class **SliderFieldPanel** (part 4 of 4).

Class **SliderFieldPanel** (Fig. 6.41) begins by specifying that it will be part of the **com.deitel.advjhttp1.beans** package (line 4). The class is a subclass of **JPanel**, so we can add a **JSlider** and a **JTextField** to it. Objects of class **SliderFieldPanel** can then be added to other containers.

Lines 19–25 declare instance variables of type **JSlider** (**slider**) and **JTextField** (**field**) that represent the subcomponents the user will use to set the **SliderFieldPanel** value, a **Box** (**boxContainer**) that will manage the layout, an **int** (**currentValue**) that stores the current value of the **SliderFieldPanel** and a **PropertyChangeSupport** (**changeSupport**) that will provide the listener registration and notification services.

Line 31 creates the **PropertyChangeSupport** object. The argument **this** specifies that an object of this class (**SliderFieldPanel**) is the source of the **PropertyChangeEvent**. Lines 49–61 of the constructor register the **ChangeListener** for **slider**. When **slider**'s value changes, line 56 calls **setCurrentValue** to update **field** and notify registered **PropertyChangeListeners** of the change in

value. Similarly, lines 64–78 register the **ActionListener** for **field**. When **field**'s value changes, lines 72–73 call **setCurrentValue** to update **slider** and notify registered **PropertyChangeListeners** of the change in value.

To support registration of listeners for changes to our **SliderFieldPanel**'s bound property, we define methods **addPropertyChangeListener** (lines 83–87) and **removePropertyChangeListener** (lines 90–94). Each of these methods calls the corresponding method in the **PropertyChangeSupport** object **changeSupport**. This object provides the event notification services when the property value changes.

### Software Engineering Observation 6.9



*To define an event for a bean, you must supply a listener interface and an event class, and the bean must define methods that allow adding and removing of listeners. For bound property events, the listener interface and the event class are already defined (**PropertyChangeListener** and **PropertyChangeEvent**, respectively). A bean that supports bound-property events must define method **addPropertyChangeListener** and method **removePropertyChangeListener** to provide listener registration services.*

Class **SliderFieldPanel** provides several properties. Methods **setMinimumValue** (lines 97–105) and **getMinimumValue** (lines 108–111) define property **minimumValue**. Property **maximumValue** is defined by methods **setMaximumValue** (lines 114–122) and **getMaximumValue** (lines 125–128). Methods **setFieldWidth** (lines 159–163) and **getFieldWidth** (lines 166–169) define property **fieldWidth**. Methods **getPreferredSize** (lines 172–175) and **getPreferredSize** (line 178–181) return the minimum size and preferred size of the **Box** object **boxContainer**, which manages the layout of the **JSlider** and **JTextField**.

### Look-and-Feel Observation 6.1



*If a bean will appear as part of a user interface, the bean should define method **getPreferredSize**, which takes no arguments and returns a **Dimension** object containing the preferred width and height of the bean. This helps the layout manager size the bean.*

Methods **setCurrentValue** (lines 131–150) and **getCurrentValue** (lines 153–156) define the bound property **currentValue**. When the bound property changes, the registered **PropertyChangeListeners** must be notified of the change. The JavaBeans specification ([java.sun.com/products/javabeans/docs/spec.html](http://java.sun.com/products/javabeans/docs/spec.html)) requires that each bound-property listener be presented with the old and new property values when notified of the change (the values can be **null** if they are not needed). For this reason, line 137 saves the previous property value. Line 140 sets the new property value. Lines 143–144 ensure that the **JSlider** and **JTextField** show the appropriate new values. Lines 147–149 invoke the **PropertyChangeSupport** object's **firePropertyChange** method to notify each registered **PropertyChangeListener**. The first argument is a **String** containing the property name that changed—**currentValue**. The second argument is the old property value. The third argument is the new property value.

### Software Engineering Observation 6.10



***PropertyChangeListeners** are notified of a property-change event with both the old and the new value of the property. If these values are not needed, they can be **null**.*



### Software Engineering Observation 6.11

**Class `PropertyChangeSupport`** is provided as a convenience to implement the listener registration and notification support for property-change events.

Remember that you should package the **SliderFieldPanel** class as a JavaBean to load it into a builder tool. Archive the class in a JAR file. The manifest file for this example is shown in Fig. 6.42. Line 2 specifies the name of the class file (**com\deitel\advjhttp1\beans\SliderFieldPanel.class**) that represents the bean. Line 3 specifies that the class named in line 1 is a JavaBean. There is no **Main-Class** header in this file, because the **SliderFieldPanel** is not an application. Finally, install **SliderFieldPanel.jar** into the builder tool.

To demonstrate the functionality of the bound property, place a **SliderFieldPanel** bean and a **LogoAnimator2** bean into a **JFrame**. Select the **SliderFieldPanel** bean (Fig. 6.43), set its **maximumValue** property to 1000 and set its **currentValue** to 50 (the default animation speed for the **LogoAnimator2**). In Forte, select **Connection Mode** from the **Component Palette**. Click the **SliderFieldPanel**; then click **LogoAnimator2**. Red squares appear at the corners of each component and the **Connection Wizard** opens.

In Step 1 of the **Connection Wizard**, select **propertyChange** as the event for the source component and click the **Next** button (Fig. 6.44). Select **LogoAnimator2**'s **animationDelay** property in Step 2 of the **Connection Wizard** (Fig. 6.45) and click **Next**. Finally, select **SliderFieldPanel**'s **currentValue** property in Step 3 (Fig. 6.46) and click **Finish**. The **animationDelay** property is now bound to the **SliderFieldPanel**'s **currentValue** property. Execute the **JFrame** to see the connected **LogoAnimator2** and **SliderFieldPanel** (Fig. 6.47).

Try adjusting the slider to see the animation speed change. Move the slider left to see the speed of the animation increase; move the slider right to see the animation speed decrease.

---

```

1
2 Name: com/deitel/advjhttp1/beans/SliderFieldPanel.class
3 Java-Bean: True

```

---

Fig. 6.42 Manifest file for the **SliderFieldPanel** JavaBean.

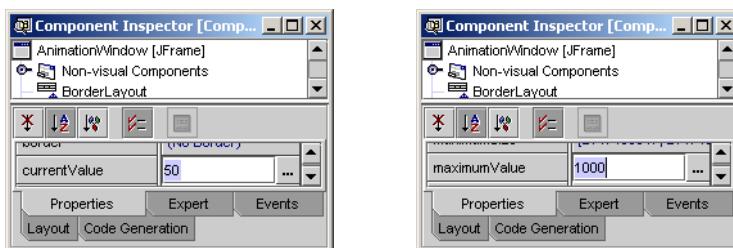


Fig. 6.43 Change properties **currentValue** and **maximumValue**.

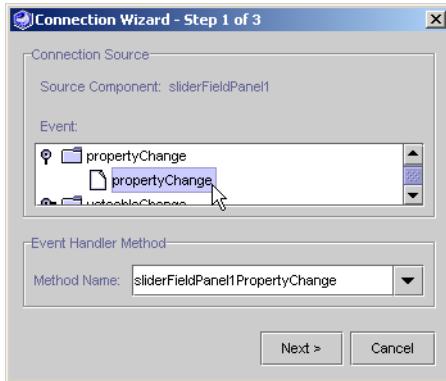


Fig. 6.44 Select **propertyChange** event.



Fig. 6.45 Select **animationDelay** property of **LogoAnimator2**.

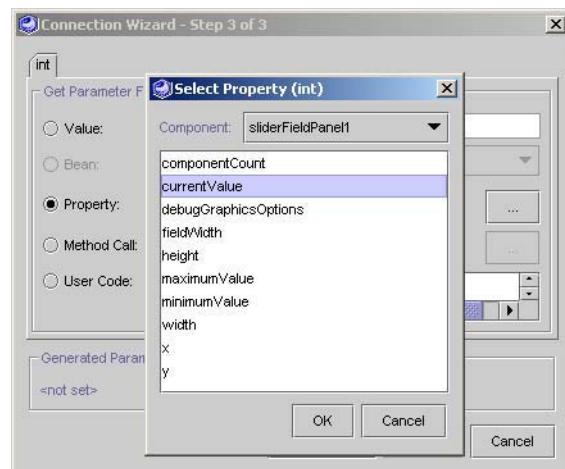


Fig. 6.46 Select **currentValue** Bound Property.



Fig. 6.47 JFrame with LogoAnimator2 and SliderFieldPanel.

## 6.7 Indexed Properties and Custom Events

Although standard properties, bound properties and standard Java events provide a great deal of functionality, JavaBeans can be further customized with other types of properties and programmer-defined events. An *indexed property* is like a standard property, except that the indexed property is an array of primitives or objects. Two *get* and two *set* methods define an indexed property. The *get* methods are of the form

```
public Datatype[] getPropertyNames()  
public Datatype getPropertyNames( int index )
```

The first *get* method returns the entire array of an indexed property. The second *get* method returns the item at the array index indicated by the *get* method's parameter. The *set* methods are of the form

```
public void setPropertyName( Datatype[] data)  
public void setPropertyName( int index, Datatype data )
```

The first *set* method sets the indexed property to the value of the argument. The second *set* method sets the item at the indicated array index to the value of the second parameter.



### Software Engineering Observation 6.12

An indexed property functions like a regular property and is exposed in the property sheet like normal properties.

A JavaBean can generate programmer-defined events. A programmer-defined event, or *custom event*, provides functionality that standard Java events do not provide. An event class extends **java.util.EventObject** and the listener interface extends **java.util.EventListener**.

Our next example demonstrates an indexed property and a custom event. In the example we create a **ColorSliderPanel** that enables a user to choose values for the red, green and blue parts of a color. The **ColorSliderPanel** maintains these three integer values in an indexed property and uses them to create **Color** objects. This custom GUI component also generates custom **ColorEvents**, so that it can notify its registered listeners when the user changes the color.

We begin by defining an **EventObject** class and an **EventListener** interface for the custom event **ColorEvent**. Figure 6.48 shows the **ColorEvent** class and Fig. 6.49 shows the **ColorListener** interface. Class **ColorEvent** is a custom event that extends class **EventObject**. Parameter **color** in the constructor (lines 15–19) represents the value of the **ColorEvent**'s **color** property. Method **setColor** (lines 22–25) sets the **color** instance variable. Method **getColor** (lines 28–31) returns the **color** property.

```
1 // Fig. 6.48 ColorEvent.java
2 // ColorEvent is an EventObject subclass that indicates a
3 // change in color.
4 package com.deitel.advjhtp1.beans;
5
6 // Java core packages
7 import java.util.*;
8 import java.awt.Color;
9
10 public class ColorEvent extends EventObject {
11
12     private Color color;
13
14     // constructor sets color property
15     public ColorEvent( Object source, Color color )
16     {
17         super( source );
18         setColor( color );
19     }
20
21     // set method for color property
22     public void setColor( Color newColor )
23     {
24         color = newColor;
25     }
26
27     // get method for color property
28     public Color getColor()
29     {
30         return color;
31     }
32
33 } // end class ColorEvent
```

Fig. 6.48 **ColorEvent** custom-event class indicating a color change.

Interface **ColorListener** (Fig. 6.49) is a custom listener interface that extends class **EventListener**. Classes that implement **ColorListener** listen for **ColorEvents**. The **ColorEvent** event source calls its registered listeners' **colorChanged** method (declared at line 11) with a **ColorEvent** object describing the change. All listeners for **ColorEvents** must implement the **ColorListener** interface.

```
1 // Fig. 6.49 ColorListener.java
2 // Color listener is the interface for custom event ColorEvent.
3 package com.deitel.advjhtp1.beans;
4
5 // Java core packages
6 import java.util.*;
7
8 public interface ColorListener extends EventListener {
```

Fig. 6.49 **ColorListener** interface for receiving **colorChanged** notifications (part 1 of 2).

```
9
10    // send colorChanged ColorEvent to listener
11    public void colorChanged( ColorEvent colorEvent );
12
13 } // end interface ColorListener
```

Fig. 6.49 **ColorListener** interface for receiving **colorChanged** notifications (part 2 of 2).

Class **ColorSliderPanel** (Fig. 6.50) is a JavaBean that issues **colorChanged** **ColorEvents** when the sliders change the color value. **ColorSliderPanel** consists of three **SliderFieldPanels** marked with **JLabels** as **Red**, **Green** and **Blue**. Three **JTextFields**, one in each **SliderFieldPanel**, display integers from zero through 255. The three values are stored in an indexed property called **redGreenBlue**. Moving a **JSlider** changes the number displayed in its **JTextField** and changes the value of **redGreenBlue**. Changing **redGreenBlue**'s value causes **ColorSliderPanel** to fire a **ColorEvent**. The **ColorEvent** contains a **Color** object initialized to the three values of **redGreenBlue**. Our purpose in defining **ColorSliderPanel** is to link one of these to the **LogoAnimator2** animation, to change the background color of **LogoAnimator2**.

```
1 // Fig. 6.50 ColorSliderPanel.java
2 // ColorSliderPanel contains 3 SliderFieldPanels connected to
3 // indexed property redGreenBlue that adjusts the red, green
4 // and blue colors of an object.
5 package com.deitel.advjhtp1.beans;
6
7 // Java core packages
8 import java.io.*;
9 import java.awt.*;
10 import java.awt.event.*;
11 import java.beans.*;
12 import java.util.*;
13
14 // Java extension packages
15 import javax.swing.*;
16 import javax.swing.event.*;
17
18 public class ColorSliderPanel extends JPanel
19     implements Serializable {
20
21     private JLabel redLabel, greenLabel, blueLabel;
22     private SliderFieldPanel redSlider, greenSlider, blueSlider;
23     private JPanel labelPanel, sliderPanel;
24     private int[] redGreenBlue;
25     public int RED_INDEX = 0;
26     public int GREEN_INDEX = 1;
27     public int BLUE_INDEX = 2;
28     private Set listeners = new HashSet();
29 }
```

Fig. 6.50 Definition of class **ColorSliderPanel** (part 1 of 5).

```
30 // constructor for ColorSliderPanel
31 public ColorSliderPanel()
32 {
33     // initialize redGreenBlue property
34     redGreenBlue = new int[] { 0, 0, 0 };
35
36     // initialize gui components for red slider
37     redLabel = new JLabel( "Red:" );
38     redSlider = new SliderFieldPanel();
39     redSlider.setMinimumValue( 0 );
40     redSlider.setMaximumValue( 255 );
41
42     // initialize gui components for green slider
43     greenLabel = new JLabel( "Green: " );
44     greenSlider = new SliderFieldPanel();
45     greenSlider.setMinimumValue( 0 );
46     greenSlider.setMaximumValue( 255 );
47
48     // initialize gui components for blue slider
49     blueLabel = new JLabel( "Blue:" );
50     blueSlider = new SliderFieldPanel();
51     blueSlider.setMinimumValue( 0 );
52     blueSlider.setMaximumValue( 255 );
53
54     // set layout and add components
55     setLayout( new BorderLayout() );
56
57     labelPanel = new JPanel( new GridLayout( 3, 1 ) );
58     labelPanel.add( redLabel );
59     labelPanel.add( greenLabel );
60     labelPanel.add( blueLabel );
61
62     sliderPanel = new JPanel( new GridLayout( 3, 1 ) );
63     sliderPanel.add( redSlider );
64     sliderPanel.add( greenSlider );
65     sliderPanel.add( blueSlider );
66
67     add( labelPanel, BorderLayout.WEST );
68     add( sliderPanel, BorderLayout.CENTER );
69
70     // add PropertyChangeListener for redSlider
71     redSlider.addPropertyChangeListener(
72
73         new PropertyChangeListener() {
74
75             // handle propertyChange for redSlider
76             public void propertyChange( PropertyChangeEvent
77                 propertyChangeEvent )
78             {
79                 setRedGreenBlue( RED_INDEX,
80                     redSlider.getCurrentValue() );
81             }
82         }
```

Fig. 6.50 Definition of class **ColorSliderPanel** (part 2 of 5).

```
83         } // end anonymous inner class
84
85     ); // end call to addPropertyChangeListener
86
87     // add PropertyChangeListener for greenSlider
88     greenSlider.addPropertyChangeListener(
89
90         new PropertyChangeListener() {
91
92             // handle propertyChange for greenSlider
93             public void propertyChange( PropertyChangeEvent
94                 propertyChangeEvent )
95             {
96                 setRedGreenBlue( GREEN_INDEX,
97                     greenSlider.getCurrentValue() );
98             }
99
100        } // end anonymous inner class
101
102    ); // end call to addPropertyChangeListener
103
104    // add PropertyChangeListener for blueSlider
105    blueSlider.addPropertyChangeListener(
106
107        new PropertyChangeListener() {
108
109            // handle propertyChange for blueSlider
110            public void propertyChange( PropertyChangeEvent
111                propertyChangeEvent )
112            {
113                setRedGreenBlue( BLUE_INDEX,
114                    blueSlider.getCurrentValue() );
115            }
116
117        } // end anonymous inner class
118
119    ); // end call to addPropertyChangeListener
120
121 } // end ColorSliderPanel constructor
122
123 // add ColorListener
124 public void addColorListener(
125     ColorListener colorListener )
126 {
127     // listeners must be accessed atomically
128     synchronized ( listeners ) {
129         listeners.add( colorListener );
130     }
131 }
132 }
```

Fig. 6.50 Definition of class **ColorSliderPanel** (part 3 of 5).

```
133 // remove ColorListener
134 public void removeColorListener(
135     ColorListener colorListener )
136 {
137     // listeners must be accessed by one thread only
138     synchronized ( listeners ) {
139         listeners.remove( colorListener );
140     }
141 }
142
143 // fire ColorEvent
144 public void fireColorChanged()
145 {
146     Iterator iterator;
147
148     // listeners must be accessed atomically
149     synchronized ( listeners ) {
150         iterator = new HashSet( listeners ).iterator();
151     }
152
153     // create new Color with values of redGreenBlue
154     // create new ColorEvent with color variable
155     Color color = new Color( redGreenBlue[ RED_INDEX ],
156                             redGreenBlue[ GREEN_INDEX ],
157                             redGreenBlue[ BLUE_INDEX ] );
158     ColorEvent colorEvent = new ColorEvent( this, color );
159
160     // notify all registered ColorListeners of ColorChange
161     while ( iterator.hasNext() ) {
162         ColorListener colorListener = ( ColorListener )
163             iterator.next();
164         colorListener.colorChanged( colorEvent );
165     }
166 }
167
168 // get redGreenBlue property
169 public int[] getRedGreenBlue()
170 {
171     return redGreenBlue;
172 }
173
174 // get redGreenBlue indexed property
175 public int getRedGreenBlue( int index )
176 {
177     return redGreenBlue[ index ];
178 }
179
180 // set redGreenBlue property
181 public void setRedGreenBlue( int[] array )
182 {
183     redGreenBlue = array;
184 }
```

Fig. 6.50 Definition of class **ColorSliderPanel** (part 4 of 5).

```
186 // set redGreenBlue indexed property
187 public void setRedGreenBlue( int index, int value )
188 {
189     redGreenBlue[ index ] = value;
190     fireColorChanged();
191 }
192 }
193 } // end class ColorSliderPanel
```

Fig. 6.50 Definition of class **ColorSliderPanel** (part 5 of 5).

Lines 31–121 contain the constructor for **ColorSliderPanel**. Line 34 initializes the **redGreenBlue** indexed property. Lines 37–52 initialize the **JLabels**' components and **SliderFieldPanels**. Each part of property **redGreenBlue** has a **JLabel** and a **SliderFieldPanel** associated with it. The **SliderFieldPanels**' **JSliders** are set to a range of 0 through 255, and the **JTextFields** are set with the initial value of the **JSliders**. Line 55 sets the layout to **BorderLayout**. Lines 57–60 add the **JLabels** to a new **JPanel** with a three-by-one **GridLayout**. Lines 62–65 add the **SliderFieldPanels** to a new **JPanel** with a three-by-one **GridLayout**. Lines 67–68 add the **JPanels** to **ColorSliderPanel**. Lines 71–119 add **PropertyChangeListener**s to the **SliderFieldPanels**. Each call to **addPropertyChangeListener** creates an instance of a **PropertyChangeListener** anonymous inner class. When a **SliderFieldPanel** fires a **PropertyChangeEvent**, the **propertyChanged** method of the appropriate **PropertyChangeListener** updates the value of indexed property **redGreenBlue**.

Methods **addColorListener** (lines 124–131) and **removeColorListener** (lines 134–141) contain **synchronized** blocks in which the **Set listeners** (line 28) is modified. **Set listeners** contains all the registered listeners of type **ColorListener**. Method **fireColorChanged** (lines 144–166) uses method **iterator** to create an **Iterator** from **listeners**. Lines 155–158 create a **ColorEvent** object with a **Color** attribute matching the values of the **redGreenBlue** property. Method **fireColorChanged** then sends the event to all registered listeners by calling method **colorChanged** on every listener.

Lines 169–191 contain methods to manipulate the **redGreenBlue** property. Method **getRedGreenBlue** (lines 169–172) with no parameters returns the **integer** array **redGreenBlue**. Method **getRedGreenBlue** (lines 175–178) with an **integer** parameter returns the value of **redGreenBlue** at the index of the parameter. Property **redGreenBlue** can be set with two versions of method **setRedGreenBlue**. Method **setRedGreenBlue** (lines 181–184) with an **integer** array parameter sets **redGreenBlue** to the parameter. Method **setRedGreenBlue** (lines 187–191) with **integer** parameters **index** and **value** sets the **value** of **redGreenBlue** at **index**. This version of the method also calls **fireColorChanged** to generate a **ColorEvent**.

Classes **ColorEvent**, **ColorListener** and **ColorSliderPanel** should be packaged in a JAR file so **ColorSliderPanel** can be used as a JavaBean. Figure 6.51 shows the manifest file for this example. Line 2 specifies the name of the class file

(**com\deitel\advjhttp1\beans\ColorSliderPanel.class**) that represents the bean. Line 3 specifies that the class named in line 2 is a JavaBean. There is no **Main-Class** header line in this file, because **ColorSliderPanel** is not an application. No entries are listed for **ColorEvent** and **ColorListener**, because they are only supporting classes.

Install **ColorSliderPanel** into the **Component Palette** and drop instances of **LogoAnimator2** and **ColorSliderPanel** into a **JFrame**. Switch to **Connection Mode** and click **ColorSliderPanel** then **LogoAnimator2**. The **Connection Wizard** opens with a list of events from which to choose. Select **colorChanged** from the menu and click the **Next** button (Fig. 6.52). In Step 2, click the **Method** radio button and select method **setBackground** (Fig. 6.53). This method of **LogoAnimator2** will be called with the **ColorEvent**'s **Color** property as the argument. In Step 3, click the **User Code:** radio button and type **evt.getColor()** into the text area then click **Finish** (Fig. 6.54). This line calls **ColorEvent**'s **getColor** method, which returns a **Color** object. **LogoAnimator2** now listens for **ColorEvents** generated by **ColorSliderPanel**.

Execute the **JFrame** to see **LogoAnimator2** and **ColorSliderPanel**. Try adjusting the three different sliders. Each slider changes one of the elements of the **Color** object of the **background** of **LogoAnimator2**. Try moving the sliders to change the **background** color and try entering a new value as text. Figure 6.55 shows several of the possible colors.

```
1  
2 Name: com/deitel/advjhttp1/beans/ColorSliderPanel.class  
3 Java-Bean: True
```

Fig. 6.51 Manifest file for the **ColorSliderPanel** JavaBean.

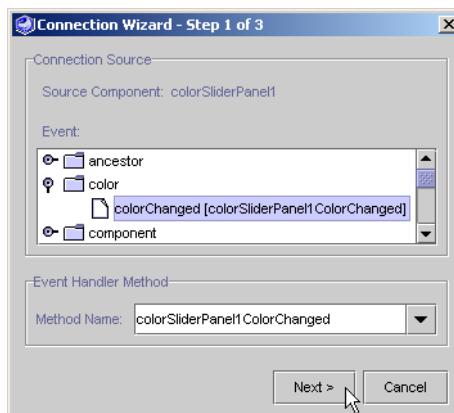


Fig. 6.52 Selecting **colorChanged** method in **Connection Wizard**.



Fig. 6.53 Selecting `setBackgroundColor` method for target `LogoAnimator2`.

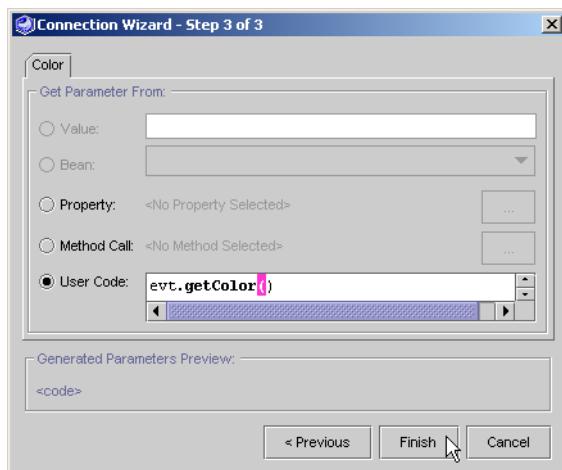


Fig. 6.54 Entering user code in Connection Wizard.



Fig. 6.55 Using the `ColorSliderPanel` to change the `background` color of `LogoAnimator2`.

## 6.8 Customizing JavaBeans for Builder Tools

As mentioned previously, builder tools use Java's introspection mechanism to expose a JavaBean's properties, methods and events if the programmer follows the proper JavaBean *design patterns* (such as the special naming conventions discussed for *set/get* method pairs that define bean properties). Builder tools use the classes and interfaces of package **java.lang.reflect** to perform introspection. For JavaBeans that do not follow the JavaBean design patterns, or for JavaBeans in which the programmer wants to customize the exposed set of properties, methods and events, the programmer can supply a class that implements interface **BeanInfo** (package **java.beans**). The **BeanInfo** class describes to the builder tool how to present the features of the bean to the programmer.



### Software Engineering Observation 6.13

A JavaBean's properties, methods and events can be exposed by a builder tool if the programmer follows the proper JavaBean design patterns.



### Software Engineering Observation 6.14

Every **BeanInfo** class must implement interface **BeanInfo**. This interface describes the methods used by a builder tool to determine the features of a bean.

Class **SliderFieldPanel** (Fig. 6.41) exposes many properties and events when it is selected in the **Component Inspector** or connected with the **Connection Wizard**. For this bean, we want the programmer to see only properties **fieldWidth**, **currentValue**, **minimumValue** and **maximumValue** (the other properties were inherited from class **JPanel** and are not truly relevant to our bean). Also, the only event we want the programmer to use for our component is the bound-property event.



### Software Engineering Observation 6.15

By convention, the **BeanInfo** class has the same name as the bean and ends with **BeanInfo** and is placed in the same **package** as the bean it describes or else it will not be found automatically.



### Software Engineering Observation 6.16

By convention, the **BeanInfo** class is included in the same JAR as the **SliderFieldPanel** JavaBean. When the bean is loaded, the builder tool determines whether the JAR file contains a **BeanInfo** class for a bean. If a **BeanInfo** class is found, it is used to determine the exposed features of the bean. Otherwise, standard introspection is used to determine the exposed features of the bean.

Figure 6.56 presents class **SliderFieldPanelBeanInfo** to customize the properties and events exposed in builder tools for our **SliderFieldPanel** bean. The screen captures in Fig. 6.57 show the exposed features of the **SliderFieldPanel** JavaBean.

---

```

1 // Fig. 6.56 SliderFieldPanelBeanInfo.java
2 // SliderFieldPanelBeanInfo is the BeanInfo class for
3 // SliderFieldPanel
4 package com.deitel.advjhtp1.beans;

```

---

**Fig. 6.56** **SliderFieldPanelBeanInfo** exposes properties and events for **SliderFieldPanel** (part 1 of 5).

```
5
6 // Java core packages
7 import java.beans.*;
8 import java.awt.Image;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class SliderFieldPanelBeanInfo extends SimpleBeanInfo {
14
15     public static final Class beanClass =
16         SliderFieldPanel.class;
17
18     // return general description of bean
19     public BeanDescriptor getBeanDescriptor()
20     {
21         BeanDescriptor descriptor = new BeanDescriptor(
22             beanClass, SliderFieldPanelCustomizer.class );
23         descriptor.setDisplayName( "Slider Field" );
24         descriptor.setShortDescription(
25             "A slider bar to change a numerical property." );
26
27         return descriptor;
28     }
29
30     // return bean icon
31     public Image getIcon( int iconKind )
32     {
33         Image image = null;
34
35         switch( iconKind ) {
36
37             case ICON_COLOR_16x16:
38                 image = loadImage( "icon1.gif" );
39                 break;
40
41             case ICON_COLOR_32x32:
42                 image = loadImage( "icon2.gif" );
43                 break;
44
45             case ICON_MONO_16x16:
46                 image = loadImage( "icon3.gif" );
47                 break;
48
49             case ICON_MONO_32x32:
50                 image = loadImage( "icon4.gif" );
51                 break;
52
53             default:
54                 break;
55         }
56     }
57 }
```

Fig. 6.56 `SliderFieldPanelBeanInfo` exposes properties and events for `SliderFieldPanel` (part 2 of 5).

```
56         return image;
57     }
58 }
59
60 // return array of MethodDescriptors for public get methods
61 // of class SliderFieldPanel
62 public MethodDescriptor[] getMethodDescriptors()
63 {
64     // create array of MethodDescriptors
65     try {
66         MethodDescriptor getMinimumValue = new
67             MethodDescriptor( beanClass.getMethod(
68                 "getMinimumValue", null ) );
69
70         MethodDescriptor getMaximumValue = new
71             MethodDescriptor( beanClass.getMethod(
72                 "getMaximumValue", null ) );
73
74         MethodDescriptor getCurrentValue = new
75             MethodDescriptor( beanClass.getMethod(
76                 "getCurrentValue", null ) );
77
78         MethodDescriptor getFieldWidth = new
79             MethodDescriptor( beanClass.getMethod(
80                 "getFieldWidth", null ) );
81         MethodDescriptor[] descriptors = { getMinimumValue,
82             getMaximumValue, getCurrentValue, getFieldWidth };
83
84         return descriptors;
85     }
86
87     // printStackTrace if NoSuchMethodException thrown
88     catch ( NoSuchMethodException methodException ) {
89         methodException.printStackTrace();
90     }
91
92     // printStackTrace if SecurityException thrown
93     catch ( SecurityException securityException ) {
94         securityException.printStackTrace();
95     }
96
97     return null;
98 }
99
100 // return PropertyDescriptor array
101 public PropertyDescriptor[] getPropertyDescriptors()
102     throws RuntimeException
103 {
104     // create array of PropertyDescriptors
105     try {
```

Fig. 6.56 **SliderFieldPanelBeanInfo** exposes properties and events for **SliderFieldPanel** (part 3 of 5).

```
107     // fieldWidth property
108     PropertyDescriptor fieldWidth = new
109         PropertyDescriptor( "fieldWidth", beanClass );
110     fieldWidth.setShortDescription(
111         "Width of the text field." );
112
113     // currentValue property
114     PropertyDescriptor currentValue = new
115         PropertyDescriptor( "currentValue", beanClass );
116     currentValue.setShortDescription(
117         "Current value of slider." );
118
119     // maximumValue property
120     PropertyDescriptor maximumValue = new
121         PropertyDescriptor( "maximumValue", beanClass );
122     maximumValue.setPropertyEditorClass(
123         MaximumValueEditor.class );
124     maximumValue.setShortDescription(
125         "Maximum value of slider." );
126
127     // minimumValue property
128     PropertyDescriptor minimumValue = new
129         PropertyDescriptor( "minimumValue", beanClass );
130     minimumValue.setShortDescription(
131         "Minimum value of slider." );
132     minimumValue.setPropertyEditorClass(
133         MinimumValueEditor.class );
134
135     // ensure PropertyChangeEvent occurs for this property
136     currentValue.setBound( true );
137
138     PropertyDescriptor descriptors[] = { fieldWidth,
139         currentValue, maximumValue, minimumValue };
140
141     return descriptors;
142 }
143
144     // throw RuntimeException if IntrospectionException
145     // thrown
146     catch ( IntrospectionException exception ) {
147         throw new RuntimeException( exception.getMessage() );
148     }
149 }
150
151     // get currentValue property index
152 public int getDefaultPropertyIndex()
153 {
154     return 1;
155 }
156
```

Fig. 6.56 **SliderFieldPanelBeanInfo** exposes properties and events for **SliderFieldPanel** (part 4 of 5).

```

157     // return EventSetDescriptors array
158     public EventSetDescriptor[] getEventSetDescriptors()
159         throws RuntimeException
160     {
161         // create array of EventSetDescriptors
162         try {
163             EventSetDescriptor changed = new
164                 EventSetDescriptor( beanClass, "propertyChange",
165                     java.beans.PropertyChangeListener.class,
166                     "propertyChange" );
167
168             // set event description and name
169             changed.setShortDescription(
170                 "Property change event for currentValue." );
171             changed.setDisplayName(
172                 "SliderFieldPanel value changed" );
173
174             EventSetDescriptor[] descriptors = { changed };
175
176             return descriptors;
177         }
178
179         // throw RuntimeException if IntrospectionException
180         // thrown
181         catch ( IntrospectionException exception ) {
182             throw new RuntimeException( exception.getMessage() );
183         }
184     }
185
186     // get PropertyChange event index
187     public int getDefaultEventIndex()
188     {
189         return 0;
190     }
191
192 } // end class SliderFieldPanelBeanInfo

```

Fig. 6.56 **SliderFieldPanelBeanInfo** exposes properties and events for **SliderFieldPanel** (part 5 of 5).

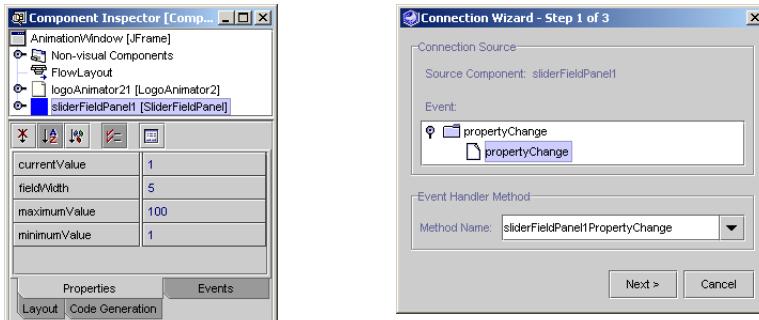


Fig. 6.57 Properties and events exposed by **SliderFieldPanelBeanInfo**.

Every **BeanInfo** class must implement interface **BeanInfo**. This interface describes the methods used by builder tools to determine the exposed features of the bean described by its corresponding **BeanInfo** class. As a convenience, the **java.beans** package includes class **SimpleBeanInfo**, which provides a default implementation of every method in interface **BeanInfo**. The programmer can extend this class and selectively override its methods to implement a proper **BeanInfo** class. Class **SliderFieldPanelBeanInfo** extends class **SimpleBeanInfo** (line 13). In Fig. 6.56, we override **BeanInfo** methods **getBeanDescriptor**, **getIcon**, **getMethodDescriptors**, **getPropertyDescriptors**, **getDefaultPropertyIndex**, **getEventSetDescriptors** and **getDefaultEventIndex**.



#### Software Engineering Observation 6.17

Class **SimpleBeanInfo** provides a default implementation of every method in interface **BeanInfo**. The programmer can selectively override methods of this class to implement a proper **BeanInfo** class.

Lines 19–28 override method **getBeanDescriptor**, to return a **BeanDescriptor** object. The constructor for **BeanDescriptor** takes as arguments the Java-Bean customizer **Class** object. A customizer provides a specialized user interface for customizing a bean. We discuss customizers and specifically the **SliderFieldPanelCustomizer** in Section 6.8.2. Methods **setDisplayName** (line 23) and **setShortDescription** (line 24) set the JavaBean's name and a short description, respectively. The builder tool extracts this information and displays it when selecting the bean.

Lines 31–58 override method **getIcon**. Interface **BeanInfo** defines the constants used by the **switch** statement. The **switch** (lines 35–55) loads the appropriate **Image**. The builder tool uses this **Image** as an icon in the **Component Palette**.



#### Software Engineering Observation 6.18

Method **getIcon** allows a programmer to customize the look of a JavaBean within a builder tool. Common icons are company logos and descriptive graphics.

Lines 62–98 override method **getMethodDescriptors** to return an array of **MethodDescriptor** objects for the **SliderFieldPanel** bean. Each **MethodDescriptor** represents a specific method exposed to the builder tool. Method **getMethodDescriptors** describes the *get* methods for properties **maximumValue**, **minimumValue**, **currentValue** and **fieldWidth**. The method calls in lines 66–80 may throw **NoSuchMethodException** and **SecurityException** exceptions.

Lines 101–149 override method **getPropertyDescriptors**, to return an array of **PropertyDescriptor** objects for **SliderFieldPanel** properties. Each **PropertyDescriptor** indicates a specific property that should be exposed by a builder tool. There are several ways to construct a **PropertyDescriptor**. In this example, each **PropertyDescriptor** constructor call has the form

```
new PropertyDescriptor( "propertyName", beanClass );
```

where *propertyName* is a **String** that specifies the name of a property defined by the pair of methods **setPropertyName** and **getPropertyName**. Note that the *propertyName* begins with a lowercase letter and the *get/set* property methods begin the property name with an uppercase letter. We defined **PropertyDescriptor**s for **fieldWidth**, **currentValue**, **minimumValue** and **maximumValue** in class **SliderFieldPanel**.

Method `setShortDescription` sets a short text description of the property. For the `maximumValue` and `minimumValue` properties, we also specify `PropertyEditors` with method `setPropertyEditorClass`. A `PropertyEditor` defines a custom user interface for editing a bean property. We discuss `PropertyEditors`—and specifically `MinimumValueEditor` and `MaximumValueEditor`—in Section 6.8.1. Line 136 specifies that property `currentValue` is a bound property. Some builder tools visually treat bound-property events separately from other events.



### Software Engineering Observation 6.19

*If the set/get methods for a property do not use the JavaBean's naming convention for properties, there are two other `PropertyDescriptor` constructors in which the actual method names are passed. This allows the builder tools to use nonstandard property methods to expose a property for manipulation by the programmer at design time. This is particularly useful in retrofitting a class as a JavaBean when that class was not originally designed and implemented using JavaBeans design patterns.*

Lines 138–139 create the `PropertyDescriptor` array that method `getProperties` returns (line 141). Note the exception handler for `IntrospectionExceptions`. If a `PropertyDescriptor` constructor is unable to confirm the property in the corresponding `Class` object that represents the class definition, the constructor throws an `IntrospectionException`. Because the `BeanInfo` class and its methods are actually used by the builder tool at design time (i.e., during the development of the program in the IDE), the `RuntimeException` thrown in the `catch` handler would normally be caught by the builder tool.

Lines 152–155 define method `getDefaultPropertyIndex` to return the value `1`, indicating that the property at position `1` in the `PropertyDescriptor` array returned from `getProperties` is the *default property* for developers to customize in a builder tool. Typically, the default property is selected when you click a bean. In this example, property `currentValue` is the default property.

Lines 158–184 override method `getEventSetDescriptors` to return an array of `EventSetDescriptor` objects that describes to a builder tool the events supported by this bean. Lines 163–166 define an `EventSetDescriptor` object for the `PropertyChangeEvent` associated with the bound property `currentValue`. The four arguments to the constructor describe the event that should be exposed by the builder tool. The first argument is the `Class` object (`beanClass`) representing the *event source* (i.e., the bean that generates the event). The second argument is a `String` representing the *event set name* (e.g., the `mouse` event set includes `mousePressed`, `mouseClicked`, `mouseReleased`, `mouseEntered` and `mouseExited`). In this example, the event set name is `propertyChange`. The third argument is the `Class` object representing the event listener interface implemented by listeners for this event. Finally, the last argument is a `String` representing the name of the listener method to call (`propertyChange`) when this event occurs.

When using the standard JavaBeans design patterns, the event set name is part of all the data type names and method names used to process the event. For example, the types and methods for the `propertyChange` event set are: `PropertyChangeListener` (the interface an object must implement to be notified of an event in this event set), `PropertyChangeEvent` (the type passed to a listener method for an event in this event set), `addPropertyChangeListener` (the method called to add a listener for an event in

this event set), **removePropertyChangeListener** (the method called to remove a listener for an event in this event set) and **firePropertyChange** (the method called to notify listeners when an event in this event set occurs—this method is named as such by convention).



### Software Engineering Observation 6.20

**EventSetDescriptors** can be constructed with other arguments to expose events that do not follow the standard JavaBeans design patterns.

A benefit of an **EventSetDescriptor** is customizing the name for the event set for display in the builder tool. Lines 171–172 call method **setDisplayName** on the **EventSetDescriptor** to indicate that its display name should be “**SliderFieldPanel value changed**.”



### Good Programming Practice 6.1

Customizing the event set name displayed by a builder tool can make the purpose of that event set more understandable to the component assembler using the bean.

Lines 174–176 create the **EventSetDescriptor** array and return it. Note the exception handler for **IntrospectionExceptions** at line 182. If an **EventSetDescriptor** constructor is unable to confirm the event in the corresponding **Class** object that represents the class definition, the constructor **throws** an **IntrospectionException**.

Lines 187–190 define method **getDefaultValueIndex** to return the value 0, indicating that the property at position 0 in the **EventSetDescriptor** array returned from **getEventSetDescriptors** is the *default event* for developers to customize in a builder tool. Typically, the default event is automatically selected when you click a bean. In this example, event **propertyChange** is the default event.

## 6.8.1 PropertyEditors

JavaBeans can be customized further by implementing other support classes in addition to **BeanInfo**. A **PropertyEditor** determines how a particular property is edited inside a builder tool. The **PropertyEditor** constrains the property to a particular range of values determined by the programmer. This prevents illegal values that would cause undesired operation in the JavaBean. A **PropertyEditor** appears often in the property sheet as a pull-down menu with a list of values. A class implementing interface **PropertyEditor** is written for every property of a JavaBean that will have a **PropertyEditor**.



### Software Engineering Observation 6.21

By convention, a **PropertyEditor** class has the same name as the property or type and ends with **Editor**.

The **PropertyEditors MaximumValueEditor** (Fig. 6.58) and **MinimumValueEditor** (Fig. 6.59) edit the **maximumValue** and **minimumValue** properties of class **SliderFieldPanel**. Both **PropertyEditors** extend class **PropertyEditorSupport**. **PropertyEditorSupport** is a simple implementation of interface **PropertyEditor**. The **PropertyEditors** each use a combo box with values from 50 through 500, in increments of 50. These values provide a wide range of animation speeds and prevent an illegal value from being entered for the properties.

```
1 // Fig. 6.58 MaximumValueEditor.java
2 // MaximumValueEditor is the PropertyEditor for the
3 // maximumValue property of the SliderFieldPanel bean.
4 package com.deitel.advjhtp1.beans;
5
6 // Java core packages
7 import java.beans.*;
8
9 public class MaximumValueEditor extends PropertyEditorSupport {
10
11     private Integer maximumValue;
12
13     // set maximumValue property
14     public void setValue( Object value )
15     {
16         maximumValue = ( Integer ) value;
17         firePropertyChange();
18     }
19
20     // get maximumValue property
21     public Object getValue()
22     {
23         return maximumValue;
24     }
25
26     // set maximumValue property from text string
27     public void setAsText( String string )
28     {
29         // decode may throw NumberFormatException
30         try {
31             maximumValue = Integer.decode( string );
32             firePropertyChange();
33         }
34
35         // throw IllegalArgumentException if decode throws
36         // NumberFormatException
37         catch ( NumberFormatException numberFormatException ) {
38             throw new IllegalArgumentException();
39         }
40     } // end method setAsText
41
42     // get String array for pull-down menu
43     public String[] getTags()
44     {
45         return new String[] { "50", "100", "150", "200", "250",
46             "300", "350", "400", "450", "500" };
47     }
48
49     // get maximumValue property as string
50     public String getAsText()
51     {
52 }
```

Fig. 6.58 MaximumValueEditor is a PropertyEditor for SliderFieldPanel's maximumValue property (part 1 of 2).

```
53     return getValue().toString();
54 }
55
56 // get initialization string for Java code
57 public String getJavaInitializationString()
58 {
59     return getValue().toString();
60 }
61
62 } // end class MaximumValueEditor
```

Fig. 6.58 `MaximumValueEditor` is a `PropertyEditor` for `SliderFieldPanel`'s `maximumValue` property (part 2 of 2).

`Integer maximumValue` (line 11) stores the value selected in the combo box. Method `setValue` (lines 14–18) takes an `Object value` as a parameter, sets `maximumValue` to `value` and calls method `firePropertyChange`. Method `getValue` (lines 21–24) returns `maximumValue`. Method `setAsText` (lines 27–41) takes a parameter `string` and decodes `string` into a new `Integer` value for `maximumValue`. Method `getTags` (lines 44–48) returns a `String` array of all of the tags that appear in the combo box. Method `getAsText` (lines 51–54) returns `maximumValue` as a `String`. Method `getJavaInitializationString` (lines 57–60) returns `maximumValue` as a `String` for use as a method parameter in generated source code.

`MinimumValueEditor`'s source code (Fig. 6.59) follows the exact same structure as `MaximumValueEditor`, but edits the `minimumValue` property of bean `SliderFieldPanel`.

```
1 // Fig. 6.59 MinimumValueEditor.java
2 // MinimumValueEditor is the PropertyEditor for the
3 // minimumValue property of the SliderFieldPanel bean.
4 package com.deitel.advjhtp1.beans;
5
6 // Java core packages
7 import java.beans.*;
8
9 public class MinimumValueEditor extends PropertyEditorSupport {
10
11     protected Integer minimumValue;
12
13     // set minimumValue property
14     public void setValue( Object value )
15     {
16         minimumValue = ( Integer ) value;
17         firePropertyChange();
18     }
19
20     // get value of property minimum
21     public Object getValue()
22     {
```

Fig. 6.59 `MinimumValueEditor` is a `PropertyEditor` for `SliderFieldPanel`'s `minimumValue` property (part 1 of 2).

```
23     return minimumValue;
24 }
25
26 // set maximumValue property from text string
27 public void setAsText( String string )
28 {
29     // decode may throw NumberFormatException
30     try {
31         minimumValue = Integer.decode( string );
32         firePropertyChange();
33     }
34
35     // throw IllegalArgumentException if decode throws
36     // NumberFormatException
37     catch ( NumberFormatException numberFormatException ) {
38         throw new IllegalArgumentException();
39     }
40 }
41
42 // string array for pull-down menu
43 public String[] getTags()
44 {
45     return new String[] { "50", "100", "150", "200", "250",
46                         "300", "350", "400", "450", "500" };
47 }
48
49 // get minValue property as string
50 public String getAsText()
51 {
52     return getValue().toString();
53 }
54
55 // get initialization string for Java code
56 public String getJavaInitializationString()
57 {
58     return getValue().toString();
59 }
60
61 } // end class MinimumValueEditor
```

Fig. 6.59 `MinimumValueEditor` is a `PropertyEditor` for `SliderFieldPanel`'s `minimumValue` property (part 2 of 2).

`MaximumValueEditor` and `MinimumValueEditor` must be compiled and packaged in the same JAR file as `SliderFieldPanel` and `SliderFieldPanel-BeanInfo`. When `SliderFieldPanel` is installed, the builder tool instantiates the `PropertyEditors`. `MaximumValueEditor` and `MinimumValueEditor` are presented as pull-down menus with values from 50–500 (Fig. 6.60). Try changing the values of `maximumValue` and `minimumValue` with the pull-down menus. When the `SliderFieldPanel` is linked to `LogoAnimator2` and executed, the selected values of `minimumValue` and `maximumValue` constrain the animation speed within the range 50–500 (Fig. 6.61).

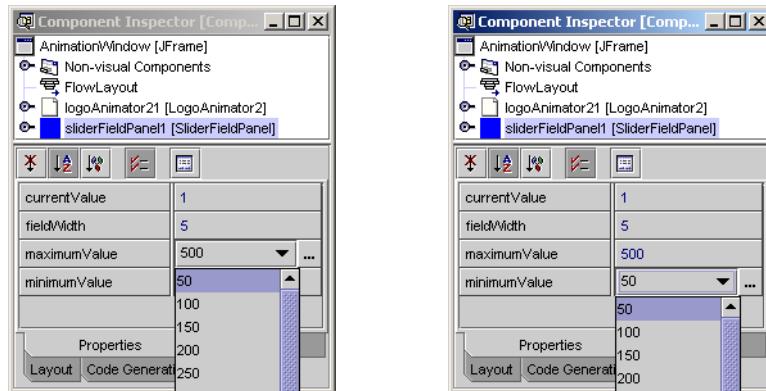


Fig. 6.60 MaximumValueEditor and MinimumValueEditor pull-down menus in Forte.



Fig. 6.61 SliderFieldPanel values constrained by PropertyEditors.

## 6.8.2 Customizers<sup>1</sup>

The final option for customizing a JavaBean is a **Customizer** class. A class that implements interface **Customizer** creates a customized interface for setting the properties of a JavaBean. This interface is separate from the builder-tool style sheet. A **Customizer** is useful for manipulating JavaBean properties that cannot be edited in the standard property sheet, such as instance fields in objects that are themselves properties.

**SliderFieldPanelCustomizer** (Fig. 6.62) implements the **Customizer** interface. A **Customizer** must extend a **Component** and provide a no-argument constructor so the builder tool can instantiate it. The constructor (lines 26–75) initializes the components of the customizer. Object **changeSupport** (line 29) registers **PropertyChangeListeners** with class **PropertyChangeSupport**. **SliderFieldPanelCustomizer** consists of two **JLabels** and two **JComboBoxes**. The **JLabels** label

1. Due to a problem in Forte that prevents bean **Customizers** from working properly, we use NetBeans 3.2 to demonstrate the example in this section. NetBeans is the open-source development environment project on which Forte is based. NetBeans can be downloaded free of charge from [www.netbeans.org](http://www.netbeans.org).

the **JComboBoxes** for the **minimumValue** and **maximumValue** properties (lines 32–33). Properties **minimumValue** and **maximumValue** can be set from 50 through 500, in increments of 50 (lines 36–39). Lines 42–69 add **ActionListeners** to the **JComboBoxes**. Selecting a value causes the **actionPerformed** method of the listener to call the right method to change either **maximumValue** or **minimumValue**.

```
1 // Fig. 6.62 SliderFieldPanelCustomizer.java
2 // SliderFieldPanelCustomizer is the Customizer class for
3 // SliderFieldPanel.
4 package com.deitel.advjhtp1.beans;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.beans.*;
10 import java.util.*;
11
12 // Java extension packages
13 import javax.swing.*;
14
15 public class SliderFieldPanelCustomizer extends JPanel
16     implements Customizer {
17
18     private JComboBox maximumCombo, minimumCombo;
19     private JLabel minimumLabel, maximumLabel;
20     protected SliderFieldPanel slider;
21     private PropertyChangeSupport changeSupport;
22     private static final String[] VALUES = { "50", "100",
23         "150", "200", "250", "300", "350", "400", "450", "500" };
24
25     // initialize GUI components
26     public SliderFieldPanelCustomizer()
27     {
28         // create PropertyChangeSupport to handle PropertyChange
29         changeSupport = new PropertyChangeSupport( this );
30
31         // labels for maximum and minimum properties
32         minimumLabel = new JLabel( "Minimum Slider Value:" );
33         maximumLabel = new JLabel( "Maximum Slider Value:" );
34
35         // combo boxes adjust maximum and minimum properties
36         minimumCombo = new JComboBox( VALUES );
37         minimumCombo.setSelectedIndex( 0 );
38         maximumCombo = new JComboBox( VALUES );
39         maximumCombo.setSelectedIndex( 9 );
40
41         // add ActionListener to minValue combo box
42         minimumCombo.addActionListener(
43             new ActionListener() { ... } );
```

Fig. 6.62 **SliderFieldPanelCustomizer** custom GUI for modifying **SliderFieldPanel** beans (part 1 of 3).

```
44         new ActionListener() {
45
46             // handle action of minimum combo box
47             public void actionPerformed( ActionEvent event )
48             {
49                 setMinimum( minimumCombo.getSelectedIndex() );
50             }
51
52         } // end anonymous inner class
53
54     ); // end addActionListener
55
56     // add ActionListener to maximumValue combo box
57     maximumCombo.addActionListener(
58
59         new ActionListener() {
60
61             // handle action of maximum combo box
62             public void actionPerformed( ActionEvent event )
63             {
64                 setMaximum( maximumCombo.getSelectedIndex() );
65             }
66
67         } // end anonymous inner class
68
69     ); // end addActionListener
70
71     add( minimumLabel );
72     add( minimumCombo );
73     add( maximumLabel );
74     add( maximumCombo );
75 }
76
77 // set the customized object
78 public void setObject( Object bean )
79 {
80     slider = ( SliderFieldPanel ) bean;
81 }
82
83 // add PropertyChangeListener with PropertyChangeSupport
84 public void addPropertyChangeListener(
85     PropertyChangeListener listener )
86 {
87     changeSupport.addPropertyChangeListener( listener );
88 }
89
90 // remove PropertyChangeListener with PropertyChangeSupport
91 public void removePropertyChangeListener(
92     PropertyChangeListener listener )
93 {
94     changeSupport.removePropertyChangeListener( listener );
95 }
```

Fig. 6.62 **SliderFieldPanelCustomizer** custom GUI for modifying **SliderFieldPanel** beans (part 2 of 3).

```

96
97     // set minimumValue property
98     public void setMinimum( int index )
99     {
100         int oldValue = slider.getMinimumValue();
101         int newValue = Integer.parseInt( VALUES[ index ] );
102
103         slider.setMinimumValue( newValue );
104         changeSupport.firePropertyChange( "minimumValue",
105             new Integer( oldValue ), new Integer( newValue ) );
106     }
107
108     // set maximumValue property
109     public void setMaximum( int index )
110     {
111         int oldValue = slider.getMaximumValue();
112         int newValue = Integer.parseInt( VALUES[ index ] );
113
114         slider.setMaximumValue( newValue );
115         changeSupport.firePropertyChange( "maximumValue",
116             new Integer( oldValue ), new Integer( newValue ) );
117     }
118 }
119 } // end class SliderFieldPanelCustomizer

```

Fig. 6.62 **SliderFieldPanelCustomizer** custom GUI for modifying **SliderFieldPanel** beans (part 3 of 3).

Method **setObject** (lines 78–81) takes as an object argument an instance of the JavaBean being customized. Line 80 casts the object reference to **SliderFieldPanel** and assigns it to instance variable **slider**.

Class **SliderFieldPanelCustomizer** provides methods for adding (lines 84–88) and removing (lines 91–95) **PropertyChangeListener**s. The builder tool registers with **SliderFieldPanelCustomizer** when the customizer is instantiated. A **PropertyChangeSupport** object (line 21) maintains the list of active listeners. Methods **setMinimum** (lines 98–106) and **setMaximum** (lines 109–117) call **firePropertyChangeEvent** to change the **minimumValue** and **maximumValue** properties of the JavaBean. Method **firePropertyChangeEvent** creates a new **PropertyChangeEvent** object with the new and old values of the changing property and sends the event to all registered listeners through **changeSupport**.

**SliderFieldPanelCustomizer** must be packaged in the same JAR file as **SliderFieldPanel** and **SliderFieldPanelBeanInfo**. Once it is installed, right click an instance of **SliderFieldPanel** and select **Customize** (Fig. 6.63). The **Customizer Dialog** opens and contains the **SliderFieldPanelCustomizer** (Fig. 6.64). Select the desired values for **minimumValue** and **maximumValue** and click the **Close** button. The new values take effect when you execute the application.

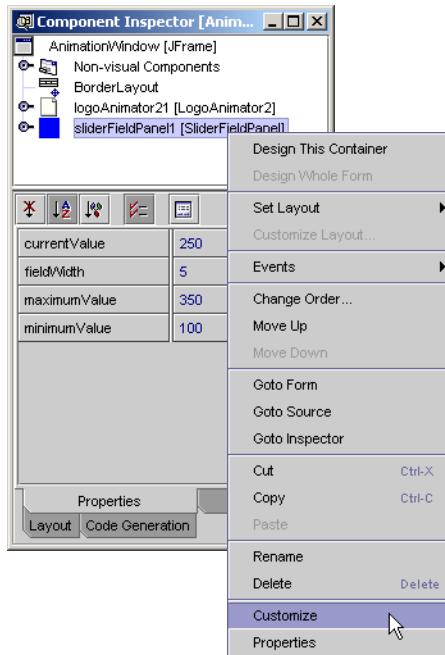


Fig. 6.63 Select **Customize** from **Component Inspector** menu.



Fig. 6.64 **SliderFieldPanel1's Customizer Dialog.**

## 6.9 Internet and World Wide Web Resources

### **java.sun.com/beans**

The JavaBeans Home Page at the Sun Microsystems, Inc., Web site. Here, you can download *the Beans Development Kit (BDK)* and other bean-related software. Other features of the site include JavaBeans documentation and specifications, a frequently asked questions list, an overview of integrated development environments that support JavaBeans development, training and support, upcoming JavaBeans events, a searchable directory of JavaBeans components, a support area for marketing your JavaBeans and a variety of on-line resources for communicating with other programmers regarding JavaBeans.

### **java.sun.com/beans/spec.html**

Visit this site to download the JavaBeans specification.

### **java.sun.com/beans/tools.html**

Visit this site for information about JavaBeans-enabled development tools.

### **java.sun.com/beans/directory**

Visit this site for a searchable directory of available beans.

## SUMMARY

- A JavaBean is a reusable software component that can be manipulated visually in a builder tool.
- JavaBeans (often called beans) allow developers to reap the benefits of rapid application development in Java by assembling predefined software components to create powerful applications and applets.
- Graphical programming and design environments (often called builder tools) that support beans provide programmers with tremendous flexibility by allowing programmers to reuse and integrate existing disparate components that in many cases, were never intended to be used together.
- The component assembler uses well-defined components to create more robust functionality.
- Sun Microsystem's Forte for Java Community Edition is an integrated development environment that provides a builder tool for assembling JavaBeans.
- A bean must be installed before it can be manipulated in Forte.
- GUI JavaBeans must be added to a Java **Container**.
- The property sheet in a builder tool displays a component's properties and allows them to be edited.
- JavaBeans can be connected with events.
- JavaBeans can be saved to disk as serialized objects or as Java Archive files (JAR). Saving a JavaBean in either of these methods allows other builder tools and code to use the JavaBean.
- Most JavaBeans are GUI components intended to be visually manipulated within a builder tool, such as Forte.
- Most Java **Swing** components, such as **JButtons**, are JavaBeans.
- By implementing **Serializable**, a customized JavaBean can be saved and reloaded in a builder tool or a Java application.
- To use a class as a JavaBean, one must first place it in a Java Archive file (JAR file). A JAR file for a JavaBean must contain a manifest file, which describes the JAR file contents. Manifest files contain attributes (called headers) that describe the individual contents of the JAR.
- When a JAR file containing a JavaBean (or a set of JavaBeans) is loaded into an IDE, the IDE looks at the manifest file to determine which of the classes in the JAR represent JavaBeans. These classes are made available to the programmer in a visual manner.
- All JavaBean-aware development environments know to look for the **MANIFEST.MF** file in the **META-INF** directory of the JAR file.
- The Java interpreter can execute an application directly from a JAR file if the manifest file specifies which class in the JAR contains method **main**.
- To execute a JavaBean from its JAR file, launch the Java interpreter with the **-jar** command-line option as follows:

```
java -jar JARFileName.jar
```

- The command

```
jar cfm JARFileName.jar manifest.tmp files
```

creates a JAR file.

- A read/write property of a bean is defined as a *set/get* method pair of the form

```
public void setPropertyName( DataType value )
public DataType getPropertyName()
```

where *PropertyName* is replaced in each case by the actual property name. These methods are often referred to as a "property *set* method" and "property *get* method," respectively.

- If the property is a **boolean** data type, the *set/get* method pair is normally defined as

```
public void setPropertyName( boolean value )
public boolean isPropertyName()
```

where the *get* method name begins with the word **is** rather than **get**.

- When a builder tool examines a bean, it inspects the bean methods for pairs of *set/get* methods that represent properties (some builder tools also expose read-only and write-only properties). This is a process known as introspection. If an appropriate *set/get* method pair is found during the introspection process, the builder tool exposes that pair of methods as a property in the builder tool's user interface.
- A bound property causes the JavaBean that owns the property to notify other objects when there is a change in the bound property's value. This is accomplished using standard Java event-handling features—registered **PropertyChangeListeners** are notified when the property's value changes. To support this feature, the **java.beans** package provides interface **PropertyChangeListener** so listeners can be configured to receive property-change notifications, class **PropertyChangeEvent** to provide information to a **PropertyChangeListener** about the change in a property's value and class **PropertyChangeSupport** to provide the listener registration and notification services (i.e., to maintain the list of listeners and notify them when an event occurs).
- To support registration of listeners for changes to a bound property, a bean defines methods **addPropertyChangeListener** and **removePropertyChangeListener**. Each of these methods calls the corresponding method in the **PropertyChangeSupport** object **changeSupport**. This object provides the event notification services when the property value changes.
- When the bound property changes, the registered **PropertyChangeListeners** must be notified of the change. Each bound-property listener is presented with the old and new property values when notified of the change (the values can be **null** if they are not needed). The **PropertyChangeSupport** object's **firePropertyChange** method notifies each registered **PropertyChangeListener**.
- An indexed property is like a standard property except that the indexed property is an array of primitives or objects. Two *get* and two *set* methods define an indexed property. The *get* methods are of the form

```
public Datatype[] getPropertyNames()
public Datatype getPropertyNames( int index )
```

The first *get* method returns the entire array of an indexed property. The second *get* method returns the item at the array index indicated by the *get* method's parameter.

- The *set* methods are of the form

```
public void setPropertyName( Datatype[] data )
public void setPropertyName( int index, Datatype data )
```

The first *set* method sets the indexed property to the value of the argument. The second *set* method sets the item at the indicated array index to the value of the second parameter.

- A JavaBean can generate programmer-defined events. A programmer-defined event, or custom event, provides functionality that standard Java events do not provide. An event class extends **java.util.EventObject** and the listener class extends **java.util.EventListener**.
- Builder tools use Java's introspection mechanism to expose a JavaBean's properties, methods and events if the programmer follows the proper JavaBean design patterns (such as the special naming conventions discussed for *set/get* method pairs that define bean properties). Builder tools use the classes and interfaces of package **java.lang.reflect** to perform introspection. For Java-

Beans that do not follow the JavaBean design patterns or for JavaBeans in which the programmer wants to customize the exposed set of properties, methods and events, the programmer can supply a class that implements interface **BeanInfo** (package **java.beans**). The **BeanInfo** class describes to the builder tool how to present the features of the bean to the programmer.

- Every **BeanInfo** class must implement interface **BeanInfo**. This interface describes the methods used by builder tools to determine the exposed features of the bean described by its corresponding **BeanInfo** class. As a convenience, the **java.beans** package includes class **SimpleBeanInfo**, which provides a default implementation of every method in interface **BeanInfo**. The programmer can extend this class and selectively override its methods to implement a proper **BeanInfo** class.
- Override method **getBeanDescriptor** to return a **BeanDescriptor** object. A **BeanDescriptor** specifies a **Customizer** class and information about the JavaBean.
- Override method **getIcon** to specify an icon to represent the bean in a builder tool.
- Override method **getMethodDescriptors** to return an array of **MethodDescriptor** objects. Each **MethodDescriptor** represents a specific method exposed to the builder tool.
- Override method **getPropertyDescriptors** to return an array of **PropertyDescriptor** objects. Each **PropertyDescriptor** indicates a specific property that should be exposed by a builder tool.
- Override method **getEventSetDescriptors** to return an array of **EventSetDescriptor** objects that describes to a builder tool the events supported by a bean.
- A **PropertyEditor** determines how a particular property is edited inside a builder tool. The **PropertyEditor** constrains the property to a particular range of values determined by the programmer. This prevents illegal values that would cause undesired operation in the JavaBean. A **PropertyEditor** may appear in the property sheet as a pull-down menu with a list of values. A class implementing interface **PropertyEditor** is written for every property of a JavaBean that will have a special **PropertyEditor**.
- A class that implements interface **Customizer** creates a customized interface for setting the properties of a JavaBean. This interface is separate from the builder-tool style sheet. A **Customizer** is useful for manipulating JavaBean properties that cannot be edited in the standard property sheet, such as instance fields in objects that are themselves properties.

## TERMINOLOGY

<b>actionPerformed</b> method of interface <b>ActionListener</b>	connecting beans
adapter class	<b>Connection mode</b> button
<b>Add to Jar</b> menu item of <b>Tools</b> menu	<b>Connection Wizard</b> dialog
<b>addPropertyChangeListener</b> method of class <b>PropertyChangeSupport</b>	“connect-the-dots” programming
bean	creating a JAR file
<b>BeanDescriptor</b> class	custom event
<b>BeanInfo</b> interface	customize a JavaBean
<b>Beans</b> tab of the <b>Component Palette</b> toolbar	<b>Customize</b> menu item
bound property of a bean	<b>Customizer</b> interface
builder tool	default property
<b>Compile</b> menu item	deserialize an object
component assembler	design pattern
<b>Component Inspector</b> window	event
<b>Component Palette</b> toolbar	event adapter class
	event hookup
	event listener

event set  
event source  
event target  
**EventListener** interface  
**EventObject** class  
**EventSetDescriptor** class  
**EventSetDescriptor** class  
**EventSetDescriptor** class  
**Explorer** window  
**Filesystems** tab of **Explorer** window  
**firePropertyChange** method of class  
    **PropertyChangeSupport**  
**Form** window  
Forte for Java Community Edition  
**getBeanDescriptor** method of  
    interface **BeanInfo**  
**getDefaultEventIndex** method of  
    interface **BeanInfo**  
**getDefaultPropertyIndex** method of  
    interface **BeanInfo**  
**getEventSetDescriptors** method of  
    interface **BeanInfo**  
**getIcon** method of interface **BeanInfo**  
**getJavaInitializationString** method  
    of interface **PropertyEditor**  
**getMethodDescriptors** method of  
    interface **BeanInfo**  
**getPropertyDescriptors** method of  
    interface **BeanInfo**  
**getTags** method of interface  
    **PropertyEditor**  
Graphical programming and design environment  
header  
hook up an event  
indexed property  
**Install New JavaBean...** menu item  
Integrated Development Environment (IDE)  
introspection  
**IntrospectionException** class  
**Iterator** class  
**jar** (Java Archive File) utility  
.jar (Java archive) file extension  
**JAR Packager** dialog  
Java Archive file (JAR file)  
**java -jar** (execute an application from a JAR)  
**java.beans** package  
**java.lang.reflect** package  
JavaBean  
**Java-Bean** header  
**JButton** icon

**Main-Class** header  
manifest file  
**manifest.tmp** file  
**META-INF** directory of a JAR file  
**Method Call** radio button of **Connection Wizard** dialog  
**MethodDescriptor** class  
**Name** header  
object serialization  
**paintComponet** method of class **JPanel**  
**Palette Category** dialog  
PNG file  
property  
property *get* method  
property *set* method  
property sheet  
**PropertyChangeEvent** class  
**PropertyChangeListener** interface  
**PropertyChangeSupport** class  
**PropertyDescriptor** class  
**PropertyEditor** interface  
**PropertyEditorSupport** class  
read/write property  
**removePropertyChangeListener** method  
    of class **PropertyChangeSupport**  
**repaint** method of class **JPanel**  
**Running** tab of Forte  
**Selection mode** button  
**Serializable** interface  
serializing a bean  
**Set Layout** menu item  
set/get method pair  
**setAsText** method of interface  
    **PropertyEditor**  
**setDisplayname** method of class  
    **BeanDescriptor**  
**setDisplayname** method of class  
    **EventSetDescriptor**  
**setObject** method of interface **Customizer**  
**setPropertyEditorClass** method of  
    class **PropertyDescriptor**  
**setShortDescription** method of class  
    **BeanDescriptor**  
**setShortDescription** method of  
    class **PropertyDescriptor**  
**setValue** method of interface  
    **PropertyEditor**  
**SimpleBeanInfo** class  
**Source Editor** window  
**stop** method of class **Timer**

**Swing Forms** option of **Template Chooser** dialog

**Swing** tab of the **Component Palette** toolbar target of an event

**Template Chooser** dialog  
**Timer** class

## SELF-REVIEW EXERCISES

**6.1** State whether each of the following is *true* or *false*. If *false*, explain why.

- A JavaBean is a reusable software component.
- Forte for Java is a builder tool.
- JavaBeans cannot generate events.
- A **Customizer** modifies an individual property of a JavaBean.
- An indexed property represents an array variable.

**6.2** Fill in the blanks in each of the following statements:

- The four windows of the Forte **GUI Editing** tab are \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- A \_\_\_\_\_ allows the programmer to customize a property's value.
- In Forte, the \_\_\_\_\_ provides access to the events supported by a bean that is an event source.
- JavaBeans should all implement the \_\_\_\_\_ interface so they can be saved from a builder tool after being customized by the programmer.
- All registered \_\_\_\_\_ are notified when a bound property's value changes.
- A builder tool uses \_\_\_\_\_ to expose a JavaBean's properties, methods and events.
- An \_\_\_\_\_ consists of an event class and a listener class.
- For JavaBeans that do not follow the JavaBean design pattern, or for JavaBeans in which the programmer wants to customize the exposed set of properties, methods and events, the programmer can supply a \_\_\_\_\_ class that describes to the builder tool how to present the features of the bean.
- A \_\_\_\_\_ object describes a property that a builder tool should expose.
- A \_\_\_\_\_ object describes an event set that a builder tool should expose.
- A \_\_\_\_\_ is a custom editor for a bean property that appears in a property sheet.

## ANSWERS TO SELF-REVIEW EXERCISES

**6.1** a) True. b) True. c) False. A JavaBean can generate Java events. d) False. A **Customizer** can modify any number of JavaBean properties. e) True.

**6.2** a) **Explorer**, **Component Inspector**, **Form**, **Source Editor**. b) property sheet. c) **Component Inspector**. d) **Serializable**. e) **PropertyChangeListeners**. f) introspection. g) event set. h) **BeanInfo**. i) **PropertyDescriptor**. j) **EventSetDescriptor**. k) **PropertyEditor**.

## EXERCISES

**6.3** Try some of the **Swing** components provided with Forte. Every **Swing** component is a JavaBean. While using each bean, try the following:

- Inspect the properties of each bean and try modifying them.
- Inspect the events supported by each bean and try using those events to hook various beans together.

**6.4** Modify **ColorSliderPanel** to provide a mechanism for viewing the selected color. For this purpose, add a **JPanel** object to the bean. Test your bean in Forte by changing the background color of a **JFrame** or other **Swing** component.

- 6.5** Create a **BeanInfo** class for the **LogoAnimator2** bean that exposes only the **background** and **animationDelay** properties. Test your bean in Forte.
- 6.6** Modify **ColorSliderPanel** to use a bound property **color** instead of indexed property **redGreenBlue** and custom event **ColorEvent**. Bound property **color** is an instance of class **Color**. Test the bean in Forte by changing the **background** color of **LogoAnimator2**.
- 6.7** Create a **Customizer** class for **ColorSliderPanel** that can set a narrower range of values than 0–255 for the red, green and blue sliders. A **BeanInfo** class must also be created to use this **Customizer**.
- 6.8** Modify **MaximumValueEditor** and **MinimumValueEditor** to accept the values 1–1000 as a **String** instead of using a pull-down menu.

# 7

# Security

## Objectives

- To understand the basic concepts of security.
- To understand public-key/private-key cryptography.
- To learn about popular security protocols, such as SSL.
- To understand digital signatures, digital certificates and certification authorities.
- To learn how Java provides solutions to security problems.
- To learn how to produce secure code with Java technology.

*Three may keep a secret, if two of them are dead.*

Benjamin Franklin

*Attack—Repeat—Attack.*

William Frederick Halsey, Jr.

*Private information is practically the source of every large modern fortune.*

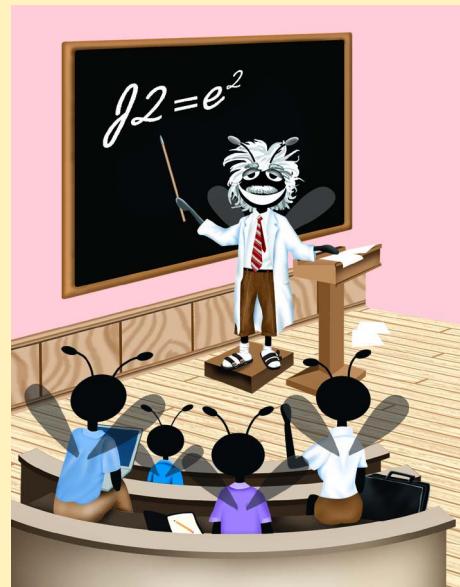
Oscar Wilde

*There must be security for all—or not one is safe.*

*The Day the Earth Stood Still*, screenplay by Edmund H. North

*No government can be long secure without formidable opposition.*

Benjamin Disraeli



## Outline

- 7.1 Introduction
- 7.2 Ancient Ciphers to Modern Cryptosystems
- 7.3 Secret-key Cryptography
- 7.4 Public-key Cryptography
- 7.5 Cryptanalysis
- 7.6 Key Agreement Protocols
- 7.7 Key Management
- 7.8 Java Cryptography Extension (JCE)
  - 7.8.1 Password-Based Encoding with JCE
  - 7.8.2 Decorator Design Pattern
- 7.9 Digital Signatures
- 7.10 Public-key Infrastructure, Certificates and Certification Authorities
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- 7.11 Java Policy Files
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- 7.13 Authentication
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- 7.14 Secure Sockets Layer (SSL)
  - 7.14.1 Java Secure Socket Extension (JSSE)
- 7.15 Java Language Security and Secure Coding
- 7.16 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Works Cited • Bibliography.*

### 7.1 Introduction

The explosion of e-business and e-commerce is forcing businesses and consumers to focus on Internet and network security. Consumers are buying products, trading stocks and banking online. They are submitting their credit-card numbers, social-security numbers and other highly confidential information to vendors through Web sites. Businesses are sending confidential information to clients and vendors over the Internet. At the same time, e-businesses are experiencing an increasing number of security attacks. Individuals and organizations are vulnerable to data theft and hacker attacks that can corrupt files and shut down systems, effectively halting business. Hence, security is fundamental.

Modern computer security addresses the various problems and concerns of protecting electronic communications and maintaining network security. There are five fundamental

requirements of a successful, secure transaction: *privacy, integrity, authentication, authorization* and *nonrepudiation*. *The privacy issue is:* How do you ensure that the information you transmit over the Internet has not been captured or passed on to a third party without your knowledge? *The integrity issue is:* How do you ensure that the information you send or receive has not been compromised or altered? *The authentication issue is:* How do the sender and receiver of a message prove their identities to each other? *The authorization issue is:* How do we ensure that users can access certain necessary resources, while valuable information is protected? *The nonrepudiation issue is:* How do you legally prove that a message was sent or received?

In this chapter, we will explore computer and Java security, from secure electronic transactions to secure coding. The Java programming language provides prevention of and solutions for many of today's security problems. The *Java Sandbox architecture* and *policy files* protect users and systems from malicious programs that would otherwise crash computers or steal valuable information. Several APIs, such as the *Java Cryptography Extension (JCE)*, *Java Secure Sockets Extension (JSSE)* and the *Java Authentication and Authorization Service (JAAS)*, provide additional security to Java applications.

We encourage you to visit the Web resources provided in Section 7.16 to learn more about the latest developments in e-commerce and Java security. These resources include many informative and entertaining demonstrations.

## 7.2 Ancient Ciphers to Modern Cryptosystems

The channels through which data pass are inherently unsecure; therefore, any private information passed through these channels must somehow be protected. To secure information, data can be encrypted. *Cryptography* transforms data by using a *cipher*, or *cryptosystem*—a mathematical algorithm for encrypting messages. A *key*—a string of alpha-numeric characters that acts as a password—is input to the cipher. The cipher uses the key to make data incomprehensible to all but the sender and intended receivers. Unencrypted data is called *plaintext*; encrypted data is called *ciphertext*. The algorithm is responsible for encrypting data, while the key acts as a variable—using different keys results in different ciphertext. Only the intended receivers should have the corresponding key to decrypt the ciphertext into plaintext.

Cryptographic ciphers have been used throughout history, first recorded by the ancient Egyptians, to conceal and protect valuable information. In ancient cryptography, messages were encrypted by hand, usually with a method based on the alphabetic characters of the message. The two main types of ciphers were *substitution ciphers* and *transposition ciphers*. In a substitution cipher, every occurrence of a given letter is replaced by a different letter; for example, if every “a” is replaced by “b,” every “b” by “c,” etc., the word “security” would encrypt to “tfdvsjuz.” The first prominent substitution cipher was credited to Julius Caesar and is referred to today as the *Caesar Cipher*. Using the Caesar Cipher, we replace every instance of a letter with the alphabetical letter three positions to the right. For example, according to the Caesar Cipher, the word “security” would encrypt to “vhfx-ulwb.” In a transposition cipher, the ordering of the letters is shifted; for example, if every other letter, starting with “s,” in the word “security” creates the first word in the ciphertext and the remaining letters create the second word in the ciphertext, the word “security” would encrypt to “scrt euuy.” Complicated ciphers are created by combining substitution and transposition ciphers. For example, with the substitution cipher first, then the transpo-

sition cipher, the word “security” would encrypt to “tdsu fvjz.” The problem with many historical ciphers is that their security relied on the sender and receiver to remember the encryption algorithm and keep it secret. Such algorithms are called *restricted algorithms*. Restricted algorithms are not feasible to implement among a large group of people. Imagine if the security of U.S. government communications relied on every U.S. government employee to keep a secret; the encryption algorithm could be compromised easily.

Modern cryptosystems are digital. Their algorithms are based on the individual *bits* or *blocks* (a group of bits) of a message, rather than letters of the alphabet. Encryption and decryption keys are binary strings with a given *key length*. For example, 128-bit encryption systems have a key length of 128 bits. Longer keys have stronger encryption; it takes more time and computing power to crack messages encrypted with longer keys.

Until January 2000, the U.S. government placed restrictions on the strength of cryptosystems that could be exported from the United States. Federal regulations limited the key length of encryption algorithms. Today, the regulations on exporting products that employ cryptography are less stringent. Any cryptography product may be exported, as long as the end user is not a foreign government or from a country with embargo restrictions on it.<sup>1</sup>

### 7.3 Secret-key Cryptography

In the past, organizations wishing to maintain a secure computing environment used *symmetric cryptography*, also known as *secret-key cryptography*. Secret-key cryptography utilizes the same secret key to encrypt and decrypt messages (Fig. 7.1). The sender encrypts a message using the secret key, then sends the encrypted message to the intended recipient. A fundamental problem with secret-key cryptography is that before two people can communicate securely, they must find a secure way to exchange the secret key. One approach is to have the key delivered by a courier, such as a mail service or FedEx. While this approach may be feasible when two individuals communicate, it is not efficient for securing communication in a large network, nor can it be considered completely secure. The privacy and the integrity of the message could be compromised if the key is intercepted as it is passed between the sender and the receiver over unsecure channels. Also, since both parties in the transaction use the same key to encipher and decipher a message, one cannot authenticate which party created the message. Finally, to keep communications with each receiver private, a sender needs a different secret key for each receiver. As a result, organizations may have huge numbers of secret keys to maintain.

An alternative approach to the key-exchange problem is to have a central authority, called a *key distribution center (KDC)*. The key distribution center shares a (different) secret key with every user in the network. In this system, the key distribution center generates a *session key* to be used for a transaction (Fig. 7.2). Next, the key distribution center distributes the session key to the sender and receiver, encrypting the session key itself with the secret key they each share with the key distribution center. For example, suppose a merchant and a customer want to conduct a secure transaction. The merchant and the customer each have unique secret keys they share with the key distribution center. The key distribution center generates a session key for the merchant and customer to use in the transaction. The key distribution center then sends the session key for the transaction to the merchant, encrypted using the secret key the merchant already shares with the center. The key distribution center sends the same session key for the transaction to the customer, encrypted using the secret key the customer already shares with the key distribution center. Once the

merchant and the customer have the session key for the transaction, they can communicate with each other, encrypting their messages using the shared session key.

Using a key distribution center reduces the number of courier deliveries (again, by means such as mail) of secret keys to each user in the network. In addition, users can have a new secret key for each communication with other users in the network, which greatly increases the overall security of the network. However, if the security of the key distribution center is compromised, then so is the security of the entire network.

One of the most commonly used symmetric encryption algorithms is the *Data Encryption Standard (DES)*. Horst Feistel of IBM created the *Lucifer* algorithm, which the United States government and the National Security Agency (NSA) chose as the DES in the 1970s.<sup>2</sup> DES has a key length of 56 bits and encrypts data in 64-bit blocks, a type of encryption known as a *block cipher*. A block cipher is an encryption method that creates groups of bits from an original message, then applies an encryption algorithm to the block as a whole, rather than as individual bits. This method reduces the amount of computer processing power and time required, while maintaining a fair level of security. For many years, DES was the encryption standard set by the U.S. government and the *American National Standards Institute (ANSI)*. However, due to advances in technology and computing speed, DES is no longer considered secure. In the late 1990s, specialized *DES cracker machines* were built that recovered DES keys after just several hours.<sup>3</sup> As a result, the old standard of symmetric encryption has been replaced by *Triple DES*, or *3DES*, a variant of DES that is essentially three DES systems in series, each having its own secret key. 3DES is more secure, however the three passes through the DES algorithm result in slower performance. The United States government recently selected a new, more secure standard for symmetric encryption to replace DES. The new standard is called the *Advanced Encryption Standard (AES)*. The *National Institute of Standards and Technology (NIST)*, which sets the cryptographic standards for the U.S. government, is evaluating *Rijndael* as the encryption method for AES. Rijndael is a block cipher developed by Dr. Joan Daemen and Dr. Vincent Rijmen of Belgium.<sup>4</sup> Rijndael can be used with key sizes and block sizes of 128, 192 or 256 bits. Rijndael was chosen over four other finalists as the AES candidate because of its high security, performance, efficiency, flexibility and low-memory requirement for computing systems. For more information about AES, visit [csrc.nist.gov/encryption/aes](http://csrc.nist.gov/encryption/aes).

## 7.4 Public-key Cryptography

In 1976, Whitfield Diffie and Martin Hellman, researchers at Stanford University, developed *public-key cryptography* to solve the problem of exchanging keys securely. Public-key cryptography is asymmetric. It uses two inversely related keys: A *public key* and a *private key*. The private key is kept secret by its owner, while the public key is freely distributed. If the public key is used to encrypt a message, only the corresponding private key can decrypt it, and vice versa (Fig. 7.3). Each party in a transaction has both a public key and a private key. To transmit a message securely, the sender uses the receiver's public key to encrypt the message. The receiver then decrypts the message using his or her unique private key. Assuming that the private key has been kept secret, the message cannot be read by anyone other than the intended receiver; the system ensures the privacy of the message. The defining property of a secure public-key algorithm is that it is computationally infeasible to deduce the private key from the public key. Although the two keys are mathematically related, deriving one from the other would take enormous amounts of computing power and

time, enough to discourage attempts to deduce the private key. An outside party cannot participate in communication without the correct keys. The security of the entire process is based on the secrecy of the private keys. Therefore, if a third party does obtain the decryption key, the security of the whole system is compromised. If a system's integrity is compromised, the user can simply change the key, instead of changing the entire encryption or decryption algorithm.

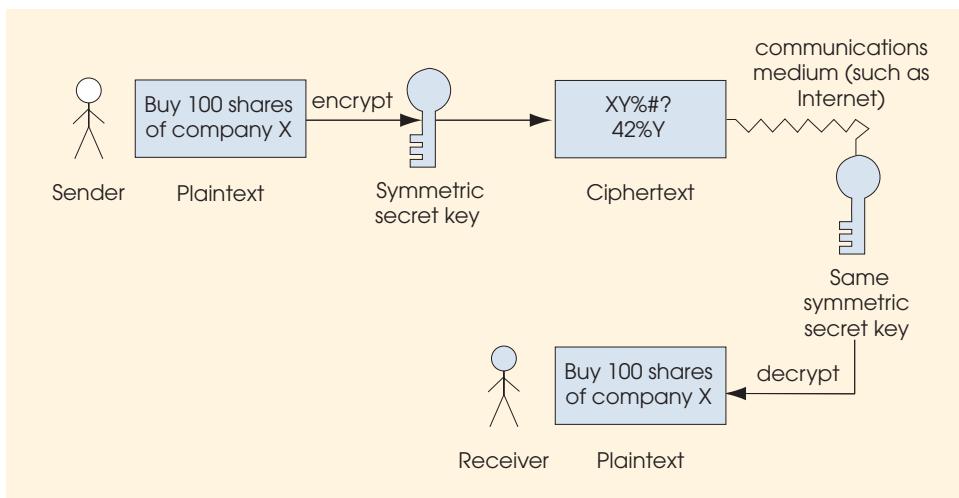


Fig. 7.1 Encrypting and decrypting a message using a symmetric secret key.

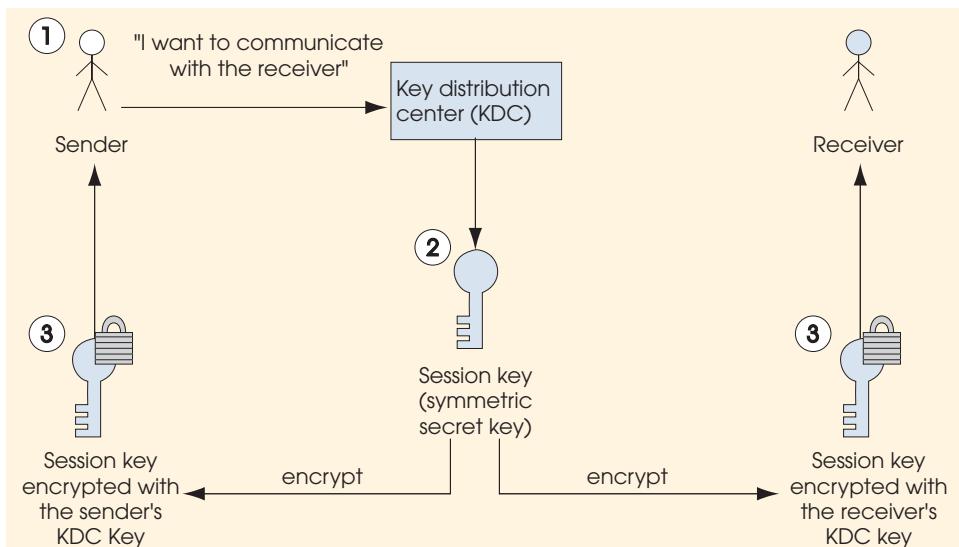


Fig. 7.2 Distributing a session key with a key distribution center.

Either the public key or the private key can be used to encrypt or decrypt messages. For example, if a customer uses a merchant's public key to encrypt a message, only the merchant can decrypt the message, using the merchant's private key. Thus, the merchant's identity can be authenticated, since only the merchant knows the private key. However, the merchant has no way of validating the customer's identity, since the encryption key the customer used is publicly available. If the encryption key is the sender's private key and the decryption key is the sender's public key, the sender of the message can be authenticated. For example, suppose a customer sends a merchant a message encrypted using the customer's private key. The merchant decrypts the message using the customer's public key. Since the customer encrypted the message using his or her private key, the merchant can be confident of the customer's identity. This process provides for authentication of the sender, not confidentiality, as anyone could decrypt the message with the sender's public key. This system works as long as the merchant can be sure that the public key with which the merchant decrypted the message belongs to the customer, and not a third party posing as the customer. The problem of proving ownership of a public key is discussed in Section 7.10.

These two methods of public-key encryption can be used together to authenticate both participants in a communication (Fig. 7.4). Suppose a merchant wants to send a message securely to a customer so that only the customer can read it, and suppose also that the merchant wants to provide proof to the customer that the merchant (not an unknown third party) actually sent the message. First, the merchant encrypts the message using the customer's public key. This step guarantees that only the customer can read the message. Then the merchant encrypts the result using the merchant's private key, which proves the identity of the merchant. The customer decrypts the message in reverse order. First, the customer uses the merchant's public key. Since only the merchant could have encrypted the message with the inversely related private key, this step authenticates the merchant. Then the customer uses the customer's private key to decrypt the next level of encryption. This step ensures that the message content was kept private in the transmission, since only the customer has the key to decrypt the message. This system provides for extremely secure transactions; however, the cost and time necessary for setting up such a system prevent this system from present use.

The most commonly used public-key algorithm is RSA, an encryption system developed in 1977 by MIT professors Ron Rivest, Adi Shamir and Leonard Adleman.<sup>5</sup> Today, their encryption and authentication technologies are used by most Fortune 1000 companies and leading e-commerce businesses. With the emergence of the Internet and the World Wide Web, their security work has become even more significant and plays a crucial role in e-commerce transactions. Their encryption products are built into hundreds of millions of copies of the most popular Internet applications, including Web browsers, commerce servers and e-mail systems. Most secure e-commerce transactions and communications on the Internet use RSA products. (For more information about RSA, cryptography and security, visit [www.rsasecurity.com](http://www.rsasecurity.com)).

Pretty Good Privacy (PGP) is a public-key encryption system used for encrypting e-mail messages and files. PGP was designed in 1991 by Phillip Zimmermann.<sup>6</sup> PGP also provides digital signatures (see Section 7.9, Digital Signatures) that confirm the author of an e-mail or public posting. PGP is based on a "web of trust"; each client in a network can vouch for another client's identity to prove ownership of a public key. Clients use the "web of trust" to authenticate one another. To learn more about PGP and to download a free copy of the software, go to the MIT distribution center for PGP at [web.mit.edu/network/pgp.html](http://web.mit.edu/network/pgp.html).

## 7.5 Cryptanalysis

Even if keys are kept secret, it may be possible to compromise the security of a system. Trying to decrypt ciphertext without knowledge of the decryption key is known as *cryptanalysis*. Commercial encryption systems are constantly being researched by cryptologists to ensure that the systems are not vulnerable to a *cryptanalytic attack*. The most common form of cryptanalytic attacks are those in which the encryption algorithm is analyzed to find relations between bits of the encryption key and bits of the ciphertext. Often, these relations are only statistical in nature and incorporate an analyzer's outside knowledge about the plaintext. The goal of such an attack is to determine the key from the ciphertext.

Weak statistical trends between ciphertext and keys can be exploited to gain knowledge about the key if enough ciphertext is known. Proper key management and expiration dates on keys help prevent cryptanalytic attacks. When a key is used for long periods of time, more ciphertext is generated that can be beneficial to an attacker trying to derive a key. If a key is unknowingly recovered by an attacker, it can be used to decrypt every message for the life of that key. Using public-key cryptography to exchange secret keys securely allows a new secret key to encrypt every message.

## 7.6 Key Agreement Protocols

A drawback of public-key algorithms is that they are not efficient for sending large amounts of data. They require significant computer power, which slows down communication. Public-key algorithms should not be thought of as a replacement for secret-key algorithms. Instead, public-key algorithms can be used to allow two parties to agree upon a key to be used for secret-key encryption over an unsecure medium. The process by which two parties can exchange keys over an unsecure medium is called a *key agreement protocol*. A *protocol* sets the rules for communication: Exactly what encryption algorithm(s) is (are) going to be used?

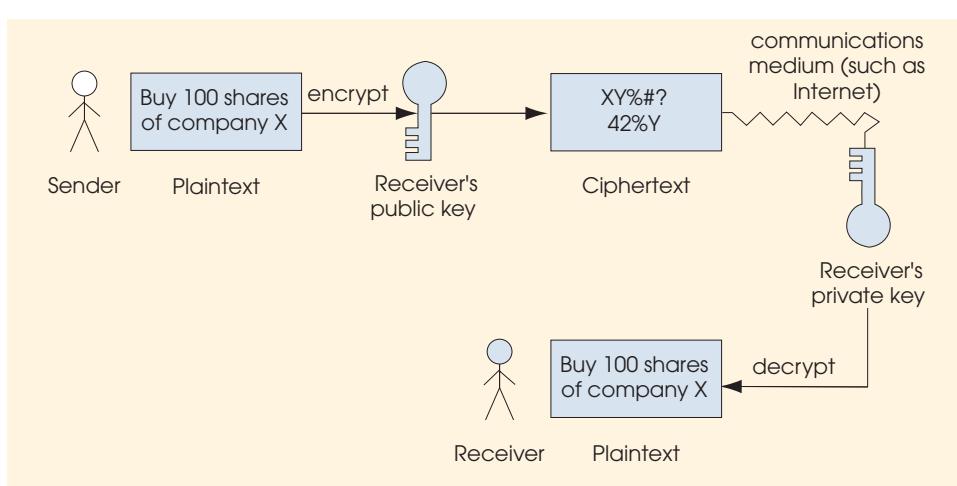
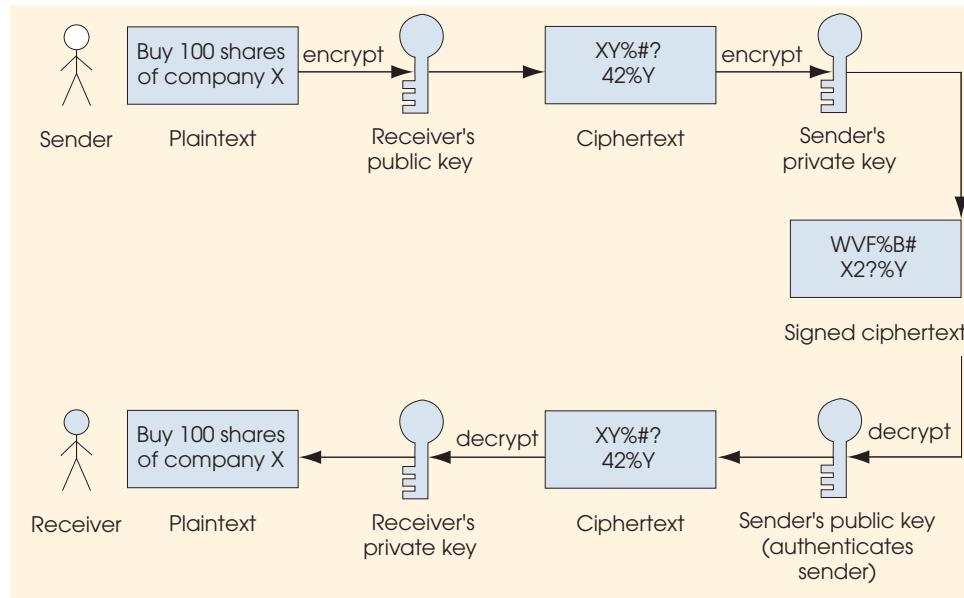


Fig. 7.3 Encrypting and decrypting a message using public-key cryptography.



**Fig. 7.4** Authentication with a public-key algorithm

The most common key agreement protocol is a *digital envelope* (Fig. 7.5). With a digital envelope, the message is encrypted using a secret key (Step 1), and the secret key is encrypted using public-key encryption (Step 2). The sender attaches the encrypted secret key to the encrypted message and sends the receiver the entire package. The sender could also digitally sign the package before sending it to prove the sender's identity to the receiver (Section 7.9). To decrypt the package, the receiver first decrypts the secret key, using the receiver's private key. Then the receiver uses the secret key to decrypt the actual message. Since only the receiver can decrypt the encrypted secret key, the sender can be sure that only the intended receiver is reading the message.

## 7.7 Key Management

Maintaining the secrecy of private keys is crucial to keeping cryptographic systems secure. Most compromises in security result from poor *key management* (e.g., the mishandling of private keys, resulting in key theft) rather than attacks that attempt to guess the keys.<sup>7</sup>

A main component of key management is *key generation*—the process by which keys are created. A malicious third party could try to decrypt a message by using every possible decryption key, a process known as *brute-force cracking*. Key-generation algorithms are sometimes unintentionally constructed to choose from only a small subset of possible keys. If the subset is too small, then the encrypted data is more susceptible to brute-force attacks. Therefore, it is important to have a key-generation program that can generate a large number of keys as randomly as possible. Keys are made more secure by choosing a key length so large that it is computationally infeasible to try all combinations.

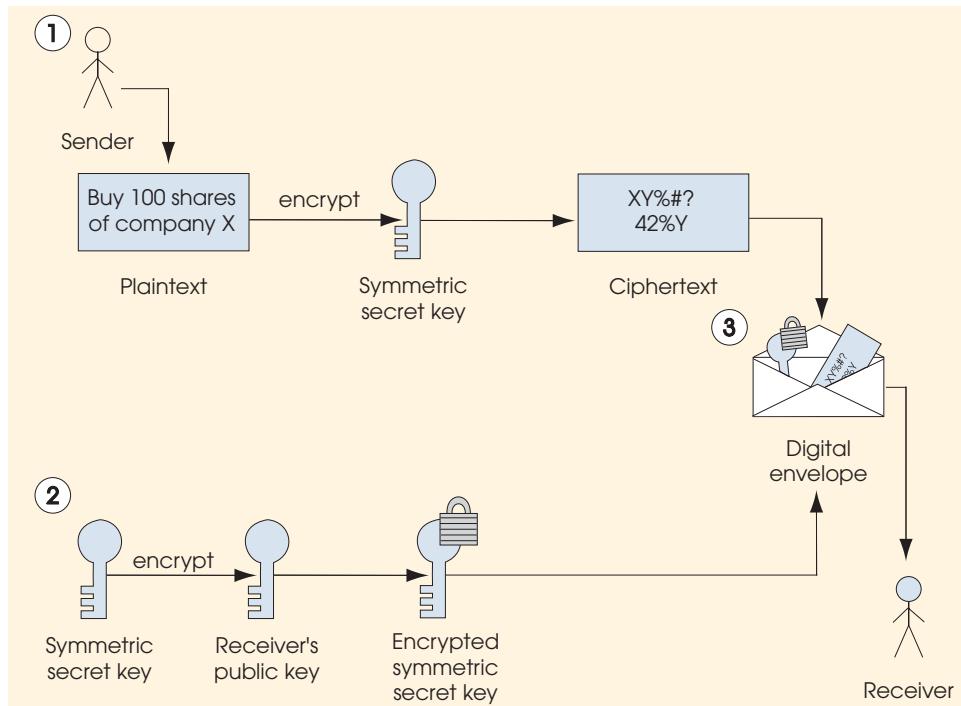


Fig. 7.5 Creating a digital envelope.

## 7.8 Java Cryptography Extension (JCE)

The *Java Cryptography Extension (JCE)* provides Java applications with several security facilities. JCE supports secret-key encryption, such as 3DES, and public-key algorithms, such as Diffie-Hellman and RSA. Customizable levels of security are available through multiple encryption algorithms and various key sizes. The JCE architecture is *provider-based*—developers can add new algorithms to their programs by adding new algorithm providers. Each provider may support many different algorithms. This feature allows developers to use their own algorithms from trusted sources with the JCE API (the API is located at [<java.sun.com/products/jce/doc/guide/API\\_users\\_guide.html>](http://java.sun.com/products/jce/doc/guide/API_users_guide.html)).

### 7.8.1 Password-Based Encoding with JCE

Class **EncipherDecipher** (Fig. 7.6) uses JCE to demonstrate Password-Based Encryption (PBE). Class **EncipherDecipher** provides users with a graphical user interface that allows them to specify the file name of a file that the application will use to write to and read from, the contents of the file to encrypt/decrypt, and the password used to encrypt/decrypt the file. The password-based encryption algorithm implementation uses an array of bytes (lines 28–31)—called a *salt*—and an integer (line 34) to randomize the sets of generated keys.

Line 45 adds a security provider implementation to the JVM. Each system must set a security provider implementation. The security provider implementation provides the various algorithm implementations that clients can use when selecting encrypting and decrypting techniques.

Constructor **EncipherDecipher** (lines 42–130) creates a **JFrame** that contains three panels. The top panel (lines 52–73) contains two labels and two textfields that allow the user to input the file name and the encryption password to use. Lines 76–88 create the middle panel which allows the user to write the contents that the application will encrypt and write to the file. Lines 91–121 create the bottom panel, which contains two buttons, button **Encrypt and Write to File** and button **Read from File and Decrypt**. When a user presses button **Encrypt and Write to File**, lines 100–103 handle the event by invoking method **encryptAndWriteToFile** (lines 131–277). When a user presses button **Read from File and Decrypt**, lines 115–118 handle the event by invoking method **readFromFileAndDecrypt** (lines 280–384).

```
1 // EncipherDecipher.java
2 // Displays a frame that allows users to specify
3 // a password and a file name. Contents written
4 // to an Editor Pane can be encrypted and written
5 // to a file, or encrypted contents can be read from
6 // a file and decrypted
7 package com.deitel.advjhtp1.security.jce;
8
9 // Java core package
10 import java.awt.*;
11 import java.awt.event.*;
12 import java.io.*;
13 import java.util.*;
14 import java.security.*;
15 import java.security.spec.*;
16
17 // third-party packages
18 import com.sun.crypto.provider.SunJCE;
19
20 // Java extension package
21 import javax.swing.*;
22 import javax.crypto.*;
23 import javax.crypto.spec.*;
24
25 public class EncipherDecipher extends JFrame {
26
27     // salt for password-based encryption-decryption algorithm
28     private static final byte[] salt = {
29         ( byte )0xf5, ( byte )0x33, ( byte )0x01, ( byte )0x2a,
30         ( byte )0xb2, ( byte )0xcc, ( byte )0xe4, ( byte )0x7f
31     };
32
33     // iteration count
34     private int iterationCount = 100;
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 1 of 8).

```
35
36     // user input components.
37     private JTextField passwordTextField;
38     private JTextField fileNameTextField;
39     private JEditorPane fileContentsEditorPane;
40
41     // frame constructor
42     public EncipherDecipher() {
43
44         // set security provider
45         Security.addProvider( new SunJCE() );
46
47         // initialize main frame
48         setSize( new Dimension( 400, 400 ) );
49         setTitle( "Encryption and Decryption Example" );
50
51         // construct top panel
52         JPanel topPanel = new JPanel();
53         topPanel.setBorder( BorderFactory.createLineBorder(
54             Color.black ) );
55         topPanel.setLayout( new BorderLayout() );
56
57         // panel where password and file name labels will be placed
58         JPanel labelsPanel = new JPanel();
59         labelsPanel.setLayout( new GridLayout( 2, 1 ) );
60         JLabel passwordLabel = new JLabel( " Password: " );
61         JLabel fileNameLabel = new JLabel( " File Name: " );
62         labelsPanel.add( fileNameLabel );
63         labelsPanel.add( passwordLabel );
64         topPanel.add( labelsPanel, BorderLayout.WEST );
65
66         // panel where password and file name textfields will be placed
67         JPanel textFieldsPanel = new JPanel();
68         textFieldsPanel.setLayout( new GridLayout( 2, 1 ) );
69         passwordTextField = new JPasswordField();
70         fileNameTextField = new JTextField();
71         textFieldsPanel.add( fileNameTextField );
72         textFieldsPanel.add( passwordTextField );
73         topPanel.add( textFieldsPanel, BorderLayout.CENTER );
74
75         // construct middle panel
76         JPanel middlePanel = new JPanel();
77         middlePanel.setLayout( new BorderLayout() );
78
79         // construct and place title label for contents pane
80         JLabel fileContentsLabel = new JLabel();
81         fileContentsLabel.setText( " File Contents" );
82         middlePanel.add( fileContentsLabel, BorderLayout.NORTH );
83
84         // initialize and place editor pane within scroll panel
85         fileContentsEditorPane = new JEditorPane();
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 2 of 8).

```
86     middlePanel.add(
87         new JScrollPane( fileContentsEditorPane ),
88         BorderLayout.CENTER );
89
90     // construct bottom panel
91     JPanel bottomPanel = new JPanel();
92
93     // create encrypt button
94     JButton encryptButton =
95         new JButton( "Encrypt and Write to File" );
96     encryptButton.addActionListener(
97
98         new ActionListener() {
99
100             public void actionPerformed( ActionEvent event )
101             {
102                 encryptAndWriteToFile();
103             }
104         }
105     );
106     bottomPanel.add( encryptButton );
107
108     // create decrypt button
109     JButton decryptButton =
110         new JButton( "Read from File and Decrypt" );
111     decryptButton.addActionListener(
112
113         new ActionListener() {
114
115             public void actionPerformed( ActionEvent event )
116             {
117                 readFromFileAndDecrypt();
118             }
119         }
120     );
121     bottomPanel.add( decryptButton );
122
123     // initialize main frame window
124     JPanel contentPane = ( JPanel ) this.getContentPane();
125     contentPane.setLayout( new BorderLayout() );
126     contentPane.add( topPanel, BorderLayout.NORTH );
127     contentPane.add( middlePanel, BorderLayout.CENTER );
128     contentPane.add( bottomPanel, BorderLayout.SOUTH );
129
130 } // end constructor
131
132 // obtain contents from editor pane and encrypt
133 private void encryptAndWriteToFile()
134 {
135
136     // obtain user input
137     String originalText = fileContentsEditorPane.getText();
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 3 of 8).

```
138     String password = passwordTextField.getText();
139     String fileName = fileNameTextField.getText();
140
141     // create secret key and get cipher instance
142     Cipher cipher = null;
143
144     try {
145
146         // create password based encryption key object
147         PBEKeySpec keySpec =
148             new PBEKeySpec( password.toCharArray() );
149
150         // obtain instance for secret key factory
151         SecretKeyFactory keyFactory =
152             SecretKeyFactory.getInstance( "PBEWithMD5AndDES" );
153
154         // generate secret key for encryption
155         SecretKey secretKey = keyFactory.generateSecret( keySpec );
156
157         // specifies parameters used with password based encryption
158         PBEParameterSpec parameterSpec =
159             new PBEParameterSpec( salt, iterationCount );
160
161         // obtain cipher instance reference
162         cipher = Cipher.getInstance( "PBEWithMD5AndDES" );
163
164         // initialize cipher in encrypt mode
165         cipher.init( Cipher.ENCRYPT_MODE, secretKey,
166             parameterSpec );
167     }
168
169     // handle NoSuchAlgorithmException
170     catch ( NoSuchAlgorithmException exception ) {
171         exception.printStackTrace();
172         System.exit( 1 );
173     }
174
175     // handle InvalidKeySpecException
176     catch ( InvalidKeySpecException exception ) {
177         exception.printStackTrace();
178         System.exit( 1 );
179     }
180
181     // handle InvalidKeyException
182     catch ( InvalidKeyException exception ) {
183         exception.printStackTrace();
184         System.exit( 1 );
185     }
186
187     // handle NoSuchPaddingException
188     catch ( NoSuchPaddingException exception ) {
189         exception.printStackTrace();
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 4 of 8).

```
190         System.exit( 1 );
191     }
192
193     // handle InvalidAlgorithmParameterException
194     catch ( InvalidAlgorithmParameterException exception ) {
195         exception.printStackTrace();
196         System.exit( 1 );
197     }
198
199     // create array of bytes
200     byte[] outputArray = null;
201
202     try {
203         outputArray = originalText.getBytes( "ISO-8859-1" );
204     }
205
206     // handle UnsupportedEncodingException
207     catch ( UnsupportedEncodingException exception ) {
208         exception.printStackTrace();
209         System.exit( 1 );
210     }
211
212     // create FileOutputStream
213     File file = new File( fileName );
214     FileOutputStream fileOutputStream = null;
215
216     try {
217         fileOutputStream = new FileOutputStream( file );
218     }
219
220     // handle IOException
221     catch ( IOException exception ) {
222         exception.printStackTrace();
223         System.exit( 1 );
224     }
225
226     // create CipherOutputStream
227     CipherOutputStream out =
228         new CipherOutputStream( fileOutputStream, cipher );
229
230     // write contents to file and close
231     try {
232         out.write( outputArray );
233         out.flush();
234         out.close();
235     }
236
237     // handle IOException
238     catch ( IOException exception ) {
239         exception.printStackTrace();
240         System.exit( 1 );
241     }
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 5 of 8).

```
242
243     // contain bytes read from file
244     Vector fileBytes = new Vector();
245
246     // read contents from file to show user encrypted text
247     try {
248         FileInputStream in = new FileInputStream( file );
249
250         // read bytes from stream.
251         byte contents;
252
253         while ( in.available() > 0 ) {
254             contents = ( byte )in.read();
255             fileBytes.add( new Byte( contents ) );
256         }
257
258         in.close();
259     }
260
261     // handle IOException
262     catch ( IOException exception ) {
263         exception.printStackTrace();
264         System.exit( 1 );
265     }
266
267     // create byte array from contents in Vector fileBytes
268     byte[] encryptedText = new byte[ fileBytes.size() ];
269
270     for ( int i = 0; i < fileBytes.size(); i++ ) {
271         encryptedText[ i ] =
272             ( ( Byte ) fileBytes.elementAt( i ) ).byteValue();
273     }
274
275     // update Editor Pane contents
276     fileContentsEditorPane.setText( new String( encryptedText ) );
277 }
278
279 // obtain contents from file and decrypt
280 private void readFromFileAndDecrypt()
281 {
282
283     // used to rebuild byte list
284     Vector fileBytes = new Vector();
285
286     // obtain user input
287     String password = passwordTextField.getText();
288     String fileName = fileNameTextField.getText();
289
290     // create secret key
291     Cipher cipher = null;
292 }
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 6 of 8).

```
293     try {
294         // create password based encryption key object
295         PBEKeySpec keySpec =
296             new PBEKeySpec( password.toCharArray() );
297
298         // obtain instance for secret key factory
299         SecretKeyFactory keyFactory =
300             SecretKeyFactory.getInstance( "PBEWithMD5AndDES" );
301
302         // generate secret key for encryption
303         SecretKey secretKey = keyFactory.generateSecret( keySpec );
304
305         // specifies parameters used with password based encryption
306         PBEParameterSpec parameterSpec =
307             new PBEParameterSpec( salt, iterationCount );
308
309         // obtain cipher instance reference.
310         cipher = Cipher.getInstance( "PBEWithMD5AndDES" );
311
312         // initialize cipher in decrypt mode
313         cipher.init( Cipher.DECRYPT_MODE, secretKey,
314             parameterSpec );
315     }
316
317     // handle NoSuchAlgorithmException
318     catch ( NoSuchAlgorithmException exception ) {
319         exception.printStackTrace();
320         System.exit( 1 );
321     }
322
323     // handle InvalidKeySpecException
324     catch ( InvalidKeySpecException exception ) {
325         exception.printStackTrace();
326         System.exit( 1 );
327     }
328
329     // handle InvalidKeyException
330     catch ( InvalidKeyException exception ) {
331         exception.printStackTrace();
332         System.exit( 1 );
333     }
334
335     // handle NoSuchPaddingException
336     catch ( NoSuchPaddingException exception ) {
337         exception.printStackTrace();
338         System.exit( 1 );
339     }
340
341     // handle InvalidAlgorithmParameterException
342     catch ( InvalidAlgorithmParameterException exception ) {
343         exception.printStackTrace();
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 7 of 8).

```
344         System.exit( 1 );
345     }
346
347
348     // read and decrypt contents from file
349     try {
350         File file = new File( fileName );
351         FileInputStream fileInputStream =
352             new FileInputStream( file );
353
354         CipherInputStream in =
355             new CipherInputStream( fileInputStream, cipher );
356
357         // read bytes from stream.
358         byte contents = ( byte ) in.read();
359
360         while ( contents != -1 ) {
361             fileBytes.add( new Byte( contents ) );
362             contents = ( byte ) in.read();
363         }
364         in.close();
365     }
366
367
368     // handle IOException
369     catch ( IOException exception ) {
370         exception.printStackTrace();
371         System.exit( 1 );
372     }
373
374     // create byte array from contents in Vector fileBytes
375     byte[] decryptedText = new byte[ fileBytes.size() ];
376
377     for ( int i = 0; i < fileBytes.size(); i++ ) {
378         decryptedText[ i ] =
379             ( ( Byte )fileBytes.elementAt( i ) ).byteValue();
380     }
381
382     // update Editor Pane contents.
383     fileContentsEditorPane.setText( new String( decryptedText ) );
384 }
385
386
387 // create frame and display
388 public static void main( String[] args )
389 {
390     EncipherDecipher crypto =
391         new EncipherDecipher();
392     crypto.validate();
393     crypto.setVisible( true );
394 }
```

Fig. 7.6 **EncipherDecipher** application for demonstrating Password-Based Encryption (part 8 of 8).

Method `encryptAndWriteToFile` (lines 131–277) obtains the user's input from the both `JTextFields` and the `JEditorPane`. Lines 147–148 create a `PBEKeySpec` instance. The `PBEKeySpec` instance acts as a wrapper for the array of characters that represents the password for encrypting and decrypting an array of bytes. Class `Cipher` is the fundamental building block for applications that use JCE. A `Cipher` performs encryption and decryption using a specified algorithm (e.g., DES, 3DES, Blowfish, etc.). Lines 151–152 obtain a reference to a `SecretKeyFactory`, which generates secret keys. Line 155 generates a `SecretKey` using the `PBEKeySpec` instance from lines 147–148. Lines 158–159 create a `PBEParameterSpec` instance, which contains randomization information such as the `salt` and the `iterationCount`. Line 162 obtains an instance of a `PBEwithMD5AndDES` algorithm `Cipher`. Line 165–166 initializes `Cipher` to encryption mode using the `SecretKey` and the `PBEParameterSpec` instances.

Lines 170–173 handle `NoSuchAlgorithmException`s, which occur when the program specifies a non-existent algorithm. Lines 176–179 handle `InvalidKeySpecException`s, which occur when an invalid key specification is handed to method `generateSecret` from `SecretKeyFactory`. Lines 182–185 handle all `InvalidKeyException`s which occur when an invalid key is handed to method `init` from `Cipher`. Lines 188–191 handle `NoSuchPaddingException`s, which occur when an application specifies an invalid padding scheme. Lines 194–197 handle `InvalidAlgorithmParameterException`s, which method `init` of class `Cipher` throws if an application specifies invalid algorithm parameters.

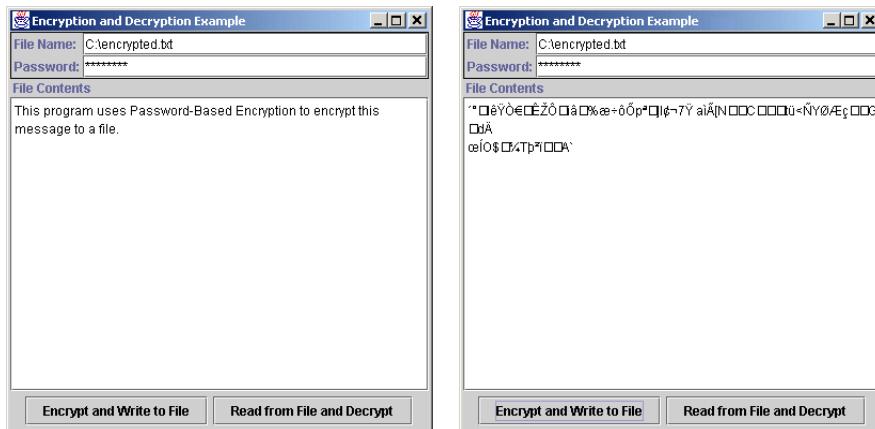
Line 203 converts the `String` obtained from `JEditorPanel` into an array of bytes. Method `getBytes` ensures that the conversion of a `String` to an array of bytes conforms to the ISO-8859-1 standard. Lines 207–210 catch an `UnsupportedEncodingException` if the application specifies an invalid character encoding standard.

Lines 213–218 instantiate a `FileOutputStream`. `CipherOutputStream` (lines 227–228) acts as the *decorator* in the *Decorator design pattern* (Section 7.8.2) to add encryption capability to the `FileOutputStream` instance. The `CipherOutputStream` encodes bytes using the specified `Cipher` object before writing those bytes to the `FileOutputStream`. Lines 232–234 write the contents to the file, and finalize the operation by closing the file. Lines 244–276 read the newly encoded file contents and display them in the `JEditorPane` so the user can see the encrypted text.

Method `readFromFileAndDecrypt` decrypts the message from the file using the specified password. Lines 291–314 create an instance of class `Cipher` and initialize the `Cipher` to decrypt data (lines 313–314). Lines 350–352 create a `FileInputStream` for the encrypted file. Lines 354–355 create a `CipherInputStream` to decrypt data from the `FileInputStream`. Lines 358–364 read the file contents from the `CipherInputStream`. Lines 375–383 create an array of bytes that contains the decrypted text and display the text in the `JEditorPane`.

Figure 7.7 displays the contents that application `EncipherDecipher` will encrypt and write to file `Testfile.txt` using password "I am a BIG secret!". The image on the right displays the contents of the file after pressing button **Encrypt and Write to File**.

For more information on JCE, please visit the JCE Web site at [java.sun.com/jce](http://java.sun.com/jce). Refer to the included documentation for download and installation instructions.



**Fig. 7.7** **EncipherDecipher** before and after encrypting contents.

### 7.8.2 Decorator Design Pattern

The preceding program uses an important design pattern—the *Decorator design pattern*. Method `encryptAndWriteToFile` writes encrypted data to a file. However, neither the `CipherOutputStream` nor the `FileOutputStream`, by itself, can encrypt data and write those data to a file. By “chaining” these two objects together—i.e., by passing a `FileOutputStream` reference to the `CipherOutputStream` constructor—the method can encrypt data and write those data to a file. This “chaining” is an example of the Decorator design pattern, which allows an object to gain additional capabilities dynamically. In this example, the `CipherOutputStream` *decorates* the `FileOutputStream`—the `CipherOutputStream` provides the `FileOutputStream` with the capability to encrypt data before writing those data to a file. One benefit to this pattern is that designers need not create additional classes (e.g., using inheritance) to extend the functionality of a particular class. For example, because a `FileOutputStream` object can gain the behavior of a `CipherOutputStream` dynamically, we need not create a separate class called `Cipher FileOutputStream`, which would implement the behaviors of both classes. Lines 227–228 accomplish the same result simply by chaining the streams together.

If necessary, we could extend this principle further and decorate a **CipherOutputStream** (which decorates a **FileOutputStream**) with an **ObjectOutputStream**. The resulting **ObjectOutputStream** instance would enable us to write encrypted objects to a file. Using the Decorator design pattern, we would write

```
ObjectOutputStream objectStream = new ObjectOutputStream( new CipherOutputStream( new FileOutputStream( filename ), cipher ) );
```

We can chain objects in this manner because **CipherOutputStream**, **ObjectOutputStream**, **putStream** and **FileOutputStream** extend abstract superclass **OutputStream**, and each subclass constructor takes an **OutputStream** reference as a parameter. If Java's stream objects did not use the Decorator pattern (i.e., did not satisfy these two requirements), we would have to design classes **CipherFileOutputStream**, **CipherObjectOutputStream**.

`putStream`, `CipherObjectFileOutputStream` and `ObjectFileOutputStream` to achieve the same functionality. If we were to chain more objects without using the Decorator pattern, the number of classes would grow exponentially.

## 7.9 Digital Signatures

*Digital signatures*—the electronic equivalent of written signatures—were developed for use in public-key cryptography to solve the problems of authentication and integrity (see Microsoft Authenticode feature). A digital signature authenticates the sender's identity and, like a written signature, is difficult to forge. To create a digital signature, a sender first takes the original plaintext message and runs it through a *hash function*, which is a mathematical calculation that gives the message a *hash value*. The Secure Hash Algorithm (SHA-1) is the standard for hash functions. Running a message through the SHA-1 algorithm produces a 160-bit hash value. For example, using SHA-1, the phrase “Buy 100 shares of company X” produces the hash value D8 A9 B6 9F 72 65 0B D5 6D 0C 47 00 95 0D FD 31 96 0A FD B5. MD5 is another popular hash function, which was developed by Ronald Rivest to verify data integrity through a 128-bit hash value of the input file.<sup>8</sup> Examples of SHA-1 and MD5 are available at [home.istar.ca/~neutron/messagedigest](http://home.istar.ca/~neutron/messagedigest). At this site, users can input text or files into a program to generate the hash value. The hash value is also known as a *message digest*. The chance that two different messages will have the same message digest is statistically insignificant. *Collision* occurs when multiple messages have the same hash value. It is computationally infeasible to compute a message from its hash value or to find two different messages with the same hash value.

Next, the sender uses its private key to encrypt the message digest. This step creates a digital signature and authenticates the sender, since only the owner of that private key could encrypt the message. The sender encrypts the original message with the receiver's public key and sends the encrypted message and the digital signature to the receiver. The receiver uses the sender's public key to decipher the original digital signature and reveal the message digest. The receiver then uses his or her own private key to decipher the original message. Finally, the receiver applies the agreed upon hash function (e.g. SHA-1 or MD5) to the original message. If the hash value of the original message matches the message digest included in the signature, there is *message integrity*—the message has not been altered in transmission.

There is a fundamental difference between digital signatures and handwritten signatures. A handwritten signature is independent of the document being signed. Thus, if someone can forge a handwritten signature, he or she can use that signature to forge multiple documents. A digital signature is created using the contents of the document. Therefore, your digital signature is different for each document you sign.

Digital signatures do not provide proof that a message has been sent. Consider the following situation: A contractor sends a company a digitally signed contract, which the contractor later would like to revoke. The contractor could do so by releasing the private key and claiming that the digitally signed contract came from an intruder who stole the contractor's private key. *Timestamping*, which binds a time and date to a digital document, can help solve the problem of non-repudiation. For example, suppose the company and the contractor are negotiating a contract. The company requires the contractor to digitally sign the contract, and have the document digitally time-stamped by a third party called a *timestamping agency*. The contractor sends the digitally signed contract to the time-stamping agency. The privacy of the message is maintained, since the timestamping agency sees only

the encrypted, digitally signed message (as opposed to the original plaintext message). The timestamping agency affixes the time and date of receipt to the encrypted, signed message and digitally signs the whole package with the timestamping agency's private key. The timestamp cannot be altered by anyone except the timestamping agency, since no one else possesses the timestamping agency's private key. Unless the contractor reports the private key to have been compromised before the document was timestamped, the contractor cannot legally prove that the document was signed by an unauthorized third party. The sender could also require the receiver to sign and timestamp the message digitally as proof of receipt. To learn more about timestamping, visit **AuthentiDate.com**.

The U.S. government's digital-authentication standard is called the *Digital Signature Algorithm (DSA)*. The U.S. government recently passed legislation that makes digital signatures as legally binding as handwritten signatures. This legislation will result in an increase in e-business. For the latest news about U.S. government legislation in information security, visit [www.itaa.org/infosec](http://www.itaa.org/infosec). For more information about the bills, visit the following government sites:

`thomas.loc.gov/cgi-bin/bdquery/z?d106:hr.01714:  
thomas.loc.gov/cgi-bin/bdquery/z?d106:s.00761:`

## 7.10 Public-key Infrastructure, Certificates and Certification Authorities

One problem with public-key cryptography is that anyone with a set of keys could assume another party's identity. For example, say a customer wants to place an order with an online merchant. How does the customer know that the Web site indeed belongs to that merchant and not to a third party that posted a site and is masquerading as a merchant to steal credit-card information? *Public-Key Infrastructure (PKI)* integrates public-key cryptography with *digital certificates* and *certificate authorities* to authenticate parties in a transaction.

A digital certificate is a digital document that identifies a user and is issued by a *certificate authority (CA)*. A digital certificate includes the name of the subject (the company or individual being certified), the subject's public key, a serial number, an expiration date, the signature of the trusted certificate authority and any other relevant information (Fig. 7.8). A CA is a financial institution or other trusted third party, such as *VeriSign*. Once issued, digital certificates are publicly available and are held by the certificate authority in *certificate repositories*.

The CA signs the certificate by encrypting either the subject's public key or a hash value of the public key using the CA's own private key. The CA has to verify every subject's public key. Thus, users must trust the public key of a CA. Usually, each CA is part of a *certificate-authority hierarchy*. A certificate authority hierarchy is a chain of certificate authorities, starting with the *root-certificate authority*, which is the Internet Policy Registration Authority (IPRA). The IPRA signs certificates using the *root key*. The root key signs certificates only for *policy-creation authorities*, which are organizations that set policies for obtaining digital certificates. In turn, policy-creation authorities sign digital certificates for CAs. CAs then sign digital certificates for individuals and organizations. The CA takes responsibility for authentication, so it must check information carefully before issuing a digital certificate. In one case, human error caused VeriSign to issue two digital certificates to an imposter posing as a Microsoft employee.<sup>9</sup> Such an error is significant: The inappropriately issued certificates can cause users to unknowingly download malicious code onto their machines.

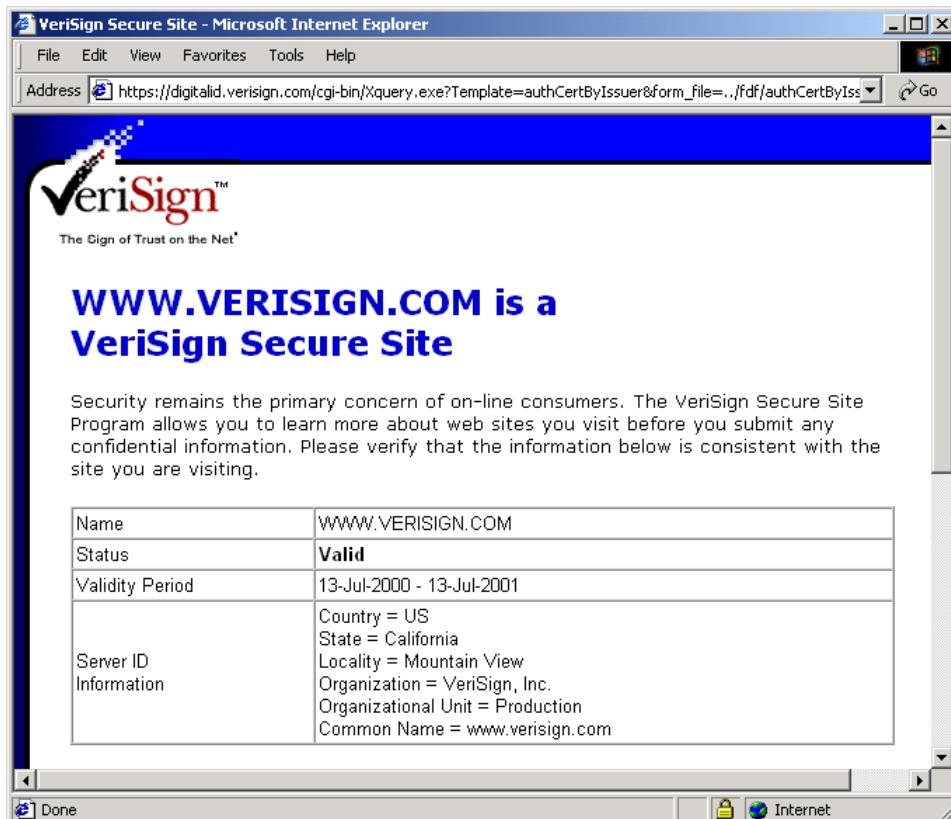


Fig. 7.8 A portion of the VeriSign digital certificate. (Courtesy of VeriSign, Inc.)

VeriSign, Inc., is a leading certificate authority. For more information about VeriSign, visit [www.verisign.com](http://www.verisign.com). For a listing of other digital-certificate vendors, see Section 7.16.

Periodically, changing key pairs is necessary to maintain a secure system, as a private key may be compromised without a user's knowledge. The longer a key pair is used, the more vulnerable the keys are to attack and cryptanalysis. As a result, digital certificates contain an expiration date to force users to switch key pairs. If a private key is compromised before its expiration date, the digital certificate can be canceled, and the user can get a new key pair and digital certificate. Canceled and revoked certificates are placed on a *certificate revocation list (CRL)*. CRLs are stored with the certificate authority that issued the certificates. It is essential for users to report immediately if they suspect that their private keys have been compromised, as the issue of non-repudiation makes certificate owners responsible for anything appearing with their digital signatures. In states with laws dealing with digital signatures, certificates legally bind certificate owners to any transactions involving their certificates.

One problem with CRLs is that they are similar to old paper lists of revoked credit card numbers that were used at the points of sale in stores.<sup>10</sup> This makes for a great inconvenience when checking the validity of a certificate. An alternative to CRLs is the *Online Cer-*

*tificate Status Protocol (OCSP)*, which validates certificates in real-time. OCSP technology is currently under development. For an overview of OCSP, read “X.509 Internet Public Key Infrastructure Online Certificate Status Protocol—OCSP” located at <ftp://ftp.isi.edu/in-notes/rfc2560.txt>.

Many people still consider e-commerce unsecure. However, transactions using PKI and digital certificates can be more secure than exchanging private information over phone lines or through the mail. They are even more secure than paying by credit card in person! After all, when you go to a restaurant and the waiter takes your credit card in back to process your bill, how do you know the waiter did not write down your credit-card information? In contrast, the key algorithms used in most secure online transactions are nearly impossible to compromise. By some estimates, the key algorithms used in public-key cryptography are so secure that even millions of today’s computers working in parallel could not break the codes in a century. However, as computing increases, key algorithms that are considered strong today could be broken in the future.

Digital-certificate capabilities are built into many e-mail packages. For example, in Microsoft Outlook, you can go to the **Tools** menu and select **Options**. Then click on the **Security** tab. At the bottom of the dialog box, you will see the option to obtain a digital ID. Selecting the option will take you to a Microsoft Web site with links to several worldwide certificate authorities. Once you have a digital certificate, you can digitally sign your e-mail messages.

To obtain a digital certificate for your personal e-mail messages, visit [www.verisign.com](http://www.verisign.com) or [www.thawte.com](http://www.thawte.com). VeriSign offers a free 60-day trial, or you can purchase the service for a yearly fee. Thawte offers free digital certificates for personal e-mail. Web server certificates may also be purchased through VeriSign and Thawte; however, they are more expensive than e-mail certificates.

### 7.10.1 Java Keystores and **keytool**

Java provides the **keytool** utility for managing and generating keys, certificates and digital signatures. The **keytool** utility enables users to generate and import keys in a *keystore*; you can use the stored keys for functions such as identification verification, encryption and decryption. A keystore is a repository for storing public and private keys. Modifying the set of keys that a keystore contains requires entering that keystore’s password. Note that if no keystore exists, the **keytool** will create one; the password is set when creating the keystore. The default keystore is in the user’s home directory (e.g., `/home/user/.keystore`). The **-genkey** command-line argument produces a public and private key pair and stores that key pair in the keystore. The user can export a certificate based on that key pair using the **-export** command-line option. To import a trusted certificate from a CA, the **-import** command is used. To list all of the contents of the keystore, use the **-list** command.<sup>11</sup> For example, to create a public and private key pair, enter the following at a command prompt:

```
keytool -genkey -alias MyCertificate
```

**MyCertificate** is an *alias* for the public and private key pair. The alias simply identifies a particular public and private key pair for later use. Keystores contain aliases for each public and private key pair. Certificates generated with **keytool** allow for identification through *commonName (CN)*, *organizationUnit (OU)*, *organizationName (O)*, *locality-*

*Name (L), stateName (S) and country (C).* When executing the above command line, **keytool** prompts the user for this information. You then can generate a certificate request to obtain a verified digital certificate from a certificate authority, such as Verisign or Thawte, using the command:

```
keytool -certreq -alias MyCertificate -file myRequest.cer
```

This creates a file called **myRequest.cer** that contains your digital certificate. Follow the instructions on the certificate authority's Web site to submit your certificate request and obtain your verified certificate.

To create a certificate that others may use to validate your signature, use the command

```
keytool -export -alias MyCertificate -file myCertificate.cer
```

This generates an X.509 certificate that other users can import into their *trusted keystores*—keystores that contain certificates that the user knows to be correct, such as those from certificate authorities—to validate information with the signature. For more information on the keytool utility, please refer to the documentation at [java.sun.com/j2se/1.3/docs/tooldocs/win32/keytool.html](http://java.sun.com/j2se/1.3/docs/tooldocs/win32/keytool.html) or [java.sun.com/j2se/1.3/docs/tooldocs/solaris/keytool.html](http://java.sun.com/j2se/1.3/docs/tooldocs/solaris/keytool.html).

## 7.11 Java Policy Files

The basis of Java security is the *Java Sandbox*—the protected environment in which Java applications and applets run. This model is similar to placing a child in a sandbox to play; it is a safe environment where certain objects are placed out of reach and can be used only with permission. On a computer, the user must grant an application or applet specific permissions to access certain system resources outside the sandbox. The Java Sandbox security model is comprised of three individual security checks: the *bytecode verifier*, the *class loader* and *security manager*.<sup>12</sup>

If a developer would like to allow certain operations that the security manager would deem potentially dangerous, *permissions* may be granted on the basis of *security policy files*. Permissions are comprised of varying levels of access to specific resources. Reading and writing to a file or directory or connecting to an identified port on a host's machine are two common permissions granted by a policy file.

Permissions may be granted on the basis of the code signer (using **signedBy**) and the source of the code (using **codeBase**). Any permission that is not declared explicitly in the policy file is not granted; therefore, it is necessary to have a policy file with at least some content for the JVM to run any applet. All of the parameters for permission granting are defined in the security policy files, which enable the Java Virtual Machine to offer a great level of access control. The security policy files are external text files with certain syntax and class names; note that, as an alternative to learning this syntax, tools such as **policytool** are available for use with JDK 1.3. Figure 7.9 describes a few of the permissions available for the Java 2 security model.<sup>13</sup>

A system-wide security policy file is responsible for granting code the permission to access files and ports on the entire system. The virtual machine loads this policy file as part of the virtual machine's initialization. The system-wide policy file (**java.policy**) is in the **lib/security** directory of the Java Runtime Environment (e.g., **C:\Program Files\JavaSoft\JRE\1.3.1\lib\security**). Particular applications can

Permission	Description
<b>java.security.AllPermission</b>	Grants all possible permissions. Developers should use this permission only for testing purposes as this permission disables all security checks.
<b>java.io.FilePermission</b>	Grants access to particular sets of files for reading, writing and deleting those files.
<b>java.lang.RuntimePermission</b>	Grants permissions for modifying runtime behavior, such as the allowing a program to exit the virtual machine, change the source of <b>System.in</b> and queue print jobs.
<b>java.net.SocketPermission</b>	Grants permission to create socket connections for connecting to other computers over the network. This permission allows fine-grained control over particular ports, host names and connection types.
<b>java.net.NetPermission</b>	Grants permission to modify to network properties, such as the host with which to validate usernames and passwords.

**Fig. 7.9** Some permissions available in the Java 2 security model.

specify custom security policy files on the command line. Loading other security policy files does not compromise the original system-wide configuration, any modifications are made in addition to the current policy files in use.<sup>14</sup>

Figure 7.10 presents class **AuthorizedFileWriter**, which accepts a file path and file body from the command line. Using a **SecurityManager** to protect against unauthorized access (line 16), lines 26–39 write the specified **fileBody** to **file**.

```

1 // AuthorizedFileWriter.java
2 // AuthorizedFileWriter writes to file using a security manager.
3 // Permissions must be given via policy files.
4 package com.deitel.advjhtp1.security.policyfile;
5
6 // Java core package
7 import java.io.*;
8
9 public class AuthorizedFileWriter {
10
11    // launch application
12    public static void main( String[] args )
13    {
14        // create and set security manager
15        System.setSecurityManager( new SecurityManager() );

```

**Fig. 7.10** **AuthorizedFileWriter** writes to file using a security manager (part 1 of 2).

```
16      // check command-line arguments for proper usage
17      if ( args.length != 2 )
18          System.err.println( "Usage: java com.deitel.advjhtp1."
19                             + "security.policyfile.AuthorizedFileWriter file "
20                             + "filebody" );
21
22      // write fileBody to file
23      else {
24
25          String file = args[ 0 ];
26          String fileBody = args[ 1 ];
27
28          // write fileBody to file
29          try {
30
31              // create FileWriter
32              FileWriter fileWriter = new FileWriter( file );
33
34              fileWriter.write( fileBody );
35
36              fileWriter.close();
37
38              System.exit( 0 );
39          }
39
40
41          // handle IO exception
42          catch ( IOException ioException ) {
43              ioException.printStackTrace();
44              System.exit( 1 );
45          }
46      }
47  }
48 }
49 }
```

Fig. 7.10 **AuthorizedFileWriter** writes to file using a security manager (part 2 of 2).

Policy file **authorized.policy** (Fig. 7.11) grants write **FilePermission** for file **authorized.txt**. Should the command line specify a different file, the **SecurityManager** will deny permission to write to it. The following command executes the **AuthorizedFileWriter** application with the **authorized.policy** policy file:

```
java -Djava.security.policy=authorized.policy com.deitel.advjhtp1.security.policyfile.AuthorizedFileWriter "authorized.txt" "Policy file authorized.policy granted file write permission for file authorized.txt."
```

Policy file **codebase\_authorized.policy** (Fig. 7.12) grants the **C:/myclasses** codebase write **FilePermission** for file **codebase\_authorized.txt**. If the code is executing from a different codebase, or the command line specifies a different file, the **SecurityManager** will deny permission to write to that file. The following executes the **AuthorizedFileWriter** application with the **codebase\_authorized.policy** policy file:

```
1 // authorized.policy
2 // Policy file that grants file write permission
3 // only to file "authorized.txt"
4
5 grant {
6     permission java.io.FilePermission
7     "authorized.txt", "write";
8 };
```

Fig. 7.11 Policy file grants permission to write to file **authorized.txt**.

```
1 // codebase_authorized.policy
2 // Policy file that grants write permission to
3 // file "codebase_authorized.txt" for codebase "C:/myclasses"
4
5 grant codebase "file:/C:/myclasses" {
6     permission java.io.FilePermission
7     "codebase_authorized.txt", "write";
8 };
```

Fig. 7.12 Policy file grants permission to the specified codebase.

```
java -Djava.security.policy=codebase_authorized.policy
com.deitel.advjhtp1.security.policyfile.AuthorizedFileWriter
"codebase_authorized.txt" "Policy file
codebase_authorized.policy granted file write permission for
file codebase_authorized.txt to codebase C:/myclasses."
```

For more information on current and upcoming uses of policy files and permissions in Java, visit the Web sites [java.sun.com/j2se/1.3/docs/guide/security/PolicyFiles.html](http://java.sun.com/j2se/1.3/docs/guide/security/PolicyFiles.html) and [java.sun.com/j2se/1.3/docs/guide/security/permissions.html](http://java.sun.com/j2se/1.3/docs/guide/security/permissions.html).

## 7.12 Digital Signatures for Java Code

Java applets run under strict security restrictions due to the unreliability of code downloaded over public networks. Unlike Java applications, Java applets run in the sandbox by default—an applet developer need not specify a security manager for an applet. Developers who wish to distribute applets with special permissions (e.g., the ability to read or write files on the user's computer) must sign those applets with digital signatures. This enables users to verify that a signed applet came from a particular company. If the user trusts that company, the user can grant that applet special permissions.

The applet of Fig. 7.13 uses class **FileTreePanel** (similar to class **FileTreeFrame** in Chapter 3) to display a tree of files on the user's hard drive. The Java sandbox does not allow applets to read or write files on the user's hard drive, so we must sign the **FileTreeApplet** with a digital signature. When the user's Web browser downloads the applet and runs it in the Java Plug-in, the plug-in prompts the user with the digital signature of the applet and allows the user to grant permission to the applet.

Signing an applet with a digital signature requires that the signing party stores the applet and its supporting classes in a JAR file. Figure 7.14 lists the contents of the JAR file

```
1 // FileTreeApplet.java
2 // A JApplet that browses files on the local file system
3 // using a FileTreePanel.
4 package com.deitel.advjhttp1.security.signatures;
5
6 // Java extension packages
7 import javax.swing.*;
8
9 // Deitel packages
10 import com.deitel.advjhttp1.security.signatures.FileTreePanel;
11
12 public class FileTreeApplet extends JApplet {
13
14     // initialize JApplet
15     public void init()
16     {
17         // get rootDirectory from user
18         String rootDirectory = JOptionPane.showInputDialog( this,
19             "Please enter a directory name:" );
20
21         // create FileTreePanel for browsing user's hard drive
22         FileTreePanel panel = new FileTreePanel( rootDirectory );
23
24         getContentPane().add( panel );
25     }
26 }
```

Fig. 7.13 Applet that browses a user's local filesystem.

Directory Name	File Name
com\deitel\advjhttp1\security\signatures\	
	FileTreeApplet.class
	FileTreePanel.class
	FileTreePanel\$1.class
com\deitel\advjhttp1\mvc\tree\filesystem\	
	FileSystemModel.class
	FileSystemModel\$TreeFile.class

Fig. 7.14 File listing for **FileTreeApplet.jar**.

**FileTreeApplet.jar**. For instructions on creating JAR files, please refer to Chapter 6, JavaBeans.

The **keytool** utility enables developers to generate public and private key pairs suitable for signing applets. The Java Plug-in supports applets signed with RSA digital signatures. To generate an RSA key pair, type the following at a command prompt:

```
keytool -genkey -keyalg RSA -alias MyCertificate
```

The **keytool** utility prompts you for your name, organization name and location. To export your digital signature into a certificate file, use the command:

```
keytool -export -alias MyCertificate -file myCertificate.cer
```

The Java Plug-in maintains a keystore for trusted certificates in its **lib/security** folder (e.g., **C:\Program Files\JavaSoft\JRE\1.3.1\lib\security**) named **cacerts**. This keystore contains certificates from certificate authorities such as Verisign and Thawte. The plug-in uses these certificates to verify digital signatures through a certificate chain. Adding a new certificate to this keystore allows the Java Plug-in to verify applets signed with that new certificate. (If your certificate has been signed by a Certificate Authority such as Verisign or Thawte, you need not add this certificate to the **cacerts** trusted keystore.) Add **myCertificate.cer** to the **cacerts** keystore using the command

```
keytool -import -alias MyTrustedCertificate -keystore
cacerts -file myCertificate.cer
```

where **cacerts** is the complete path to the **cacerts** keystore in the Java Plug-in's **lib/security** folder. When prompted for a password, enter **changeit**, which is the **cacert** keystore's default password.

Next, sign the applet's JAR file with your digital signature using the **jarsigner** utility. The **jarsigner** utility updates the manifest file in the JAR with the appropriate security information and signs each class in the JAR file. To sign the JAR, enter the following at a command prompt:

```
jarsigner FileTreeApplet.jar MyCertificate
```

Next, create an HTML file that contains an **applet** element for the **FileTreeApplet**. Figure 7.15 contains a basic HTML file for this purpose.

```
1 <html>
2
3 <head>
4   <title>FileTreeApplet Signed Applet</title>
5 </head>
6
7 <body>
8
9 <h1>File Browser</h1>
10
11 <applet
12   code = "com.deitel.advjhtp1.security.signatures.FileTreeApplet"
13   archive = "FileTreeApplet.jar" width = "400" height = "200">
14 </applet>
15
16 </body>
17
18 </html>
```

Fig. 7.15 HTML file for **FileTreeApplet**.

To enable the Web browser to load the Java Plug-in instead of the Web browser's own Java Virtual Machine, use the **htmlconverter** utility to convert the **applet** element into appropriate object and embed elements using the command

```
htmlconverter signedApplet.html
```

and load the resulting Web page in a Web browser. When the Java Plug-in loads the applet, the plug-in displays the **Java Plug-in Security Warning** dialog (Fig. 7.16). This dialog displays information about the signing certificate and enables the user to grant special permission to the applet. The user can click **Grant this Session** to allow the applet **AllPermission** for the current browsing session, **Deny** to deny special permission to the applet, **Grant Always** to allow the applet **AllPermission** for this and future browsing sessions, or **More Info** to display detailed information about the applet's signature.

Figure 7.17 shows the applet running with **AllPermission**. The applet prompts the user to enter a directory to use as the root of the **JTree**. The user then can browse through the filesystem and click on individual files or folders to view information about those files and folders in the right-hand pane. The user also can rename files in the **JTree**.



Fig. 7.16 Java Plug-in security warning when loading a signed applet.

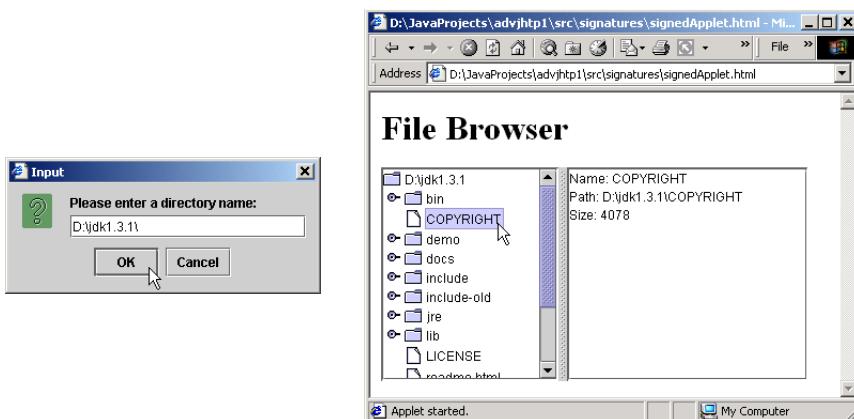


Fig. 7.17 **FileTreeApplet** browsing the **D:\jdk1.3.1\** directory.

## 7.13 Authentication

Ensuring that users actually are who they claim to be is a large part of computer security, known as authentication. Current authentication models restrict access to certain aspects of a program, allow users to connect to a network and regulate the resources available to users on the network. Java uses the *Java Authentication and Authorization Service (JAAS)* for authenticating and authorizing users. JAAS is based on a plug-in framework, which allows *Kerberos* and *single sign-on* to be implemented for authentication and authorization.

### 7.13.1 Kerberos

*Kerberos* is a freely available open-source protocol developed at MIT. It employs secret-key cryptography to authenticate users in a network and to maintain the integrity and privacy of network communications.

Authentication in a Kerberos system is handled by the main Kerberos system and a secondary *Ticket Granting Service (TGS)*. The latter system is similar to key distribution centers, which were described in Section 7.3. The main Kerberos system authenticates a client's identity to the TGS, which in turn authenticates client's rights to access specific network services.

Each client in the network shares a secret key with the Kerberos system. This secret key may be used by multiple TGSs in the Kerberos system. The client starts by entering a login name and password into the Kerberos authentication server, which maintains a database of all clients in the network. The authentication server returns a *Ticket-Granting Ticket (TGT)* encrypted with the client's secret key that it shared with the authentication server. Since the secret key is known only by the authentication server and the client, only the client can decrypt the TGT, thus authenticating the client's identity. Next, the client sends the decrypted TGT to the Ticket Granting Service to request a *service ticket*, which authorizes the client's access to specific network services. Service tickets have a set expiration time. Tickets may be renewed by the TGS.

### 7.13.2 Single Sign-On

To access multiple applications on different servers, users must provide a separate password for authentication on each. Remembering multiple passwords is cumbersome. People tend to write their passwords down, creating security threats.

*Single sign-on* systems allow users to log in once with a single password. Users can access multiple applications. It is important to secure single sign-on passwords, because if the password becomes available to hackers, all applications can be accessed and attacked.

There are three types of single sign-on services: *workstation logon scripts*, *authentication server scripts* and *tokens*. Workstation logon scripts are the simplest form of single sign-on. Users log in at their workstations, then choose applications from a menu. The workstation logon script sends the user's password to the application servers, and the user is authenticated for future access to those applications. Workstation logon scripts do not provide a sufficient amount of security since user passwords are stored on the workstation in plaintext. Anyone who can access the workstation can obtain the user's password. Authentication server scripts authenticate users with a central server. The central server controls connections between the user and the applications the user wishes to access. Authentication server scripts are more secure than workstation logon scripts because passwords are kept on the server, which is more secure than the individual PC.

The most advanced single sign-on systems use token-based authentication. Once a user is authenticated, a non-reusable token is issued to the user to access specific applications. The logon for creating the token is secured with encryption or with a single password, which is the only password the user needs to remember or change. The only problem with token authentication is that all applications must be built to accept tokens instead of traditional logon passwords.<sup>15</sup>

### 7.13.3 Java Authentication and Authorization Service (JAAS)

Java addresses the problems often associated with authenticating users and controlling access with the *Java Authentication and Authorization Service (JAAS)* API. Whereas policy files and permissions protect a user from running malicious programs, JAAS protects applications from unauthorized users.<sup>16</sup>

The *Pluggable Authentication Module (PAM)* architecture is the standard method for authentication on which JAAS is based.<sup>17</sup> The PAM framework supports multiple authentication systems, including Kerberos tickets and smart cards. Additionally, PAM allows different systems to be combined to create even greater levels of security. Developers determine what forms of authentication will be used in the associated security policy. PAM also supports single sign-on systems. Java's implementation of PAM in JAAS enables Java programs to identify users, allowing developers to establish access controls to protect those programs from unauthorized access.

After a user has been authenticated, JAAS can grant or restrict access to certain resources of an application. JAAS can control access by group, user or role-based security policies.<sup>18</sup> User-based access control governs access to resources on an individual user basis. After providing a password, Kerberos ticket or other means of identification to the Java application, the privileges of the individual user are determined and applied. Group-based authorization identifies a user as a part of a group and grants access to certain resources based on the identifying group. For example, a member of the group "doctors" would be able to access patient databases, connect to remote hospitals and write prescriptions that are sent electronically to a pharmacy. *Role-based access control (RBAC)* is used in addition to group-access control, allowing for more control over resources. Users request specific roles, each of which have corresponding privileges, based on what tasks the user would need to access. Roles and the corresponding permissions are based on the makeup of an organization. What separates roles from groups is the fact that by default, roles are not enabled. This feature increases security by allowing users to access only necessary applications. Using the "doctors" example, it would be risky for an application to allow the doctor to delete a patient's profile by default. Deleting patient files should be an available option only when it is necessary. Therefore, in order to gain access to a deletion resource, the doctor would have to present additional identification.<sup>19</sup>

Class **AuthenticateNT** (Fig. 7.18) uses a sample login module available for JAAS that authenticates the current user with the Windows NT authentication system. Lines 20–21 create a new **LoginContext** with the name **AuthenticateNT**. This **LoginContext** is associated with a specific login module in the configuration file of Fig. 7.20. Line 24 invokes method **login** of class **LoginContext**. This begins the authentication process. The Windows NT sample login module does not prompt the user for login information, it simply obtains the credentials for the currently logged-in user. Other login modules may use a **CallbackHandler** to prompt the user to enter a username, password and

other authentication information. If the login is successful (i.e., invoking method `login` does not generate any exceptions), line 28 prints a message indicating so.

```
1 // AuthenticateNT.java
2 // Authenticates a user using the NTLoginModule and performs
3 // a WriteFileAction PrivilegedAction.
4 package com.deitel.advjhttp1.security.jaas;
5
6 // Java extension packages
7 import javax.swing.*;
8 import javax.security.auth.*;
9 import javax.security.auth.login.*;
10
11 public class AuthenticateNT {
12
13     // launch application
14     public static void main( String[] args )
15     {
16         // authenticate user and perform PrivilegedAction
17         try {
18
19             // create LoginContext for AuthenticateNT context
20             LoginContext loginContext =
21                 new LoginContext( "AuthenticateNT" );
22
23             // perform login
24             loginContext.login();
25
26             // if login executes without exceptions, login
27             // was successful
28             System.out.println( "Login Successful" );
29
30             // get Subject now associated with LoginContext
31             Subject subject = loginContext.getSubject();
32
33             // display Subject details
34             System.out.println( subject );
35
36             // perform the WriteFileAction as current Subject
37             Subject.doAs( subject, new WriteFileAction() );
38
39             // log out current Subject
40             loginContext.logout();
41
42             System.exit( 0 );
43
44     } // end try
45
46     // handle exception logging in
47     catch ( LoginException loginException ) {
48         loginException.printStackTrace();
```

Fig. 7.18 `AuthenticateNT` uses the `NTLoginModule` to authenticate a user and invoke a `PrivilegedAction` (part 1 of 2).

```
49         System.exit( -1 );
50     }
51
52 } // end method main
53 }
```

```
Login Successful
Subject:
Principal: NTUserPrincipal:
userName: santry

Principal: NTDomainPrincipal:
domainName DEITEL

Principal: NTsidUserPrincipal:
NTSid: S-1-5-21-1275210071-1682526488-1343024091-1000

Principal: NTsidPrimaryGroupPrincipal:
NTSid: S-1-5-21-1275210071-1682526488-1343024091-513

Principal: NTsidGroupPrincipal:
NTSid: S-1-5-21-1275210071-1682526488-1343024091-513

Principal: NTsidGroupPrincipal:
NTSid: S-1-1-0

Principal: NTsidGroupPrincipal:
NTSid: S-1-5-32-544

Principal: NTsidGroupPrincipal:
NTSid: S-1-5-32-545

Principal: NTsidGroupPrincipal:
NTSid: S-1-5-5-0-39645

Principal: NTsidGroupPrincipal:
NTSid: S-1-2-0

Principal: NTsidGroupPrincipal:
NTSid: S-1-5-4

Principal: NTsidGroupPrincipal:
NTSid: S-1-5-11

Public Credential: NTNumericCredential:
value: 896
```

Fig. 7.18 `AuthenticateNT` uses the `NTLoginModule` to authenticate a user and invoke a `PrivilegedAction` (part 2 of 2).

Line 31 obtains a **Subject** from the current **LoginContext**. A **Subject** represents a particular user or other entity (e.g., an automated service) that requests an action. Each **Subject** has associated **Principals**. These **Principals** represent the different roles or identities that a user can assume during a particular login session. The security

restrictions in place for a particular application can grant permissions for **Principals** to make certain requests (e.g., read from a particular file). Line 34 prints the **Subject**'s information, including a list of the **Subject**'s **Principals**.

Line 37 invokes method **doAs** of class **Subject** to make a request using the given **Subject**. Method **doAs** takes as arguments the **Subject** for the request and a **PrivilegedAction** that contains the request. For this example, line 37 passes a new **WriteFileAction** (Fig. 7.19), which writes a simple message to a text file. Line 40 logs out from the current **LoginContext**.

Class **WriteFileAction** (Fig. 7.19) implements interface **PrivilegedAction**. **PrivilegedActions** execute in the context of an **AccessController**, which verifies that the **Subject** invoking the **PrivilegedAction** has the appropriate permissions. Interface **PrivilegedAction** requires that implementations define method **run** (lines 13–32). Method **run** of class **WriteFileAction** creates a text file and writes a message to that text file.

```
1 // WriteFileAction.java
2 // WriteFileAction is a PrivilegedAction implementation that
3 // simply writes a file to the local file system.
4 package com.deitel.advjhtp1.security.jaas;
5
6 // Java core packages
7 import java.io.*;
8 import java.security.PrivilegedAction;
9
10 public class WriteFileAction implements PrivilegedAction {
11
12     // perform the PrivilegedAction
13     public Object run()
14     {
15         // attempt to write a message to the specified file
16         try {
17             File file = new File( "D:/", "privilegedFile.txt" );
18             FileWriter fileWriter = new FileWriter( file );
19
20             // write message to File and close FileWriter
21             fileWriter.write( "Welcome to JAAS!" );
22             fileWriter.close();
23         }
24
25         // handle exception writing file
26         catch ( IOException ioException ) {
27             ioException.printStackTrace();
28         }
29
30         return null;
31
32     } // end method run
33 }
```

Fig. 7.19 **WriteFileAction** is a **PrivilegedAction** for writing a simple text file.

The configuration file of Fig. 7.20 specifies the **LoginModules** to use for the **AuthenticateNT LoginContext**. Line 5 specifies that the **Subject** must authenticate with the **NTLoginModule** for a successful login. **LoginContexts** can require a sequence of several **LoginModules** for proper authentication. For more information on JAAS configuration files, please refer to the JAAS documentation at [java.sun.com/security/jaas/doc/api.html](http://java.sun.com/security/jaas/doc/api.html).

The policy file of Fig. 7.21 grants permissions to the specified **Principal** when executing code in the specified **codeBase**. JAAS offers fine-grained permissions control. This example grants read and write **FilePermission** to the **Principal "santry"** when executing code in the **file:d:/JavaProjects/advjhttp1/src/-** codebase.

The policy file of Fig. 7.22 specifies permissions for JAAS itself and for the **AuthenticateNT** class codebase. Lines 5–7 grant **AllPermission** to the JAAS standard extension. This permission enables JAAS to perform authentication on behalf of this application. Line 13 grants permission to execute **PrivilegedActions** using method **doAs**. Lines 15–19 grant permission to read and write the text file **D:\privileged-File.txt**.

```

1 // jaas.config
2 // Configures JAAS to use NTLoginModule
3 // for authentication.
4 AuthenticateNT {
5     com.sun.security.auth.module.NTLoginModule required debug=false;
6 };

```

Fig. 7.20 Configuration file for authentication using **NTLoginModule**.

```

1 // jaas.policy
2 // Policy file defining the permissions for the named Principal
3 grant codeBase "file:D:/JavaProjects/advjhttp1/src/-",
4     Principal com.sun.security.auth.NTUserPrincipal "santry" {
5
6     permission java.io.FilePermission "D:/privilegedFile.txt",
7         "write";
8
9     permission java.io.FilePermission "D:/privilegedFile.txt",
10        "read";
11 };

```

Fig. 7.21 JAAS policy file for granting permissions to a **Principal** and codebase.

```

1 // java.policy
2 // Policy file that grants AllPermission
3 // to JAAS modules and specific permissions
4 // to the D:\Projects\Java codebase.
5 grant codebase "file:D:/jdk1.3.1/jre/lib/ext/jaas.jar" {
6     permission java.security.AllPermission;
7 };
8

```

Fig. 7.22 Policy file for JAAS application (part 1 of 2).

```
9 grant codebase "file:/D:/JavaProjects/advjhttp1/src/-" {  
10    permission javax.security.auth.AuthPermission  
11        "createLoginContext";  
12  
13    permission javax.security.auth.AuthPermission "doAs";  
14  
15    permission java.io.FilePermission "D:/privilegedFile.txt",  
16        "write";  
17  
18    permission java.io.FilePermission "D:/privilegedFile.txt",  
19        "read";  
20};
```

Fig. 7.22 Policy file for JAAS application (part 2 of 2).

Executing the **AuthenticateNT** example requires several command-line options to the Java virtual machine. Enter the following at a command prompt:

```
java -Djava.security.policy==java.policy  
      -Djava.security.auth.policy==jaas.policy  
      -Djava.security.auth.login.config==jaas.config  
      com.deitel.advjhttp1.security.jaas.AuthenticateNT
```

where **java.policy** is the policy file of Fig. 7.22, **jaas.policy** is the policy file of Fig. 7.21 and **jaas.config** is the configuration file of Fig. 7.20.

## 7.14 Secure Sockets Layer (SSL)

Currently, most e-businesses use SSL for secure online transactions, although SSL is not designed specifically for securing transactions. Rather, SSL secures World Wide Web connections. The Secure Sockets Layer (SSL) protocol, developed by Netscape Communications, is a nonproprietary protocol commonly used to secure communication between two computers on the Internet and the Web.<sup>20</sup> SSL is built into many Web browsers, including Netscape *Communicator* and Microsoft *Internet Explorer*, as well as numerous other software products. It operates between the Internet's TCP/IP communications protocol and the application software.<sup>21</sup>

SSL implements public-key technology using the RSA algorithm and digital certificates to authenticate the server in a transaction and to protect private information as it passes from one party to another over the Internet. SSL transactions do not require client authentication; many servers consider a valid credit-card number to be sufficient for authentication in secure purchases. To begin, a client sends a message to a server. The server responds and sends its digital certificate to the client for authentication. Using public-key cryptography to communicate securely, the client and server negotiate *session keys* to continue the transaction. Session keys are secret keys used for the duration of that transaction. Once the keys are established, the communication proceeds between the client and the server using the session keys and digital certificates. Encrypted data are passed through TCP/IP, just as regular packets travel over the Internet. However, before sending a message with TCP/IP, the SSL protocol breaks the information into blocks and compresses and encrypts those blocks. Conversely, after the data reach the receiver through

TCP/IP, the SSL protocol decrypts the packets, then decompresses and assembles the data. These extra processes provide an extra layer of security between TCP/IP and applications. SSL is used primarily to secure *point-to-point connections*—transmissions of data from one computer to another.<sup>22</sup> SSL allows for the authentication of the server, the client, both or neither; in most Internet SSL sessions, only the server is authenticated. The Transport Layer Security (TLS) protocol, designed by the Internet Engineering Task Force, is similar to SSL. For more information on TLS, visit: [www.ietf.org/rfc/rfc2246.txt](http://www.ietf.org/rfc/rfc2246.txt).

Although SSL protects information as it is passed over the Internet, it does not protect private information, such as credit-card numbers, once the information is stored on the merchant's server. When a merchant receives credit-card information with an order, the information is often decrypted and stored on the merchant's server until the order is placed. If the server is not secure and the data are not encrypted, an unauthorized party can access the information. For more information about the SSL protocol, check out the Netscape SSL tutorial at [developer.netscape.com/tech/security/ssl/protocol.html](http://developer.netscape.com/tech/security/ssl/protocol.html) and the Netscape Security Center site at [www.netscape.com/security/index.html](http://www.netscape.com/security/index.html).

### 7.14.1 Java Secure Socket Extension (JSSE)

The strength of SSL encryption has been integrated into Java technology through Sun's *Java Secure Socket Extension (JSSE)*. Java applications that use JSSE can secure a passage between a client and a server over TCP/IP. JSSE provides encryption, message integrity checks and authentication of the server and client.<sup>23</sup> JSSE uses keystores to secure storage of key pairs and certificates used in PKI. A *truststore* is a keystore containing keys and certificates used to validate the identities of servers and clients.<sup>24 25</sup>

The algorithms used in JSSE for encryption, key agreement and authentication include DES, 3DES, Diffie-Hellman and DSA. Like JCE, JSSE uses a provider-based model that enables third parties to provide additional cryptographic algorithms. JSSE is free for commercial use and is available for free download at [java.sun.com/products/jsse](http://java.sun.com/products/jsse).

Class **LoginServer** (Fig. 7.23) uses an **SSLServerSocket** to listen for SSL connections on port **7070**. JSSE uses the Factory design pattern for constructing **SSLServerSockets** and **SSLSockets**. Line 25 invokes **static** method **getDefault** of class **SSLServerSocketFactory** to obtain the default **SSLServerSocketFactory**. Line 29 invokes method **createServerSocket** of class **SSLServerSocketFactory** to create the **SSLServerSocket**. This method takes as an argument the port number on which the **SSLServerSocket** will listen.

Method **runServer** (lines 34–84) starts **LoginServer**. Line 46 invokes method **accept** of class **SSLServerSocket** to accept a new client connection. Method **accept** is a blocking call that returns an **SSLSocket** when a client connects. Lines 49–55 obtain the **InputStream** and **OutputStream** for the **SSLSocket** and lines 57–58 read two lines of text. Lines 60–61 validate the client's user name and password against constants **CORRECT\_USER\_NAME** and **CORRECT\_PASSWORD**. If the user name and password are correct, line 63 sends a welcome message to the client. If the user name and password are incorrect, line 67 notifies the client that the login failed. Lines 71–73 close the **InputStream**, **OutputStream** and **SSLSocket**.

Note that using **SSLServerSockets** and **SSLSockets** is identical to using standard **ServerSockets** and **Sockets**. JSSE hides the details of the SSL protocol and encryption from the programmer entirely.

```
1 // LoginServer.java
2 // LoginServer uses an SSLServerSocket to demonstrate JSSE's
3 // SSL implementation.
4 package com.deitel.advjhttp1.security.jsse;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.net.ssl.*;
11
12 public class LoginServer {
13
14     private static final String CORRECT_USER_NAME = "Java";
15     private static final String CORRECT_PASSWORD = "HowToProgram";
16
17     private SSLServerSocket serverSocket;
18
19     // LoginServer constructor
20     public LoginServer() throws Exception
21     {
22         // SSLServerSocketFactory for building SSLServerSockets
23         SSLServerSocketFactory socketFactory =
24             ( SSLServerSocketFactory )
25             SSLServerSocketFactory.getDefault();
26
27         // create SSLServerSocket on specified port
28         serverSocket = ( SSLServerSocket )
29             socketFactory.createServerSocket( 7070 );
30
31     } // end LoginServer constructor
32
33     // start server and listen for clients
34     private void runServer()
35     {
36         // perpetually listen for clients
37         while ( true ) {
38
39             // wait for client connection and check login information
40             try {
41
42                 System.err.println( "Waiting for connection..." );
43
44                 // create new SSLSocket for client
45                 SSLSocket socket =
46                     ( SSLSocket ) serverSocket.accept();
47
48                 // open BufferedReader for reading data from client
49                 BufferedReader input = new BufferedReader(
50                     new InputStreamReader( socket.getInputStream() ) );
51 }
```

Fig. 7.23 **LoginServer** uses an **SSLServerSocket** for secure communication (part 1 of 2).

```
52          // open PrintWriter for writing data to client
53          PrintWriter output = new PrintWriter(
54              new OutputStreamWriter(
55                  socket.getOutputStream() ) );
56
57          String userName = input.readLine();
58          String password = input.readLine();
59
60          if ( userName.equals( CORRECT_USER_NAME ) &&
61              password.equals( CORRECT_PASSWORD ) ) {
62
63              output.println( "Welcome, " + userName );
64          }
65
66          else {
67              output.println( "Login Failed." );
68          }
69
70          // clean up streams and SSLSocket
71          output.close();
72          input.close();
73          socket.close();
74
75      } // end try
76
77      // handle exception communicating with client
78      catch ( IOException ioException ) {
79          ioException.printStackTrace();
80      }
81
82  } // end while
83
84 } // end method runServer
85
86 // execute application
87 public static void main( String args[] ) throws Exception
88 {
89     LoginServer server = new LoginServer();
90     server.runServer();
91 }
92 }
```

Fig. 7.23 **LoginServer** uses an **SSLServerSocket** for secure communication (part 2 of 2).

Class **LoginClient** (Fig. 7.24) uses an **SSLocket** to communicate with the **LoginServer**. Lines 22–23 invoke method **getDefautl** of class **SSLocketFactory** to obtain the default **SSLocketFactory**. Lines 26–28 invoke method **createSocket** of class **SSLocketFactory** to create a new **SSLocket** that connects to **localhost** on port **7070**. Lines 31–32 create a new **PrintWriter** for the **SSLocket**'s **OutputStream** to facilitate sending data to the server. Lines 35–48 prompt the user for a username and password and send them to the server. Lines 51–58 then read the response from the server and display this response in a **JOptionPane** message

dialog. Note that once the client establishes the connection with the **SSLocket**, the fact that SSL encrypts the communication between the client and server is transparent to the programmer.

```
1 // LoginClient.java
2 // LoginClient uses an SSLocket to transmit fake login
3 // information to LoginServer.
4 package com.deitel.advjhttp1.security.jsse;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.swing.*;
11 import javax.net.ssl.*;
12
13 public class LoginClient {
14
15     // LoginClient constructor
16     public LoginClient()
17     {
18         // open SSLocket connection to server and send login
19         try {
20
21             // obtain SSLocketFactory for creating SSLockets
22             SSLocketFactory socketFactory =
23                 ( SSLocketFactory ) SSLocketFactory.getDefault();
24
25             // create SSLocket from factory
26             SSLocket socket =
27                 ( SSLocket ) socketFactory.createSocket(
28                     "localhost", 7070 );
29
30             // create PrintWriter for sending login to server
31             PrintWriter output = new PrintWriter(
32                 new OutputStreamWriter( socket.getOutputStream() ) );
33
34             // prompt user for user name
35             String userName = JOptionPane.showInputDialog( null,
36                 "Enter User Name:" );
37
38             // send user name to server
39             output.println( userName );
40
41             // prompt user for password
42             String password = JOptionPane.showInputDialog( null,
43                 "Enter Password:" );
44
45             // send password to server
46             output.println( password );
47
48             output.flush();
```

Fig. 7.24 **LoginClient** communicates with **LoginServer** via SSL (part 1 of 2).

```
49         // create BufferedReader for reading server response
50         BufferedReader input = new BufferedReader(
51             new InputStreamReader( socket.getInputStream () ) );
52
53         // read response from server
54         String response = input.readLine();
55
56         // display response to user
57         JOptionPane.showMessageDialog( null, response );
58
59         // clean up streams and SSLSocket
60         output.close();
61         input.close();
62         socket.close();
63
64     } // end try
65
66
67     // handle exception communicating with server
68     catch ( IOException ioException ) {
69         ioException.printStackTrace();
70     }
71
72     // exit application
73     finally {
74         System.exit( 0 );
75     }
76
77 } // end LoginClient constructor
78
79 // execute application
80 public static void main( String args[] )
81 {
82     new LoginClient();
83 }
84 }
```

Fig. 7.24 **LoginClient** communicates with **LoginServer** via SSL (part 2 of 2).

Enabling SSL requires that **LoginServer** uses a certificate that **LoginClient** trusts. Use the **keytool** to generate a new certificate and keystore for this purpose:

```
keytool -genkey -keystore SSLStore -alias SSLCertificate
```

Next, launch **LoginServer** and specify the keystore that contains the **LoginServer**'s certificate:

```
java -Djavax.net.ssl.keyStore=SSLStore
      -Djavax.net.ssl.keyStorePassword=password
      com.deitel.advjhtp1.security.jsse.LoginServer
```

where password is the password you specified for the **SSLStore** keystore. Finally, launch the **LoginClient** and specify the truststore for that client. The truststore contains certificates that the client trusts for the purposes of digital-signature validation. For simplicity in this example, we use the same keystore as both the **LoginServer**'s keystore and the **Login-**

**Client**'s truststore. In real-world applications, the client's truststore should contain trusted certificates, such as those from certificate authorities. Execute the client using the command

```
java -Djavax.net.ssl.trustStore=SSLStore  
-Djavax.net.ssl.trustStorePassword=password  
com.deitel.advjhtp1.security.jsse.LoginClient
```

Figure 7.25 shows two executions of class **LoginClient**. The first execution (the left column) shows a successful login. The second execution shows a failed login. For each execution, the **LoginServer** and **LoginClient** used SSL to encrypt all data transfer.

## 7.15 Java Language Security and Secure Coding

The Java language provides programmers with a security advantage that other languages do not. Java code goes through several stages before and during execution that help to ensure that the Java code is not malicious. Each stage prevents many exploitations that other programming languages allow. For example, the Java Virtual Machine ensures that programs cannot read memory beyond the end of an array. This prevents programs from reading data from arbitrary locations in memory.

The Java compiler performs several security checks in the normal process of compiling Java source code into bytecode. The compiler ensures that the program does not read from uninitialized variables—a common technique for reading data from arbitrary memory locations. Also, the compiler checks the access modifiers for each method invocation and variable to ensure that the program accesses private data only from the proper classes. The compiler also can detect certain illegal casts between data types. These simple steps help prevent many types of security attacks.

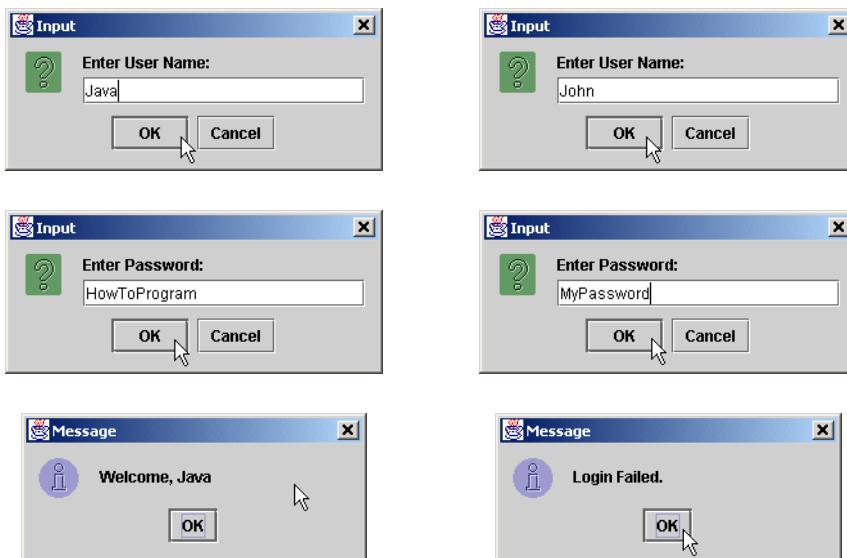


Fig. 7.25 Two sample executions of class **LoginClient**.

Before the Java Virtual Machine executes a Java program, the bytecodes for that program must pass through the *bytecode verifier*. The bytecode verifier ensures that the bytecodes are valid Java bytecodes that do not perform certain illegal operations (according to the rules of the Java language). For example, the bytecode verifier checks that no class has more than one superclass and that final classes do not have subclasses. The bytecode verifier also checks that classes have the proper format. This second stage helps eliminate security risks that the compiler could not detect.

The Java Virtual Machine performs the remaining integrity checks on Java programs. The virtual machine checks any remaining cast operations to ensure their validity and performs array-bounds checking to prevent programs from reading arbitrary memory locations. The Java Virtual Machine uses *class loaders* to read class definitions from `.class` files and produce class representations in memory. The class loader uses separate *namespaces* to prevent malicious code from interacting with safe code.<sup>26</sup> Every class that the JVM loads is assigned a corresponding set of unique names, known as a namespace. Namespaces in Java act as barriers between classes. The JVM allows classes within the same namespace to interact, but requires explicit permission for classes from separate namespaces to operate together. To protect trusted classes, developers can use different class loaders for trusted and untrusted packages. This allows for trusted code to belong to the same *runtime package*. A runtime package is code that was loaded by the same class loader and belong to the same package. The *bootstrap* class loader loads all of the trusted core Java classes, so that additional, potentially unsecure classes will belong to a separate runtime package and can not interfere with the core classes.

The Java security manager is the module that performs security checks while code is running. If, during run-time, code attempts to execute a dangerous operation, a *security exception* is generated. Class operations that the security manager considers dangerous include: deleting a file, reading from a file, appending or editing a file, adding or loading a class to a package, and opening a socket connection.<sup>27</sup> When untrusted code attempts one of these operations, the security manager throws an **AccessControlException**.

Although the Java language and the associated compiler, bytecode verifier and virtual machine enforce a number of security constraints, Java developers still may need to take certain steps to secure their code. For example, when developing classes, programmers can declare those classes as final. Final classes cannot be subclassed, and can help make an application more secure by preventing attackers from creating malicious subclasses that can cause damage to an application or gain access to protected information. A hacker would generally exploit an ordinary class by creating a subclass to replace the original. This new class could expose the same public interface as the original class, and would deceive the compiler into using the hostile class.<sup>28</sup>

Fortunately, the compiler will not compile a class that attempts to extent a final class. The bytecode verifier also checks to ensure that classes are not subclasses of a final class. If declaring an entire class as final is excessive for a program's needs, final methods prevent subclasses from overriding particular methods.

## 7.16 Internet and World Wide Web Resources

The notation <[www.domain-name.com](#)> indicates that the citation is for information found at that Web site.

### **Security Resource Sites**

#### **[www.securitysearch.com](http://www.securitysearch.com)**

This is a comprehensive resource for computer security. The site has thousands of links to products, security companies, tools and more. The site also offers a free weekly newsletter with information about vulnerabilities.

#### **[www.securityfocus.com](http://www.securityfocus.com)**

A site covering all aspects of computer security, with special sections in the basics, numerous operating systems, intrusion detection and viruses. This site is also responsible for maintaining the BugTraq list.

#### **[www.esecurityonline.com](http://www.esecurityonline.com)**

This site is a great resource for information on online security. The site has links to news, tools, events, training and other valuable security information and resources.

#### **[www.epic.org](http://www.epic.org)**

The *Electronic Privacy Information Center* deals with protecting privacy and civil liberties. Visit this site to learn more about the organization and its latest initiatives.

#### **[theory.lcs.mit.edu/~rivest/crypto-security.html](http://theory.lcs.mit.edu/~rivest/crypto-security.html)**

The *Ronald L. Rivest: Cryptography and Security* site has an extensive list of links to security resources, including newsgroups, government agencies, FAQs, tutorials and more.

#### **[www.w3.org/Security/Overview.html](http://www.w3.org/Security/Overview.html)**

The *W3C Security Resources* site has FAQs, information about W3C security and e-commerce initiatives and links to other security related Web sites.

#### **[web.mit.edu/network/ietf/sa](http://web.mit.edu/network/ietf/sa)**

The Internet Engineering Task Force (IETF), which is an organization concerned with the architecture of the Internet, has working groups dedicated to Internet Security. Visit the *IETF Security Area* to learn about the working groups, join the mailing list or check out the latest drafts of the IETF's work.

#### **[dir.yahoo.com/Computers\\_and\\_Internet/Security\\_and\\_Encryption](http://dir.yahoo.com/Computers_and_Internet/Security_and_Encryption)**

The *Yahoo Security and Encryption* page is a great resource for links to Web sites security and encryption.

#### **[www.counterpane.com/hotlist.html](http://www.counterpane.com/hotlist.html)**

The Counterpane Internet Security, Inc., site includes links to downloads, source code, FAQs, tutorials, alert groups, news and more.

#### **[www.rsasecurity.com/rsalabs/faq](http://www.rsasecurity.com/rsalabs/faq)**

This site is an excellent set of FAQs about cryptography from RSA Laboratories, one of the leading makers of public key cryptosystems.

#### **[www.nsi.org/compsec.html](http://www.nsi.org/compsec.html)**

Visit the National Security Institute's *Security Resource Net* for the latest security alerts, government standards, and legislation, as well as security FAQs links and other helpful resources.

#### **[www.itaa.org/infosec](http://www.itaa.org/infosec)**

The Information Technology Association of America (ITAA) *InfoSec* site has information about the latest U.S. government legislation related to information security.

#### **[staff.washington.edu/dittrich/misc/ddos](http://staff.washington.edu/dittrich/misc/ddos)**

The *Distributed Denial of Service Attacks* site has links to news articles, tools, advisory organizations and even a section on security humor.

#### **[www.infoworld.com/cgi-bin/displayNew.pl?/security/links/security\\_corner.htm](http://www.infoworld.com/cgi-bin/displayNew.pl?/security/links/security_corner.htm)**

The *Security Watch* site on **Infoworld.com** has loads of links to security resources.

**www.antionline.com**

AntiOnline has security-related news and information, a tutorial titled “Fight-back! Against Hackers,” information about hackers and an archive of hacked sites.

**www.microsoft.com/security/default.asp**

The Microsoft security site has links to downloads, security bulletins and tutorials.

**www.grc.com**

This site offers a service to test the security of your computer’s Internet connection.

### **General Security Sites**

**www.sans.org/giac.html**

Sans Institute presents information on system and security updates, along with new research and discoveries. The site offers current publications, projects, and weekly digests.

**www.packetstorm.securify.com**

The Packet Storm page describes the twenty latest advisories, tools, and exploits. This site also provides links to the top security news stories.

**www.xforce.iss.net**

This site allows one to search a virus by name, reported date, expected risk, or affected platforms. Updated news reports can be found on this page.

**www.ntbugtraq.com**

This site provides a list and description of various Windows NT Security Exploits/Bugs encountered by Windows NT users. One can download updated service applications.

**nsi.org/compsec.html**

The Security Resource Net page states various warnings, threats, legislation and documents of viruses and security in an organized outline.

**www.tno.nl/instit/fel/intern/wkinfsec.html**

This site includes numerous links to other security sites.

**www.microsoft.com/security**

The Microsoft security site offers news, product information and tools.

**www.securitystats.com**

This computer security site provides statistics on viruses, web defacements and security spending.

### **Magazines, Newsletters and News sites**

**www.networkcomputing.com/consensus**

The *Security Alert Consensus* is a free weekly newsletter with information about security threats, holes, solutions and more.

**www.infosecuritymag.com**

*Information Security Magazine* has the latest Web security news and vendor information.

**www.issl.org/cipher.html**

*Cipher* is an electronic newsletter on security and privacy from the Institute of Electrical and Electronics Engineers (IEEE). You can view current and past issues online.

**securityportal.com**

The *Security Portal* has news and information about security, cryptography and the latest viruses.

**www.scmagazine.com**

*SC Magazine* has news, product reviews and a conference schedule for security events.

**www.cnn.com/TECH/specials/hackers**

*Insurgency on the Internet* from CNN Interactive has news on hacking, plus a gallery of hacked sites.

**[rootshell.com/beta/news.html](http://rootshell.com/beta/news.html)**

Visit Rootshell for security-related news and white papers.

***Government Sites for Computer Security*****[www.cit.nih.gov/security.html](http://www.cit.nih.gov/security.html)**

This site has links to security organizations, security resources and tutorials on PKI, SSL and other protocols.

**[cs-www.ncsl.nist.gov](http://cs-www.ncsl.nist.gov)**

The *Computer Security Resource Clearing House* is a resource for network administrators and others concerned with security. This site has links to incident-reporting centers, information about security standards, events, publications and other resources.

**[www.cdt.org/crypto](http://www.cdt.org/crypto)**

Visit the Center for Democracy and Technology for U. S. legislation and policy news regarding cryptography.

**[www.epm.ornl.gov/~dunigan/security.html](http://www.epm.ornl.gov/~dunigan/security.html)**

This site has links to loads of security-related sites. The links are organized by subject and include resources on digital signatures, PKI, smart cards, viruses, commercial providers, intrusion detection and several other topics.

**[www.alw.nih.gov/Security](http://www.alw.nih.gov/Security)**

The *Computer Security Information* page is an excellent resource, providing links to news, newsgroups, organizations, software, FAQs and an extensive number of Web links.

**[www.fedcirc.gov](http://www.fedcirc.gov)**

The Federal Computer Incident Response Capability deals with the security of government and civilian agencies. This site has information about incident statistics, advisories, tools, patches and more.

**[axion.physics.ubc.ca/pgp.html](http://axion.physics.ubc.ca/pgp.html)**

This site has a list of freely available cryptosystems, along with a discussion of each system and links to FAQs and tutorials.

**[www.ifccfbi.gov](http://www.ifccfbi.gov)**

The Internet Fraud Complaint Center, founded by the Justice Department and the FBI, fields reports of Internet fraud.

**[www.disa.mil/infosec/iaweb/default.html](http://www.disa.mil/infosec/iaweb/default.html)**

The Defense Information Systems Agency's *Information Assurance* page includes links to sites on vulnerability warnings, virus information and incident-reporting instructions, as well as other helpful links.

**[www.nswc.navy.mil/ISSEC/](http://www.nswc.navy.mil/ISSEC/)**

The objective of this site is to provide information on protecting your computer systems from security hazards. Contains a page on hoax versus real viruses.

**[www.cit.nih.gov/security.html](http://www.cit.nih.gov/security.html)**

You can report security issues at this site. The site also lists official federal security policies, regulations, and guidelines.

**[cs-www.ncsl.nist.gov/](http://cs-www.ncsl.nist.gov/)**

The Computer Security Resource Center provides services for vendors and end users. The site includes information on security testing, management, technology, education and applications.

***Advanced Encryption Standard (AES)*****[csrc.nist.gov/encryption/aes](http://csrc.nist.gov/encryption/aes)**

This is the official site for the AES; this site includes press releases and a discussion forum.

**[www.esat.kuleuven.ac.be/~rijmen/rijndael/](http://www.esat.kuleuven.ac.be/~rijmen/rijndael/)**

Visit this site for information about the Rijndael algorithm, including links to various implementations of the algorithm and a small FAQ.

**[home.ecn.ab.ca/~jsavard/crypto/co040801.htm](http://home.ecn.ab.ca/~jsavard/crypto/co040801.htm)**

This site is dedicated to AES. It includes an explanation of the algorithm with diagrams and examples.

### **Internet Security Vendors**

**[www.rsasecurity.com](http://www.rsasecurity.com)**

RSA is one of the leaders in electronic security. Visit its site for more information about its current products and tools, which are used by companies worldwide.

**[www.ca.com/protection](http://www.ca.com/protection)**

*Computer Associates* is a vendor of Internet security software. It has various software packages to help companies set up a firewall, scan files for viruses and protect against viruses.

**[www.checkpoint.com](http://www.checkpoint.com)**

Check Point™ Software Technologies Ltd. is a leading provider of Internet security products and services.

**[www.opsec.com](http://www.opsec.com)**

The Open Platform for Security (OPSEC) has over 200 partners that develop security products and solutions using the OPSEC to allow for interoperability and increased security over a network.

**[www.baltimore.com](http://www.baltimore.com)**

Baltimore Security is an e-commerce security solutions provider. Their UniCERT digital certificate product is used in PKI applications.

**[www.ncipher.com](http://www.ncipher.com)**

nCipher is a vendor of hardware and software products, including an SSL accelerator that increases the speed of secure Web server transactions and a secure key management system.

**[www.entrust.com](http://www.entrust.com)**

Entrust Technologies provides e-security products and services.

**[www.tenfour.co.uk](http://www.tenfour.co.uk)**

TenFour provides software for secure e-mail.

**[www.antivirus.com](http://www.antivirus.com)**

*ScanMail*® is an e-mail virus detection program for Microsoft Exchange.

**[www.contenttechnologies.com/ads](http://www.contenttechnologies.com/ads)**

Content Technologies is a security software provider. Its products include firewall and secure e-mail programs.

**[www.zixmail.com](http://www.zixmail.com)**

*Zixmail*™ is a secure e-mail product that allows you to encrypt and digitally sign your messages using different e-mail programs.

**[web.mit.edu/network/pgp.html](http://web.mit.edu/network/pgp.html)**

Visit this site to download *Pretty Good Privacy*® freeware. PGP allows you to send messages and files securely.

**[www.certicom.com](http://www.certicom.com)**

Certicom provides security solutions for the wireless Internet.

**[www.raytheon.com](http://www.raytheon.com)**

Raytheon Corporation's *SilentRunner* monitors activity on a network to find internal threats, such as data theft or fraud.

## SSL

### **developer.netscape.com/tech/security/ssl/protocol.html**

This Netscape page has a brief description of SSL, plus links to an SSL tutorial and FAQs.

### **www.netscape.com/security/index.html**

The *Netscape Security Center* is an extensive resource for Internet and Web security. You will find news, tutorials, products and services on this site.

### **psych.psy.uq.oz.au/~ftp/Crypto**

This FAQs page has an extensive list of questions and answers about SSL technology.

### **www.visa.com/nt/ecomm/security/main.html**

*Visa International's* security page includes information on SSL and SET. The page includes a demonstration of an online shopping transaction, which explains how SET works.

### **www.openssl.org**

The *Open SSL Project* provides a free, open source toolkit for SSL.

## *Public-key Cryptography*

### **www.entrust.com**

Entrust produces effective security software products using Public Key Infrastructure (PKI).

### **www.cse.dnd.ca**

The *Communication Security Establishment* has a short tutorial on Public Key Infrastructure (PKI) that defines PKI, public-key cryptography and digital signatures.

### **www.magnet.state.ma.us/itd/legal/pki.htm**

The Commonwealth of Massachusetts Information Technology page has loads of links to sites related to PKI that contain information about standards, vendors, trade groups and government organizations.

### **www.ftech.net/~monark/crypto/index.htm**

*The Beginner's Guide to Cryptography* is an online tutorial and includes links to other sites on privacy and cryptography.

### **www.faqs.org/faqs/cryptography-faq**

The *Cryptography FAQ* has an extensive list of questions and answers.

### **www.pkiforum.org**

The PKI Forum promotes the use of PKI.

### **www.counterpane.com/pki-risks.html**

Visit the Counterpane Internet Security, Inc.'s site to read the article "Ten Risks of PKI: What You're Not Being Told About Public Key Infrastructure."

## *Digital Signatures*

### **www.ietf.org/html.charters/xmldsig-charter.html**

The *XML Digital Signatures* site was created by a group working to develop digital signatures using XML. You can view the group's goals and drafts of their work.

### **www.elock.com**

*E-Lock Technologies* is a vendor of digital-signature products used in Public Key Infrastructure. This site has an FAQs list covering cryptography, keys, certificates and signatures.

### **www.digsigtrust.com**

*The Digital Signature Trust Co.* is a vendor of Digital Signature and Public Key Infrastructure products. It has a tutorial titled "Digital Signatures and Public Key Infrastructure (PKI) 101."

### Digital Certificates

#### **www.verisign.com**

*VeriSign* creates digital IDs for individuals, small businesses and large corporations. Check out its Web site for product information, news and downloads.

#### **www.thawte.com**

*Thawte Digital Certificate Services* offers SSL, developer and personal certificates.

#### **www.silanis.com/index.htm**

*Silanis Technology* is a vendor of digital-certificate software.

#### **www.belsign.be**

*Belsign* issues digital certificates in Europe. It is the European authority for digital certificates.

#### **www.certco.com**

*Certco* issues digital certificates to financial institutions.

#### **www.openca.org**

Set up your own CA using open-source software from The OpenCA Project.

### Kerberos

#### **www.nrl.navy.mil/CCS/people/kenh/kerberos-faq.html**

This site is an extensive list of FAQs on Kerberos from the Naval Research Laboratory.

#### **web.mit.edu/kerberos/www**

*Kerberos: The Network Authentication Protocol* is a list of FAQs provided by MIT.

#### **www.contrib.andrew.cmu.edu/~shadow/kerberos.html**

*The Kerberos Reference Page* has links to several informational sites, technical sites and other helpful resources.

#### **www.pdc.kth.se/kth-krb**

Visit this site to download various Kerberos white papers and documentation.

### Newsgroups

#### **news://comp.security.firewalls**

#### **news://comp.security.unix**

#### **news://comp.security.misc**

#### **news://comp.protocols.kerberos**

## SUMMARY

- There are five fundamental requirements of a successful, secure transaction: privacy, integrity, authentication, authorization and nonrepudiation.
- Network security addresses the issue of availability: How do we ensure that the network and the computer systems it connects will stay in operation continuously?
- The Java Sandbox architecture and policy files protect users and systems from malicious programs that would otherwise crash computers or steal valuable information.
- To secure information, data can be encrypted. Cryptography transforms data by using a cipher, or cryptosystem—a mathematical algorithm for encrypting messages. Unencrypted data is called plaintext; encrypted data is called ciphertext.
- A key—a string of alpha-numeric characters that acts as a password—is input to the cipher. The cipher uses the key to make data incomprehensible to all but the sender and intended receivers.

- Encryption and decryption keys are binary strings with a given key length. Symmetric cryptography, also known as secret-key cryptography, utilizes the same secret key to encrypt and decrypt messages.
- A key distribution center shares a (different) secret key with every user in the network; the key distribution center generates a session key to be used for a transaction.
- One of the most commonly used symmetric encryption algorithms is the Data Encryption Standard (DES).
- A block cipher is an encryption method that creates groups of bits from an original message, then applies an encryption algorithm to the block as a whole, rather than as individual bits.
- Triple DES, or 3DES, is a variant of DES that is essentially three DES systems in a row, each having its own secret key.
- The new standard for encryption is called the Advanced Encryption Standard (AES). Rijndael—a candidate for AES—is an encryption method that can be used with key sizes and block sizes of 128, 192 or 256 bits.
- Public-key cryptography is asymmetric—it uses two inversely related keys: A public key and a private key. The most commonly used public-key algorithm is RSA, an encryption system developed in 1977 by MIT professors Ron Rivest, Adi Shamir and Leonard Adleman.
- Pretty Good Privacy (PGP) is a public-key encryption system used for encrypting e-mail messages and files. PGP was designed in 1991 by Phillip Zimmermann.
- Public-key algorithms should not be thought of as a replacement for secret-key algorithms. Instead, public-key algorithms can be used to allow two parties to agree upon a key to be used for secret-key encryption over an unsecure medium.
- The process by which two parties can exchange keys over an unsecure medium is called a key agreement protocol. A protocol sets the rules for communication: Exactly what encryption algorithm(s) is (are) going to be used? The most common key agreement protocol is a digital envelope.
- Maintaining the secrecy of private keys is crucial to keeping cryptographic systems secure. Most compromises in security result from poor key management (e.g., the mishandling of private keys, resulting in key theft) rather than attacks that attempt to guess the keys.
- A main component of key management is key generation—the process by which keys are created. A malicious third party could try to decrypt a message by using every possible decryption key, a process known as brute-force cracking.
- The Java Cryptography Extension (JCE) provides Java applications with secret-key encryption, such as 3DES, and public-key algorithms, such as Diffie-Hellman and RSA.
- The JCE architecture is provider-based—developers can add new algorithms to their programs by adding a new algorithm provider.
- Class **Cipher** is the fundamental building block for applications that use JCE. A **Cipher** performs encryption and decryption using a specified algorithm (e.g., DES, 3DES, Blowfish, etc.).
- The JCE includes the **SunJCE** provider, which has support for several common algorithms.
- A digital signature—the electronic equivalent of written signature—authenticates the sender's identity and, like a written signature, is difficult to forge. To create a digital signature, a sender first takes the original plaintext message and runs it through a hash function, which is a mathematical calculation that gives the message a hash value.
- The Secure Hash Algorithm (SHA-1) is the standard for hash functions. Running a message through the SHA-1 algorithm produces a 160-bit hash value.
- MD5 is another popular hash function, which was developed by Ronald Rivest to verify data integrity through a 128-bit hash value of the input file.

- The hash value is also known as a message digest. The chance that two different messages will have the same message digest is statistically insignificant.
- A digital certificate is a digital document that identifies a user and is issued by a certificate authority (CA). Digital certificates contain an expiration date to force users to switch key pairs. Canceled and revoked certificates are placed on a certificate revocation list (CRL). An alternative to CRLs is the Online Certificate Status Protocol (OCSP), which validates certificates in real-time. OCSP technology is currently under development.
- Java provides the **keytool** utility for managing and generating keys, certificates and digital signatures. A keystore is a repository for storing public and private keys. An alias identifies a particular public and private key pair.
- A trusted keystore is a keystore that contains certificates that the user knows to be correct, such as those from certificate authorities—to validate information with the signature.
- The basis of Java security is the Java Sandbox—the protected environment in which Java applications and applets run. The Java Sandbox security model is comprised of three individual security checks: the bytecode verifier, the class loader and security manager.
- Permissions may be granted on the basis of security policy files. Permissions are comprised of varying levels of access to specific resources. Any permission that is not declared explicitly in the policy file is not granted. The security policy files are external text files with certain syntax and class names.
- A system-wide security policy file is responsible for granting code the permission to access files and ports on the entire system. The virtual machine loads this policy file as part of the virtual machine's initialization. Particular applications can specify custom security policy files on the command line.
- Java applets run under strict security restrictions due to the unreliability of code downloading over public networks. Developers who wish to distribute applets with special permissions must sign those applets with digital signatures.
- Signing an applet with a digital signature requires that the signing party stores the applet and its supporting classes in a JAR file.
- Ensuring that users actually are who they claim to be is a large part of computer security, known as authentication. Java uses the Java Authentication and Authorization Service (JAAS) for authenticating and authorizing users.
- JAAS is based on a plug-in framework, which allows Kerberos and single sign-on to be implemented for authentication and authorization.
- Kerberos is a freely available open-source protocol developed at MIT. It employs secret-key cryptography to authenticate users in a network and to maintain the integrity and privacy of network communications.
- Java addresses the problems often associated with authenticating users and controlling access with the Java Authentication and Authorization Service (JAAS) API.
- The Pluggable Authentication Module (PAM) architecture is the standard method for authentication on which JAAS is based.
- After a user has been authenticated, JAAS can grant or restrict access to certain resources of an application. JAAS can control access by group, user or role-based security policies.
- User-based access control governs access to resources on an individual user basis. Group-based authorization identifies a user as a part of a group and grants access to certain resources based on the identifying group. Role-based access control (RBAC) is used in addition to group-access control, allowing for more control over resources.

- The Secure Sockets Layer (SSL) protocol, developed by Netscape Communications, is a nonproprietary protocol commonly used to secure communication between two computers on the Internet and the Web. SSL operates between the Internet's TCP/IP communications protocol and the application software.
- SSL implements public-key technology using the RSA algorithm and digital certificates to authenticate the server in a transaction and to protect private information.
- SSL is used primarily to secure point-to-point connections—transmissions of data from one computer to another. The Transport Layer Security (TLS) protocol, designed by the Internet Engineering Task Force, is similar to SSL.
- Sun's Java Secure Socket Extension (JSSE) provides encryption, message integrity checks and authentication of the server and client.
- Before the Java Virtual Machine executes a Java program, the bytecodes for that program must pass through the bytecode verifier. The bytecode verifier ensures that the bytecodes are valid Java bytecodes that do not perform certain illegal operations.
- The Java Virtual Machine checks any remaining cast operations to ensure their validity and performs array-bounds checking to prevent programs from reading arbitrary memory locations.
- The Java Virtual Machine uses class loaders to read class definitions from **.class** files and produce class representations in memory.
- The class loader uses separate namespaces to prevent malicious code from interacting with safe code. Every class that the JVM loads is assigned a corresponding set of unique names, known as a namespace. Namespaces in Java act as barriers between classes.
- The bootstrap class loader loads all of the trusted core Java classes.
- The Java security manager is the module that performs security checks while code is running. If, during run-time, code attempts to execute a dangerous operation, a security exception is generated.
- Final classes cannot be subclassed, and can help make an application more secure by preventing attackers from creating malicious subclasses that can cause damage to an application or gain access to protected information.

## TERMINOLOGY

Advanced Encryption Standard (AES)	collision
asymmetric algorithms	cryptanalysis
authentication	cryptography
block	cryptosystem
block-cipher	Data Encryption Standard (DES)
bootstrap class loader	Decorator design pattern
brute-force	decryption
byte-code verifier	DES cracker machine
Caesar cipher	Diffie-Hellman Key Agreement Protocol
certificate authority hierarchy	digital certificate
certificate repository	digital envelope
certificate revocation list (CRL)	digital IDs
certification authority (CA)	digital signature
cipher	Digital Signature Algorithm (DSA)
<b>Cipher</b> class	encryption
ciphertext	hacker
class loader	hash function
codebase	hash value

integrity	private key
Internet Engineering Task Force (IETF)	protocol
Internet Policy Registration Authority (IPRA)	provider-based architecture
Internet Protocol (IP)	public key
Internet Security Architecture	Public Key Infrastructure (PKI)
Java Authentication and Authorization Service (JAAS)	public-key algorithms
Java Cryptography Extension (JCE)	public-key cryptography
Java Sandbox	restricted algorithms
Java Secure Socket Extension (JSSE)	Rijndael
Kerberos	Role-Based Access Control (RBAC)
key	root certification authority
key agreement protocol	root key
key distribution center	RSA Security, Inc.
key generation	runtime package
key length	secret key
key management	<b>SecretKey</b> class
keystore	Secure Sockets Layer (SSL)
<b>keytool</b> utility	security manager
message digest	service ticket
message integrity	session keys
namespace	single sign-on
National Institute of Standards and Technology	socket
network security	strong encryption
nonrepudiation	substitution cipher
Password-Based Encryption (PBE)	symmetric encryption algorithms
permissions	Ticket Granting Service (TGS)
plaintext	Ticket Granting Ticket (TGT)
Pluggable Authentication Module (PAM)	timestamping
point-to-point connection	timestamping agency
policy creation authorities	token
policy file	transposition cipher
<b>policytool</b>	Triple DES
privacy	VeriSign

## SELF-REVIEW EXERCISES

- 7.1** State whether the following are *true* or *false*. If the answer is *false*, explain why.
- In a public-key algorithm, one key is used for both encryption and decryption.
  - Digital certificates are intended to be used indefinitely.
  - Secure Sockets Layer protects data stored on a merchant's server.
  - Transport Layer Security is similar to the Secure Sockets Layer protocol.
  - Digital signatures can be used to provide undeniable proof of the author of a document.
  - In a network of 10 users communicating using public-key cryptography, only 10 keys are needed in total.
  - The security of modern cryptosystems lies in the secrecy of the algorithm.
  - Users should avoid changing keys as much as possible, unless they have reason to believe that the security of the key has been compromised.
  - Increasing the security of a network often decreases its functionality and efficiency.
  - Kerberos is an authentication protocol that is used over TCP/IP networks.
  - SSL can be used to connect a network of computers over the Internet.

- 7.2** Fill in the blanks in each of the following statements:
- Cryptographic algorithms in which the message's sender and receiver both hold an identical key are called \_\_\_\_\_.
  - A \_\_\_\_\_ is used to authenticate the sender of a document.
  - In a \_\_\_\_\_, a document is encrypted using a symmetric secret key and sent with that symmetric secret key, encrypted using a public-key algorithm.
  - A certificate that needs to be revoked before its expiration date is placed on a \_\_\_\_\_.
  - A digital fingerprint of a document can be created using a \_\_\_\_\_.
  - The four main issues addressed by cryptography are \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
  - Trying to decrypt ciphertext without knowing the decryption key is known as \_\_\_\_\_.
  - A hacker that tries every possible solution to crack a code is using a method known as \_\_\_\_\_.

### ANSWERS TO SELF-REVIEW EXERCISES

**7.1** a) False. The encryption key is different from the decryption key. One is made public, and the other is kept private. b) False. Digital certificates are created with an expiration date to encourage users to periodically change their public/private-key pair. c) False. Secure Sockets Layer is an Internet security protocol, which secures the transfer of information in electronic communication. It does not protect data stored on a merchant's server. d) True. e) False. A user who digitally signed a document could later intentionally give up his or her private key and then claim that the document was written by an imposter. Thus, timestamping a document is necessary, so that users cannot repudiate documents written before the public/private-key pair is reported as invalidated. f) False. Each user needs a public key and a private key. Thus, in a network of 10 users, 20 keys are needed in total. g) False. The security of modern cryptosystems lies in the secrecy of the encryption and decryption keys. h) False. Changing keys often is a good way to maintain the security of a communication system. i) True. j) True. k) False, IPSec can connect a whole network of computers, while SSL can only connect two secure systems.

**7.2** a) symmetric key algorithms. b) digital signature. c) digital envelope. d) certificate revocation list. e) hash function. f) privacy, authentication, integrity, nonrepudiation. g) cryptanalysis. h) brute-force hacking.

### EXERCISES

**7.3** Define each of the following security terms, and give an example of how it is used:

- secret-key cryptography
- public-key cryptography
- digital signature
- digital certificate
- hash function
- SSL
- Kerberos

**7.4** Write the full name and describe each of the following acronyms:

- PKI
- CRL
- AES
- SSL

- 7.5** List the four problems addressed by cryptography, and give a real-world example of each.
- 7.6** Compare symmetric-key algorithms with public-key algorithms. What are the benefits and drawbacks of each type of algorithm? How are these differences manifested in the real-world uses of the two types of algorithms?
- 7.7** Create a simple application that reads a file; the application should accept the file path from the command line. Install a **SecurityManager** to control access and create two policy files—one that grants read permission to a particular directory (e.g., a **C:\readonly** directory), and another that grants read permission to that directory for a specific codebase (e.g., the **C:/myclasses** codebase). [Note: Code always has read permission to the directory in which it is running and any subdirectories.]
- 7.8** Using your solution to Exercise 7.7, store your application in a JAR file. Sign the JAR file with a digital signature (use the **keytool** to create a public/private key pair); grant read permission to the directory for code signed by this signature in a policy file. [Note: To grant permission for a particular digital signature, use the **signedBy** field in a **grant** statement. The **signedBy** field requires that you specify the keystore in which this public/private key pair is stored using a **keystore "keystore\_URL";** statement outside of the **grant** statements in the policy file.]

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# 8

# Java Database Connectivity (JDBC)

## Objectives

- To understand the relational-database model.
- To understand basic database queries using Structured Query Language (SQL).
- To use the classes and interfaces of package `java.sql` to manipulate databases.
- To use transaction processing to prevent database updates from modifying the database if an error occurs during a transaction.
- To introduce the JDBC 2.0 optional package `javax.sql`'s capabilities for obtaining database connections, creating connection pools and treating result sets as JavaBeans.

*It is a capital mistake to theorize before one has data.*

Arthur Conan Doyle

*Now go, write it before them in a table, and note it in a book, that it may be for the time to come for ever and ever.*

The Holy Bible: The Old Testament

*Let's look at the record.*

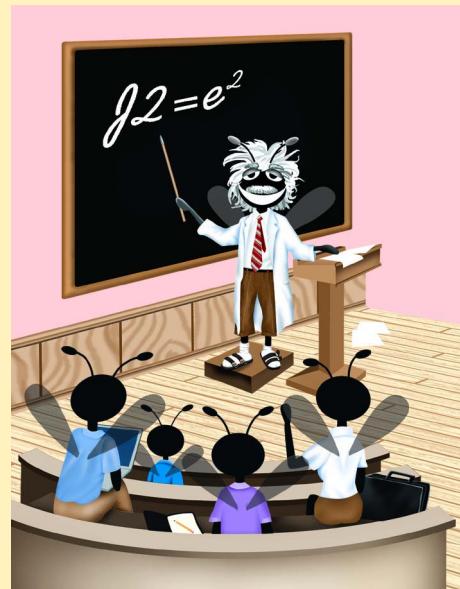
Alfred Emanuel Smith

*Get your facts first, and then you can distort them as much as you please.*

Mark Twain

*I like two kinds of men: domestic and foreign.*

Mae West



## Outline

- 8.1 Introduction
- 8.2 Relational-Database Model
- 8.3 Relational Database Overview: The `books` Database
- 8.4 Structured Query Language (SQL)
  - 8.4.1 Basic `SELECT` Query
  - 8.4.2 `WHERE` Clause
  - 8.4.3 `ORDER BY` Clause
  - 8.4.4 Merging Data from Multiple Tables: Joining
  - 8.4.5 `INSERT INTO` Statement
  - 8.4.6 `UPDATE` Statement
  - 8.4.7 `DELETE FROM` Statement
- 8.5 Creating Database `books` in Cloudscape
- 8.6 Manipulating Databases with JDBC
  - 8.6.1 Connecting to and Querying a JDBC Data Source
  - 8.6.2 Querying the `books` Database
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## 8.1 Introduction

A *database* is an integrated collection of data. There are many different strategies for organizing data to facilitate easy access and manipulation of the data. A *database management system (DBMS)* provides mechanisms for storing and organizing data in a manner consistent with the database's format. Database management systems allow for the access and storage of data without worrying about the internal representation of databases.

Today's most popular database systems are *relational databases*. A language called *Structured Query Language (SQL)*—pronounced as its individual letters, or as “sequel”) is used almost universally with relational-database systems to perform *queries* (i.e., to request information that satisfies given criteria) and to manipulate data. [Note: In this chapter, we assume that SQL is pronounced as its individual letters. For this reason, we often precede SQL with the article “an,” as in “an SQL database” or “an SQL statement.”]

Some popular enterprise-level relational-database systems are Microsoft SQL Server, Oracle, Sybase, DB2, Informix and MySQL. In this chapter, we present examples using *Cloudscape 3.6.4*—a pure-Java database management system from Informix Software. Cloudscape 3.6.4 is on the CD that accompanies this book and can be downloaded from [www.cloudscape.com](http://www.cloudscape.com). Later chapters reuse the material presented in this chapter. Chapter 11 introduces the *Java 2 Enterprise Edition reference implementation*, which includes an earlier version of Cloudscape. That chapter discusses how to integrate the latest version of Cloudscape with the Java 2 Enterprise Edition. [Note: We discuss basic Cloudscape features required to execute the examples in this chapter. Please refer to the detailed Cloudscape documentation for complete information on using Cloudscape.]

Java programs communicate with databases and manipulate their data using the *Java Database Connectivity (JDBC) API*. A *JDBC driver* implements the interface to a particular database. This separation of the API from particular drivers enables developers to change the underlying database without modifying Java code that accesses the database. Most popular database management systems now include JDBC drivers. There are also many third-party JDBC drivers available. In this chapter, we introduce JDBC and use it to manipulate a Cloudscape database. The techniques demonstrated here also can be used to manipulate other databases that have JDBC drivers. Check your database management system's documentation to determine whether your DBMS comes with a JDBC driver. Even if your DBMS does not come with a JDBC driver, many third-party vendors provide JDBC drivers for a wide variety of databases. For more information on JDBC, visit

**`java.sun.com/products/jdbc/`**

This site contains information concerning JDBC, including the JDBC specifications, FAQs on JDBC, a learning resource center, software downloads and other important information. For a list of available JDBC drivers, visit

**`industry.java.sun.com/products/jdbc/drivers/`**

This site provides a search engine to help you locate drivers appropriate to your DBMS.

## 8.2 Relational-Database Model

The *relational-database model* is a logical representation of data that allows the relationships between the data to be examined without consideration of the physical structure of the data. A relational database is composed of *tables*. Figure 8.1 illustrates a sample table that might be used in a personnel system. The table name is **Employee**, and its primary purpose is to illustrate the attributes of an employee and how they are related to a specific employee. Each row of the table is called a *record*. This table consists of six records. The **Number** field (or *column*) of each record in this table is the *primary key* for referencing data in the table. A primary key is a field (or fields) in a table that contain(s) unique data that cannot be duplicated in other records. This guarantees that each record can be identified by a unique value. Good

Number	Name	Department	Salary	Location
23603	Jones	413	1100	New Jersey
24568	Kerwin	413	2000	New Jersey
34589	Larson	642	1800	Los Angeles
35761	Myers	611	1400	Orlando
47132	Neumann	413	9000	New Jersey
78321	Stephens	611	8500	Orlando

Fig. 8.1 Relational-database structure of an **Employee** table.

examples of primary key fields are a Social Security number, an employee ID number and a part number in an inventory system. The records of Fig. 8.1 are *ordered* by primary key. In this case, the records are listed in increasing order; we could also use decreasing order.

Each column of the table represents a different *field* (or *column*, or *attribute*). Records are normally unique (by primary key) within a table, but particular field values may be duplicated between records. For example, three different records in the **Employee** table's **Department** field contain number 413.

Different users of a database often are interested in different data and different relationships among those data. Some users require only subsets of the table columns. To obtain table subsets, we use SQL statements to specify the data to *select* from a table. SQL provides a complete set of commands (including **SELECT**) that enable programmers to define complex *queries* that select data from a table. The results of a query are commonly called *result sets* (or *record sets*). For example, we might select data from the table in Fig. 8.1 to create a new result set that shows where departments are located. This result set is shown in Fig. 8.2. SQL queries are discussed in Section 8.4.

### 8.3 Relational Database Overview: The **books** Database

This section gives an overview of SQL in the context of a sample **books** database we created for this chapter. Before we discuss SQL, we overview the tables of the **books** database. We use this to introduce various database concepts, including the use of SQL to obtain useful information from the database and to manipulate the database. We provide a script to create the database. You can find the script in the examples directory for this chapter on the CD that accompanies this book. Section 8.5 explains how to use this script.

Department	Location
413	New Jersey
611	Orlando
642	Los Angeles

Fig. 8.2 Result set formed by selecting **Department** and **Location** data from the **Employee** table.

The database consists of four tables: **authors**, **publishers**, **authorISBN** and **titles**. The **authors** table (described in Fig. 8.3) consists of three fields (or columns) that maintain each author's unique ID number, first name and last name. Figure 8.4 contains the data from the **authors** table of the **books** database.

The **publishers** table (described in Fig. 8.5) consists of two fields representing each publisher's unique ID and name. Figure 8.6 contains the data from the **publishers** table of the **books** database.

Field	Description
<b>authorID</b>	Author's ID number in the database. In the <b>books</b> database, this integer field is defined as an <i>autoincremented field</i> . For each new record inserted in this table, the database automatically increments the <b>authorID</b> value to ensure that each record has a unique <b>authorID</b> . This field represents the table's primary key.
<b>firstName</b>	Author's first name (a string).
<b>lastName</b>	Author's last name (a string).

Fig. 8.3 **authors** table from **books**.

authorID	firstName	lastName
1	Harvey	Deitel
2	Paul	Deitel
3	Tem	Nieto
4	Sean	Santry

Fig. 8.4 Data from the **authors** table of **books**.

Field	Description
<b>publisherID</b>	The publisher's ID number in the database. This autoincremented integer is the table's primary-key field.
<b>publisherName</b>	The name of the publisher (a string).

Fig. 8.5 **publishers** table from **books**.

publisherID	publisherName
1	Prentice Hall
2	Prentice Hall PTG

Fig. 8.6 Data from the **publishers** table of **books**.

The **authorISBN** table (described in Fig. 8.7) consists of two fields that maintain each ISBN number and its corresponding author's ID number. This table helps associate the names of the authors with the titles of their books. Figure 8.8 contains the data from the **authorISBN** table of the **books** database. ISBN is an abbreviation for “International Standard Book Number”—a numbering scheme that publishers worldwide use to give every book a unique identification number. [Note: To save space, we have split the contents of this table into two columns, each containing the **authorID** and **isbn** fields.]

Field	Description
<b>authorID</b>	The author's ID number, which allows the database to associate each book with a specific author. The integer ID number in this field must also appear in the <b>authors</b> table.
<b>isbn</b>	The ISBN number for a book (a string).

Fig. 8.7 **authorISBN** table from **books**.

authorID	isbn	authorID	isbn
1	0130895725	2	0139163050
1	0132261197	2	013028419x
1	0130895717	2	0130161438
1	0135289106	2	0130856118
1	0139163050	2	0130125075
1	013028419x	2	0138993947
1	0130161438	2	0130852473
1	0130856118	2	0130829277
1	0130125075	2	0134569555
1	0138993947	2	0130829293
1	0130852473	2	0130284173
1	0130829277	2	0130284181
1	0134569555	2	0130895601
1	0130829293	3	013028419x
1	0130284173	3	0130161438
1	0130284181	3	0130856118
1	0130895601	3	0134569555
2	0130895725	3	0130829293
2	0132261197	3	0130284173
2	0130895717	3	0130284181
2	0135289106	4	0130895601

Fig. 8.8 Data from the **authorISBN** table of **books**.

The **titles** table (described in Fig. 8.9) consists of six fields that maintain general information about each book in the database, including the ISBN number, title, edition number, copyright year, publisher's ID number, name of a file containing an image of the book cover, and finally, the price. Figure 8.10 contains the data from the **titles** table.

Field	Description
<b>isbn</b>	ISBN number of the book (a string).
<b>title</b>	Title of the book (a string).
<b>editionNumber</b>	Edition number of the book (an integer).
<b>copyright</b>	Copyright year of the book (a string).
<b>publisherID</b>	Publisher's ID number (an integer). This value must correspond to an ID number in the <b>publishers</b> table.
<b>imageFile</b>	Name of the file containing the book's cover image (a string).
<b>price</b>	Suggested retail price of the book (a real number). [Note: The prices shown in this book are for example purposes only.]

Fig. 8.9 **titles** table from **books**.

isbn	title	edition- Number	copy- right	publish- erID	image-File	price
0130895725	C How to Program	3	2001	1	<b>chtp3.jpg</b>	69.95
0132261197	C How to Program	2	1994	1	<b>chtp2.jpg</b>	49.95
0130895717	C++ How to Program	3	2001	1	<b>cpphtp3.jpg</b>	69.95
0135289106	C++ How to Program	2	1998	1	<b>cpphtp2.jpg</b>	49.95
0139163050	The Complete C++ Training Course	3	2001	2	<b>cppctc3.jpg</b>	109.95
013028419x	e-Business and e-Commerce How to Program	1	2001	1	<b>ebechtp1.jpg</b>	69.95
0130161438	Internet and World Wide Web How to Program	1	2000	1	<b>iw3htp1.jpg</b>	69.95
0130856118	The Complete Internet and World Wide Web Programming Training Course	1	2000	2	<b>iw3ctc1.jpg</b>	109.95
0130125075	Java How to Program (Java 2)	3	2000	1	<b>jhtp3.jpg</b>	69.95
0138993947	Java How to Program (Java 1.1)	2	1998	1	<b>jhtp2.jpg</b>	49.95

Fig. 8.10 Data from the **titles** table of **books** (part 1 of 2).

isbn	title	edition-Number	copy-right	publish-erID	image-File	price
0130852473	The Complete Java 2 Training Course	3	2000	2	<b>javactc3.jpg</b>	109.95
0130829277	The Complete Java Training Course (Java 1.1)	2	1998	2	<b>javactc2.jpg</b>	99.95
0134569555	Visual Basic 6 How to Program	1	1999	1	<b>vbhtp1.jpg</b>	69.95
0130829293	The Complete Visual Basic 6 Training Course	1	1999	2	<b>vbctc1.jpg</b>	109.95
0130284173	XML How to Program	1	2001	1	<b>xmlhtp1.jpg</b>	69.95
0130284181	Perl How to Program	1	2001	1	<b>perlhtp1.jpg</b>	69.95
0130895601	Advanced Java 2 Platform How to Program	1	2002	1	<b>advjhtp1.jpg</b>	69.95

Fig. 8.10 Data from the **titles** table of **books** (part 2 of 2).

Figure 8.11 illustrates the relationships among the tables in the **books** database. The first line in each table is the table's name. The field name in green contains that table's primary key. A table's primary key uniquely identifies each record in the table. Every record must have a value in the primary-key field, and the value must be unique. This is known as the *Rule of Entity Integrity*.



### Common Programming Error 8.1

*Not providing a value for a primary-key field in every record breaks the Rule of Entity Integrity and causes the DBMS to report an error.*



### Common Programming Error 8.2

*Providing duplicate values for the primary-key field in multiple records causes the DBMS to report an error.*

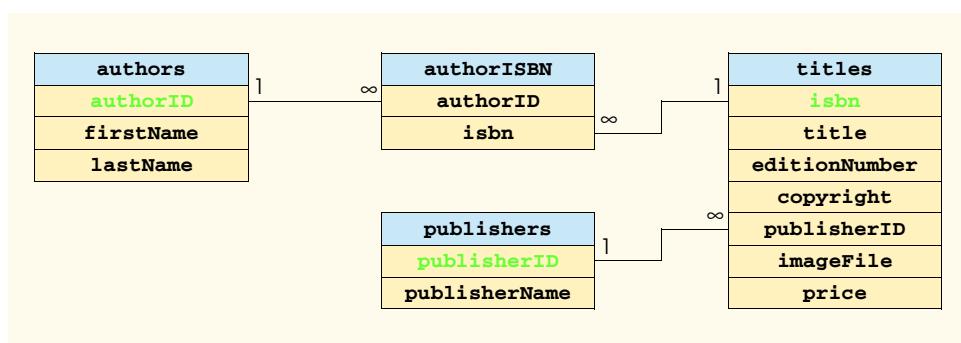


Fig. 8.11 Table relationships in **books**.

The lines connecting the tables in Fig. 8.11 represent the *relationships* between the tables. Consider the line between the **publishers** and **titles** tables. On the **publishers** end of the line, there is a 1, and on the **titles** end, there is an infinity ( $\infty$ ) symbol, indicating a *one-to-many relationship* in which every publisher in the **publishers** table can have an arbitrarily large number of books in the **titles** table. Note that the relationship line links the **publisherID** field in the table **publishers** to the **publisherID** field in table **titles**. The **publisherID** field in the **titles** table is a *foreign key*—a field for which every entry has a unique value in another table and where the field in the other table is the primary key for that table (e.g., **publisherID** in the **publishers** table). Foreign keys are specified when creating a table. The foreign key helps maintain the *Rule of Referential Integrity*: Every foreign key-field value must appear in another table's primary-key field. Foreign keys enable information from multiple tables to be *joined* together for analysis purposes. There is a one-to-many relationship between a primary key and its corresponding foreign key. This means that a foreign key-field value can appear many times in its own table, but can only appear once as the primary key of another table. The line between the tables represents the link between the foreign key in one table and the primary key in another table.



### Common Programming Error 8.3

Providing a foreign-key value that does not appear as a primary-key value in another table breaks the Rule of Referential Integrity and causes the DBMS to report an error.

The line between the **authorISBN** and **authors** tables indicates that for each author in the **authors** table, there can be an arbitrary number of ISBNs for books written by that author in the **authorISBN** table. The **authorID** field in the **authorISBN** table is a foreign key of the **authorID** field (the primary key) of the **authors** table. Note again that the line between the tables links the foreign key of table **authorISBN** to the corresponding primary key in table **authors**. The **authorISBN** table links information in the **titles** and **authors** tables.

Finally, the line between the **titles** and **authorISBN** tables illustrates a one-to-many relationship; a title can be written by any number of authors. In fact, the sole purpose of the **authorISBN** table is to represent a many-to-many relationship between the **authors** and **titles** tables; an author can write any number of books and a book can have any number of authors.

## 8.4 Structured Query Language (SQL)

In this section, we provide an overview of SQL in the context of our **books** sample database. You will be able to use the SQL queries discussed here in the examples later in the chapter.

The SQL keywords listed in Fig. 8.12 are discussed in the context of complete SQL queries in the next several subsections; other SQL keywords are beyond the scope of this text. [Note: For more information on SQL, please refer to the World Wide Web resources in Section 8.13 and the bibliography at the end of this chapter.]

SQL keyword	Description
<b>SELECT</b>	Select (retrieve) fields from one or more tables.
<b>FROM</b>	Tables from which to get fields. Required in every <b>SELECT</b> .
<b>WHERE</b>	Criteria for selection that determine the rows to be retrieved.
<b>GROUP BY</b>	Criteria for grouping records.
<b>ORDER BY</b>	Criteria for ordering records.
<b>INSERT INTO</b>	Insert data into a specified table.
<b>UPDATE</b>	Update data in a specified table.
<b>DELETE FROM</b>	Delete data from a specified table.

Fig. 8.12 SQL query keywords.

#### 8.4.1 Basic **SELECT** Query

Let us consider several SQL queries that extract information from database **books**. A typical SQL query “selects” information from one or more tables in a database. Such selections are performed by **SELECT queries**. The simplest format of a **SELECT** query is

```
SELECT * FROM tableName
```

In this query, the asterisk (\*) indicates that all rows and columns from the *tableName* table of the database should be selected. For example, to select the entire contents of the **authors** table (i.e., all the data in Fig. 8.4), use the query

```
SELECT * FROM authors
```

To select specific fields from a table, replace the asterisk (\*) with a comma-separated list of the field names to select. For example, to select only the fields **authorID** and **lastName** for all rows in the **authors** table, use the query

```
SELECT authorID, lastName FROM authors
```

This query returns the data listed in Fig. 8.13. [Note: If a field name contains spaces, it must be enclosed in square brackets ([ ]) in the query. For example, if the field name is **first name**, the field name would appear in the query as **[first name]**.]

authorID	lastName
1	Deitel
2	Deitel
3	Nieto
4	Santry

Fig. 8.13 **authorID** and **lastName** from the **authors** table.



### Software Engineering Observation 8.1

For most SQL statements, the asterisk (\*) should not be used to specify field names to select from a table (or several tables). In general, programmers process result sets by knowing in advance the order of the fields in the result set. For example, selecting **authorID** and **lastName** from table **authors** guarantees that the fields will appear in the result set with **authorID** as the first field and **lastName** as the second field. As you will see, programs typically process result set fields by specifying the column number in the result set (column numbers start at 1 for the first field in the result set).



### Software Engineering Observation 8.2

Specifying the field names to select from a table (or several tables) guarantees that the fields are always returned in the specified order and also avoid returning unused fields, even if the actual order of the fields in the database table(s) changes.



### Common Programming Error 8.4

If a programmer assumes that the fields in a result set are always returned in the same order from an SQL statement that uses the asterisk (\*) to select fields, the program may process the result set incorrectly. If the field order in the database table(s) changes, the order of the fields in the result set would change accordingly.



### Performance Tip 8.1

If the order of fields in a result set is unknown to a program, the program must process the fields by name. This can require a linear search of the field names in the result set. Specifying the field names to select from a table (or several tables) enables the application receiving the result set to know the order of the fields in advance. In this case, the program can process the data more efficiently, because fields can be accessed directly by column number.

## 8.4.2 WHERE Clause

In most cases, it is necessary to locate records in a database that satisfy certain *selection criteria*. Only records that match the selection criteria are selected. SQL uses the optional **WHERE clause** in a **SELECT** query to specify the selection criteria for the query. The simplest format of a **SELECT** query with selection criteria is

```
SELECT fieldName1, fieldName2, ... FROM tableName WHERE criteria
```

For example, to select the **title**, **editionNumber** and **copyright** fields from table **titles** for which the **copyright** date is greater than **1999**, use the query

```
SELECT title, editionNumber, copyright
  FROM titles
 WHERE copyright > 1999
```

Figure 8.14 shows the results of the preceding query. [Note: When we construct a query for use in Java, we simply create a **String** containing the entire query. When we display queries in the text, we often use multiple lines and indentation for readability.]



### Performance Tip 8.2

Using selection criteria improves performance by selecting a portion of the database that is normally smaller than the entire database. Working with a smaller portion of the data is more efficient than working with the entire set of data stored in the database.

<b>title</b>	<b>editionNumber</b>	<b>copyright</b>
C How to Program	3	2001
C++ How to Program	3	2001
The Complete C++ Training Course	3	2001
e-Business and e-Commerce How to Program	1	2001
Internet and World Wide Web How to Program	1	2000
The Complete Internet and World Wide Web Programming Training Course	1	2000
Java How to Program (Java 2)	3	2000
The Complete Java 2 Training Course	3	2000
XML How to Program	1	2001
Perl How to Program	1	2001
Advanced Java 2 Platform How to Program	1	2002

Fig. 8.14 Titles with copyrights after 1999 from table **titles**.

The **WHERE** clause condition can contain operators **<**, **>**, **<=**, **>=**, **=**, **<>** and **LIKE**. Operator **LIKE** is used for *pattern matching* with wildcard characters *percent* (%) and *underscore* (\_). Pattern matching allows SQL to search for similar strings that match a given pattern.

A pattern that contains a percent character (%) searches for strings that have zero or more characters at the percent character's position in the pattern. For example, the following query locates the records of all the authors whose last name starts with the letter **D**:

```
SELECT authorID, firstName, lastName
  FROM authors
 WHERE lastName LIKE 'D%'
```

The preceding query selects the two records shown in Fig. 8.15, because two of the four authors in our database have a last name starting with the letter **D** (followed by zero or more characters). The % in the **WHERE** clause's **LIKE** pattern indicates that any number of characters can appear after the letter **D** in the **lastName** field. Notice that the pattern string is surrounded by single-quote characters.

<b>authorID</b>	<b>firstName</b>	<b>lastName</b>
1	Harvey	Deitel
2	Paul	Deitel

Fig. 8.15 Authors whose last name starts with **D** from the **authors** table.



### Portability Tip 8.1

See the documentation for your database system to determine whether SQL is case sensitive on your system and to determine the syntax for SQL keywords (i.e., should they be all uppercase letters, all lowercase letters or some combination of the two?).



### Portability Tip 8.2

Not all database systems support the **LIKE** operator, so be sure to read your database system's documentation carefully.



### Portability Tip 8.3

Some databases use the \* character in place of the % character in a **LIKE** expression.



### Portability Tip 8.4

In some databases (including Cloudscape), string data is case sensitive.



### Good Programming Practice 8.1

By convention, SQL keywords should use all uppercase letters on systems that are not case sensitive, to emphasize the SQL keywords in an SQL statement.

An underscore ( \_) in the pattern string indicates a single character at that position in the pattern. For example, the following query locates the records of all the authors whose last name starts with any character (specified by \_), followed by the letter **i**, followed by any number of additional characters (specified by %):

```
SELECT authorID, firstName, lastName
      FROM authors
     WHERE lastName LIKE '_i%'
```

The preceding query produces the record shown in Fig. 8.16, because only one author in our database has a last name that contains the letter **i** as its second letter.



### Portability Tip 8.5

Some databases use the ? character in place of the \_ character in a **LIKE** expression.

#### 8.4.3 ORDER BY Clause

The results of a query can be arranged in ascending or descending order by using the optional **ORDER BY clause**. The simplest form of an **ORDER BY** clause is

```
SELECT fieldName1, fieldName2, ... FROM tableName ORDER BY field ASC
SELECT fieldName1, fieldName2, ... FROM tableName ORDER BY field DESC
```

authorID	firstName	lastName
3	Tem	Nieto

Fig. 8.16 The only author from the **authors** table whose last name contains **i** as the second letter.

where **ASC** specifies ascending order (lowest to highest), **DESC** specifies descending order (highest to lowest) and *field* specifies the field on which the sort is based.

For example, to obtain the list of authors in ascending order by last name (Fig. 8.17), use the query

```
SELECT authorID, firstName, lastName
  FROM authors
 ORDER BY lastName ASC
```

Note that the default sorting order is ascending, so **ASC** is optional. To obtain the same list of authors in descending order by last name (Fig. 8.18), use the query

```
SELECT authorID, firstName, lastName
  FROM authors
 ORDER BY lastName DESC
```

Multiple fields can be used for ordering purposes with an **ORDER BY** clause of the form

```
ORDER BY field1 sortOrder, field2 sortOrder, ...
```

where *sortOrder* is either **ASC** or **DESC**. Note that the *sortOrder* does not have to be identical for each field. The query

```
SELECT authorID, firstName, lastName
  FROM authors
 ORDER BY lastName, firstName
```

sorts in ascending order all the authors by last name, then by first name. If any authors have the same last name, their records are returned in sorted order by their first name (Fig. 8.19).

authorID	firstName	lastName
2	Paul	Deitel
1	Harvey	Deitel
3	Tem	Nieto
4	Sean	Santry

Fig. 8.17 Authors from table **authors** in ascending order by **lastName**.

authorID	firstName	lastName
4	Sean	Santry
3	Tem	Nieto
2	Paul	Deitel
1	Harvey	Deitel

Fig. 8.18 Authors from table **authors** in descending order by **lastName**.

authorID	firstName	lastName
1	Harvey	Deitel
2	Paul	Deitel
3	Tem	Nieto
4	Sean	Santry

Fig. 8.19 Authors from table **authors** in ascending order by **lastName** and by **firstName**.

The **WHERE** and **ORDER BY** clauses can be combined in one query. For example, the query

```
SELECT isbn, title, editionNumber, copyright, price
  FROM titles
 WHERE title
   LIKE '%How to Program' ORDER BY title ASC
```

returns the **isbn**, **title**, **editionNumber**, **copyright** and **price** of each book in the **titles** table that has a **title** ending with “**How to Program**” and orders them in ascending order by **title**. The results of the query are shown in Fig. 8.20. Note that the title “e-Business and e-Commerce How to Program” appears at the end of the list, because Cloudscape uses the Unicode numeric values of the characters for comparison purposes. Remember that lowercase letters have larger numeric values than uppercase letters.

isbn	title	edition- Number	copy- right	price
0130895601	Advanced Java 2 Platform How to Program	1	2002	69.95
0132261197	C How to Program	2	1994	49.95
0130895725	C How to Program	3	2001	69.95
0135289106	C++ How to Program	2	1998	49.95
0130895717	C++ How to Program	3	2001	69.95
0130161438	Internet and World Wide Web How to Program	1	2000	69.95
0130284181	Perl How to Program	1	2001	69.95
0134569555	Visual Basic 6 How to Program	1	1999	69.95
0130284173	XML How to Program	1	2001	69.95
013028419x	e-Business and e-Commerce How to Program	1	2001	69.95

Fig. 8.20 Books from table **titles** whose title ends with **How to Program** in ascending order by **title**.

#### 8.4.4 Merging Data from Multiple Tables: Joining

Often, it is necessary to merge data from multiple tables into a single view for analysis purposes. This is referred to as *joining* the tables and is accomplished by using a comma-separated list of tables in the **FROM** clause of a **SELECT** query. A join merges records from two or more tables by testing for matching values in a field that is common to both tables. The simplest format of a join is

```
SELECT fieldName1, fieldName2, ...
  FROM table1, table2
 WHERE table1.fieldName = table2.fieldName
```

The query's **WHERE** clause specifies the fields from each table that should be compared to determine which records will be selected. These fields normally represent the primary key in one table and the corresponding foreign key in the other table. For example, the following query produces a list of authors and the ISBN numbers for the books that each author wrote:

```
SELECT firstName, lastName, isbn
  FROM authors, authorISBN
 WHERE authors.authorID = authorISBN.authorID
 ORDER BY lastName, firstName
```

The query merges the **firstName** and **lastName** fields from table **authors** and the **isbn** field from table **authorISBN** and sorts the results in ascending order by **lastName** and **firstName**. Notice the use of the syntax *tableName.fieldName* in the **WHERE** clause of the query. This syntax (called a *fully qualified name*) specifies the fields from each table that should be compared to join the tables. The “*tableName.*” syntax is required if the fields have the same name in both tables.

#### Software Engineering Observation 8.3



If an SQL statement uses fields with the same name from multiple tables, the field name must be fully qualified with its table name and a dot operator (.), as in **authors.authorID**.

#### Common Programming Error 8.5



In a query, not providing fully qualified names for fields with the same name from two or more tables is an error.

As always, the **FROM** clause can be followed by an **ORDER BY** clause. Figure 8.21 shows the results of the preceding query. [Note: To save space, we split the results of the query into two columns, each containing the **firstName**, **lastName** and **isbn** fields.]

firstName	lastName	isbn	firstName	lastName	isbn
Harvey	Deitel	0130895601	Harvey	Deitel	0130284173
Harvey	Deitel	0130284181	Harvey	Deitel	0130829293

**Fig. 8.21** Authors and the ISBN numbers for the books they have written in ascending order by **lastName** and **firstName** (part 1 of 2).

firstName	lastName	isbn	firstName	lastName	isbn
Harvey	Deitel	0134569555	Paul	Deitel	0130852473
Harvey	Deitel	0130829277	Paul	Deitel	0138993947
Harvey	Deitel	0130852473	Paul	Deitel	0130125075
Harvey	Deitel	0138993947	Paul	Deitel	0130856118
Harvey	Deitel	0130125075	Paul	Deitel	0130161438
Harvey	Deitel	0130856118	Paul	Deitel	013028419x
Harvey	Deitel	0130161438	Paul	Deitel	0139163050
Harvey	Deitel	013028419x	Paul	Deitel	0135289106
Harvey	Deitel	0139163050	Paul	Deitel	0130895717
Harvey	Deitel	0135289106	Paul	Deitel	0132261197
Harvey	Deitel	0130895717	Paul	Deitel	0130895725
Harvey	Deitel	0132261197	Tem	Nieto	0130284181
Harvey	Deitel	0130895725	Tem	Nieto	0130284173
Paul	Deitel	0130895601	Tem	Nieto	0130829293
Paul	Deitel	0130284181	Tem	Nieto	0134569555
Paul	Deitel	0130284173	Tem	Nieto	0130856118
Paul	Deitel	0130829293	Tem	Nieto	0130161438
Paul	Deitel	0134569555	Tem	Nieto	013028419x
Paul	Deitel	0130829277	Sean	Santry	0130895601

**Fig. 8.21** Authors and the ISBN numbers for the books they have written in ascending order by `lastName` and `firstName` (part 2 of 2).

#### 8.4.5 INSERT INTO Statement

The **INSERT INTO** statement inserts a new record into a table. The simplest form of this statement is

```
INSERT INTO tableName ( fieldName1, fieldName2, ..., fieldNameN )
VALUES ( value1, value2, ..., valueN )
```

where *tableName* is the table in which to insert the record. The *tableName* is followed by a comma-separated list of field names in parentheses (this list is not required if the **INSERT INTO** operation specifies a value for every column of the table in the correct order). The list of field names is followed by the SQL keyword **VALUES** and a comma-separated list of values in parentheses. The values specified here should match the field names specified after the table name in order and type (i.e., if *fieldName1* is supposed to be the **firstName** field, then *value1* should be a string in single quotes representing the first name). Always use the list of field names when inserting new records. If the order of the fields changes in the table, entering only **VALUES** may cause an error. The **INSERT INTO** statement

```
INSERT INTO authors ( firstName, lastName )
VALUES ( 'Sue', 'Smith' )
```

inserts a record into the **authors** table. The statement indicates that values will be inserted for the **firstName** and **lastName** fields. The corresponding values to insert are '**Sue**' and '**Smith**'. We do not specify an **authorID** in this example, because **authorID** is an *autoincremented field* in the Cloudscape database. For every new record added to this table, Cloudscape assigns a unique **authorID** value that is the next value in the autoincremented sequence (i.e., 1, 2, 3 and so on). In this case, Sue Smith would be assigned **authorID** number 5. Figure 8.22 shows the **authors** table after the **INSERT INTO** operation.



### Common Programming Error 8.6

*It is an error to specify a value for an autoincrement field.*



### Common Programming Error 8.7

*SQL statements use the single-quote (' ) character as a delimiter for strings. To specify a string containing a single quote (such as O'Malley) in an SQL statement, the string must have two single quotes in the position where the single-quote character appears in the string (e.g., 'O''Malley'). The first of the two single-quote characters acts as an escape character for the second. Not escaping single-quote characters in a string that is part of an SQL statement is an SQL syntax error.*

## 8.4.6 UPDATE Statement

An **UPDATE** statement modifies data in a table. The simplest form for an **UPDATE** statement is

```
UPDATE tableName  
    SET fieldName1 = value1, fieldName2 = value2, ..., fieldNameN = valueN  
    WHERE criteria
```

where *tableName* is the table in which to update a record (or records). The *tableName* is followed by keyword **SET** and a comma-separated list of field name/value pairs in the format *fieldName* = *value*. The **WHERE** clause provides the criteria that specify which record(s) to update. The **UPDATE** statement

```
UPDATE authors  
    SET lastName = 'Jones'  
    WHERE lastName = 'Smith' AND firstName = 'Sue'
```

authorID	firstName	lastName
1	Harvey	Deitel
2	Paul	Deitel
3	Tem	Nieto
4	Sean	Santry
5	Sue	Smith

Fig. 8.22 Table **Authors** after an **INSERT INTO** operation to add a record.

updates a record in the **authors** table. The statement indicates that the **lastName** will be assigned the value **Jones** for the record in which **lastName** is equal to **Smith** and **firstName** is equal to **Sue**. [Note: If there are multiple records with the first name “Sue” and the last name “Smith,” this statement will modify all such records to have the last name “Jones.”] If we know the **authorID** in advance of the **UPDATE** operation (possibly because we searched for the record previously), the **WHERE** clause could be simplified as follows:

```
WHERE AuthorID = 5
```

Figure 8.23 shows the **authors** table after the **UPDATE** operation has taken place.

#### 8.4.7 DELETE FROM Statement

An SQL **DELETE** statement removes data from a table. The simplest form for a **DELETE** statement is

```
DELETE FROM tableName WHERE criteria
```

where *tableName* is the table from which to delete a record (or records). The **WHERE** clause specifies the criteria used to determine which record(s) to delete. The **DELETE** statement

```
DELETE FROM authors
WHERE lastName = 'Jones' AND firstName = 'Sue'
```

deletes the record for Sue Jones in the **authors** table. If we know the **authorID** in advance of the **DELETE** operation, the **WHERE** clause could be simplified as follows:

```
WHERE authorID = 5
```

Figure 8.24 shows the **authors** table after the **DELETE** operation has taken place.

authorID	firstName	lastName
1	Harvey	Deitel
2	Paul	Deitel
3	Tem	Nieto
4	Sean	Santry
5	Sue	Jones

Fig. 8.23 Table **authors** after an **UPDATE** operation to change a record.

authorID	firstName	lastName
1	Harvey	Deitel
2	Paul	Deitel
3	Tem	Nieto
4	Sean	Santry

Fig. 8.24 Table **authors** after a **DELETE** operation to remove a record.

## 8.5 Creating Database **books** in Cloudscape

The CD that accompanies this book includes *Cloudscape 3.6.4*, a pure-Java database management system from Informix Software. A complete set of information on Cloudscape is available from [www.cloudscape.com](http://www.cloudscape.com). Follow the provided instructions to install Cloudscape. Cloudscape executes on many platforms, including Windows, Solaris, Linux, Macintosh and others. For a complete list of platforms on which Cloudscape 3.6 has been tested, visit

```
cloudweb1.cloudscape.com/support/servepage.jsp?  
page=fyi_cert36vms.html
```

The Cloudscape server must be executing to create and manipulate databases in Cloudscape. To execute the server, begin by opening a command window. Change directories to the Cloudscape installation directory (**Cloudscape\_3.6** by default). In that directory is a **frameworks** directory. Cloudscape comes with two frameworks in which it can execute: **embedded** and **RmiJdbc**. The **embedded** framework enables Cloudscape to execute as part of a Java application. The **RmiJdbc** framework enables Cloudscape to execute as a stand-alone database server, which is how we use Cloudscape in this book. Each framework directory has a **bin** subdirectory containing batch files (Windows) and shell scripts (Linux/UNIX) to set environment variables and execute Cloudscape. Change directories to the **bin** directory in the **RmiJdbc** framework. Execute the batch file or shell script starting with the name **setServerCloudscapeCP** to set the environment variables required by the server. Then execute the batch file or shell script starting with the name **startCS** to launch the Cloudscape database server. Figure 8.25 shows the command-line output when Cloudscape is executed from a Windows 2000 command window. Note that you can shut down the server by executing the script **stopCS** from another command window.

For each Cloudscape database we discuss in this book, we provide an SQL script that will set up the database and its tables. These scripts can be executed with an interactive command line tool, called **ij**, that is part of Cloudscape. We provide a batch file (**createDatabase.bat**) and a shell script (**createDatabase.ksh**) that you can use to start **ij** and execute the SQL scripts. In the examples directory for this chapter on the CD that accompanies this book, you will find the **createDatabase** scripts and the SQL script **books.sql**. To create database **books**, first ensure that the Cloudscape server is executing. Open a new command prompt, then change to Cloudscape's **frameworks\RmiJdbc\bin** directory. In that directory, execute the batch file or shell script starting with the name **setClientCloudscapeCP**. This sets the environment variables required by our **createDatabase** script. Next, change to the directory where you placed our JDBC examples on your computer and type

```
createDatabase books.sql
```

to execute the SQL script. After completing this task, you are ready to proceed to the first JDBC example. [Note: We wrote this script such that you can execute the script again at any time to restore the database's original contents. When you run this script the first time, it will generate four error messages as it tries to delete the four tables in the books database. This occurs because the database does not exist, so there are no tables to delete. You can simply ignore these messages.]

```
C:\WINNT\system32\cmd.exe - startCS.bat
D:\Cloudscape_3.6\frameworks\RmiJdbc\bin>setServerCloudscapeCP.bat
D:\Cloudscape_3.6\frameworks\RmiJdbc\bin>set CLOUDSCAPE_INSTALL=D:\Cloudscape_3.6
D:\Cloudscape_3.6\frameworks\RmiJdbc\bin>set CLASSPATH=D:\Cloudscape_3.6\lib\cloudscape.jar;D:\Cloudscape_3.6\frameworks\RmiJdbc\classes\RmiJdbc.jar;
D:\Cloudscape_3.6\frameworks\RmiJdbc\bin>startCS.bat
D:\Cloudscape_3.6\frameworks\RmiJdbc\bin>java -ms32M -mx32M RmiJdbc.RJJdbcServer
COM.cloudscape.core.JDBCDriver
Sun Apr 08 20:08:05 EDT 2001: [RmiJdbc] COM.cloudscape.core.JDBCDriver registered in DriverManager
Sun Apr 08 20:08:05 EDT 2001: [RmiJdbc] Binding RmiJdbcServer...
Sun Apr 08 20:08:05 EDT 2001: [RmiJdbc] No installation of RMI Security Manager.
Sun Apr 08 20:08:05 EDT 2001: [RmiJdbc] RmiJdbcServer bound in rmi registry
```

**Fig. 8.25** Executing Cloudscape from a command prompt in Windows 2000.

## 8.6 Manipulating Databases with JDBC

In this section, we present two examples that introduce how to connect to a database, query the database and display the results of the query.

### 8.6.1 Connecting to and Querying a JDBC Data Source

The first example (Fig. 8.26) performs a simple query on the **books** database that retrieves the entire **authors** table and displays the data in a **JTextArea**. The program illustrates connecting to the database, querying the database and processing the results. The following discussion presents the key JDBC aspects of the program. [Note: Section 8.5 demonstrates how to execute the Cloudscape database server and how to create the **books** database. The steps in Section 8.5 must be performed before executing the program of Fig. 8.26.]

```
1 // Fig. 8.26: DisplayAuthors.java
2 // Displaying the contents of table authors in database books.
3 package com.deitel.advjhtp1.jdbc;
4
5 // Java core packages
6 import java.awt.*;
7 import java.sql.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class DisplayAuthors extends JFrame {
14
15     // constructor connects to database, queries database,
16     // processes results and displays results in window
17     public DisplayAuthors()
18     {
19         super( "Authors Table of Books Database" );
20
21     }
```

**Fig. 8.26** Displaying the **authors** table from the **books** database (part 1 of 3).

```
22     // connect to database books and query database
23     try {
24
25         // load database driver class
26         Class.forName( "COM.cloudscape.core.RmiJdbcDriver" );
27
28         // connect to database
29         Connection connection = DriverManager.getConnection(
30             "jdbc:cloudscape:rmi:books" );
31
32         // create Statement to query database
33         Statement statement = connection.createStatement();
34
35         // query database
36         ResultSet resultSet =
37             statement.executeQuery( "SELECT * FROM authors" );
38
39         // process query results
40         StringBuffer results = new StringBuffer();
41         ResultSetMetaData metaData = resultSet.getMetaData();
42         int numberOfColumns = metaData.getColumnCount();
43
44         for ( int i = 1; i <= numberOfColumns; i++ ) {
45             results.append( metaData.getColumnName( i )
46                         + "\t" );
47         }
48
49         results.append( "\n" );
50
51         while ( resultSet.next() ) {
52
53             for ( int i = 1; i <= numberOfColumns; i++ ) {
54                 results.append( resultSet.getObject( i )
55                             + "\t" );
56             }
57
58             results += "\n";
59         }
60
61         // close statement and connection
62         statement.close();
63         connection.close();
64
65         // set up GUI and display window
66         JTextArea textArea = new JTextArea(
67             results.toString() );
68         Container container = getContentPane();
69
70         container.add( new JScrollPane( textArea ) );
71
72         setSize( 300, 100 ); // set window size
73         setVisible( true ); // display window
74     } // end try
```

Fig. 8.26 Displaying the **authors** table from the **books** database (part 2 of 3).

```

75      // detect problems interacting with the database
76      catch ( SQLException sqlException ) {
77          JOptionPane.showMessageDialog( null,
78              sqlException.getMessage(), "Database Error",
79              JOptionPane.ERROR_MESSAGE );
80
81          System.exit( 1 );
82      }
83
84
85      // detect problems loading database driver
86      catch ( ClassNotFoundException classNotFound ) {
87          JOptionPane.showMessageDialog( null,
88              classNotFound.getMessage(), "Driver Not Found",
89              JOptionPane.ERROR_MESSAGE );
90
91          System.exit( 1 );
92      }
93 } // end DisplayAuthors constructor definition
94
95 // launch the application
96 public static void main( String args[] )
97 {
98     DisplayAuthors window = new DisplayAuthors();
99
100    window.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
101 }
102 } // end class DisplayAuthors

```

AUTHORID	FIRSTNAME	LASTNAME
1	Harvey	Deitel
2	Paul	Deitel
3	Tem	Nieta
4	Sean	Santry

Fig. 8.26 Displaying the **authors** table from the **books** database (part 3 of 3).

Line 7 imports package **java.sql**, which contains classes and interfaces for the JDBC API. The **DisplayAuthors** constructor (lines 17–93) connects to the books database, queries the database, displays the results of the query and closes the database connection.

The program must load the database driver class before the program can connect to the database. Line 26 loads the class definition for the database driver. This line throws a checked exception of type **java.lang.ClassNotFoundException** if the class loader cannot locate the driver class. Notice that the statement specifies the complete package name and class name for the Cloudscape driver—**COM.cloudscape.core.RmiJdbcDriver**.

JDBC supports four categories of drivers: *JDBC-to-ODBC bridge driver* (Type 1), *Native-API partly Java driver* (Type 2); *JDBC-Net pure Java driver* (Type 3) and *Native-Protocol pure Java driver* (Type 4). A description of each driver type is shown in Fig. 8.27.

Type	Description
1	The <i>JDBC-to-ODBC bridge driver</i> connects Java to a Microsoft ODBC (Open Database Connectivity) data source. The Java 2 Software Development Kit from Sun Microsystems, Inc. includes the JDBC-to-ODBC bridge driver ( <b><code>sun.jdbc.odbc.JdbcOdbcDriver</code></b> ). This driver typically requires the ODBC driver to be installed on the client computer and normally requires configuration of the ODBC data source. The bridge driver was introduced primarily to allow Java programmers to build data-driven Java applications before the database vendors had Type 3 and Type 4 drivers.
2	<i>Native-API, partly Java drivers</i> enable JDBC programs to use database-specific APIs (normally written in C or C++) that allow client programs to access databases via the Java Native Interface. This driver type translates JDBC into database-specific code. Type 2 drivers were introduced for reasons similar to the Type 1 ODBC bridge driver.
3	<i>JDBC-Net pure Java drivers</i> take JDBC requests and translate them into a network protocol that is not database specific. These requests are sent to a server, which translates the database requests into a database-specific protocol.
4	<i>Native-protocol pure Java drivers</i> convert JDBC requests to database-specific network protocols, so that Java programs can connect directly to a database.

**Fig. 8.27** JDBC driver types.

Type 3 and 4 drivers are preferred, because they are pure Java solutions. As mentioned in Fig. 8.27, Type 1 and Type 2 drivers were provided primarily to allow Java programmers to create data-driven solutions before the database vendors created pure Java drivers. The Cloudscape driver **`COM.cloudscape.core.RmiJdbcDriver`** is a Type 4 driver.



#### Software Engineering Observation 8.4

*Most major database vendors provide their own JDBC database drivers, and many third-party vendors provide JDBC drivers as well. For more information on JDBC drivers, visit the Sun Microsystems JDBC Web site, [java.sun.com/products/jdbc](http://java.sun.com/products/jdbc).*



#### Software Engineering Observation 8.5

*On the Microsoft Windows platform, most databases support access via Open Database Connectivity (ODBC). ODBC is a technology developed by Microsoft to allow generic access to disparate database systems on the Windows platform (and some UNIX platforms). The Java 2 Software Development Kit (J2SDK) comes with the JDBC-to-ODBC-bridge database driver to allow any Java program to access any ODBC data source. The driver is defined by class **`JdbcOdbcDriver`** in package **`sun.jdbc.odbc`**.*

Lines 29–30 of Fig. 8.26 declare and initialize a **`Connection`** reference (package **`java.sql`**) called **`connection`**. An object that implements interface **`Connection`** manages the connection between the Java program and the database. **`Connection`** objects enable programs to create SQL statements that manipulate databases and to perform *transaction processing* (discussed later in this chapter). The program initializes **`connection`** with the result of a call to **`static`** method **`getConnection`** of class **`DriverManager`** (package **`java.sql`**), which attempts to connect to the database specified by its URL argument. The URL helps the program locate the database (possibly on a network or in the local file system of the computer). The URL **`jdbc:cloudscape:rmi:books`**

specifies the *protocol* for communication (**jdbc**), the *subprotocol* for communication (**cloudscape:rmi**) and the name of the database (**books**). The subprotocol **cloudscape:rmi** indicates that the program uses **jdbc** to connect to a Cloudscape database via *remote method invocation (RMI)*. [Note: Knowledge of the RMI networking technology is not required for this chapter. We discuss RMI in Chapter 13.] If the **DriverManager** cannot connect to the database, method **getConnection** throws an **SQLException** (package **java.sql**).



### Software Engineering Observation 8.6

Most database management systems require the user to log in before accessing the database contents. **DriverManager** method **getConnection** is overloaded with versions that enable the program to supply the user name and password to gain access.

Line 33 invokes **Connection** method **createStatement** to obtain an object that implements interface **Statement** (package **java.sql**). The program uses the **Statement** object to submit SQL statements to the database.

Lines 36–37 use the **Statement** object's **executeQuery** method to execute a query that selects all the author information from table **authors**. This method returns an object that implements interface **ResultSet** and contains the results of the query. The **ResultSet** methods enable the program to manipulate the query results.

Lines 30–59 process the **ResultSet**. Line 41 obtains the *metadata* for the **ResultSet** and assigns it to a **ResultSetMetaData** (package **java.sql**) reference. The metadata describes the **ResultSet**'s contents. Programs can use metadata programmatically to obtain information about the **ResultSet**'s column names and types. Line 42 uses **ResultSetMetaData** method **getColumnCount** to retrieve the number of columns in the **ResultSet**. Lines 44–47 append the column names to the **StringBuffer** **results**.



### Software Engineering Observation 8.7

Metadata enables programs to process **ResultSet** contents dynamically when detailed information about the **ResultSet** is not known in advance of a query.

Lines 51–59 appends the data in each **ResultSet** row to the **StringBuffer** **results**. Before processing the **ResultSet**, the program positions the **ResultSet cursor** to the first record in the **ResultSet** with method **next** (line 51). The cursor keeps track of the current record (or row). Method **next** returns **boolean** value **true** if it is able to position to the next record; otherwise the method returns **false**.



### Common Programming Error 8.8

Initially, a **ResultSet** cursor is positioned before the first record. Attempting to access a **ResultSet**'s contents before positioning the **ResultSet** cursor to the first record with method **next** causes an **SQLException**.

If there are records in the **ResultSet**, lines 53–56 extract the contents of the current row. When processing a **ResultSet**, it is possible to extract each column of the **ResultSet** as a specific Java data type. In fact, **ResultSetMetaData** method **getColumnType** returns a constant integer from class **Types** (package **java.sql**) that indicates the type of the data for a specific column. Programs can use such information in a **switch** structure to invoke a **ResultSet** method that returns the column value as the appropriate Java data type. For example, if the type of a column is **Types.INT**,

**ResultSet** method **getInt** returns the column value as an **int**. **ResultSet** **get** methods typically receive as an argument either a *column number* (as an **int**) or a *column name* (as a **String**) indicating which column's value to obtain. Visit

[java.sun.com/j2se/1.3/docs/guide/jdbc/getstart/  
GettingStartedTOC.fm.html](http://java.sun.com/j2se/1.3/docs/guide/jdbc/getstart/GettingStartedTOC.fm.html)

for detailed mappings of SQL types to Java types and to determine the appropriate **ResultSet** method to call for each SQL type.



### Performance Tip 8.3

If a query specifies the exact fields to select from the database, the **ResultSet** contains the fields in the specified order. In this case, using the column number to obtain the column's value is more efficient than using the column's name. The column number is similar to an array subscript in that the column number provides direct access to the specified column. Using the column's name requires a linear search of the column names to locate the appropriate column.

For simplicity, this example treats each column's value as an **Object**. The program retrieves each column value with **ResultSet** method **getObject** (line 54) and appends the **String** representation of the **Object** to **results**. When **ResultSet** processing completes, the program closes the **Statement** (line 63) and the database **Connection** (line 64). Notice that, unlike array subscripts, which start at 0, **ResultSet** column numbers start at 1.



### Common Programming Error 8.9

Specifying column number 0 when obtaining values from a **ResultSet** causes an **SQLException**.



### Common Programming Error 8.10

Attempting to manipulate a **ResultSet** after closing the **Statement** that created the **ResultSet** causes an **SQLException**. The program discards the **ResultSet** when the corresponding **Statement** is closed.



### Software Engineering Observation 8.8

Each **Statement** object can open only one **ResultSet** object at a time. When a **Statement** returns a new **ResultSet**, the **Statement** closes the prior **ResultSet**. To use multiple **ResultSets** in parallel, separate **Statement** objects must return the **ResultSets**.

Lines 66–73 create the GUI that displays the **StringBuffer results**, set the size of the application window and show the application window.

To run this example as well as the others in the Chapter, the **classpath** in the following command line must be used<sup>1</sup>

```
java -classpath f:\Cloudscape_3.6\lib\cloudscape.jar;  
f:\Cloudscape_3.6\frameworks\RmiJdbc\classes\RmiJdbc.jar;.com.deitel.advjhttp1.jdbc.DisplayAuthors
```

1. You will need to modify this command line to indicate the proper location of your Cloudscape installation and to use directory separators that are appropriate to your operating system (e.g., colons on UNIX/Linux).

These JARs (**cloudscape.jar** and **RmiJdbc.jar**) must be present in the **classpath** or none of the examples in this Chapter will execute. Note that the **classpath** includes **.** for the current directory. When setting the **classpath** at the command line, this ensures that the interpreter can locate classes in the current directory. You can also set the **classpath** using Cloudscape's **setServerCloudscapeCP** batch file or shell script discussed earlier in this section.

### 8.6.2 Querying the books Database

The next example (Fig. 8.28 and Fig. 8.31) enhances the example of Fig. 8.26 by allowing the user to enter any query into the program. The example displays the results of a query in a **JTable**, using a **TableModel** object to provide the **ResultSet** data to the **JTable**. Class **ResultSetTableModel** (Fig. 8.28) performs the connection to the database and maintains the model. Class **DisplayQueryResults** (Fig. 8.31) creates the GUI and specifies an instance of class **ResultSetTableModel** as the model for the **JTable**.

Class **ResultSetTableModel** (Fig. 8.28) extends class **AbstractTableModel** (package **javax.swing.table**), which implements interface **TableModel**. Class **ResultSetTableModel** overrides **TableModel** methods **getColumnClass**, **getColumnCount**, **getColumnName**, **getRowCount** and **getValueAt**. The default implementations of **TableModel** methods **isCellEditable** and **setValueAt** (provided by **AbstractTableModel**) are not overridden, because this example does not support editing the **JTable** cells. Also, the default implementations of **TableModel** methods **addTableModelListener** and **removeTableModelListener** (provided by **AbstractTableModel**) are not overridden, because the implementations of these methods from **AbstractTableModel** properly add and remove event listeners.

```
1 // Fig. 8.28: ResultSetTableModel.java
2 // A TableModel that supplies ResultSet data to a JTable.
3 package com.deitel.advjhtp1.jdbc;
4
5 // Java core packages
6 import java.sql.*;
7 import java.util.*;
8
9 // Java extension packages
10 import javax.swing.table.*;
11
12 // ResultSet rows and columns are counted from 1 and JTable
13 // rows and columns are counted from 0. When processing
14 // ResultSet rows or columns for use in a JTable, it is
15 // necessary to add 1 to the row or column number to manipulate
16 // the appropriate ResultSet column (i.e., JTable column 0 is
17 // ResultSet column 1 and JTable row 0 is ResultSet row 1).
18 public class ResultSetTableModel extends AbstractTableModel {
19     private Connection connection;
20     private Statement statement;
```

Fig. 8.28 **ResultSetTableModel** enables a **JTable** to display the contents of a **ResultSet** (part 1 of 4).

```
21  private ResultSet resultSet;
22  private ResultSetMetaData metaData;
23  private int numberOfRows;
24
25  // initialize resultSet and obtain its meta data object;
26  // determine number of rows
27  public ResultSetTableModel( String driver, String url,
28      String query ) throws SQLException, ClassNotFoundException
29  {
30      // load database driver class
31      Class.forName( driver );
32
33      // connect to database
34      connection = DriverManager.getConnection( url );
35
36      // create Statement to query database
37      statement = connection.createStatement(
38          ResultSet.TYPE_SCROLL_INSENSITIVE,
39          ResultSet.CONCUR_READ_ONLY );
40
41      // set query and execute it
42      setQuery( query );
43  }
44
45  // get class that represents column type
46  public Class getColumnClass( int column )
47  {
48      // determine Java class of column
49      try {
50          String className =
51              metaData.getColumnClassName( column + 1 );
52
53          // return Class object that represents className
54          return Class.forName( className );
55      }
56
57      // catch SQLExceptions and ClassNotFoundExceptions
58      catch ( Exception exception ) {
59          exception.printStackTrace();
60      }
61
62      // if problems occur above, assume type Object
63      return Object.class;
64  }
65
66  // get number of columns in ResultSet
67  public int getColumnCount()
68  {
69      // determine number of columns
70      try {
71          return metaData.getColumnCount();
72      }
```

Fig. 8.28 **ResultSetTableModel** enables a **JTable** to display the contents of a **ResultSet** (part 2 of 4).

```
73      // catch SQLExceptions and print error message
74      catch ( SQLException sqlException ) {
75          sqlException.printStackTrace();
76      }
77  }
78
79      // if problems occur above, return 0 for number of columns
80  return 0;
81 }
82
83     // get name of a particular column in ResultSet
84  public String getColumn Name( int column )
85  {
86      // determine column name
87      try {
88          return metaData.getColumnName( column + 1 );
89      }
90
91      // catch SQLExceptions and print error message
92      catch ( SQLException sqlException ) {
93          sqlException.printStackTrace();
94      }
95
96      // if problems, return empty string for column name
97  return "";
98 }
99
100    // return number of rows in ResultSet
101  public int getRowCount()
102  {
103      return numberOfRows;
104  }
105
106    // obtain value in particular row and column
107  public Object getValueAt( int row, int column )
108  {
109      // obtain a value at specified ResultSet row and column
110      try {
111          resultSet.absolute( row + 1 );
112
113          return resultSet.getObject( column + 1 );
114      }
115
116      // catch SQLExceptions and print error message
117      catch ( SQLException sqlException ) {
118          sqlException.printStackTrace();
119      }
120
121      // if problems, return empty string object
122  return "";
123 }
124 }
```

Fig. 8.28 **ResultSetTableModel** enables a **JTable** to display the contents of a **ResultSet** (part 3 of 4).

```
125 // close Statement and Connection
126 protected void finalize()
127 {
128     // close Statement and Connection
129     try {
130         statement.close();
131         connection.close();
132     }
133
134     // catch SQLExceptions and print error message
135     catch ( SQLException sqlException ) {
136         sqlException.printStackTrace();
137     }
138 }
139
140 // set new database query string
141 public void setQuery( String query ) throws SQLException
142 {
143     // specify query and execute it
144     resultSet = statement.executeQuery( query );
145
146     // obtain meta data for ResultSet
147     metaData = resultSet.getMetaData();
148
149     // determine number of rows in ResultSet
150     resultSet.last();                                // move to last row
151     numberOfRows = resultSet.getRow();   // get row number
152
153     // notify JTable that model has changed
154     fireTableStructureChanged();
155 }
156 } // end class ResultSetTableModel
```

Fig. 8.28 **ResultSetTableModel** enables a **JTable** to display the contents of a **ResultSet** (part 4 of 4).

The **ResultSetTableModel** constructor (lines 27–43) receives three **String** arguments—the driver class name, the URL of the database and the default query to perform. The constructor throws any exceptions that occur in its body back to the application that created the **ResultSetTableModel** object, so that the application can determine how to handle the exception (e.g., report an error and terminate the application). Line 31 loads the database driver. Line 34 establishes a connection to the database. Line 37 invokes **Connection** method **createStatement** to create a **Statement** object. This example uses a version of method **createStatement** that takes two arguments—the *result-set type* and the *result-set concurrency*. The result-set type (Fig. 8.29) specifies whether the **ResultSet**'s cursor is able to scroll in both directions or forward only and whether the **ResultSet** is sensitive to changes. **ResultSets** that are sensitive to changes reflect those changes immediately after they are made with methods of interface **ResultSet**. If a **ResultSet** is insensitive to changes, the query that produced the **ResultSet** must be executed again to reflect any changes made. The result-set concurrency (Fig. 8.30) specifies whether the **ResultSet** can be updated with **ResultSet**'s update methods. This example uses a **ResultSet** that is scrollable, insensitive to changes

and read only. Line 42 invokes **ResultSetTableModel** method **setQuery** (lines 141–155) to perform the default query.



### Portability Tip 8.6

Some **ResultSet** implementations do not support scrollable **ResultSets**. In such cases, typically the driver returns a **ResultSet** in which the cursor can move only forward. For more information, see your database-driver documentation.



### Portability Tip 8.7

Some **ResultSet** implementations do not support updatable **ResultSets**. In such cases, typically the driver returns a read-only **ResultSet**. For more information, see your database-driver documentation.



### Common Programming Error 8.11

Attempting to update a **ResultSet** when the database driver does not support updatable **ResultSets** causes **SQLExceptions**.



### Common Programming Error 8.12

Attempting to move the cursor backwards through a **ResultSet** when the database driver does not support backwards scrolling causes an **SQLException**.

Method **getColumnClass** (lines 46–64) returns a **Class** object that represents the superclass of all objects in a particular column. The **JTable** uses this information to configure the default cell renderer and cell editor for that column in the **JTable**. Lines 50–51 use **ResultSetMetaData** method **getColumnName** to obtain the fully qualified class name for the specified column. Line 54 loads the class definition for that class and returns the corresponding **Class** object. If an exception occurs, the **catch** at lines 58–60 prints a stack trace and line 63 returns **Object.class**—the **Class** instance that represents class **Object**—as the default type. [Note: Line 51 uses the argument **column + 1**. Like arrays, **JTable** row and column numbers are counted from 0. However, **ResultSet** row and column numbers are counted from 1. Thus, when processing **ResultSet** rows or columns for use in a **JTable**, it is necessary to add 1 to the row or column number to manipulate the appropriate **ResultSet** row or column.]

<b>ResultSet static type constant</b>	<b>Description</b>
---------------------------------------	--------------------

#### **TYPE\_FORWARD\_ONLY**

Specifies that a **ResultSet**'s cursor can move only in the forward direction (i.e., from the first record to the last record in the **ResultSet**).

#### **TYPE\_SCROLL\_INSENSITIVE**

Specifies that a **ResultSet**'s cursor can scroll in either direction and that the changes made to the **ResultSet** during **ResultSet** processing are not reflected in the **ResultSet** unless the program queries the database again.

Fig. 8.29 **ResultSet** constants for specifying **ResultSet** type (part 1 of 2).

<b>ResultSet static type constant</b>	<b>Description</b>
<b>TYPE_SCROLL_SENSITIVE</b>	Specifies that a <b>ResultSet</b> 's cursor can scroll in either direction and that the changes made to the <b>ResultSet</b> during <b>ResultSet</b> processing are reflected immediately in the <b>ResultSet</b> .

Fig. 8.29 **ResultSet** constants for specifying **ResultSet** type (part 2 of 2).

<b>ResultSet static concurrency constant</b>	<b>Description</b>
<b>CONCUR_READ_ONLY</b>	Specifies that a <b>ResultSet</b> cannot be updated (i.e., changes to the <b>ResultSet</b> contents cannot be reflected in the database with <b>ResultSet</b> 's <i>update</i> methods).
<b>CONCUR_UPDATABLE</b>	Specifies that a <b>ResultSet</b> can be updated (i.e., changes to the <b>ResultSet</b> contents can be reflected in the database with <b>ResultSet</b> 's <i>update</i> methods).

Fig. 8.30 **ResultSet** constants for specifying result set properties.

Method **getColumnNameCount** (lines 67–81) returns the number of columns in the model's underlying **ResultSet**. Line 71 uses **ResultSetMetaData** method **getColumnCount** to obtain the number of columns in the **ResultSet**. If an exception occurs, the **catch** at lines 75–77 prints a stack trace and line 80 returns 0 as the default number of columns.

Method **getColumnName** (lines 84–98) returns the name of the column in the model's underlying **ResultSet**. Line 88 uses **ResultSetMetaData** method **getColumnName** to obtain the column name from the **ResultSet**. If an exception occurs, the **catch** at lines 92–94 prints a stack trace and line 97 returns the empty string as the default column name.

Method **getRowCount** (lines 101–104) returns the number of rows in the model's underlying **ResultSet**. When method **setQuery** (lines 141–155) performs a query, it stores the number of rows in variable **numberOfRows**.

Method **getValueAt** (lines 107–123) returns the **Object** in a particular row and column of the model's underlying **ResultSet**. Line 111 uses **ResultSet** method **absolute** to position the **ResultSet** cursor at a specific row. Line 113 uses **ResultSet** method **getObject** to obtain the **Object** in a specific column of the current row. If an exception occurs, the **catch** at lines 117–119 prints a stack trace and line 122 returns the empty string object as the default value.

Method **finalize** (lines 126–138) closes the **Statement** and **Connection** objects if a **ResultSetTableModel** object is garbage collected.

Method **setQuery** (lines 141–155) executes the query it receives as an argument to obtain a new **ResultSet** (line 144). Line 147 gets the **ResultSetMetaData** for the new **ResultSet**. Line 150 uses **ResultSet** method **last** to position the **ResultSet** cursor at the last row in the **ResultSet**. Line 151 uses **ResultSet** method **getRow** to obtain the row number for the current row in the **ResultSet**. Line 154 invokes method **fireTableStructureChanged** (inherited from class **AbstractTableModel**) to notify any **JTable** using this **ResultSetTableModel** object as its model that the structure of the model has changed (i.e., the underlying **ResultSet** contains new data or new columns). This causes the **JTable** to repopulate its rows and columns with the new **ResultSet** data. Method **setQuery** throws any exceptions that occur in its body back to the application that invoked **setQuery**.

The **DisplayQueryResults** (Fig. 8.31) constructor (lines 21–121) creates a **ResultSetTableModel** object and defines the GUI for the application. Lines 26, 29 and 32 define the database driver class name, database URL and default query that are passed to the **ResultSetTableModel** constructor to make the initial connection to the database and perform the default query. Line 61 creates the **JTable** object and passes a **ResultSetTableModel** object to the **JTable** constructor, which then registers the **JTable** as a listener for **TableModelEvents** generated by the **ResultSetTableModel**. Lines 70–94 register an event handler for the **submitButton** that the user clicks to submit a query to the database. When the user clicks the button, method **actionPerformed** (lines 75–90) invokes **ResultSetTableModel** method **setQuery** to execute the new query. The screen captures in Fig. 8.31 show the results of two queries. The first screen capture shows the default query that selects all the authors from table **authors** of database **books**. The second screen capture shows a query that selects each author's first name and last name from the **authors** table and combines that information with the title and edition number from the **titles** table. Try entering your own queries in the text area and clicking the **Submit Query** button to execute the query.

```
1 // Fig. 8.31: DisplayQueryResults.java
2 // Display the contents of the Authors table in the
3 // Books database.
4 package com.deitel.advjhtp1.jdbc;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.sql.*;
10 import java.util.*;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.swing.table.*;
15
16 public class DisplayQueryResults extends JFrame {
17     private ResultSetTableModel tableModel;
18     private JTextArea queryArea;
19 }
```

Fig. 8.31 **DisplayQueryResults** enables a user to query database **books**.

```
20 // create ResultSetTableModel and GUI
21 public DisplayQueryResults()
22 {
23     super( "Displaying Query Results" );
24
25     // Cloudscape database driver class name
26     String driver = "COM.cloudscape.core.RmiJdbcDriver";
27
28     // URL to connect to books database
29     String url = "jdbc:cloudscape:rmi:books";
30
31     // query to select entire authors table
32     String query = "SELECT * FROM authors";
33
34     // create ResultSetTableModel and display database table
35     try {
36
37         // create TableModel for results of query
38         // SELECT * FROM authors
39         tableModel =
40             new ResultSetTableModel( driver, url, query );
41
42         // set up JTextArea in which user types queries
43         queryArea = new JTextArea( query, 3, 100 );
44         queryArea.setWrapStyleWord( true );
45         queryArea.setLineWrap( true );
46
47         JScrollPane scrollPane = new JScrollPane( queryArea,
48             ScrollPaneConstants.VERTICAL_SCROLLBAR_AS_NEEDED,
49             ScrollPaneConstants.HORIZONTAL_SCROLLBAR_NEVER );
50
51         // set up JButton for submitting queries
52         JButton submitButton = new JButton( "Submit Query" );
53
54         // create Box to manage placement of queryArea and
55         // submitButton in GUI
56         Box box = Box.createHorizontalBox();
57         box.add( scrollPane );
58         box.add( submitButton );
59
60         // create JTable delegate for tableModel
61         JTable resultTable = new JTable( tableModel );
62
63         // place GUI components on content pane
64         Container c = getContentPane();
65         c.add( box, BorderLayout.NORTH );
66         c.add( new JScrollPane( resultTable ),
67             BorderLayout.CENTER );
68
69         // create event listener for submitButton
70         submitButton.addActionListener(
71
72             new ActionListener() {
```

Fig. 8.31 `DisplayQueryResults` enables a user to query database `books`.

```
73          // pass query to table model
74      public void actionPerformed( ActionEvent e ) {
75          {
76              // perform a new query
77              try {
78                  tableModel.setQuery( queryArea.getText() );
79              }
80
81              // catch SQLExceptions that occur when
82              // performing a new query
83              catch ( SQLException sqlException ) {
84                  JOptionPane.showMessageDialog( null,
85                      sqlException.toString(),
86                      "Database error",
87                      JOptionPane.ERROR_MESSAGE );
88              }
89          } // end actionPerformed
90      } // end ActionListener inner class
91
92  } // end call to addActionListener
93
94 } // end window size and display window
95
96 setSize( 500, 250 );
97 setVisible( true );
98 } // end try
99
100 // catch ClassNotFoundException thrown by
101 // ResultSetTableModel if database driver not found
102 catch ( ClassNotFoundException classNotFound ) {
103     JOptionPane.showMessageDialog( null,
104         "Cloudscape driver not found", "Driver not found",
105         JOptionPane.ERROR_MESSAGE );
106
107     System.exit( 1 ); // terminate application
108 }
109
110 // catch SQLException thrown by ResultSetTableModel
111 // if problems occur while setting up database
112 // connection and querying database
113 catch ( SQLException sqlException ) {
114     JOptionPane.showMessageDialog( null,
115         sqlException.toString(),
116         "Database error", JOptionPane.ERROR_MESSAGE );
117
118     System.exit( 1 ); // terminate application
119 }
120
121 } // end DisplayQueryResults constructor
122
123 // execute application
124 public static void main( String args[] )
125 {
```

Fig. 8.31 **DisplayQueryResults** enables a user to query database **books**.

```

126     DisplayQueryResults app = new DisplayQueryResults();
127
128     app.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
129 }
130 } // end class DisplayQueryResults

```

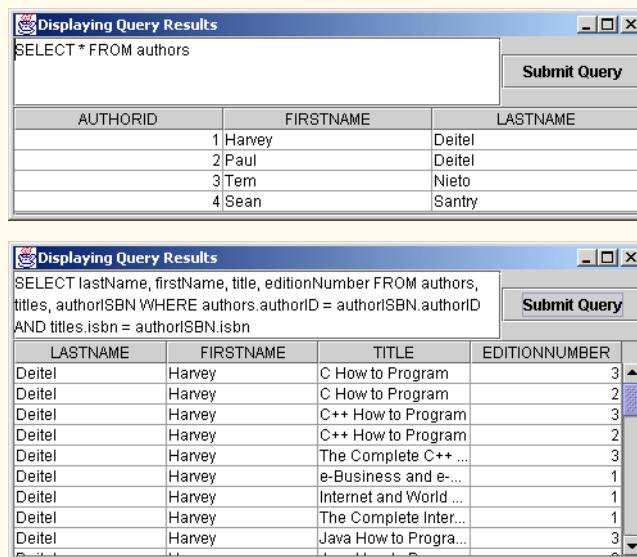


Fig. 8.31 `DisplayQueryResults` enables a user to query database `books`.

## 8.7 Case Study: Address-Book Application

Our next example uses the SQL and JDBC concepts presented so far to implement a substantial address-book application that enables the user to insert, locate, update and delete address-book entries in the Cloudscape database `addressbook`. [Note: An SQL script to create this database is provided with the example code for this chapter. Section 8.5 demonstrates executing an SQL script with Cloudscape.]

Database `addressbook` contains four tables: `names`, `addresses`, `phoneNumbers` and `emailAddresses`. Figure 8.32 shows the relationships between the tables. The first line in each table is the table's name. Each table's primary-key field is highlighted in green. Tables `addresses`, `phoneNumbers` and `emailAddresses` each have `personID` as a foreign key. Thus, a program cannot place records in those tables unless the `personID` is a valid value in table `names`. Although the address-book application currently allows only one address, one phone number and one e-mail address per person, the database was designed to support multiple addresses, phone numbers and e-mail addresses for each person. So there is a one-to-many relationship between a record in the `names` table and records in the other tables. Note that the relationship lines between the tables link the foreign key (`personID`) of tables `phoneNumbers`, `emailAddresses` and `addresses` to the primary key of table `names`. In each of the tables, fields `personID`, `addressID`, `emailID` and `phoneID` are integers. All other fields are strings.

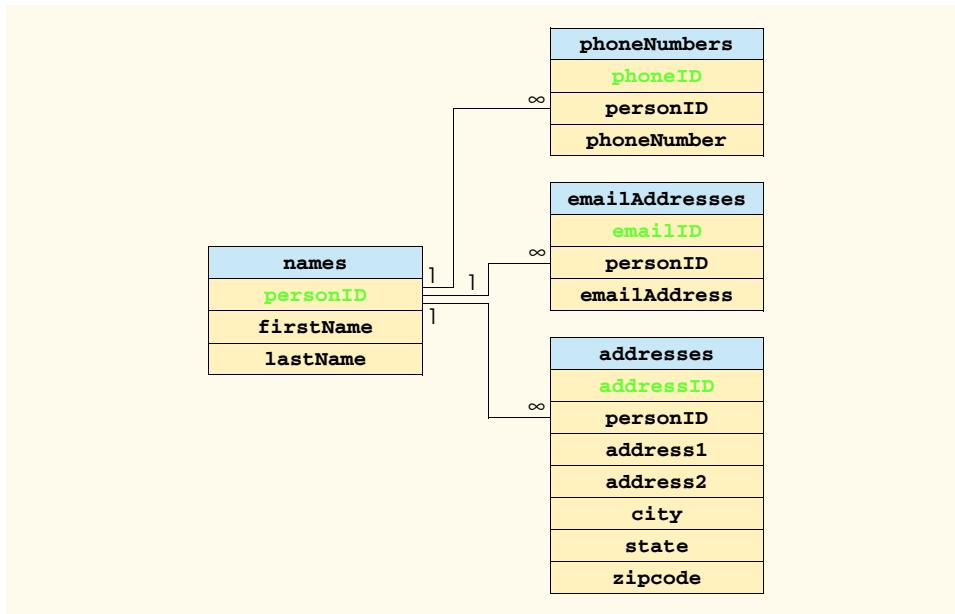


Fig. 8.32 Table relationships in database **addressbook**.

This example introduces two new concepts: **PreparedStatement** and *transaction processing*. Section 8.7.1 and Section 8.7.2 discuss these new concepts. Then, Section 8.7.3 presents the **AddressBook** application and its supporting classes.

## 8.7.1 PreparedStatements

Interface **PreparedStatement** enables an application programmer to create SQL statements that are maintained in a compiled form that enables the statements to execute more efficiently than **Statement** objects. **PreparedStatement** objects also are more flexible than **Statement** objects, because they can specify parameters. This allows programs to execute the same query repeatedly with different parameter values. For example, in the **books** database, you might want to locate all book titles for an author with a specific last name and first name, and you might want to execute that query for several authors. With a **PreparedStatement**, that query is defined as follows:

```

PreparedStatement authorBooks = connection.prepareStatement(
    "SELECT lastName, firstName, title " +
    "FROM authors, titles, authorISBN " +
    "WHERE authors.authorID = authorISBN.authorID AND " +
    "titles.ISBN = authorISBN.isbn AND " +
    "lastName = ? AND firstName = ?");
  
```

Note the two *question marks* (?) in the last line of the preceding statement. These characters represent placeholders for values that will be passed as part of the query to the database. Before the program executes a **PreparedStatement**, the program must specify the values of those parameters by using the *set* methods of interface **PreparedStatement**.

For the preceding query, both parameters are strings that can be set with **PreparedStatement** method **setString** as follows:

```
authorBooks.setString( 1, "Deitel" );
authorBooks.setString( 2, "Paul" );
```

Method **setString**'s first argument represents the number of the parameter being set and the second argument is the value to set for that parameter. Parameter numbers are counted from 1, starting with the first question mark (?) in the SQL statement. When the program executes the preceding **PreparedStatement** with the parameter values shown here, the SQL statement passed to the database is

```
SELECT lastName, firstName, title
FROM authors, titles, authorISBN
WHERE authors.authorID = authorISBN.authorID AND
titles.ISBN = authorISBN.isbn AND
lastName = 'Deitel' AND firstName = 'Paul'
```

It is important to note that method **setString** escapes **String** parameter values properly. For example, if the last name is O'Brien, the statement

```
authorBooks.setString( 1, "O'Brien" );
```

escapes the ' character in O'Brien by replacing it with two single-quote characters.



#### Performance Tip 8.4

In programs that execute SQL statements multiple times with different parameter values, **PreparedStatement**s are more efficient than **Statements**, because **PreparedStatement**s maintain the SQL statement in a compiled format. This is a very important performance enhancement.



#### Software Engineering Observation 8.9

**PreparedStatement**s are more flexible than **Statements**, because **PreparedStatement**s support customization of a query with parameter values. With a **Statement**, the program must create a new **String** containing an SQL statement for each new query.



#### Good Programming Practice 8.2

Use **PreparedStatement**s with parameters for queries that receive **String** values as arguments to ensure that the **Strings** are quoted properly in the SQL statement.

Interface **PreparedStatement** provides *set* methods for each SQL type supported. It is important to use the *set* method that is appropriate for the SQL type of the parameter in the database; otherwise, **SQLExceptions** can occur when the program attempts to convert the parameter value to an incorrect type. For a complete list of these *set* methods, see the Java API documentation for interface **PreparedStatement**.



#### Common Programming Error 8.13

Using the incorrect **PreparedStatement** set method can cause **SQLExceptions** if an attempt is made to convert a parameter value to an incorrect data type.

## 8.7.2 Transaction Processing

Many database applications require guarantees that a series of database insertions, updates and deletions executes properly before the applications continue processing the next database operation. For example, when you transfer money electronically between bank accounts, several factors determine if the transaction is successful. You begin by specifying the source account and the amount you wish to transfer from that account to a destination account. Next, you specify the destination account. The bank checks the source account to determine if there are sufficient funds in the account to complete the transfer. If so, the bank withdraws the specified amount from the source account and, if all goes well, deposits the money into the destination account to complete the transfer. What happens if the transfer fails after the bank withdraws the money from the source account? In a proper banking system, the bank redeposits the money in the source account. How would you feel if the money was subtracted from your source account and the bank *did not* deposit the money in the destination account?

*Transaction processing* enables a program that interacts with a database to treat a database operation (or set of operations) as a single operation. Such an operation also is known as an *atomic operation* or a *transaction*. At the end of a transaction, a decision can be made either to *commit the transaction* or *back the transaction*. Committing the transaction finalizes the database operation(s); all insertions, updates and deletions performed as part of the transaction cannot be reversed without performing a new database operation. Rolling back the transaction leaves the database in its state prior to the database operation. This is useful when a portion of a transaction fails to complete properly. In our bank-account-transfer discussion, the transaction would be rolled back if the deposit could not be made into the destination account.

Java provides transaction processing via methods of interface **Connection**. Method **setAutoCommit** specifies whether each SQL statement commits after it completes (a **true** argument) or if several SQL statements should be grouped as a transaction (a **false** argument). If the argument to **setAutoCommit** is **false**, the program must follow the last SQL statement in the transaction with a call to **Connection** method **commit** (to commit the changes to the database) or **Connection** method **rollback** (to return the database to its state prior to the transaction). Interface **Connection** also provides method **getAutoCommit** to determine the autocommit state for the **Connection**.

### Software Engineering Observation 8.10



By default, a **Connection** is in autocommit mode.

### Software Engineering Observation 8.11



Most JDBC drivers support transaction processing. Those that do not are not JDBC compliant drivers.

## 8.7.3 Address-Book Application

The address-book application consists of five classes and interfaces: class **AddressBookEntry** (Fig. 8.33), interface **AddressBookDataAccess** (Fig. 8.34), class **DataAccessException** (Fig. 8.35), class **CloudscapeDataAccess** (Fig. 8.36), class **AddressBookEntryFrame** (Fig. 8.37) and class **AddressBook** (Fig. 8.38).

Class **AddressBookEntry** (Fig. 8.33) represents the data for an entry in the address book. The class contains properties for all the fields in the four tables of database **addressbook**.

```
1 // Fig. 8.33: AddressBookEntry.java
2 // JavaBean to represent one address book entry.
3 package com.deitel.advjhtp1.jdbc.addressbook;
4
5 public class AddressBookEntry {
6     private String firstName = "";
7     private String lastName = "";
8     private String address1 = "";
9     private String address2 = "";
10    private String city = "";
11    private String state = "";
12    private String zipcode = "";
13    private String phoneNumber = "";
14    private String emailAddress = "";
15    private int personID;
16    private int addressID;
17    private int phoneID;
18    private int emailID;
19
20    // empty constructor
21    public AddressBookEntry()
22    {
23    }
24
25    // set person's id
26    public AddressBookEntry( int id )
27    {
28        personID = id;
29    }
30
31    // set person's first name
32    public void setFirstName( String first )
33    {
34        firstName = first;
35    }
36
37    // get person's first name
38    public String getFirstName()
39    {
40        return firstName;
41    }
42
43    // set person's last name
44    public void setLastName( String last )
45    {
46        lastName = last;
47    }
48
```

Fig. 8.33 **AddressBookEntry** bean represents an address book entry (part 1 of 4).

```
49 // get person's last name
50 public String getLastname()
51 {
52     return lastName;
53 }
54
55 // set first line of person's address
56 public void setAddress1( String firstLine )
57 {
58     address1 = firstLine;
59 }
60
61 // get first line of person's address
62 public String getAddress1()
63 {
64     return address1;
65 }
66
67 // set second line of person's address
68 public void setAddress2( String secondLine )
69 {
70     address2 = secondLine;
71 }
72
73 // get second line of person's address
74 public String getAddress2()
75 {
76     return address2;
77 }
78
79 // set city in which person lives
80 public void setCity( String personCity )
81 {
82     city = personCity;
83 }
84
85 // get city in which person lives
86 public String getCity()
87 {
88     return city;
89 }
90
91 // set state in which person lives
92 public void setState( String personState )
93 {
94     state = personState;
95 }
96
97 // get state in which person lives
98 public String getState()
99 {
100    return state;
101 }
```

Fig. 8.33 AddressBookEntry bean represents an address book entry (part 2 of 4).

```
102      // set person's zip code
103    public void setZipcode( String zip )
104    {
105        zipcode = zip;
106    }
107
108
109    // get person's zip code
110    public String getZipcode()
111    {
112        return zipcode;
113    }
114
115    // set person's phone number
116    public void setPhoneNumber( String number )
117    {
118        phoneNumber = number;
119    }
120
121    // get person's phone number
122    public String getPhoneNumber()
123    {
124        return phoneNumber;
125    }
126
127    // set person's email address
128    public void setEmailAddress( String email )
129    {
130        emailAddress = email;
131    }
132
133    // get person's email address
134    public String getEmailAddress()
135    {
136        return emailAddress;
137    }
138
139    // get person's ID
140    public int getPersonID()
141    {
142        return personID;
143    }
144
145    // set person's addressID
146    public void setAddressID( int id )
147    {
148        addressID = id;
149    }
150
151    // get person's addressID
152    public int getAddressID()
153    {
154        return addressID;
```

Fig. 8.33 **AddressBookEntry** bean represents an address book entry (part 3 of 4).

```
155     }
156
157     // set person's phoneID
158     public void setPhoneID( int id )
159     {
160         phoneID = id;
161     }
162
163     // get person's phoneID
164     public int getPhoneID()
165     {
166         return phoneID;
167     }
168
169     // set person's emailID
170     public void setEmailID( int id )
171     {
172         emailID = id;
173     }
174
175     // get person's emailID
176     public int getEmailID()
177     {
178         return emailID;
179     }
180 } // end class AddressBookEntry
```

Fig. 8.33 **AddressBookEntry** bean represents an address book entry (part 4 of 4).

Interface **AddressBookDataAccess** (Fig. 8.34) describes methods required by the address-book application to perform insertions, updates, deletions and searches with the **addressbook** database. Any class that implements this interface can be used by the **AddressBook** application class to interact with the database. Thus, if you want to modify the application to use a database other than Cloudscape, you can do so by providing your own implementation of class **AddressBookDataAccess**.

```
1 // Fig. 8.34: AddressBookDataAccess.java
2 // Interface that specifies the methods for inserting,
3 // updating, deleting and finding records.
4 package com.deitel.advjhtp1.jdbc.addressbook;
5
6 // Java core packages
7 import java.sql.*;
8
9 public interface AddressBookDataAccess {
10
11     // Locate specified person by last name. Return
12     // AddressBookEntry containing information.
13     public AddressBookEntry findPerson( String lastName );
14 }
```

Fig. 8.34 **AddressBookDataAccess** interface describes the methods for accessing the **addressbook** database (part 1 of 2).

```
15     // Update information for specified person.  
16     // Return boolean indicating success or failure.  
17     public boolean savePerson(  
18         AddressBookEntry person ) throws DataAccessException;  
19  
20     // Insert a new person. Return boolean indicating  
21     // success or failure.  
22     public boolean newPerson( AddressBookEntry person )  
23         throws DataAccessException;  
24  
25     // Delete specified person. Return boolean indicating if  
26     // success or failure.  
27     public boolean deletePerson(  
28         AddressBookEntry person ) throws DataAccessException;  
29  
30     // close database connection  
31     public void close();  
32 } // end interface AddressBookDataAccess
```

Fig. 8.34 **AddressBookDataAccess** interface describes the methods for accessing the **addressbook** database (part 2 of 2).

Interface **AddressBookDataAccess** contains five methods. Method **findPerson** (line 13) receives an **String** argument containing the last name of the person for which to search. The method returns the **AddressBookEntry** containing the person's complete information if the person was found in the database; otherwise, the method returns **false**. Method **savePerson** (lines 17–18) receives an **AddressBookEntry** argument containing the data to save and updates the corresponding record in the database. Method **newPerson** (lines 22–23) receives an **AddressBookEntry** argument containing the information for a new person and inserts the person's information in the database. Method **deletePerson** (lines 27–28) receives an **AddressBookEntry** argument containing the person to delete from the database and uses the **personID** to remove the records that represent the person from all four tables in the database. Method **close** (line 31) closes the statements and the connection to the database.

Class **DataAccessException** (Fig. 8.35) extends class **Exception**. Some of the methods of interface **AddressBookDataAccess** throw **DataAccessExceptions** when there is a problem with the data source connection.

```
1 // Fig. 8.35 DataAccessException.java  
2 // Class AddressBookDataAccess throws DataAccessExceptions  
3 // when there is a problem accessing the data source.  
4 package com.deitel.advjhtp1.jdbc.addressbook;  
5  
6 public class DataAccessException extends Exception {  
7  
8     private Exception exception;  
9 }
```

Fig. 8.35 **DataAccessException** is thrown when there is a problem accessing the data source (part 1 of 2).

---

```

10   // constructor with String argument
11  public DataAccessException( String message )
12  {
13      super( message );
14  }
15
16  // constructor with Exception argument
17  public DataAccessException( Exception exception )
18  {
19      exception = this.exception;
20  }
21
22  // printStackTrace of exception from constructor
23  public void printStackTrace()
24  {
25      exception.printStackTrace();
26  }
27 }
```

---

**Fig. 8.35** `DataAccessException` is thrown when there is a problem accessing the data source (part 2 of 2).

Class `CloudscapeDataAccess` (Fig. 8.36) implements interface `AddressBookDataAccess` to interact with our `addressbook` database in Cloudscape. An object of this class contains a reference to a `Connection` object (line 13) that maintains the connection to the database and several references to `PreparedStatement` objects (lines 16–37) that represent the interactions with the database for inserting, updating, deleting and finding records.

---

```

1 // Fig. 8.36: CloudscapeDataAccess.java
2 // An implementation of interface AddressBookDataAccess that
3 // performs database operations with PreparedStatements.
4 package com.deitel.advjhtp1.jdbc.addressbook;
5
6 // Java core packages
7 import java.sql.*;
8
9 public class CloudscapeDataAccess
10    implements AddressBookDataAccess {
11
12    // reference to database connection
13    private Connection connection;
14
15    // reference to prepared statement for locating entry
16    private PreparedStatement sqlFind;
17
18    // reference to prepared statement for determining personID
19    private PreparedStatement sqlPersonID;
20 }
```

---

**Fig. 8.36** `CloudscapeDataAccess` implements interface `AddressBookDataAccess` to perform the connection to the database and the database interactions (part 1 of 10).

```
21 // references to prepared statements for inserting entry
22 private PreparedStatement sqlInsertName;
23 private PreparedStatement sqlInsertAddress;
24 private PreparedStatement sqlInsertPhone;
25 private PreparedStatement sqlInsertEmail;
26
27 // references to prepared statements for updating entry
28 private PreparedStatement sqlUpdateName;
29 private PreparedStatement sqlUpdateAddress;
30 private PreparedStatement sqlUpdatePhone;
31 private PreparedStatement sqlUpdateEmail;
32
33 // references to prepared statements for updating entry
34 private PreparedStatement sqlDeleteName;
35 private PreparedStatement sqlDeleteAddress;
36 private PreparedStatement sqlDeletePhone;
37 private PreparedStatement sqlDeleteEmail;
38
39 // set up PreparedStatements to access database
40 public CloudscapeDataAccess() throws Exception
41 {
42     // connect to addressbook database
43     connect();
44
45     // locate person
46     sqlFind = connection.prepareStatement(
47         "SELECT names.personID, firstName, lastName, " +
48             "addressID, address1, address2, city, state, " +
49             "zipcode, phoneID, phoneNumber, emailID, " +
50             "emailAddress " +
51         "FROM names, addresses, phoneNumbers, emailAddresses " +
52         "WHERE lastName = ? AND " +
53             "names.personID = addresses.personID AND " +
54             "names.personID = phoneNumbers.personID AND " +
55             "names.personID = emailAddresses.personID" );
56
57     // Obtain personID for last person inserted in database.
58     // [This is a Cloudscape-specific database operation.]
59     sqlPersonID = connection.prepareStatement(
60         "VALUES ConnectionInfo.lastAutoincrementValue( " +
61             "'APP', 'NAMES', 'PERSONID')" );
62
63     // Insert first and last names in table names.
64     // For referential integrity, this must be performed
65     // before sqlInsertAddress, sqlInsertPhone and
66     // sqlInsertEmail.
67     sqlInsertName = connection.prepareStatement(
68         "INSERT INTO names ( firstName, lastName ) " +
69         "VALUES ( ?, ? )" );
```

Fig. 8.36 `CloudscapeDataAccess` implements interface `AddressBookDataAccess` to perform the connection to the database and the database interactions (part 2 of 10).

```
71     // insert address in table addresses
72     sqlInsertAddress = connection.prepareStatement(
73         "INSERT INTO addresses ( personID, address1, " +
74             "address2, city, state, zipcode ) " +
75             "VALUES ( ?, ?, ?, ?, ?, ?, ? )" );
76
77     // insert phone number in table phoneNumbers
78     sqlInsertPhone = connection.prepareStatement(
79         "INSERT INTO phoneNumbers " +
80             "( personID, phoneNumber ) " +
81             "VALUES ( ?, ? )" );
82
83     // insert email in table emailAddresses
84     sqlInsertEmail = connection.prepareStatement(
85         "INSERT INTO emailAddresses " +
86             "( personID, emailAddress ) " +
87             "VALUES ( ?, ? )" );
88
89     // update first and last names in table names
90     sqlUpdateName = connection.prepareStatement(
91         "UPDATE names SET firstName = ?, lastName = ? " +
92         "WHERE personID = ?" );
93
94     // update address in table addresses
95     sqlUpdateAddress = connection.prepareStatement(
96         "UPDATE addresses SET address1 = ?, address2 = ?, " +
97             "city = ?, state = ?, zipcode = ? " +
98             "WHERE addressID = ?" );
99
100    // update phone number in table phoneNumbers
101    sqlUpdatePhone = connection.prepareStatement(
102        "UPDATE phoneNumbers SET phoneNumber = ? " +
103        "WHERE phoneID = ?" );
104
105    // update email in table emailAddresses
106    sqlUpdateEmail = connection.prepareStatement(
107        "UPDATE emailAddresses SET emailAddress = ? " +
108        "WHERE emailID = ?" );
109
110    // Delete row from table names. This must be executed
111    // after sqlDeleteAddress, sqlDeletePhone and
112    // sqlDeleteEmail, because of referential integrity.
113    sqlDeleteName = connection.prepareStatement(
114        "DELETE FROM names WHERE personID = ?" );
115
116    // delete address from table addresses
117    sqlDeleteAddress = connection.prepareStatement(
118        "DELETE FROM addresses WHERE personID = ?" );
119
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 3 of 10).

```
120     // delete phone number from table phoneNumbers
121     sqlDeletePhone = connection.prepareStatement(
122         "DELETE FROM phoneNumbers WHERE personID = ?" );
123
124     // delete email address from table emailAddresses
125     sqlDeleteEmail = connection.prepareStatement(
126         "DELETE FROM emailAddresses WHERE personID = ?" );
127 } // end CloudscapeDataAccess constructor
128
129 // Obtain a connection to addressbook database. Method may
130 // may throw ClassNotFoundException or SQLException. If so,
131 // exception is passed via this class's constructor back to
132 // the AddressBook application so the application can display
133 // an error message and terminate.
134 private void connect() throws Exception
135 {
136     // Cloudscape database driver class name
137     String driver = "COM.cloudscape.core.RmiJdbcDriver";
138
139     // URL to connect to addressbook database
140     String url = "jdbc:cloudscape:rmi:addressbook";
141
142     // load database driver class
143     Class.forName( driver );
144
145     // connect to database
146     connection = DriverManager.getConnection( url );
147
148     // Require manual commit for transactions. This enables
149     // the program to rollback transactions that do not
150     // complete and commit transactions that complete properly.
151     connection.setAutoCommit( false );
152 }
153
154 // Locate specified person. Method returns AddressBookEntry
155 // containing information.
156 public AddressBookEntry findPerson( String lastName )
157 {
158     try {
159         // set query parameter and execute query
160         sqlFind.setString( 1, lastName );
161         ResultSet resultSet = sqlFind.executeQuery();
162
163         // if no records found, return immediately
164         if ( !resultSet.next() )
165             return null;
166
167         // create new AddressBookEntry
168         AddressBookEntry person = new AddressBookEntry(
169             resultSet.getInt( 1 ) );
170 }
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 4 of 10).

```
171     // set AddressBookEntry properties
172     person.setFirstName( resultSet.getString( 2 ) );
173     person.setLastName( resultSet.getString( 3 ) );
174
175     person.setAddressID( resultSet.getInt( 4 ) );
176     person.setAddress1( resultSet.getString( 5 ) );
177     person.setAddress2( resultSet.getString( 6 ) );
178     person.setCity( resultSet.getString( 7 ) );
179     person.setState( resultSet.getString( 8 ) );
180     person.setZipcode( resultSet.getString( 9 ) );
181
182     person.setPhoneID( resultSet.getInt( 10 ) );
183     person.setPhoneNumber( resultSet.getString( 11 ) );
184
185     person.setEmailID( resultSet.getInt( 12 ) );
186     person.setEmailAddress( resultSet.getString( 13 ) );
187
188     // return AddressBookEntry
189     return person;
190 }
191
192     // catch SQLException
193     catch ( SQLException sqlException ) {
194         return null;
195     }
196 } // end method findPerson
197
198 // Update an entry. Method returns boolean indicating
199 // success or failure.
200 public boolean savePerson( AddressBookEntry person )
201     throws DataAccessException
202 {
203     // update person in database
204     try {
205         int result;
206
207         // update names table
208         sqlUpdateName.setString( 1, person.getFirstName() );
209         sqlUpdateName.setString( 2, person.getLastName() );
210         sqlUpdateName.setInt( 3, person.getPersonID() );
211         result = sqlUpdateName.executeUpdate();
212
213         // if update fails, rollback and discontinue
214         if ( result == 0 ) {
215             connection.rollback(); // rollback update
216             return false; // update unsuccessful
217         }
218
219         // update addresses table
220         sqlUpdateAddress.setString( 1, person.getAddress1() );
221         sqlUpdateAddress.setString( 2, person.getAddress2() );
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 5 of 10).

```
222     sqlUpdateAddress.setString( 3, person.getCity() );
223     sqlUpdateAddress.setString( 4, person.getState() );
224     sqlUpdateAddress.setString( 5, person.getZipcode() );
225     sqlUpdateAddress.setInt( 6, person.getAddressID() );
226     result = sqlUpdateAddress.executeUpdate();
227
228     // if update fails, rollback and discontinue
229     if ( result == 0 ) {
230         connection.rollback(); // rollback update
231         return false; // update unsuccessful
232     }
233
234     // update phoneNumbers table
235     sqlUpdatePhone.setString( 1, person.getPhoneNumber() );
236     sqlUpdatePhone.setInt( 2, person.getPhoneID() );
237     result = sqlUpdatePhone.executeUpdate();
238
239     // if update fails, rollback and discontinue
240     if ( result == 0 ) {
241         connection.rollback(); // rollback update
242         return false; // update unsuccessful
243     }
244
245     // update emailAddresses table
246     sqlUpdateEmail.setString( 1, person.getEmailAddress() );
247     sqlUpdateEmail.setInt( 2, person.getEmailID() );
248     result = sqlUpdateEmail.executeUpdate();
249
250     // if update fails, rollback and discontinue
251     if ( result == 0 ) {
252         connection.rollback(); // rollback update
253         return false; // update unsuccessful
254     }
255
256     connection.commit(); // commit update
257     return true; // update successful
258 } // end try
259
260 // detect problems updating database
261 catch ( SQLException sqlException ) {
262
263     // rollback transaction
264     try {
265         connection.rollback(); // rollback update
266         return false; // update unsuccessful
267     }
268
269     // handle exception rolling back transaction
270     catch ( SQLException exception ) {
271         throw new DataAccessException( exception );
272     }
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 6 of 10).

```
273     }
274 } // end method savePerson
275
276 // Insert new entry. Method returns boolean indicating
277 // success or failure.
278 public boolean newPerson( AddressBookEntry person )
279     throws DataAccessException
280 {
281     // insert person in database
282     try {
283         int result;
284
285         // insert first and last name in names table
286         sqlInsertName.setString( 1, person.getFirstName() );
287         sqlInsertName.setString( 2, person.getLastName() );
288         result = sqlInsertName.executeUpdate();
289
290         // if insert fails, rollback and discontinue
291         if ( result == 0 ) {
292             connection.rollback(); // rollback insert
293             return false; // insert unsuccessful
294         }
295
296         // determine new personID
297         ResultSet resultPersonID = sqlPersonID.executeQuery();
298
299         if ( resultPersonID.next() ) {
300             int personID = resultPersonID.getInt( 1 );
301
302             // insert address in addresses table
303             sqlInsertAddress.setInt( 1, personID );
304             sqlInsertAddress.setString( 2,
305                 person.getAddress1() );
306             sqlInsertAddress.setString( 3,
307                 person.getAddress2() );
308             sqlInsertAddress.setString( 4,
309                 person.getCity() );
310             sqlInsertAddress.setString( 5,
311                 person.getState() );
312             sqlInsertAddress.setString( 6,
313                 person.getZipcode() );
314             result = sqlInsertAddress.executeUpdate();
315
316             // if insert fails, rollback and discontinue
317             if ( result == 0 ) {
318                 connection.rollback(); // rollback insert
319                 return false; // insert unsuccessful
320             }
321
322             // insert phone number in phoneNumbers table
323             sqlInsertPhone.setInt( 1, personID );
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 7 of 10).

```
324         sqlInsertPhone.setString( 2,
325             person.getPhoneNumber() );
326         result = sqlInsertPhone.executeUpdate();
327
328         // if insert fails, rollback and discontinue
329         if ( result == 0 ) {
330             connection.rollback(); // rollback insert
331             return false; // insert unsuccessful
332         }
333
334         // insert email address in emailAddresses table
335         sqlInsertEmail.setInt( 1, personID );
336         sqlInsertEmail.setString( 2,
337             person.getEmailAddress() );
338         result = sqlInsertEmail.executeUpdate();
339
340         // if insert fails, rollback and discontinue
341         if ( result == 0 ) {
342             connection.rollback(); // rollback insert
343             return false; // insert unsuccessful
344         }
345
346         connection.commit(); // commit insert
347         return true; // insert successful
348     }
349
350     else
351         return false;
352 } // end try
353
354 // detect problems updating database
355 catch ( SQLException sqlException ) {
356     // rollback transaction
357     try {
358         connection.rollback(); // rollback update
359         return false; // update unsuccessful
360     }
361
362     // handle exception rolling back transaction
363     catch ( SQLException exception ) {
364         throw new DataAccessException( exception );
365     }
366 }
367 } // end method newPerson
368
369 // Delete an entry. Method returns boolean indicating
370 // success or failure.
371 public boolean deletePerson( AddressBookEntry person )
372     throws DataAccessException
373 {
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 8 of 10).

```
374     // delete a person from database
375     try {
376         int result;
377
378         // delete address from addresses table
379         sqlDeleteAddress.setInt( 1, person.getPersonID() );
380         result = sqlDeleteAddress.executeUpdate();
381
382         // if delete fails, rollback and discontinue
383         if ( result == 0 ) {
384             connection.rollback(); // rollback delete
385             return false; // delete unsuccessful
386         }
387
388         // delete phone number from phoneNumbers table
389         sqlDeletePhone.setInt( 1, person.getPersonID() );
390         result = sqlDeletePhone.executeUpdate();
391
392         // if delete fails, rollback and discontinue
393         if ( result == 0 ) {
394             connection.rollback(); // rollback delete
395             return false; // delete unsuccessful
396         }
397
398         // delete email address from emailAddresses table
399         sqlDeleteEmail.setInt( 1, person.getPersonID() );
400         result = sqlDeleteEmail.executeUpdate();
401
402         // if delete fails, rollback and discontinue
403         if ( result == 0 ) {
404             connection.rollback(); // rollback delete
405             return false; // delete unsuccessful
406         }
407
408         // delete name from names table
409         sqlDeleteName.setInt( 1, person.getPersonID() );
410         result = sqlDeleteName.executeUpdate();
411
412         // if delete fails, rollback and discontinue
413         if ( result == 0 ) {
414             connection.rollback(); // rollback delete
415             return false; // delete unsuccessful
416         }
417
418         connection.commit(); // commit delete
419         return true; // delete successful
420     } // end try
421
422     // detect problems updating database
423     catch ( SQLException sqlException ) {
424         // rollback transaction
```

Fig. 8.36 `CloudscapeDataAccess` implements interface `AddressBookDataAccess` to perform the connection to the database and the database interactions (part 9 of 10).

```
425         try {
426             connection.rollback(); // rollback update
427             return false;           // update unsuccessful
428         }
429
430         // handle exception rolling back transaction
431         catch ( SQLException exception ) {
432             throw new DataAccessException( exception );
433         }
434     }
435 } // end method deletePerson
436
437 // method to close statements and database connection
438 public void close()
439 {
440     // close database connection
441     try {
442         sqlFind.close();
443         sqlPersonID.close();
444         sqlInsertName.close();
445         sqlInsertAddress.close();
446         sqlInsertPhone.close();
447         sqlInsertEmail.close();
448         sqlUpdateName.close();
449         sqlUpdateAddress.close();
450         sqlUpdatePhone.close();
451         sqlUpdateEmail.close();
452         sqlDeleteName.close();
453         sqlDeleteAddress.close();
454         sqlDeletePhone.close();
455         sqlDeleteEmail.close();
456         connection.close();
457     } // end try
458
459     // detect problems closing statements and connection
460     catch ( SQLException sqlException ) {
461         sqlException.printStackTrace();
462     }
463 } // end method close
464
465 // Method to clean up database connection. Provided in case
466 // CloudscapeDataAccess object is garbage collected.
467 protected void finalize()
468 {
469     close();
470 }
471 } // end class CloudscapeDataAccess
```

Fig. 8.36 **CloudscapeDataAccess** implements interface **AddressBookDataAccess** to perform the connection to the database and the database interactions (part 10 of 10).

Line 43 of the **CloudscapeDataAccess** constructor (lines 40–127) invokes utility method **connect** (defined at lines 134–152) to perform the connection to the database.

Any exceptions that occur in method `connect` are thrown back to class `AddressBook`, so the application can determine an appropriate course of action to take for a failed connection. If the connection is successful, lines 46–126 invoke `Connection` method `prepareStatement` to create each of the SQL statements that manipulate database `addressbook`. These `PreparedStatement`s perform standard `SELECT`, `INSERT`, `UPDATE` and `DELETE` operations, as discussed in Section 8.4. The question marks (?) in each `PreparedStatement` represent the parameters that must be set before the program executes each statement.

`PreparedStatement` `sqlFind` (lines 46–55) selects all the data for a person with a specific `lastName` from the four tables in database `addressbook`. Note that the `WHERE` clause uses `ANDed` conditions to ensure that the query retrieves the appropriate data from each table. These conditions compare the `personID` fields in each table. The only records this query returns are those with the specified last name where the `personID` field in table `names` matches the `personID` field in tables `addresses`, `phoneNumbers` and `emailAddresses`. [Note: As implemented, this application assumes that all last names are unique.]

`PreparedStatement` `sqlPersonID` (lines 59–61) is a Cloudscape-specific operation to determine the last autoincrement value for the `names` table's `personID` field. `ConnectionInfo.lastAutoincrementValue` is a `static` Java method built into Cloudscape. The method receives three SQL string arguments that represent the name of the database *schema* ('`APP`') containing the table, the name of the table containing the autoincrement field ('`NAMES`') and the name of the autoincrement field ('`PERSONID`'). Cloudscape *requires* each of these names to be in all uppercase letters. In a database, it is possible to group tables into sets of tables with a specific schema name. SQL statements can qualify table names with schema names to interact with tables from different schemas in the same SQL statement. Cloudscape places database tables in schema `APP` by default.

The remaining `PreparedStatement`s are straightforward. For more detail on the SQL used in those statements, refer back to Section 8.4.

`CloudscapeDataAccess` method `connect` (lines 134–152) establishes the connection to database `addressbook` with the techniques shown earlier in this chapter. Any exceptions that occur while attempting to load the database driver and connect to the database are thrown from this method back to the called method (the constructor). The database connection in this example differs from those in prior examples in that line 151 disables automatic commitment of transactions. Thus, the program must indicate when a transaction should be committed to the database or rolled back to maintain the database's state before the transaction. This enables `CloudscapeDataAccess` to execute a series of SQL statements and commit the results only if all the statements in the series are successful.

`CloudscapeDataAccess` method `findPerson` (lines 156–196) receives a `String` containing the last name of the person to locate in the database and uses that last name to set the parameter in `PreparedStatement` `sqlFind` (line 160). Line 161 executes `sqlFind`. If a record is found, lines 168–186 set the properties of the `AddressBookEntry`, and line 189 returns the `AddressBookEntry`. If no records are found for the specified last name, the method returns `null`.

`CloudscapeDataAccess` method `savePerson` (lines 200–274) receives an `AddressBookEntry` containing the complete information for a person to update in the

database and uses that information to set the parameters of **PreparedStatement** **sqlUpdateName** (lines 208–210), **sqlUpdateAddress** (lines 220–225), **sqlUpdatePhone** (lines 235–236) and **sqlUpdateEmail** (lines 246–247). Note that parameter values are set by invoking **PreparedStatement** *set* methods for the appropriate data type. In this example, the ID parameters are all integers and the remaining data are all strings, so the program uses methods **.setInt** and **setString** to specify parameters. After setting the parameters for a particular **PreparedStatement**, the method calls that statement's **executeUpdate** method (lines 211, 226, 237 and 248), which returns an integer indicating the number of rows modified by the update. The execution of each **PreparedStatement** is followed by an **if** structure that tests the return value of **executeUpdate**. If **executeUpdate** returns 0, the **PreparedStatement** did not update any records. Therefore, **savePerson** invokes **Connection** method **rollback** to restore the database to its state before the **PreparedStatement** executed and returns **false** to indicate to the **AddressBook** application that the update failed. If **savePerson** reaches line 256, it commits the transaction in the database and returns **true** to indicate that the update was successful.

**CloudscapeDataAccess** method **newPerson** (lines 278–367) is similar to method **savePerson**. Method **newPerson** receives an **AddressBookEntry** containing the complete information for a person to insert in the database and uses that information to set the parameters of **PreparedStatement**s **sqlInsertName** (lines 286–287), **sqlInsertAddress** (lines 303–313), **sqlInsertPhone** (lines 323–325) and **sqlInsertEmail** (lines 335–337). The primary difference between **newPerson** and **savePerson** is that the entry does not exist in the database yet. To insert rows in tables **addresses**, **phoneNumbers** and **emailAddresses**, the **personID** foreign-key field for each new record must correspond to the **personID** primary-key field in the **names** table. The new **personID** in table **names** is not known until the program inserts the new record in the table. So, after inserting a new record into table **names**, line 297 executes **PreparedStatement** **sqlPersonID** to obtain the **personID** number for the last new person added to table **names**. Line 300 places this value in the local variable **personID**. Then, the program inserts records in tables **addresses**, **phoneNumbers** and **emailAddresses**, using the new **personID** as the value of the foreign-key field in each table. As in method **savePerson**, if no records are inserted after a given **PreparedStatement** executes, method **newPerson** rolls back the transaction and returns **false** to indicate that the insertion failed. Otherwise, method **newPerson** commits the transaction and returns **true** to indicate that the insertion succeeded.

**CloudscapeDataAccess** method **deletePerson** (lines 371–435) receives an **AddressBookEntry** containing the **personID** of the person to remove from the database and uses that ID as the parameter value for the **PreparedStatement**s **sqlDeleteName**, **sqlDeleteAddress**, **sqlDeletePhone** and **sqlDeleteEmail**. When each **PreparedStatement** executes, it deletes all records with the specified **personID** in the appropriate table. If any part of the delete fails, method **deletePerson** rolls back the transaction and returns **false** to indicate that the deletion failed. Otherwise, method **deletePerson** commits the transaction and returns **true** to indicate that the deletion succeeded. In the future, if this program supports multiple addresses, phone numbers and e-mail addresses for each person, this **deletePerson** method will delete all the information for a particular entry properly.

**CloudscapeDataAccess** methods **close** (lines 438–463) and **finalize** (lines 467–470) close the **PreparedStatement**s and database connection. Method **finalize** is provided in case an object of class **CloudscapeDataAccess** gets garbage collected and the client forgot to call **close** explicitly.

Class **AddressBookEntryFrame** (Fig. 8.37) is a subclass of **JInternalFrame** that enables address-book application users to view or edit the details of an **AddressBookEntry**. The **AddressBook** application class (Fig. 8.38) creates a new **AddressBookEntryFrame** to display the results of a search for an entry and to enable the user to input information for a new entry. **AddressBookEntryFrame** maintains a reference to the currently displayed **AddressBookEntry** and provides *set* and *get* methods to specify an **AddressBookEntry** to display and to return the currently displayed **AddressBookEntry**, respectively. The class also has several **private** utility methods for setting up the GUI and accessing the individual **JTextFields** in the GUI. Objects of class **AddressBookEntryFrame** are managed by class **AddressBook**, which contains a **JDesktopPane**.

```
1 // Fig. 8.37: AddressBookEntryFrame.java
2 // A subclass of JInternalFrame customized to display and
3 // an AddressBookEntry or set an AddressBookEntry's properties
4 // based on the current data in the UI.
5 package com.deitel.advjhtp1.jdbc.addressbook;
6
7 // Java core packages
8 import java.util.*;
9 import java.awt.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class AddressBookEntryFrame extends JInternalFrame {
15
16     // HashMap to store JTextField references for quick access
17     private HashMap fields;
18
19     // current AddressBookEntry set by AddressBook application
20     private AddressBookEntry person;
21
22     // panels to organize GUI
23     private JPanel leftPanel, rightPanel;
24
25     // static integers used to determine new window positions
26     // for cascading windows
27     private static int xOffset = 0, yOffset = 0;
28
29     // static Strings that represent name of each text field.
30     // These are placed on JLabels and used as keys in
31     // HashMap fields.
32     private static final String FIRST_NAME = "First Name",
```

Fig. 8.37 **AddressBookEntryFrame** for viewing and editing an **AddressBookEntry** (part 1 of 3).

```
33     LAST_NAME = "Last Name", ADDRESS1 = "Address 1",
34     ADDRESS2 = "Address 2", CITY = "City", STATE = "State",
35     ZIPCODE = "Zipcode", PHONE = "Phone", EMAIL = "Email";
36
37 // construct GUI
38 public AddressBookEntryFrame()
39 {
40     super( "Address Book Entry", true, true );
41
42     fields = new HashMap();
43
44     leftPanel = new JPanel();
45     leftPanel.setLayout( new GridLayout( 9, 1, 0, 5 ) );
46     rightPanel = new JPanel();
47     rightPanel.setLayout( new GridLayout( 9, 1, 0, 5 ) );
48
49     createRow( FIRST_NAME );
50     createRow( LAST_NAME );
51     createRow( ADDRESS1 );
52     createRow( ADDRESS2 );
53     createRow( CITY );
54     createRow( STATE );
55     createRow( ZIPCODE );
56     createRow( PHONE );
57     createRow( EMAIL );
58
59     Container container = getContentPane();
60     container.add( leftPanel, BorderLayout.WEST );
61     container.add( rightPanel, BorderLayout.CENTER );
62
63     setBounds( xOffset, yOffset, 300, 300 );
64     xOffset = ( xOffset + 30 ) % 300;
65     yOffset = ( yOffset + 30 ) % 300;
66 }
67
68 // set AddressBookEntry then use its properties to
69 // place data in each JTextField
70 public void setAddressBookEntry( AddressBookEntry entry )
71 {
72     person = entry;
73
74     setField( FIRST_NAME, person.getFirstName() );
75     setField( LAST_NAME, person.getLastName() );
76     setField( ADDRESS1, person.getAddress1() );
77     setField( ADDRESS2, person.getAddress2() );
78     setField( CITY, person.getCity() );
79     setField( STATE, person.getState() );
80     setField( ZIPCODE, person.getZipcode() );
81     setField( PHONE, person.getPhoneNumber() );
82     setField( EMAIL, person.getEmailAddress() );
83 }
84 }
```

Fig. 8.37 AddressBookEntryFrame for viewing and editing an AddressBookEntry (part 2 of 3).

```
85     // store AddressBookEntry data from GUI and return
86     // AddressBookEntry
87     public AddressBookEntry getAddressBookEntry()
88     {
89         person.setFirstName( getField( FIRST_NAME ) );
90         person.setLastName( getField( LAST_NAME ) );
91         person.setAddress1( getField( ADDRESS1 ) );
92         person.setAddress2( getField( ADDRESS2 ) );
93         person.setCity( getField( CITY ) );
94         person.setState( getField( STATE ) );
95         person.setZipcode( getField( ZIPCODE ) );
96         person.setPhoneNumber( getField( PHONE ) );
97         person.setEmailAddress( getField( EMAIL ) );
98
99         return person;
100    }
101
102    // set text in JTextField by specifying field's
103    // name and value
104    private void setField( String fieldName, String value )
105    {
106        JTextField field =
107            ( JTextField ) fields.get( fieldName );
108
109        field.setText( value );
110    }
111
112    // get text in JTextField by specifying field's name
113    private String getField( String fieldName )
114    {
115        JTextField field =
116            ( JTextField ) fields.get( fieldName );
117
118        return field.getText();
119    }
120
121    // utility method used by constructor to create one row in
122    // GUI containing JLabel and JTextField
123    private void createRow( String name )
124    {
125        JLabel label = new JLabel( name, SwingConstants.RIGHT );
126        label.setBorder(
127            BorderFactory.createEmptyBorder( 5, 5, 5, 5 ) );
128        leftPanel.add( label );
129
130        JTextField field = new JTextField( 30 );
131        rightPanel.add( field );
132
133        fields.put( name, field );
134    }
135 } // end class AddressBookEntryFrame
```

Fig. 8.37 AddressBookEntryFrame for viewing and editing an AddressBookEntry (part 3 of 3).

Class **AddressBook** (Fig. 8.38) is the main application class for the address-book application. **AddressBook** uses several of the GUI techniques presented in Chapter 2, including tool bars, menus, actions and multiple-document interfaces. The discussion of class **AddressBook** concentrates on the functionality, rather than on the GUI details. Screen captures demonstrating the program's execution appear in Fig. 8.39.

```
1 // Fig. 8.38: AddressBook.java
2 // An address book database example that allows information to
3 // be inserted, updated and deleted. The example uses
4 // transactions to ensure that the operations complete
5 // successfully.
6 package com.deitel.advjhtp1.jdbc.addressbook;
7
8 // Java core packages
9 import java.awt.*;
10 import java.awt.event.*;
11 import java.sql.*;
12
13 // Java extension packages
14 import javax.swing.*;
15 import javax.swing.event.*;
16
17 public class AddressBook extends JFrame {
18
19     // reference for manipulating multiple document interface
20     private JDesktopPane desktop;
21
22     // reference to database access object
23     private AddressBookDataAccess database;
24
25     // references to Actions
26     Action newAction, saveAction, deleteAction,
27         searchAction, exitAction;
28
29     // set up database connection and GUI
30     public AddressBook()
31     {
32         super( "Address Book" );
33
34         // create database connection
35         try {
36             database = new CloudscapeDataAccess();
37         }
38
39         // detect problems with database connection
40         catch ( Exception exception ) {
41             exception.printStackTrace();
42             System.exit( 1 );
43         }
44     }
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 1 of 8).

```
45     // database connection successful, create GUI
46     JToolBar toolBar = new JToolBar();
47     JMenu fileMenu = new JMenu( "File" );
48     fileMenu.setMnemonic( 'F' );
49
50     // Set up actions for common operations. Private inner
51     // classes encapsulate the processing of each action.
52     newAction = new NewAction();
53     saveAction = new SaveAction();
54     saveAction.setEnabled( false );      // disabled by default
55     deleteAction = new DeleteAction();
56     deleteAction.setEnabled( false );    // disabled by default
57     searchAction = new SearchAction();
58     exitAction = new ExitAction();
59
60     // add actions to tool bar
61     toolBar.add( newAction );
62     toolBar.add( saveAction );
63     toolBar.add( deleteAction );
64     toolBar.add( new JToolBar.Separator() );
65     toolBar.add( searchAction );
66
67     // add actions to File menu
68     fileMenu.add( newAction );
69     fileMenu.add( saveAction );
70     fileMenu.add( deleteAction );
71     fileMenu.addSeparator();
72     fileMenu.add( searchAction );
73     fileMenu.addSeparator();
74     fileMenu.add( exitAction );
75
76     // set up menu bar
77     JMenuBar menuBar = new JMenuBar();
78     menuBar.add( fileMenu );
79     setJMenuBar( menuBar );
80
81     // set up desktop
82     desktop = new JDesktopPane();
83
84     // get the content pane to set up GUI
85     Container c = getContentPane();
86     c.add( toolBar, BorderLayout.NORTH );
87     c.add( desktop, BorderLayout.CENTER );
88
89     // register for windowClosing event in case user
90     // does not select Exit from File menu to terminate
91     // application
92     addWindowListener(
93         new WindowAdapter() {
94             public void windowClosing( WindowEvent event )
95             {
96                 shutDown();
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 2 of 8).

```
97         }
98     }
99 );
100
101    // set window size and display window
102 Toolkit toolkit = getToolkit();
103 Dimension dimension = toolkit.getScreenSize();
104
105    // center window on screen
106 setBounds( 100, 100, dimension.width - 200,
107             dimension.height - 200 );
108
109    setVisible( true );
110 } // end AddressBook constructor
111
112 // close database connection and terminate program
113 private void shutDown()
114 {
115     database.close(); // close database connection
116     System.exit( 0 ); // terminate program
117 }
118
119 // create a new AddressBookEntryFrame and register listener
120 private AddressBookEntryFrame createAddressBookEntryFrame()
121 {
122     AddressBookEntryFrame frame = new AddressBookEntryFrame();
123     setDefaultCloseOperation( DISPOSE_ON_CLOSE );
124     frame.addInternalFrameListener(
125         new InternalFrameAdapter() {
126
127             // internal frame becomes active frame on desktop
128             public void internalFrameActivated(
129                 InternalFrameEvent event )
130             {
131                 saveAction.setEnabled( true );
132                 deleteAction.setEnabled( true );
133             }
134
135             // internal frame becomes inactive frame on desktop
136             public void internalFrameDeactivated(
137                 InternalFrameEvent event )
138             {
139                 saveAction.setEnabled( false );
140                 deleteAction.setEnabled( false );
141             }
142         } // end InternalFrameAdapter anonymous inner class
143     ); // end call to addInternalFrameListener
144
145     return frame;
146 } // end method createAddressBookEntryFrame
147
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 3 of 8).

```
148 // method to launch program execution
149 public static void main( String args[] )
150 {
151     new AddressBook();
152 }
153
154 // Private inner class defines action that enables
155 // user to input new entry. User must "Save" entry
156 // after inputting data.
157 private class NewAction extends AbstractAction {
158
159     // set up action's name, icon, descriptions and mnemonic
160     public NewAction()
161     {
162         putValue( NAME, "New" );
163         putValue( SMALL_ICON, new ImageIcon(
164             getClass().getResource( "images/New24.png" ) ) );
165         putValue( SHORT_DESCRIPTION, "New" );
166         putValue( LONG_DESCRIPTION,
167             "Add a new address book entry" );
168         putValue( MNEMONIC_KEY, new Integer( 'N' ) );
169     }
170
171     // display window in which user can input entry
172     public void actionPerformed( ActionEvent e )
173     {
174         // create new internal window
175         AddressBookEntryFrame entryFrame =
176             createAddressBookEntryFrame();
177
178         // set new AddressBookEntry in window
179         entryFrame.setAddressBookEntry(
180             new AddressBookEntry() );
181
182         // display window
183         desktop.add( entryFrame );
184         entryFrame.setVisible( true );
185     }
186
187 } // end inner class NewAction
188
189 // inner class defines an action that can save new or
190 // updated entry
191 private class SaveAction extends AbstractAction {
192
193     // set up action's name, icon, descriptions and mnemonic
194     public SaveAction()
195     {
196         putValue( NAME, "Save" );
197         putValue( SMALL_ICON, new ImageIcon(
198             getClass().getResource( "images/Save24.png" ) ) );
199         putValue( SHORT_DESCRIPTION, "Save" );
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 4 of 8).

```
200     putValue( LONG_DESCRIPTION,
201             "Save an address book entry" );
202     putValue( MNEMONIC_KEY, new Integer( 'S' ) );
203 }
204
205 // save new entry or update existing entry
206 public void actionPerformed( ActionEvent e )
207 {
208     // get currently active window
209     AddressBookEntryFrame currentFrame =
210         ( AddressBookEntryFrame ) desktop.getSelectedFrame();
211
212     // obtain AddressBookEntry from window
213     AddressBookEntry person =
214         currentFrame.getAddressBookEntry();
215
216     // insert person in address book
217     try {
218
219         // Get personID. If 0, this is a new entry;
220         // otherwise an update must be performed.
221         int personID = person.getPersonID();
222
223         // determine string for message dialogs
224         String operation =
225             ( personID == 0 ) ? "Insertion" : "Update";
226
227         // insert or update entry
228         if ( personID == 0 )
229             database.newPerson( person );
230         else
231             database.savePerson( person );
232
233         // display success or failure message
234         JOptionPane.showMessageDialog( desktop,
235             operation + " successful" );
236     } // end try
237
238     // detect database errors
239     catch ( DataAccessException exception ) {
240         JOptionPane.showMessageDialog( desktop, exception,
241             "DataAccessException",
242             JOptionPane.ERROR_MESSAGE );
243         exception.printStackTrace();
244     }
245
246     // close current window and dispose of resources
247     currentFrame.dispose();
248
249 } // end method actionPerformed
250
251 } // end inner class SaveAction
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 5 of 8).

```
252
253 // inner class defines action that deletes entry
254 private class DeleteAction extends AbstractAction {
255
256     // set up action's name, icon, descriptions and mnemonic
257     public DeleteAction() {
258         {
259             putValue( NAME, "Delete" );
260             putValue( SMALL_ICON, new ImageIcon(
261                 getClass().getResource( "images/Delete24.png" ) ) );
262             putValue( SHORT_DESCRIPTION, "Delete" );
263             putValue( LONG_DESCRIPTION,
264                     "Delete an address book entry" );
265             putValue( MNEMONIC_KEY, new Integer( 'D' ) );
266         }
267
268         // delete entry
269         public void actionPerformed( ActionEvent e )
270         {
271             // get currently active window
272             AddressBookEntryFrame currentFrame =
273                 ( AddressBookEntryFrame ) desktop.getSelectedFrame();
274
275             // get AddressBookEntry from window
276             AddressBookEntry person =
277                 currentFrame.getAddressBookEntry();
278
279             // If personID is 0, this is new entry that has not
280             // been inserted. Therefore, delete is not necessary.
281             // Display message and return.
282             if ( person.getPersonID() == 0 ) {
283                 JOptionPane.showMessageDialog( desktop,
284                     "New entries must be saved before they can be " +
285                     "deleted. \nTo cancel a new entry, simply " +
286                     "close the window containing the entry" );
287                 return;
288             }
289
290             // delete person
291             try {
292                 database.deletePerson( person );
293
294                 // display message indicating success
295                 JOptionPane.showMessageDialog( desktop,
296                     "Deletion successful" );
297             }
298
299             // detect problems deleting person
300             catch ( DataAccessException exception ) {
301                 JOptionPane.showMessageDialog( desktop, exception,
302                     "Deletion failed", JOptionPane.ERROR_MESSAGE );
303             }
304         }
305     }
306 }
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 6 of 8).

```
303             exception.printStackTrace();
304         }
305
306         // close current window and dispose of resources
307         currentFrame.dispose();
308
309     } // end method actionPerformed
310
311 } // end inner class DeleteAction
312
313 // inner class defines action that locates entry
314 private class SearchAction extends AbstractAction {
315
316     // set up action's name, icon, descriptions and mnemonic
317     public SearchAction()
318     {
319         putValue( NAME, "Search" );
320         putValue( SMALL_ICON, new ImageIcon(
321             getClass().getResource( "images/Find24.png" ) ) );
322         putValue( SHORT_DESCRIPTION, "Search" );
323         putValue( LONG_DESCRIPTION,
324             "Search for an address book entry" );
325         putValue( MNEMONIC_KEY, new Integer( 'r' ) );
326     }
327
328     // locate existing entry
329     public void actionPerformed( ActionEvent e )
330     {
331         String lastName =
332             JOptionPane.showInputDialog( desktop,
333                 "Enter last name" );
334
335         // if last name was input, search for it; otherwise,
336         // do nothing
337         if ( lastName != null ) {
338
339             // Execute search. If found, AddressBookEntry
340             // is returned containing data.
341             AddressBookEntry person = database.findPerson(
342                 lastName );
343
344             if ( person != null ) {
345
346                 // create window to display AddressBookEntry
347                 AddressBookEntryFrame entryFrame =
348                     createAddressBookEntryFrame();
349
350                 // set AddressBookEntry to display
351                 entryFrame.setAddressBookEntry( person );
352
353                 // display window
354                 desktop.add( entryFrame );
```

Fig. 8.38 **AddressBook** application class that enables the user to interact with the **addressbook** database (part 7 of 8).

---

```

355             entryFrame.setVisible( true );
356         }
357     else
358         JOptionPane.showMessageDialog( desktop,
359             "Entry with last name '" + lastName +
360             "' not found in address book" );
361     } // end "if ( lastName == null )"
362   } // end method actionPerformed
363
364 } // end inner class SearchAction
365
366 // inner class defines action that closes connection to
367 // database and terminates program
368 private class ExitAction extends AbstractAction {
369
370     // set up action's name, descriptions and mnemonic
371     public ExitAction()
372     {
373         putValue( NAME, "Exit" );
374         putValue( SHORT_DESCRIPTION, "Exit" );
375         putValue( LONG_DESCRIPTION, "Terminate the program" );
376         putValue( MNEMONIC_KEY, new Integer( 'x' ) );
377     }
378
379     // terminate program
380     public void actionPerformed( ActionEvent e )
381     {
382         shutDown(); // close database connection and terminate
383     }
384   } // end inner class ExitAction
385 }
```

---

**Fig. 8.38** **AddressBook** application class that enables the user to interact with the **addressbook** database (part 8 of 8).

Class **AddressBook**'s constructor (lines 30–110) creates a **Cloudscape-DataAccess** object to interact with the database (line 36), builds the GUI (lines 46–87), registers an event handler for the window-closing event (lines 92–99) and displays the application window (lines 102–109). As part of building the tool bar and menu for the application, lines 52–58 of the constructor create instances of five **private** inner classes that implement the actions for the GUI—**NewAction** (lines 157–187), **SaveAction** (lines 191–251), **DeleteAction** (lines 254–311), **SearchAction** (lines 314–366) and **ExitAction** (lines 370–387). Note that the program disables the **SaveAction** and **DeleteAction** by default. These are enabled only if there is an active internal frame on the desktop.

Each action (except **ExitAction**) uses a standard icon from the Sun Microsystems *Java Look and Feel Graphics Repository*, located at [developer.java.sun.com/developer/techDocs/hi/repository](http://developer.java.sun.com/developer/techDocs/hi/repository). The first screen capture of Fig. 8.39 describes each of the icons in the GUI.

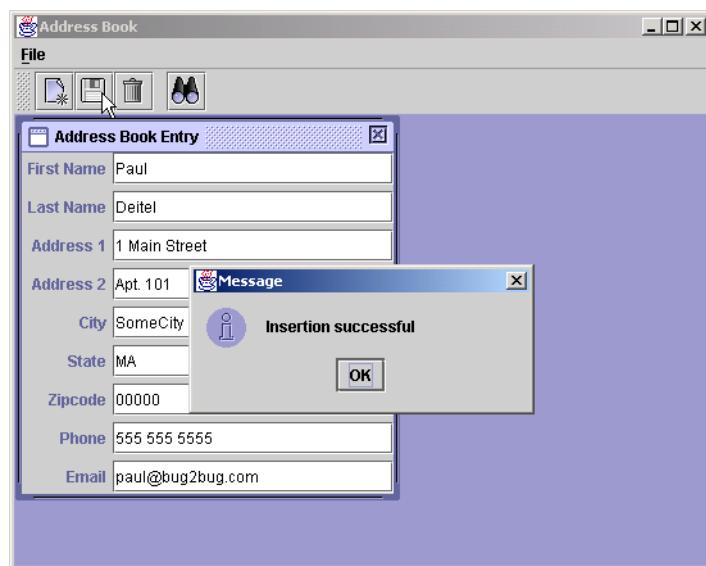
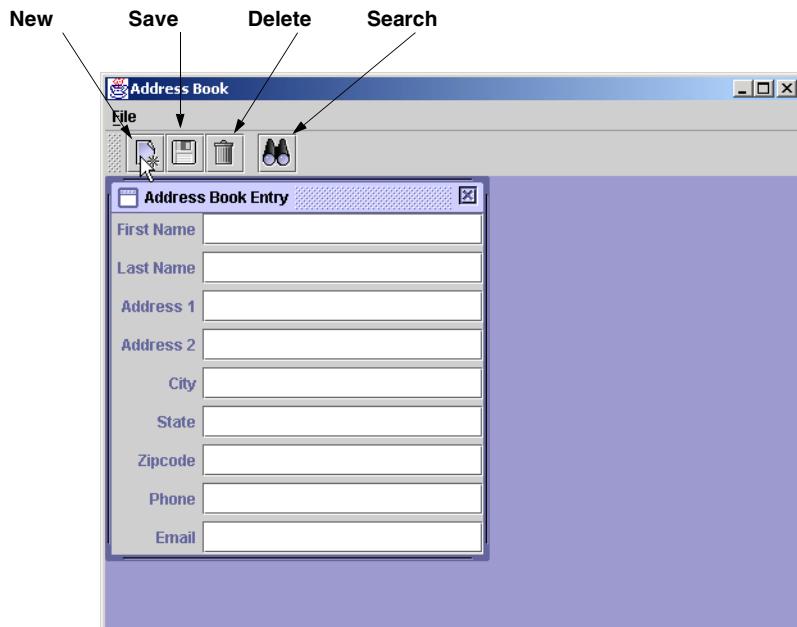


Fig. 8.39 Screen captures of the **AddressBook** application (part 1 of 3).

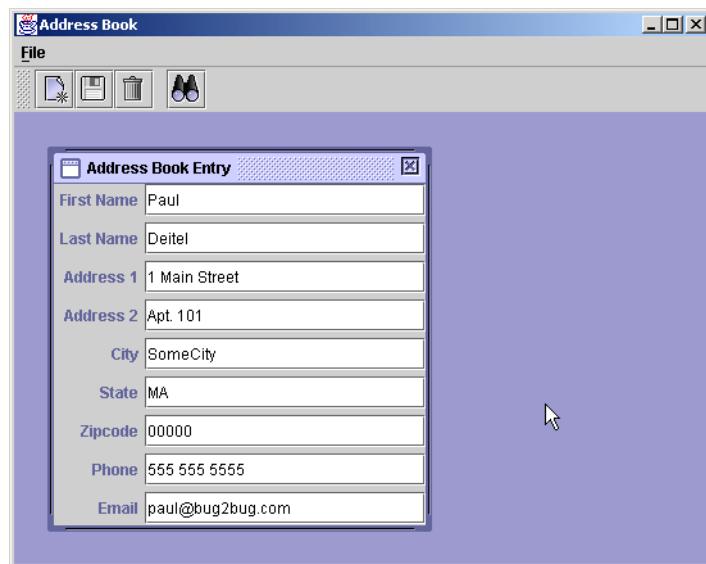
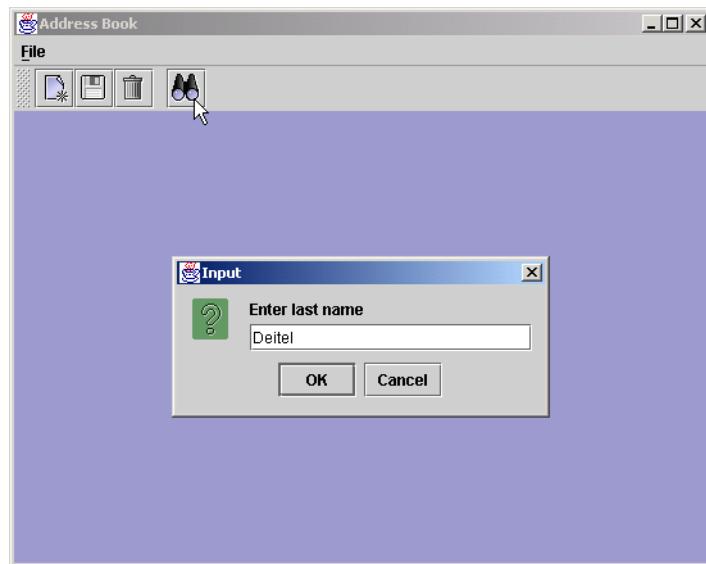


Fig. 8.39 Screen captures of the **AddressBook** application (part 2 of 3).

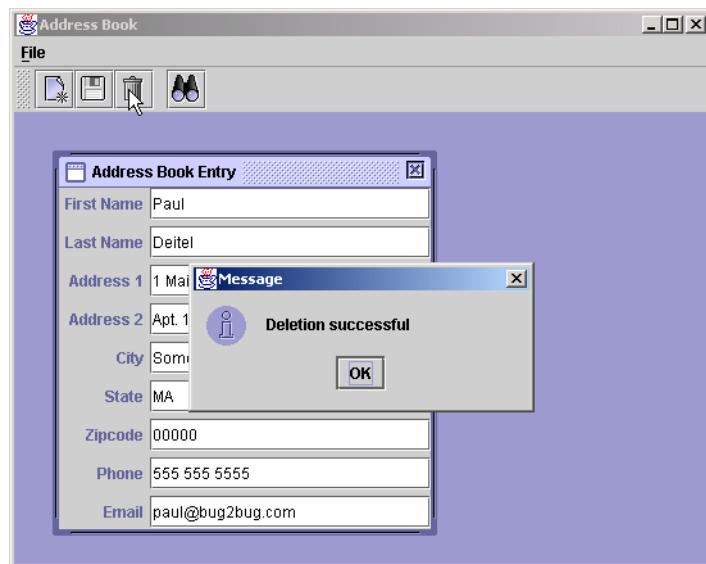
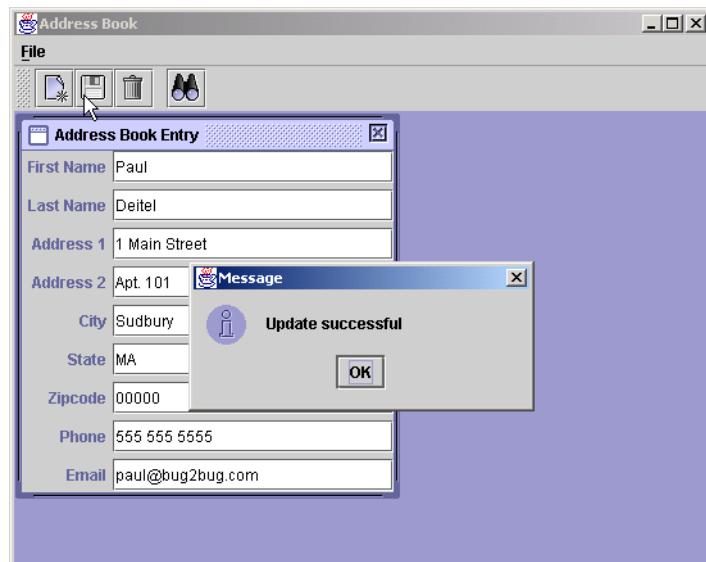


Fig. 8.39 Screen captures of the **AddressBook** application (part 3 of 3).

**NewAction** (lines 157–187) does not perform any database manipulations. It simply displays an **AddressBookEntryFrame** in which the user inputs the information for a new address book entry. To perform the actual insert into the database, the user must click the **Save** button or select **Save** from the **File** menu, which invokes the **SaveAction**. Class **NewAction**'s **actionPerformed** method (lines 172–185) creates a new **AddressBookEntryFrame** (lines 175–176), sets a new **AddressBookEntry** for the frame (lines 179–180), attaches the frame to the **JDesktopPane** (line 183) and displays the frame (line 184).

**SaveAction** (lines 191–251) determines whether to save a new entry or update an existing entry based on the **personID** for the **AddressBookEntry** in the currently active internal frame. Method **actionPerformed** (lines 206–249) obtains a reference to the active internal frame (lines 209–210) and gets the **AddressBookEntry** currently displayed (lines 213–214). Line 221 gets the **personID** from the **AddressBookEntry**. If the **personID** is 0, the **AddressBookEntry** represents a new address book entry, and line 229 invokes the **CloudscapeDataAccess** object's **newPerson** method to insert a new record in the database. If the **personID** is not 0, the **AddressBookEntry** represents an existing address book entry to update, and line 231 invokes the **CloudscapeDataAccess** object's **savePerson** method to update the record in the database. Methods **newPerson** and **savePerson** each receive an **AddressBookEntry** as an argument. Line 247 disposes of the active internal frame after the save operation completes.

**DeleteAction** (lines 254–311) uses the **AddressBookEntry** in the currently active internal frame to remove an entry from the database. Method **actionPerformed** (lines 269–309) obtains a reference to the active internal frame (lines 272–273) and gets the currently displayed **AddressBookEntry** (lines 276–277). If the **personID** in the **AddressBookEntry** is 0, the entry has not been stored in the database, so **actionPerformed** displays a message to the user and terminates (lines 282–288). Line 292 invokes the **CloudscapeDataAccess** object's **deletePerson** method, passing the **AddressBookEntry** to delete as an argument. Line 307 disposes of the active internal frame after the delete operation completes.

**SearchAction** (lines 314–366) searches for an address book entry based on the last name of the person input by the user. Method **actionPerformed** (lines 329–364) obtains the last name for which to search (lines 331–333). If the last name is not **null** (i.e., the user did not click the **Cancel** button in the input dialog), lines 341–342 create a new **AddressBookEntry** reference and invokes **database**'s **findPerson** method to locate the person in the database. If the person exists, **findPerson** returns the **AddressBookEntry** containing the information for that person. Then, **actionPerformed** creates a new **AddressBookEntryFrame** (lines 347–348), sets the **AddressBookEntry** for the frame (line 351), attaches the frame to the **JDesktopPane** (line 354) and displays the frame (line 355). Otherwise, **actionPerformed** displays a message dialog indicating that the record was not found.

In Fig. 8.39, the first screen capture shows the address-book application after the user clicks the **New** button to create a new entry. The second screen capture shows the results after the user inputs the information for the new entry and clicks the **Save** button to insert the data in the database. The third and fourth screen captures demonstrate searching for an entry in the database. The fifth screen capture demonstrates updating the person's city information. The sixth screen capture demonstrates deleting the record for the currently dis-

played entry. [Note: The screen captures do not show that after completing a **Save** or **Delete** operation, the internal frame that displays the entry is removed from the screen.]

## 8.8 Stored Procedures

Many database management systems can store individual SQL statements or sets of SQL statements in a database, so that programs accessing that database can invoke them. Such SQL statements are called *stored procedures*. JDBC enables programs to invoke stored procedures using objects that implement interface **CallableStatement**. Like **PreparedStatement**, **CallableStatements** can receive arguments specified with the methods inherited from interface **PreparedStatement**. In addition, **CallableStatements** can specify *output parameters* in which a stored procedure can place return values. Interface **CallableStatement** includes methods to specify which parameters in a stored procedure are output parameters. The interface also includes methods to obtain the values of output parameters returned from a stored procedure.



### Portability Tip 8.8

Although the syntax for creating stored procedures differs across database management systems, interface **CallableStatement** provides a uniform interface for specifying input and output parameters for stored procedures and for invoking stored procedures.



### Portability Tip 8.9

According to the Java API documentation for interface **CallableStatement**, for maximum portability between database systems, programs should process the update counts or **ResultSets** returned from a **CallableStatement** before obtaining the values of any output parameters.

## 8.9 Batch Processing

A series of database updates (e.g., inserts, updates, deletes) can be performed in a *batch update* to the database. JDBC **Statements**, **PreparedStatement**s and **CallableStatements** provide an **addBatch** method that enables the program to add SQL statements to a batch for future execution. Each **Statement**, **PreparedStatement** or **CallableStatement** object maintains its own list of SQL statements to perform in a batch update. Figure 8.40 describes the batch-processing methods of interfaces **Statement** and **PreparedStatement**. (**CallableStatements** inherit the methods of interface **PreparedStatement**.)

Method	Description
<code>public void addBatch( String sql )</code>	Method of interface <b>Statement</b> that receives a <b>String</b> argument specifying an SQL statement to add to the <b>Statement</b> 's batch for future execution. This method should not be used with <b>PreparedStatement</b> s and <b>CallableStatements</b> .

Fig. 8.40 **Statement** and **PreparedStatement** methods for batch updates (part 1 of 2).

Method	Description
<code>public void addBatch()</code>	Method of interface <b>PreparedStatement</b> that adds the statement to a batch for future execution. This method should be called after setting the parameters for the <b>PreparedStatement</b> . This version of <b>addBatch</b> also can be used with <b>CallableStatements</b> .
<code>public void clearBatch()</code>	Method of interface <b>Statement</b> that clears the statement's batch.
<code>public int[] executeBatch()</code>	Method of interface <b>Statement</b> that executes the statement's batch. The method returns an array of <b>int</b> values indicating the status of each SQL statement in the batch. The order of the values in the array corresponds to the order in which the SQL statements are added to the batch.

Fig. 8.40 **Statement** and **PreparedStatement** methods for batch updates (part 2 of 2).

Each method in Fig. 8.40 throws a **BatchUpdateException** (a subclass of **SQLException**) if database errors occur while executing any of the SQL statements or if the particular database management system does not support batch update processing. Method **executeBatch** also throws **BatchUpdateExceptions** if the batch update contains any SQL statements that return **ResultSets**.



### Common Programming Error 8.14

Batch updates are for use only with SQL statements that do not return **ResultSets**. Executing an SQL statement that returns a **ResultSet** as part of a batch update causes a **BatchUpdateException**.

After adding statements to a batch update, a program invokes **Statement** method **executeBatch** to execute the SQL statements in the batch. This method performs each SQL statement and returns an array of **int** values containing the status of each SQL statement. If the database connection is in autocommit mode, the database commits each statement as it completes execution. Otherwise, the program can determine whether or not to commit the transaction by inspecting the array of return values and then invoke the **Connection**'s **commit** or **rollback** method as appropriate. Figure 8.41 summarizes the return values of method **executeBatch**.

Return value	Description
a value greater than or equal to 0	Indicates successful execution of the SQL statements in the batch update. The value specifies the actual number of rows updated in the database.
-2	Indicates successful execution of the SQL statements in the batch update and that the affected number of rows is unknown.

Fig. 8.41 Return values of method **executeBatch** (part 1 of 2).

Return value	Description
-3	Indicates an SQL statement that failed to execute properly during a batch update. When the batch update is allowed to complete its processing, the array returned by <code>getUpdateCounts</code> contains the value -3 for any SQL statement that failed. When the batch update is not allowed to continue after an exception, the array returned by <code>getUpdateCounts</code> contains elements for only the SQL statements that executed successfully before the exception occurred. When a failure occurs, <code>executeUpdate</code> throws a <code>BatchUpdateException</code> . In such cases, the program can catch the exception and invoke <code>BatchUpdateException</code> method <code>getUpdateCounts</code> to obtain the array of update counts. Some databases allow a batch update to continue executing when an exception occurs, while others do not.

Fig. 8.41 Return values of method `executeBatch` (part 2 of 2).



### Software Engineering Observation 8.12

Normally, programs disable autocommit mode for a `Connection` before executing a batch update. Otherwise, each SQL statement in the batch update is committed individually, which prevents programs from deciding whether groups of SQL statements should be committed or rolled back, based on logic in the program.

## 8.10 Processing Multiple ResultSets or Update Counts

Some `Statements`, `PreparedStatement`s and `CallableStatement`s return multiple `ResultSets` or update counts. In such cases, programs should use `Statement` method `execute` to execute the SQL statements. After executing SQL statements, method `execute` returns a `boolean` indicating whether the first result is a `ResultSet` (`true`) or an update count (`false`). Based on `execute`'s return value, the program invokes method `getResultSet` or method `getUpdateCount` to obtain the first result. The program can obtain subsequent results by calling method `getMoreResults`. Figure 8.42 summarizes the methods for processing multiple results. [Note: Each of the methods in Fig. 8.42 is defined in interface `Statement` and inherited into interfaces `PreparedStatement` and `CallableStatement`.]

Method	Description
<code>public boolean execute()</code>	Programs use this method to execute SQL statements that can return multiple <code>ResultSets</code> or update counts. This method returns a <code>boolean</code> indicating whether the first result is a <code>ResultSet</code> ( <code>true</code> ) or an update count ( <code>false</code> ). Based on the value returned, the program can call <code>getResultSet</code> or <code>getUpdateCount</code> to obtain the first result.

Fig. 8.42 `Statement` methods that enable processing of multiple results returned by method `execute` (part 1 of 2).

Method	Description
<code>public boolean getMoreResults()</code>	After obtaining the first result returned from method <code>execute</code> , a program invokes this method to move to the next result. This method returns a <code>boolean</code> indicating whether the next result is a <code>ResultSet</code> ( <code>true</code> ) or an update count ( <code>false</code> ). Based on the value returned, the program can call <code>getResultSet</code> or <code>getUpdateCount</code> to obtain the next result.
<code>public ResultSet getResultSet()</code>	Obtains a <code>ResultSet</code> from the results returned by method <code>execute</code> . This method returns <code>null</code> if the result is not a <code>ResultSet</code> or if there are no more results.
<code>public int getUpdateCount()</code>	Obtains an update count from the results returned by method <code>execute</code> . This method returns <code>-1</code> if the result is not an update count or if there are no more results.

Fig. 8.42 `Statement` methods that enable processing of multiple results returned by method `execute` (part 2 of 2).



### Software Engineering Observation 8.13

A program has completed processing the results returned by method `execute` when method `getMoreResults` returns `false` and method `getUpdateCount` returns `-1`.

## 8.11 Updatable ResultSets

Some JDBC drivers support *updatable ResultSets*. Such `ResultSets` enable a program to insert, update and delete records using methods of interface `ResultSet`. If the JDBC driver supports updatable `ResultSets`, the program can invoke `Connection` method `createStatement`, `prepareStatement` or `prepareCall` and specify the constant `ResultSet.CONCUR_UPDATABLE` as the second argument (the first argument specifies the type of scrolling supported by the `ResultSet`).



### Software Engineering Observation 8.14

Normally, a query that produces an updatable `ResultSet` must select a table's primary key, so that updates can determine the proper records to manipulate in the database. Otherwise, the query returns a read-only `ResultSet`.

Interface `ResultSet` provides update methods that enable the program to specify new values for particular columns in the current `ResultSet` row. In addition, interface `ResultSet` provides methods `deleteRow`, `insertRow` and `updateRow` to manipulate the `ResultSet` and the underlying database. Method `deleteRow` deletes the current `ResultSet` row from the `ResultSet` and the database. Method `updateRow` updates the current row in the `ResultSet` and the database. Method `insertRow` inserts a new row in the `ResultSet` and the database. Every updatable `ResultSet` maintains

an insert row where the program can build a new record before inserting it in the **ResultSet** and the database. Before invoking **ResultSet**'s update methods to build the new record, the program must invoke **ResultSet** method **moveToInsertRow**. The **ResultSet** keeps track of the cursor's location before that operation. The program can return to the cursor location to continue processing the **ResultSet** by invoking **ResultSet** method **moveToCurrentRow**.

## 8.12 JDBC 2.0 Optional Package `javax.sql`

In addition to the classes and interfaces of package `java.sql`, many database vendors now support the JDBC 2.0 optional package `javax.sql`. Typically, this package is included with the implementation of the Java 2 Enterprise Edition. Some of the key interfaces in package `javax.sql` include **DataSource**, **ConnectionPoolDataSource**, **PooledConnection** and **RowSet**. Each of these interfaces is explained briefly in the next several subsections.

### 8.12.1 **DataSource**

A **DataSource** is new way for programs to obtain database connections. Enterprise Java applications often access information and resources (such as databases) that are external to those applications. In some cases, resources are distributed across a network. Enterprise application components must be able to locate the resources they use. An Enterprise Java application container must provide a *naming service* that implements the *Java Naming and Directory Interface (JNDI)* and enables the components executing in that container to perform name lookups to locate resources. Typically, **DataSources** are registered with a JNDI service that enables a program to locate the **DataSource**. Chapter 11 demonstrates our first Enterprise Java application that uses a JNDI service to look up a **DataSource** and connect to a database.

### 8.12.2 Connection Pooling

The process of connecting to a database requires substantial overhead in both time and resources. In a program that performs many separate database connections (such as a server in a Web-based shopping-cart application), such overhead can become a burden on the program. Applications can establish *connection pools* that maintain many database connections to eliminate the overhead of connecting to the database while many clients are waiting for responses in distributed applications. These connection objects can be shared between the application clients.

Databases that provide full support for the JDBC optional package include implementations of interfaces **ConnectionPoolDataSource** and **PooledConnection**. Like **DataSources** **ConnectionPoolDataSources** typically are registered with a JNDI service, so that a program can locate them dynamically. After obtaining a reference to a **ConnectionPoolDataSource**, a program can invoke its **getPooledConnection** method to obtain a **PooledConnection** object that represents the connection to the database. **PooledConnection** method **getConnection** returns the underlying **Connection** object that the program uses to create **Statements**, **PreparedStatement**s and **CallableStatements** for executing SQL statements.

### 8.12.3 RowSets

The JDBC optional package introduces a new interface, **RowSet**, for manipulating tabular data sources such as **ResultSets**. **RowSets** are not implemented as part of the database driver. Instead, they are implemented as JavaBeans that encapsulate a tabular data source.

Interface **RowSet** extends interface **ResultSet**. Thus, a **RowSet** object has all the functionality of a **ResultSet**, including the ability to scroll through the records, insert new records, update existing records and delete existing records. What makes a **RowSet** interesting is that all of these features are supported regardless of whether the **ResultSet** implementation provided by a particular database driver supports these features. For example, a program can create a **RowSet** based on a **ResultSet**, disconnect from the database and allow the program to update the data in the **RowSet**. Then the **RowSet** can connect to the database and update it, based on the changes made to the data in the **RowSet**. All of this can be accomplished even if the database driver does not support updatable **ResultSets**. **RowSets** that disconnect from the database and then reconnect to perform updates are called *disconnected RowSets*.

Unlike **ResultSets**, **RowSets** implementations can be serializable, so they can be saved locally or transmitted across a network. **RowSets** also support JavaBean events (with interface **RowSetListener** and class **RowSetEvent**) that enable an application using a **RowSet** to be notified when the **RowSet** cursor moves, a record is inserted, a record is updated, a record is deleted or the entire set of data in the **RowSet** changes. **RowSets** also allow a program to set parameters to the **RowSet**'s *command string*—normally, the SQL statement that obtains the data.

If you are interested in experimenting with **RowSets**, Sun Microsystems has three early access **RowSet** implementations available at

```
developer.java.sun.com/developer/earlyAccess/crs
```

These implementations are **CachedRowSet**, **WebRowSet** and **JDBCRowSet**.

Class **CachedRowSet** defines a disconnected **RowSet** that can be serialized. **CachedRowSet** provides full support for scrolling through data and updating data—both particularly useful in applications that require these capabilities even if the database driver's **ResultSet** implementation does not support scrolling through and updating data. The fact that **CachedRowSets** are serializable enables them to be sent across a network in a distributed network application.

Class **WebRowSet** is a subclass of **CachedRowSet** that enables **RowSet** data to be output as an XML document. Class **JDBCRowSet** defines a connected **RowSet** that encapsulates a **ResultSet** to make the **ResultSet** appear like a JavaBean to the program.

For a tutorial on using the Sun Microsystems, Inc., **RowSet** implementations, visit

```
developer.java.sun.com/developer/Books/JDBCTutorial/
chapter5.html
```

Also, check your database management system's documentation to determine whether your database provides any **RowSet** implementations.

## 8.13 Internet and World Wide Web Resources

[java.sun.com/products/jdbc](http://java.sun.com/products/jdbc)

Sun Microsystems, Inc.'s JDBC home page.

**[java.sun.com/docs/books/tutorial/jdbc/index.html](http://java.sun.com/docs/books/tutorial/jdbc/index.html)**

The Sun Microsystems, Inc., Java Tutorial's JDBC track.

**[www.sql.org](http://www.sql.org)**

This SQL portal provides links to many resources, including SQL syntax, tips, tutorials, books, magazines, discussion groups, companies with SQL services, SQL consultants and free software.

**[industry.java.sun.com/products/jdbc/drivers](http://industry.java.sun.com/products/jdbc/drivers)**

Sun Microsystems, Inc., search engine for locating JDBC drivers.

**[java.sun.com/j2se/1.3/docs/guide/jdbc/index.html](http://java.sun.com/j2se/1.3/docs/guide/jdbc/index.html)**

Sun Microsystems, Inc.'s JDBC API documentation.

**[java.sun.com/products/jdbc/faq.html](http://java.sun.com/products/jdbc/faq.html)**

Sun Microsystems, Inc.'s frequently asked questions on JDBC.

**[www.jguru.com/jguru/faq/faqpage.jsp?name=JDBC](http://www.jguru.com/jguru/faq/faqpage.jsp?name=JDBC)**

The JGuru JDBC FAQs.

**[www.cloudscape.com](http://www.cloudscape.com)**

This site is Informix's Cloudscape database home page. Here, you can download the latest version of Cloudscape and access all of its documentation on line.

**[java.sun.com/products/jdbc/articles/package2.html](http://java.sun.com/products/jdbc/articles/package2.html)**

An overview of the JDBC 2.0 optional package API.

**[developer.java.sun.com/developer/earlyAccess/crs](http://developer.java.sun.com/developer/earlyAccess/crs)**

Early access to the Sun **RowSet** implementations. [Note: You may need to register at the Java Developer Connection ([developer.java.sun.com/developer/index.html](http://developer.java.sun.com/developer/index.html)) before downloading from this site.]

**[developer.java.sun.com/developer/Books/JDBCTutorial/chapter5.html](http://developer.java.sun.com/developer/Books/JDBCTutorial/chapter5.html)**

Chapter 5 (**RowSet** Tutorial) of the book *The JDBC 2.0 API Tutorial and Reference, Second Edition*.

## SUMMARY

- A database is an integrated collection of data. A database management system (DBMS) provides mechanisms for storing and organizing data.
- Today's most popular database systems are relational databases.
- A language called Structured Query Language (SQL) is used almost universally with relational database systems to perform queries and manipulate data.
- A programming language connects to, and interacts with, relational databases via an interface—software that facilitates communications between a database management system and a program.
- Java programmers communicate with databases and manipulate their data using the Java Database Connectivity (JDBC) API. A JDBC driver implements the interface to a particular database.
- A relational database is composed of tables. A row of a table is called a record (or row).
- A primary key is a field that contains unique data that cannot be duplicated in other records.
- Each column of the table represents a different field (or column or attribute).
- The primary key can be composed of more than one column (or field) in the database.
- SQL provides a complete set of commands that enable programmers to define complex queries that select data from a table. The results of a query are commonly called result sets (or record sets).
- Every record must have a value in the primary-key field, and that value must be unique. This is known as the Rule of Entity Integrity.

- A one-to-many relationship between tables indicates that a record in one table can have many records in a separate table.
- A foreign key is a field for which every entry in one table has a unique value in another table and where the field in the other table is the primary key for that table.
- The foreign key helps maintain the Rule of Referential Integrity: Every foreign key field value must appear in another table's primary key field. Foreign keys enable information from multiple tables to be joined together for analysis purposes. There is a one-to-many relationship between a primary key and its corresponding foreign key.
- The simplest format of a **SELECT** query is

```
SELECT * FROM tableName
```

where the asterisk (\*) indicates that all rows and columns from *tableName* should be selected and *tableName* specifies the table in the database from which the data will be selected.

- To select specific fields from a table, replace the asterisk (\*) with a comma-separated list of the field names to select.
- Programmers process result sets by knowing in advance the order of the fields in the result set. Specifying the field names to select guarantees that the fields are always returned in the specified order, even if the actual order of the fields in the database table(s) changes.
- The optional **WHERE** clause in a **SELECT** query specifies the selection criteria for the query. The simplest format of a **SELECT** query with selection criteria is

```
SELECT fieldName1, fieldName2, ... FROM tableName WHERE criteria
```

- The **WHERE** clause condition can contain operators <, >, <=, >=, =, <> and **LIKE**. Operator **LIKE** is used for pattern matching with wildcard characters percent (%) and underscore (\_).
- A percent character (%) in a pattern indicates that a string matching the pattern can have zero or more characters at the percent character's location in the pattern.
- An underscore (\_) in the pattern string indicates a single character at that position in the pattern.
- The results of a query can be arranged in ascending or descending order using the optional **ORDER BY** clause. The simplest form of an **ORDER BY** clause is

```
SELECT fieldName1, fieldName2, ... FROM tableName ORDER BY field ASC  
SELECT fieldName1, fieldName2, ... FROM tableName ORDER BY field DESC
```

where **ASC** specifies ascending order, **DESC** specifies descending order and *field* specifies the field on which the sort is based. The default sorting order is ascending, so **ASC** is optional.

- Multiple fields can be used for ordering purposes with an **ORDER BY** clause of the form

```
ORDER BY field1 sortingOrder, field2 sortingOrder, ...
```

- The **WHERE** and **ORDER BY** clauses can be combined in one query.
- A join merges records from two or more tables by testing for matching values in a field that is common to both tables. The simplest format of a join is

```
SELECT fieldName1, fieldName2, ...  
FROM table1, table2  
WHERE table1.fieldName = table2.fieldName
```

The query's **WHERE** clause specifies the fields from each table that should be compared to determine which records will be selected. These fields normally represent the primary key in one table and the corresponding foreign key in the other table.

- If an SQL statement uses fields with the same name from multiple tables, the field names must be fully qualified with its table name and a dot operator ( . ).
- An **INSERT INTO** statement inserts a new record in a table. The simplest form of this statement is

```
INSERT INTO tableName ( fieldName1, fieldName2, ..., fieldNameN )
    VALUES ( value1, value2, ..., valueN )
```

where *tableName* is the table in which to insert the record. The *tableName* is followed by a comma-separated list of field names in parentheses. The list of field names is followed by the SQL keyword **VALUES** and a comma-separated list of values in parentheses.

- SQL statements use single quote ( ' ) as a delimiter for strings. To specify a string containing a single quote in an SQL statement, the single quote must be escaped with another single quote.
- An **UPDATE** statement modifies data in a table. The simplest form for an **UPDATE** statement is

```
UPDATE tableName
    SET fieldName1 = value1, fieldName2 = value2, ..., fieldNameN = valueN
    WHERE criteria
```

where *tableName* is the table in which to update a record (or records). The *tableName* is followed by keyword **SET** and a comma-separated list of field name/value pairs in the format *fieldName* = *value*. The **WHERE** clause *criteria* determines the record(s) to update.

- A **DELETE** statement removes data from a table. The simplest form for a **DELETE** statement is

```
DELETE FROM tableName WHERE criteria
```

where *tableName* is the table from which to delete a record (or records). The **WHERE** *criteria* determines which record(s) to delete.

- Package **java.sql** contains classes and interfaces for manipulating relational databases in Java.
- A program must load the database driver class before the program can connect to the database.
- JDBC supports four categories of drivers: JDBC-to-ODBC bridge driver (Type 1); Native-API, partly Java driver (Type 2); JDBC-Net pure Java driver (Type 3) and Native-Protocol pure Java driver (Type 4). Type 3 and 4 drivers are preferred, because they are pure Java solutions.
- An object that implements interface **Connection** manages the connection between the Java program and the database. **Connection** objects enable programs to create SQL statements that manipulate databases and to perform transaction processing.
- Method **getConnection** of class **DriverManager** attempts to connect to a database specified by its URL argument. The URL helps the program locate the database. The URL includes the protocol for communication, the subprotocol for communication and the name of the database.
- **Connection** method **createStatement** creates an object of type **Statement**. The program uses the **Statement** object to submit SQL statements to the database.
- **Statement** method **executeQuery** executes a query that selects information from a table or set of tables and returns an object that implements interface **ResultSet** containing the query results. **ResultSet** methods enable a program to manipulate query results.
- A **ResultSetMetaData** object describes a **ResultSet**'s contents. Programs can use metadata programmatically to obtain information about the **ResultSet** column names and types.
- **ResultSetMetaData** method **getColumnName** retrieves the number of columns in the **ResultSet**.
- **ResultSet** method **next** positions the **ResultSet** cursor to the next record in the **ResultSet**. The cursor keeps track of the current record. Method **next** returns **boolean** value **true**

if it is able to position to the next record; otherwise, the method returns **false**. This method must be called to begin processing a **ResultSet**.

- When processing **ResultSets**, it is possible to extract each column of the **ResultSet** as a specific Java data type. **ResultSetMetaData** method **getColumnType** returns a constant integer from class **Types** (package **java.sql**) indicating the type of the data for a specific column.
- **ResultSet** *get* methods typically receive as an argument either a column number (as an **int**) or a column name (as a **String**) indicating which column's value to obtain.
- **ResultSet** column numbers start at 1.
- Each **Statement** object can open only one **ResultSet** object at a time. When a **Statement** returns a new **ResultSet**, the **Statement** closes the prior **ResultSet**.
- **Connection** method **createStatement** has an overloaded version that takes two arguments: the result set type and the result set concurrency. The result set type specifies whether the **ResultSet**'s cursor is able to scroll in both directions or forward only and whether the **ResultSet** is sensitive to changes. The result set concurrency specifies whether the **ResultSet** can be updated with **ResultSet**'s update methods.
- Some **ResultSet** implementations do not support scrollable and/or updatable **ResultSets**.
- **TableModel** method **getColumnClass** returns a **Class** object that represents the superclass of all objects in a particular column. **JTable** uses this information to set up the default cell renderer and cell editor for that column in a **JTable**.
- **ResultSetMetaData** method **getColumnClassName** obtains the fully qualified class name of the specified column.
- **TableModel** method **getColumnCount** returns the number of columns in the model's underlying **ResultSet**.
- **ResultSetMetaData** method **getColumnCount** obtains the number of columns in the **ResultSet**.
- **TableModel** method **getColumnName** returns the name of the column in the model's underlying **ResultSet**.
- **ResultSetMetaData** method **getColumnName** obtains the column name from the **ResultSet**.
- **TableModel** method **getRowCount** returns the number of rows in the model's underlying **ResultSet**.
- **TableModel** method **getValueAt** returns the **Object** in a particular row and column of the model's underlying **ResultSet**.
- **ResultSet** method **absolute** positions the **ResultSet** cursor at a specific row.
- **AbstractTableModel** method **fireTableStructureChanged** notifies any **JTable** using a particular **TableModel** object as its model that the data in the model has changed.
- Interface **PreparedStatement** enables an application programmer to create SQL statements that are maintained in a compiled form that enables the statements to execute more efficiently than **Statement** objects. **PreparedStatement** objects are more flexible than **Statement** objects, because they can specify parameters.
- Question marks (?) in the SQL of a **PreparedStatement** represent placeholders for values that will be passed as part of the SQL statement to the database. Before the program executes a **PreparedStatement**, the program must specify the values of those parameters by using interface **PreparedStatement**'s *set* methods.
- Transaction processing enables a program that interacts with a database to treat a database operation (or set of operations) as a transaction. When the transaction completes, a decision can be made

to either commit the transaction or roll back the transaction. Java provides transaction processing via methods of interface **Connection**.

- Method **setAutoCommit** specifies whether each SQL statement commits after it completes (a **true** argument) or if SQL statements should be grouped as a transaction (a **false** argument).
- If autocommit is disabled the program must follow the last SQL statement in the transaction with a call to **Connection** method **commit** or **rollback**.
- JDBC enables programs to invoke stored procedures using objects that implement interface **CallableStatement**.
- **CallableStatements** can receive arguments specified with the methods inherited from interface **PreparedStatement**. In addition, **CallableStatements** can specify output parameters in which a stored procedure can place return values.
- A series of database updates can be performed in a batch update to the database. JDBC **Statements**, **PreparedStatements** and **CallableStatements** provide an **addBatch** method that enables the program to add SQL statements to a batch for future execution. Each **Statement**, **PreparedStatement** or **CallableStatement** object maintains its own list of SQL statements to perform in a batch update.
- **Statement** method **executeBatch** executes the SQL statements in a batch and returns an array of **int** values containing the status of each SQL statement. If the database connection is in autocommit mode, the database commits each statement as it completes execution. Otherwise, **Connection** methods **commit** or **rollback** must be called as appropriate.
- Programs use **Statement** method **execute** to execute **Statements**, **PreparedStatements** and **CallableStatements** that return multiple **ResultSets** or update counts. Method **execute** returns a **boolean** indicating whether the first result is a **ResultSet** (**true**) or an update count (**false**). The program invokes method **getResultSet** or method **getUpdateCount** to obtain the first result and obtains subsequent results with **getMoreResults**.
- Some JDBC drivers support updatable **ResultSets**. Such **ResultSets** enable a program to insert, update and delete records using methods of interface **ResultSet**.
- Interface **ResultSet** provides *update* methods that enable the program to specify new values for particular columns in the current **ResultSet** row.
- Interface **ResultSet** provides methods **deleteRow**, **insertRow** and **updateRow** to manipulate the **ResultSet** and the underlying database.
- Every updatable **ResultSet** maintains an insert row where the program can build a new record before inserting it into the **ResultSet** and the database. Before invoking **ResultSet**'s *update* methods to build the new record, the program must invoke **ResultSet** method **moveToInsertRow**. The **ResultSet** keeps track of the cursor's location before that operation and can return to the cursor location to continue processing the **ResultSet** by invoking **ResultSet** method **moveToCurrentRow**.
- A **DataSource** is new way for programs to obtain database connections that access databases which are external to those applications.
- Applications can establish connection pools that maintain many database connections. Databases that provide full support for the JDBC optional package include implementations of interfaces **ConnectionPoolDataSource** and **PooledConnection** for this purpose.
- The JDBC optional package introduces a new interface, **RowSet**, for manipulating tabular data sources such as **ResultSets**. **RowSets** are not implemented as part of the database driver. Instead, they are implemented as JavaBeans that encapsulate a tabular data source.

- Interface **RowSet** extends interface **ResultSet**. Thus, a **RowSet** object has all the functionality of a **ResultSet**, including the ability to scroll through the records, insert new records, update existing records and delete existing records.
- Unlike **ResultSets**, **RowSets** implementations can be serializable so they can be saved locally or transmitted across a network.
- **RowSets** support JavaBean events that enable an application using a **RowSet** to be notified when the **RowSet** cursor is moved, a record is inserted, a record is updated, a record is deleted or the entire set of data in the **RowSet** changes.
- Class **CachedRowSet** defines a disconnected **RowSet** that can be serialized. **CachedRowSet** provides full support for scrolling through data and updating data.
- Class **WebRowSet** is a subclass of **CachedRowSet** that enables **RowSet** data to be output as an XML document.
- Class **JDBCRowSet** defines a connected **RowSet** that encapsulates a **ResultSet** to make the **ResultSet** appear like a JavaBean to the program.

## TERMINOLOGY

% SQL wildcard character	<b>executeBatch</b> method of <b>Statement</b>
_ SQL wildcard character	<b>executeQuery</b> method of <b>Statement</b>
<b>absolute</b> method of <b>ResultSet</b>	<b>executeUpdate</b> method of <b>Statement</b>
<b>AbstractTableModel</b> class	field
<b>addBatch</b> method of <b>PreparedStatement</b>	<b>fireTableStructureChanged</b> method of <b>AbstractTableModel</b>
<b>addBatch</b> method of <b>Statement</b>	foreign key
<b>addTableModelListener</b> method of <b>TableModel</b>	<b>getAutoCommit</b> method of <b>Connection</b>
autocommit state	<b>getColumnClass</b> method of <b>TableModel</b>
batch processing	<b>getColumnName</b> method of <b>ResultSetMetaData</b>
<b>BatchUpdateException</b> class	<b>getColumnName</b> method of <b>TableModel</b>
<b>CachedRowSet</b> class	<b>getCount</b> method of <b>ResultSetMetaData</b>
<b>CallableStatement</b> interface	<b>getColumnName</b> method of <b>TableModel</b>
<b>clearBatch</b> method of <b>Statement</b>	<b>getColumnCount</b> method of <b>ResultSetMetaData</b>
<b>close</b> method of <b>Connection</b>	<b>getColumnCount</b> method of <b>TableModel</b>
<b>close</b> method of <b>Statement</b>	<b>getColumnName</b> method of <b>ResultSetMetaData</b>
Cloudscape database	<b>getColumnName</b> method of <b>TableModel</b>
<b>COM.cloudscape.core.RmiJdbcDriver</b>	<b>getColumnType</b> method of <b>ResultSetMetaData</b>
commit a transaction	<b>getConnection</b> method of <b>DriverManager</b>
<b>commit</b> method of <b>Connection</b>	<b>getConnection</b> method of <b>PooledConnection</b>
connect to a database	<b>getMetaData</b> method of <b>ResultSet</b>
<b>Connection</b> interface	<b>getMoreResults</b> method of <b>Statement</b>
connection pool	<b>getObject</b> method of <b>ResultSet</b>
<b>ConnectionPoolDataSource</b> interface	<b>getPooledConnection</b> method of <b>ConnectionPoolDataSource</b>
<b>createStatement</b> method of <b>Connection</b>	<b>getResultSet</b> method of <b>Statement</b>
database	<b>getRow</b> method of <b>ResultSet</b>
database driver	<b>getRowCount</b> method of <b>TableModel</b>
<b>DataSource</b> interface	<b>getUpdateCount</b> method of <b>Statement</b>
<b>DELETE FROM</b> SQL statement	<b>getUpdateCounts</b> method of <b>BatchUpdateException</b>
<b>deleteRow</b> method of <b>ResultSet</b>	
disconnected <b>RowSet</b>	
<b>DriverManager</b> class	
<b>execute</b> method of <b>Statement</b>	

<b>getValueAt</b> method of <b>TableModel</b>	<b>ResultSet</b> types
<b>INSERT INTO</b> SQL statement	<b>ResultSetMetaData</b> interface
<b>insertRow</b> method of <b>ResultSet</b>	roll back a transaction
Java Database Connectivity (JDBC)	<b>rollback</b> method of <b>Connection</b>
Java Look and Feel Graphics Repository	<b>RowSet</b> command string
Java Naming and Directory Interface (JNDI)	<b>RowSet</b> interface
<b>java.sql</b> package	<b>RowSetEvent</b> class
<b>javax.sql</b> package	<b>RowSetListener</b> interface
<b>javax.swing.table</b> package	Rule of Entity Integrity
JDBC driver	Rule of Referential Integrity
<b>jdbc:cloudscape:rmi:books</b>	<b>SELECT</b> SQL statement
<b>JdbcOdbcDriver</b>	selection criteria
<b>JDBCRowSet</b> class	<b>setAutoCommit</b> method of <b>Connection</b>
<b>last</b> method of <b>ResultSet</b>	<b>setString</b> method of <b>PreparedStatement</b>
metadata	SQL (Structured Query Language)
<b>moveToCurrentRow</b> method of <b>ResultSet</b>	SQL script
<b>moveToInsertRow</b> method of <b>ResultSet</b>	<b>SQLException</b> class
<b>next</b> method of <b>ResultSet</b>	<b>Statement</b> interface
one-to-many relationship	stored procedure
<b>ORDER BY</b> clause of an SQL statement	table column
ordering records	table row
pattern matching	<b>TableModel</b> interface
<b>PooledConnection</b> interface	<b>TableModelEvent</b> class
<b>PreparedStatement</b> interface	transaction processing
<b>prepareStatement</b> method of <b>Connection</b>	Type 1 (JDBC-to-ODBC bridge) driver
primary key	Type 2 (Native-API, partly Java) driver
query a database	Type 3 (JDBC-Net pure Java) driver
record	Type 4 (Native-Protocol pure Java) driver
record set	<b>Types</b> class
relational database	updatable <b>ResultSet</b>
<b>removeTableModelListener</b> method of	<b>UPDATE</b> operation
<b>TableModel</b>	<b>updateRow</b> method of <b>ResultSet</b>
result set	<b>WebRowSet</b> class
<b>ResultSet</b> interface	<b>WHERE</b> clause of an SQL statement

## SELF-REVIEW EXERCISES

### 8.1 Fill in the blanks in each of the following statements:

- a) The most popular database query language is \_\_\_\_\_.
- b) A table in a database consists of \_\_\_\_\_ and \_\_\_\_\_.
- c) Tables are manipulated in Java as \_\_\_\_\_ objects.
- d) The \_\_\_\_\_ uniquely identifies each record in a table.
- e) SQL keyword \_\_\_\_\_ is followed by the selection criteria that specify the records to select in a query.
- f) SQL keywords \_\_\_\_\_ specify the order in which records are sorted in a query.
- g) Selecting data from multiple database tables is called \_\_\_\_\_ the data.
- h) A \_\_\_\_\_ is an integrated collection of data that is centrally controlled.
- i) A \_\_\_\_\_ is a field in a table for which every entry has a unique value in another table and where the field in the other table is the primary key for that table.
- j) Package \_\_\_\_\_ contains classes and interfaces for manipulating relational databases in Java.

- k) Interface \_\_\_\_\_ helps manage the connection between the Java program and the database.
- l) A \_\_\_\_\_ object is used to submit a query to a database.

## ANSWERS TO SELF-REVIEW EXERCISES

**8.1** a) SQL. b) rows, columns. c) **ResultSet**. d) primary key. e) **WHERE**. f) **ORDER BY**. g) joining. h) database. i) foreign key. j) **java.sql**. k) **Connection**. l) **Statement**.

## EXERCISES

**8.2** Using the techniques shown in this chapter, define a complete query application for the **books** database. Provide a series of predefined queries, with an appropriate name for each query, displayed in a **JComboBox**. Also allow users to supply their own queries and add them to the **JComboBox**. Provide the following predefined queries:

- a) Select all authors from the **Authors** table.
- b) Select all publishers from the **Publishers** table.
- c) Select a specific author and list all books for that author. Include the title, year and ISBN number. Order the information alphabetically by the author's last name and first name.
- d) Select a specific publisher and list all books published by that publisher. Include the title, year and ISBN number. Order the information alphabetically by title.
- e) Provide any other queries you feel are appropriate.

**8.3** Modify Exercise 8.2 to define a complete database manipulation application for the **books** database. In addition to the querying, the user should be able to edit existing data and add new data to the database (obeying referential and entity integrity constraints). Allow the user to edit the database in the following ways:

- a) Add a new author.
- b) Edit the existing information for an author.
- c) Add a new title for an author. (Remember that the book must have an entry in the **AuthorISBN** table.) Be sure to specify the publisher of the title.
- d) Add a new publisher.
- e) Edit the existing information for a publisher.
- f) For each of the preceding database manipulations, design an appropriate GUI to allow the user to perform the data manipulation.

**8.4** Modify the **Search** capability in the address book example of Fig. 8.33–Fig. 8.38 to allow the user to scroll through the **ResultSet** in case there is more than one person with the specified last name in the **addressbook** database. Provide an appropriate GUI.

**8.5** Modify the address book example of Fig. 8.33–Fig. 8.38 to enable each address book entry to have multiple addresses, phone numbers and e-mail addresses. The user of the program should be able to view multiple addresses, phone numbers and e-mail addresses. The user also should be able to add, update or delete individual addresses, phone numbers and e-mail addresses. [Note: This exercise is large and requires substantial modifications to the original classes in the address book example.]

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# 9

# Servlets

## Objectives

- To execute servlets with the Apache Tomcat server.
- To be able to respond to HTTP requests from an **HttpServlet**.
- To be able to redirect requests to static and dynamic Web resources.
- To be able to maintain session information with cookies and **HttpSession** objects.
- To be able to access a database from a servlet.

*A fair request should be followed by the deed in silence.*

Dante Alighieri

*The longest part of the journey is said to be the passing of the gate.*

Marcus Terentius Varro

*If nominated, I will not accept; if elected, I will not serve.*

General William T. Sherman

*Me want cookie!*

The Cookie Monster, Sesame Street

*When to the sessions of sweet silent thought*

*I summon up remembrance of things past, ...*

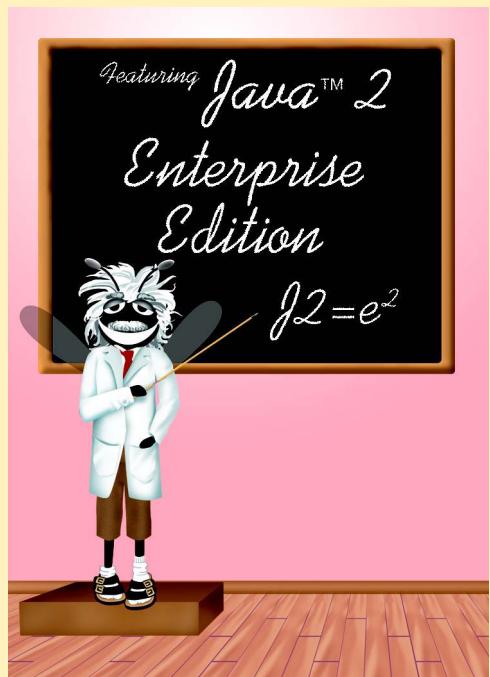
William Shakespeare

*Friends share all things.*

Pythagorus

*If at first you don't succeed, destroy all evidence that you tried.*

Newt Heilscher



## Outline

- 9.1 Introduction**
- 9.2 Servlet Overview and Architecture**
  - 9.2.1 Interface `Servlet` and the Servlet Life Cycle**
  - 9.2.2 `HttpServlet` Class**
  - 9.2.3 `HttpServletRequest` Interface**
  - 9.2.4 `HttpServletResponse` Interface**
- 9.3 Handling HTTP `get` Requests**
  - 9.3.1 Setting Up the Apache Tomcat Server**
  - 9.3.2 Deploying a Web Application**
- 9.4 Handling HTTP `get` Requests Containing Data**
- 9.5 Handling HTTP `post` Requests**
- 9.6 Redirecting Requests to Other Resources**
- 9.7 Session Tracking**
  - 9.7.1 Cookies**
  - 9.7.2 Session Tracking with `HttpSession`**
- 9.8 Multi-tier Applications: Using JDBC from a Servlet**
- 9.9 `HttpUtils` Class**
- 9.10 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

## 9.1 Introduction

There is much excitement over the Internet and the World Wide Web. The Internet ties the “information world” together. The World Wide Web makes the Internet easy to use and gives it the flair and sizzle of multimedia. Organizations see the Internet and the Web as crucial to their information systems strategies. Java provides a number of built-in networking capabilities that make it easy to develop Internet-based and Web-based applications. Not only can Java specify parallelism through multithreading, but it can enable programs to search the world for information and to collaborate with programs running on other computers internationally, nationally or just within an organization. Java can even enable applets and applications running on the same computer to communicate with one another, subject to security constraints.

Networking is a massive and complex topic. Computer science and computer engineering students typically take a full-semester, upper-level course in computer networking and continue with further study at the graduate level. Java provides a rich complement of networking capabilities and will likely be used as an implementation vehicle in computer networking courses. In *Advanced Java 2 Platform How to Program* we introduce several Java networking concepts and capabilities.

Java’s networking capabilities are grouped into several packages. The fundamental networking capabilities are defined by classes and interfaces of package **`java.net`**,

through which Java offers *socket-based communications* that enable applications to view networking as streams of data—a program can read from a *socket* or write to a socket as simply as reading from a file or writing to a file. The classes and interfaces of package **java.net** also offer *packet-based communications* that enable individual *packets* of information to be transmitted—commonly used to transmit audio and video over the Internet. Our book *Java How to Program, Fourth Edition* shows how to create and manipulate sockets and how to communicate with packets of data.

Higher-level views of networking are provided by classes and interfaces in the **java.rmi** packages (five packages) for *Remote Method Invocation (RMI)* and **org.omg** packages (seven packages) for *Common Object Request Broker Architecture (CORBA)* that are part of the Java 2 API. The RMI packages allow Java objects running on separate Java Virtual Machines (normally on separate computers) to communicate via remote method calls. Such method calls appear to be to an object in the same program, but actually have built-in networking (based on the capabilities of package **java.net**) that communicates the method calls to another object on a separate computer. The CORBA packages provide similar functionality to the RMI packages. A key difference between RMI and CORBA is that RMI can only be used between Java objects, whereas CORBA can be used between any two applications that understand CORBA—including applications written in other programming languages. In Chapter 13 of *Advanced Java 2 Platform How to Program*, we present Java’s RMI capabilities. Chapters 26–27 of *Advanced Java 2 Platform How to Program* discuss the basic CORBA concepts and present a case study that implements a distributed system in CORBA.

Our discussion of networking over the next two chapters focuses on both sides of a *client-server relationship*. The *client* requests that some action be performed and the *server* performs the action and responds to the client. This request-response model of communication is the foundation for the highest-level views of networking in Java—*servlets* and *JavaServer Pages (JSP)*. A servlet extends the functionality of a server. Packages **javax.servlet** and **javax.servlet.http** provide the classes and interfaces to define servlets. Packages **javax.servlet.jsp** and **javax.servlet.jsp.tagext** provide the classes and interfaces that extend the servlet capabilities for JavaServer Pages. Using special syntax, JSP allows Web-page implementors to create pages that use encapsulated Java functionality and even to write *scriptlets* of actual Java code directly in the page.

A common implementation of the request-response model is between World Wide Web browsers and World Wide Web servers. When a user selects a Web site to browse through their browser (the client application), a request is sent to the appropriate Web server (the server application). The server normally responds to the client by sending the appropriate XHTML Web page. Servlets are effective for developing Web-based solutions that help provide secure access to a Web site, interact with databases on behalf of a client, dynamically generate custom XHTML documents to be displayed by browsers and maintain unique session information for each client.



### Software Engineering Observation 9.1

Although servlets typically are used in distributed Web applications, not all servlets are required to enhance the functionality of a Web server.

This chapter begins our networking discussions with servlets that enhance the functionality of World Wide Web servers—the most common form of servlet today. Chapter 10 discusses JSPs, which are translated into servlets. JSPs are a convenient and powerful way

to implement the request/response mechanism of the Web without getting into the lower-level details of servlets. Together, servlets and JSPs form the Web tier of the Java 2 Enterprise Edition (J2EE).

Many developers feel that servlets are the right solution for database-intensive applications that communicate with so-called *thin clients*—applications that require minimal client-side support. The server is responsible for database access. Clients connect to the server using standard protocols available on most client platforms. Thus, the presentation-logic code for generating dynamic content can be written once and reside on the server for access by clients, to allow programmers to create efficient thin clients.

In this chapter, our servlet examples demonstrate the Web's request/response mechanism (primarily with **get** and **post** requests), session-tracking capabilities, redirecting requests to other resources and interacting with databases through JDBC. We placed this chapter after our discussion of JDBC and databases intentionally, so that we can build multi-tier, client–server applications that access databases. In Chapter 11, we build a book-store Web application, using XML technologies (Appendices A-D), JDBC technology from Chapter 8, the servlet technology from this chapter and the JSP technology from Chapter 10. We present additional servlet capabilities in the case study.

Sun Microsystems, through the *Java Community Process*, is responsible for the development of the servlet and JavaServer Pages specifications. The reference implementation of both these standards is under development by the *Apache Software Foundation* ([www.apache.org](http://www.apache.org)) as part of the *Jakarta Project* ([jakarta.apache.org](http://jakarta.apache.org)). As stated on the Jakarta Project's home page, “The goal of the Jakarta Project is to provide commercial-quality server solutions based on the Java Platform that are developed in an open and cooperative fashion.” There are many subprojects under the Jakarta project to help commercial server-side developers. The servlet and JSP part of the Jakarta Project is called *Tomcat*. This is the official reference implementation of the JSP and servlet standards. We use Tomcat to demonstrate the servlets in this chapter. The most recent implementation of Tomcat at the time of this writing was version 3.2.3. For your convenience, Tomcat 3.2.3 is included on the CD that accompanies *Advanced Java 2 Platform How to Program*. However, the most recent version always can be downloaded from the Apache Group's Web site. To execute the servlets in this chapter, you must install Tomcat or an equivalent servlet and JavaServer Pages implementation. We discuss the set up and configuration of Tomcat in Section 9.3.1 and Section 9.3.2 after we introduce our first example.

In our directions for testing each of the examples in this chapter, we indicate that you should copy files into specific Tomcat directories. All the example files for this chapter are located on the CD that accompanies this book and on our Web site [www.deitel.com](http://www.deitel.com).

[*Note:* At the end of Section 9.10, we provide a list of Internet specifications (as discussed in the Servlet 2.2 Specification) for technologies related to servlet development. Each is listed with its RFC (Request for Comments) number. We provide the URL of a Web site that allows you to locate each specification for your review.]

## 9.2 Servlet Overview and Architecture

In this section, we overview Java servlet technology. We discuss at a high level the servlet-related classes, methods and exceptions. The next several sections present live-code examples in which we build multi-tier client–server systems using servlet and JDBC technology.

The Internet offers many protocols. The *HTTP (Hypertext Transfer Protocol)* that forms the basis of the World Wide Web uses *URIs (Uniform Resource Identifiers)*—sometimes called *Universal Resource Locators* or *URLs*) to locate resources on the Internet. Common URIs represent files or directories and can represent complex tasks such as database lookups and Internet searches. For more information on URL formats, visit

**[www.w3.org/Addressing](http://www.w3.org/Addressing)**

For more information on the HTTP protocol, visit

**[www.w3.org/Protocols/HTTP](http://www.w3.org/Protocols/HTTP)**

For information on a variety of World Wide Web topics, visit

**[www.w3.org](http://www.w3.org)**

JavaServer Pages technology is an extension of servlet technology. Normally, JSPs are used primarily when most of the content sent to the client is static text and markup, and only a small portion of the content is generated dynamically with Java code. Normally, servlets are used when a small portion of the content sent to the client is static text or markup. In fact, some servlets do not produce content. Rather, they perform a task on behalf of the client, then invoke other servlets or JSPs to provide a response. Note that in most cases servlet and JSP technologies are interchangeable. The server that executes a servlet often is referred to as the  *servlet container* or  *servlet engine*.

Servlets and JavaServer Pages have become so popular that they are now supported directly or with third-party plug-ins by most major Web servers and application servers, including the Netscape iPlanet Application Server, Microsoft's Internet Information Server (IIS), the Apache HTTP Server, BEA's WebLogic application server, IBM's WebSphere application server, the World Wide Web Consortium's Jigsaw Web server, and many more.

The servlets in this chapter demonstrate communication between clients and servers via the HTTP protocol. A client sends an HTTP request to the server or servlet container. The server or servlet container receives the request and directs it to be processed by the appropriate servlet. The servlet does its processing, which may include interacting with a database or other server-side components such as other servlets, JSPs or Enterprise JavaBeans (Chapter 16). The servlet returns its results to the client—normally in the form of an HTML, XHTML or XML document to display in a browser, but other data formats, such as images and binary data, can be returned.

### 9.2.1 Interface **Servlet** and the Servlet Life Cycle

Architecturally, all servlets must implement the **Servlet** interface. As with many key applet methods, the methods of interface **Servlet** are invoked automatically (by the server on which the servlet is installed, also known as the servlet container). This interface defines five methods described in Fig. 9.1.



#### Software Engineering Observation 9.2

All servlets must implement the **Servlet** interface of package **javax.servlet**.

Method	Description
<b>void init( ServletConfig config )</b>	This method is automatically called once during a servlet’s execution cycle to initialize the servlet. The <b>ServletConfig</b> argument is supplied by the servlet container that executes the servlet.
<b>ServletConfig getServletConfig()</b>	This method returns a reference to an object that implements interface <b>ServletConfig</b> . This object provides access to the servlet’s configuration information such as servlet initialization parameters and the servlet’s <b>ServletContext</b> , which provides the servlet with access to its environment (i.e., the servlet container in which the servlet executes).
<b>String getServletInfo()</b>	This method is defined by a servlet programmer to return a <b>String</b> containing servlet information such as the servlet’s author and version.
<b>void service( ServletRequest request, ServletResponse response )</b>	The servlet container calls this method to respond to a client request to the servlet.
<b>void destroy()</b>	This “cleanup” method is called when a servlet is terminated by its servlet container. Resources used by the servlet, such as an open file or an open database connection, should be deallocated here.

Fig. 9.1 Methods of interface **Servlet** (package `javax.servlet`).

A servlet’s life cycle begins when the servlet container loads the servlet into memory—normally, in response to the first request that the servlet receives. Before the servlet can handle that request, the servlet container invokes the servlet’s **init** method. After **init** completes execution, the servlet can respond to its first request. All requests are handled by a servlet’s **service** method, which receives the request, processes the request and sends a response to the client. During a servlet’s life cycle, method **service** is called once per request. Each new request typically results in a new thread of execution (created by the servlet container) in which method **service** executes. When the servlet container terminates the servlet, the servlet’s **destroy** method is called to release servlet resources.



### Performance Tip 9.1

*Starting a new thread for each request is more efficient than starting an entirely new process, as is the case in some other server-side technologies such as CGI. [Note: Like servlets, Fast CGI eliminates the overhead of starting a new process for each request.]*

The servlet packages define two **abstract** classes that implement the interface **Servlet**—class **GenericServlet** (from the package `javax.servlet`) and class **HttpServlet** (from the package `javax.servlet.http`). These classes provide default implementations of all the **Servlet** methods. Most servlets extend either **GenericServlet** or **HttpServlet** and override some or all of their methods.

The examples in this chapter all extend class **HttpServlet**, which defines enhanced processing capabilities for servlets that extend the functionality of a Web server. The key method in every servlet is **service**, which receives both a **ServletRequest** object and a **ServletResponse** object. These objects provide access to input and output streams that allow the servlet to read data from the client and send data to the client. These streams can be either byte based or character based. If problems occur during the execution of a servlet, either **ServletExceptions** or **IOExceptions** are thrown to indicate the problem.



#### Software Engineering Observation 9.3

Servlets can implement tagging interface `javax.servlet.SingleThreadModel` to indicate that only one thread of execution may enter method **service** on a particular servlet instance at a time. When a servlet implements **SingleThreadModel**, the servlet container can create multiple instances of the servlet to handle multiple requests to the servlet in parallel. In this case, you may need to provide synchronized access to shared resources used by method **service**.

### 9.2.2 HttpServlet Class

Web-based servlets typically extend class **HttpServlet**. Class **HttpServlet** overrides method **service** to distinguish between the typical requests received from a client Web browser. The two most common *HTTP request types* (also known as *request methods*) are **get** and **post**. A **get** request *gets* (or *retrieves*) information from a server. Common uses of **get** requests are to retrieve an HTML document or an image. A **post** request *posts* (or *sends*) data to a server. Common uses of **post** requests typically send information, such as authentication information or data from a *form* that obtains user input, to a server.

Class **HttpServlet** defines methods **doGet** and **doPost** to respond to **get** and **post** requests from a client, respectively. These methods are called by the **service** method, which is called when a request arrives at the server. Method **service** first determines the request type, then calls the appropriate method for handling such a request. Other less common request types are beyond the scope of this book. Methods of class **HttpServlet** that respond to the other request types are shown in Fig. 9.2. They all receive parameters of type **HttpServletRequest** and **HttpServletResponse** and return **void**. The methods of Fig. 9.2 are not frequently used. For more information on the HTTP protocol, visit

[www.w3.org/Protocols](http://www.w3.org/Protocols).



#### Software Engineering Observation 9.4

Do not override method **service** in an **HttpServlet** subclass. Doing so prevents the servlet from distinguishing between request types.

Methods **doGet** and **doPost** receive as arguments an **HttpServletRequest** object and an **HttpServletResponse** object that enable interaction between the client and the server. The methods of **HttpServletRequest** make it easy to access the data supplied as part of the request. The **HttpServletResponse** methods make it easy to return the servlet's results to the Web client. Interfaces **HttpServletRequest** and **HttpServletResponse** are discussed in the next two sections.

Method	Description
<b>doDelete</b>	Called in response to an HTTP <b>delete</b> request. Such a request is normally used to delete a file from a server. This may not be available on some servers, because of its inherent security risks (i.e., the client could delete a file that is critical to the execution of the server or an application).
<b>doOptions</b>	Called in response to an HTTP <b>options</b> request. This returns information to the client indicating the HTTP options supported by the server, such as the version of HTTP (1.0 or 1.1) and the request methods the server supports.
<b>doPut</b>	Called in response to an HTTP <b>put</b> request. Such a request is normally used to store a file on the server. This may not be available on some servers, because of its inherent security risks (i.e., the client could place an executable application on the server, which, if executed, could damage the server—perhaps by deleting critical files or occupying resources).
<b>doTrace</b>	Called in response to an HTTP <b>trace</b> request. Such a request is normally used for debugging. The implementation of this method automatically returns an HTML document to the client containing the request header information (data sent by the browser as part of the request).

Fig. 9.2 Other methods of class **HttpServlet**.

### 9.2.3 **HttpServletRequest** Interface

Every call to **doGet** or **doPost** for an **HttpServlet** receives an object that implements interface **HttpServletRequest**. The Web server that executes the servlet creates an **HttpServletRequest** object and passes this to the servlet's **service** method (which, in turn, passes it to **doGet** or **doPost**). This object contains the request from the client. A variety of methods are provided to enable the servlet to process the client's request. Some of these methods are from interface **ServletRequest**—the interface that **HttpServletRequest** extends. A few key methods used in this chapter are presented in Fig. 9.3. You can view a complete list of **HttpServletRequest** methods online at

[java.sun.com/j2ee/j2sdkee/techdocs/api/javax/servlet/http/  
HttpServletRequest.html](http://java.sun.com/j2ee/j2sdkee/techdocs/api/javax/servlet/http/HttpServletRequest.html)

or you can download and install Tomcat (discussed in Section 9.3.1) and view the documentation on your local computer.

Method	Description
<b>String getParameter( String name )</b>	Obtains the value of a parameter sent to the servlet as part of a <b>get</b> or <b>post</b> request. The <b>name</b> argument represents the parameter name.

Fig. 9.3 Some methods of interface **HttpServletRequest** (part 1 of 2).

Method	Description
<code>Enumeration getParameterNames()</code>	Returns the names of all the parameters sent to the servlet as part of a <code>post</code> request.
<code>String[] getParameterValues( String name )</code>	For a parameter with multiple values, this method returns an array of <code>Strings</code> containing the values for a specified servlet parameter.
<code>Cookie[] getCookies()</code>	Returns an array of <code>Cookie</code> objects stored on the client by the server. <code>Cookies</code> can be used to uniquely identify clients to the servlet.
<code>HttpSession getSession( boolean create )</code>	Returns an <code>HttpSession</code> object associated with the client's current browsing session. An <code>HttpSession</code> object can be created by this method ( <code>true</code> argument) if an <code>HttpSession</code> object does not already exist for the client. <code>HttpSession</code> objects can be used in similar ways to <code>Cookies</code> for uniquely identifying clients.

Fig. 9.3 Some methods of interface `HttpServletRequest` (part 2 of 2).

#### 9.2.4 `HttpServletResponse` Interface

Every call to `doGet` or `doPost` for an `HttpServlet` receives an object that implements interface `HttpServletResponse`. The Web server that executes the servlet creates an `HttpServletResponse` object and passes it to the servlet's `service` method (which, in turn, passes it to `doGet` or `doPost`). This object provides a variety of methods that enable the servlet to formulate the response to the client. Some of these methods are from interface `ServletResponse`—the interface that `HttpServletResponse` extends. A few key methods used in this chapter are presented in Fig. 9.4. You can view a complete list of `HttpServletResponse` methods online at

[java.sun.com/j2ee/j2sdkee/techdocs/api/javax/servlet/http/HttpServletResponse.html](http://java.sun.com/j2ee/j2sdkee/techdocs/api/javax/servlet/http/HttpServletResponse.html)

or you can download and install Tomcat (discussed in Section 9.3.1) and view the documentation on your local computer..

Method	Description
<code>void addCookie( Cookie cookie )</code>	Used to add a <code>Cookie</code> to the header of the response to the client. The <code>Cookie</code> 's maximum age and whether <code>Cookies</code> are enabled on the client determine if <code>Cookies</code> are stored on the client.

Fig. 9.4 Some methods of interface `HttpServletResponse` (part 1 of 2).

Method	Description
<code>ServletOutputStream getOutputStream()</code>	Obtains a byte-based output stream for sending binary data to the client.
<code>PrintWriter getWriter()</code>	Obtains a character-based output stream for sending text data to the client.
<code>void setContentType( String type )</code>	Specifies the MIME type of the response to the browser. The MIME type helps the browser determine how to display the data (or possibly what other application to execute to process the data). For example, MIME type " <code>text/html</code> " indicates that the response is an HTML document, so the browser displays the HTML page. For more information on

Fig. 9.4 Some methods of interface `HttpServletResponse` (part 2 of 2).

### 9.3 Handling HTTP `get` Requests

The primary purpose of an HTTP `get` request is to retrieve the content of a specified URL—normally the content is an HTML or XHTML document (i.e., a Web page). The servlet of Fig. 9.5 and the XHTML document of Fig. 9.6 demonstrate a servlet that handles HTTP `get` requests. When the user clicks the **Get HTML Document** button (Fig. 9.6), a `get` request is sent to the servlet `WelcomeServlet` (Fig. 9.5). The servlet responds to the request by generating dynamically an XHTML document for the client that displays “**Welcome to Servlets!**”. Figure 9.5 shows the `WelcomeServlet` source code. Figure 9.6 shows the XHTML document the client loads to access the servlet and shows screen captures of the client’s browser window before and after the interaction with the servlet. [Note: Section 9.3.1 discusses how to set up and configure Tomcat to execute this example.]

Lines 5 and 6 import the `javax.servlet` and `javax.servlet.http` packages. We use several data types from these packages in the example.

Package `javax.servlet.http` provides superclass `HttpServlet` for servlets that handle HTTP `get` requests and HTTP `post` requests. This class implements interface `javax.servlet.Servlet` and adds methods that support HTTP protocol requests. Class `WelcomeServlet` extends `HttpServlet` (line 9) for this reason.

Superclass `HttpServlet` provides method `doGet` to respond to `get` requests. Its default functionality is to indicate a “Method not allowed” error. Typically, this error is indicated in Internet Explorer with a Web page that states “This page cannot be displayed” and in Netscape Navigator with a Web page that states “Error: 405.” Lines 12–44 override method `doGet` to provide custom `get` request processing. Method `doGet` receives two arguments—an `HttpServletRequest` object and an `HttpServletResponse` object (both from package `javax.servlet.http`). The `HttpServletRequest` object represents the client’s request, and the `HttpServletResponse` object represents the server’s response to the client. If method `doGet` is unable to handle a client’s request, it throws an exception of type `javax.servlet.ServletException`. If `doGet` encounters an error during stream processing (reading from the client or writing to the client), it throws a `java.io.IOException`.

```
1 // Fig. 9.5: WelcomeServlet.java
2 // A simple servlet to process get requests.
3 package com.deitel.advjhttp1.servlets;
4
5 import javax.servlet.*;
6 import javax.servlet.http.*;
7 import java.io.*;
8
9 public class WelcomeServlet extends HttpServlet {
10
11     // process "get" requests from clients
12     protected void doGet( HttpServletRequest request,
13                         HttpServletResponse response )
14             throws ServletException, IOException
15     {
16         response.setContentType( "text/html" );
17         PrintWriter out = response.getWriter();
18
19         // send XHTML page to client
20
21         // start XHTML document
22         out.println( "<?xml version = \"1.0\"?>" );
23
24         out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
25                     "XHTML 1.0 Strict//EN" \"http://www.w3.org" +
26                     "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
27
28         out.println(
29             "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
30
31         // head section of document
32         out.println( "<head>" );
33         out.println( "<title>A Simple Servlet Example</title>" );
34         out.println( "</head>" );
35
36         // body section of document
37         out.println( "<body>" );
38         out.println( "<h1>Welcome to Servlets!</h1>" );
39         out.println( "</body>" );
40
41         // end XHTML document
42         out.println( "</html>" );
43         out.close(); // close stream to complete the page
44     }
45 }
```

Fig. 9.5 **WelcomeServlet** that responds to a simple HTTP **get** request.

To demonstrate a response to a **get** request, our servlet creates an XHTML document containing the text “**Welcome to Servlets!**”. The text of the XHTML document is the response to the client. The response is sent to the client through the **PrintWriter** object obtained from the **HttpServletResponse** object.

Line 16 uses the **response** object's **setContentType** method to specify the content type of the data to be sent as the response to the client. This enables the client browser to understand and handle the content. The content type also is known as the *MIME* type (*Multipurpose Internet Mail Extension*) of the data. In this example, the content type is **text/html** to indicate to the browser that the response is an XHTML document. The browser knows that it must read the XHTML tags in the document, format the document according to the tags and display the document in the browser window. For more information on MIME types visit [www.irvine.com/~mime](http://www.irvine.com/~mime).

Line 17 uses the **response** object's **getWriter** method to obtain a reference to the **PrintWriter** object that enables the servlet to send content to the client. [Note: If the response is binary data, such as an image, method **getOutputStream** is used to obtain a reference to a **ServletOutputStream** object.]

Lines 22–42 create the XHTML document by writing strings with the **out** object's **println** method. This method outputs a newline character after its **String** argument. When rendering the Web page, the browser does not use the newline character. Rather, the newline character appears in the XHTML source that you can see by selecting **Source** from the **View** menu in Internet Explorer or **Page Source** from the **View** menu in Netscape Navigator. Line 43 closes the output stream, flushes the output buffer and sends the information to the client. This commits the response to the client.

The XHTML document in Fig. 9.6 provides a **form** that invokes the servlet defined in Fig. 9.5. The **form**'s **action** (`/advjhttp1/welcome`) specifies the URL path that invokes the servlet, and the **form**'s **method** indicates that the browser sends a **get** request to the server, which results in a call to the servlet's **doGet** method. The URL specified as the **action** in this example is discussed in detail in Section 9.3.2 after we show how to set up and configure the *Apache Tomcat server* to execute the servlet in Fig. 9.5.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 9.6: WelcomeServlet.html -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8 <head>
9   <title>Handling an HTTP Get Request</title>
10 </head>
11
12 <body>
13   <form action = "/advjhttp1/welcome1" method = "get">
14
15     <p><label>Click the button to invoke the servlet
16       <input type = "submit" value = "Get HTML Document" />
17     </label></p>
18
19   </form>
20 </body>
21 </html>
```

Fig. 9.6 HTML document in which the **form**'s **action** invokes **WelcomeServlet** through the alias **welcome1** specified in **web.xml** (part 1 of 2).

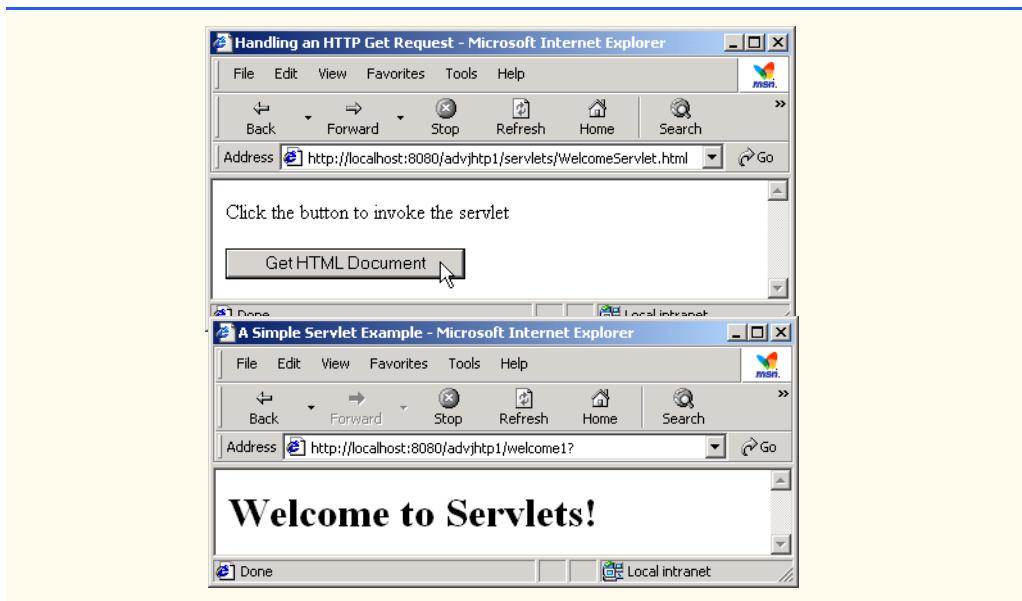


Fig. 9.6 HTML document in which the `form's action` invokes `WelcomeServlet` through the alias `welcome1` specified in `web.xml` (part 2 of 2).

Note that the sample screen captures show a URL containing the server name **localhost**—a well-known server *host name* on most computers that support TCP/IP-based networking protocols such as HTTP. We often use **localhost** to demonstrate networking programs on the local computer, so that readers without a network connection can still learn network programming concepts. In this example, **localhost** indicates that the server on which the servlet is installed is running on the local machine. The server host name is followed by **:8080**, specifying the TCP port number at which the Tomcat server awaits requests from clients. Web browsers assume TCP port 80 by default as the server port at which clients make requests, but the Tomcat server awaits client requests at TCP port 8080. This allows Tomcat to execute on the same computer as a standard Web server application without affecting the Web server application’s ability to handle requests. If we do not explicitly specify the port number in the URL, the servlet never will receive our request and an error message will be displayed in the browser.



#### Software Engineering Observation 9.5

The Tomcat documentation specifies how to integrate Tomcat with popular Web server applications such as the Apache HTTP Server and Microsoft’s IIS.

Ports in this case are not physical hardware ports to which you attach cables; rather, they are logical locations named with integer values that allow clients to request different services on the same server. The port number specifies the logical location where a server waits for and receives connections from clients—this is also called the *handshake point*. When a client connects to a server to request a service, the client must specify the port number for that service; otherwise, the client request cannot be processed. Port numbers are positive integers with values up to 65,535, and there are separate sets of these port numbers for both the TCP and UDP protocols. Many operating systems reserve port numbers below

1024 for system services (such as email and World Wide Web servers). Generally, these ports should not be specified as connection ports in your own server programs. In fact, some operating systems require special access privileges to use port numbers below 1024.

With so many ports from which to choose, how does a client know which port to use when requesting a service? The term *well-known port number* often is used when describing popular services on the Internet such as Web servers and email servers. For example, a Web server waits for clients to make requests at port 80 by default. All Web browsers know this number as the well-known port on a Web server where requests for HTML documents are made. So when you type a URL into a Web browser, the browser normally connects to port 80 on the server. Similarly, the Tomcat server uses port 8080 as its port number. Thus, requests to Tomcat for Web pages or to invoke servlets and JavaServer Pages must specify that the Tomcat server waiting for requests on port 8080.

The client can access the servlet only if the servlet is installed on a server that can respond to servlet requests. In some cases, servlet support is built directly into the Web server, and no special configuration is required to handle servlet requests. In other cases, it is necessary to integrate a servlet container with a Web server (as can be done with Tomcat and the Apache or IIS Web servers). Web servers that support servlets normally have an installation procedure for servlets. If you intend to execute your servlet as part of a Web server, please refer to your Web server's documentation on how to install a servlet. For our examples, we demonstrate servlets with the Apache Tomcat server. Section 9.3.1 discusses the setup and configuration of Tomcat for use with this chapter. Section 9.3.2 discusses the deployment of the servlet in Fig. 9.5.

### 9.3.1 Setting Up the Apache Tomcat Server

Tomcat is a fully functional implementation of the JSP and servlet standards. It includes a Web server, so it can be used as a standalone test container for JSPs and servlets. Tomcat also can be specified as the handler for JSP and servlet requests received by popular Web servers such as the Apache Software Foundation's Apache Web server or Microsoft's Internet Information Server (IIS). Tomcat is integrated into the Java 2 Enterprise Edition reference implementation from Sun Microsystems.

The most recent release of Tomcat (version 3.2.3) can be downloaded from

[jakarta.apache.org/builds/jakarta-tomcat/release/v3.2.3/bin/](http://jakarta.apache.org/builds/jakarta-tomcat/release/v3.2.3/bin/)

where there are a number of archive files. The complete Tomcat implementation is contained in the files that begin with the name **jakarta-tomcat-3.2.3**. Zip, tar and compressed tar files are provided for Windows, Linux and Solaris.

Extract the contents of the archive file to a directory on your hard disk. By default, the name of the directory containing Tomcat is **jakarta-tomcat-3.2.3**. For Tomcat to work correctly, you must define environment variables **JAVA\_HOME** and **TOMCAT\_HOME**. **JAVA\_HOME** should point to the directory containing your Java installation (ours is **d:\jdk1.3.1**), and **TOMCAT\_HOME** should point to the directory that contains Tomcat (ours is **d:\jakarta-tomcat-3.2.3**).

#### Testing and Debugging Tip 9.1



*On some platforms you may need to restart your computer for the new environment variables to take effect.*

After setting the environment variables, you can start the Tomcat server. Open a command prompt (or shell) and change directories to **bin** in **jakarta-tomcat-3.2.3**. In this directory are the files **tomcat.bat** and **tomcat.sh**, for starting the Tomcat server on Windows and UNIX (Linux or Solaris), respectively. To start the server, type

```
tomcat start
```

This launches the Tomcat server. The Tomcat server executes on TCP port 8080 to prevent conflicts with standard Web servers that typically execute on TCP port 80. To prove that Tomcat is executing and can respond to requests, open your Web browser and enter the URL

```
http://localhost:8080/
```

This should display the Tomcat documentation home page (Fig. 9.7). The host **localhost** indicates to the Web browser that it should request the home page from the Tomcat server on the local computer.

If the Tomcat documentation home page does not display, try the URL

```
http://127.0.0.1:8080/
```

The host **localhost** translates to the IP address **127.0.0.1**.



### Testing and Debugging Tip 9.2

*If the host name **localhost** does not work on your computer, substitute the IP address **127.0.0.1** instead.*

To shut down the Tomcat server, issue the command

```
tomcat stop
```

from a command prompt (or shell).



Fig. 9.7 Tomcat documentation home page. (Courtesy of The Apache Software Foundation.)

### 9.3.2 Deploying a Web Application

JSPs, servlets and their supporting files are deployed as part of *Web applications*. Normally, Web applications are deployed in the **webapps** subdirectory of **jakarta-tomcat-3.2.3**. A Web application has a well-known directory structure in which all the files that are part of the application reside. This directory structure can be created by the server administrator in the **webapps** directory, or the entire directory structure can be archived in a *Web application archive file*. Such an archive is known as a *WAR file* and ends with the **.war** file extension. If a WAR file is placed in the **webapps** directory, then, when the Tomcat server begins execution, it extracts the contents of the WAR file into the appropriate **webapps** subdirectory structure. For simplicity as we teach servlets and JavaServer Pages, we create the already expanded directory structure for all the examples in this chapter and Chapter 10.

The Web application directory structure contains a *context root*—the top-level directory for an entire Web application—and several subdirectories. These are described in Fig. 9.8.



#### Common Programming Error 9.1

Using “servlet” or “servlets” as a context root may prevent a servlet from working correctly on some servers.

Configuring the context root for a Web application in Tomcat simply requires creating a subdirectory in the **webapps** directory. When Tomcat begins execution, it creates a context root for each subdirectory of **webapps**, using each subdirectory’s name as a context root name. To test the examples in this chapter and Chapter 10, create the directory **advjhttp1** in Tomcat’s **webapps** directory.

Directory	Description
context root	This is the root directory for the Web application. The name of this directory is chosen by the Web application developer. All the JSPs, HTML documents, servlets and supporting files such as images and class files reside in this directory or its subdirectories. The name of this directory is specified by the Web application creator. To provide structure in a Web application, subdirectories can be placed in the context root. For example, if your application uses many images, you might place an images subdirectory in this directory. The examples of this chapter and Chapter 10 use <b>advjhttp1</b> as the context root.
<b>WEB-INF</b>	This directory contains the Web application <i>deployment descriptor</i> ( <b>web.xml</b> ).
<b>WEB-INF/classes</b>	This directory contains the servlet class files and other supporting class files used in a Web application. If the classes are part of a package, the complete package directory structure would begin here.
<b>WEB-INF/lib</b>	This directory contains Java archive (JAR) files. The JAR files can contain servlet class files and other supporting class files used in a Web application.

Fig. 9.8 Web application standard directories.

After configuring the context root, we must configure our Web application to handle the requests. This configuration occurs in a *deployment descriptor*, which is stored in a file called **web.xml**. The deployment descriptor specifies various configuration parameters such as the name used to invoke the servlet (i.e., its *alias*), a description of the servlet, the servlet's fully qualified class name and a  *servlet mapping* (i.e., the path or paths that cause the servlet container to invoke the servlet). You must create the **web.xml** file for this example. Many Java Web-application deployment tools create the **web.xml** file for you. The **web.xml** file for the first example in this chapter is shown in Fig. 9.9. We enhance this file as we add other servlets to the Web application throughout this chapter.

```
1 <!DOCTYPE web-app PUBLIC
2   "-//Sun Microsystems, Inc.//DTD Web Application 2.2//EN"
3   "http://java.sun.com/j2ee/dtds/web-app_2_2.dtd">
4
5 <web-app>
6
7   <!-- General description of your Web application -->
8   <display-name>
9     Advanced Java How to Program JSP
10    and Servlet Chapter Examples
11   </display-name>
12
13  <description>
14    This is the Web application in which we
15    demonstrate our JSP and Servlet examples.
16  </description>
17
18  <!-- Servlet definitions -->
19  <servlet>
20    <servlet-name>welcome1</servlet-name>
21
22    <description>
23      A simple servlet that handles an HTTP get request.
24    </description>
25
26    <servlet-class>
27      com.deitel.advjhttp1.servlets.WelcomeServlet
28    </servlet-class>
29  </servlet>
30
31  <!-- Servlet mappings -->
32  <servlet-mapping>
33    <servlet-name>welcome1</servlet-name>
34    <url-pattern>/welcome1</url-pattern>
35  </servlet-mapping>
36
37 </web-app>
```

Fig. 9.9 Deployment descriptor (**web.xml**) for the **advjhttp1** Web application.

Lines 1–3 specify the document type for the Web application deployment descriptor and the location of the DTD for this XML file. Element **web-app** (lines 5–37) defines the configuration of each servlet in the Web application and the servlet mapping for each servlet. Element **display-name** (lines 8–11) specifies a name that can be displayed to the administrator of the server on which the Web application is installed. Element **description** (lines 13–16) specifies a description of the Web application that might be displayed to the administrator of the server.

Element **servlet** (lines 19–29) describes a servlet. Element **servlet-name** (line 20) is the name we chose for the servlet (**welcome1**). Element **description** (lines 22–24) specifies a description for this particular servlet. Again, this can be displayed to the administrator of the Web server. Element **servlet-class** (lines 26–28) specifies compiled servlet's fully qualified class name. Thus, the servlet **welcome1** is defined by class **com.deitel.advjhttp1.servlets.WelcomeServlet**.

Element **servlet-mapping** (lines 32–35) specifies **servlet-name** and **url-pattern** elements. The *URL pattern* helps the server determine which requests are sent to the servlet (**welcome1**). Our Web application will be installed as part of the **advjhttp1** context root discussed in Section 9.3.2. Thus, the URL we supply to the browser to invoke the servlet in this example is

```
/advjhttp1/welcome1
```

where **/advjhttp1** specifies the context root that helps the server determine which Web application handles the request and **/welcome1** specifies the URL pattern that is mapped to servlet **welcome1** to handle the request. Note that the server on which the servlet resides is not specified here, although it is possible to do so as follows:

```
http://localhost:8080/advjhttp1/welcome1
```

If the explicit server and port number are not specified as part of the URL, the browser assumes that the form handler (i.e., the servlet specified in the **action** property of the **form** element) resides at the same server and port number from which the browser downloaded the Web page containing the **form**.

There are several URL pattern formats that can be used. The **/welcome1** URL pattern requires an exact match of the pattern. You can also specify *path mappings*, extension mappings and a *default servlet* for a Web application. A path mapping begins with a / and ends with a /\*. For example, the URL pattern

```
/advjhttp1/example/*
```

indicates that any URL path beginning with **/advjhttp1/example/** will be sent to the servlet that has the preceding URL pattern. An extension mapping begins with \*. and ends with a file name extension. For example, the URL pattern

```
*.jsp
```

indicates that any request for a file with the extension **.jsp** will be sent to the servlet that handles JSP requests. In fact, servers with JSP containers have an implicit mapping of the **.jsp** extension to a servlet that handles JSP requests. The URL pattern / represents the default servlet for the Web application. This is similar to the default document of a Web

server. For example, if you type the URL `www.deitel.com` into your Web browser, the document you receive from our Web server is the default document `index.html`. If the URL pattern matches the default servlet for a Web application, that servlet is invoked to return a default response to the client. This can be useful for personalizing Web content to specific users. We discuss personalization in Section 9.7, Session Tracking.

Finally, we are ready to place our files into the appropriate directories to complete the deployment of our first servlet, so we can test it. There are three files we must place in the appropriate directories—`WelcomeServlet.html`, `WelcomeServlet.class` and `web.xml`. In the `webapps` subdirectory of your `jakarta-tomcat-3.2.3` directory, create the `advjhttp1` subdirectory that represents the context root for our Web application. In this directory, create subdirectories named `servlets` and `WEB-INF`. We place our HTML files for this servlets chapter in the `servlets` directory. Copy the `WelcomeServlet.html` file into the `servlets` directory. In the `WEB-INF` directory, create the subdirectory `classes`, then copy the `web.xml` file into the `WEB-INF` directory, and copy the `WelcomeServlet.class` file, including all its package name directories, into the `classes` directory. Thus, the directory and file structure under the `webapps` directory should be as shown in Fig. 9.10 (file names are in italics).



### Testing and Debugging Tip 9.3

*Restart the Tomcat server after modifying the `web.xml` deployment descriptor file. Otherwise, Tomcat will not recognize your new Web application.*

After the files are placed in the proper directories, start the Tomcat server, open your browser and type the following URL—

`http://localhost:8080/advjhttp1/servlets/WelcomeServlet.html`

—to load `WelcomeServlet.html` into the Web browser. Then, click the **Get HTML Document** button to invoke the servlet. You should see the results shown in Fig. 9.6. You can try this servlet from several different Web browsers to demonstrate that the results are the same across Web browsers.

#### WelcomeServlet Web application directory and file structure

```
advjhttp1
  servlets
    WelcomeServlet.html
  WEB-INF
    web.xml
    classes
      com
        deitel
          advjhttp1
            servlets
              WelcomeServlet.class
```

Fig. 9.10 Web application directory and file structure for `WelcomeServlet`.



### Common Programming Error 9.2

*Not placing servlet or other class files in the appropriate package directory prevents the server from locating those classes properly. This, in turn, results in an error response to the client Web browser. This error response normally is “Not Found (404)” in Netscape Navigator and “The page cannot be found” plus an explanation in Microsoft Internet Explorer.*

Actually, the HTML file in Fig. 9.6 was not necessary to invoke this servlet. A **get** request can be sent to a server simply by typing the URL in the Web browser. In fact, that is exactly what you are doing when you request a Web page in the browser. In this example, you can type

**http://localhost:8080/advjhttp1/welcome1**

in the **Address** or **Location** field of your browser to invoke the servlet directly.



### Testing and Debugging Tip 9.4

*You can test a servlet that handles HTTP **get** requests by typing the URL that invokes the servlet directly into your browser’s **Address** or **Location** field.*

## 9.4 Handling HTTP get Requests Containing Data

When requesting a document or resource from a Web server, it is possible to supply data as part of the request. The servlet **WelcomeServlet2** of Fig. 9.11 responds to an HTTP **get** request that contains a name supplied by the user. The servlet uses the name as part of the response to the client.

```
1 // Fig. 9.11: WelcomeServlet2.java
2 // Processing HTTP get requests containing data.
3 package com.deitel.advjhttp1.servlets;
4
5 import javax.servlet.*;
6 import javax.servlet.http.*;
7 import java.io.*;
8
9 public class WelcomeServlet2 extends HttpServlet {
10
11     // process "get" request from client
12     protected void doGet( HttpServletRequest request,
13             HttpServletResponse response )
14             throws ServletException, IOException
15     {
16         String firstName = request.getParameter( "firstname" );
17
18         response.setContentType( "text/html" );
19         PrintWriter out = response.getWriter();
20     }
}
```

Fig. 9.11 **WelcomeServlet2** responds to a **get** request that contains data (part 1 of 2).

```

21     // send XHTML document to client
22
23     // start XHTML document
24     out.println( "<?xml version = \"1.0\"?>" );
25
26     out.println( "<!DOCTYPE html PUBLIC \"-//W3C//DTD " +
27         "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
28         "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
29
30     out.println(
31         "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
32
33     // head section of document
34     out.println( "<head>" );
35     out.println(
36         "<title>Processing get requests with data</title>" );
37     out.println( "</head>" );
38
39     // body section of document
40     out.println( "<body>" );
41     out.println( "<h1>Hello " + firstName + ",<br />" );
42     out.println( "Welcome to Servlets!</h1>" );
43     out.println( "</body>" );
44
45     // end XHTML document
46     out.println( "</html>" );
47     out.close(); // close stream to complete the page
48 }
49 }
```

Fig. 9.11 `WelcomeServlet2` responds to a `get` request that contains data (part 2 of 2).

Parameters are passed as name/value pairs in a `get` request. Line 16 demonstrates how to obtain information that was passed to the servlet as part of the client request. The `request` object's `getParameter` method receives the parameter name as an argument and returns the corresponding `String` value, or `null` if the parameter is not part of the request. Line 41 uses the result of line 16 as part of the response to the client.

The `WelcomeServlet2.html` document (Fig. 9.12) provides a `form` in which the user can input a name in the text `input` element `firstname` (line 17) and click the `Submit` button to invoke `WelcomeServlet2`. When the user presses the `Submit` button, the values of the `input` elements are placed in name/value pairs as part of the request to the server. In the second screen capture of Fig. 9.12, notice that the browser appended

`?firstname=Paul`

to the end of the `action` URL. The `?` separates the *query string* (i.e., the data passed as part of the `get` request) from the rest of the URL in a `get` request. The name/value pairs are passed with the name and the value separated by `=`. If there is more than one name/value pair, each name/value pair is separated by `&`.

```

1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 9.12: WelcomeServlet2.html -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8 <head>
9   <title>Processing get requests with data</title>
10 </head>
11
12 <body>
13   <form action = "/advjhttp1/welcome2" method = "get">
14
15     <p><label>
16       Type your first name and press the Submit button
17       <br /><input type = "text" name = "firstname" />
18       <input type = "submit" value = "Submit" />
19     </p></label>
20
21   </form>
22 </body>
23 </html>

```



**Fig. 9.12** HTML document in which the **form**'s **action** invokes **WelcomeServlet2** through the alias **welcome2** specified in **web.xml**.

Once again, we use our **advjhttp1** context root to demonstrate the servlet of Fig. 9.11. Place **WelcomeServlet2.html** in the **servlets** directory created in Section 9.3.2. Place **WelcomeServlet2.class** in the **classes** subdirectory of **WEB-INF** in the

**advjhttp1** context root. Remember that classes in a package must be placed in the appropriate package directory structure. Then, edit the **web.xml** deployment descriptor in the **WEB-INF** directory to include the information specified in Fig. 9.13. This table contains the information for the  **servlet** and  **servlet-mapping** elements that you will add to the **web.xml** deployment descriptor. You should not type the italic text into the deployment descriptor. Restart Tomcat and type the following URL in your Web browser:

```
http://localhost:8080/advjhttp1/servlets/WelcomeServlet2.html
```

Type your name in the text field of the Web page, then click **Submit** to invoke the servlet.

Once again, note that the **get** request could have been typed directly into the browser's **Address** or **Location** field as follows:

```
http://localhost:8080/advjhttp1/welcome2?firstname=Paul
```

Try it with your own name.

## 9.5 Handling HTTP post Requests

An HTTP **post** request is often used to post data from an HTML form to a server-side form handler that processes the data. For example, when you respond to a Web-based survey, a **post** request normally supplies the information you specify in the HTML form to the Web server.

Browsers often *cache* (save on disk) Web pages so they can quickly reload the pages. If there are no changes between the last version stored in the cache and the current version on the Web, this helps speed up your browsing experience. The browser first asks the server if the document has changed or expired since the date the file was cached. If not, the browser loads the document from the cache. Thus, the browser minimizes the amount of data that must be downloaded for you to view a Web page. Browsers typically do not cache the server's response to a **post** request, because the next **post** might not return the same result. For example, in a survey, many users could visit the same Web page and respond to a question. The survey results could then be displayed for the user. Each new response changes the overall results of the survey.

Descriptor element	Value
<b> servlet element</b>	
<b> servlet-name</b>	<b>welcome2</b>
<b> description</b>	<b>Handling HTTP get requests with data.</b>
<b> servlet-class</b>	<b>com.deitel.advjhttp1.servlets.WelcomeServlet2</b>
<b> servlet-mapping element</b>	
<b> servlet-name</b>	<b>welcome2</b>
<b> url-pattern</b>	<b>/welcome2</b>

Fig. 9.13 Deployment descriptor information for servlet **WelcomeServlet2**.

When you use a Web-based search engine, the browser normally supplies the information you specify in an HTML form to the search engine with a **get** request. The search engine performs the search, then returns the results to you as a Web page. Such pages are often cached by the browser in case you perform the same search again. As with **post** requests, **get** requests can supply parameters as part of the request to the Web server.

The **WelcomeServlet3** servlet of Fig. 9.14 is identical to the servlet of Fig. 9.11, except that it defines a **doPost** method (line 12) to respond to **post** requests rather than a **doGet** method. The default functionality of **doPost** is to indicate a “Method not allowed” error. We override this method to provide custom **post** request processing. Method **doPost** receives the same two arguments as **doGet**—an object that implements interface **HttpServletRequest** to represent the client’s request and an object that implements interface **HttpServletResponse** to represent the servlet’s response. As with **doGet**, method **doPost** throws a **ServletException** if it is unable to handle a client’s request and throws an **IOException** if a problem occurs during stream processing.

```
1 // Fig. 9.14: WelcomeServlet3.java
2 // Processing post requests containing data.
3 package com.deitel.advjhtp1.servlets;
4
5 import javax.servlet.*;
6 import javax.servlet.http.*;
7 import java.io.*;
8
9 public class WelcomeServlet3 extends HttpServlet {
10
11    // process "post" request from client
12    protected void doPost( HttpServletRequest request,
13                          HttpServletResponse response )
14        throws ServletException, IOException
15    {
16        String firstName = request.getParameter( "firstname" );
17
18        response.setContentType( "text/html" );
19        PrintWriter out = response.getWriter();
20
21        // send XHTML page to client
22
23        // start XHTML document
24        out.println( "<?xml version = \"1.0\"?>" );
25
26        out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
27                     "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
28                     "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
29
30        out.println(
31            "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
32
33        // head section of document
34        out.println( "<head>" );
```

Fig. 9.14 **WelcomeServlet3** responds to a **post** request that contains data (part 1 of 2).

```

35     out.println(
36         "<title>Processing post requests with data</title>" );
37     out.println( "</head>" );
38
39     // body section of document
40     out.println( "<body>" );
41     out.println( "<h1>Hello " + firstName + ",<br />" );
42     out.println( "Welcome to Servlets!</h1>" );
43     out.println( "</body>" );
44
45     // end XHTML document
46     out.println( "</html>" );
47     out.close(); // close stream to complete the page
48 }
49 }
```

Fig. 9.14 `WelcomeServlet3` responds to a `post` request that contains data (part 2 of 2).

`WelcomeServlet3.html` (Fig. 9.15) provides a `form` (lines 13–21) in which the user can input a name in the text `input` element `firstname` (line 17), then click the **Submit** button to invoke `WelcomeServlet3`. When the user presses the **Submit** button, the values of the `input` elements are sent to the server as part of the request. However, note that the form's `method` in this example is `post`. Also, note that a `post` request cannot be typed into the browser's **Address** or **Location** field and users cannot bookmark `post` requests in their browsers.

```

1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 9.15: WelcomeServlet3.html -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8 <head>
9   <title>Handling an HTTP Post Request with Data</title>
10 </head>
11
12 <body>
13   <form action = "/advjhtp1/welcome3" method = "post">
14
15     <p><label>
16       Type your first name and press the Submit button
17       <br /><input type = "text" name = "firstname" />
18       <input type = "submit" value = "Submit" />
19     </label></p>
20
21   </form>
22 </body>
23 </html>
```

Fig. 9.15 HTML document in which the `form`'s `action` invokes `WelcomeServlet3` through the alias `welcome3` specified in `web.xml` (part 1 of 2).

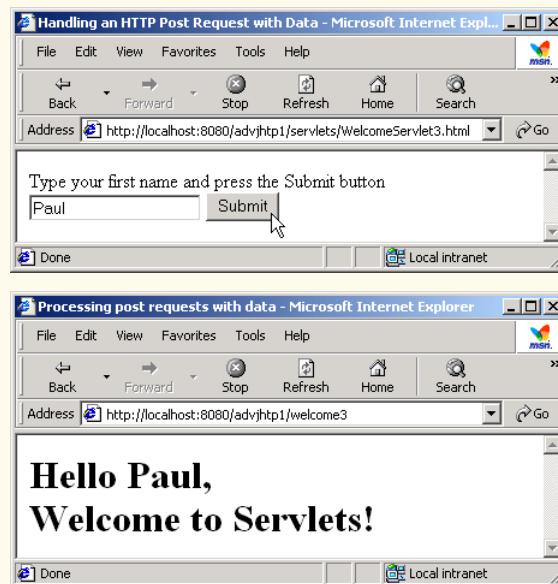


Fig. 9.15 HTML document in which the `form's action` invokes `WelcomeServlet3` through the alias `welcome3` specified in `web.xml` (part 2 of 2).

We use our `advjhttp1` context root to demonstrate the servlet of Fig. 9.14. Place `WelcomeServlet3.html` in the `servlets` directory created in Section 9.3.2. Place `WelcomeServlet3.class` in the `classes` subdirectory of `WEB-INF` in the `advjhttp1` context root. Then, edit the `web.xml` deployment descriptor in the `WEB-INF` directory to include the information specified in Fig. 9.16. Restart Tomcat and type the following URL in your Web browser:

`http://localhost:8080/advjhttp1/servlets/WelcomeServlet3.html`

Type your name in the text field of the Web page, then click **Submit** to invoke the servlet.

Descriptor element	Value
<code>servlet element</code>	
<code>servlet-name</code>	<code>welcome3</code>
<code>description</code>	<code>Handling HTTP post requests with data.</code>
<code>servlet-class</code>	<code>com.deitel.advjhttp1.servlets.WelcomeServlet3</code>
<code>servlet-mapping element</code>	
<code>servlet-name</code>	<code>welcome3</code>
<code>url-pattern</code>	<code>/welcome3</code>

Fig. 9.16 Deployment descriptor information for servlet `WelcomeServlet3`.

## 9.6 Redirecting Requests to Other Resources

Sometimes it is useful to redirect a request to a different resource. For example, a servlet could determine the type of the client browser and redirect the request to a Web page that was designed specifically for that browser. The **RedirectServlet** of Fig. 9.17 receives a page parameter as part of a **get** request, then uses that parameter to redirect the request to a different resource.

```
1 // Fig. 9.17: RedirectServlet.java
2 // Redirecting a user to a different Web page.
3 package com.deitel.advjhttp1.servlets;
4
5 import javax.servlet.*;
6 import javax.servlet.http.*;
7 import java.io.*;
8
9 public class RedirectServlet extends HttpServlet {
10
11     // process "get" request from client
12     protected void doGet( HttpServletRequest request,
13             HttpServletResponse response )
14             throws ServletException, IOException
15     {
16         String location = request.getParameter( "page" );
17
18         if ( location != null )
19
20             if ( location.equals( "deitel" ) )
21                 response.sendRedirect( "http://www.deitel.com" );
22             else
23                 if ( location.equals( "welcome1" ) )
24                     response.sendRedirect( "welcome1" );
25
26         // code that executes only if this servlet
27         // does not redirect the user to another page
28
29         response.setContentType( "text/html" );
30         PrintWriter out = response.getWriter();
31
32         // start XHTML document
33         out.println( "<?xml version = \"1.0\"?>" );
34
35         out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
36             "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
37             "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
38
39         out.println(
40             "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
41
42         // head section of document
43         out.println( "<head>" );
44         out.println( "<title>Invalid page</title>" );
```

Fig. 9.17 Redirecting requests to other resources (part 1 of 2).

```
45     out.println( "</head>" );
46
47     // body section of document
48     out.println( "<body>" );
49     out.println( "<h1>Invalid page requested</h1>" );
50     out.println( "<p><a href = " +
51         "\"servlets/RedirectServlet.html\">" );
52     out.println( "Click here to choose again</a></p>" );
53     out.println( "</body>" );
54
55     // end XHTML document
56     out.println( "</html>" );
57     out.close(); // close stream to complete the page
58 }
59 }
```

Fig. 9.17 Redirecting requests to other resources (part 2 of 2).

Line 16 obtains the **page** parameter from the request. If the value returned is not **null**, the **if/else** structure at lines 20–24 determines if the value is either “**deitel**” or “**welcome1**.” If the value is “**deitel**,” the **response** object’s **sendRedirect** method (line 21) redirects the request to **www.deitel.com**. If the value is “**welcome1**,” line 24 redirect the request to the servlet of Fig. 9.5. Note that line 24 does not explicitly specify the **advjhtp1** context root for our Web application. When a servlet uses a relative path to reference another static or dynamic resource, the servlet assumes the same base URL and context root as the one that invoked the servlet—unless a complete URL is specified for the resource. So, line 24 actually is requesting the resource located at

**http://localhost:8080/advjhtp1/welcome1**

Similarly, line 51 actually is requesting the resource located at

**http://localhost:8080/advjhtp1/servlets/RedirectServlet.html**



### Software Engineering Observation 9.6

*Using relative paths to reference resources in the same context root makes your Web application more flexible. For example, you can change the context root without making changes to the static and dynamic resources in the application.*

Once method **sendRedirect** executes, processing of the original request by the **RedirectServlet** terminates. If method **sendRedirect** is not called, the remainder of method **doPost** outputs a Web page indicating that an invalid request was made. The page allows the user to try again by returning to the XHTML document of Fig. 9.18. Note that one of the redirects is sent to a static XHTML Web page and the other is sent to a servlet.

The **RedirectServlet.html** document (Fig. 9.18) provides two hyperlinks (lines 15–16 and 17–18) that allow the user to invoke the servlet **RedirectServlet**. Note that each hyperlink specifies a **page** parameter as part of the URL. To demonstrate passing an invalid page, you can type the URL into your browser with no value for the **page** parameter.

```

1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 9.18: RedirectServlet.html -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8 <head>
9   <title>Redirecting a Request to Another Site</title>
10 </head>
11
12 <body>
13   <p>Click a link to be redirected to the appropriate page</p>
14   <p>
15     <a href = "/advjhtp1/redirect?page=deitel">
16       www.deitel.com</a><br />
17     <a href = "/advjhtp1/redirect?page=welcome1">
18       Welcome servlet</a>
19   </p>
20 </body>
21 </html>

```

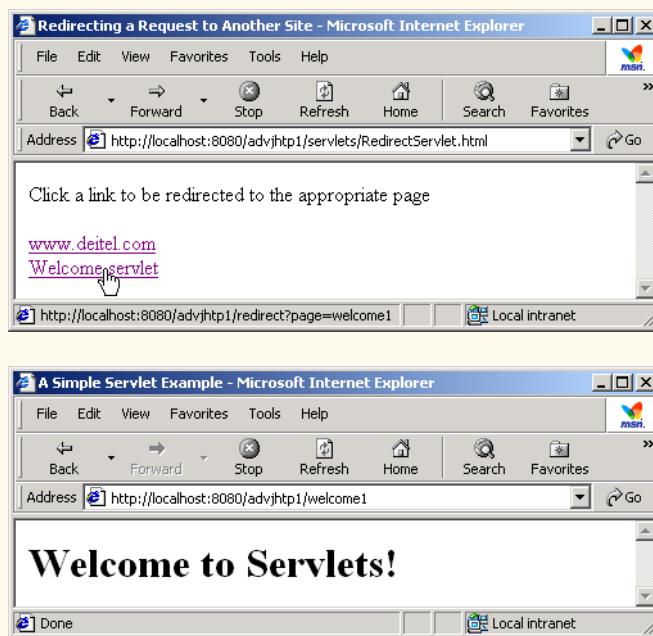


Fig. 9.18 `RedirectServlet.html` document to demonstrate redirecting requests to other resources.

We use our `advjhtp1` context root to demonstrate the servlet of Fig. 9.17. Place `RedirectServlet.html` in the `servlets` directory created in Section 9.3.2. Place `RedirectServlet.class` in the `classes` subdirectory of `WEB-INF` in the `advjhtp1` context root. Then, edit the `web.xml` deployment descriptor in the `WEB-INF`

directory to include the information specified in Fig. 9.19. Restart Tomcat, and type the following URL in your Web browser:

```
http://localhost:8080/advjhttp1/servlets/RedirectServlet.html
```

Click a hyperlink in the Web page to invoke the servlet.

When redirecting requests, the request parameters from the original request are passed as parameters to the new request. Additional request parameters also can be passed. For example, the URL passed to `sendRedirect` could contain name/value pairs. Any new parameters are added to the existing parameters. If a new parameter has the same name as an existing parameter, the new parameter value takes precedence over the original value. However, all the values are still passed. In this case, the complete set of values for a given parameter name can be obtained by calling method `getParameterValues` from interface `HttpServletRequest`. This method receives the parameter name as an argument and returns an array of `Strings` containing the parameter values in order from most recent to least recent.

## 9.7 Session Tracking

Many e-businesses can personalize users' browsing experiences, tailoring Web pages to their users' individual preferences and letting users bypass irrelevant content. This is done by tracking the consumer's movement through the Internet and combining that data with information provided by the consumer, which could include billing information, interests and hobbies, among other things. *Personalization* is making it easier and more pleasant for many people to surf the Internet and find what they want. Consumers and companies can benefit from the unique treatment resulting from personalization. Providing content of special interest to your visitor can help establish a relationship that you can build upon each time that person returns to your site. Targeting consumers with personal offers, advertisements, promotions and services may lead to more customer loyalty—many customers enjoy the individual attention that a customized site provides. Originally, the Internet lacked personal assistance when compared with the individual service often experienced in bricks-and-mortar stores. Sophisticated technology helps many Web sites offer a personal touch

Descriptor element	Value
<b>servlet element</b>	
<b>servlet-name</b>	<b>redirect</b>
<b>description</b>	<b>Redirecting to static Web pages and other serv-lets.</b>
<b>servlet-class</b>	<b>com.deitel.advjhttp1.servlets.RedirectServlet</b>
<b>servlet-mapping element</b>	
<b>servlet-name</b>	<b>redirect</b>
<b>url-pattern</b>	<b>/redirect</b>

Fig. 9.19 Deployment descriptor information for servlet `RedirectServlet`.

to their visitors. For example, Web sites such as MSN.com and CNN.com allow you to customize their home page to suit your needs. Online shopping sites often customize their Web pages to individuals, and such sites must distinguish between clients so the company can determine the proper items and charge the proper amount for each client. Personalization is important for Internet marketing and for managing customer relationships to increase customer loyalty.

Hand in hand with the promise of personalization, however, comes the problem of *privacy invasion*. What if the e-business to which you give your personal data sells or gives those data to another organization without your knowledge? What if you do not want your movements on the Internet to be tracked by unknown parties? What if an unauthorized party gains access to your private data, such as credit-card numbers or medical history? These are some of the many questions that must be addressed by consumers, e-businesses and lawmakers alike.

As we have discussed, the request/response mechanism of the Web is based on HTTP. Unfortunately, HTTP is a *stateless protocol*—it does not support persistent information that could help a Web server determine that a request is from a particular client. As far as a Web server is concerned, every request could be from the same client or every request could be from a different client. Thus, sites like MSN.com and CNN.com need a mechanism to identify individual clients. To help the server distinguish between clients, each client must identify itself to the server. There are a number of popular techniques for distinguishing between clients. We introduce two techniques to track clients individually—*cookies* (Section 9.7.1) and *session tracking* (Section 9.7.2). Two other techniques not discussed in this chapter are using **input** form elements of type "**hidden**" and *URL rewriting*. With "hidden" form elements, the servlet can write session-tracking data into a **form** in the Web page it returns to the client to satisfy a prior request. When the user submits the form in the new Web page, all the form data, including the "hidden" fields, are sent to the form handler on the server. With URL rewriting, the servlet embeds session-tracking information as **get** parameters directly in the URLs of hyperlinks that the user might click to make the next request to the Web server.

## 9.7.1 Cookies

A popular way to customize Web pages is via *cookies*. Browsers can store cookies on the user's computer for retrieval later in the same browsing session or in future browsing sessions. For example, cookies could be used in a shopping application to store unique identifiers for the users. When users add items to their online shopping carts or perform other tasks resulting in a request to the Web server, the server receives cookies containing unique identifiers for each user. The server then uses the unique identifier to locate the shopping carts and perform the necessary processing. Cookies could also be used to indicate the client's shopping preferences. When the servlet receives the client's next communication, the servlet can examine the cookie(s) it sent to the client in a previous communication, identify the client's preferences and immediately display products of interest to the client.

Cookies are text-based data that are sent by servlets (or other similar server-side technologies) as part of responses to clients. Every HTTP-based interaction between a client and a server includes a *header* containing information about the request (when the communication is from the client to the server) or information about the response (when the communication is from the server to the client). When an **HttpServlet** receives a request,

the header includes information such as the request type (e.g., **get** or **post**) and the cookies that are sent by the server to be stored on the client machine. When the server formulates its response, the header information includes any cookies the server wants to store on the client computer and other information such as the MIME type of the response.



### Testing and Debugging Tip 9.5

*Some clients do not accept cookies. When a client declines a cookie, the Web site or the browser application can inform the client that the site may not function correctly without cookies enabled.*

Depending on the *maximum age* of a cookie, the Web browser either maintains the cookie for the duration of the browsing session (i.e., until the user closes the Web browser) or stores the cookie on the client computer for future use. When the browser requests a resource from a server, cookies previously sent to the client by that server are returned to the server as part of the request formulated by the browser. Cookies are deleted automatically when they *expire* (i.e., reach their maximum age).

Figure 9.20 demonstrates cookies. The example allows the user to select a favorite programming language and **post** the choice to the server. The response is a Web page in which the user can select another favorite language or click a link to view a list of book recommendations. When the user selects the list of book recommendations, a **get** request is sent to the server. The cookies previously stored on the client are read by the servlet and used to form a Web page containing the book recommendations.

**CookieServlet** (Fig. 9.20) handles both the **get** and the **post** requests. The **CookieSelectLanguage.html** document of Fig. 9.21 contains four radio buttons (**C**, **C++**, **Java** and **VB 6**) and a **Submit** button. When the user presses **Submit**, the **CookieServlet** is invoked with a **post** request. The servlet adds a cookie containing the selected language to the response header and sends an XHTML document to the client. Each time the user clicks **Submit**, a cookie is sent to the client.

Line 11 defines **Map books** as a **HashMap** (package **java.util**) in which we store key/value pairs that use the programming language as the key and the ISBN number of the recommended book as the value. The **CookieServlet init** method (line 14–20) populates books with four key/value pairs of books. Method **doPost** (lines 24–69) is invoked in response to the **post** request from the XHTML document of Fig. 9.21. Line 28 uses method **getParameter** to obtain the user's **language** selection (the value of the selected radio button on the Web page). Line 29 obtains the ISBN number for the selected language from **books**.

```
1 // Fig. 9.20: CookieServlet.java
2 // Using cookies to store data on the client computer.
3 package com.deitel.advjhtp1.servlets;
4
5 import javax.servlet.*;
6 import javax.servlet.http.*;
7 import java.io.*;
8 import java.util.*;
```

Fig. 9.20 Storing user data on the client computer with cookies (part 1 of 4).

```
10 public class CookieServlet extends HttpServlet {
11     private final Map books = new HashMap();
12
13     // initialize Map books
14     public void init()
15     {
16         books.put( "C", "0130895725" );
17         books.put( "C++", "0130895717" );
18         books.put( "Java", "0130125075" );
19         books.put( "VB6", "0134569555" );
20     }
21
22     // receive language selection and send cookie containing
23     // recommended book to the client
24     protected void doPost( HttpServletRequest request,
25                           HttpServletResponse response )
26                           throws ServletException, IOException
27     {
28         String language = request.getParameter( "language" );
29         String isbn = books.get( language ).toString();
30         Cookie cookie = new Cookie( language, isbn );
31
32         response.addCookie( cookie ); // must precede getWriter
33         response.setContentType( "text/html" );
34         PrintWriter out = response.getWriter();
35
36         // send XHTML page to client
37
38         // start XHTML document
39         out.println( "<?xml version = \"1.0\"?>" );
40
41         out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
42                     "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
43                     "/TR/xhtml1/DTD/xhtml1-strict.dtd\\>" );
44
45         out.println(
46             "<html xmlns = \"http://www.w3.org/1999/xhtml\\>" );
47
48         // head section of document
49         out.println( "<head>" );
50         out.println( "<title>Welcome to Cookies</title>" );
51         out.println( "</head>" );
52
53         // body section of document
54         out.println( "<body>" );
55         out.println( "<p>Welcome to Cookies! You selected " +
56                     language + "</p>" );
57
58         out.println( "<p><a href = " +
59                     "\"/advjhttp1/servlets/CookieSelectLanguage.html\\>" +
60                     "Click here to choose another language</a></p>" );
61
```

Fig. 9.20 Storing user data on the client computer with cookies (part 2 of 4).

```
62         out.println( "<p><a href = \"/advjhttp1/cookies\">" +
63             "Click here to get book recommendations</a></p>" );
64         out.println( "</body>" );
65
66         // end XHTML document
67         out.println( "</html>" );
68         out.close();      // close stream
69     }
70
71     // read cookies from client and create XHTML document
72     // containing recommended books
73     protected void doGet( HttpServletRequest request,
74         HttpServletResponse response )
75             throws ServletException, IOException
76     {
77         Cookie cookies[] = request.getCookies();    // get cookies
78
79         response.setContentType( "text/html" );
80         PrintWriter out = response.getWriter();
81
82         // start XHTML document
83         out.println( "<?xml version = \"1.0\"?>" );
84
85         out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
86             "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
87             "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
88
89         out.println(
90             "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
91
92         // head section of document
93         out.println( "<head>" );
94         out.println( "<title>Recommendations</title>" );
95         out.println( "</head>" );
96
97         // body section of document
98         out.println( "<body>" );
99
100        // if there are any cookies, recommend a book for each ISBN
101        if ( cookies != null && cookies.length != 0 ) {
102            out.println( "<h1>Recommendations</h1>" );
103            out.println( "<p>" );
104
105            // get the name of each cookie
106            for ( int i = 0; i < cookies.length; i++ )
107                out.println( cookies[ i ].getName() +
108                    " How to Program. ISBN#: " +
109                    cookies[ i ].getValue() + "<br />" );
110
111            out.println( "</p>" );
112        }
113        else {    // there were no cookies
114            out.println( "<h1>No Recommendations</h1>" );
```

Fig. 9.20 Storing user data on the client computer with cookies (part 3 of 4).

```
115         out.println( "<p>You did not select a language.</p>" );
116     }
117
118     out.println( "</body>" );
119
120     // end XHTML document
121     out.println( "</html>" );
122     out.close();      // close stream
123 }
124 }
```

Fig. 9.20 Storing user data on the client computer with cookies (part 4 of 4).

Line 30 creates a new **Cookie** object (package **javax.servlet.http**), using the **language** and **isbn** values as the *cookie name* and *cookie value*, respectively. The cookie name identifies the cookie; the cookie value is the information associated with the cookie. Browsers that support cookies must be able to store a minimum of 20 cookies per Web site and 300 cookies per user. Browsers may limit the cookie size to 4K (4096 bytes). Each cookie stored on the client includes a domain. The browser sends a cookie only to the domain stored in the cookie.



### Software Engineering Observation 9.7

Browser users can disable cookies, so Web applications that use cookies may not function properly for clients with cookies disabled.



### Software Engineering Observation 9.8

By default, cookies exist only for the current browsing session (until the user closes the browser). To make cookies persist beyond the current session, call **Cookie** method **setMaxAge** to indicate the number of seconds until the cookie expires.

Line 32 adds the cookie to the **response** with method **addCookie** of interface **HttpServletResponse**. Cookies are sent to the client as part of the HTTP header. The header information is always provided to the client first, so the cookies should be added to the **response** with **addCookie** before any data is written as part of the response. After the cookie is added, the servlet sends an XHTML document to the client (see the second screen capture of Fig. 9.21).



### Common Programming Error 9.3

Writing response data to the client before calling method **addCookie** to add a cookie to the response is a logic error. Cookies must be added to the header first.

The XHTML document sent to the client in response to a **post** request includes a hyperlink that invokes method **doGet** (lines 73–123). The method reads any **Cookies** that were written to the client in **doPost**. For each **Cookie** written, the servlet recommends a Deitel book on the subject. Up to four books are displayed on the Web page created by the servlet.

Line 77 retrieves the cookies from the client using **HttpServletRequest** method **getCookies**, which returns an array of **Cookie** objects. When a **get** or **post** operation is performed to invoke a servlet, the cookies associated with that server's domain are automatically sent to the servlet.

If method **getCookies** does not return **null** (i.e., there were no cookies), lines 106–109 retrieve the name of each **Cookie** using **Cookie** method **getName**, retrieve the value of each **Cookie** using **Cookie** method **getValue** and write a line to the client indicating the name of a recommended book and its ISBN number.



### Software Engineering Observation 9.9

Normally, each servlet class handles one request type (e.g., **get** or **post**, but not both).

Figure 9.21 shows the XHTML document the user loads to select a language. When the user presses **Submit**, the value of the currently selected radio button is sent to the server as part of the **post** request to the **CookieServlet**, which we refer to as **cookies** in this example.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 9.21: CookieSelectLanguage.html -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8 <head>
9   <title>Using Cookies</title>
10 </head>
11
12 <body>
13   <form action = "/advjhttp1/cookies" method = "post">
14
15     <p>Select a programming language:</p>
16     <p>
17       <input type = "radio" name = "language"
18         value = "C" />C <br />
19
20       <input type = "radio" name = "language"
21         value = "C++" />C++ <br />
22
23       <!-- this radio button checked by default -->
24       <input type = "radio" name = "language"
25         value = "Java" checked = "checked" />Java<br />
26
27       <input type = "radio" name = "language"
28         value = "VB6" />VB 6
29     </p>
30
31   <p><input type = "submit" value = "Submit" /></p>
32
33 </form>
34 </body>
35 </html>
```

Fig. 9.21 **CookieSelectLanguage.html** document for selecting a programming language and posting the data to the **CookieServlet** (part 1 of 3).

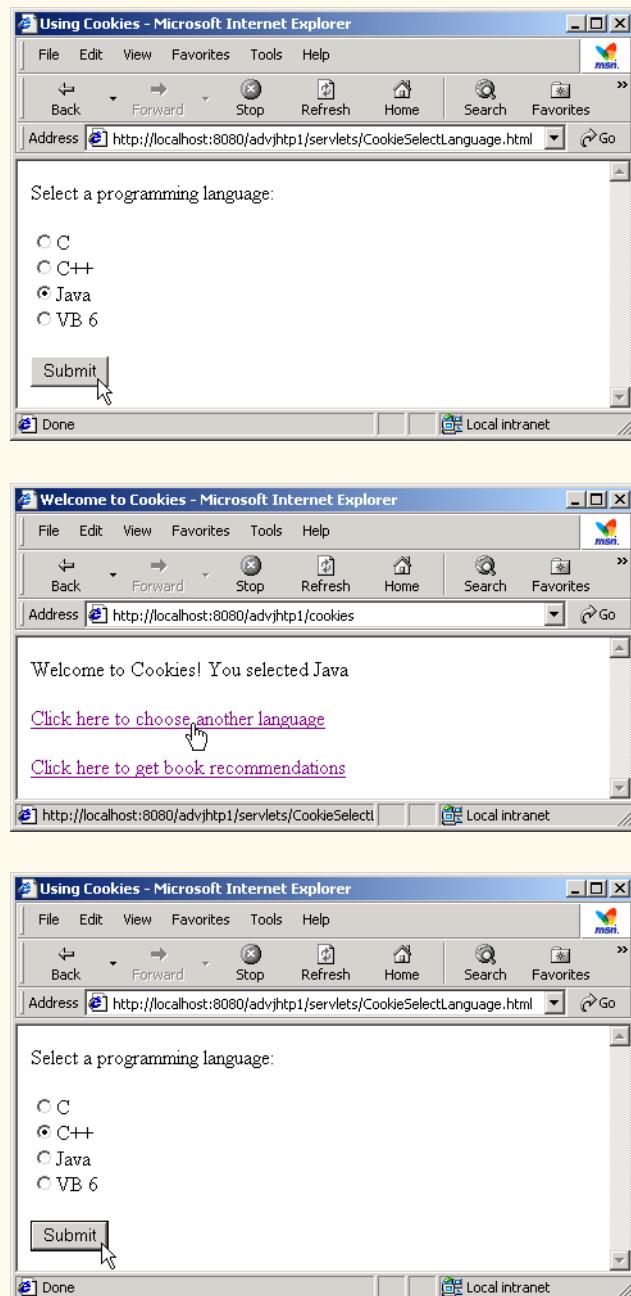


Fig. 9.21 **CookieSelectLanguage.html** document for selecting a programming language and posting the data to the **CookieServlet** (part 2 of 3).

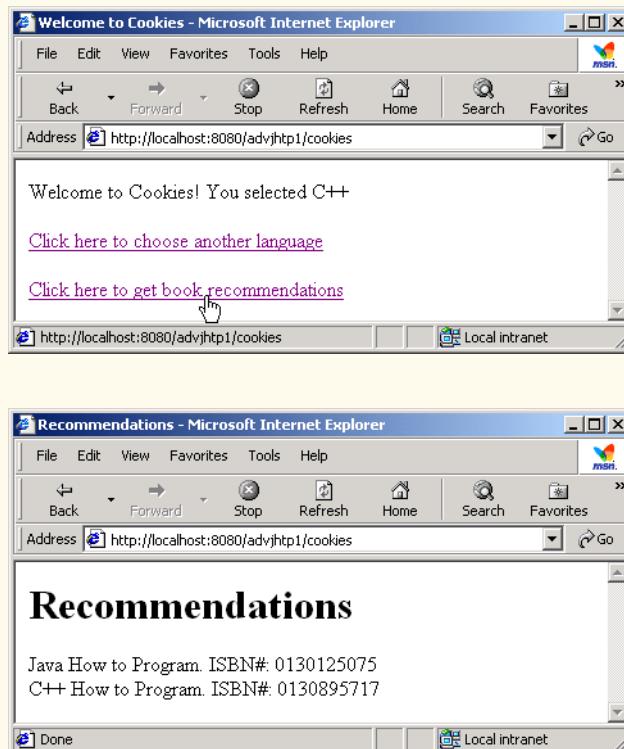


Fig. 9.21 `CookieSelectLanguage.html` document for selecting a programming language and posting the data to the `CookieServlet` (part 3 of 3).

We use our `advjhttp1` context root to demonstrate the servlet of Fig. 9.20. Place `CookieSelectLanguage.html` in the `servlets` directory created previously. Place `CookieServlet.class` in the `classes` subdirectory of `WEB-INF` in the `advjhttp1` context root. Then, edit the `web.xml` deployment descriptor in the `WEB-INF` directory to include the information specified in Fig. 9.22. Restart Tomcat and type the following URL in your Web browser:

```
http://localhost:8080/advjhttp1/servlets/  
CookieSelectLanguage.html
```

Select a language, and press the **Submit** button in the Web page to invoke the servlet.

Various `Cookie` methods are provided to manipulate the members of a `Cookie`. Some of these methods are listed in Fig. 9.23.

Descriptor element	Value
<b>servlet element</b>	
<b>servlet-name</b>	<b>cookies</b>
<b>description</b>	Using cookies to maintain state information.
<b>servlet-class</b>	<b>com.deitel.advjhttp1.servlets.CookieServlet</b>
<b>servlet-mapping element</b>	
<b>servlet-name</b>	<b>cookies</b>
<b>url-pattern</b>	<b>/cookies</b>

Fig. 9.22 Deployment descriptor information for servlet **CookieServlet**.

Method	Description
<b>getComment ()</b>	Returns a <b>String</b> describing the purpose of the cookie ( <b>null</b> if no comment has been set with <b>setComment</b> ).
<b>getDomain ()</b>	Returns a <b>String</b> containing the cookie's domain. This determines which servers can receive the cookie. By default, cookies are sent to the server that originally sent the cookie to the client.
<b>getMaxAge ()</b>	Returns an <b>int</b> representing the maximum age of the cookie in seconds.
<b>getName ()</b>	Returns a <b>String</b> containing the name of the cookie as set by the constructor.
<b>getPath ()</b>	Returns a <b>String</b> containing the URL prefix for the cookie. Cookies can be "targeted" to specific URLs that include directories on the Web server. By default, a cookie is returned to services operating in the same directory as the service that sent the cookie or a subdirectory of that directory.
<b>getSecure ()</b>	Returns a <b>boolean</b> value indicating if the cookie should be transmitted using a secure protocol ( <b>true</b> ).
<b>getValue ()</b>	Returns a <b>String</b> containing the value of the cookie as set with <b>setValue</b> or the constructor.
<b>getVersion ()</b>	Returns an <b>int</b> containing the version of the cookie protocol used to create the cookie. A value of 0 (the default) indicates the original cookie protocol as defined by Netscape. A value of 1 indicates the current version, which is based on <i>Request for Comments (RFC) 2109</i> .
<b>setComment ( String )</b>	The comment describing the purpose of the cookie that is presented by the browser to the user. (Some browsers allow the user to accept cookies on a per-cookie basis.)

Fig. 9.23 Important methods of class **Cookie** (part 1 of 2).

Method	Description
<code>setDomain( String )</code>	This determines which servers can receive the cookie. By default, cookies are sent to the server that originally sent the cookie to the client. The domain is specified in the form ".deitel.com", indicating that all servers ending with .deitel.com can receive this cookie.
<code>setMaxAge( int )</code>	Sets the maximum age of the cookie in seconds.
<code>setPath( String )</code>	Sets the "target" URL prefix indicating the directories on the server that lead to the services that can receive this cookie.
<code>setSecure( boolean )</code>	A <code>true</code> value indicates that the cookie should only be sent using a secure protocol.
<code>setValue( String )</code>	Sets the value of a cookie.
<code>setVersion( int )</code>	Sets the cookie protocol for this cookie.

Fig. 9.23 Important methods of class `Cookie` (part 2 of 2).

## 9.7.2 Session Tracking with `HttpSession`

Java provides enhanced session tracking support with the servlet API's `HttpSession` interface. To demonstrate basic session-tracking techniques, we modified the servlet from Fig. 9.20 to use `HttpSession` objects (Fig. 9.24). Once again, the servlet handles both `get` and `post` requests. The document `SessionSelectLanguage.html` of Fig. 9.25 contains four radio buttons (**C**, **C++**, **Java** and **VB 6**) and a **Submit** button. When the user presses **Submit**, `SessionServlet` is invoked with a `post` request. The servlet responds by creating an object of type `HttpSession` for the client (or using an existing session for the client) and adds the selected language and an ISBN number for the recommended book to the `HttpSession` object. Then, the servlet sends an XHTML page to the client. Each time the user clicks **Submit**, a new language/ISBN pair is added to the `HttpSession` object.



### Software Engineering Observation 9.10

A servlet should not use instance variables to maintain client state information, because clients accessing that servlet in parallel might overwrite the shared instance variables. Servlets should maintain client state information in `HttpSession` objects.

```

1 // Fig. 9.24: SessionServlet.java
2 // Using HttpSession to maintain client state information.
3 package com.deitel.advjhtp1.servlets;
4
5 import javax.servlet.*;
6 import javax.servlet.http.*;
7 import java.io.*;
8 import java.util.*;
```

Fig. 9.24 Maintaining state information with `HttpSession` objects (part 1 of 4).

```
9
10 public class SessionServlet extends HttpServlet {
11     private final Map books = new HashMap();
12
13     // initialize Map books
14     public void init()
15     {
16         books.put( "C", "0130895725" );
17         books.put( "C++", "0130895717" );
18         books.put( "Java", "0130125075" );
19         books.put( "VB6", "0134569555" );
20     }
21
22     // receive language selection and create HttpSession object
23     // containing recommended book for the client
24     protected void doPost( HttpServletRequest request,
25                           HttpServletResponse response )
26                           throws ServletException, IOException
27     {
28         String language = request.getParameter( "language" );
29
30         // Get the user's session object.
31         // Create a session (true) if one does not exist.
32         HttpSession session = request.getSession( true );
33
34         // add a value for user's choice to session
35         session.setAttribute( language, books.get( language ) );
36
37         response.setContentType( "text/html" );
38         PrintWriter out = response.getWriter();
39
40         // send XHTML page to client
41
42         // start XHTML document
43         out.println( "<?xml version = \"1.0\"?>" );
44
45         out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
46                     "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
47                     "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
48
49         out.println(
50             "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
51
52         // head section of document
53         out.println( "<head>" );
54         out.println( "<title>Welcome to Sessions</title>" );
55         out.println( "</head>" );
56
57         // body section of document
58         out.println( "<body>" );
59         out.println( "<p>Welcome to Sessions! You selected " +
60                     language + ".</p>" );
61     }
```

Fig. 9.24 Maintaining state information with **HttpSession** objects (part 2 of 4).

```
62     // display information about the session
63     out.println( "<p>Your unique session ID is: " +
64         session.getId() + "<br />" );
65
66     out.println(
67         "This " + ( session.isNew() ? "is" : "is not" ) +
68         " a new session<br />" );
69
70     out.println( "The session was created at: " +
71         new Date( session.getCreationTime() ) + "<br />" );
72
73     out.println( "You last accessed the session at: " +
74         new Date( session.getLastAccessedTime() ) + "<br />" );
75
76     out.println( "The maximum inactive interval is: " +
77         session.getMaxInactiveInterval() + " seconds</p>" );
78
79     out.println( "<p><a href = " +
80         "\"/servlets/SessionSelectLanguage.html\">" +
81         "Click here to choose another language</a></p>" );
82
83     out.println( "<p><a href = \"sessions\">" +
84         "Click here to get book recommendations</a></p>" );
85     out.println( "</body>" );
86
87     // end XHTML document
88     out.println( "</html>" );
89     out.close();    // close stream
90 }
91
92 // read session attributes and create XHTML document
93 // containing recommended books
94 protected void doGet( HttpServletRequest request,
95     HttpServletResponse response )
96     throws ServletException, IOException
97 {
98     // Get the user's session object.
99     // Do not create a session (false) if one does not exist.
100    HttpSession session = request.getSession( false );
101
102    // get names of session object's values
103    Enumeration valueNames;
104
105    if ( session != null )
106        valueNames = session.getAttributeNames();
107    else
108        valueNames = null;
109
110    PrintWriter out = response.getWriter();
111    response.setContentType( "text/html" );
112
113    // start XHTML document
114    out.println( "<?xml version = \"1.0\"?>" );
```

Fig. 9.24 Maintaining state information with **HttpSession** objects (part 3 of 4).

```
115
116     out.println( "<!DOCTYPE html PUBLIC \"-//W3C//DTD " +
117         "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
118         "/TR/xhtml1/DTD/xhtml1-strict.dtd\">" );
119
120     out.println(
121         "<html xmlns = \"http://www.w3.org/1999/xhtml\">" );
122
123     // head section of document
124     out.println( "<head>" );
125     out.println( "<title>Recommendations</title>" );
126     out.println( "</head>" );
127
128     // body section of document
129     out.println( "<body>" );
130
131     if ( valueNames != null &&
132         valueNames.hasMoreElements() ) {
133         out.println( "<h1>Recommendations</h1>" );
134         out.println( "<p>" );
135
136         String name, value;
137
138         // get value for each name in valueNames
139         while ( valueNames.hasMoreElements() ) {
140             name = valueNames.nextElement().toString();
141             value = session.getAttribute( name ).toString();
142
143             out.println( name + " How to Program. " +
144                         "ISBN#: " + value + "<br />" );
145         }
146
147         out.println( "</p>" );
148     }
149     else {
150         out.println( "<h1>No Recommendations</h1>" );
151         out.println( "<p>You did not select a language.</p>" );
152     }
153
154     out.println( "</body>" );
155
156     // end XHTML document
157     out.println( "</html>" );
158     out.close();    // close stream
159 }
160 }
```

Fig. 9.24 Maintaining state information with **HttpSession** objects (part 4 of 4).

Most of class **SessionServlet** is identical to **CookieServlet** (Fig. 9.20), so we concentrate on only the new features here. When the user selects a language from the document **SessionSelectLanguage.html** (Fig. 9.25) and presses **Submit**, method **doPost** (lines 24–90) is invoked. Line 28 gets the user's **language** selection. Then, line 32 uses method **getSession** of interface **HttpServletRequest** to obtain the

**HttpSession** object for the client. If the server has an existing **HttpSession** object for the client from a previous request, method **getSession** returns that **HttpSession** object. Otherwise, the **true** argument to method **getSession** indicates that the servlet should create a unique new **HttpSession** object for the client. A **false** argument would cause method **getSession** to return **null** if the **HttpSession** object for the client did not already exist. Using a **false** argument could help determine whether a client has logged into a Web application.

Like a cookie, an **HttpSession** object can store name/value pairs. In session terminology, these are called *attributes*, and they are placed into an **HttpSession** object with method **setAttribute**. Line 35 uses **setAttribute** to put the language and the corresponding recommended book's ISBN number into the **HttpSession** object. One of the primary benefits of using **HttpSession** objects rather than cookies is that **HttpSession** objects can store any object (not just **Strings**) as the value of an attribute. This allows Java programmers flexibility in determining the type of state information they wish to maintain for clients of their Web applications. If an attribute with a particular name already exists when **setAttribute** is called, the object associated with that attribute name is replaced.

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Name/value pairs added to an **HttpSession** object with **setAttribute** remain available until the client's current browsing session ends or until the session is invalidated explicitly by a call to the **HttpSession** object's **invalidate** method. Also, if the servlet container is restarted, these attributes may be lost.

After the values are added to the **HttpSession** object, the servlet sends an XHTML document to the client (see the second screen capture of Fig. 9.25). In this example, the document contains various information about the **HttpSession** object for the current client. Line 64 uses **HttpSession** method **getID** to obtain the session's unique ID number. Line 67 determines whether the session is new or already exists with method **isNew**, which returns **true** or **false**. Line 71 obtains the time at which the session was created with method **getCreationTime**. Line 74 obtains the time at which the session was last accessed with method **getLastAccessedTime**. Line 77 uses method **getMaxInactiveInterval** to obtain the maximum amount of time that an **HttpSession** object can be inactive before the servlet container discards it.

The XHTML document sent to the client in response to a **post** request includes a hyperlink that invokes method **doGet** (lines 94–159). The method obtains the **HttpSession** object for the client with method **getSession** (line 100). We do not want to make any recommendations if the client does not have an existing **HttpSession** object. So, this call to **getSession** uses a **false** argument. Thus, **getSession** returns an **HttpSession** object only if one already exists for the client.

If method **getSession** does not return **null**, line 106 uses **HttpSession** method **getAttributeNames** to retrieve an **Enumeration** of the attribute names (i.e., the names used as the first argument to **HttpSession** method **setAttribute**). Each name is passed as an argument to **HttpSession** method **getAttribute** (line 141) to retrieve the ISBN of a book from the **HttpSession** object. Method **getAttribute** receives the name and returns an **Object** reference to the corresponding value. Next, a line is written in the response to the client containing the title and ISBN number of the recommended book.

Figure 9.25 shows the XHTML document the user loads to select a language. When the user presses **Submit**, the value of the currently selected radio button is sent to the

server as part of the **post** request to the **SessionServlet**, which we refer to as **sessions** in this example.

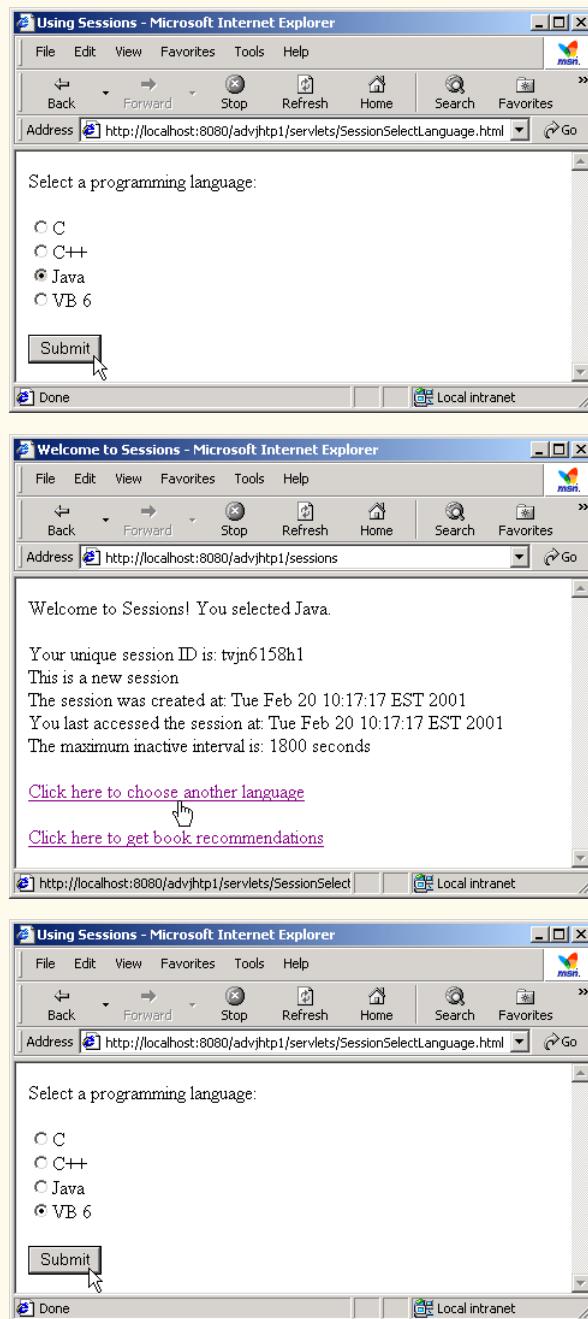
We use our **advjhttp1** context root to demonstrate the servlet of Fig. 9.24. Place **SessionSelectLanguage.html** in the **servlets** directory created previously. Place **SessionServlet.class** in the **classes** subdirectory of **WEB-INF** in the **advjhttp1** context root. Then, edit the **web.xml** deployment descriptor in the **WEB-INF** directory to include the information specified in Fig. 9.26. Restart Tomcat and type the following URL in your Web browser:

```
http://localhost:8080/advjhttp1/servlets/  
SessionSelectLanguage.html
```

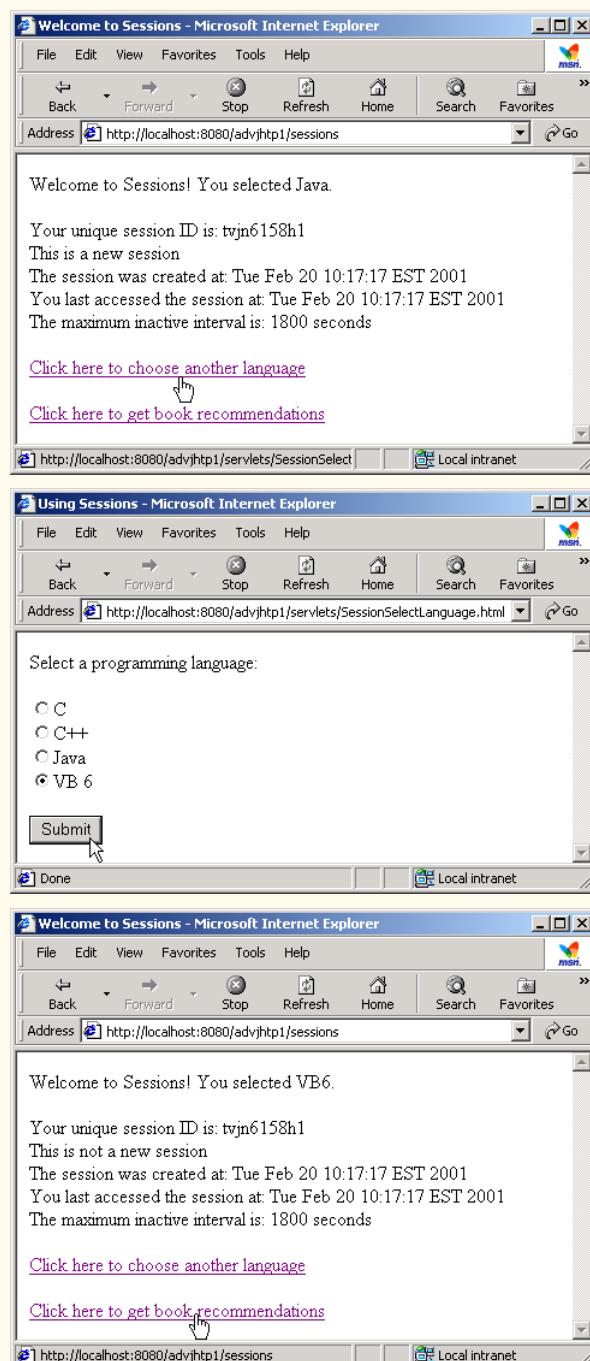
Select a language, and press the **Submit** button in the Web page to invoke the servlet.

```
1 <?xml version = "1.0"?>  
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"  
3     "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">  
4  
5 <!-- Fig. 9.25: SessionSelectLanguage.html -->  
6  
7 <html xmlns = "http://www.w3.org/1999/xhtml">  
8 <head>  
9     <title>Using Sessions</title>  
10 </head>  
11  
12 <body>  
13     <form action = "/advjhttp1/sessions" method = "post">  
14  
15         <p>Select a programming language:</p>  
16         <p>  
17             <input type = "radio" name = "language"  
18                 value = "C" />C <br />  
19  
20             <input type = "radio" name = "language"  
21                 value = "C++" />C++ <br />  
22  
23             <!-- this radio button checked by default -->  
24             <input type = "radio" name = "language"  
25                 value = "Java" checked = "checked" />Java<br />  
26  
27             <input type = "radio" name = "language"  
28                 value = "VB6" />VB 6  
29         </p>  
30  
31         <p><input type = "submit" value = "Submit" /></p>  
32  
33     </form>  
34 </body>  
35 </html>
```

Fig. 9.25 **SessionSelectLanguage.html** document for selecting a programming language and posting the data to the **SessionServlet** (part 1 of 4).



**Fig. 9.25** **SessionSelectLanguage.html** document for selecting a programming language and posting the data to the **SessionServlet** (part 2 of 4).



**Fig. 9.25** **SessionSelectLanguage.html** document for selecting a programming language and posting the data to the **SessionServlet** (part 3 of 4).

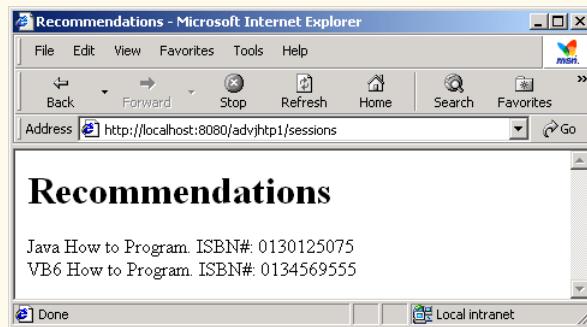


Fig. 9.25 `SessionSelectLanguage.html` document for selecting a programming language and posting the data to the `SessionServlet` (part 4 of 4).

Descriptor element	Value
<code>servlet element</code>	
<code>servlet-name</code>	<code>sessions</code>
<code>description</code>	Using sessions to maintain state information.
<code>servlet-class</code>	<code>com.deitel.advjhttp1.servlets.SessionServlet</code>
<code>servlet-mapping element</code>	
<code>servlet-name</code>	<code>sessions</code>
<code>url-pattern</code>	<code>/sessions</code>

Fig. 9.26 Deployment descriptor information for servlet `WelcomeServlet2`.

## 9.8 Multi-tier Applications: Using JDBC from a Servlet

Servlets can communicate with databases via JDBC (Java Database Connectivity). As we discussed in Chapter 8, JDBC provides a uniform way for a Java program to connect with a variety of databases in a general manner without having to deal with the specifics of those database systems.

Many of today's applications are *three-tier distributed applications*, consisting of a *user interface*, *business logic* and *database access*. The user interface in such an application is often created using HTML, XHTML (as shown in this chapter) or Dynamic HTML. In some cases, Java applets are also used for this tier. HTML and XHTML are the preferred mechanisms for representing the user interface in systems where portability is a concern. Because HTML is supported by all browsers, designing the user interface to be accessed through a Web browser guarantees portability across all platforms that have browsers. Using the networking provided automatically by the browser, the user interface can communicate with the middle-tier business logic. The middle tier can then access the database

to manipulate the data. The three tiers can reside on separate computers that are connected to a network.

In multi-tier architectures, Web servers often represent the middle tier. They provide the business logic that manipulates data from databases and that communicates with client Web browsers. Servlets, through JDBC, can interact with popular database systems. Developers do not need to be familiar with the specifics of each database system. Rather, developers use SQL-based queries and the JDBC driver handles the specifics of interacting with each database system.

The **SurveyServlet** of Fig. 9.27 and the **Survey.html** document of Fig. 9.28 demonstrate a three-tier distributed application that displays the user interface in a browser using XHTML. The middle tier is a Java servlet that handles requests from the client browser and provides access to the third tier—a Cloudscape database accessed via JDBC. The servlet in this example is a survey servlet that allows users to vote for their favorite animal. When the servlet receives a **post** request from the **Survey.html** document, the servlet updates the total number of votes for that animal in the database and returns a dynamically generated XHTML document containing the survey results to the client.

```
1 // Fig. 9.27: SurveyServlet.java
2 // A Web-based survey that uses JDBC from a servlet.
3 package com.deitel.advjhtp1.servlets;
4
5 import java.io.*;
6 import java.text.*;
7 import java.sql.*;
8 import javax.servlet.*;
9 import javax.servlet.http.*;
10
11 public class SurveyServlet extends HttpServlet {
12     private Connection connection;
13     private PreparedStatement updateVotes, totalVotes, results;
14
15     // set up database connection and prepare SQL statements
16     public void init( ServletConfig config )
17         throws ServletException
18     {
19         // attempt database connection and create PreparedStatements
20         try {
21             Class.forName( "COM.cloudscape.core.RmiJdbcDriver" );
22             connection = DriverManager.getConnection(
23                 "jdbc:rmi:jdbc:cloudscape:animalsurvey" );
24
25             // PreparedStatement to add one to vote total for a
26             // specific animal
27             updateVotes =
28                 connection.prepareStatement(
29                     "UPDATE surveyresults SET votes = votes + 1 " +
30                     "WHERE id = ?"
31                 );
32 }
```

Fig. 9.27 Multi-tier Web-based survey using XHTML, servlets and JDBC (part 1 of 4).

```
33         // PreparedStatement to sum the votes
34         totalVotes =
35             connection.prepareStatement(
36                 "SELECT sum( votes ) FROM surveyresults"
37             );
38
39         // PreparedStatement to obtain surveyoption table's data
40         results =
41             connection.prepareStatement(
42                 "SELECT surveyoption, votes, id " +
43                 "FROM surveyresults ORDER BY id"
44             );
45     }
46
47     // for any exception throw an UnavailableException to
48     // indicate that the servlet is not currently available
49     catch ( Exception exception ) {
50         exception.printStackTrace();
51         throw new UnavailableException(exception.getMessage());
52     }
53
54 } // end of init method
55
56 // process survey response
57 protected void doPost( HttpServletRequest request,
58     HttpServletResponse response )
59     throws ServletException, IOException
60 {
61     // set up response to client
62     response.setContentType( "text/html" );
63     PrintWriter out = response.getWriter();
64     DecimalFormat twoDigits = new DecimalFormat( "0.00" );
65
66     // start XHTML document
67     out.println( "<?xml version = \"1.0\"?>" );
68
69     out.println( "<!DOCTYPE html PUBLIC "-//W3C//DTD " +
70         "XHTML 1.0 Strict//EN\" \"http://www.w3.org" +
71         "/TR/xhtml1/DTD/xhtml1-strict.dtd\\>" );
72
73     out.println(
74         "<html xmlns = \"http://www.w3.org/1999/xhtml\\>" );
75
76     // head section of document
77     out.println( "<head>" );
78
79     // read current survey response
80     int value =
81         Integer.parseInt( request.getParameter( "animal" ) );
82
83     // attempt to process a vote and display current results
84     try {
85 }
```

Fig. 9.27 Multi-tier Web-based survey using XHTML, servlets and JDBC (part 2 of 4).

```
86         // update total for current survey response
87         updateVotes.setInt( 1, value );
88         updateVotes.executeUpdate();
89
90         // get total of all survey responses
91         ResultSet totalRS = totalVotes.executeQuery();
92         totalRS.next();
93         int total = totalRS.getInt( 1 );
94
95         // get results
96         ResultSet resultsRS = results.executeQuery();
97         out.println( "<title>Thank you!</title>" );
98         out.println( "</head>" );
99
100        out.println( "<body>" );
101        out.println( "<p>Thank you for participating." );
102        out.println( "<br />Results:</p><pre>" );
103
104        // process results
105        int votes;
106
107        while ( resultsRS.next() ) {
108            out.print( resultsRS.getString( 1 ) );
109            out.print( ":" );
110            votes = resultsRS.getInt( 2 );
111            out.print( twoDigits.format(
112                ( double ) votes / total * 100 ) );
113            out.print( "% responses: " );
114            out.println( votes );
115        }
116
117        resultsRS.close();
118
119        out.print( "Total responses: " );
120        out.print( total );
121
122        // end XHTML document
123        out.println( "</pre></body></html>" );
124        out.close();
125    }
126
127    // if database exception occurs, return error page
128    catch ( SQLException sqlException ) {
129        sqlException.printStackTrace();
130        out.println( "<title>Error</title>" );
131        out.println( "</head>" );
132        out.println( "<body><p>Database error occurred. " );
133        out.println( "Try again later.</p></body></html>" );
134        out.close();
135    }
136
137 } // end of doPost method
138
```

Fig. 9.27 Multi-tier Web-based survey using XHTML, servlets and JDBC (part 3 of 4).

```
139 // close SQL statements and database when servlet terminates
140 public void destroy()
141 {
142     // attempt to close statements and database connection
143     try {
144         updateVotes.close();
145         totalVotes.close();
146         results.close();
147         connection.close();
148     }
149
150     // handle database exceptions by returning error to client
151     catch( SQLException sqlException ) {
152         sqlException.printStackTrace();
153     }
154 } // end of destroy method
155 }
```

Fig. 9.27 Multi-tier Web-based survey using XHTML, servlets and JDBC (part 4 of 4).

Lines 12 and 13 begin by declaring a **Connection** reference to manage the database connection and three **PreparedStatement** references for updating the vote count for an animal, totalling all the votes and obtaining the complete survey results.

Servlets are initialized by overriding method **init** (lines 16–54). Method **init** is called exactly once in a servlet's lifetime, before any client requests are accepted. Method **init** takes a **ServletConfig** argument and throws a **ServletException**. The argument provides the servlet with information about its *initialization parameters* (i.e., parameters not associated with a request, but passed to the servlet for initializing servlet variables). These parameters are specified in the **web.xml** deployment descriptor file as part of a **servlet** element. Each parameter appears in an **init-param** element of the following form:

```
<init-param>
    <param-name>parameter name goes here</param-name>
    <param-value>parameter value goes here</param-value>
</init-param>
```

Servlets can obtain initialization parameter values by invoking **ServletConfig** method **getInitParameter**, which receives a string representing the name of the parameter.

In this example, the servlet's **init** method (lines 16–54) performs the connection to the Cloudscape database. Line 21 loads the driver (**COM.cloudscape.core.Rmi-JdbcDriver**). Lines 22–23 attempt to open a connection to the **animalsurvey** database. The database contains one table (**surveyresults**) that consists of three fields—a unique integer to identify each record called **id**, a string representing the survey option called **surveyoption** and an integer representing the number of votes for a survey option called **votes**. [Note: The examples folder for this chapter contains an SQL script (**animalsurvey.sql**) that you can use to create the **animalsurvey** database for this example. For information on starting the Cloudscape server and executing the SQL script, please refer back to Chapter 8.]

Lines 27–44 create **PreparedStatement** objects called **updateVotes**, **totalVotes** and **results**. The **updateVotes** statement adds one to the **votes**

value for the record with the specified ID. The **totalVotes** statement uses SQL's built-in **sum** capability to total all the **votes** in the **surveyresults** table. The results statement returns all the data in the **surveyresults** table.

When a user submits a survey response, method **doPost** (lines 57–137) handles the request. Lines 80–81 obtain the survey response, then the **try** block (lines 84–125) attempts to process the response. Lines 87–88 set the first parameter of **PreparedStatement updateVotes** to the survey response and update the database. Lines 91–93 execute **PreparedStatement totalVotes** to retrieve the total number of votes received. Then, lines 96–123 execute **PreparedStatement results** and process the **ResultSet** to create the survey summary for the client. When the servlet container terminates the servlet, method **destroy** (lines 140–154) closes each **PreparedStatement**, then closes the database connection. Figure 9.28 shows survey.html, which invokes **SurveyServlet** with the alias **animalsurvey** when the user submits the form.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 9.28: Survey.html -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8 <head>
9   <title>Survey</title>
10 </head>
11
12 <body>
13 <form method = "post" action = "/advjhttp1/animalsurvey">
14
15   <p>What is your favorite pet?</p>
16
17   <p>
18     <input type = "radio" name = "animal"
19       value = "1" />Dog<br />
20     <input type = "radio" name = "animal"
21       value = "2" />Cat<br />
22     <input type = "radio" name = "animal"
23       value = "3" />Bird<br />
24     <input type = "radio" name = "animal"
25       value = "4" />Snake<br />
26     <input type = "radio" name = "animal"
27       value = "5" checked = "checked" />None
28   </p>
29
30   <p><input type = "submit" value = "Submit" /></p>
31
32 </form>
33 </body>
34 </html>
```

Fig. 9.28 Survey.html document that allows users to submit survey responses to SurveyServlet (part 1 of 2).

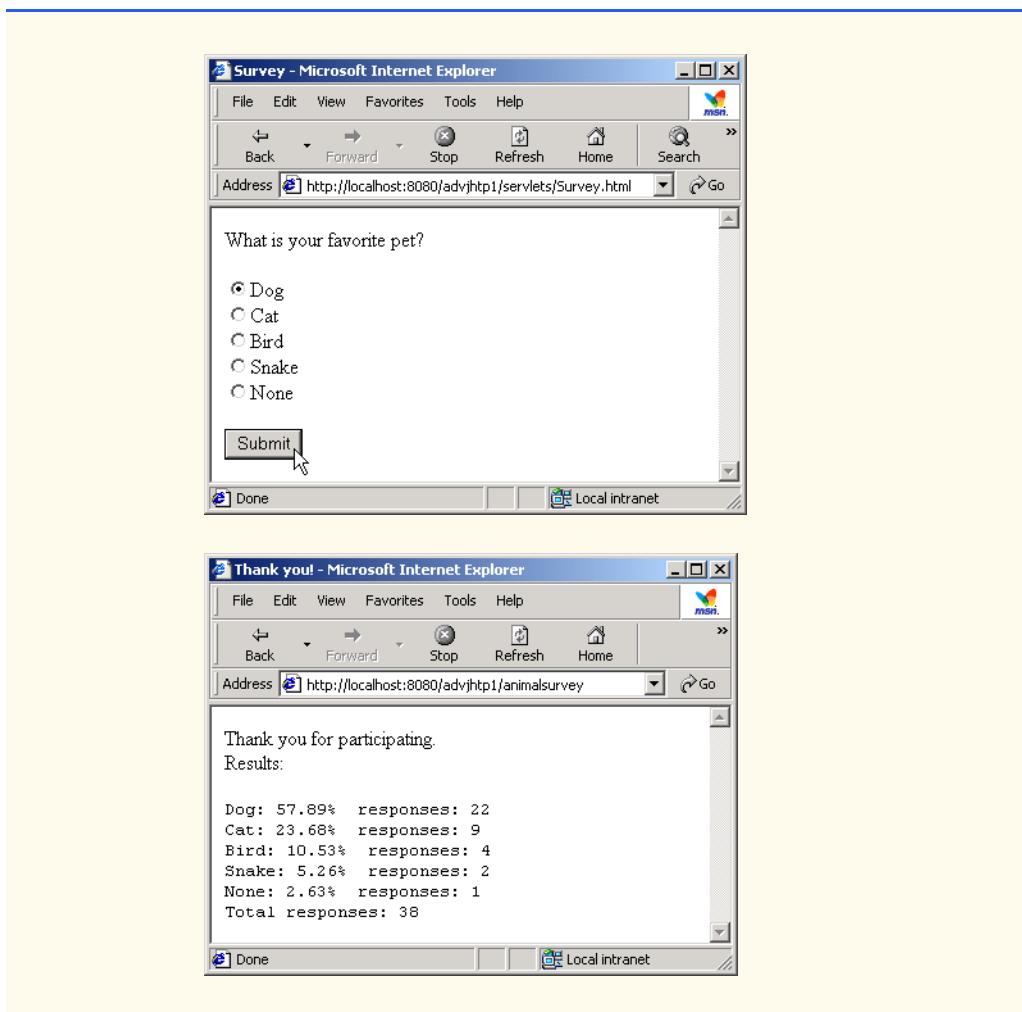


Fig. 9.28 Survey.html document that allows users to submit survey responses to SurveyServlet (part 2 of 2).

We use our **advjhttp1** context root to demonstrate the servlet of Fig. 9.27. Place **Survey.html** in the **servlets** directory created previously. Place **SurveyServlet.class** in the **classes** subdirectory of **WEB-INF** in the **advjhttp1** context root. Then, edit the **web.xml** deployment descriptor in the **WEB-INF** directory to include the information specified in Fig. 9.29. Also, this program cannot execute in Tomcat unless the Web application is aware of the JAR files **cloudscape.jar** and **RmiJdbc.jar** that contain the Cloudscape database driver and its supporting classes. The **cloudscape.jar** file is located in your Cloudscape installation's **lib** directory. The **RmiJdbc.jar** file is located in your Cloudscape installation's **frameworks\RmiJdbc\classes** directory. Place *copies* of these files in the **WEB-INF** subdirectory **lib** to make them available to the Web application. Please refer back to Chapter 8 for more information on the set up and configuration of Cloudscape.

Descriptor element	Value
<i>servlet element</i>	
<b>servlet-name</b>	<b>animalsurvey</b>
<b>description</b>	<b>Connecting to a database from a servlet.</b>
<b>servlet-class</b>	<b>com.deitel.advjhttp1.servlets.SurveyServlet</b>
<i>servlet-mapping element</i>	
<b>servlet-name</b>	<b>animalsurvey</b>
<b>url-pattern</b>	<b>/animalsurvey</b>

Fig. 9.29 Deployment descriptor information for servlet **SurveyServlet**.

A copy of these files should be placed in the **advjhttp1** context root's **WEB-INF** subdirectory called **lib**. After copying these files, restart Tomcat and type the following URL in your Web browser:

```
http://localhost:8080/advjhttp1/servlets/Survey.html
```

Select a survey response, and press the **Submit** button in the Web page to invoke the servlet.

## 9.9 HttpUtils Class

Class **HttpUtils** provides three **static** utility methods to simplify servlet programming. These methods are discussed in Fig. 9.30.

Method	Description
<b>getRequestURL</b>	This method takes the <b>HttpServletRequest</b> object as an argument and returns a <b>StringBuffer</b> containing the original URL that initiated the request.
<b>parsepostData</b>	This method receives an integer and <b>ServletInputStream</b> as arguments. The integer represents the number of bytes in the <b>ServletInputStream</b> . The <b>ServletInputStream</b> contains the key/value pairs <b>posted</b> to the servlet from a <b>form</b> . The method returns a <b>Hashtable</b> containing the key/value pairs.
<b>parseQueryString</b>	This method receives a <b>String</b> representing the query string in a <b>get</b> request as an argument and returns a <b>Hashtable</b> containing the key/value pairs in the query string. The value of each key is an array of <b>Strings</b> . The query string can be obtained with <b>HttpServletRequest</b> method <b>getQueryString</b> .

Fig. 9.30 **HttpUtils** class methods.

## 9.10 Internet and World Wide Web Resources

This section lists a variety of servlet resources available on the Internet and provides a brief description of each.

### **[java.sun.com/products/servlet/index.html](http://java.sun.com/products/servlet/index.html)**

The servlet page at the Sun Microsystems, Inc., Java Web site provides access to the latest servlet information and servlet resources.

### **[jakarta.apache.org](http://jakarta.apache.org)**

This is the Apache Project's home page for the *Jakarta Project*. *Tomcat*—the servlets and JavaServer Pages reference implementation—is one of many subprojects of the Jakarta Project.

### **[jakarta.apache.org/tomcat/index.html](http://jakarta.apache.org/tomcat/index.html)**

Home page for the Tomcat servlets and JavaServer Pages reference implementation.

### **[java.apache.org](http://java.apache.org)**

This is the Apache Project's home page for all Java-related technologies. This site provides access to many Java packages useful to servlet and JSP developers.

### **[www.servlets.com](http://www.servlets.com)**

This is the Web site for the book *Java Servlet Programming* published by O'Reilly. The book provides a variety of resources. This book is an excellent resource for programmers who are learning servlets.

### **[theserverside.com](http://theserverside.com)**

*TheServerSide.com* is dedicated to information and resources for Enterprise Java.

### **[www.servletsource.com](http://www.servletsource.com)**

*ServletSource.com* is a general servlet resource site containing code, tips, tutorials and links to many other Web sites with information on servlets.

### **[www.cookiecentral.com](http://www.cookiecentral.com)**

A good all-around resource site for cookies.

### **[developer.netscape.com/docs/manuals/communicator/jsguide4/cookies.htm](http://developer.netscape.com/docs/manuals/communicator/jsguide4/cookies.htm)**

A description of Netscape cookies.

### **[www.javacorporate.com](http://www.javacorporate.com)**

Home of the open-source *Expresso Framework*, which includes a library of extensible servlet components to help speed Web application development.

### **[www.servlet.com/srvdev.jhtml](http://www.servlet.com/srvdev.jhtml)**

*ServlethInc's Servlet Developers Forum* provides resources for server-side Java developers and information about Web servers that support servlet technologies.

### **[www.servletforum.com](http://www.servletforum.com)**

*ServletForum.com* is a newsgroup where you can post questions and have them answered by your peers.

### **[www.coolservlets.com](http://www.coolservlets.com)**

Provides free open-source Java servlets.

### **[www.cetus-links.org/oo\\_java\\_servlets.html](http://www.cetus-links.org/oo_java_servlets.html)**

Provides a list of links to resources on servlets and other technologies.

### **[www.javaskyline.com](http://www.javaskyline.com)**

*Java Skyline* is an online magazine for servlet developers.

### **[www.rfc-editor.org](http://www.rfc-editor.org)**

The RFC Editor provides a search engine for RFCs (Request for Comments). Many of these RFCs provide details of Web-related technologies. RFCs of interest to servlet developers include *URIs*

(RFC 1630), *URLs* (RFC 1738) URL, *Relative URLs* (RFC 1808), *HTTP/1.0* (RFC 1945), *MIME* (RFCs 2045–2049), *HTTP State Management Mechanism* (RFC 2109), *Use and Interpretation of HTTP Version Numbers* (RFC 2145), *Hypertext Coffee Pot Control Protocol* (RFC 2324), *HTTP/1.1* (RFC 2616) and *HTTP Authentication: Basic and Digest Authentication* (RFC 2617).

#### [www.irvine.com/~mime](http://www.irvine.com/~mime)

The *Multipurpose Internet Mail Extensions FAQ* provides information on MIME and a list of many registered MIME types, as well as links to other MIME resources.

## SUMMARY

- The classes and interfaces used to define servlets are found in packages **javax.servlet** and **javax.servlet.http**.
- The Internet offers many protocols. The HTTP protocol (Hypertext Transfer Protocol) that forms the basis of the World Wide Web uses URIs (Uniform Resource Identifiers) to locate resources on the Internet.
- Common URLs represent files or directories and can represent complex tasks such as database lookups and Internet searches.
- JavaServer Pages technology is an extension of servlet technology.
- Servlets are normally executed as part of a Web server (also known as the servlet container).
- Servlets and JavaServer Pages have become so popular that they are now supported by most major Web servers and application servers.
- All servlets must implement the **Servlet** interface. The methods of interface **Servlet** are invoked automatically by the servlet container.
- A servlet's life cycle begins when the servlet container loads the servlet into memory—normally in response to the first request to that servlet. Before the servlet can handle the first request, the servlet container invokes the servlet's **init** method. After **init** completes execution, the servlet can respond to its first request. All requests are handled by a servlet's **service** method, which may be called many times during the life cycle of a servlet. When the servlet container terminates the servlet, the servlet's **destroy** method is called to release servlet resources.
- The servlet packages define two **abstract** classes that implement the interface **Servlet**—class **GenericServlet** and class **HttpServlet**. Most servlets extend one of these classes and override some or all of their methods with appropriate customized behaviors.
- The key method in every servlet is method **service**, which receives both a **ServletRequest** object and a **ServletResponse** object. These objects provide access to input and output streams that allow the servlet to read data from the client and send data to the client.
- Web-based servlets typically extend class **HttpServlet**. Class **HttpServlet** overrides method **service** to distinguish between the typical requests received from a client Web browser. The two most common HTTP request types (also known as request methods) are **get** and **post**.
- Class **HttpServlet** defines methods **doGet** and **doPost** to respond to **get** and **post** requests from a client, respectively. These methods are called by the **HttpServlet** class's **service** method, which is called when a request arrives at the server.
- Methods **doGet** and **doPost** receive as arguments an **HttpServletRequest** object and an **HttpServletResponse** object that enable interaction between the client and the server.
- A response is sent to the client through a **PrintWriter** object returned by the **getWriter** method of the **HttpServletResponse** object.
- The **HttpServletResponse** object's **setContentType** method specifies the MIME type of the response to the client. This enables the client browser to understand and handle the content.

- The server **localhost** (IP address **127.0.0.1**) is a well-known server host name on most computers that support TCP/IP-based networking protocols such as HTTP. This host name can be used to test TCP/IP applications on the local computer.
- The Tomcat server awaits requests from clients on port 8080. This port number must be specified as part of the URL to request a servlet running in Tomcat.
- The client can access a servlet only if that servlet is installed on a server that can respond to servlet requests. Web servers that support servlets normally have an installation procedure for servlets.
- Tomcat is a fully functional implementation of the JSP and servlet standards. It includes a Web server, so it can be used as a stand-alone test container for JSPs and servlets.
- Tomcat can be specified as the handler for JSP and servlet requests received by popular Web servers such as Apache and IIS. Tomcat also is integrated into the Java 2 Enterprise Edition reference implementation from Sun Microsystems.
- JSPs, servlets and their supporting files are deployed as part of Web applications. In Tomcat, Web applications are deployed in the **webapps** subdirectory of the Tomcat installation.
- A Web application has a well-known directory structure in which all the files that are part of the application reside. This directory structure can be set up by the Tomcat server administrator in the **webapps** directory, or the entire directory structure can be archived in a Web application archive file. Such an archive is known as a WAR file and ends with the **.war** file extension.
- If a WAR file is placed in the **webapps** directory, when the Tomcat server starts up it extracts the contents of the WAR file into the appropriate **webapps** subdirectory structure.
- The Web application directory structure is separated into a context root—the top-level directory for an entire Web application—and several subdirectories. The context root is the root directory for the Web application. All the JSPs, HTML documents, servlets and supporting files such as images and class files reside in this directory or its subdirectories. The **WEB-INF** directory contains the Web application deployment descriptor (**web.xml**). The **WEB-INF/classes** directory contains the servlet class files and other supporting class files used in a Web application. The **WEB-INF/lib** directory contains Java archive (JAR) files that may include servlet class files and other supporting class files used in a Web application.
- Before deploying a Web application, the servlet container must be made aware of the context root for the Web application. In Tomcat, this can be done simply by placing a directory in the **webapps** subdirectory. Tomcat uses the directory name as the context name.
- Deploying a Web application requires the creation of a deployment descriptor (**web.xml**).
- HTTP **get** requests can be typed directly into your browser's **Address** or **Location** field.
- Parameters are passed as name/value pairs in a **get** request. A **?** separates the URL from the data passed as part of a **get** request. Name/value pairs are passed with the name and the value separated by **=**. If there is more than one name/value pair, each name/value pair is separated by **&**.
- Method **getParameter** of interface **HttpServletRequest** receives the parameter name as an argument and returns the corresponding **String** value, or **null** if the parameter is not part of the request.
- An HTTP **post** request is often used to post data from an Web-page form to a server-side form handler that processes the data.
- Browsers often cache (save on disk) Web pages so they can quickly reload the pages. Browsers do not cache the server's response to a **post** request.
- Method **doPost** receives the same two arguments as **doGet**—an object that implements interface **HttpServletRequest** to represent the client's request and an object that implements interface **HttpServletResponse** to represent the servlet's response.

- Method **sendRedirect** of **HttpServletResponse** redirects a request to the specified URL.
- When a servlet uses a relative path to reference another static or dynamic resource, the servlet assumes the same context root unless a complete URL is specified for the resource.
- Once method **sendRedirect** executes, processing of the request by the servlet that called **sendRedirect** terminates.
- When redirecting requests, the request parameters from the original request are passed as parameters to the new request. Additional request parameters also can be passed.
- New parameters are added to the existing request parameters. If a new parameter has the same name as an existing parameter, the new parameter value takes precedence over the original value. However, all the values are still passed.
- The complete set of values for a given request-parameter name can be obtained by calling method **getParameterValues** from interface **HttpServletRequest**, which receives the parameter name as an argument and returns an array of **Strings** containing the parameter values in order from the most recently added value for that parameter to the least recently added.
- Many Web sites today provide custom Web pages and/or functionality on a client-by-client basis.
- HTTP is a stateless protocol—it does not support persistent information that could help a Web server determine that a request is from a particular client.
- Cookies can store information on the user's computer for retrieval later in the same or in future browsing sessions.
- Cookies are text-based data that are sent by servlets (or other similar technologies) as part of responses to clients.
- Every HTTP-based interaction between a client and a server includes a header containing information about the request (when the communication is from the client to the server) or information about the response (when the communication is from the server to the client).
- When the server receives a request, the header includes information such as the request type (e.g., **get** or **post**) and the cookies stored on the client machine by the server.
- When the server formulates its response, the header information includes any cookies the server wants to store on the client computer and other information such as the MIME type of the response.
- Depending on the maximum age of a cookie, the Web browser either maintains the cookie for the duration of the browsing session or stores the cookie on the client computer for future use. When the browser requests a resource from a server, cookies previously sent to the client by that server are returned to the server as part of the request formulated by the browser. Cookies are deleted automatically when they expire.
- By default, cookies only exist for the current browsing session (until the user closes the browser). To make cookies persist beyond the current session, call **Cookie** method **setMaxAge** to indicate the number of seconds until the cookie expires.
- Method **addCookie** of interface **HttpServletResponse** adds a cookie to the response. Cookies are sent to the client as part of the HTTP header. The header information is always provided to the client first, so the cookies should be added before the response is output.
- **HttpServletRequest** method **getCookies** returns an array of **Cookie** objects. Method **getCookies** returns **null** if there are no cookies in the request.
- **Cookie** method **getName** retrieves the name of a cookie. **Cookie** method **getValue** retrieves the value of a cookie.
- Java provides enhanced session An alternative approach to cookies is to track a session with **HttpSessions**, which eliminate the problems associated with clients disabling cookies in their browsers by making the session-tracking mechanism transparent to the programmer.

- Method **getSession** of interface **HttpServletRequest** obtains an **HttpSession** object for the client.
- Like a cookie, an **HttpSession** object can store name/value pairs. In sessions, these are called attributes, and they are stored with **setAttribute** and retrieved with **getAttribute**.
- Name/value pairs added to an **HttpSession** object with **setAttribute** remain available until the client's current browsing session ends or until the session is explicitly invalidated by a call to the **HttpSession** object's **invalidate** method.
- **HttpSession** method **getID** obtains the session's unique ID number.
- **HttpSession** method **isNew** determines whether a session is new or already exists. Method **getCreationTime** obtains the time at which the session was created.
- **HttpSession** method **getLastAccessedTime** obtains the time at which the session was last accessed.
- **HttpSession** method **getMaxInactiveInterval** obtains the maximum amount of time that an **HttpSession** object can be inactive before the servlet container discards it.
- Many of today's applications are three-tier distributed applications, consisting of a user interface, business logic and database access.
- In multi-tier architectures, Web servers often represent the middle tier. They provide the business logic that manipulates data from databases and that communicates with client Web browsers.
- **Servlet** method **init** takes a **ServletConfig** argument and throws a **ServletException**. The argument provides the servlet with information about its initialization parameters that are specified in a  **servlet** element in the deployment descriptor. Each parameter appears in an **init-param** element with child elements **param-name** and **param-value**.

## TERMINOLOGY

<b>addCookie</b> method of	<b>getLastErrorAccessedTime</b> method of
<b>HttpServletResponse</b>	<b>HttpSession</b>
Apache Tomcat server	<b>getMaxInactiveInterval</b> method of
cache a Web page	<b>HttpSession</b>
commit a response	<b>getName</b> method of <b>Cookie</b>
context root	<b>getOutputStream</b> method of
<b>Cookie</b> class	<b>HTTPServletResponse</b>
<b>delete</b> request	<b>getParameter</b> method of
deploy a Web application	<b>HttpServletRequest</b>
deployment descriptor	<b>getParameterNames</b> method of
<b>destroy</b> method of <b>Servlet</b>	<b>HttpServletRequest</b>
<b>doGet</b> method of <b>HttpServlet</b>	<b>getParameterValues</b> method of
<b>doPost</b> method of <b>HttpServlet</b>	<b>HttpServletRequest</b>
<b>GenericServlet</b> class from	<b>getServletConfig</b> method of <b>Servlet</b>
<b>javax.servlet</b>	<b>getServletInfo</b> method of <b>Servlet</b>
<b>get</b> request	<b>getSession</b> method of
<b>HttpServletResponse</b>	<b>HttpServletRequest</b>
<b>getAttribute</b> method of <b>HttpSession</b>	<b>getValue</b> method of <b>Cookie</b>
<b>getAttributeNames</b> method of	<b>getWriter</b> method of
<b>HttpSession</b>	<b>HTTPServletResponse</b>
<b>getCookies</b> method of	host name
<b>HttpServletRequest</b>	
<b>getCreationTime</b> method of <b>HttpSession</b>	HTTP (Hypertext Transfer Protocol)
<b>getID</b> method of <b>HttpSession</b>	HTTP header

HTTP request	servlet container
<b>HttpServlet</b> interface	<b>Servlet</b> interface
<b>HttpServletRequest</b> interface	servlet life cycle
<b>HttpServletResponse</b> interface	servlet mapping
<b>HttpSession</b> interface	<b>ServletConfig</b> interface
<b>init</b> method of <b>Servlet</b>	<b>ServletContext</b> interface
initialization parameter	<b>ServletException</b> class
<b>invalidate</b> method of <b>HttpSession</b>	<b>ServletOutputStream</b> class
<b>isNew</b> method of <b>HttpSession</b>	<b>ServletRequest</b> interface
Jakarta project	<b>ServletResponse</b> interface
<b>JAVA_HOME</b> environment variable	session tracking
<b>javax.servlet</b> package	<b>setAttribute</b> method of <b>HttpSession</b>
<b>javax.servlet.http</b> package	<b>setContentType</b> method of <b>HttpServletResponse</b>
Jigsaw Web server	shopping cart
<b>localhost (127.0.0.1)</b>	<b>text/html</b> MIME type
maximum age of a cookie	thin client
MIME type	<b>TOMCAT_HOME</b> environment variable
<b>options</b> request	<b>trace</b> request
<b>path</b> attribute	URL pattern
port	WAR (Web application archive) file
<b>post</b> request	Web application
<b>put</b> request	Web application deployment
redirect a request	descriptor ( <b>web.xml</b> )
request method	<b>webapps</b> directory
request parameter	<b>WEB-INF</b> directory
<b>sendRedirect</b> method of <b>HttpServletResponse</b>	<b>WEB-INF/classes</b> directory
<b>service</b> method of <b>Servlet</b>	<b>WEB-INF/lib</b> directory
servlet	well-known port number

## SELF-REVIEW EXERCISES

- 9.1** Fill in the blanks in each of the following statements:
- Classes **HttpServlet** and **GenericServlet** implement the \_\_\_\_\_ interface.
  - Class **HttpServlet** defines the methods \_\_\_\_\_ and \_\_\_\_\_ to respond to **get** and **post** requests from a client.
  - HttpServletResponse** method \_\_\_\_\_ obtains a character-based output stream that enables text data to be sent to the client.
  - The **form** attribute \_\_\_\_\_ specifies the server-side *form handler*, i.e., the program that handles the request.
  - \_\_\_\_\_ is the well-known host name that refers to your own computer.
  - Cookie** method \_\_\_\_\_ returns a **String** the name of the cookie as set with \_\_\_\_\_ or the constructor.
  - HttpServletRequest** method **getSession** returns an \_\_\_\_\_ object for the client.
- 9.2** State whether each of the following is *true* or *false*. If *false*, explain why.
- Servlets usually are used on the client side of a networking application.
  - Servlet methods are executed automatically.
  - The two most common HTTP requests are **get** and **put**.
  - The well-known port number for Web requests is 55.

- e) **Cookies** never expire.
- f) **HttpSessions** expire only when the browsing session ends or when the **invalidate** method is called.
- g) The **HttpSession** method **getAttribute** returns the object associated with a particular name.

## ANSWERS TO SELF-REVIEW EXERCISES

**9.1** a) **Servlet**. b) **doGet**, **doPost**. c) **getWriter**. d) **action**. e) **localhost**. f) **getName**, **setName**. g) **HttpSession**.

- 9.2**
- a) False. Servlets are usually used on the server side.
  - b) True.
  - c) False. The two most common HTTP request types are **get** and **post**.
  - d) False. The well-known port number for Web requests is 80.
  - e) False. **Cookies** expire when they reach their maximum age.
  - f) True.
  - g) True.

## EXERCISES

**9.3** Modify the **Cookie** example of Fig. 9.20 to list prices for each book in the book recommendations. Also, allow the user to select some or all of the recommended books and “order” them. Deploy your Web application on the Tomcat server.

**9.4** Modify the **HttpSession** example of Fig. 9.24 to list prices for each book in the book recommendations. Also, allow the user to select some or all of the recommended books and “order” them. Deploy your Web application on the Tomcat server.

**9.5** Create a Web application for dynamic FAQs. The application should obtain the information to create the dynamic FAQ Web page from a database that consists of a **Topics** table and an **FAQ** table. The **Topics** table should have two fields—a unique integer ID for each topic (**topicID**) and a name for each topic (**topicName**). The **FAQ** table should have three fields—the **topicID** (a foreign key), a string representing the question (**question**) and the answer to the question (**answer**). When the servlet is invoked, it should read the data from the database and return a dynamically created Web page containing each question and answer, sorted by topic.

**9.6** Modify the Web application of Exercise 9.5 so that the initial request to the servlet returns a Web page of topics in the FAQ database. Then, the user can hyperlink to another servlet that returns only the frequently asked questions for a particular topic.

**9.7** Modify the Web application of Fig. 9.27 to allow the user to see the survey results without responding to the survey.

**9.8** Fig. 9.27 would allow users to vote as many times as they want by simply returning to the survey Web page and submitting additional votes. Modify your solution to Exercise 9.7 such that it uses cookies that last for one day to prevent users from voting more than once a day. When a user returns to the site, the cookie previously stored on their system is sent to the server. The servlet should check for the cookie and, if it exists, indicate that the client already voted in the last 24 hours. The servlet should also return the current survey results.

**9.9** Modify the Web application of Fig. 9.27 to make it generic for use with any survey of the appropriate form. Use servlet parameters (as discussed in Section 9.8) to specify the survey options. When the user requests the survey, dynamically generate a **form** containing the survey options. Deploy this Web application twice using different context roots. *Note:* You may need to modify the database in this example so that it can store multiple surveys at once.

**9.10** Write a Web application that consists of a servlet (**DirectoryServlet**) and several Web documents. Document **index.html** should be the first document the user sees. In that document, you should have a series of hyperlinks for other Web pages in your site. When clicked, each hyperlink should invoke the servlet with a **get** request that contains a **page** parameter. The servlet should obtain parameter **page** and redirect the request to the appropriate document.

**9.11** Modify the Web application of Exercise 9.10 so that the first document the user sees in the browser is dynamically generated from servlet initialization parameters (as discussed in Section 9.8) by servlet **HomePageServlet**. There should be a separate initialization parameter for each page in the Web site. The **HomePageServlet** reads each parameter name and value and creates a **HashMap** of the parameter name/value pairs. This information should be used to create the initial home page dynamically. The **HashMap** also should be placed in the **ServletContext** with method **setAttribute**, so that the **HashMap** can be used in the **DirectoryServlet** to determine where to direct each request. The dynamic home page should have hyperlinks to each document in the Web site. As in Exercise 9.10, when the user clicks a link, servlet **DirectoryServlet** should be invoked and passed a page parameter. Then, the **DirectoryServlet** should obtain the **HashMap** from the **ServletContext**, look up the corresponding document and redirect the user to that document.

# 10

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# JavaServer Pages (JSP)

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## Objectives

- To be able to create and deploy JavaServer Pages.
- To use JSP's implicit objects and Java to create dynamic Web pages.
- To specify global JSP information with directives.
- To use actions to manipulate JavaBeans in a JSP, to include resources dynamically and to forward requests to other JSPs.
- To create custom tag libraries that encapsulate complex functionality in new tags that can be reused by JSP programmers and Web-page designers.

*A tomato does not communicate with a tomato, we believe.  
We could be wrong.*

Gustav Eckstein

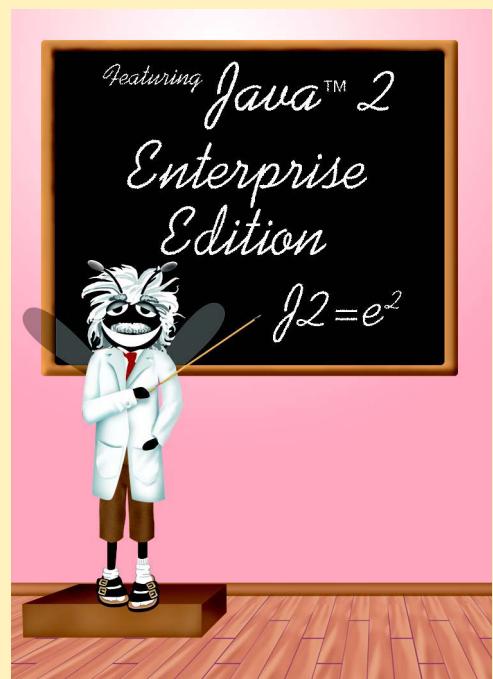
*A donkey appears to me like a horse translated into Dutch.*  
Georg Christoph Lichtenberg

*Talent is a question of quantity. Talent does not write one page: it writes three hundred.*

Jules Renard

*Every action must be due to one or other of seven causes:  
chance, nature, compulsion, habit, reasoning, anger, or  
appetite.*

Aristotle



## Outline

- 10.1 Introduction
- 10.2 JavaServer Pages Overview
- 10.3 A First JavaServer Page Example
- 10.4 Implicit Objects
- 10.5 Scripting
  - 10.5.1 Scripting Components
  - 10.5.2 Scripting Example
- 10.6 Standard Actions
  - 10.6.1 <jsp:include> Action
  - 10.6.2 <jsp:forward> Action
  - 10.6.3 <jsp:plugin> Action
  - 10.6.4 <jsp:useBean> Action
- 10.7 Directives
  - 10.7.1 page Directive
  - 10.7.2 include Directive
- 10.8 Custom Tag Libraries
  - 10.8.1 Simple Custom Tag
  - 10.8.2 Custom Tag with Attributes
  - 10.8.3 Evaluating the Body of a Custom Tag
- 10.9 World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 10.1 Introduction

Our discussion of client–server networking continues in this chapter with *JavaServer Pages (JSP)*—an extension of servlet technology. JavaServer Pages simplify the delivery of dynamic Web content. They enable Web application programmers to create dynamic content by reusing predefined components and by interacting with components using server-side scripting. JavaServer Page programmers can reuse JavaBeans and create custom tag libraries that encapsulate complex, dynamic functionality. Custom-tag libraries even enable Web-page designers who are not familiar with Java to enhance Web pages with powerful dynamic content and processing capabilities.

In addition to the classes and interfaces for programming servlets (from packages **javax.servlet** and **javax.servlet.http**), classes and interfaces specific to JavaServer Pages programming are located in packages **javax.servlet.jsp** and **javax.servlet.jsp.tagext**. We discuss many of these classes and interfaces throughout this chapter as we present JavaServer Pages fundamentals. For a complete description of JavaServer Pages, see the JavaServer Pages 1.1 specification, which can be downloaded from [java.sun.com/products/jsp/download.html](http://java.sun.com/products/jsp/download.html). We also

include other JSP resources in Section 10.9. [Note: The source code and images for all the examples in this chapter can be found on the CD that accompanies this book and on our Web site [www.deitel.com](http://www.deitel.com).]

## 10.2 JavaServer Pages Overview

There are four key components to JSPs: *directives*, *actions*, *scriptlets* and *tag libraries*. Directives are messages to the JSP container that enable the programmer to specify page settings, to include content from other resources and to specify custom tag libraries for use in a JSP. Actions encapsulate functionality in predefined tags that programmers can embed in a JSP. Actions often are performed based on the information sent to the server as part of a particular client request. They also can create Java objects for use in JSP scriptlets. Scriptlets, or *scripting elements*, enable programmers to insert Java code that interacts with components in a JSP (and possibly other Web application components) to perform request processing. Tag libraries are part of the *tag extension mechanism* that enables programmers to create custom tags. Such tags enable programmers to manipulate JSP content. These JSP component types are discussed in detail in subsequent sections.

In many ways, Java Server Pages look like standard XHTML or XML documents. In fact, JSPs normally include XHTML or XML markup. Such markup is known as *fixed-template data* or *fixed-template text*. Fixed-template data often help a programmer decide whether to use a servlet or a JSP. Programmers tend to use JSPs when most of the content sent to the client is fixed template data and only a small portion of the content is generated dynamically with Java code. Programmers use servlets when only a small portion of the content sent to the client is fixed-template data. In fact, some servlets do not produce content. Rather, they perform a task on behalf of the client, then invoke other servlets or JSPs to provide a response. Note that in most cases, servlet and JSP technologies are interchangeable. As with servlets, JSPs normally execute as part of a Web server. The server often is referred to as the *JSP container*.



### Software Engineering Observation 10.1

Literal text in a JSP becomes string literals in the servlet that represents the translated JSP.

When a JSP-enabled server receives the first request for a JSP, the JSP container translates that JSP into a Java servlet that handles the current request and future requests to the JSP. If there are any errors compiling the new servlet, these errors result in *translation-time errors*. The JSP container places the Java statements that implement the JSP's response in method `_jspService` at translation time. If the new servlet compiles properly, the JSP container invokes method `_jspService` to process the request. The JSP may respond directly to the request or may invoke other Web application components to assist in processing the request. Any errors that occur during request processing are known as *request-time errors*.



### Performance Tip 10.1

Some JSP containers translate JSPs to servlets at installation time. This eliminates the translation overhead for the first client that requests each JSP.

Overall, the request/response mechanism and life cycle of a JSP is the same as that of a servlet. JSPs can define methods `jspInit` and `jspDestroy` (similar to servlet

methods **init** and **destroy**), which the JSP container invokes when initializing a JSP and terminating a JSP, respectively. JSP programmers can define these methods using JSP *declarations*—part of the JSP scripting mechanism.

### 10.3 A First JavaServer Page Example

We begin our introduction to JavaServer Pages with a simple example (Fig. 10.1) in which the current date and time are inserted into a Web page using a JSP expression.

As you can see, most of **clock.jsp** consists of XHTML markup. In cases like this, JSPs are easier to implement than servlets. In a servlet that performs the same task as this JSP, each line of XHTML markup typically is a separate Java statement that outputs the string representing the markup as part of the response to the client. Writing code to output markup can often lead to errors. Most JSP editors provide syntax coloring to help programmers check that their markup follows proper syntax.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.1: clock.jsp -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8
9   <head>
10    <meta http-equiv = "refresh" content = "60" />
11
12   <title>A Simple JSP Example</title>
13
14   <style type = "text/css">
15     .big { font-family: helvetica, arial, sans-serif;
16           font-weight: bold;
17           font-size: 2em; }
18   </style>
19 </head>
20
21 <body>
22   <p class = "big">Simple JSP Example</p>
23
24   <table style = "border: 6px outset;">
25     <tr>
26       <td style = "background-color: black;">
27         <p class = "big" style = "color: cyan;">
28           <!-- JSP expression to insert date/time -->
29           <%= new java.util.Date() %>
30
31         </p>
32       </td>
33     </tr>
34   </table>
35 </body>
```

Fig. 10.1 Using a JSP expression to insert the date and time in a Web page (part 1 of 2).

```
37  
38  </html>
```

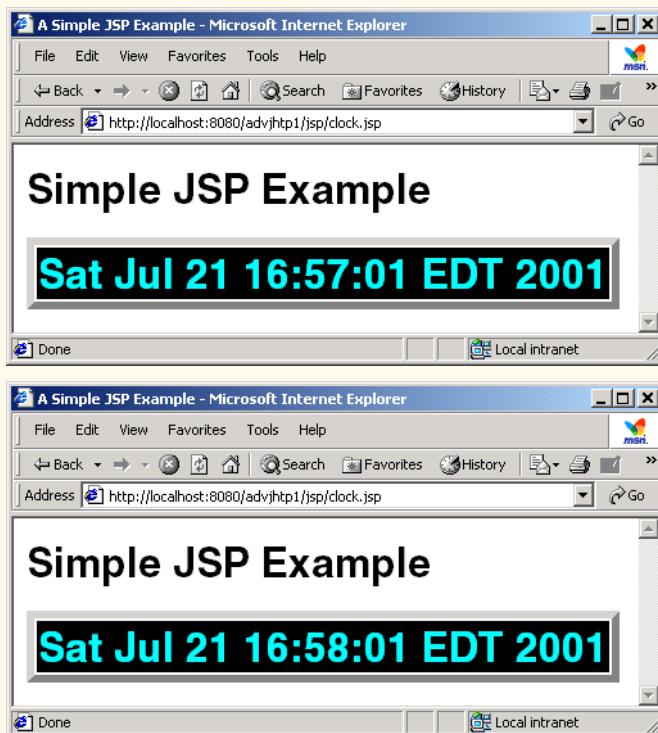


Fig. 10.1 Using a JSP expression to insert the date and time in a Web page (part 2 of 2).



### Software Engineering Observation 10.2

JavaServer Pages are easier to implement than servlets when the response to a client request consists primarily of markup that remains constant between requests.

The JSP of Fig. 10.1 generates an XHTML document that displays the current date and time. The key line in this JSP (line 30) is the expression

```
<%= new java.util.Date() %>
```

JSP expressions are delimited by `<%=` and `%>`. This particular expression creates a new instance of class **Date** from package **java.util**. When the client requests this JSP, the preceding expression inserts the **String** representation of the date and time in the response to the client. [Note: Proper internationalization requires that the JSP return the date in the client locale's format. In this example, the server's local determines the **String** representation of the **Date**. In Fig. 10.9, **clock2.jsp** demonstrates how to determine the client's locale and uses a **DateFormat** (package **java.text**) object to format the date using that locale.]



### Software Engineering Observation 10.3

The JSP container converts the result of every JSP expression into a **String** that is output as part of the response to the client.

Note that we use the XHTML **meta** element on line 10 to set a *refresh interval* of 60 seconds for the document. This causes the browser to request **clock.jsp** every 60 seconds. For each request to **clock.jsp**, the JSP container reevaluates the expression on line 30, creating a new **Date** object with the server's current date and time.

As in Chapter 9, we use Apache Tomcat to test our JSPs in the **advjhttp1** Web application we created previously. For details on creating and configuring the **advjhttp1** Web application, review Section 9.3.1 and Section 9.3.2. To test **clock.jsp**, create a new directory called **jsp** in the **advjhttp1** subdirectory of Tomcat's **webapps** directory. Next, copy **clock.jsp** into the **jsp** directory. Open your Web browser and enter the following URL to test **clock.jsp**:

```
http://localhost:8080/advjhttp1/jsp/clock.jsp
```

When you first invoke the JSP, notice the delay as Tomcat translates the JSP into a servlet and invokes the servlet to respond to your request. [Note: It is not necessary to create a directory named **jsp** in a Web application. We use this directory to separate the examples in this chapter from the servlet examples in Chapter 9.]

## 10.4 Implicit Objects

*Implicit objects* provide programmers with access to many servlet capabilities in the context of a JavaServer Page. Implicit objects have four scopes: *application*, *page*, *request* and *session*. The JSP and servlet container application owns objects with *application scope*. Any servlet or JSP can manipulate such objects. Objects with *page scope* exist only in the page that defines them. Each page has its own instances of the page-scope implicit objects. Objects with *request scope* exist for the duration of the request. For example, a JSP can partially process a request, then forward the request to another servlet or JSP for further processing. Request-scope objects go out of scope when request processing completes with a response to the client. Objects with *session scope* exist for the client's entire browsing session. Figure 10.2 describes the JSP implicit objects and their scopes. This chapter demonstrates several of these objects.

Implicit Object	Description
<i>Application Scope</i>	
<b>application</b>	This <b>javax.servlet.ServletContext</b> object represents the container in which the JSP executes.
<i>Page Scope</i>	
<b>config</b>	This <b>javax.servlet.ServletConfig</b> object represents the JSP configuration options. As with servlets, configuration options can be specified in a Web application descriptor.
<b>exception</b>	This <b>java.lang.Throwable</b> object represents the exception that is passed to the JSP error page. This object is available only in a JSP error page.

Fig. 10.2 JSP implicit objects (part 1 of 2).

Implicit Object	Description
<b>out</b>	This <b>javax.servlet.jsp.JspWriter</b> object writes text as part of the response to a request. This object is used implicitly with JSP expressions and actions that insert string content in a response.
<b>page</b>	This <b>java.lang.Object</b> object represents the <b>this</b> reference for the current JSP instance.
<b>pageContext</b>	This <b>javax.servlet.jsp.PageContext</b> object hides the implementation details of the underlying servlet and JSP container and provides JSP programmers with access to the implicit objects discussed in this table.
<b>response</b>	This object represents the response to the client. The object normally is an instance of a class that implements <b>HttpServletResponse</b> (package <b>javax.servlet.http</b> ). If a protocol other than HTTP is used, this object is an instance of a class that implements <b>javax.servlet.ServletResponse</b> .
<i>Request Scope</i>	
<b>request</b>	This object represents the client request. The object normally is an instance of a class that implements <b>HttpServletRequest</b> (package <b>javax.servlet.http</b> ). If a protocol other than HTTP is used, this object is an instance of a subclass of <b>javax.servlet.ServletRequest</b> .
<i>Session Scope</i>	
<b>session</b>	This <b>javax.servlet.http.HttpSession</b> object represents the client session information if such a session has been created. This object is available only in pages that participate in a session.

Fig. 10.2 JSP implicit objects (part 2 of 2).

Note that many of the implicit objects extend classes or implement interfaces discussed in Chapter 9. Thus, JSPs can use the same methods that servlets use to interact with such objects, as described in Chapter 9. Most of the examples in this chapter use one or more of the implicit objects in Fig. 10.2.

## 10.5 Scripting

JavaServer Pages often present dynamically generated content as part of an XHTML document sent to the client in response to a request. In some cases, the content is static, but is output only if certain conditions are met during a request (such as providing values in a **form** that submits a request). JSP programmers can insert Java code and logic in a JSP using scripting.



### Software Engineering Observation 10.4

JavaServer Pages currently support scripting only with Java. Future JSP versions may support other scripting languages.

### 10.5.1 Scripting Components

JSP scripting components include scriptlets, comments, expressions, declarations and escape sequences. This section describes each of these scripting components. Many of these scripting components are demonstrated in Fig. 10.4 at the end of Section 10.5.2.

Scriptlets are blocks of code delimited by `<%` and `%>`. They contain Java statements that the container places in method `_jspService` at translation time.

JSPs support three comment styles: JSP comments, XHTML comments and comments from the scripting language. *JSP comments* are delimited by `<%--` and `--%>`. Such comments can be placed throughout a JSP, but not inside scriptlets. *XHTML comments* are delimited with `<!--` and `-->`. These comments can be placed throughout a JSP, but not inside scriptlets. Scripting language comments are currently Java comments, because Java is the only JSP scripting language at the present time. Scriptlets can use Java's single-line comments (delimited by `/` and `/`) and multiline comments (delimited by `/*` and `*/`).



#### Common Programming Error 10.1

Placing a JSP comment or XHTML comment inside a scriptlet is a translation-time syntax error that prevents the JSP from being translated properly.

JSP comments and scripting-language comments are ignored and do not appear in the response to a client. When clients view the source code of a JSP response, they will see only the XHTML comments in the source code. The different comment styles are useful for separating comments that the user should be able to see from comments that document logic processed on the server.

A JSP expression, delimited by `<%=` and `%>`, contains a Java expression that is evaluated when a client requests the JSP containing the expression. The container converts the result of a JSP expression to a **String** object, then outputs the **String** as part of the response to the client.

Declarations (delimited by `<%!` and `%>`) enable a JSP programmer to define variables and methods. Variables become instance variables of the servlet class that represents the translated JSP. Similarly, methods become members of the class that represents the translated JSP. Declarations of variables and methods in a JSP use Java syntax. Thus, a variable declaration must end in a semicolon, as in

```
<%! int counter = 0; %>
```



#### Common Programming Error 10.2

Declaring a variable without using a terminating semicolon is a syntax error.



#### Software Engineering Observation 10.5

Variables and methods declared in JSP declarations are initialized when the JSP is initialized and are available for use in all scriptlets and expressions in that JSP. Variables declared in this manner become instance variables of the servlet class that represents the translated JSP.



#### Software Engineering Observation 10.6

As with servlets, JSPs should not store client state information in instance variables. Rather, JSPs should use the JSP implicit **session** object.

Special characters or character sequences that the JSP container normally uses to delimit JSP code can be included in a JSP as literal characters in scripting elements, fixed template data and attribute values using *escape sequences*. Figure 10.3 shows the literal character or characters and the corresponding escape sequences and discusses where to use the escape sequences.

### 10.5.2 Scripting Example

The JSP of Fig. 10.4 demonstrates basic scripting capabilities by responding to **get** requests. The JSP enables the user to input a first name, then outputs that name as part of the response. Using scripting, the JSP determines whether a **firstName** parameter was passed to the JSP as part of the request; if not, the JSP returns an XHTML document containing a **form** through which the user can input a first name. Otherwise, the JSP obtains the **firstName** value and uses it as part of an XHTML document that welcomes the user to JavaServer Pages.

Literal	Escape sequence	Description
<%	<\%	The character sequence <% normally indicates the beginning of a scriptlet. The <\% escape sequence places the literal characters <% in the response to the client.
%>	%\>	The character sequence %> normally indicates the end of a scriptlet. The %\> escape sequence places the literal characters %> in the response to the client.
'	\'	As with string literals in a Java program, the escape sequences for characters ' and " allow these characters to appear in attribute values. Remember that the literal text in a JSP becomes string literals in the servlet that represents the translated JSP.
"	\"	
\	\\	

Fig. 10.3 JSP escape sequences.

```
1  <?xml version = "1.0"?>
2  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3      "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5  <!-- Fig. 10.4: welcome.jsp -->
6  <!-- JSP that processes a "get" request containing data. -->
7
8  <html xmlns = "http://www.w3.org/1999/xhtml">
9
10     <!-- head section of document -->
11     <head>
12         <title>Processing "get" requests with data</title>
13     </head>
14
```

Fig. 10.4 Scripting a JavaServer Page—**welcome.jsp** (part 1 of 3).

```
15    <!-- body section of document -->
16    <body>
17        <% // begin scriptlet
18
19            String name = request.getParameter( "firstName" );
20
21            if ( name != null ) {
22
23                %> <%-- end scriptlet to insert fixed template data --%>
24
25                <h1>
26                    Hello <%= name %>, <br />
27                    Welcome to JavaServer Pages!
28                </h1>
29
30            <% // continue scriptlet
31
32        } // end if
33        else {
34
35            %> <%-- end scriptlet to insert fixed template data --%>
36
37            <form action = "welcome.jsp" method = "get">
38                <p>Type your first name and press Submit</p>
39
40                <p><input type = "text" name = "firstName" />
41                    <input type = "submit" value = "Submit" />
42                </p>
43            </form>
44
45            <% // continue scriptlet
46
47        } // end else
48
49        %> <%-- end scriptlet --%>
50    </body>
51
52 </html> <!-- end XHTML document -->
```

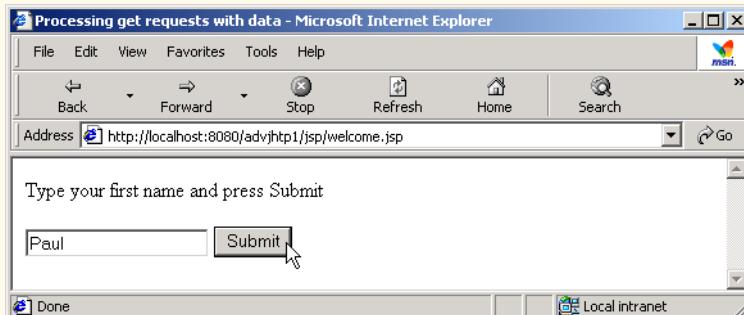


Fig. 10.4 Scripting a JavaServer Page—**welcome.jsp** (part 2 of 3).



Fig. 10.4 Scripting a JavaServer Page—**welcome.jsp** (part 3 of 3).

Notice that the majority of the code in Fig. 10.4 is XHTML markup (i.e., fixed template data). Throughout the **body** element are several scriptlets (lines 17–23, 30–35 and 45–49) and a JSP expression (line 26). Note that three comment styles appear in this JSP.

The scriptlets define an **if/else** structure that determines whether the JSP received a value for the first name as part of the request. Line 19 uses method **getParameter** of JSP implicit object **request** (an **HttpServletRequest** object) to obtain the value for parameter **firstName** and assigns the result to variable **name**. Line 21 determines if **name** is not **null**, (i.e., a value for the first name was passed to the JSP as part of the request). If this condition is **true**, the scriptlet terminates temporarily so the fixed template data at lines 25–28 can be output. The JSP expression in line 26 outputs the value of variable **name** (i.e., the first name passed to the JSP as a request parameter). The scriptlet continues at lines 30–35 with the closing curly brace of the **if** structure's body and the beginning of the **else** part of the **if/else** structure. If the condition at line 21 is **false**, lines 25–28 are not output. Instead, lines 37–43 output a **form** element. The user can type a first name in the **form** and press the **Submit** button to request the JSP again and execute the **if** structure's body (lines 25–28).

### Software Engineering Observation 10.7



Scriptlets, expressions and fixed template data can be intermixed in a JSP to create different responses based on information in a request to a JSP.

### Testing and Debugging Tip 10.1



It is sometimes difficult to debug errors in a JSP, because the line numbers reported by a JSP container normally refer to the servlet that represents the translated JSP, not the original JSP line numbers. Program development environments such as Sun Microsystems, Inc.'s Forte for Java Community Edition enable JSPs to be compiled in the environment, so you can see syntax error messages. These messages include the statement in the servlet that represents the translated JSP, which can be helpful in determining the error.

### Testing and Debugging Tip 10.2



Many JSP containers store the servlets representing the translated JSPs. For example, the Tomcat installation directory contains a subdirectory called **work** in which you can find the source code for the servlets translated by Tomcat.

To test Fig. 10.4 in Tomcat, copy `welcome.jsp` into the `jsp` directory created in Section 10.3. Open your Web browser and enter the following URL to test `welcome.jsp`:

```
http://localhost:8080/advjhttp1/jsp/welcome.jsp
```

When you first execute the JSP, it displays the `form` in which you can enter your first name, because the preceding URL does not pass a `firstName` parameter to the JSP. After you submit your first name, your browser should appear as shown in the second screen capture of Fig. 10.4. *Note:* As with servlets, it is possible to pass `get` request arguments as part of the URL. The following URL supplies the `firstName` parameter to `welcome.jsp`:

```
http://localhost:8080/advjhttp1/jsp/welcome.jsp?firstName=Paul
```

## 10.6 Standard Actions

We continue our JSP discussion with the *JSP standard actions* (Fig. 10.5). These actions provide JSP implementors with access to several of the most common tasks performed in a JSP, such as including content from other resources, forwarding requests to other resources and interacting with JavaBeans. JSP containers process actions at request time. Actions are delimited by `<jsp:action>` and `</jsp:action>`, where *action* is the standard action name. In cases where nothing appears between the starting and ending tags, the XML empty element syntax `<jsp:action />` can be used. Figure 10.5 summarizes the JSP standard actions. We use the actions in the next several subsections.

Action	Description
<code>&lt;jsp:include&gt;</code>	Dynamically includes another resource in a JSP. As the JSP executes, the referenced resource is included and processed.
<code>&lt;jsp:forward&gt;</code>	Forwards request processing to another JSP, servlet or static page. This action terminates the current JSP's execution.
<code>&lt;jsp:plugin&gt;</code>	Allows a plug-in component to be added to a page in the form of a browser-specific <code>object</code> or <code>embed</code> HTML element. In the case of a Java applet, this action enables the downloading and installation of the <i>Java Plug-in</i> , if it is not already installed on the client computer.
<code>&lt;jsp:param&gt;</code>	Used with the <code>include</code> , <code>forward</code> and <code>plugin</code> actions to specify additional name/value pairs of information for use by these actions.
<i>JavaBean Manipulation</i>	
<code>&lt;jsp:useBean&gt;</code>	Specifies that the JSP uses a JavaBean instance. This action specifies the scope of the bean and assigns it an ID that scripting components can use to manipulate the bean.

Fig. 10.5 JSP standard actions (part 1 of 2).

Action	Description
<code>&lt;jsp:setProperty&gt;</code>	Sets a property in the specified JavaBean instance. A special feature of this action is automatic matching of request parameters to bean properties of the same name.
<code>&lt;jsp:getProperty&gt;</code>	Gets a property in the specified JavaBean instance and converts the result to a string for output in the response.

Fig. 10.5 JSP standard actions (part 2 of 2).

### 10.6.1 `<jsp:include>` Action

JavaServer Pages support two include mechanisms—the `<jsp:include> action` and the `include directive`. Action `<jsp:include>` enables dynamic content to be included in a JavaServer Page. If the included resource changes between requests, the next request to the JSP containing the `<jsp:include>` action includes the new content of the resource. On the other hand, the `include directive` copies the content into the JSP once, at JSP translation time. If the included resource changes, the new content will not be reflected in the JSP that used the `include directive` unless that JSP is recompiled. Figure 10.6 describes the attributes of action `<jsp:include>`.



#### Software Engineering Observation 10.8

According to the JavaServer Pages 1.1 specification, a JSP container is allowed to determine whether a resource included with the `include directive` has changed. If so, the container can recompile the JSP that included the resource. However, the specification does not provide a mechanism to indicate a change in an included resource to the container.



**Performance Tip 10.2**  
The `<jsp:include>` action is more flexible than the `include directive`, but requires more overhead when page contents change frequently. Use the `<jsp:include>` action only when dynamic content is necessary.



#### Common Programming Error 10.3

Setting the `<jsp:include>` action's `flush` attribute to `false` is a translation-time error. Currently, the `flush` attribute supports only `true` values.

Attribute	Description
<code>page</code>	Specifies the relative URI path of the resource to include. The resource must be part of the same Web application.
<code>flush</code>	Specifies whether the buffer should be flushed after the <code>include</code> is performed. In JSP 1.1, this attribute is required to be <code>true</code> .

Fig. 10.6 Action `<jsp:include>` attributes.



### Common Programming Error 10.4

*Not specifying the `<jsp:include>` action's **flush** attribute is a translation-time error. Specifying this attribute is mandatory.*



### Common Programming Error 10.5

*Specifying in a `<jsp:include>` action a page that is not part of the same Web application is a request-time error. In such a case, the `<jsp:include>` action does not include any content.*

The next example demonstrates action `<jsp:include>` using four XHTML and JSP resources that represent both static and dynamic content. JavaServer Page **include.jsp** (Fig. 10.10) includes three other resources: **banner.html** (Fig. 10.7), **toc.html** (Fig. 10.8) and **clock2.jsp** (Fig. 10.9). JavaServer Page **include.jsp** creates an XHTML document containing a **table** in which **banner.html** spans two columns across the top of the **table**, **toc.html** is the left column of the second row and **clock2.jsp** (a simplified version of Fig. 10.1) is the right column of the second row. Figure 10.10 uses three `<jsp:include>` actions (lines 38–39, 48 and 55–56) as the content in **td** elements of the **table**. Using two XHTML documents and a JSP in Fig. 10.10 demonstrates that JSPs can include both static and dynamic content. The output windows in Fig. 10.10 demonstrate the results of two separate requests to **include.jsp**.

Figure 10.9 (**clock2.jsp**) demonstrates how to determine the client's **Locale** (package **java.util**) and uses that **Locale** to format a **Date** with a **DateFormat** (package **java.text**) object. Line 14 invokes the **request** object's **getLocale** method, which returns the client's **Locale**. Lines 17–20 invoke **DateFormat** static method **getDateTimeInstance** to obtain a **DateFormat** object. The first two arguments indicate that the date and time formats should each be **LONG** format (other options are **FULL**, **MEDIUM**, **SHORT** and **DEFAULT**). The third argument specifies the **Locale** for which the **DateFormat** object should format the date. Line 25 invokes the **DateFormat** object's **format** method to produce a **String** representation of the **Date**. The **DateFormat** object formats this **String** for the **Locale** specified on lines 17–20. [Note: This example works for Western languages that use the ISO-8859-1 character set. However, for languages that do not use this character set, the JSP must specify the proper character set using the JSP **page** directive (Section 10.7.1). At the site **java.sun.com/j2se/1.3/docs/guide/intl/encoding.doc.html**, Sun provides a list of character encodings. The response's content type defines the character set to use in the response. The content type has the form: "**contentType; charset=encoding**" (e.g., **"text/html; charset=ISO-8859-1"**.)]

To test Fig. 10.10 in Tomcat, copy **banner.html**, **toc.html**, **clock2.jsp**, **include.jsp** and the **images** directory into the **jsp** directory created in Section 10.3. Open your Web browser and enter the following URL to test **welcome.jsp**:

```
http://localhost:8080/advjhtp1/jsp/include.jsp
```

```
1 <!-- Fig. 10.7: banner.html -->
2 <!-- banner to include in another document -->
```

Fig. 10.7 Banner(**banner.html**) to include across the top of the XHTML document created by Fig. 10.10 (part 1 of 2).

```
3 <div style = "width: 580px">
4   <p>
5     Java(TM), C, C++, Visual Basic(R),
6     Object Technology, and <br /> Internet and
7     World Wide Web Programming Training&nbsp;<br />
8     On-Site Seminars Delivered Worldwide
9   </p>
10
11  <p>
12    <a href = "mailto:deitel@deitel.com">
13      deitel@deitel.com</a><br />
14
15    978.579.9911<br />
16    490B Boston Post Road, Suite 200,
17    Sudbury, MA 01776
18  </p>
19 </div>
```

Fig. 10.7 Banner(**banner.html**) to include across the top of the XHTML document created by Fig. 10.10 (part 2 of 2).

```
1 <!-- Fig. 10.8: toc.html -->
2 <!-- contents to include in another document -->
3
4 <p><a href = "http://www.deitel.com/books/index.html">
5   Publications/BookStore
6 </a></p>
7
8 <p><a href = "http://www.deitel.com/whatsnew.html">
9   What's New
10 </a></p>
11
12 <p><a href = "http://www.deitel.com/books/downloads.html">
13   Downloads/Resources
14 </a></p>
15
16 <p><a href = "http://www.deitel.com/faq/index.html">
17   FAQ (Frequently Asked Questions)
18 </a></p>
19
20 <p><a href = "http://www.deitel.com/intro.html">
21   Who we are
22 </a></p>
23
24 <p><a href = "http://www.deitel.com/index.html">
25   Home Page
26 </a></p>
27
28 <p>Send questions or comments about this site to
29   <a href = "mailto:deitel@deitel.com">
30     deitel@deitel.com
```

Fig. 10.8 Table of contents (**toc.html**) to include down the left side of the XHTML document created by Fig. 10.10 (part 1 of 2).

```

31   </a><br />
32 Copyright 1995-2002 by Deitel & Associates, Inc.
33 All Rights Reserved.
34 </p>

```

Fig. 10.8 Table of contents (`toc.html`) to include down the left side of the XHTML document created by Fig. 10.10 (part 2 of 2).

```

1  <!-- Fig. 10.9: clock2.jsp -->
2  <!-- date and time to include in another document -->
3
4  <table>
5    <tr>
6      <td style = "background-color: black;">
7        <p class = "big" style = "color: cyan; font-size: 3em;
8          font-weight: bold;">
9
10         <%-- script to determine client local and --%>
11         <%-- format date accordingly --%>
12         <%
13           // get client locale
14           java.util.Locale locale = request.getLocale();
15
16           // get DateFormat for client's Locale
17           java.text.DateFormat dateFormat =
18             java.text.DateFormat.getDateInstance(
19               java.text.DateFormat.LONG,
20               java.text.DateFormat.LONG, locale );
21
22         %> <%-- end script --%>
23
24         <%-- output date --%>
25         <%= dateFormat.format( new java.util.Date() ) %>
26       </p>
27     </td>
28   </tr>
29 </table>

```

Fig. 10.9 JSP `clock2.jsp` to include as the main content in the XHTML document created by Fig. 10.10.

```

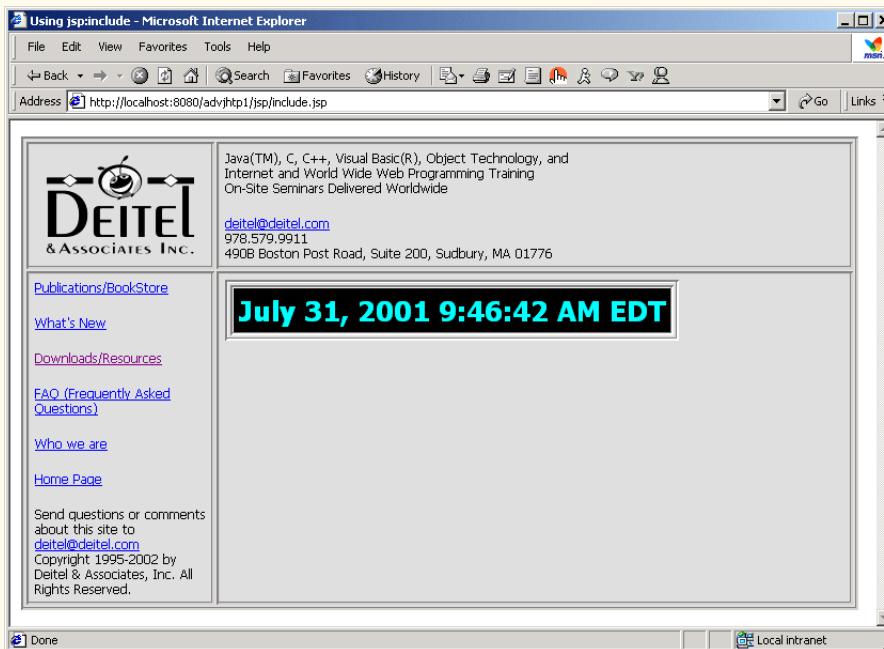
1  <?xml version = "1.0"?>
2  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3    "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5  <!-- Fig. 10.7: include.jsp -->
6
7  <html xmlns = "http://www.w3.org/1999/xhtml">
8
9    <head>
10      <title>Using jsp:include</title>

```

Fig. 10.10 JSP `include.jsp` includes resources with `<jsp:include>` (part 1 of 3).

```
11
12     <style type = "text/css">
13         body {
14             font-family: tahoma, helvetica, arial, sans-serif;
15         }
16
17         table, tr, td {
18             font-size: .9em;
19             border: 3px groove;
20             padding: 5px;
21             background-color: #dddddd;
22         }
23     </style>
24 </head>
25
26 <body>
27     <table>
28         <tr>
29             <td style = "width: 160px; text-align: center">
30                 <img src = "images/logotiny.png"
31                     width = "140" height = "93"
32                     alt = "Deitel & Associates, Inc. Logo" />
33             </td>
34
35             <td>
36
37                 <%-- include banner.html in this JSP --%>
38                 <jsp:include page = "banner.html"
39                     flush = "true" />
40
41             </td>
42         </tr>
43
44         <tr>
45             <td style = "width: 160px">
46
47                 <%-- include toc.html in this JSP --%>
48                 <jsp:include page = "toc.html" flush = "true" />
49
50             </td>
51
52             <td style = "vertical-align: top">
53
54                 <%-- include clock2.jsp in this JSP --%>
55                 <jsp:include page = "clock2.jsp"
56                     flush = "true" />
57
58             </td>
59         </tr>
60     </table>
61 </body>
62 </html>
```

Fig. 10.10 JSP `include.jsp` includes resources with `<jsp:include>` (part 2 of 3).



**Fig. 10.10** JSP `include.jsp` includes resources with `<jsp:include>` (part 3 of 3).

### 10.6.2 `<jsp:forward>` Action

Action `<jsp:forward>` enables a JSP to forward request processing to a different resource. Request processing by the original JSP terminates as soon as the JSP forwards the request. Action `<jsp:forward>` has only a **page** attribute that specifies the relative URI of the resource (in the same Web application) to which the request should be forwarded.



#### Software Engineering Observation 10.9

When using the `<jsp:forward>` action, the resource to which the request will be forwarded must be in the same context (Web application) as the JSP that originally received the request.

JavaServer Page `forward1.jsp` (Fig. 10.11) is a modified version of `welcome.jsp` (Fig. 10.4). The primary difference is in lines 22–25 in which JavaServer Page `forward1.jsp` forwards the request to JavaServer Page `forward2.jsp` (Fig. 10.12). Notice the `<jsp:param>` action in lines 23–24. This action adds a request parameter representing the date and time at which the initial request was received to the request object that is forwarded to `forward2.jsp`.

The `<jsp:param>` action specifies name/value pairs of information that are passed to the `<jsp:include>`, `<jsp:forward>` and `<jsp:plugin>` actions. Every `<jsp:param>` action has two required attributes: **name** and **value**. If a `<jsp:param>` action specifies a parameter that already exists in the request, the new value for the parameter takes precedence over the original value. All values for that parameter can be obtained by using the JSP implicit object `request`'s `getParameterValues` method, which returns an array of **Strings**.

JSP **forward2.jsp** uses the **name** specified in the **<jsp:param>** action ("date") to obtain the date and time. It also uses the **firstName** parameter originally passed to **forward1.jsp** to obtain the user's first name. JSP expressions in Fig. 10.12 (lines 23 and 31) insert the request parameter values in the response to the client. The screen capture in Fig. 10.11 shows the initial interaction with the client. The screen capture in Fig. 10.12 shows the results returned to the client after the request was forwarded to **forward2.jsp**.

To test Fig. 10.11 and Fig. 10.12 in Tomcat, copy **forward1.jsp** and **forward2.jsp** into the **jsp** directory created in Section 10.3. Open your Web browser and enter the following URL to test **welcome.jsp**:

```
http://localhost:8080/advjhttp1/jsp/forward1.jsp
```

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.11: forward1.jsp -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8
9 <head>
10   <title>Forward request to another JSP</title>
11 </head>
12
13 <body>
14   <% // begin scriptlet
15
16     String name = request.getParameter( "firstName" );
17
18     if ( name != null ) {
19
20       <%> <%-- end scriptlet to insert fixed template data --%>
21
22         <jsp:forward page = "forward2.jsp">
23           <jsp:param name = "date"
24             value = "<%= new java.util.Date() %>" />
25         </jsp:forward>
26
27       <% // continue scriptlet
28
29     } // end if
30     else {
31
32       <%> <%-- end scriptlet to insert fixed template data --%>
33
34         <form action = "forward1.jsp" method = "get">
35           <p>Type your first name and press Submit</p>
36
```

Fig. 10.11 JSP **forward1.jsp** receives a **firstName** parameter, adds a date to the request parameters and forwards the request to **forward2.jsp** for further processing (part 1 of 2).

```

37         <p><input type = "text" name = "firstName" />
38             <input type = "submit" value = "Submit" />
39         </p>
40     </form>
41
42     <% // continue scriptlet
43
44     } // end else
45
46     %> <%-- end scriptlet --%>
47 </body>
48
49 </html> <!-- end XHTML document -->
```



Fig. 10.11 JSP **forward1.jsp** receives a **firstName** parameter, adds a date to the request parameters and forwards the request to **forward2.jsp** for further processing (part 2 of 2).

```

1  <?xml version = "1.0"?>
2  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3      "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5  <!-- forward2.jsp -->
6
7  <html xmlns = "http://www.w3.org/1999/xhtml" v
8
9  <head>
10     <title>Processing a forwarded request</title>
11
12     <style type = "text/css">
13         .big {
14             font-family: tahoma, helvetica, arial, sans-serif;
15             font-weight: bold;
16             font-size: 2em;
17         }
18     </style>
19 </head>
20
```

Fig. 10.12 JSP **forward2.jsp** receives a request (from **forward1.jsp** in this example) and uses the request parameters as part of the response to the client (part 1 of 2).

```

21 <body>
22   <p class = "big">
23     Hello <%= request.getParameter( "firstName" ) %>, <br />
24     Your request was received <br /> and forwarded at
25   </p>
26
27   <table style = "border: 6px outset;">
28     <tr>
29       <td style = "background-color: black;">
30         <p class = "big" style = "color: cyan;">
31           <%= request.getParameter( "date" ) %>
32         </p>
33       </td>
34     </tr>
35   </table>
36 </body>
37
38 </html>

```

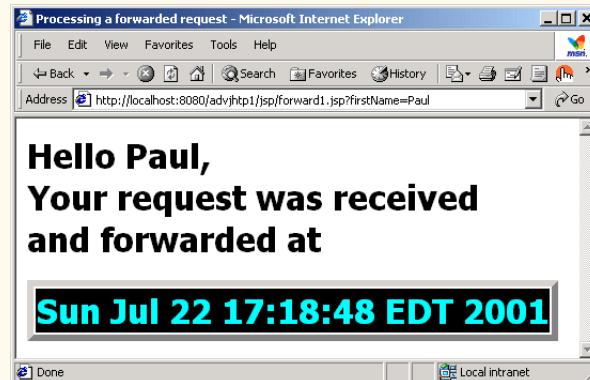


Fig. 10.12 JSP **forward2.jsp** receives a request (from **forward1.jsp** in this example) and uses the request parameters as part of the response to the client (part 2 of 2).

### 10.6.3 <jsp:plugin> Action

Action **<jsp:plugin>** adds an applet or JavaBean to a Web page in the form of a browser-specific **object** or **embed** XHTML element. This action also enables the client to download and install the *Java Plug-in* if it is not already installed. Figure 10.13 describes the attributes of action **<jsp:plugin>**.

Attribute	Description
<b>type</b>	Component type—bean or applet.
<b>code</b>	Class that represents the component.

Fig. 10.13 Attributes of the **<jsp:plugin>** action (part 1 of 2).

Attribute	Description
<b>codebase</b>	Location of the class specified in the <b>code</b> attribute and the archives specified in the <b>archive</b> attribute.
<b>align</b>	Alignment of the component.
<b>archive</b>	A space-separated list of archive files that contain resources used by the component. Such an archive may include the class specified by the <b>code</b> attribute.
<b>height</b>	Component height in the page specified in pixels or percentage.
<b>hspace</b>	Number of pixels of space that appear to the left and to the right of the component.
<b>jreversion</b>	Version of the Java Runtime Environment and plug-in required to execute the component. The default value is 1.1.
<b>name</b>	Name of the component.
<b>vspace</b>	Number of pixels of space that appear above and below the component.
<b>title</b>	Text that describes the component.
<b>width</b>	Component width in the page specified in pixels or percentage.
<b>nspluginurl</b>	Location for download of the Java Plug-in for Netscape Navigator.
<b>iepluginurl</b>	Location for download of the Java Plug-in for Internet Explorer.

Fig. 10.13 Attributes of the `<jsp:plugin>` action (part 2 of 2).

Figure 10.14 defines an applet that draws a picture using the Java2D API. The applet has three parameters that enable the JSP implementor to specify the background color for the drawing. The parameters represent the **red**, **green** and **blue** portions of an RGB color with values in the range 0–255. The applet obtains the parameter values in lines 21–23. If any exceptions occur while processing the parameters, the exceptions are caught at line 32 and ignored, leaving the applet with its default white background color.

```

1 // Fig. 10.14: ShapesApplet.java
2 // Applet that demonstrates a Java2D GeneralPath.
3 package com.deitel.advjhttp1.jsp.applet;
4
5 // Java core packages
6 import java.applet.*;
7 import java.awt.event.*;
8 import java.awt.*;
9 import java.awt.geom.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class ShapesApplet extends JApplet {
15

```

Fig. 10.14 An applet to demonstrate `<jsp:plugin>` in Fig. 10.15 (part 1 of 3).

```
16 // initialize the applet
17 public void init()
18 {
19     // obtain color parameters from XHTML file
20     try {
21         int red = Integer.parseInt( getParameter( "red" ) );
22         int green = Integer.parseInt( getParameter( "green" ) );
23         int blue = Integer.parseInt( getParameter( "blue" ) );
24
25         Color backgroundColor = new Color( red, green, blue );
26
27         setBackground( backgroundColor );
28     }
29
30     // if there is an exception while processing the color
31     // parameters, catch it and ignore it
32     catch ( Exception exception ) {
33         // do nothing
34     }
35 }
36
37 public void paint( Graphics g )
38 {
39     // create arrays of x and y coordinates
40     int xPoints[] =
41         { 55, 67, 109, 73, 83, 55, 27, 37, 1, 43 };
42     int yPoints[] =
43         { 0, 36, 36, 54, 96, 72, 96, 54, 36, 36 };
44
45     // obtain reference to a Graphics2D object
46     Graphics2D g2d = ( Graphics2D ) g;
47
48     // create a star from a series of points
49     GeneralPath star = new GeneralPath();
50
51     // set the initial coordinate of the GeneralPath
52     star.moveTo( xPoints[ 0 ], yPoints[ 0 ] );
53
54     // create the star--this does not draw the star
55     for ( int k = 1; k < xPoints.length; k++ )
56         star.lineTo( xPoints[ k ], yPoints[ k ] );
57
58     // close the shape
59     star.closePath();
60
61     // translate the origin to (200, 200)
62     g2d.translate( 200, 200 );
63
64     // rotate around origin and draw stars in random colors
65     for ( int j = 1; j <= 20; j++ ) {
66         g2d.rotate( Math.PI / 10.0 );
67 }
```

Fig. 10.14 An applet to demonstrate <jsp:plugin> in Fig. 10.15 (part 2 of 3).

```

68         g2d.setColor(
69             new Color( ( int ) ( Math.random() * 256 ),
70                     ( int ) ( Math.random() * 256 ),
71                     ( int ) ( Math.random() * 256 ) ) );
72
73         g2d.fill( star );    // draw a filled star
74     }
75 }
76 }
```

Fig. 10.14 An applet to demonstrate <jsp:plugin> in Fig. 10.15 (part 3 of 3).

Most Web browsers in use today do not support applets written for the Java 2 platform. Executing such applets in most of today's browsers requires the Java Plug-in. Figure 10.15 uses the <jsp:plugin> action (lines 10–22) to embed the Java Plug-in. Line 11 indicates the package name and class name of the applet class. Line 12 indicates the **code-base** from which the applet should be downloaded. Line 13 indicates that the applet should be 400 pixels wide and line 14 indicates that the applet should be 400 pixels tall. Lines 16–20 specify the applet parameters. You can change the background color in the applet by changing the red, green and blue values. Note that the <jsp:plugin> action requires any <jsp:param> actions to appear in a <jsp:params> action.

To test the <jsp:plugin> action in Tomcat, copy **plugin.jsp** and **ShapesApplet.class** into the **jsp** directory created in Section 10.3. [Note: **ShapesApplet** is defined in package **com.deitel.advjhttp1.jsp.applet**. This example will work only if the proper package directory structure is defined in the **classes** directory.] Open your Web browser and enter the following URL to test **plugin.jsp**:

```
http://localhost:8080/advjhttp1/jsp/plugin.jsp
```

The screen captures in Fig. 10.15 show the applet executing in Microsoft Internet Explorer 5.5 and Netscape Navigator 6.0.

```

1  <!-- Fig. 10.15: plugin.jsp -->
2
3  <html>
4
5      <head>
6          <title>Using jsp:plugin to load an applet</title>
7      </head>
8
9      <body>
10         <jsp:plugin type = "applet"
11             code = "com.deitel.advjhttp1.jsp.applet.ShapesApplet"
12             codebase = "/advjhttp1/jsp"
13             width = "400"
14             height = "400">
15
16             <jsp:params>
17                 <jsp:param name = "red" value = "255" />
```

Fig. 10.15 Using <jsp:plugin> to embed a Java 2 applet in a JSP (part 1 of 2).

```
18          <jsp:param name = "green" value = "255" />
19          <jsp:param name = "blue" value = "0" />
20      </jsp:params>
21
22      </jsp:plugin>
23  </body>
24 </html>
```

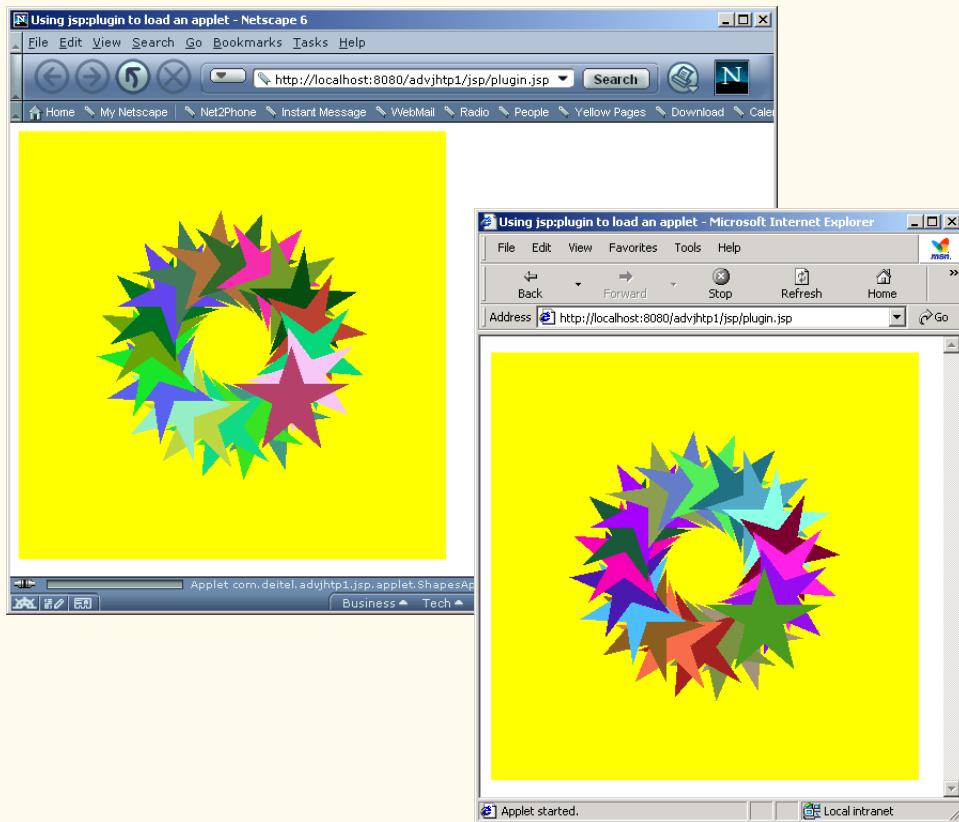


Fig. 10.15 Using `<jsp:plugin>` to embed a Java 2 applet in a JSP (part 2 of 2).

#### 10.6.4 `<jsp:useBean>` Action

Action `<jsp:useBean>` enables a JSP to manipulate a Java object. This action creates a Java object or locates an existing object for use in the JSP. Figure 10.16 summarizes action `<jsp:useBean>`'s attributes. If attributes `class` and `beanName` are not specified, the JSP container attempts to locate an existing object of the type specified in attribute `type`. Like JSP implicit objects, objects specified with action `<jsp:useBean>` have `page`, `request`, `session` or `application` scope that indicates where they can be used in a Web application. Objects with `page` scope are accessible only to the page in which they are defined. Multiple JSP pages potentially can access objects with other scopes. For example, all JSPs that process a single request can access an object with `request` scope.



### Common Programming Error 10.6

*One or both of the <jsp:useBean> attributes **class** and **type** must be specified; otherwise, a translation-time error occurs.*

Many Web sites today place rotating advertisements on their Web pages. Each visit to one of these pages typically results in a different advertisement being displayed in the user's Web browser. Typically, clicking an advertisement takes you to the Web site of the company that placed the advertisement. Our first example of `<jsp:useBean>` demonstrates a simple advertisement rotator bean that cycles through a list of five advertisements. In this example, the advertisements are covers for some of our books. Clicking a cover takes you to the Amazon.com Web site where you can read about and possibly order the book.

The **Rotator** bean (Fig. 10.17) has three methods: `getImage`, `getLink` and `nextAd`. Method `getImage` returns the image file name for the book cover image. Method `getLink` returns the hyperlink to the book at Amazon.com. Method `nextAd` updates the **Rotator** so the next calls to `getImage` and `getLink` return information for a different advertisement. Methods `getImage` and `getLink` each represent a read-only JavaBean property—`image` and `link`, respectively. **Rotator** keeps track of the current advertisement with its `selectedIndex` variable, which is updated by invoking method `nextAd`.

Attribute	Description
<b>id</b>	The name used to manipulate the Java object with actions <code>&lt;jsp:setProperty&gt;</code> and <code>&lt;jsp:getProperty&gt;</code> . A variable of this name is also declared for use in JSP scripting elements. The name specified here is case sensitive.
<b>scope</b>	The scope in which the Java object is accessible— <code>page</code> , <code>request</code> , <code>session</code> or <code>application</code> . The default scope is <code>page</code> .
<b>class</b>	The fully qualified class name of the Java object.
<b>beanName</b>	The name of a bean that can be used with method <code>instantiate</code> of class <code>java.beans.Beans</code> to load a JavaBean into memory.
<b>type</b>	The type of the JavaBean. This can be the same type as the <code>class</code> attribute, a superclass of that type or an interface implemented by that type. The default value is the same as for attribute <code>class</code> . A <code>ClassCastException</code> occurs if the Java object is not of the type specified with attribute <code>type</code> .

Fig. 10.16 Attributes of the `<jsp:useBean>` action.

```

1 // Fig. 10.17: Rotator.java
2 // A JavaBean that rotates advertisements.
3 package com.deitel.advjhtp1.jsp.beans;
4
5 public class Rotator {
6     private String images[] = { "images/jhttp3.jpg",
7         "images/xmlhttp1.jpg", "images/ebechtp1.jpg",
8         "images/iw3http1.jpg", "images/cpphttp3.jpg" };
9

```

Fig. 10.17 **Rotator** bean that maintains a set of advertisements (part 1 of 2).

```
10    private String links[] = {
11        "http://www.amazon.com/exec/obidos/ASIN/0130125075/" +
12        "deitelassociatin",
13        "http://www.amazon.com/exec/obidos/ASIN/0130284173/" +
14        "deitelassociatin",
15        "http://www.amazon.com/exec/obidos/ASIN/013028419X/" +
16        "deitelassociatin",
17        "http://www.amazon.com/exec/obidos/ASIN/0130161438/" +
18        "deitelassociatin",
19        "http://www.amazon.com/exec/obidos/ASIN/0130895717/" +
20        "deitelassociatin" };
21
22    private int selectedIndex = 0;
23
24    // returns image file name for current ad
25    public String getImage()
26    {
27        return images[ selectedIndex ];
28    }
29
30    // returns the URL for ad's corresponding Web site
31    public String getLink()
32    {
33        return links[ selectedIndex ];
34    }
35
36    // update selectedIndex so next calls to getImage and
37    // getLink return a different advertisement
38    public void nextAd()
39    {
40        selectedIndex = ( selectedIndex + 1 ) % images.length;
41    }
42 }
```

Fig. 10.17 **Rotator** bean that maintains a set of advertisements (part 2 of 2).

Lines 7–8 of JavaServer Page **adrotator.jsp** (Fig. 10.18) obtain a reference to an instance of class **Rotator**. The **id** for the bean is **rotator**. The JSP uses this name to manipulate the bean. The scope of the object is **session**, so that each individual client will see the same sequence of ads during their browsing session. When **adrotator.jsp** receives a request from a new client, the JSP container creates the bean and stores it in JSP that client's **session** (an **HttpSession** object). In each request to this JSP, line 22 uses the **rotator** reference created in line 7 to invoke the **Rotator** bean's **nextAd** method. Thus, each request will receive the next advertisement maintained by the **Rotator** bean. Lines 29–34 define a hyperlink to the Amazon.com site for a particular book. Lines 29–30 introduce action **<jsp:getProperty>** to obtain the value of the **Rotator** bean's **link** property. Action **<jsp:getProperty>** has two attributes—**name** and **property**—that specify the bean object to manipulate and the property to get. If the JavaBean object uses standard JavaBean naming conventions, the method used to obtain the **link** property value from the bean should be **getLink**. Action **<jsp:getProperty>** invokes **getLink** on the bean referenced with **rotator**, converts the return value into a **String** and outputs the **String** as part of the response to the client. The **link** property becomes the value of the

hyperlink's **href** attribute. The hyperlink is represented in the resulting Web page as the book cover image. Lines 32–33 create an **img** element and use another **<jsp:getProperty>** action to obtain the **Rotator** bean's **image** property value.

Note that the link and image properties also can be obtained with JSP expressions. For example, the **<jsp:getProperty>** action in lines 29–30 can be replaced with the expression

```
<%= rotator.getLink() %>
```

Similarly, the **<jsp:getProperty>** action in lines 32–33 can be replaced with the expression

```
<%= rotator.getImage() %>
```

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.18: adrotator.jsp -->
6
7 <jsp:useBean id = "rotator" scope = "application"
8   class = "com.deitel.advjhtp1.jsp.beans.Rotator" />
9
10 <html xmlns = "http://www.w3.org/1999/xhtml">
11
12   <head>
13     <title>AdRotator Example</title>
14
15     <style type = "text/css">
16       .big { font-family: helvetica, arial, sans-serif;
17             font-weight: bold;
18             font-size: 2em }
19     </style>
20
21     <%-- update advertisement --%>
22     <% rotator.nextAd(); %>
23   </head>
24
25   <body>
26     <p class = "big">AdRotator Example</p>
27
28     <p>
29       <a href = "<jsp:getProperty name = "rotator"
30         property = "link" />">
31
32         <img src = "<jsp:getProperty name = "rotator"
33           property = "image" />" alt = "advertisement" />
34       </a>
35     </p>
36   </body>
37 </html>
```

Fig. 10.18 JSP **adrotator.jsp** uses a **Rotator** bean to display a different advertisement on each request to the page (part 1 of 2).

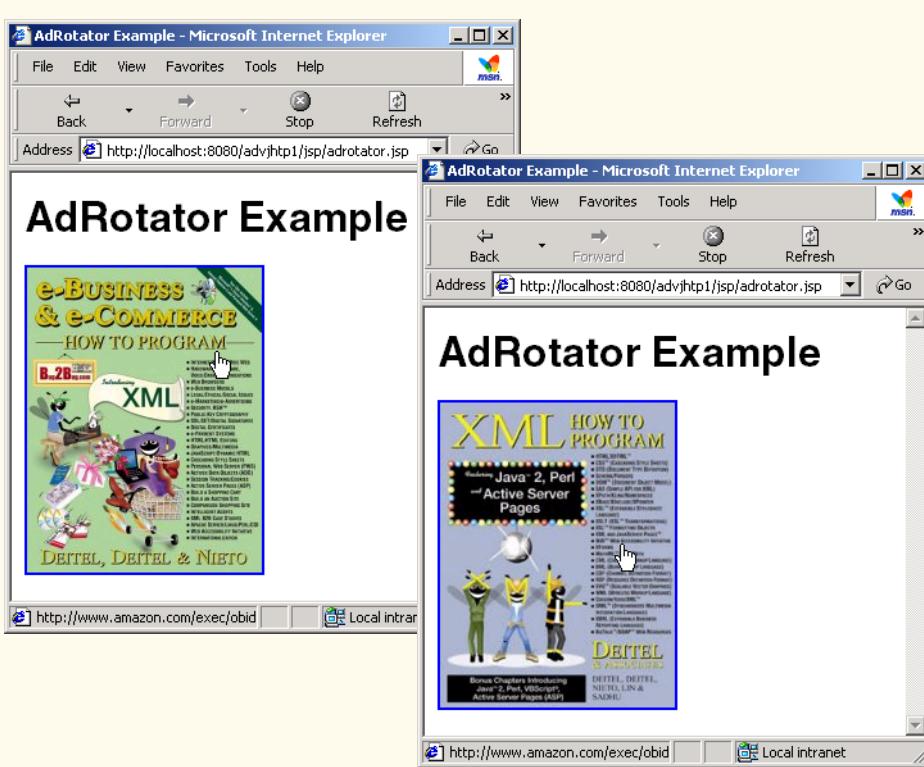


Fig. 10.18 JSP `adrotator.jsp` uses a `Rotator` bean to display a different advertisement on each request to the page (part 2 of 2).

To test `adrotator.jsp` in Tomcat, copy `adrotator.jsp` into the `jsp` directory created in Section 10.3. You should have copied the `images` directory into the `jsp` directory when you tested Fig. 10.10. If not, you must copy the `images` directory there now. Copy `Rotator.class` into the `advjhttp1` Web application's `WEB-INF\classes` directory in Tomcat. [Note: This example will work only if the proper package directory structure for `Rotator` is defined in the `classes` directory. `Rotator` is defined in package `com.deitel.advjhttp1.jsp.beans`.] Open your Web browser and enter the following URL to test `adrotator.jsp`:

```
http://localhost:8080/advjhttp1/jsp/adrotator.jsp
```

Try reloading this JSP several times in your browser to see the advertisement change with each request.

Action `<jsp:setProperty>` can set JavaBean property values. This action is particularly useful for mapping request parameter values to JavaBean properties. Request parameters can be used to set properties of primitive types `boolean`, `byte`, `char`, `int`, `long`, `float` and `double` and `java.lang` types `String`, `Boolean`, `Byte`, `Character`, `Integer`, `Long`, `Float` and `Double`. Figure 10.19 summarizes the `<jsp:setProperty>` attributes.

Attribute	Description
<b>name</b>	The ID of the JavaBean for which a property (or properties) will be set.
<b>property</b>	The name of the property to set. Specifying "*" for this attribute causes the JSP to match the request parameters to the properties of the bean. For each request parameter that matches (i.e., the name of the request parameter is identical to the bean's property name), the corresponding property in the bean is set to the value of the parameter. If the value of the request parameter is "", the property value in the bean remains unchanged.
<b>param</b>	If request parameter names do not match bean property names, this attribute can be used to specify which request parameter should be used to obtain the value for a specific bean property. This attribute is optional. If this attribute is omitted, the request parameter names must match bean property names.
<b>value</b>	The value to assign to a bean property. The value typically is the result of a JSP expression. This attribute is particularly useful for setting bean properties that cannot be set using request parameters. This attribute is optional. If this attribute is omitted, the JavaBean property must be of a data type that can be set using request parameters.

Fig. 10.19 Attributes of the `<jsp:setProperty>` action.



### Common Programming Error 10.7

Use action `<jsp:setProperty>`'s **value** attribute to set JavaBean property types that cannot be set with request parameters; otherwise, conversion errors occur.



### Software Engineering Observation 10.10

Action `<jsp:setProperty>` can use request-parameter values to set JavaBean properties only for properties of the following types: **Strings**, primitive types (**boolean**, **byte**, **char**, **short**, **int**, **long**, **float** and **double**) and type wrapper classes (**Boolean**, **Byte**, **Character**, **Short**, **Integer**, **Long**, **Float** and **Double**).

Our next example is a guest book that enables users to place their first name, last name and e-mail address into a guest book database. After submitting their information, users see a Web page containing all the users in the guest book. Each person's e-mail address is displayed as a hyperlink that allows the user to send an e-mail message to the person. The example demonstrates action `<jsp:setProperty>`. In addition, the example introduces the JSP **page** directive and JSP error pages.

The guest book example consists of JavaBeans **GuestBean** (Fig. 10.20) and **GuestDataBean** (Fig. 10.21), and JSPs **guestBookLogin.jsp** (Fig. 10.22), **guestBookView.jsp** (Fig. 10.23) and **guestBookErrorPage.jsp** (Fig. 10.24). Sample outputs from this example are shown in Fig. 10.25.

JavaBean **GuestBean** (Fig. 10.20) defines three guest properties: **firstName**, **lastName** and **email**. Each is a read/write property with *set* and *get* methods to manipulate the property.

```
1 // Fig. 10.20: GuestBean.java
2 // JavaBean to store data for a guest in the guest book.
3 package com.deitel.advjhtp1.jsp.beans;
4
5 public class GuestBean {
6     private String firstName, lastName, email;
7
8     // set the guest's first name
9     public void setFirstName( String name )
10    {
11        firstName = name;
12    }
13
14    // get the guest's first name
15    public String getFirstName()
16    {
17        return firstName;
18    }
19
20    // set the guest's last name
21    public void setLastName( String name )
22    {
23        lastName = name;
24    }
25
26    // get the guest's last name
27    public String getLastname()
28    {
29        return lastName;
30    }
31
32    // set the guest's email address
33    public void setEmail( String address )
34    {
35        email = address;
36    }
37
38    // get the guest's email address
39    public String getEmail()
40    {
41        return email;
42    }
43 }
```

Fig. 10.20 **GuestBean** stores information for one guest.

JavaBean **GuestDataBean** (Fig. 10.21) connects to the **guestbook** database and provides methods **getGuestList** and **addGuest** to manipulate the database. The guestbook database has a single table (**guests**) containing three columns (**firstName**, **lastName** and **email**). We provide an SQL script (**guestbook.sql**) with this example that can be used with the Cloudscape DBMS to create the **guestbook** database. For further details on creating a database with Cloudscape, refer back to Chapter 8.

```
1 // Fig. 10.21: GuestDataBean.java
2 // Class GuestDataBean makes a database connection and supports
3 // inserting and retrieving data from the database.
4 package com.deitel.advjhtp1.jsp.beans;
5
6 // Java core packages
7 import java.io.*;
8 import java.sql.*;
9 import java.util.*;
10
11 public class GuestDataBean {
12     private Connection connection;
13     private PreparedStatement addRecord, getRecords;
14
15     // construct TitlesBean object
16     public GuestDataBean() throws Exception
17     {
18         // load the Cloudscape driver
19         Class.forName( "COM.cloudscape.core.RmiJdbcDriver" );
20
21         // connect to the database
22         connection = DriverManager.getConnection(
23             "jdbc:rmi:jdbc:cloudscape:guestbook" );
24
25         getRecords =
26             connection.prepareStatement(
27                 "SELECT firstName, lastName, email FROM guests"
28             );
29
30         addRecord =
31             connection.prepareStatement(
32                 "INSERT INTO guests ( " +
33                     "firstName, lastName, email ) " +
34                     "VALUES ( ?, ?, ? )"
35             );
36     }
37
38     // return an ArrayList of GuestBeans
39     public ArrayList getGuestList() throws SQLException
40     {
41         ArrayList guestList = new ArrayList();
42
43         // obtain list of titles
44         ResultSet results = getRecords.executeQuery();
45
46         // get row data
47         while ( results.next() ) {
48             GuestBean guest = new GuestBean();
49
50             guest.setFirstName( results.getString( 1 ) );
51             guest.setLastName( results.getString( 2 ) );
52             guest.setEmail( results.getString( 3 ) );
```

Fig. 10.21 `GuestDataBean` performs database access on behalf of `guestBookLogin.jsp` (part 1 of 2).

```
53         guestList.add( guest );
54     }
55 }
56
57     return guestList;
58 }
59
60 // insert a guest in guestbook database
61 public void addGuest( GuestBean guest ) throws SQLException
62 {
63     addRecord.setString( 1, guest.getFirstName() );
64     addRecord.setString( 2, guest.getLastName() );
65     addRecord.setString( 3, guest.getEmail() );
66
67     addRecord.executeUpdate();
68 }
69
70 // close statements and terminate database connection
71 protected void finalize()
72 {
73     // attempt to close database connection
74     try {
75         getRecords.close();
76         addRecord.close();
77         connection.close();
78     }
79
80     // process SQLException on close operation
81     catch ( SQLException sqlException ) {
82         sqlException.printStackTrace();
83     }
84 }
85 }
```

Fig. 10.21 **GuestDataBean** performs database access on behalf of **guestBookLogin.jsp** (part 2 of 2).

**GuestDataBean** method **getGuestList** (lines 39–58) returns an **ArrayList** of **GuestBean** objects representing the guests in the database. Method **getGuestList** creates the **GuestBean** objects from the **ResultSet** returned by **PreparedStatement getRecords** (defined at lines 25–28 and executed at line 44).

**GuestDataBean** method **addGuest** (lines 61–68) receives a **GuestBean** as an argument and uses the **GuestBean**'s properties as the arguments to **PreparedStatement addRecord** (defined at lines 30–35). This **PreparedStatement** (executed at line 67) inserts a new guest in the database.

Note that the **GuestDataBean**'s constructor, **getGuestList** and **addGuest** methods do not process potential exceptions. In the constructor, line 19 can throw a **ClassNotFoundException**, and the other statements can throw **SQLExceptions**. Similarly, **SQLExceptions** can be thrown from the bodies of methods **getGuestList** and **addGuest**. In this example, we purposely let any exceptions that occur get passed

back to the JSP that invokes the **GuestDataBean**'s constructor or methods. This enables us to demonstrate JSP error pages. When a JSP performs an operation that causes an exception, the JSP can include scriptlets that catch the exception and process it. Exceptions that are not caught can be forwarded to a JSP error page for handling.

JavaServer Page **guestBookLogin.jsp** (Fig. 10.22) is a modified version of **forward1.jsp** (Fig. 10.11) that displays a **form** in which users can enter their first name, last name and e-mail address. When the user submits the **form**, **guestBookLogin.jsp** is requested again, so it can ensure that all the data values were entered. If not, the **guestBookLogin.jsp** responds with the **form** again, so the user can fill in missing field(s). If the user supplies all three pieces of information, **guestBookLogin.jsp** forwards the request to **guestBookView.jsp**, which displays the guest book contents.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.22: guestBookLogin.jsp -->
6
7 <%-- page settings --%>
8 <%@ page errorPage = "guestBookErrorPage.jsp" %>
9
10 <%-- beans used in this JSP --%>
11 <jsp:useBean id = "guest" scope = "page"
12   class = "com.deitel.advjhttp1.jsp.beans.GuestBean" />
13 <jsp:useBean id = "guestData" scope = "request"
14   class = "com.deitel.advjhttp1.jsp.beans.GuestDataBean" />
15
16 <html xmlns = "http://www.w3.org/1999/xhtml">
17
18 <head>
19   <title>Guest Book Login</title>
20
21   <style type = "text/css">
22     body {
23       font-family: tahoma, helvetica, arial, sans-serif;
24     }
25
26     table, tr, td {
27       font-size: .9em;
28       border: 3px groove;
29       padding: 5px;
30       background-color: #dddddd;
31     }
32   </style>
33 </head>
34
```

Fig. 10.22 JavaServer page **guestBookLogin.jsp** enables the user to submit a first name, a last name and an e-mail address to be placed in the guest book (part 1 of 3).

```
35  <body>
36      <jsp:setProperty name = "guest" property = "*" />
37
38      <% // start scriptlet
39
40          if ( guest.getFirstName() == null || 
41              guest.getLastName() == null || 
42              guest.getEmail() == null ) {
43
44      %> <%-- end scriptlet to insert fixed template data --%>
45
46          <form method = "post" action = "guestBookLogin.jsp">
47              <p>Enter your first name, last name and email
48                  address to register in our guest book.</p>
49
50              <table>
51                  <tr>
52                      <td>First name</td>
53
54                      <td>
55                          <input type = "text" name = "firstName" />
56                      </td>
57                  </tr>
58
59                  <tr>
60                      <td>Last name</td>
61
62                      <td>
63                          <input type = "text" name = "lastName" />
64                      </td>
65                  </tr>
66
67                  <tr>
68                      <td>Email</td>
69
70                      <td>
71                          <input type = "text" name = "email" />
72                      </td>
73                  </tr>
74
75                  <tr>
76                      <td colspan = "2">
77                          <input type = "submit"
78                              value = "Submit" />
79                      </td>
80                  </tr>
81              </table>
82          </form>
83
```

Fig. 10.22 JavaServer page **guestBookLogin.jsp** enables the user to submit a first name, a last name and an e-mail address to be placed in the guest book (part 2 of 3).

```
84     <% // continue scriptlet
85
86     } // end if
87     else {
88         guestData.addGuest( guest );
89
90     %> <%-- end scriptlet to insert jsp:forward action --%
91
92         <%-- forward to display guest book contents --%>
93         <jsp:forward page = "guestBookView.jsp" />
94
95     <% // continue scriptlet
96
97     } // end else
98
99    %> <%-- end scriptlet --%
100 </body>
101
102 </html>
```

Fig. 10.22 JavaServer page **guestBookLogin.jsp** enables the user to submit a first name, a last name and an e-mail address to be placed in the guest book (part 3 of 3).

Line 8 of **guestBookLogin.jsp** introduces the **page directive**, which defines information that is globally available in a JSP. Directives are delimited by `<%@` and `%>`. In this case, the **page directive's errorPage attribute** is set to **guestBookErrorHandler.jsp** (Fig. 10.24), indicating that all uncaught exceptions are forwarded to **guestBookErrorHandler.jsp** for processing. A complete description of the **page directive** appears in Section 10.7.

Lines 11–14 define two `<jsp:useBean>` actions. Lines 11–12 create an instance of **GuestBean** called **guest**. This bean has **page** scope—it exists for use only in this page. Lines 14–15 create an instance of **GuestDataBean** called **guestData**. This bean has **request** scope—it exists for use in this page and any other page that helps process a single client request. Thus, when **guestBookLogin.jsp** forwards a request to **guestBookView.jsp**, the **GuestDataBean** is still available for use in **guestBookView.jsp**.

Line 36 demonstrates setting properties of the **GuestBean** called **guest** with request parameter values. The **input** elements on lines 55, 63 and 71 have the same names as the **GuestBean** properties. So, we use action `<jsp:setProperty>`'s ability to match request parameters to properties by specifying "\*" for attribute **property**. Line 36 also can set the properties individually with the following lines:

```
<jsp:setProperty name = "guest" property = "firstName"
                  param = "firstName" />

<jsp:setProperty name = "guest" property = "lastName"
                  param = "lastName" />

<jsp:setProperty name = "guest" property = "email"
                  param = "email" />
```

If the request parameters had names that differed from **GuestBean**'s properties, the **param** attribute in each of the preceding **<jsp:setProperty>** actions could be changed to the appropriate request parameter name.

JavaServer Page **guestBookView.jsp** (Fig. 10.23) outputs an XHTML document containing the guest book entries in tabular format. Lines 8–10 define three **page** directives. Line 8 specifies that the error page for this JSP is **guestBookErrorPage.jsp**. Lines 9–10 introduce attribute **import** of the **page** directive. Attribute **import** enables programmers to specify Java classes and packages that are used in the context of the JSP. Line 9 indicates that classes from package **java.util** are used in this JSP, and line 10 indicates that classes from our package **com.deitel.advjhttp1.jsp.beans** also are used.

Lines 13–14 specify a **<jsp:useBean>** action that obtains a reference to a **GuestDataBean** object. If a **GuestDataBean** object already exists, the action returns a reference to the existing object. Otherwise, the action creates a **GuestDataBean** for use in this JSP. Lines 50–59 define a scriptlet that gets the guest list from the **GuestDataBean** and begin a loop to output the entries. Lines 61–70 combine fixed template text with JSP expressions to create rows in the table of guest book data that will be displayed on the client. The scriptlet at lines 72–76 terminates the loop.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.23: guestBookView.jsp -->
6
7 <%-- page settings --%>
8 <%@ page errorPage = "guestBookErrorPage.jsp" %>
9 <%@ page import = "java.util.*" %>
10 <%@ page import = "com.deitel.advjhttp1.jsp.beans.*" %>
11
12 <%-- GuestDataBean to obtain guest list --%>
13 <jsp:useBean id = "guestData" scope = "request"
14   class = "com.deitel.advjhttp1.jsp.beans.GuestDataBean" />
15
16 <html xmlns = "http://www.w3.org/1999/xhtml">
17
18   <head>
19     <title>Guest List</title>
20
21     <style type = "text/css">
22       body {
23         font-family: tahoma, helvetica, arial, sans-serif;
24       }
25
26       table, tr, td, th {
27         text-align: center;
28         font-size: .9em;
29         border: 3px groove;
30         padding: 5px;
```

Fig. 10.23 JavaServer page **guestBookView.jsp** displays the contents of the guest book (part 1 of 2).

```
31         background-color: #dddddd;
32     }
33     </style>
34 </head>
35
36 <body>
37     <p style = "font-size: 2em;">Guest List</p>
38
39     <table>
40         <thead>
41             <tr>
42                 <th style = "width: 100px;">Last name</th>
43                 <th style = "width: 100px;">First name</th>
44                 <th style = "width: 200px;">Email</th>
45             </tr>
46         </thead>
47
48         <tbody>
49
50         <% // start scriptlet
51
52             List guestList = guestData.getGuestList();
53             Iterator guestListIterator = guestList.iterator();
54             GuestBean guest;
55
56             while ( guestListIterator.hasNext() ) {
57                 guest = ( GuestBean ) guestListIterator.next();
58
59             %> <%-- end scriptlet; insert fixed template data --%>
60
61             <tr>
62                 <td><%= guest.getLastName() %></td>
63
64                 <td><%= guest.getFirstName() %></td>
65
66                 <td>
67                     <a href = "mailto:<%= guest.getEmail() %>">
68                         <%= guest.getEmail() %></a>
69                     </td>
70             </tr>
71
72         <% // continue scriptlet
73
74     } // end while
75
76     %> <%-- end scriptlet --%>
77
78     </tbody>
79     </table>
80     </body>
81
82 </html>
```

Fig. 10.23 JavaServer page **guestBookView.jsp** displays the contents of the guest book (part 2 of 2).

JavaServer Page **guestBookErrorPage.jsp** (Fig. 10.24) outputs an XHTML document containing an error message based on the type of exception that causes this error page to be invoked. Lines 8–10 define several **page** directives. Line 8 introduces **page** directive attribute **isErrorHandler**. Setting this attribute to **true** makes the JSP an error page and enables access to the JSP implicit object **exception** that refers to an exception object indicating the problem that occurred.



### Common Programming Error 10.8

*JSP implicit object **exception** can be used only in error pages. Using this object in other JSPs results in a translation-time error.*

Lines 29–46 define scriptlets that determine the type of exception that occurred and begin outputting an appropriate error message with fixed template data. The actual error message from the exception is output at line 56.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <%-- Fig. 10.24: guestBookErrorPage.jsp -->
6
7 <%-- page settings --%>
8 <%@ page isErrorPage = "true" %>
9 <%@ page import = "java.util.*" %>
10 <%@ page import = "java.sql.*" %>
11
12 <html xmlns = "http://www.w3.org/1999/xhtml">
13
14   <head>
15     <title>Error!</title>
16
17     <style type = "text/css">
18       .bigRed {
19         font-size: 2em;
20         color: red;
21         font-weight: bold;
22       }
23     </style>
24   </head>
25
26   <body>
27     <p class = "bigRed">
28
29       <% // scriptlet to determine exception type
30         // and output beginning of error message
31         if ( exception instanceof SQLException )
32       %>
33
34       An SQLException
35
```

Fig. 10.24 JavaServer page **guestBookErrorPage.jsp** responds to exceptions in **guestBookLogin.jsp** and **guestBookView.jsp** (part 1 of 2).

```
36      <%
37      else if ( exception instanceof ClassNotFoundException )
38      %>
39
40      A ClassNotFoundException
41
42      <%
43      else
44      %>
45
46      An exception
47
48      <%-- end scriptlet to insert fixed template data --%>
49
50      <%-- continue error message output --%>
51      occurred while interacting with the guestbook database.
52      </p>
53
54      <p class = "bigRed">
55          The error message was:<br />
56          <%= exception.getMessage() %>
57      </p>
58
59      <p class = "bigRed">Please try again later</p>
60      </body>
61
62  </html>
```

Fig. 10.24 JavaServer page `guestBookErrorPage.jsp` responds to exceptions in `guestBookLogin.jsp` and `guestBookView.jsp` (part 2 of 2).

Figure 10.25 shows sample interactions between the user and the JSPs in the guest book example. In the first two rows of output, separate users entered their first name, last name and e-mail. In each case, the current contents of the guest book are returned and displayed for the user. In the final interaction, a third user specified an e-mail address that already existed in the database. The e-mail address is the primary key in the `guests` table of the `guestbook` database, so its values must be unique. Thus, the database prevents the new record from being inserted, and an exception occurs. The exception is forwarded to `guestBookErrorPage.jsp` for processing, which results in the last screen capture.

To test the guest book in Tomcat, copy `guestBookLogin.jsp`, `guestBookView.jsp` and `guestBookErrorPage.jsp` into the `jsp` directory created in Section 10.3. Copy `GuestBean.class` and `GuestDataBean.class` into the `advjhttp1` Web application's `WEB-INF\classes` directory in Tomcat. [Note: This example will work only if the proper package directory structure for `GuestBean` and `GuestDataBean` is defined in the `classes` directory. These classes are defined in package `com.deitel.advjhttp1.jsp.beans`.] Open your Web browser and enter the following URL to test `guestBookLogin.jsp`:

`http://localhost:8080/advjhttp1/jsp/guestBookLogin.jsp`

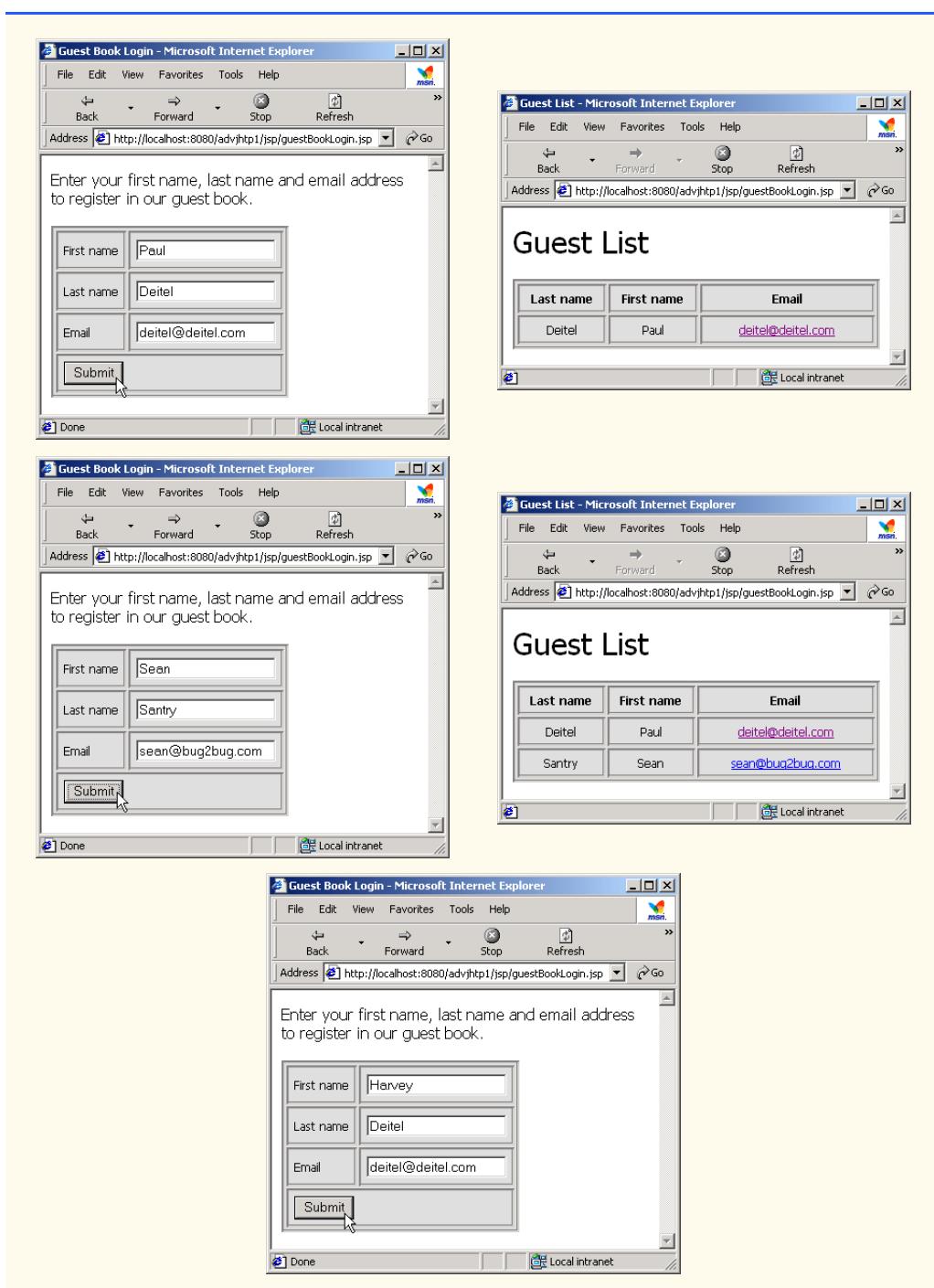


Fig. 10.25 JSP guest book sample output windows.

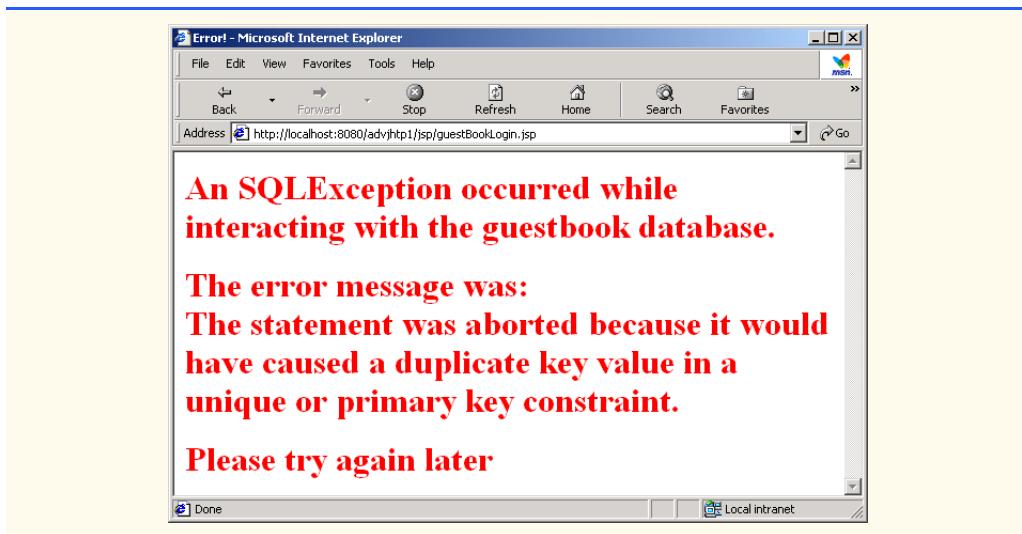


Fig. 10.25 JSP guest book sample output windows.

## 10.7 Directives

*Directives* are messages to the JSP container that enable the programmer to specify page settings (such as the error page), to include content from other resources and to specify custom-tag libraries for use in a JSP. Directives (delimited by `<%@` and `%>`) are processed at translation time. Thus, directives do not produce any immediate output, because they are processed before the JSP accepts any requests. Figure 10.26 summarizes the three directive types. These directives are discussed in the next several subsections.

### 10.7.1 page Directive

The **page** directive specifies global settings for the JSP in the JSP container. There can be many **page** directives, provided that there is only one occurrence of each attribute. The only exception to this rule is the **import** attribute, which can be used repeatedly to import Java packages used in the JSP. Figure 10.27 summarizes the attributes of the **page** directive.

Directive	Description
<b>page</b>	Defines page settings for the JSP container to process.
<b>include</b>	Causes the JSP container to perform a translation-time insertion of another resource's content. As the JSP is translated into a servlet and compiled, the referenced file replaces the <b>include</b> directive and is translated as if it were originally part of the JSP.
<b>taglib</b>	Allows programmers to include their own new tags in the form of <i>tag libraries</i> . These libraries can be used to encapsulate functionality and simplify the coding of a JSP.

Fig. 10.26 JSP directives.



## Common Programming Error 10.9

Providing multiple `page` directives with one or more attributes in common is a JSP translation-time error.



## Common Programming Error 10.10

Providing a `page` directive with an attribute or value that is not recognized is a JSP translation-time error.

Attribute	Description
<b>language</b>	The scripting language used in the JSP. Currently, the only valid value for this attribute is <code>java</code> .
<b>extends</b>	Specifies the class from which the translated JSP will be inherited. This attribute must be a fully qualified package and class name.
<b>import</b>	Specifies a comma-separated list of fully qualified class names and/or packages that will be used in the current JSP. When the scripting language is <code>java</code> , the default import list is <code>java.lang.*</code> , <code>javax.servlet.*</code> , <code>javax.servlet.jsp.*</code> and <code>javax.servlet.http.*</code> . If multiple <b>import</b> properties are specified, the package names are placed in a list by the container.
<b>session</b>	Specifies whether the page participates in a session. The values for this attribute are <code>true</code> (participates in a session—the default) or <code>false</code> (does not participate in a session). When the page is part of a session, the JSP implicit object <code>session</code> is available for use in the page. Otherwise, <code>session</code> is not available. In the latter case, using <code>session</code> in the scripting code results in a translation-time error.
<b>buffer</b>	Specifies the size of the output buffer used with the implicit object <code>out</code> . The value of this attribute can be <code>none</code> for no buffering, or a value such as <code>8kb</code> (the default buffer size). The JSP specification indicates that the buffer used must be at least the size specified.
<b>autoFlush</b>	When set to <code>true</code> (the default value), this attribute indicates that the output buffer used with implicit object <code>out</code> should be flushed automatically when the buffer fills. If set to <code>false</code> , an exception occurs if the buffer overflows. This attribute's value must be <code>true</code> if the buffer attribute is set to <code>none</code> .
<b>isThreadSafe</b>	Specifies if the page is thread safe. If <code>true</code> (the default), the page is considered to be thread safe, and it can process multiple requests at the same time. If <code>false</code> , the servlet that represents the page implements interface <code>java.lang.SingleThreadModel</code> and only one request can be processed by that JSP at a time. The JSP standard allows multiple instances of a JSP to exist for JSPs that are not thread safe. This enables the container to handle requests more efficiently. However, this does not guarantee that resources shared across JSP instances are accessed in a thread-safe manner.
<b>info</b>	Specifies an information string that describes the page. This string is returned by the <code>getServletInfo</code> method of the servlet that represents the translated JSP. This method can be invoked through the JSP's implicit <code>page</code> object.

Fig. 10.27 Attributes of the `page` directive (part 1 of 2).

Attribute	Description
<b>errorPage</b>	Any exceptions in the current page that are not caught are sent to the error page for processing. The error page implicit object <b>exception</b> references the original exception.
<b>isErrorPage</b>	Specifies if the current page is an error page that will be invoked in response to an error on another page. If the attribute value is <b>true</b> , the implicit object <b>exception</b> is created and references the original exception that occurred. If <b>false</b> (the default), any use of the <b>exception</b> object in the page results in a translation-time error.
<b>contentType</b>	Specifies the MIME type of the data in the response to the client. The default type is <b>text/html</b> .

Fig. 10.27 Attributes of the **page** directive (part 2 of 2).



### Software Engineering Observation 10.11

According to the JSP specification section 2.7.1, the **extends** attribute “should not be used without careful consideration as it restricts the ability of the JSP container to provide specialized superclasses that may improve on the quality of rendered service.” Rememeber that a Java class can extend exactly one other class. If your JSP specifies an explicit superclass, the JSP container cannot translate your JSP into a subclass of one of the container application’s own enhanced servlet classes.



### Common Programming Error 10.11

Using JSP implicit object **session** in a JSP that does not have its **page** directive attribute **session** set to **true** is a translation-time error.

## 10.7.2 include Directive

The **include** directive includes the content of another resource once, at JSP translation time. The **include** directive has only one attribute—**file**—that specifies the URL of the page to include. The difference between directive **include** and action **<jsp:include>** is noticeable only if the included content changes. For example, if the definition of an XHTML document changes after it is included with directive **include**, future invocations of the JSP will show the original content of the XHTML document, not the new content. In contrast, action **<jsp:include>** is processed in each request to the JSP. Therefore, changes to included content would be apparent in the next request to the JSP that uses action **<jsp:include>**.



### Software Engineering Observation 10.12

The JavaServer Pages 1.1 specification does not provide a mechanism for updating text included in a JSP with the **include** directive. Version 1.2 of the JSP specification allows the container to provide such a mechanism, but the specification does not provide for this directly.

JavaServer Page **includeDirective.jsp** (Fig. 10.28) reimplements JavaServer Page **include.jsp** (Fig. 10.10) using **include** directives. To test **includeDirective.jsp** in Tomcat, copy **includeDirective.jsp** into the **jsp** directory created

in Section 10.3. Open your Web browser and enter the following URL to test **includeDirective.jsp**:

```
http://localhost:8080/advjhtp1/jsp/includeDirective.jsp
```

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.28: includeDirective.jsp -->
6
7 <html xmlns = "http://www.w3.org/1999/xhtml">
8
9   <head>
10    <title>Using the include directive</title>
11
12    <style type = "text/css">
13      body {
14        font-family: tahoma, helvetica, arial, sans-serif;
15      }
16
17      table, tr, td {
18        font-size: .9em;
19        border: 3px groove;
20        padding: 5px;
21        background-color: #dddddd;
22      }
23    </style>
24  </head>
25
26  <body>
27    <table>
28      <tr>
29        <td style = "width: 160px; text-align: center">
30          <img src = "images/logotiny.png"
31              width = "140" height = "93"
32              alt = "Deitel & Associates, Inc. Logo" />
33        </td>
34
35        <td>
36
37          <%-- include banner.html in this JSP --%>
38          <%@ include file = "banner.html" %>
39
40        </td>
41      </tr>
42
43      <tr>
44        <td style = "width: 160px">
45
46          <%-- include toc.html in this JSP --%>
47          <%@ include file = "toc.html" %>
```

Fig. 10.28 JSP **includeDirective.jsp** demonstrates including content at translation-time with directive **include** (part 1 of 2).

```
48
49          </td>
50
51          <td style = "vertical-align: top">
52
53              <%-- include clock2.jsp in this JSP --%>
54              <%@ include file = "clock2.jsp" %>
55
56          </td>
57      </tr>
58  </table>
59 </body>
60 </html>
```

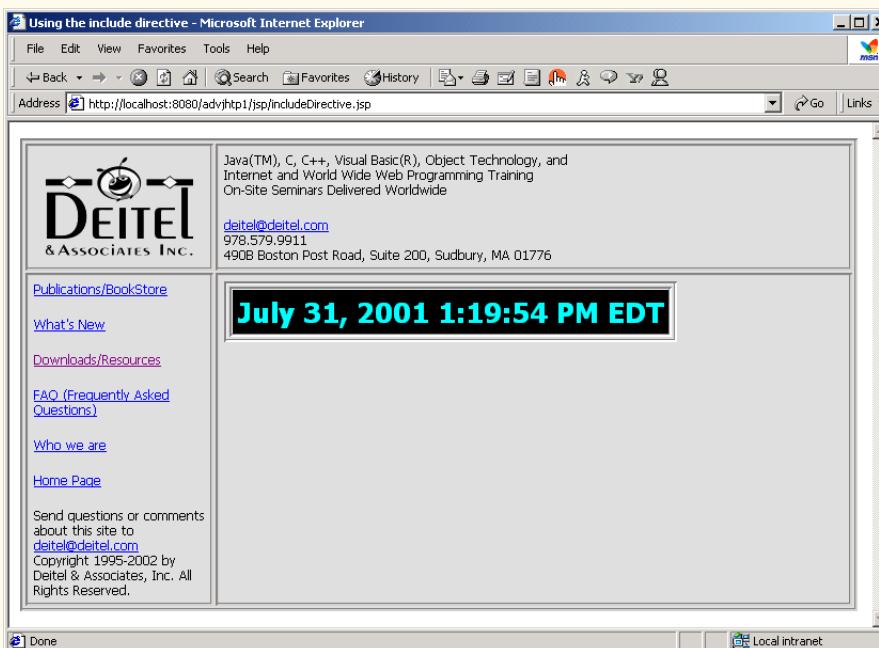


Fig. 10.28 JSP `includeDirective.jsp` demonstrates including content at translation-time with directive `include` (part 2 of 2).

## 10.8 Custom Tag Libraries

Throughout this chapter, you have seen how JavaServer Pages can simplify the delivery of dynamic Web content. Our discussion continues with JSP *custom tag libraries*, which provide another mechanism for encapsulating complex functionality for use in JSPs. Custom tag libraries define one or more *custom tags* that JSP implementors can use to create dynamic content. The functionality of these custom tags is defined in Java classes that implement interface `Tag` (package `javax.servlet.jsp.tagext`), normally by extending class `TagSupport` or `BodyTagSupport`. This mechanism enables Java programmers to create complex functionality for Web page designers who have no Java programming knowledge.

Previously, we introduced action `<jsp:useBean>` and JavaBeans to incorporate complex, encapsulated functionality in a JSP. In many cases, action `<jsp:useBean>` and JavaBeans can perform the same tasks as custom tags can. However, action `<jsp:useBean>` and JavaBeans have disadvantages—JavaBeans cannot manipulate JSP content and Web page designers must have some Java knowledge to use JavaBeans in a page. With custom tags, it is possible for Web page designers to use complex functionality without knowing any Java.

In this section, we present three examples of custom tags. Each tag is part of a single custom tag library that we refer to as `advjhttp1`. A JSP includes a custom tag library with the `taglib directive`. Figure 10.29 summarizes the `taglib` directive's attributes.

Each of the examples in this section uses directive `taglib`. There are several types of custom tags that have different levels of complexity. We demonstrate simple tags, simple tags with attributes and tags that can process their body elements. For complete details on custom tag libraries, see the resources in Section 10.9.

### 10.8.1 Simple Custom Tag

Our first custom tag example implements a simple custom tag that inserts the string “**Welcome to JSP Tag Libraries**” in a JSP. When implementing custom tags, you must define a tag-handler class for each tag that implements the tag’s functionality, a *tag library descriptor* that provides information about the tag library and its custom tags to the JSP container and a JSP that uses the custom tag. Figure 10.30 (`customTagWelcome.jsp`) demonstrates our first custom tag. At the end of this section, we discuss how to configure this example for testing on Tomcat.

Attribute	Description
<code>uri</code>	Specifies the relative or absolute URI of the tag library descriptor.
<code>tagPrefix</code>	Specifies the required prefix that distinguishes custom tags from built-in tags. The prefix names <code>jsp</code> , <code>jspx</code> , <code>java</code> , <code>javax</code> , <code>servlet</code> , <code>sun</code> and <code>sunw</code> are reserved.

Fig. 10.29 Attributes of the `taglib` directive.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.30: customTagWelcome.jsp -->
6 <!-- JSP that uses a custom tag to output content. -->
7
8 <%-- taglib directive --%>
9 <%@ taglib uri = "advjhttp1-taglib.tld" prefix = "advjhttp1" %>
10
11 <html xmlns = "http://www.w3.org/1999/xhtml">
```

Fig. 10.30 JSP `customTagWelcome.jsp` uses a simple custom tag (part 1 of 2).

```

12
13     <head>
14         <title>Simple Custom Tag Example</title>
15     </head>
16
17     <body>
18         <p>The following text demonstrates a custom tag:</p>
19         <h1>
20             <advjhttp1:welcome />
21         </h1>
22     </body>
23
24 </html>

```



Fig. 10.30 JSP `customTagWelcome.jsp` uses a simple custom tag (part 2 of 2).

The **taglib** directive at line 9 enables the JSP to use the tags in our tag library. The directive specifies the **uri** of the tag library descriptor file (**advjhttp1-taglib.tld**; Fig. 10.32) that provides information about our tag library to the JSP container and the **prefix** for each tag (**advjhttp1**). JSP programmers use the tag library **prefix** when referring to tags in a specific tag library. Line 20 uses a custom tag called **welcome** to insert text in the JSP. Note that the prefix **advjhttp1:** precedes the tag name. This enables the JSP container to interpret the meaning of the tag and invoke the appropriate *tag handler*. Also note that line 20 can be written with start and end tags as follows:

```
<advjhttp1:welcome> </advjhttp1:welcome>
```

Figure 10.31 defines class **WelcomeTagHandler**—the tag handler that implements the functionality of our custom tag **welcome**. Every tag handler must implement interface **Tag**, which defines the methods a JSP container invokes to incorporate a tag's functionality in a JSP. Most tag handler classes implement interface **Tag** by extending either class **TagSupport** or class **BodyTagSupport**.



### Software Engineering Observation 10.13

*Classes that define custom tag handlers must implement interface **Tag** from package **javax.servlet.jsp.tagext**.*



### Software Engineering Observation 10.14

*A custom tag handler class should extend class **TagSupport** if the body of the tag is ignored or simply output during custom tag processing.*



### Software Engineering Observation 10.15

A custom tag handler class should extend class **BodyTagSupport** if the handler interacts with the tag's body content.



### Software Engineering Observation 10.16

Custom tag handlers must be defined in Java packages.

Class **WelcomeTagHandler** implements interface **Tag** by extending class **TagSupport** (both from package **java.servlet.jsp.tagext**). The most important methods of interface **Tag** are **doStartTag** and **doEndTag**. The JSP container invokes these methods when it encounters the starting custom tag and the ending custom tag, respectively. These methods throw **JspExceptions** if problems are encountered during custom-tag processing.

```
1 // Fig. 10.31: WelcomeTagHandler.java
2 // Custom tag handler that handles a simple tag.
3 package com.deitel.advjhttp1.jsp.taglibrary;
4
5 // Java core packages
6 import java.io.*;
7
8 // Java extension packages
9 import javax.servlet.jsp.*;
10 import javax.servlet.jsp.tagext.*;
11
12 public class WelcomeTagHandler extends TagSupport {
13
14     // Method called to begin tag processing
15     public int doStartTag() throws JspException
16     {
17         // attempt tag processing
18         try {
19             // obtain JspWriter to output content
20             JspWriter out = pageContext.getOut();
21
22             // output content
23             out.print( "Welcome to JSP Tag Libraries!" );
24         }
25
26         // rethrow IOException to JSP container as JspException
27         catch( IOException ioException ) {
28             throw new JspException( ioException.getMessage() );
29         }
30
31         return SKIP_BODY; // ignore the tag's body
32     }
33 }
```

Fig. 10.31 **WelcomeTagHandler** custom tag handler.



### Software Engineering Observation 10.17

If exceptions other than **JspExceptions** occur in a custom tag handler class, the exceptions should be caught and processed. If such exceptions would prevent proper tag processing, the exceptions should be rethrown as **JspExceptions**.

In this example, class **WelcomeTagHandler** overrides method **doStartTag** to output text that becomes part of the JSP's response. Line 20 uses the custom tag handler's **pageContext** object (inherited from class **TagSupport**) to obtain the JSP's **JspWriter** object that method **doStartTag** uses to output text. Line 23 uses the **JspWriter** to output a string. Line 31 returns the **static** integer constant **SKIP\_BODY** (defined in interface **Tag**) to indicate that the JSP container should ignore any text or other elements that appear in the tag's body. To include the body content as part of the response, specify **static** integer constant **EVAL\_BODY\_INCLUDE** as the return value. This example does not require any processing when the ending tag is encountered by the JSP container, so we did not override **doEndTag**.

Figure 10.32 defines the custom tag library descriptor file. This XML document specifies information required by the JSP container such as the version number of the tag library (element **tlibversion**), the JSP version number (element **jspversion**), information about the library (element **info**) and information about the tags in the library (one **tag** element for each tag). In this tag library descriptor, the **tag** element at lines 18–30 describes our **welcome** tag. Line 19 specifies the tag's **name**—used by JSP programmers to access the custom functionality in a JSP. Lines 21–23 specify the **tagclass**—the custom tag handler class. This element associates the tag name with a specific tag handler class. Element **bodycontent** (line 25) specifies that our custom tag has an **empty** body. This value can also be **tagdependent** or **JSP**. Lines 27–29 specify information about the tag with an **info** element. [Note: We introduce other elements of the tag library descriptor as necessary. For a complete description of the tag library descriptor, see the JavaServer Pages 1.1 specification, which can be downloaded from [java.sun.com/products/jsp/download.html](http://java.sun.com/products/jsp/download.html).]



### Software Engineering Observation 10.18

The custom tag handler class must be specified with its full package name in the **tagclass** element of the tag library descriptor.

```

1 <?xml version = "1.0" encoding = "ISO-8859-1" ?>
2 <!DOCTYPE taglib PUBLIC
3   "-//Sun Microsystems, Inc.//DTD JSP Tag Library 1.1//EN"
4   "http://java.sun.com/j2ee/dtds/web-jsptaglibrary_1_1.dtd">
5
6 <!-- a tag library descriptor -->
7
8 <taglib>
9   <tlibversion>1.0</tlibversion>
10  <jspversion>1.1</jspversion>
11  <shortname>advjhttp1</shortname>
12

```

Fig. 10.32 Custom tag library descriptor file **advjhttp1-taglib.tld** (part 1 of 2).

```
13    <info>
14        A simple tag library for the examples
15    </info>
16
17    <!-- A simple tag that outputs content -->
18    <tag>
19        <name>welcome</name>
20
21        <tagclass>
22            com.deitel.advjhttp1.jsp.taglibrary.WelcomeTagHandler
23        </tagclass>
24
25        <bodycontent>empty</bodycontent>
26
27        <info>
28            Inserts content welcoming user to tag libraries
29        </info>
30    </tag>
31 </taglib>
```

Fig. 10.32 Custom tag library descriptor file **advjhttp1-taglib.tld** (part 2 of 2).

To test **customTagWelcome.jsp** in Tomcat, copy **customTagWelcome.jsp** and **advjhttp1-taglib.tld** into the **jsp** directory created in Section 10.3. Copy **WelcomeTagHandler.class** into the **advjhttp1** Web application's **WEB-INF\classes** directory in Tomcat. [Note: Class **WelcomeTagHandler** must appear in its proper package director structure in **classes** directory. **WelcomeTagHandler** is defined in package **com.deitel.advjhttp1.jsp.taglibrary**.] Open your Web browser and enter the following URL to test **customTagWelcome.jsp**:

```
http://localhost:8080/advjhttp1/jsp/customTagWelcome.jsp
```

## 10.8.2 Custom Tag with Attributes

Many XHTML and JSP elements use attributes to customize functionality. For example, an XHTML element can specify a **style** attribute that indicates how the element should be formatted in a client's Web browser. Similarly, the JSP action elements have attributes that help customize their behavior in a JSP. Our next example demonstrates how to specify attributes for your custom tags.

Figure 10.33 (**customTagAttribute.jsp**) is similar to Fig. 10.30. This example uses a new tag called, **welcome2**, to insert text in the JSP that is customized based on the value of attribute **firstName**. The screen capture shows the results of the **welcome2** tags on lines 20 and 30. The tag at line 20 specifies the value "**Paul**" for attribute **firstName**. Lines 26–28 define a scriptlet that obtains the value of request parameter **name** and assign it to **String** reference **name**. Line 30 uses the **name** in a JSP expression as the value for the **firstName** attribute. In the sample screen capture, this JSP was invoked with the following URL:

```
http://localhost:8080/advjhttp1/jsp/
customTagAttribute.jsp?firstName=Sean
```

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3      "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5 <!-- Fig. 10.x: customTagAttribute.jsp          -->
6 <!-- JSP that uses a custom tag to output content. -->
7
8 <%-- taglib directive --%>
9 <%@ taglib uri = "advjhtp1-taglib.tld" prefix = "advjhtp1" %>
10
11 <html xmlns = "http://www.w3.org/1999/xhtml">
12
13     <head>
14         <title>Specifying Custom Tag Attributes</title>
15     </head>
16
17     <body>
18         <p>Demonstrating an attribute with a string value</p>
19         <h1>
20             <advjhtp1:welcome2 firstName = "Paul" />
21         </h1>
22
23         <p>Demonstrating an attribute with an expression value</p>
24         <h1>
25             <%-- scriptlet to obtain "name" request parameter --%>
26             <%
27                 String name = request.getParameter( "name" );
28             %>
29
30             <advjhtp1:welcome2 firstName = "<%= name %>" />
31         </h1>
32     </body>
33
34 </html>
```

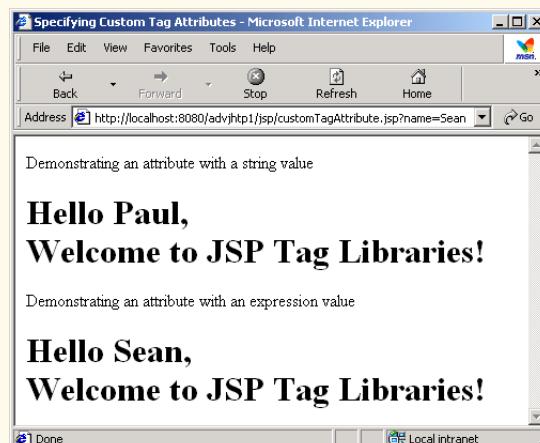


Fig. 10.33 Specifying attributes for a custom tag.

When defining the custom tag handler for a tag with attributes, you must provide methods that enable the JSP container to set the attribute values in the tag handler. Methods that manipulate attributes follow the same *set-* and *get-*method naming conventions as do JavaBean properties. Thus, the custom tag's **firstName** attribute is set with method **setFirstName**. Similarly, the method to obtain the **firstName** attribute's value would be **getFirstName** (we did not define this method for this example). Class **Welcome2TagHandler** (Fig. 10.34) defines its **firstName** variable at line 13 and a corresponding *set* method **setFirstName** (lines 37–40). When the JSP container encounters a **welcome2** tag in a JSP, it creates a new **Welcome2TagHandler** object to process the tag and sets the tag's attributes. Next, the container invokes method **doStartTag** (lines 16–34) to perform the custom tag processing. Lines 24–25 use the **firstName** attribute value as part of the text output by the custom tag.

```
1 // Fig. 10.34: Welcome2TagHandler.java
2 // Custom tag handler that handles a simple tag.
3 package com.deitel.advjhtp1.jsp.taglibrary;
4
5 // Java core packages
6 import java.io.*;
7
8 // Java extension packages
9 import javax.servlet.jsp.*;
10 import javax.servlet.jsp.tagext.*;
11
12 public class Welcome2TagHandler extends TagSupport {
13     private String firstName = "";
14
15     // Method called to begin tag processing
16     public int doStartTag() throws JspException
17     {
18         // attempt tag processing
19         try {
20             // obtain JspWriter to output content
21             JspWriter out = pageContext.getOut();
22
23             // output content
24             out.print( "Hello " + firstName +
25                     ", <br />Welcome to JSP Tag Libraries!" );
26         }
27
28         // rethrow IOException to JSP container as JspException
29         catch( IOException ioException ) {
30             throw new JspException( ioException.getMessage() );
31         }
32
33         return SKIP_BODY; // ignore the tag's body
34     }
35 }
```

Fig. 10.34 **Welcome2TagHandler** custom tag handler for a tag with an attribute (part 1 of 2).

```

36 // set firstName attribute to the users first name
37 public void setFirstName( String username )
38 {
39     firstName = username;
40 }
41 }
```

Fig. 10.34 `Welcome2TagHandler` custom tag handler for a tag with an attribute (part 2 of 2).

Before the `welcome2` tag can be used in a JSP, we must make the JSP container aware of the tag by adding it to a tag library. To do this, add the tag element of Fig. 10.35 as a child of element `taglib` in the tag library descriptor `advjhttp1-taglib.tld`. As in the previous example, element `tag` contains elements `name`, `tagclass`, `bodycontent` and `info`. Lines 16–20 introduce element `attribute` for specifying the characteristics of a tag's attributes. Each attribute must have a separate attribute element that contains the `name`, `required` and `rtextprvalue` elements. Element `name` (line 17) specifies the attribute's name. Element `required` specifies whether the attribute is required (`true`) or optional (`false`). Element `rtextprvalue` specifies whether the value of the attribute can be the result of a JSP expression evaluated at runtime (`true`) or whether it must be a string literal (`false`).

To test `customTagAttribute.jsp` in Tomcat, copy `customTagAttribute.jsp` and the updated `advjhttp1-taglib.tld` into the `jsp` directory created in Section 10.3. Copy `Welcome2TagHandler.class` into the `advjhttp1` Web application's `WEB-INF\classes` directory in Tomcat. [Note: This example will work only if the proper package-directory structure for `Welcome2TagHandler` is defined in the `classes` directory.] Open your Web browser and enter the following URL to test `customTagAttribute.jsp`:

```
http://localhost:8080/advjhttp1/jsp/
customTagAttribute.jsp?firstName=Sean
```

The text `?firstName=Sean` in the preceding URL specifies the value for request parameter `name` that is used by the custom tag `welcome2` at line 30 in Fig. 10.33.

```

1 <!-- A tag with an attribute -->
2 <tag>
3   <name>welcome2</name>
4
5   <tagclass>
6     com.deitel.advjhttp1.jsp.taglibrary.Welcome2TagHandler
7   </tagclass>
8
9   <bodycontent>empty</bodycontent>
10
11  <info>
12    Inserts content welcoming user to tag libraries. Uses
13    attribute "name" to insert the user's name.
14  </info>
```

Fig. 10.35 Element `tag` for the `welcome2` custom tag (part 1 of 2).

```
15      <attribute>
16          <name>firstName</name>
17          <required>true</required>
18          <rteprvalue>true</rteprvalue>
19      </attribute>
20  </tag>
```

Fig. 10.35 Element **tag** for the **welcome2** custom tag (part 2 of 2).

### 10.8.3 Evaluating the Body of a Custom Tag

Custom tags are particularly powerful for processing the element body. When a custom tag interacts with the element body, additional methods are required to perform those interactions. The methods are defined in class **BodyTagSupport**. In our next example, we reimplement **guestBookView.jsp** (Fig. 10.23) and replace the JavaBean processing performed in the JSP with a custom **guestlist** tag.

Figure 10.36 (**customTagBody.jsp**) uses the custom **guestlist** tag at lines 41–52. Note that the JSP expressions in the body of element **guestlist** use variable names that are not defined in the JSP. These variables are defined by the custom tag handler when the custom tag is encountered. The custom tag handler places the variables in the JSP's **PageContext**, so the variables can be used throughout the page. Although no repetition is defined in the JSP, the custom tag handler is defined to iterate over all the guests in the **guestbook** database. This action results in the creation of a table row in the resulting Web page for each guest in the database.

```
1  <?xml version = "1.0"?>
2  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3      "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4
5  <!-- customTagBody.jsp -->
6
7  <%-- taglib directive --%>
8  <%@ taglib uri = "advjhttp1-taglib.tld" prefix = "advjhttp1" %>
9
10 <html xmlns = "http://www.w3.org/1999/xhtml">
11
12     <head>
13         <title>Guest List</title>
14
15         <style type = "text/css">
16             body {
17                 font-family: tahoma, helvetica, arial, sans-serif
18             }
19
20             table, tr, td, th {
21                 text-align: center;
22                 font-size: .9em;
23                 border: 3px groove;
```

Fig. 10.36 Using a custom tag that interacts with its body (part 1 of 2).

```
24         padding: 5px;
25         background-color: #dddddd
26     }
27     </style>
28 </head>
29
30 <body>
31     <p style = "font-size: 2em">Guest List</p>
32
33     <table>
34         <thead>
35             <th style = "width: 100px">Last name</th>
36             <th style = "width: 100px">First name</th>
37             <th style = "width: 200px">Email</th>
38         </thead>
39
40         <%-- guestlist custom tag --%>
41         <advjhttp1:guestlist>
42             <tr>
43                 <td><%= lastName %></td>
44
45                 <td><%= firstName %></td>
46
47                 <td>
48                     <a href = "mailto:<%= email %>">
49                         <%= email %></a>
50                 </td>
51             </tr>
52         </advjhttp1:guestlist>
53     </table>
54 </body>
55
56 </html>
```

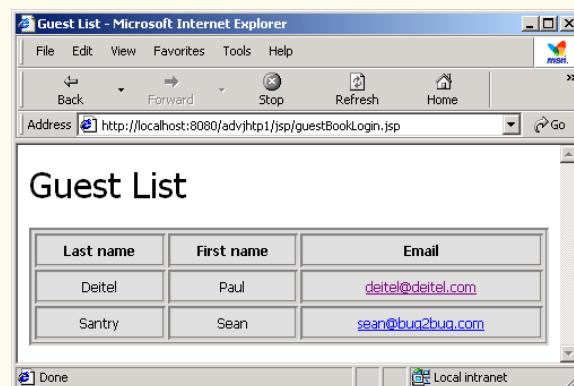


Fig. 10.36 Using a custom tag that interacts with its body (part 2 of 2).

As in `guestBookView.jsp`, the custom tag handler `GuestBookTag` (Fig. 10.37) creates a `GuestDataBean` to access the `guestbook` database. Class `GuestBookTag` extends `BodyTagSupport`, which contains several new methods including `doInit-`

**Body** and **doAfterBody** (from interface **BodyTag**). Method **doInitBody** is called once, after **doStartTag** and before **doAfterBody**. Method **doAfterBody** can be called many times to process the body of a custom tag.



### Software Engineering Observation 10.19

Method **doInitBody** typically performs one-time processing before method **doAfterBody** processes the body of a custom tag. If method **doStartTag** returns **Tag.SKIP\_BODY**, method **doInitBody** will not be called.

```
1 // Fig. 10.37: GuestBookTag.java
2 // Custom tag handler that reads information from the guestbook
3 // database and makes that data available in a JSP.
4 package com.deitel.advjhttp1.jsp.taglibrary;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.jsp.*;
12 import javax.servlet.jsp.tagext.*;
13
14 // Deitel packages
15 import com.deitel.advjhttp1.jsp.beans.*;
16
17 public class GuestBookTag extends BodyTagSupport {
18     private String firstName;
19     private String lastName;
20     private String email;
21
22     private GuestDataBean guestData;
23     private GuestBean guest;
24     private Iterator iterator;
25
26     // Method called to begin tag processing
27     public int doStartTag() throws JspException
28     {
29         // attempt tag processing
30         try {
31             guestData = new GuestDataBean();
32
33             List list = guestData.getGuestList();
34             iterator = list.iterator();
35
36             if ( iterator.hasNext() ) {
37                 processNextGuest();
38
39                 return EVAL_BODY_TAG;      // continue body processing
40             }
41             else
42                 return SKIP_BODY;       // terminate body processing
43         }
```

Fig. 10.37 **GuestBookTag** custom tag handler (part 1 of 2).

```
44      // if any exceptions occur, do not continue processing
45      // tag's body
46      catch( Exception exception ) {
47          exception.printStackTrace();
48          return SKIP_BODY;    // ignore the tag's body
49      }
50  }
51 }
52
53 // process body and determine if body processing
54 // should continue
55 public int doAfterBody()
56 {
57     // attempt to output body data
58     try {
59         bodyContent.writeOut( getPreviousOut() );
60     }
61
62     // if exception occurs, terminate body processing
63     catch ( IOException ioException ) {
64         ioException.printStackTrace();
65         return SKIP_BODY;        // terminate body processing
66     }
67
68     bodyContent.clearBody();
69
70     if ( iterator.hasNext() ) {
71         processNextGuest();
72
73         return EVAL_BODY_TAG;    // continue body processing
74     }
75     else
76         return SKIP_BODY;        // terminate body processing
77 }
78
79 // obtains the next GuestBean and extracts its data
80 private void processNextGuest()
81 {
82     // get next guest
83     guest = ( GuestBean ) iterator.next();
84
85     pageContext.setAttribute(
86         "firstName", guest.getFirstName() );
87
88     pageContext.setAttribute(
89         "lastName", guest.getLastName() );
90
91     pageContext.setAttribute(
92         "email", guest.getEmail() );
93 }
94 }
```

Fig. 10.37 **GuestBookTag** custom tag handler (part 2 of 2).

The JSP container invokes method `doStartTag` (lines 27–51) when it encounters the custom `guestlist` tag in a JSP. Lines 31–34 create a new `GuestDataBean`, obtain a `List` of `GuestBeans` from the `GuestDataBean` and create an `Iterator` for manipulating the `ArrayList` contents. If there are no elements in the list (tested at line 36), line 42 returns `SKIP_BODY` to indicate that the container should perform no further processing of the `guestlist` tag's body. Otherwise, line 37 invokes `private` method `processNextGuest` (lines 80–93) to extract the information for the first guest and create variables containing that information in the JSP's `PageContext` (represented with variable `pageContext` that was inherited from `BodyTagSupport`). Method `processNextGuest` uses `PageContext` method `setAttribute` to specify each variable's name and value. The container is responsible for creating the actual variables used in the JSP. This is accomplished with the help of class `GuestBookTagExtraInfo` (Fig. 10.38).

Method `doAfterBody` (lines 55–77) performs the repetitive processing of the `guestlist` tag's body. The JSP container determines whether method `doAfterBody` should be called again, based on the method's return value. If `doAfterBody` returns `EVAL_BODY_TAG`, the container calls method `doAfterBody` again. If `doAfterBody` returns `SKIP_BODY`, the container stops processing the body and invokes the custom tag handler's `doEndTag` method to complete the custom processing. Line 59 invokes `writeOut` on variable `bodyContent` (inherited from `BodyTagSupport`) to process the first client's data (stored when `doStartTag` was called). Variable `bodyContent` refers to an object of class `BodyContent` from package `javax.servlet.jsp.tagext`. The argument to method `writeOut` is the result of method `getPreviousOut` (inherited from class `BodyTagSupport`), which returns the `JspWriter` object for the JSP that invokes the custom tag. This enables the custom tag to continue building the response to the client using the same output stream as the JSP. Next, line 68 invokes `bodyContent`'s method `clearBody` to ensure that the body content that was just output does not get processed as part of the next call to `doAfterBody`. Lines 70–76 determine whether there are more guests to process. If so, `doAfterBody` invokes `private` method `processNextGuest` to obtain the data for the next guest and returns `EVAL_BODY_TAG` to indicate that the container should call `doAfterBody` again. Otherwise, `doAfterBody` returns `SKIP_BODY` to terminate processing of the body.

The JSP container cannot create variables in the `PageContext` unless the container knows the names and types of those variables. This information is specified by a class with the same name as the custom tag handler and that ends with `ExtraInfo` (`GuestBookTagExtraInfo` in Fig. 10.38). `ExtraInfo` classes extend class `TagExtraInfo` (package `javax.servlet.jsp.tagext`). The container uses the information specified by a subclass of `TagExtraInfo` to determine what variables it should create (or use) in the `PageContext`. To specify variable information, override method `getVariableInfo`. This method returns an array of `VariableInfo` objects that the container uses either to create new variables in the `PageContext` or to enable a custom tag to use existing variables in the `PageContext`. The `VariableInfo` constructor receives four arguments—a `String` representing the name of the variable, a `String` representing the variable's class name, a `boolean` indicating whether or not the variable should be created by the container (`true` if so) and a `static` integer constant representing the variable's scope in the JSP. The constants in class `VariableInfo` are `NESTED`, `AT_BEGIN` and

**AT\_END\_NESTED** indicates that the variable can be used only in the custom tag's body. **AT\_BEGIN** indicates that the variable can be used anywhere in the JSP after the starting tag of the custom tag is encountered. **AT\_END** indicates that the variable can be used anywhere in the JSP after the ending tag of the custom tag.

Before the **guestlist** tag can be used in a JSP, we must make the JSP container aware of the tag by adding it to a tag library. To do this, add the **tag** element of Fig. 10.39 as a child of element **taglib** in the tag library descriptor **advjhttp1-taglib.tld**. As in the previous example, element **tag** contains elements **name**, **tagclass**, **bodycontent** and **info**. Lines 10–12 introduce element **teiclass** for specifying the custom tag's **ExtraInfo** class.

To test **customTagBody.jsp** in Tomcat, copy **customTagBody.jsp** and the updated **advjhttp1-taglib.tld** into the **jsp** directory created in Section 10.3. Copy **GuestBookTag.class** and **GuestBookTagExtraInfo.class** into the **advjhttp1** Web application's **WEB-INF\classes** directory in Tomcat. [Note: This example will work only if the proper package directory structure for **GuestBookTag** and **GuestBookTagExtraInfo** is defined in the **classes** directory.] Open your Web browser and enter the following URL to test **customTagBody.jsp**:

```
http://localhost:8080/advjhttp1/jsp/customTagBody.jsp
```

```
1 // Fig. 10.38: GuestBookTagExtraInfo.java
2 // Class that defines the variable names and types created by
3 // custom tag handler GuestBookTag.
4 package com.deitel.advjhttp1.jsp.taglibrary;
5
6 // Java core packages
7 import javax.servlet.jsp.tagext.*;
8
9 public class GuestBookTagExtraInfo extends TagExtraInfo {
10
11    // method that returns information about the variables
12    // GuestBookTag creates for use in a JSP
13    public VariableInfo [] getVariableInfo( TagData tagData )
14    {
15        VariableInfo firstName = new VariableInfo( "firstName",
16            "String", true, VariableInfo.NESTED );
17
18        VariableInfo lastName = new VariableInfo( "lastName",
19            "String", true, VariableInfo.NESTED );
20
21        VariableInfo email = new VariableInfo( "email",
22            "String", true, VariableInfo.NESTED );
23
24        VariableInfo varableInfo [] =
25            { firstName, lastName, email };
26
27        return varableInfo;
28    }
29}
```

Fig. 10.38 **GuestBookTagExtraInfo** used by the container to define scripting variables in a JSP that uses the **guestlist** custom tag.

```
1  <!-- A tag that iterates over an ArrayList of GuestBean -->
2  <!-- objects, so they can be output in a JSP -->
3  <tag>
4      <name>guestlist</name>
5
6      <tagclass>
7          com.deitel.advjhttp1.jsp.taglibrary.GuestBookTag
8      </tagclass>
9
10     <teiclass>
11         com.deitel.advjhttp1.jsp.taglibrary.GuestBookTagExtraInfo
12     </teiclass>
13
14     <bodycontent>JSP</bodycontent>
15
16     <info>
17         Iterates over a list of GuestBean objects
18     </info>
19 </tag>
```

Fig. 10.39 Element **tag** for the **guestlist** custom tag.

This chapter has presented many JSP capabilities. However, there are additional features that are beyond the scope of this book. For a complete description of JavaServer Pages, see the JavaServer Pages 1.1 specification, which can be downloaded from [java.sun.com/products/jsp/download.html](http://java.sun.com/products/jsp/download.html). Other JSP resources are listed in Section 10.9. The next chapter continues our JSP and servlet discussion by presenting a substantial e-business case study in which we build an online bookstore. The case study integrates many topics discussed up to this point in the text, including JDBC, servlets, JSP and XML. Also, we discuss several additional servlet features as part of the case study. The techniques shown in the case study provide a foundation for the capstone e-business case study presented in Chapters 16 through 19.

## 10.9 World Wide Web Resources

### [java.sun.com/products/jsp](http://java.sun.com/products/jsp)

The home page for information about JavaServer Pages at the Sun Microsystems Java site.

### [java.sun.com/products/servlet](http://java.sun.com/products/servlet)

The home page for information about servlets at the Sun Microsystems Java site.

### [java.sun.com/j2ee](http://java.sun.com/j2ee)

The home page for the Java 2 Enterprise Edition at the Sun Microsystems Java site.

### [www.w3.org](http://www.w3.org)

The World Wide Web Consortium home page. This site provides information about current and developing Internet and Web standards, such as XHTML, XML and CSS.

### [jsptags.com](http://jsptags.com)

This site includes tutorials, tag libraries, software and other resources for JSP programmers.

### [jspspider.com](http://jspspider.com)

This Web programming site concentrates on resources for JSP programmers. It includes software, tutorials, articles, sample code, references and links to other JSP and Web programming resources.

## SUMMARY

- JavaServer Pages (JSPs) are an extension of servlet technology.
- JavaServer Pages enable Web application programmers to create dynamic content by reusing pre-defined components and by interacting with components using server-side scripting.
- JSP programmers can create custom tag libraries that enable Web-page designers who are not familiar with Java programming to enhance their Web pages with powerful dynamic content and processing capabilities.
- Classes and interfaces specific to JavaServer Pages programming are located in packages **javax.servlet.jsp** and **javax.servlet.jsp.tagext**.
- The JavaServer Pages 1.1 specification can be downloaded from [java.sun.com/products/jsp/download.html](http://java.sun.com/products/jsp/download.html).
- There are four key components to JSPs—directives, actions, scriptlets and tag libraries.
- Directives specify global information that is not associated with a particular JSP request.
- Actions encapsulate functionality in predefined tags that programmers can embed in a JSP.
- Scriptlets, or scripting elements, enable programmers to insert Java code that interacts with components in a JSP (and possibly other Web application components) to perform request processing.
- Tag libraries are part of the tag extension mechanism that enables programmers to create new tags that encapsulate complex Java functionality.
- JSPs normally include XHTML or XML markup. Such markup is known as fixed template data or fixed template text.
- Programmers tend to use JSPs when most of the content sent to the client is fixed template data and only a small portion of the content is generated dynamically with Java code.
- Programmers use servlets when a small portion of the content is fixed template data.
- JSPs normally execute as part of a Web server. The server often is referred to as the JSP container.
- When a JSP-enabled server receives the first request for a JSP, the JSP container translates that JSP into a Java servlet that handles the current request and future requests to the JSP.
- The JSP container places the Java statements that implement a JSP's response in method **\_jspService** at translation time.
- The request/response mechanism and life cycle of a JSP are the same as those of a servlet.
- JSPs can define methods **jspInit** and **jspDestroy** that are invoked when the container initializes a JSP and when the container terminates a JSP, respectively.
- JSP expressions are delimited by `<%=` and `%>`. Such expressions are converted to **strings** by the JSP container and are output as part of the response.
- The XHTML **meta** element can set a refresh interval for a document that is loaded into a browser. This causes the browser to request the document repeatedly at the specified interval in seconds.
- When you first invoke a JSP in Tomcat, there is a delay as Tomcat translates the JSP into a servlet and invokes the servlet to respond to your request.
- Implicit objects provide programmers with servlet capabilities in the context of a JavaServer Page.
- Implicit objects have four scopes—application, page, request and session.
- Objects with application scope are part of the JSP and servlet container application.
- Objects with page scope exist only as part of the page in which they are used. Each page has its own instances of the page-scope implicit objects.
- Objects with request scope exist for the duration of the request. Request-scope objects go out of scope when request processing completes with a response to the client.

- Objects with session scope exist for the client's entire browsing session.
- JSP scripting components include scriptlets, comments, expressions, declarations and escape sequences.
- Scriptlets are blocks of code delimited by <% and %>. They contain Java statements that are placed in method `_jspService` when the container translates a JSP into a servlet.
- JSP comments are delimited by <%-- and --%>. XHTML comments are delimited by <!-- and -->. Java's single-line comments (//) and multiline comments (delimited by /\* and \*/) can be used inside scriptlets.
- JSP comments and scripting language comments are ignored and do not appear in the response.
- A JSP expression, delimited by <%= and %>, contains a Java expression that is evaluated when a client requests the JSP containing the expression. The container converts the result of a JSP expression to a **String** object, then outputs the **String** as part of the response to the client.
- Declarations, delimited by <%! and %>, enable a JSP programmer to define variables and methods. Variables become instance variables of the class that represents the translated JSP. Similarly, methods become members of the class that represents the translated JSP.
- Special characters or character sequences that the JSP container normally uses to delimit JSP code can be included in a JSP as literal characters in scripting elements, fixed template data and attribute values by using escape sequences.
- JSP standard actions provide JSP implementors with access to several of the most common tasks performed in a JSP. JSP containers process actions at request time.
- JavaServer Pages support two include mechanisms—the `<jsp:include>` action and the `include` directive.
- Action `<jsp:include>` enables dynamic content to be included in a JavaServer Page. If the included resource changes between requests, the next request to the JSP containing the `<jsp:include>` action includes the new content of the resource.
- The `include` directive is processed once, at JSP translation time, and causes the content to be copied into the JSP. If the included resource changes, the new content will not be reflected in the JSP that used the include directive unless that JSP is recompiled.
- Action `<jsp:forward>` enables a JSP to forward the processing of a request to a different resource. Processing of the request by the original JSP terminates as soon as the request is forwarded.
- Action `<jsp:param>` specifies name/value pairs of information that are passed to the `include`, `forward` and `plugin` actions. Every `<jsp:param>` action has two required attributes—`name` and `value`. If a `param` action specifies a parameter that already exists in the request, the new value for the parameter takes precedence over the original value. All values for that parameter can be obtained with the JSP implicit object `request`'s `getParameterValues` method, which returns an array of **Strings**.
- JSP action `<jsp:plugin>` enables an applet or JavaBean to be added to a Web page in the form of a browser-specific `object` or `embed` XHTML element. This action also enables the downloading and installation of the Java Plug-in if it is not already installed on the client computer.
- Action `<jsp:useBean>` enables a JSP to manipulate a Java object. This action can be used to create a Java object for use in the JSP or to locate an existing object.
- Like JSP implicit objects, objects specified with action `<jsp:useBean>` have `page`, `request`, `session` or `application` scope that indicates where they can be used in a Web application.
- Action `<jsp:getProperty>` obtains the value of JavaBean's property. Action `<jsp:getProperty>` has two attributes—`name` and `property`—that specify the bean object to manipulate and the property to get.

- JavaBean property values can be set with action `<jsp:setProperty>`. This action is particularly useful for mapping request parameter values to JavaBean properties. Request parameters can be used to set properties of primitive types `boolean`, `byte`, `char`, `int`, `long`, `float` and `double` and `java.lang` types `String`, `Boolean`, `Byte`, `Character`, `Integer`, `Long`, `Float` and `Double`.
- The `page` directive defines information that is globally available in a JSP. Directives are delimited by `<%@` and `%>`. The `page` directive's `errorCode` attribute indicates where all uncaught exceptions are forwarded for processing.
- Action `<jsp:setProperty>` has the ability to match request parameters to properties of the same name in a bean by specifying `"**"` for attribute `property`.
- Attribute `import` of the `page` directive enables programmers to specify Java classes and packages that are used in the context of a JSP.
- If the attribute `isErrorPage` of the `page` directive is set to `true`, the JSP is an error page. This condition enables access to the JSP implicit object `exception` that refers to an exception object indicating the problem that occurred.
- Directives are messages to the JSP container that enable the programmer to specify page settings (such as the error page), to include content from other resources and to specify custom tag libraries that can be used in a JSP. Directives are processed at the time a JSP is translated into a servlet and compiled. Thus, directives do not produce any immediate output.
- The `page` directive specifies global settings for a JSP in the JSP container. There can be many `page` directives, provided that there is only one occurrence of each attribute. The exception to this rule is the `import` attribute, which can be used repeatedly to import Java packages.
- Custom tag libraries define one or more custom tags that JSP implementors can use to create dynamic content. The functionality of these custom tags is defined in Java classes that implement interface `Tag` (package `javax.servlet.jsp.tagext`), normally by extending class `TagSupport` or `BodyTagSupport`.
- A JSP can include a custom tag library with the `taglib` directive.
- When implementing custom tags, you must define a tag handler class for each tag that provides the tag's functionality, a tag library descriptor that provides information about the tag library and its custom tags to the JSP container and a JSP that uses the custom tag.
- The most important methods of interface `Tag` are `doStartTag` and `doEndTag`. The JSP container invokes these methods when it encounters the starting custom tag and the ending custom tag, respectively.
- A custom tag library descriptor file is an XML document that specifies information about the tag library that is required by the JSP container.
- Class `BodyTagSupport` contains several methods for interacting with the body of a custom tag, including `doInitBody` and `doAfterBody` (from interface `BodyTag`). Method `doInitBody` is called once after `doStartTag` and once before `doAfterBody`. Method `doAfterBody` can be called many times to process the body of a custom tag.

## TERMINOLOGY

<code>\&gt;</code> escape sequence for <code>%&gt;</code>	<code>&lt;%@</code> and <code>%&gt;</code> directive delimiters
<code>&lt;!--</code> and <code>--&gt;</code> XHTML comment delimiters	<code>&lt;\%&gt;</code> escape sequence for <code>&lt;%</code>
<code>&lt;%--</code> and <code>--%&gt;</code> JSP comment delimiters	action
<code>&lt;%</code> and <code>%&gt;</code> scriptlet delimiters	<code>align</code> attribute of <code>&lt;jsp:plugin&gt;</code> action
<code>&lt;%!</code> and <code>%&gt;</code> declaration delimiters	<code>application</code> implicit object
<code>&lt;%=</code> and <code>%&gt;</code> JSP expression delimiters	application scope

**archive** attribute of `<jsp:plugin>` action  
**AT\_BEGIN** constant  
**AT\_END** constant  
**attribute** of tag library descriptor  
**autoFlush** attribute of `page` directive  
**beanName** attribute of `<jsp:useBean>` action  
**bodycontent** element of tag library descriptor  
**BodyContent** interface  
**BodyTag** interface  
**BodyTagSupport** class  
**buffer** attribute of `page` directive  
**class** attribute of `<jsp:useBean>` action  
client-server networking  
**code** attribute of `<jsp:plugin>` action  
**codebase** attribute of `<jsp:plugin>` action  
comment  
**config** implicit object  
container  
**contentType** attribute of `page` directive  
custom tag  
custom tag attribute  
custom tag handler  
custom tag library  
custom tag with attributes  
declaration  
directive  
**doAfterBody** method of interface **BodyTag**  
**doEndTag** method of interface **Tag**  
**doInitBody** method of interface **BodyTag**  
**doStartTag** method of interface **Tag**  
dynamic content  
error page  
**errorCode** attribute of `page` directive  
escape sequence  
**EVAL\_BODY\_INCLUDE** constant  
**exception** implicit object  
expression  
**extends** attribute of `page` directive  
**file** attribute of `include` directive  
fixed template data  
fixed template text  
**flush** attribute of `<jsp:include>` action  
forward a request  
**getParameterValues** method of  
    **request** object  
**getVariableInfo** method of  
    **TagExtraInfo**  
**height** attribute of `<jsp:plugin>`  
**hspace** attribute of `<jsp:plugin>`  
**HttpSession (javax.servlet.http)**  
**id** attribute of `<jsp:useBean>` action  
**iepluginurl** attribute of `<jsp:plugin>`  
implicit object  
implicit object scopes  
**import** attribute of `page` directive  
include a resource  
**include** directive  
**info** attribute of `page` directive  
**isErrorPage** attribute of `page` directive  
**isThreadSafe** attribute of `page` directive  
Java Plug-in  
JavaServer Pages (JSPs)  
JavaServer Pages 1.1 specification  
`javax.servlet.jsp` package  
`javax.servlet.jsp.tagext` package  
**jreversion** attribute of `<jsp:plugin>`  
`<jsp:forward>` action  
`<jsp:getProperty>` action  
`<jsp:include>` action  
`<jsp:param>` action  
`<jsp:plugin>` action  
`<jsp:setProperty>` action  
`<jsp:useBean>` action  
**jspDestroy** method  
**jspInit** method  
**\_jspService** method  
**jspversion** element of tag library descriptor  
**JspWriter** (package `javax.servlet.jsp`)  
**language** attribute of `page` directive  
match request parameters  
**meta** element  
**name** attribute of `<jsp:param>`  
**name** attribute of `<jsp:plugin>`  
**name** attribute of `<jsp:setProperty>`  
**name** element of tag library descriptor  
name/value pair  
**NESTED** constant  
**nspluginurl** attribute of `<jsp:plugin>`  
**out** implicit object  
**page** attribute of `<jsp:forward>`  
**page** attribute of `<jsp:include>`  
**page** directive  
**page** implicit object  
page scope  
**PageContext** interface  
**pageContext** implicit object  
**param** attribute of `<jsp:setProperty>`  
**prefix** attribute of `taglib` directive  
**property** attribute of `<jsp:setProperty>`  
refresh interval

<b>request</b> implicit object	<b>Tag</b> interface
request scope	tag library
request-time error	tag library descriptor
<b>required</b> element of tag library descriptor	<b>tagclass</b> element of tag library descriptor
<b>response</b> implicit object	<b>TagExtraInfo</b> class
<b>rtpexprvalue</b> element of tag library descriptor	<b>taglib</b> directive
<b>scope</b> attribute of <b>&lt;jsp:useBean&gt;</b>	<b>tagPrefix</b> attribute of <b>taglib</b> directive
scope of a bean	<b>TagSupport</b> class
scripting element	<b>teiclass</b> element of tag library descriptor
scriptlet	<b>title</b> attribute of <b>&lt;jsp:plugin&gt;</b>
<b>session</b> attribute of <b>page</b> directive	<b>tlibversion</b> element of tag library descriptor
<b>session</b> implicit object	translation-time error
session scope	translation-time include
<b>setAttribute</b> method of <b>PageContext</b>	<b>type</b> attribute of <b>&lt;jsp:plugin&gt;</b>
simple custom tag	<b>type</b> attribute of <b>&lt;jsp:useBean&gt;</b>
<b>SKIP_BODY</b> constant	<b>uri</b> attribute of <b>taglib</b> directive
specify attributes of a custom tag	<b>value</b> attribute of <b>&lt;jsp:param&gt;</b>
standard actions	<b>value</b> attribute of <b>&lt;jsp:setProperty&gt;</b>
<b>tag</b> element of tag library descriptor	<b>vspace</b> attribute of <b>&lt;jsp:plugin&gt;</b>
tag extension mechanism	<b>width</b> attribute of <b>&lt;jsp:plugin&gt;</b>
tag handler	

## SELF-REVIEW EXERCISES

### 10.1 Fill in the blanks in each of the following statements:

- JSP action \_\_\_\_\_ enables an applet or JavaBean to be added to a Web page in the form of a browser-specific **object** or **embed** XHTML element.
- Action \_\_\_\_\_ has the ability to match request parameters to properties of the same name in a bean by specifying "\*" for attribute **property**.
- There are four key components to JSPs: \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- A JSP can include a custom tag library with the \_\_\_\_\_ directive.
- The implicit objects have four scopes: \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- The \_\_\_\_\_ directive is processed once, at JSP translation time and causes content to be copied into the JSP.
- Classes and interfaces specific to JavaServer Pages programming are located in packages \_\_\_\_\_ and \_\_\_\_\_.
- JSPs normally execute as part of a Web server that is referred to as the \_\_\_\_\_.
- Method \_\_\_\_\_ can be called repeatedly to process the body of a custom tag.
- JSP scripting components include \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.

### 10.2 State whether each of the following is *true* or *false*. If *false*, explain why.

- An object with page scope exists in every JSP of a particular Web application.
- Directives specify global information that is not associated with a particular JSP request.
- The JSP container invokes methods **doInitBody** and **doAfterBody** when it encounters the starting custom tag and the ending custom tag, respectively.
- Tag libraries are part of the tag extension mechanism that enables programmers to create new tags that encapsulate complex Java functionality.
- Action **<jsp:include>** is evaluated once at page translation time.

- f) Like XHTML comments, JSP comments and script language comments appear in the response to the client.
- g) Objects with application scope are part of a particular Web application.
- h) Each page has its own instances of the page-scope implicit objects.
- i) Action `<jsp:setProperty>` has the ability to match request parameters to properties of the same name in a bean by specifying "\*" for attribute `property`.
- j) Objects with session scope exist for the client's entire browsing session.

## ANSWERS TO SELF-REVIEW EXERCISES

**10.1** a) `<jsp:plugin>`. b) `<jsp:setProperty>`. c) directives, actions, scriptlets, tag libraries. d) `taglib`. e) application, page, request and session. f) `include`. g) `javax.servlet.jsp`, `javax.servlet.jsp.tagext`. h) JSP container. i) `doAfterBody`. j) scriptlets, comments, expressions, declarations, escape sequences.

**10.2** a) False. Objects with page scope exist only as part of the page in which they are used. b) True. c) False. The JSP container invokes methods `doStartTag` and `doEndTag` when it encounters the starting custom tag and the ending custom tag, respectively. d) True. e) False. Action `<jsp:include>` enables dynamic content to be included in a JavaServer Page. f) False. JSP comments and script language comments are ignored and do not appear in the response. g) False. Objects with application scope are part of the JSP and servlet container application. h) True. i) True. j) True.

## EXERCISES

**10.3** Create class `ResultSetTag` (a custom tag handler) that can display information from any `ResultSet`. Use class `GuestBookTag` of Fig. 10.37 as a guide. The `pageContext` attribute names should be the column names in the `ResultSet`. The column names can be obtained through the `ResultSetMetaData` associated with the `ResultSet`. Create the tag library descriptor for the custom tag in this exercise and test the custom tag in a JSP.

**10.4** Create a JSP and JDBC-based address book. Use the guest book example of Fig. 10.20 through Fig. 10.24 as a guide. Your address book should allow one to insert entries, delete entries and search for entries.

**10.5** Incorporate the `ResultSetTag` of Exercise 10.3 into the address book example in Exercise 10.4.

**10.6** Reimplement your solution to Exercise 9.5 (Dynamic Web FAQs) using JSPs rather than servlets. Create a custom tag handler similar to the one you created in Exercise 10.3 to help display the FAQs information.

**10.7** Modify your solution to Exercise 10.6 so that the first JSP invoked by the user returns a list of FAQs topics from which to choose. Each topic should be a hyperlink that invokes another JSP with an argument indicating which topic the user would like to view. The JSP should query the FAQs database and return an XHTML document containing only FAQs for that topic.

**10.8** Reimplement the Web application of Fig. 9.27 (favorite animal survey) using JSPs.

**10.9** Modify your solution to Exercise 10.8 to allow the user to see the survey results without responding to the survey.

**10.10** Reimplement Fig. 9.24 (book recommendations) using JSPs. Use the JSP implicit object `session` to track the user's selections and determine appropriate book recommendations. Remember to use the `page` directive to indicate that each JSP participates in a session.

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# Case Study: Servlet and JSP Bookstore

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## Objectives

- To build a three-tier, client/server, distributed Web application using Java servlet and JavaServer Pages technology.
- To be able to perform servlet/JSP interactions.
- To be able to use a **RequestDispatcher** to forward requests to another resource for further processing.
- To be able to create XML from a servlet and XSL transformations to convert the XML into a format the client can display.
- To introduce the Java 2 Enterprise Edition reference implementation server.
- To be able to deploy a Web application using the Java 2 Enterprise Edition.

*The world is a book, and those who do not travel,  
read only a page.*

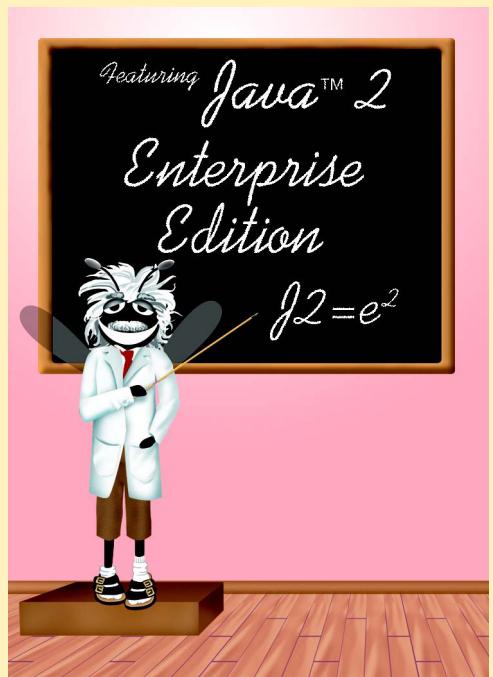
Saint Augustine

*If we do not lay out ourselves in the service of mankind,  
whom should we serve?*

John Adams

*We must take the current when it serves, or lose our ventures.*

William Shakespeare



## Outline

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*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

## 11.1 Introduction

This chapter serves as a capstone for our presentation of JSP and servlets. Here, we implement a bookstore Web application that integrates JDBC, XML, JSP and servlet technologies. The case study introduces additional servlet features that are discussed as they are encountered in the case study.

This chapter also serves as an introduction to the *Java 2 Enterprise Edition 1.2.1 reference implementation* used in Chapters 14–18. Unlike the JSP and servlet chapters, which demonstrated examples using Apache's Tomcat JSP and servlet container, this chapter deploys the bookstore application on the J2EE 1.2.1 reference implementation application server software, which is downloadable from [java.sun.com/j2ee/download.html](http://java.sun.com/j2ee/download.html) (see Appendix E for installation and configuration instructions). The J2EE 1.2.1 reference implementation includes the Apache Tomcat JSP and servlet container. After reading this chapter, you will be able to implement a substantial distributed Web application with many components, and you will be able to deploy that application on the J2EE 1.2.1 application server.

## 11.2 Bookstore Architecture

This section overviews the architecture of the **Bug2Bug.com** bookstore application. We present a diagram of the basic interactions between XHTML documents, JSPs and servlets. Also, we present a table of all the documents and classes used in the case study. Our sample outputs demonstrate how the XHTML documents sent to the client are rendered.

Our **Bug2Bug.com** shopping-cart case study consists of a series of XHTML documents, JSPs and servlets that interact to simulate a bookstore selling Deitel publications. This case study is implemented as a distributed, three-tier, Web-based application. The client tier is represented by the user's Web browser. The browser displays static XHTML documents and dynamically created XHTML documents that allow the user to interact with the server tier. The server tier consists of several JSPs and servlets that act on behalf of the client. These JSPs and servlets perform tasks such as creating a list of publications, creating documents containing the details about a publication, adding items to the shopping cart, viewing the shopping cart and processing the final order. Some of the JSPs and servlets perform database interactions on behalf of the client.

The database tier uses the **books** database introduced in Chapter 8, Java Database Connectivity. In this case study, we use only the **titles** table from the database (see Chapter 8).

Figure 11.1 illustrates the interactions between the bookstore's application components. In the diagram, names without file extensions (**displayBook** and **addToCart**) represent servlet aliases (i.e., the names used to invoke the servlets). As you will see when we deploy the case study in Section 11.10, the Java 2 Enterprise Edition 1.2.1 reference implementation includes an *Application Deployment Tool*. Among its many features, this tool enables us to specify the alias used to invoke a servlet. For example, **addToCart** is the alias for servlet **AddToCartServlet**. The Application Deployment Tool creates the deployment descriptor for a servlet as part of deploying an application.

After the application is deployed, users can visit the bookstore by entering the following URL in a browser:

**http://localhost:8000/advjhttp1/store/**

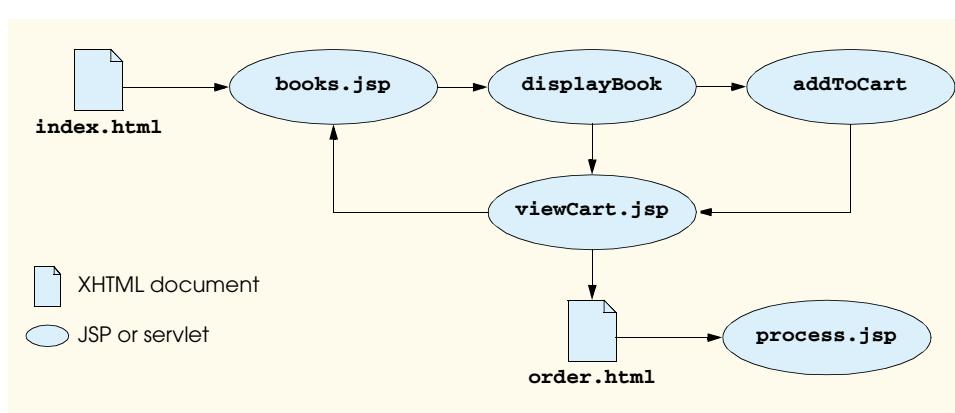


Fig. 11.1 **Bug2Bug.com** bookstore component interactions.

This URL requests the default home page for the store (**index.html**). The user can view the list of products by clicking a button on the home page. This invokes **books.jsp**, which interacts with a database to create the list of books dynamically. The result is an XHTML document containing links to the servlet with alias **displayBook**. This servlet receives as a parameter the ISBN number for the selected book and returns an XHTML document containing the information for that book. From this document, the user can click buttons to place the current book in the shopping cart or view the shopping cart. Adding a book to a shopping cart invokes the servlet with alias **addToCart**. Viewing the contents of the cart invokes **viewCart.jsp** to return an XHTML document containing the contents of the cart, subtotals the dollar cost of each item and a total dollar cost of all the items in the cart. When the user adds an item to the shopping cart, the **addToCart** servlet processes the user's request, then forwards it to **viewCart.jsp** to create the document that displays the current cart. At this point, the user can either continue shopping (**books.jsp**) or proceed to checkout (**order.html**). In the latter case, the user is presented with a form to input name, address and credit-card information. Then, the user submits the form to invoke **process.jsp**, which completes the transaction by sending a confirmation document to the user.

Figure 11.2 overviews the XHTML documents, JSPs, servlets, JavaBeans and other files used in this case study.

File	Description
<b>index.html</b>	This is the default home page for the bookstore, which is displayed by entering the following URL in the client's Web browser:  <b>http://localhost:8000/advjhtp1/store</b>
<b>styles.css</b>	This Cascading Style Sheet (CSS) file is linked to all XHTML documents rendered on the client. The CSS file allows us to apply uniform formatting across all the XHTML static and dynamic documents rendered.
<b>books.jsp</b>	This JSP uses <b>BookBean</b> objects and a <b>TitlesBean</b> object to create an XHTML document containing the product list. The <b>TitlesBean</b> object queries the <b>books</b> database to obtain the list of titles in the database. The results are processed and placed in an <b>ArrayList</b> of <b>BookBean</b> objects. The list is stored as a session attribute for the client.
<b>BookBean.java</b>	An instance of this JavaBean represents the data for one book. The bean's <b>getXML</b> method returns an XML <b>Element</b> representing the book.
<b>TitlesBean.java</b>	JSP <b>books.jsp</b> uses an instance of this JavaBean to obtain an <b>ArrayList</b> containing a <b>BookBean</b> for every product in the database.

Fig. 11.2 Servlet and JSP components for bookstore case study (part 1 of 2).

File	Description
<b>BookServlet.java</b>	This servlet (aliased as <b>displayBook</b> in Fig. 11.1) obtains the XML representation of a book selected by the user, then applies an XSL transformation to the XML to produce an XHTML document that can be rendered by the client. In this example, the client is assumed to be a browser that supports Cascading Style Sheets (CSS). Later examples in this book apply different XSL transformations for different client types.
<b>book.xsl</b>	This XSL style sheet specifies how to transform the XML representation of a book into an XHTML document that the client browser can render.
<b>CartItemBean.java</b>	An instance of this JavaBean maintains a <b>BookBean</b> and the current quantity for that book in the shopping cart. These beans are stored in a <b>HashMap</b> that represents the contents of the shopping cart.
<b>AddToCartServlet.java</b>	This servlet (aliased as <b>addToCart</b> in Fig. 11.1) updates the shopping cart. If the cart does not exist, the servlet creates a cart (a <b>HashMap</b> in this example). If a <b>CartItemBean</b> for the item is already in the cart, the servlet updates the quantity of that item in the bean. Otherwise, the servlet creates a new <b>CartItemBean</b> with a quantity of 1. After updating the cart, the user is forwarded to <b>viewCart.jsp</b> to view the current cart contents.
<b>viewCart.jsp</b>	This JSP extracts the <b>CartItemBeans</b> from the shopping cart, subtotals each item in the cart, totals all the items in the cart and creates an XHTML document that allows the client to view the cart in tabular form.
<b>order.html</b>	When viewing the cart, the user can click a <b>Check Out</b> button to view this order form. In this example, the form has no functionality. However, it is provided to help complete the application.
<b>process.jsp</b>	This final JSP pretends to process the user's credit-card information and creates an XHTML document indicating that the order was processed and the total order value.

Fig. 11.2 Servlet and JSP components for bookstore case study (part 2 of 2).

### 11.3 Entering the Bookstore

Figure 11.3 (**index.html**) is the default home page for the **Bug2Bug.com** bookstore. This file is also known as the *welcome file*—an option specified at application deployment time (see Section 11.10). When the bookstore application is running on your computer in the Java 2 Enterprise Edition 1.2.1 reference implementation, you can enter the following URL in your Web browser to display the home page:

**http://localhost:8000/advjhtp1/store**

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4 <!-- index.html -->
5
6 <html xmlns = "http://www.w3.org/1999/xhtml">
7
8 <head>
9   <title>Shopping Cart Case Study</title>
10
11  <link rel = "stylesheet" href = "styles.css"
12    type = "text/css" />
13 </head>
14
15 <body>
16   <p class = "bigFont">Bug2Bug.com</p>
17
18   <p class = "bigFont italic">
19     Deitel & Associates, Inc.<br />
20     Shopping Cart Case Study
21   </p>
22
23 <!-- form to request books.jsp -->
24 <form method = "get" action = "books.jsp">
25   <p><input type = "submit" name = "enterButton"
26     value = "Click here to enter store" /></p>
27 </form>
28 </body>
29
30 </html>
```



Fig. 11.3 Bookstore home page (`index.html`).

Lines 11–12 specify a linked style sheet **styles.css** (Fig. 11.4). All XHTML documents sent to the client use this style sheet, so that uniform formatting can be applied to

the documents. The **form** at lines 24–27 provides a **submit** button that enables you to enter the store. Clicking this button invokes **books.jsp** (Fig. 11.7), which creates and returns an XHTML document containing the product list.

Figure 11.4 (**styles.css**) defines the common styles for rendering XHTML documents in this case study. Lines 1–2 indicate that all text in the **body** element should be centered and that the background color of the body should be steel blue. The background color is represented by the hexadecimal number **#b0c4de**. Line 3 defines class **.bold** to apply bold font weight to text. Lines 4–7 define class **.bigFont** with four CSS attributes. Elements to which this class is applied appear in bold, Helvetica font, which is double the size of the base-text font. The color of the font is dark blue (represented by the hexadecimal number **#00008b**). If the Helvetica font is not available, the browser will attempt to use Arial, and then the generic font **sans-serif** as a last resort. Line 8 defines class **.italic** to apply italic font style to text. Line 9 defines class **.right** to right justify text. Lines 10–11 indicate that all **table**, **th** (table head data) and **td** (table data) elements should have a three-pixel, grooved border with five pixels of internal padding between the text in a table cell and the border of that cell. Lines 12–14 indicate that all **table** elements should have a bright-blue background color (represented by the hexadecimal number **#6495ed**) and that all **table** elements should use automatically determined margins on both their left and right sides. This causes the table to be centered on the page. Not all of these styles are used in every XHTML document. However, using a single linked style sheet allows us to change the look and feel of our store quickly and easily by modifying the CSS file. For more information on CSS visit

[www.w3.org/Style/CSS](http://www.w3.org/Style/CSS)

At this Web site, you will find the CSS specifications. Each specification includes an index of all the current CSS attributes and their permitted values.



### Portability Tip 11.1

*Different browsers have different levels of support for Cascading Style Sheets.*

```
1  body          { text-align: center;           }
2                  background-color: #B0C4DE;   }
3  .bold          { font-weight: bold;        }
4  .bigFont        { font-family: helvetica, arial, sans-serif;
5                  font-weight: bold;
6                  font-size: 2em;
7                  color: #00008B;    }
8  .italic         { font-style: italic;      }
9  .right          { text-align: right;       }
10 table, th, td { border: 3px groove;
11                  padding: 5px;     }
12 table          { background-color: #6495ed;
13                  margin-left: auto;
14                  margin-right: auto }
```

Fig. 11.4 Shared cascading style sheet (**styles.css**) used to apply common formatting across XHTML documents rendered on the client.

## 11.4 Obtaining the Book List from the Database

JavaServer Pages often generate XHTML that is sent to the client for rendering. JSP **books.jsp** (Fig. 11.7) generates an XHTML document containing a list of hyperlinks to information about each book in the **titles** table of the **books** database. From this list, the user can view information about a particular book by clicking the hyperlink for that book. This JSP uses a **TitlesBean** (Fig. 11.5) object and **BookBean** (Fig. 11.6) objects to create the product list. Each of the JavaBeans and **books.jsp** are discussed in this section. Figure 11.7 shows the rendering of the XHTML document sent to the browser by **books.jsp**.

The **TitlesBean** (Fig. 11.5) JavaBean performs a database query to obtain the list of titles in the database. Then, the results are processed and placed in an **ArrayList** of **BookBean** objects. As we will see in Fig. 11.7, the **ArrayList** is stored by **books.jsp** as a session attribute for the client.

```
1 // TitlesBean.java
2 // Class TitlesBean makes a database connection and retrieves
3 // the books from the database.
4 package com.deitel.advjhtp1.store;
5
6 // Java core packages
7 import java.io.*;
8 import java.sql.*;
9 import java.util.*;
10
11 // Java extension packages
12 import javax.naming.*;
13 import javax.sql.*;
14
15 public class TitlesBean implements Serializable {
16     private Connection connection;
17     private PreparedStatement titlesQuery;
18
19     // construct TitlesBean object
20     public TitlesBean()
21     {
22         // attempt database connection and setup SQL statements
23         try {
24             InitialContext ic = new InitialContext();
25
26             DataSource source =
27                 (DataSource ) ic.lookup(
28                     "java:comp/env/jdbc/books" );
29
30             connection = source.getConnection();
31         }
```

Fig. 11.5 **TitlesBean** for obtaining book information from the **books** database and creating an **ArrayList** of **BookBean** objects (part 1 of 3).

```
32         titlesQuery =
33             connection.prepareStatement(
34                 "SELECT isbn, title, editionNumber, " +
35                 "copyright, publisherID, imageFile, price " +
36                 "FROM titles ORDER BY title"
37             );
38     }
39
40     // process exceptions during database setup
41     catch ( SQLException sqlException ) {
42         sqlException.printStackTrace();
43     }
44
45     // process problems locating data source
46     catch ( NamingException namingException ) {
47         namingException.printStackTrace();
48     }
49 }
50
51 // return a List of BookBeans
52 public List getTitles()
53 {
54     List titlesList = new ArrayList();
55
56     // obtain list of titles
57     try {
58         ResultSet results = titlesQuery.executeQuery();
59
60         // get row data
61         while ( results.next() ) {
62             BookBean book = new BookBean();
63
64             book.setISBN( results.getString( "isbn" ) );
65             book.setTitle( results.getString( "title" ) );
66             book.setEditionNumber(
67                 results.getInt( "editionNumber" ) );
68             book.setCopyright( results.getString( "copyright" ) );
69             book.setPublisherID(
70                 results.getInt( "publisherID" ) );
71             book.setImageFile( results.getString( "imageFile" ) );
72             book.setPrice( results.getDouble( "price" ) );
73
74             titlesList.add( book );
75         }
76     }
77
78     // process exceptions during database query
79     catch ( SQLException exception ) {
80         exception.printStackTrace();
81     }
82 }
```

Fig. 11.5 **TitlesBean** for obtaining book information from the **books** database and creating an **ArrayList** of **BookBean** objects (part 2 of 3).

```
83     // return the list of titles
84     finally {
85         return titlesList;
86     }
87 }
88
89 // close statements and terminate database connection
90 protected void finalize()
91 {
92     // attempt to close database connection
93     try {
94         connection.close();
95     }
96
97     // process SQLException on close operation
98     catch ( SQLException sqlException ) {
99         sqlException.printStackTrace();
100    }
101 }
102 }
```

Fig. 11.5 **TitlesBean** for obtaining book information from the **books** database and creating an **ArrayList** of **BookBean** objects (part 3 of 3).

The JavaBean **TitlesBean** requires us to introduce the *Java Naming and Directory Interface (JNDI)*. Enterprise Java applications often access information and resources (such as databases) that are external to those applications. In some cases, those resources are distributed across a network. Just as an RMI client uses the RMI registry to locate a server object so the client can request a server, Enterprise application components must be able to locate the resources they use. An Enterprise Java application container must provide a *naming service* that implements JNDI and enables the components executing in that container to perform name lookups to locate resources. The J2EE 1.2.1 reference implementation server includes such a naming service that we use to locate our **books** database at execution time.

The **TitlesBean** uses JNDI to interact with the naming service and locate the data source (i.e., the **books** database). The **TitlesBean** constructor (lines 20–49) attempts the connection to the database using class **InitialContext** from package **javax.naming** and interface **DataSource** from package **javax.sql**. [These packages must be available to your compiler to compile this example.] When you deploy an Enterprise Java application (see Section 11.10), you specify the resources (such as databases) used by the application and the JNDI names for those resources. Using an **InitialContext**, an Enterprise application component can look up a resource. The **InitialContext** provides access to the application's *naming environment*.

Line 24 creates a new **InitialContext**. The **InitialContext** constructor throws a **NamingException** if it cannot locate a naming service. Lines 26–28 invoke **InitialContext** method **lookup** to locate our **books** data source. In the argument, the text **java:comp/env** indicates that method **lookup** should search for the resource in the application's component environment entries (i.e., the resource names specified at deployment time). The text **jdbc/books** indicates that the resource is a JDBC data source called **books**. Method **lookup** returns a **DataSource** object and throws a

**NamingException** if it cannot resolve the name it receives as an argument. Line 25 uses the **DataSource** to connect to the database. Lines 32–37 create a **PreparedStatement** that, when executed, returns the information about each title from the **titles** table of the **books** database.

Method **getTitles** (lines 52–87) returns a **List (titlesList)** containing a **BookBean** JavaBean for each title in the database. Line 58 executes **titlesQuery**. Lines 57–76 process the **ResultSet (results)**. For each row in **results**, line 62 creates a new **BookBean**, and lines 64–72 set the attributes of the **BookBean** to columns in that **ResultSet** row. **ResultSet** methods **getString**, **getInt** and **getDouble** return the column data in the appropriate formats. Line 74 adds the new **BookBean** to **titlesList**. In the **finally** block, **titlesList** is returned. If there is an exception while performing the database interactions or if there are no records in the database, the **List** will be empty.

An instance of the **BookBean** (Fig. 11.6) JavaBean represents the properties for one book, including the book's ISBN number, title, copyright, cover image file name, edition number, publisher ID number and price. Each of these properties is a read/write property. Some of this information is not used in this example. **BookBean** method **getXML** returns an XML **Element** representing the book.

```
1 // BookBean.java
2 // A BookBean object contains the data for one book.
3 package com.deitel.advjhttp1.store;
4
5 // Java core packages
6 import java.io.*;
7 import java.text.*;
8 import java.util.*;
9
10 // third-party packages
11 import org.w3c.dom.*;
12
13 public class BookBean implements Serializable {
14     private String ISBN, title, copyright, imageFile;
15     private int editionNumber, publisherID;
16     private double price;
17
18     // set ISBN number
19     public void setISBN( String isbn )
20     {
21         ISBN = isbn;
22     }
23
24     // return ISBN number
25     public String getISBN()
26     {
27         return ISBN;
28     }
```

Fig. 11.6 BookBean that represents a single book's information and defines the XML format of that information (part 1 of 4).

```
29      // set book title
30      public void setTitle( String bookTitle )
31      {
32          title = bookTitle;
33      }
34
35      // return book title
36      public String getTitle()
37      {
38          return title;
39      }
40
41      // set copyright year
42      public void setCopyright( String year )
43      {
44          copyright = year;
45      }
46
47      // return copyright year
48      public String getCopyright()
49      {
50          return copyright;
51      }
52
53      // set file name of image representing product cover
54      public void setImageFile( String fileName )
55      {
56          imageFile = fileName;
57      }
58
59      // return file name of image representing product cover
60      public String getImageFile()
61      {
62          return imageFile;
63      }
64
65      // set edition number
66      public void setEditionNumber( int edition )
67      {
68          editionNumber = edition;
69      }
70
71      // return edition number
72      public int getEditionNumber()
73      {
74          return editionNumber;
75      }
76
77      // set publisher ID number
78      public void setPublisherID( int id )
79      {
80      }
```

Fig. 11.6 **BookBean** that represents a single book's information and defines the XML format of that information (part 2 of 4).

```
81     publisherID = id;
82 }
83
84 // return publisher ID number
85 public int getPublisherID()
86 {
87     return publisherID;
88 }
89
90 // set price
91 public void setPrice( double amount )
92 {
93     price = amount;
94 }
95
96 // return price
97 public double getPrice()
98 {
99     return price;
100}
101
102// get an XML representation of the Product
103public Element getXML( Document document )
104{
105    // create product root element
106    Element product = document.createElement( "product" );
107
108    // create isbn element, append as child of product
109    Element temp = document.createElement( "isbn" );
110    temp.appendChild( document.createTextNode( getISBN() ) );
111    product.appendChild( temp );
112
113    // create title element, append as child of product
114    temp = document.createElement( "title" );
115    temp.appendChild( document.createTextNode( getTitle() ) );
116    product.appendChild( temp );
117
118    // create a currency formatting object for US dollars
119    NumberFormat priceFormatter =
120        NumberFormat.getCurrencyInstance( Locale.US );
121
122    // create price element, append as child of product
123    temp = document.createElement( "price" );
124    temp.appendChild( document.createTextNode(
125        priceFormatter.format( getPrice() ) ) );
126    product.appendChild( temp );
127
128    // create imageFile element, append as child of product
129    temp = document.createElement( "imageFile" );
130    temp.appendChild(
131        document.createTextNode( getImageFile() ) );
132    product.appendChild( temp );
```

Fig. 11.6 **BookBean** that represents a single book's information and defines the XML format of that information (part 3 of 4).

```
133     // create copyright element, append as child of product
134     temp = document.createElement( "copyright" );
135     temp.appendChild(
136         document.createTextNode( getCopyright() ) );
137     product.appendChild( temp );
138
139     // create publisherID element, append as child of product
140     temp = document.createElement( "publisherID" );
141     temp.appendChild( document.createTextNode(
142         String.valueOf( getPublisherID() ) ) );
143     product.appendChild( temp );
144
145     // create editionNumber element, append as child of product
146     temp = document.createElement( "editionNumber" );
147     temp.appendChild( document.createTextNode(
148         String.valueOf( getEditionNumber() ) ) );
149     product.appendChild( temp );
150
151
152     // return product element
153     return product;
154 }
155 }
```

Fig. 11.6 **BookBean** that represents a single book's information and defines the XML format of that information (part 4 of 4).

Method **getXML** (lines 103–154) uses the **org.w3c.dom** package's **Document** and **Element** interfaces to create an XML representation of the book data as part of the **Document** that is passed to the method as an argument. The complete information for one book is placed in a **product** element (created at line 106). The elements for the individual properties of a book are appended to the **product** element as children. For example, line 109 uses **Document** method **createElement** to create element **isbn**. Line 110 uses **Document** method **createTextNode** to specify the text in the **isbn** element, and **Element** method **appendChild** to append the text to element **isbn**. Then, line 111 appends element **isbn** as a child of element **product** with **Element** method **appendChild**. Similar operations are performed for the other book properties. Lines 119–120 obtain a **NumberFormat** object that formats currency for the U. S. locale to format the book price in US dollars (line 125). Line 150 returns element **product** to the caller. We revisit method **getXML** in our **BookServlet** discussion (Fig. 11.8). For more information about XML and Java, refer to Appendices A–F.

JavaServer Page **books.jsp** dynamically generates the list of titles as an XHTML document to be rendered on the client. Lines 7–11 specify the JSP page settings. This JSP uses classes from our store package (**com.deitel.advjhttp1.store**) and package **java.util**. Also, this JSP uses session-tracking features. The dynamic parts of this JSP are defined in lines 31–64 with JSP scriptlets and expressions.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4 <!-- books.jsp -->
5
6 <%-- JSP page settings --%>
7 <%@
8   page language = "java"
9   import = "com.deitel.advjhtp1.store.*, java.util.*"
10  session = "true"
11 %>
12
13 <!-- begin document -->
14 <html xmlns = "http://www.w3.org/1999/xhtml">
15
16 <head>
17   <title>Book List</title>
18
19   <link rel = "stylesheet" href = "styles.css"
20     type = "text/css" />
21 </head>
22
23 <body>
24   <p class = "bigFont">Available Books</p>
25
26   <p class = "bold">Click a link to view book information</p>
27
28   <p>
29
30   <%-- begin JSP scriptlet to create list of books --%>
31 <%
32     TitlesBean titlesBean = new TitlesBean();
33     List titles = titlesBean.getTitles();
34     BookBean currentBook;
35
36     // store titles in session for further use
37     session.setAttribute( "titles", titles );
38
39     // obtain an Iterator to the set of keys in the List
40     Iterator iterator = titles.iterator();
41
42     // use the Iterator to get each BookBean and create
43     // a link to each book
44     while ( iterator.hasNext() ) {
45       currentBook = ( BookBean ) iterator.next();
46
47     <%> <%-- end scriptlet to insert literal XHTML and --%>
48     <%-- JSP expressions output from this loop      --%>
49
50     <%-- link to a book's information --%>
51     <span class = "bold">
```

Fig. 11.7 JSP **books.jsp** returns to the client an XHTML document containing the book list (part 1 of 2).

```
52         <a href =
53             "displayBook?isbn=<%= currentBook.getISBN() %>">
54
55             <%= currentBook.getTitle() + ", " +
56             currentBook.getEditionNumber() + "e" %>
57         </a>
58     </span><br />
59
60     <% // continue scriptlet
61
62     } // end while loop
63
64     %> <%-- end scriptlet --%>
65
66     </p>
67 </body>
68
69 </html>
```

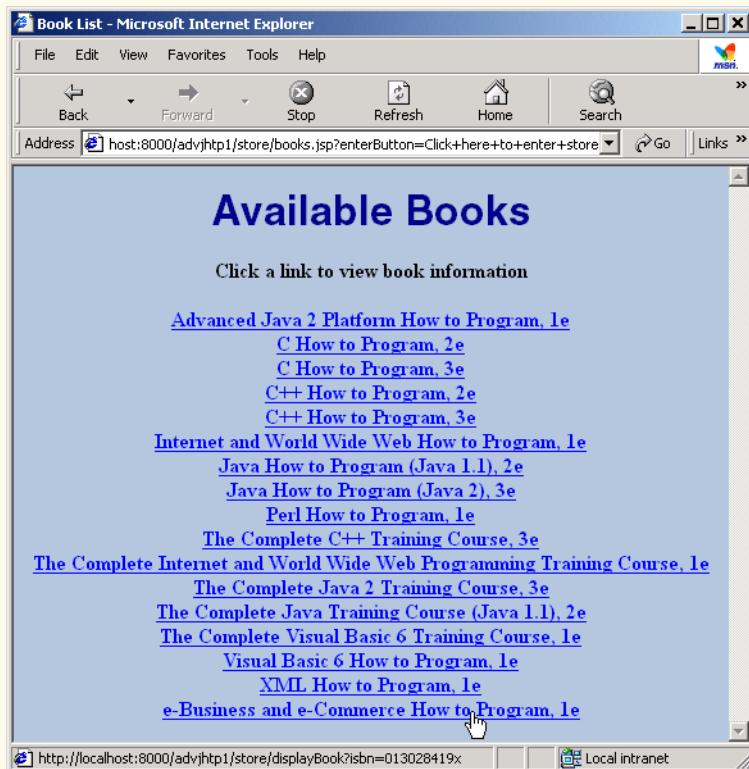


Fig. 11.7 JSP **books.jsp** returns to the client an XHTML document containing the book list (part 2 of 2).

The scriptlet begins at line 31. Line 32 creates a **TitlesBean**, and line 33 invokes its **getTitles** method to obtain the **List** of **BookBean** objects. Line 37 sets a **titles** session attribute to store the **List** for use later in the client's session. Line 40 obtains an

**Iterator** for the **List**. Lines 44–45 begin a loop that uses the **Iterator** to output each hyperlink. The scriptlet temporarily terminates here so that lines 51–58 can insert XHTML markup. In this markup, line 53 uses a JSP expression to insert the book’s ISBN number as the value in a name/value pair that is passed to the **displayBook** servlet (**BookServlet**) as an argument. Lines 55–56 use another JSP expression to insert the book’s title and edition number as the text displayed for the hyperlink. Lines 60–64 continue the scriptlet with the closing curly brace of the **while** loop that started at line 44.

## 11.5 Viewing a Book’s Details

Like many companies, **Bug2Bug.com** is beginning to use XML on its Web site. When the user selects a book in **books.jsp**, **Bug2Bug.com** converts the book’s information to XML. **BookServlet** (Fig. 11.8) transforms the XML representation of the book into an XHTML document using XSL style sheet **book.xsl** (Fig. 11.9).

There are two major parts in **BookServlet**’s **doGet** method (lines 24–103). Lines 28–62 locate the **BookBean** for the book selected by the user in **books.jsp**. Lines 65–102 process the XML representation of a book and apply an XSL transformation to that XML.

```
1 // BookServlet.java
2 // Servlet to return one book's information to the client.
3 // The servlet produces XML which is transformed with XSL to
4 // produce the client XHTML page.
5 package com.deitel.advjhttp1.store;
6
7 // Java core packages
8 import java.io.*;
9 import java.util.*;
10
11 // Java extension packages
12 import javax.servlet.*;
13 import javax.servlet.http.*;
14 import javax.xml.parsers.*;
15 import javax.xml.transform.*;
16 import javax.xml.transform.dom.*;
17 import javax.xml.transform.stream.*;
18
19 // third-party packages
20 import org.w3c.dom.*;
21 import org.xml.sax.*;
22
23 public class BookServlet extends HttpServlet {
24     protected void doGet( HttpServletRequest request,
25             HttpServletResponse response )
26             throws ServletException, IOException
27     {
28         HttpSession session = request.getSession( false );
29     }
30 }
```

Fig. 11.8 **BookServlet** obtains the XML representation of a book and applies an XSL transformation to output an XHTML document as the response to the client (part 1 of 4).

```
30      // RequestDispatcher to forward client to bookstore home
31      // page if no session exists or no books are selected
32      RequestDispatcher dispatcher =
33          request.getRequestDispatcher( "/index.html" );
34
35      // if session does not exist, forward to index.html
36      if ( session == null )
37          dispatcher.forward( request, response );
38
39      // get books from session object
40      List titles =
41          ( List ) session.getAttribute( "titles" );
42
43      // locate BookBean object for selected book
44      Iterator iterator = titles.iterator();
45      BookBean book = null;
46
47      String isbn = request.getParameter( "isbn" );
48
49      while ( iterator.hasNext() ) {
50          book = ( BookBean ) iterator.next();
51
52          if ( isbn.equals( book.getISBN() ) ) {
53
54              // save the book in a session attribute
55              session.setAttribute( "bookToAdd", book );
56              break; // isbn matches current book
57          }
58      }
59
60      // if book is not in list, forward to index.html
61      if ( book == null )
62          dispatcher.forward( request, response );
63
64      // get XML document and transform for browser client
65      try {
66          // get a DocumentBuilderFactory for creating
67          // a DocumentBuilder (i.e., an XML parser)
68          DocumentBuilderFactory factory =
69              DocumentBuilderFactory.newInstance();
70
71          // get a DocumentBuilder for building the DOM tree
72          DocumentBuilder builder =
73              factory.newDocumentBuilder();
74
75          // create a new Document (empty DOM tree)
76          Document messageDocument = builder.newDocument();
77
78          // get XML from BookBean and append to Document
79          Element bookElement = book.getXML( messageDocument );
80          messageDocument.appendChild( bookElement );
```

Fig. 11.8 **BookServlet** obtains the XML representation of a book and applies an XSL transformation to output an XHTML document as the response to the client (part 2 of 4).

```
81
82     // get PrintWriter for writing data to client
83     response.setContentType( "text/html" );
84     PrintWriter out = response.getWriter();
85
86     // open InputStream for XSL document
87     InputStream xslStream =
88         getServletContext().getResourceAsStream(
89             "/book.xsl" );
90
91     // transform XML document using XSLT
92     transform( messageDocument, xslStream, out );
93
94     // flush and close PrintWriter
95     out.flush();
96     out.close();
97 }
98
99 // catch XML parser exceptions
100 catch ( ParserConfigurationException pcException ) {
101     pcException.printStackTrace();
102 }
103 }
104
105 // transform XML document using provided XSLT InputStream
106 // and write resulting document to provided PrintWriter
107 private void transform( Document document,
108     InputStream xslStream, PrintWriter output )
109 {
110     try {
111         // create DOMSource for source XML document
112         Source xmlSource = new DOMSource( document );
113
114         // create StreamSource for XSLT document
115         Source xslSource =
116             new StreamSource( xslStream );
117
118         // create StreamResult for transformation result
119         Result result = new StreamResult( output );
120
121         // create TransformerFactory to obtain a Transformer
122         TransformerFactory transformerFactory =
123             TransformerFactory.newInstance();
124
125         // create Transformer for performing XSL transformation
126         Transformer transformer =
127             transformerFactory.newTransformer( xslSource );
128
129         // perform transformation and deliver content to client
130         transformer.transform( xmlSource, result );
131     }
```

Fig. 11.8 **BookServlet** obtains the XML representation of a book and applies an XSL transformation to output an XHTML document as the response to the client (part 3 of 4).

```
132
133     // handle exception when transforming XML document
134     catch ( TransformerException transformerException ) {
135         transformerException.printStackTrace( System.err );
136     }
137 }
138 }
```

Fig. 11.8 **BookServlet** obtains the XML representation of a book and applies an XSL transformation to output an XHTML document as the response to the client (part 4 of 4).

Line 28 obtains the **HttpSession** object for the current client. This object contains a session attribute indicating the book selected by the user in **books.jsp**. Lines 32–33 obtain a **RequestDispatcher** for the "**/index.html**" document by calling **ServletRequest** method **getRequestDispatcher**. A **RequestDispatcher** (package **javax.servlet**) provides two methods—**forward** and **include**—that enable a servlet to forward a client request to another resource or include content from another resource in a servlet's response. In this example, if there is no session object for the current client (lines 36–37) or if there is no book selected (lines 61–62), the request is forwarded back to the **index.html** home page of our bookstore. Methods **forward** and **include** each take two arguments—the **HttpServletRequest** and **HttpServletResponse** objects for the current request.

Note that **RequestDispatcher** objects can be obtained with method **getRequestDispatcher** from an object that implements interface **ServletRequest** or from the **ServletContext** with methods **getRequestDispatcher** or **getNamedDispatcher**. **ServletContext** method **getNamedDispatcher** receives the name of a servlet as an argument, then searches the **ServletContext** for a servlet by that name. If no such servlet is found, the method returns **null**. Both the **ServletRequest** and the **ServletContext getRequestDispatcher** methods simply return to the client browser the content of the specified path if the path does not represent a servlet.

Lines 40–41 get the **List** of **BookBeans** from the session object. Lines 44–58 perform a linear search to locate the **BookBean** for the selected book. (Note: For larger databases, it would be more appropriate to use a **Map** rather than a **List**.) The ISBN number for that book is stored in an **isbn** parameter passed to the servlet (retrieved at line 47). If the **BookBean** is found, line 55 sets session attribute **bookToAdd** with that **BookBean** as the attribute's value. **AddToCartServlet** (Fig. 11.10) uses this attribute to update the shopping cart.

The **try** block (lines 65–97) performs the XML and XSL processing that result in an XHTML document containing a single book's information. Before the XML and XSL capabilities can be used, you must download and install Sun's *Java API for XML Parsing (JAXP)* version 1.1 from [java.sun.com/xml/download.htm](http://java.sun.com/xml/download.htm). The root directory of JAXP (**jaxp-1.1**) contains three JAR files—**crimson.jar**, **jaxp.jar** and **xalan.jar**—that are required for compiling and running programs that use JAXP. These files must be added to the Java extension mechanism for your Java 2 Standard Edi-

tion installation. Place a *copy* of these files in your Java installation's extensions directory (**jre/lib/ext** on Linux/UNIX, and **jre\lib\ext** on Windows).



### Software Engineering Observation 11.1

JAXP 1.1 is part of the J2EE 1.3 reference implementation.

Creating a Document Object Model (DOM) tree from an XML document requires a **DocumentBuilder** parser object. **DocumentBuilder** objects are obtained from a **DocumentBuilderFactory**. Lines 68–69 obtain a **DocumentBuilderFactory**. Lines 72–73 obtain a **DocumentBuilder** parser object that enables the program to create a **Document** object tree in which the XML document elements are represented as **Element** objects. Line 76 uses the **DocumentBuilder** object to create a new **Document**. Line 79 invokes the **BookBean**'s **getXML** method to obtain an **Element** representation of the book. Line 80 appends this **Element** to **messageDocument** (the **Document** object). Classes **DocumentBuilderFactory** and **DocumentBuilder** are located in package **javax.xml.parsers**. Classes **Document** and **Element** are located in package **org.w3c.dom**. [Note: For detailed information on XML, see Appendices A–D.]

Next, line 83 specifies the response content type, and line 84 obtains a **PrintWriter** to output the response to the client. Lines 87–89 create an **InputStream** that will be used by the XSL transformation processor to read the XSL file. The response is created by the XSL transformation performed in method **transform** (lines 107–137). We pass three arguments to this method—the XML **Document** to which the XSL transformation will be applied (**messageDocument**), the **InputStream** that reads the XSL file (**xslStream**) and the target stream to which the results should be written (**out**). The output target can be one of several types, including a character stream (i.e., the **response** object's **PrintWriter** in this example).

Line 112 creates a **DOMSource** that represents the XML document. This serves as the source of the XML to transform. Lines 115–116 create a **StreamSource** for the XSL file. This serves as the source of the XSL that transforms the **DOMSource**. Line 119 creates a **StreamResult** for the **PrintWriter** to which the results of the XSL transformation are written. Lines 122–123 create a **TransformerFactory** with **static** method **newInstance**. This object enables the program to obtain a **Transformer** object that applies the XSL transformation. Lines 126–127 create a **Transformer** using **TransformerFactory** method **newTransformer**, which receives a **StreamSource** argument representing the XSL (**xslSource** in this example). Line 130 invokes **Transformer** method **transform** to perform the XSL transformation on the given **DOMSource** object (**xmlSource**) and writes the result to the given **StreamResult** object (**result**). Lines 134–136 catch a **TransformerException** if a problem occurs when creating the **TransformerFactory**, creating the **Transformer** or performing the transformation.

Figure 11.9 contains the **book.xsl** style sheet file used in the XSL transformation. The values of six elements in the XML document are placed in the resulting XHTML document. Lines 23 and 30 place the book's **title** in the document's **title** element and in a paragraph at the beginning of the document's **body** element, respectively. Line 36 specifies an **img** element in which the value of the **imageFile** element of an XML

document specifies the name of the file representing the book's cover image. Line 37 specifies the **alt** attribute of the **img** element using the book's **title**. Lines 43, 51, 59 and 67 place the book's **price**, **isbn**, **editionNumber** and **copyright** in table cells. The resulting XHTML document is shown in the screen capture at the end of Fig. 11.9. For more details on XSL, refer to Appendix D.

```
1 <?xml version = "1.0"?>
2
3 <xsl:stylesheet xmlns:xsl = "http://www.w3.org/1999/XSL/Transform"
4   version = "1.0">
5
6 <xsl:output method = "xml" omit-xml-declaration = "no"
7   indent = "yes" doctype-system =
8   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"
9   doctype-public = "-//W3C//DTD XHTML 1.0 Strict//EN"/>
10
11 <!-- book.xsl                                     -->
12 <!-- XSL document that transforms XML into XHTML -->
13
14 <!-- specify the root of the XML document -->
15 <!-- that references this stylesheet      -->
16 <xsl:template match = "product">
17
18   <html xmlns = "http://www.w3.org/1999/xhtml">
19
20     <head>
21
22       <!-- obtain book title from JSP to place in title -->
23       <title><xsl:value-of select = "title"/></title>
24
25       <link rel = "stylesheet" href = "styles.css"
26         type = "text/css" />
27     </head>
28
29     <body>
30       <p class = "bigFont"><xsl:value-of select = "title"/></p>
31
32       <table>
33         <tr>
34           <!-- create table cell for product image -->
35           <td rowspan = "5"> <!-- cell spans 5 rows -->
36             <img border = "thin solid black" src =
37               "images/{ imageFile }" alt = "{ title }" />
38           </td>
39
40           <!-- create table cells for price in row 1 -->
41           <td class = "bold">Price:</td>
42
43           <td><xsl:value-of select = "price"/></td>
44         </tr>
```

Fig. 11.9 XSL style sheet (**books.xsl**) that transforms a book's XML representation into an XHTML document (part 1 of 3).

```
45      <tr>
46          <!-- create table cells for ISBN in row 2 -->
47          <td class = "bold">ISBN #:</td>
48
49          <td><xsl:value-of select = "isbn"/></td>
50      </tr>
51
52      <tr>
53          <!-- create table cells for edition in row 3 -->
54          <td class = "bold">Edition:</td>
55
56          <td><xsl:value-of select = "editionNumber"/></td>
57      </tr>
58
59      <tr>
60          <!-- create table cells for copyright in row 4 -->
61          <td class = "bold">Copyright:</td>
62
63          <td><xsl:value-of select = "copyright"/></td>
64      </tr>
65
66      <tr>
67          <!-- create Add to Cart button in row 5 -->
68          <td>
69              <form method = "post" action = "addToCart">
70                  <input type = "submit" value = "Add to Cart" />
71              </form>
72          </td>
73
74          <!-- create View Cart button in row 5 -->
75          <td>
76              <form method = "get" action = "viewCart.jsp">
77                  <input type = "submit" value = "View Cart" />
78              </form>
79          </td>
80      </tr>
81
82      </table>
83
84  </body>
85
86  </html>
87
88</xsl:template>
89
90</xsl:stylesheet>
```

Fig. 11.9 XSL style sheet (**books.xsl**) that transforms a book's XML representation into an XHTML document (part 2 of 3).

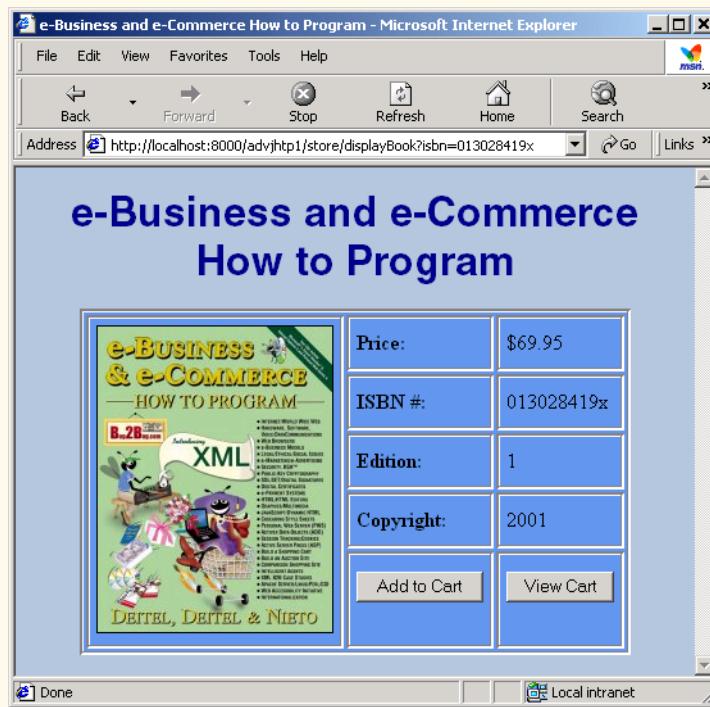


Fig. 11.9 XSL style sheet (`books.xsl`) that transforms a book's XML representation into an XHTML document (part 3 of 3).

## 11.6 Adding an Item to the Shopping Cart

When the user clicks the **Add to Cart** button in the XHTML document produced in the last section, the **AddToCartServlet** (aliased as **addToCart**) updates the shopping cart. If the cart does not exist, the servlet creates a shopping cart (a **HashMap** in this example). Items in the shopping cart are represented with **CartItemBean** objects. An instance of this JavaBean maintains a **BookBean** and the current quantity for that book in the shopping cart. When the user adds an item to the cart, if that item already is represented in the cart with a **CartItemBean**, the quantity of that item is updated in the bean. Otherwise, the servlet creates a new **CartItemBean** with a quantity of 1. After updating the cart, the user is forwarded to **viewCart.jsp** to view the current cart contents.

Class **CartItemBean** (Fig. 11.10) stores a **BookBean** and a quantity for that book. It maintains the **BookBean** as a read-only property of the bean and the **quantity** as a read-write property of the bean.

```

1 // CartItemBean.java
2 // Class that maintains a book and its quantity.
3 package com.deitel.advjhtp1.store;

```

Fig. 11.10 **CartItemBeans** contain a **BookBean** and the **quantity** of a book in the shopping cart (part 1 of 2).

```
4 import java.io.*;
5
6 public class CartItemBean implements Serializable {
7     private BookBean book;
8     private int quantity;
9
10    // initialize a CartItemBean
11    public CartItemBean( BookBean bookToAdd, int number )
12    {
13        book = bookToAdd;
14        quantity = number;
15    }
16
17    // get the book (this is a read-only property)
18    public BookBean getBook()
19    {
20        return book;
21    }
22
23    // set the quantity
24    public void setQuantity( int number )
25    {
26        quantity = number;
27    }
28
29    // get the quantity
30    public int getQuantity()
31    {
32        return quantity;
33    }
34
35 }
```

Fig. 11.10 **CartItemBeans** contain a **BookBean** and the **quantity** of a book in the shopping cart (part 2 of 2).

Class **AddToCartServlet** is shown in Fig. 11.11. The **AddToCartServlet**'s **doPost** method obtains the **HttpSession** object for the current client (line 18). If a session does not exist for this client, a **RequestDispatcher** forwards the request to the bookstore home page **index.html** (lines 22–26). Otherwise, line 29 obtains the value of session attribute **cart**—the **Map** that represents the shopping cart. Lines 30–31 obtain the value of session attribute **bookToAdd**—the **BookBean** representing the book to add to the shopping cart. If the shopping cart does not exist, lines 34–39 create a new **HashMap** to store the cart contents, then place the **HashMap** in the "**cart**" attribute of the **session** object. Lines 42–43 attempt to locate the **CartItemBean** for the book being added to the cart. If one exists, line 48 increments the quantity for that **CartItemBean**. Otherwise, line 50 creates a new **CartItemBean** with a quantity of 1 and puts it into the shopping cart (**Map cart**). Then lines 53–55 create a **RequestDispatcher** for JSP **viewCart.jsp** and **forward** the processing of the request to that JSP, so it can display the cart contents.

```
1 // AddToCartServlet.java
2 // Servlet to add a book to the shopping cart.
3 package com.deitel.advjhtp1.store;
4
5 // Java core packages
6 import java.io.*;
7 import java.util.*;
8
9 // Java extension packages
10 import javax.servlet.*;
11 import javax.servlet.http.*;
12
13 public class AddToCartServlet extends HttpServlet {
14     protected void doPost( HttpServletRequest request,
15                           HttpServletResponse response )
16     throws ServletException, IOException
17     {
18         HttpSession session = request.getSession( false );
19         RequestDispatcher dispatcher;
20
21         // if session does not exist, forward to index.html
22         if ( session == null ) {
23             dispatcher =
24                 request.getRequestDispatcher( "/index.html" );
25             dispatcher.forward( request, response );
26         }
27
28         // session exists, get cart Map and book to add
29         Map cart = ( Map ) session.getAttribute( "cart" );
30         BookBean book =
31             ( BookBean ) session.getAttribute( "bookToAdd" );
32
33         // if cart does not exist, create it
34         if ( cart == null ) {
35             cart = new HashMap();
36
37             // update the cart attribute
38             session.setAttribute( "cart", cart );
39         }
40
41         // determine if book is in cart
42         CartItemBean cartItem =
43             ( CartItemBean ) cart.get( book.getISBN() );
44
45         // If book is already in cart, update its quantity.
46         // Otherwise, create an entry in the cart.
47         if ( cartItem != null )
48             cartItem.setQuantity( cartItem.getQuantity() + 1 );
49         else
50             cart.put( book.getISBN(), new CartItemBean( book, 1 ) );
51 }
```

Fig. 11.11 **AddToCartServlet** places an item in the shopping cart and invokes **viewCart.jsp** to display the cart contents (part 1 of 2).

```

52     // send the user to viewCart.jsp
53     dispatcher =
54         request.getRequestDispatcher( "/viewCart.jsp" );
55     dispatcher.forward( request, response );
56 }
57 }
```

Fig. 11.11 **AddToCartServlet** places an item in the shopping cart and invokes **viewCart.jsp** to display the cart contents (part 2 of 2).

## 11.7 Viewing the Shopping Cart

JSP **viewCart.jsp** (Fi. 11.12) extracts the **CartItemBeans** from the shopping cart, subtotals each item in the cart, totals all the items in the cart and creates an XHTML document that allows the client to view the cart in tabular format. This JSP uses classes from our bookstore package (**com.deitel.advjhtp1.store**) and from packages **java.util** and **java.text**.

The scriptlet at lines 25–43 begins by retrieving the session attribute for the shopping cart **Map** (line 26). If there is no shopping cart, the JSP simply outputs a message indicating that the cart is empty. Otherwise, lines 34–41 create the variables used to obtain the information that is displayed in the resulting XHTML document. In particular, line 34 obtains the **Set** of keys in **Map cart**. These keys are used to retrieve the **CartItemBean**'s that represent each book in the cart.

Lines 45–51 output the literal XHTML markup that begins the table that appears in the document. Lines 55–63 continue the scriptlet with a loop that uses each key in the **Map** to obtain the corresponding **CartItemBean**, extracts the data from that bean, calculates the dollar subtotal for that product and calculates the dollar total of all products so far. The last part of the loop body appears outside the scriptlet at lines 70–86, in which the preceding data is formatted into a row in the XHTML table. JSP expressions are used to place each data value into the appropriate table cell. After the loop completes (line 90), lines 95–100 output the dollar total of all items in the cart and line 105 sets a session attribute containing the total. This value is used by **process.jsp** (Fig. 11.14) to display the dollar total as part of the order-processing confirmation. Line 101 outputs the dollar total of all items in the cart as the last row in the XHTML table.

```

1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3     "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4 <!-- viewCart.jsp -->
5
6 <%-- JSP page settings --%>
7 <%@ page language = "java" session = "true" %>
8 <%@ page import = "com.deitel.advjhtp1.store.*" %>
9 <%@ page import = "java.util.*" %>
10 <%@ page import = "java.text.*" %>
11
```

Fig. 11.12 JSP **viewCart.jsp** obtains the shopping cart and outputs an XHTML document with the cart contents in tabular format (part 1 of 4).

```
12 <html xmlns = "http://www.w3.org/1999/xhtml">
13 <head>
14   <title>Shopping Cart</title>
15   <link rel = "stylesheet" href = "styles.css"
16     type = "text/css" />
17 </head>
18 <body>
19   <p class = "bigFont">Shopping Cart</p>
20
21 <%-- start scriptlet to display shopping cart contents --%>
22 <%
23   Map cart = ( Map ) session.getAttribute( "cart" );
24   double total = 0;
25
26   if ( cart == null || cart.size() == 0 )
27     out.println( "<p>Shopping cart is currently empty.</p>" );
28   else {
29
30     // create variables used in display of cart
31     Set cartItems = cart.keySet();
32     Iterator iterator = cartItems.iterator();
33
34     BookBean book;
35     CartItemBean cartItem;
36
37     int quantity;
38     double price, subtotal;
39
40   %> <%-- end scriptlet for literal XHTML output --%>
41
42   <table>
43     <thead><tr>
44       <th>Product</th>
45       <th>Quantity</th>
46       <th>Price</th>
47       <th>Total</th>
48     </tr></thead>
49
50   <% // continue scriptlet
51
52     while ( iterator.hasNext() ) {
53
54       // get book data; calculate subtotal and total
55       cartItem = ( CartItemBean ) cart.get( iterator.next() );
56       book = cartItem.getBook();
57       quantity = cartItem.getQuantity();
58       price = book.getPrice();
59       subtotal = quantity * price;
60       total += subtotal;
61
62
63
```

Fig. 11.12 JSP **viewCart.jsp** obtains the shopping cart and outputs an XHTML document with the cart contents in tabular format (part 2 of 4).

```
64
65  %> <%-- end scriptlet for literal XHTML and --%>
66  <%-- JSP expressions output from this loop --%>
67
68      <%-- display table row of book title, quantity, --%>
69      <%-- price and subtotal --%>
70      <tr>
71          <td><%= book.getTitle() %></td>
72
73          <td><%= quantity %></td>
74
75          <td class = "right">
76              <%
77                  new DecimalFormat( "0.00" ).format( price )
78              %>
79          </td>
80
81          <td class = "bold right">
82              <%
83                  new DecimalFormat( "0.00" ).format( subtotal )
84              %>
85          </td>
86      </tr>
87
88  <% // continue scriptlet
89
90      } // end of while loop
91
92  %> <%-- end scriptlet for literal XHTML and --%>
93
94      <%-- display table row containing shopping cart total --%>
95      <tr>
96          <td colspan = "4" class = "bold right">Total:
97              <%= new DecimalFormat( "0.00" ).format( total ) %>
98          </td>
99      </tr>
100     </table>
101
102 <% // continue scriptlet
103
104     // make current total a session attribute
105     session.setAttribute( "total", new Double( total ) );
106 } // end of else
107
108 %> <%-- end scriptlet --%>
109
110     <!-- link back to books.jsp to continue shopping -->
111     <p class = "bold green">
112         <a href = "books.jsp">Continue Shopping</a>
113     </p>
114
```

Fig. 11.12 JSP **viewCart.jsp** obtains the shopping cart and outputs an XHTML document with the cart contents in tabular format (part 3 of 4).

```

115    <!-- form to proceed to checkout -->
116    <form method = "get" action = "order.html">
117      <p><input type = "submit" value = "Check Out" /></p>
118    </form>
119  </body>
120
121 </html>

```



Fig. 11.12 JSP `viewCart.jsp` obtains the shopping cart and outputs an XHTML document with the cart contents in tabular format (part 4 of 4).

From the XHTML document produced in this JSP, the user can either continue shopping or click the **Check Out** button to proceed to the `order.html` ordering page (Fig. 11.13).

## 11.8 Checking Out

When viewing the cart, the user can click a **Check Out** button to view `order.html` (Fig. 11.13). In this example, the form has no functionality. However, it is provided to help complete the application. Normally, there would be some client-side validation of the form elements, some server-side validation of form elements or a combination of both. When the user clicks the **Submit** button, the browser requests `process.jsp` to finalize the order.

```

1  <?xml version = "1.0"?>
2  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3  "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4  <!-- order.html -->

```

Fig. 11.13 Order form (`order.html`) in which the user inputs name, address and credit-card information to complete an order (part 1 of 4).

```
5
6 <html xmlns = "http://www.w3.org/1999/xhtml">
7
8 <head>
9   <title>Order</title>
10
11  <link rel = "stylesheet" href = "styles.css"
12    type = "text/css" />
13 </head>
14
15 <body>
16   <p class = "bigFont">Shopping Cart Check Out</p>
17
18   <!-- Form to input user information and credit card. -->
19   <!-- Note: No need to input real data in this example. -->
20   <form method = "post" action = "process.jsp">
21
22     <p style = "font-weight: bold">
23       Please input the following information.</p>
24
25     <!-- table of form elements -->
26     <table>
27       <tr>
28         <td class = "right bold">First name:</td>
29
30         <td>
31           <input type = "text" name = "firstname"
32             size = "25" />
33         </td>
34       </tr>
35
36       <tr>
37         <td class = "right bold">Last name:</td>
38
39         <td>
40           <input type = "text" name = "lastname"
41             size = "25" />
42         </td>
43       </tr>
44
45       <tr>
46         <td class = "right bold">Street:</td>
47
48         <td>
49           <input type = "text" name = "street" size = "25" />
50         </td>
51       </tr>
52
53       <tr>
54         <td class = "right bold">City:</td>
```

Fig. 11.13 Order form (**order.html**) in which the user inputs name, address and credit-card information to complete an order (part 2 of 4).

```
56          <td>
57              <input type = "text" name = "city" size = "25" />
58          </td>
59      </tr>
60
61      <tr>
62          <td class = "right bold">State:</td>
63
64          <td>
65              <input type = "text" name = "state" size = "2" />
66          </td>
67      </tr>
68
69      <tr>
70          <td class = "right bold">Zip code:</td>
71
72          <td>
73              <input type = "text" name = "zipcode"
74                  size = "10" />
75          </td>
76      </tr>
77
78      <tr>
79          <td class = "right bold">Phone #:</td>
80
81          <td>
82              (
83                  <input type = "text" name = "phone" size = "3" />
84              )
85
86          <input type = "text" name = "phone2"
87              size = "3" /> -
88
89          <input type = "text" name = "phone3" size = "4" />
90      </td>
91  </tr>
92
93  <tr>
94      <td class = "right bold">Credit Card #:</td>
95
96      <td>
97          <input type = "text" name = "creditcard"
98              size = "25" />
99      </td>
100  </tr>
101
102  <tr>
103      <td class = "right bold">Expiration (mm/yy) :</td>
104
105      <td>
106          <input type = "text" name = "expires"
107              size = "2" /> /
```

Fig. 11.13 Order form (`order.html`) in which the user inputs name, address and credit-card information to complete an order (part 3 of 4).

```
108      <input type = "text" name = "expires2"
109          size = "2" />
110      </td>
111  </tr>
112 </table>
113
114      <!-- enable user to submit the form -->
115      <p><input type = "submit" value = "Submit" /></p>
116  </form>
117 </body>
118
119
120 </html>
```

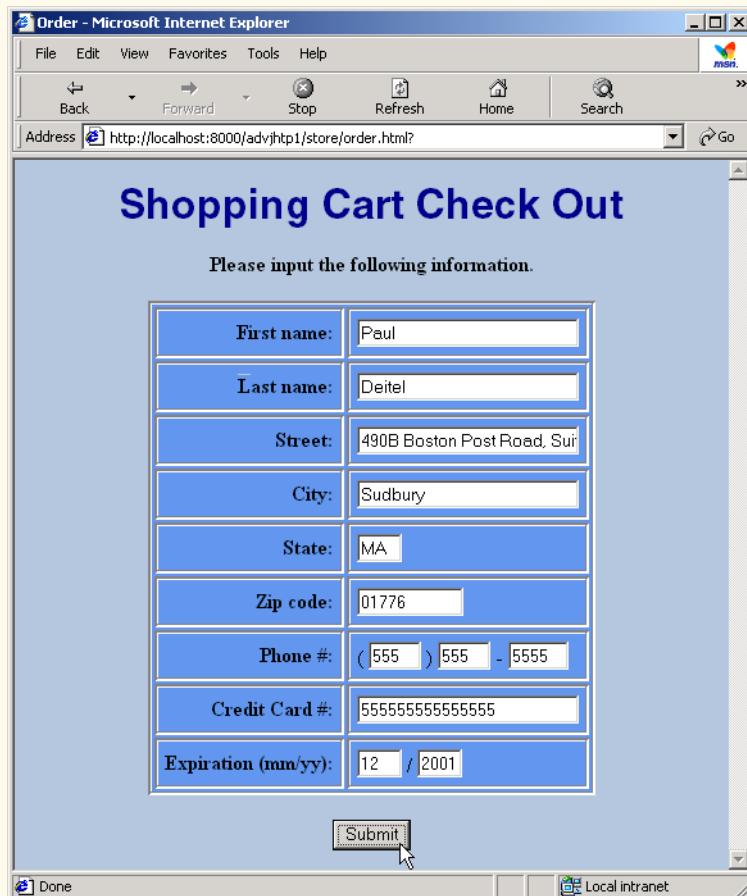


Fig. 11.13 Order form (**order.html**) in which the user inputs name, address and credit-card information to complete an order (part 4 of 4).

## 11.9 Processing the Order

JSP **process.jsp** (Fig. 11.14) pretends to process the user's credit-card information and creates an XHTML document containing a message that the order was processed and the final order dollar total. The scriptlet at lines 19–28 obtains the session attribute **total**. The **Double** object returned is converted to a **double** and stored in Java variable **total**. Our simulation of a bookstore does not perform real credit-card processing, so the transaction is now complete. Therefore, line 26 invokes **HttpSession** method **invalidate** to discard the session object for the current client. In a real store, the session would not be invalidated until the purchase is confirmed by the credit-card company. Lines 30–40 define the body of the XHTML document sent to the client. Line 37 uses a JSP expression to insert the dollar total of all items purchased.

```
1 <?xml version = "1.0"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
4 <!-- process.jsp -->
5
6 <%-- JSP page settings --%>
7 <%@ page language = "java" session = "true" %>
8 <%@ page import = "java.text.*" %>
9
10 <html xmlns = "http://www.w3.org/1999/xhtml">
11
12 <head>
13   <title>Thank You!</title>
14
15   <link rel = "stylesheet" href = "styles.css"
16     type = "text/css" />
17 </head>
18
19 <% // start scriptlet
20
21   // get total order amount
22   Double d = ( Double ) session.getAttribute( "total" );
23   double total = d.doubleValue();
24
25   // invalidate session because processing is complete
26   session.invalidate();
27
28 %> <%-- end scriptlet --%>
29
30 <body>
31   <p class = "bigFont">Thank You</p>
32
33   <p>Your order has been processed.</p>
34
35   <p>Your credit card has been billed:
36     <span class = "bold">
37       $<%= new DecimalFormat( "0.00" ).format( total ) %>
38     </span>
```

Fig. 11.14 JSP **process.jsp** performs the final order processing (part 1 of 2).

```
39      </p>
40  </body>
41
42  </html>
```



Fig. 11.14 JSP `process.jsp` performs the final order processing (part 2 of 2).

## 11.10 Deploying the Bookstore Application in J2EE 1.2.1

Next, we deploy the bookstore application in the Java 2 Enterprise Edition 1.2.1 reference implementation. This section assumes that you have downloaded and installed J2EE 1.2.1. If not, please refer to Appendix E for installation and configuration instructions. Note that the files for this entire bookstore application can be found on the CD that accompanies this book and at [www.deitel.com](http://www.deitel.com).

In Section 11.10.1 through Section 11.10.8, we demonstrate the steps needed to deploy this application:

1. Configure the **books** data source for use with the J2EE 1.2.1 reference implementation server.
2. Launch the Cloudscape database server and the J2EE 1.2.1 reference implementation server for deployment and execution of the application.
3. Launch the **Application Deployment Tool**. This tool provides a graphical user interface for deploying applications on the J2EE 1.2.1 server.
4. Create a new application in the **Application Deployment Tool**.
5. Add library JAR files to the application. These files are available to all application components.
6. Create a new Web component in the application for the **BookServlet**.
7. Create a new Web component in the application for the **AddToCartServlet**.
8. Add the nonservlet components to the application. These include XHTML documents, JSPs, images, CSS files, XSL files and JavaBeans used in the application.
9. Specify the Web context that causes this J2EE application to execute. This determines the URL that will be used to invoke the application.

10. Specify the database resource (i.e., **books**) used by our application.
11. Set up the JNDI name for the database in the application. This is used to register the name with the Java Naming and Directory Service so the database can be located at execution time.
12. Set up the *welcome file* for the application. This is the initial file that is returned when the user invokes the bookstore application.
13. Deploy the application.
14. Run the application.

At the end of Section 11.10.8, you will be able to deploy and test the bookstore application.

### 11.10.1 Configuring the **books** Data Source

Before deploying the bookstore application, you must configure the **books** data source so the J2EE server registers the data source with the naming server. This enables the application to use JNDI to locate the data source at execution time. J2EE comes with Cloudscape—a pure-Java database application from Informix Software. We use Cloudscape to perform our database manipulations in this case study.

To configure the Cloudscape data source, you must modify the J2EE default configuration file **default.properties** in the J2EE installation's **config** directory. Below the comment **JDBC URL Examples** is a line that begins with **jdbc.datasources**. Append the following text to this line

```
| jdbc/books|jdbc:cloudscape:rmi:books;create=true
```

The vertical bar, |, at the beginning of the text separates the new data source we are registering from a data source that is registered by default when you install J2EE. The text **jdbc/books** is the JNDI name for the database. After the second | character in the preceding text is the JDBC URL **jdbc:cloudscape:rmi:books**. The URL indicates that the J2EE will use the JDBC protocol to interact with the Cloudscape subprotocol, which, in turn, uses RMI to communicate with the database (**books** in this case). Finally, **create=true** specifies that J2EE should create a database if the database does not already exist. [Remember, that the **books** database was created in Chapter 8.] After configuring the database, save the **default.properties** file. This completes *Step 1* of Section 11.10.

#### Portability Tip 11.2



Each database driver typically has its own URL format that enables an application to interact with databases hosted on that database server. See your database server's documentation for more information.

### 11.10.2 Launching the Cloudscape Database and J2EE Servers

*Step 2* of Section 11.10 specifies that you must launch the Cloudscape database server and the J2EE server, so you can deploy and execute the application. First, open a command prompt (or shell) and launch the Cloudscape server as discussed in Section 8.5. Next, open

a command prompt (or shell) and change directories to the **bin** subdirectory of your J2EE installation. Then, issue the following command:

**j2ee -verbose**

to start the J2EE server. Note that the J2EE server includes the Tomcat JSP and servlet container discussed in Chapter 9.



### Portability Tip 11.3

*On some UNIX/Linux systems, you may need to precede the commands that launch the Cloudscape server and the J2EE server with ./, to indicate that the command is located in the current directory.*



### Testing and Debugging Tip 11.1

*Use separate command prompts (or shells) to execute the commands that launch the Cloudscape database server and the J2EE 1.2.1 server, so you can see any error messages generated by these programs.*



### Testing and Debugging Tip 11.2

*To ensure that the J2EE server communicates properly with the Cloudscape server (or any other database server), always launch the database server before the J2EE server. Otherwise, exceptions will occur when the J2EE server attempts to configure its data sources.*

To shut down the J2EE server, use a command prompt (or shell) to execute the following command from the **bin** subdirectory of your J2EE installation:

**j2ee -stop**



### Testing and Debugging Tip 11.3

*Always shut down the J2EE server before the Cloudscape database server to ensure that the J2EE server does not attempt to communicate with the Cloudscape database server after the database server has been shut down. If Cloudscape is terminated first, it is possible that the J2EE server will receive another request and attempt to access the database again. This will result in exceptions.*

## 11.10.3 Launching the J2EE Application Deployment Tool

Step 3 of Section 11.10 begins the process of deploying our bookstore application. The J2EE reference implementation comes with a graphical application, called the **Application Deployment Tool**, that helps you deploy Enterprise Java applications. In Chapter 9, we created an XML deployment descriptor by hand to deploy our servlets. The **Application Deployment Tool** is nice in that it writes the deployment descriptor files for you and automatically archives the Web application's components. The tool places all Web application components and auxiliary files for a particular application into a single *Enterprise Application Archive (EAR) file*. This file contains deployment descriptor information, WAR files with Web application components and additional information that is discussed later in the book.

Execute the deployment tool by opening a command prompt (or shell) and changing directories to the **bin** subdirectory of your J2EE installation. Then, type the following command:

**deploytool**

The **Application Deployment Tool** window (Fig. 11.15) appears. [Note: In our deployment discussion, we cover only those aspects of the deployment tool required to deploy this bookstore application. Later in the book, we discuss other aspects of this tool in detail.]

#### 11.10.4 Creating the Bookstore Application

The **Application Deployment Tool** simplifies the task of deploying Enterprise applications. Next (Step 4 of Section 11.10), we create the new application. Click the **New Application** button to display the **New Application** window (Fig. 11.16).

In the **Application File Name** field, you can type the name of the EAR file in which the **Application Deployment Tool** stores the application components, or you can click **Browse** to specify both the name and location of the file. In the **Application Display Name** field, you can specify the name for your application. This name will appear in the **Local Applications** area of the deployment tool's main window (Fig. 11.15). Click **OK** to create the application. The main **Application Deployment Tool** window now appears as shown in Fig. 11.17.

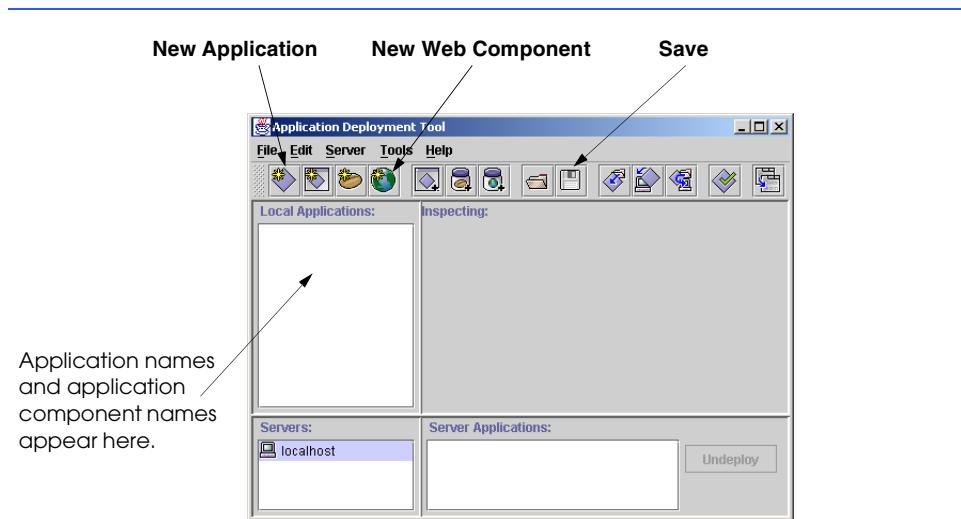
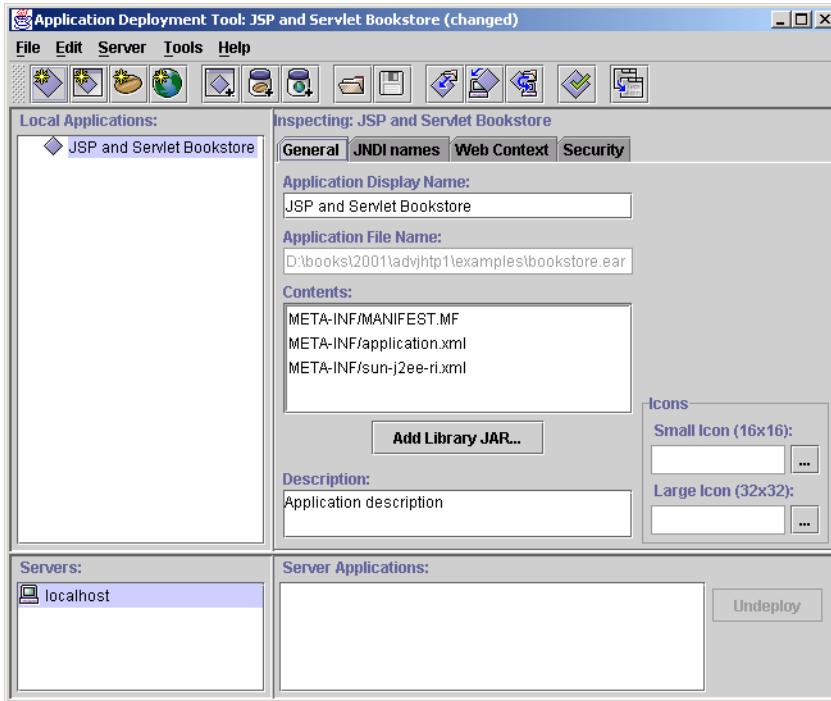


Fig. 11.15 Application Deployment Tool main window.



Fig. 11.16 New Application window.



**Fig. 11.17 Application Deployment Tool** main window after creating a new application.

### 11.10.5 Creating BookServlet and AddToCartServlet Web Components

Step 6 of Section 11.10 is to create Web components for the **BookServlet** and the **AddToCartServlet**. This will enable us to specify the alias that is used to invoke each servlet. We will show the details of creating the **BookServlet** Web component. Then, you can repeat the steps to create the **AddToCartServlet** Web component.

To begin, click the **New Web Component** button (see Fig. 11.15) to display the **Introduction** window of the **New Web Component Wizard** (Fig. 11.18).

Click the **Next >** button to display the **WAR File General Properties** (Fig. 11.19) window of the **New Web Component Wizard**.

Ensure that **JSP and Servlet Bookstore** is selected in the **Web Component will Go In:** drop-down list. In the **WAR Display Name** field, type a name (**Store Components**) for the WAR that will appear in the **Local Applications** area of the deployment tool's main window (see Fig. 11.15). Then, click the **Add...** button to display the **Add Files to .WAR - Add Content Files** window (Fig. 11.20). Content files are non-servlet files such as images, XHTML documents, style sheets and JSPs. We will be adding these in another step later, so click **Next >** to proceed to the **Add Files to .WAR - Add Class Files** window (Fig. 11.21).

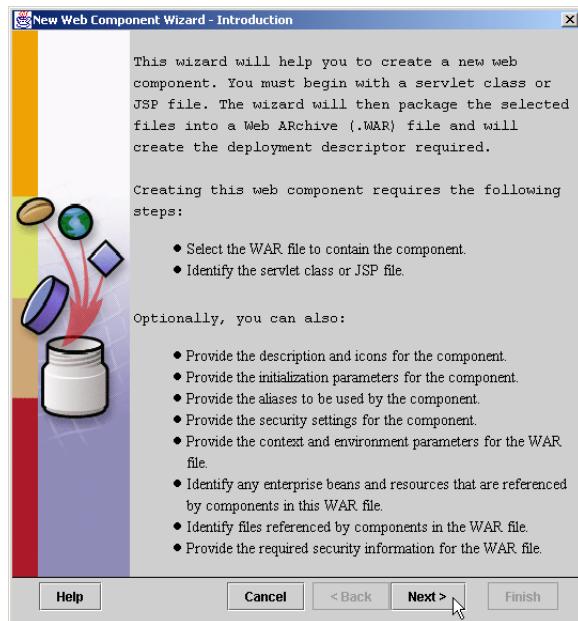


Fig. 11.18 New Web Component Wizard - Introduction window.

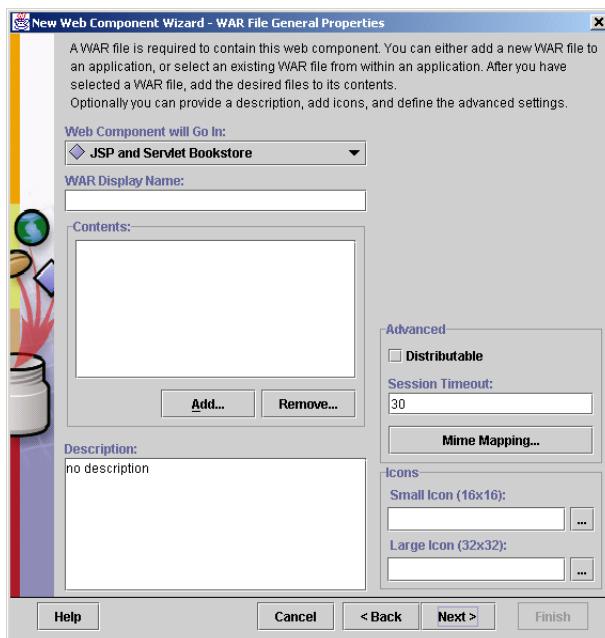


Fig. 11.19 New Web Component Wizard - WAR File General Properties window.

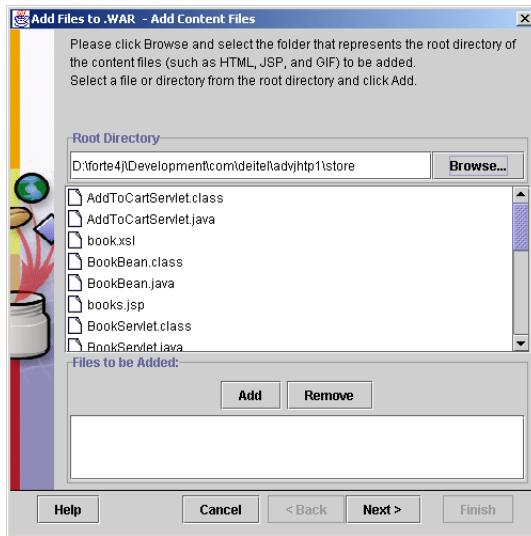


Fig. 11.20 Add Files to .WAR - Add Content Files window.

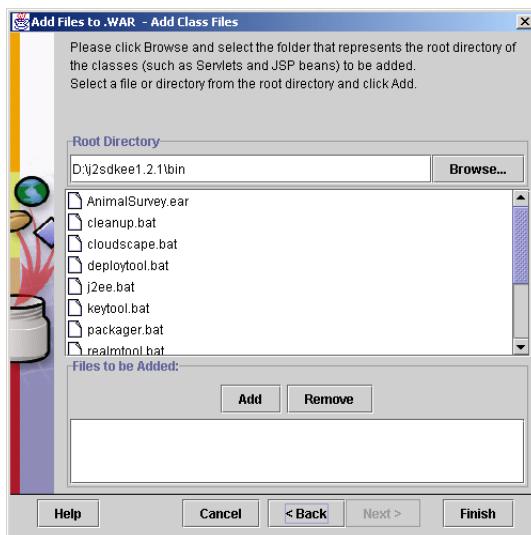


Fig. 11.21 Add Files to .WAR - Add Class Files window.

To add the **BookServlet.class** file, click the **Browse...** button to display the **Choose Root Directory** window (Fig. 11.22).

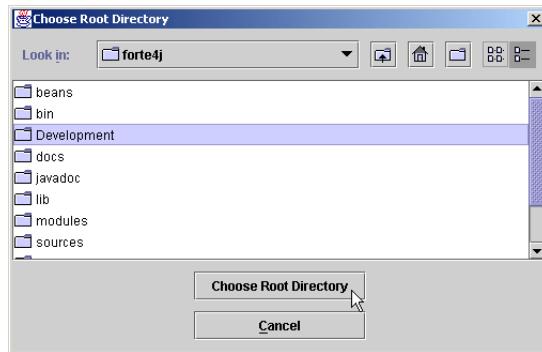


Fig. 11.22 Choose Root Directory window.

When adding a class file for a class in a package (as all classes are in this example), it is imperative that the files be added and maintained in their full package directory structure or as part of a JAR file that contains the full package directory structure. In this example, we did not create a JAR file containing the entire **com.deitel.advjhttp1.store** package. Therefore, we need to locate the directory in which the first package directory name is found.

On our system, the **com** directory that starts the package name is located in a directory called **Development**. When you click the **Choose Root Directory** button, you are returned to the **Add Files to .WAR - Add Class Files** window. In that window, you should be able to locate the **com** directory (Fig. 11.23).

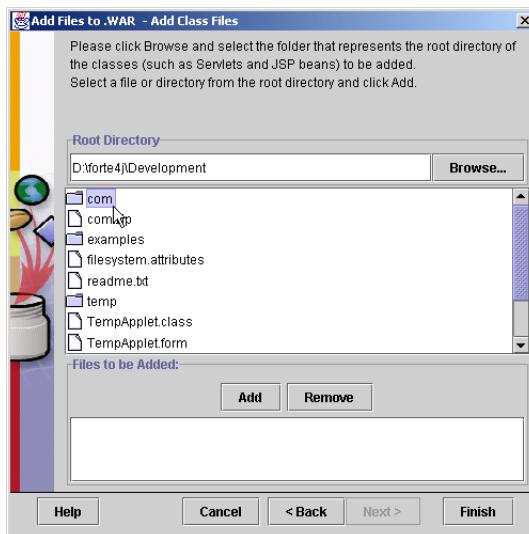


Fig. 11.23 Add Files to .WAR - Add Class Files window after selecting the root directory in which the files are located.

Double click the **com** directory name to expand its contents in the window. Do the same for the subdirectory **deitel**, then the subdirectory **advjhttp1** and finally, for the directory **store**. In the **store** directory, select the **.class** file for **BookServlet**, then click the **Add** button. At the bottom of the **Add Files to .WAR - Add Class Files** window, the **.class** file should be displayed with its full package directory structure. After doing this, click the **Finish** button to return to the **New Web Component Wizard - WAR File General Properties** window. Note that the files selected with the **Add Files to .WAR** window now appear in the **Contents** text area of the window (Fig. 11.24).



### Common Programming Error 11.1

*Not including the full package directory structure for a class in a package will prevent the application from loading the class and from executing properly.*

Click **Next >** to proceed to the **New Web Component Wizard - Choose Component Type** window and select **Servlet** (Fig. 11.25).

Click **Next >** to proceed to the **New Web Component Wizard - Component General Properties** window (Fig. 11.26). Select the **BookServlet** class in the **Servlet Class** drop-down list and type **Book Servlet** in the **Web Component Display Name** field.

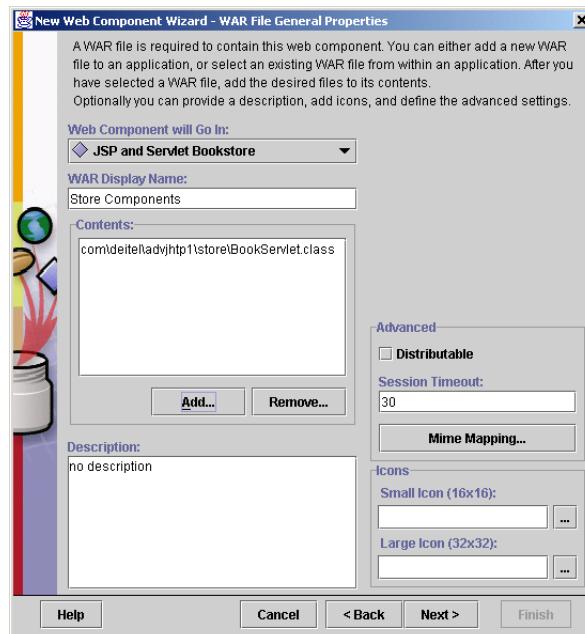


Fig. 11.24 New Web Component Wizard - WAR File General Properties window after selecting the file **BookServlet.class**.



Fig. 11.25 New Web Component Wizard - Choose Component Type window.

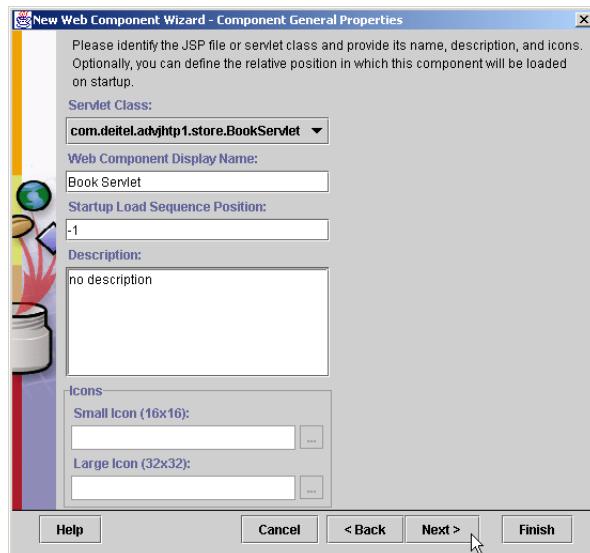


Fig. 11.26 New Web Component Wizard - Component General Properties window.

Click **Next >** twice to display the **New Web Component Wizard - Component Aliases** window (Fig. 11.27). Click **Add** to specify an alias for the **BookServlet**. Click the white box that appears in the window, type **displayBook** as the alias for the servlet and press *Enter*. Next, click **Finish** to complete the setup of the **BookServlet**.



Fig. 11.27 New Web Component Wizard - Component Aliases window.

Now, create a Web component for **AddToCartServlet** (*Step 7* of Section 11.10), by repeating the steps shown in this section. For this Web component, specify **Add to Cart Servlet** as the **Web Component Display Name** and **addToCart** as the alias for the servlet. After adding the two servlet Web components, the **Application Deployment Tool** window should appear as shown in Fig. 11.28.

### 11.10.6 Adding Non-Servlet Components to the Application

Next, we will add our non-servlet components to the application (*Step 8* of Section 11.10). These files include JSPs, XHTML documents, style sheets, images and JavaBeans used in the application.

Begin by expanding the application component tree and clicking **Store Components** in the **Local Applications** area of the **Application Deployment Tool** window (see Fig. 11.28). In the contents area of the **Application Deployment Tool** window, click the **Add...** button to display the **Add Files to .WAR - Add Content Files** window (Fig. 11.29).

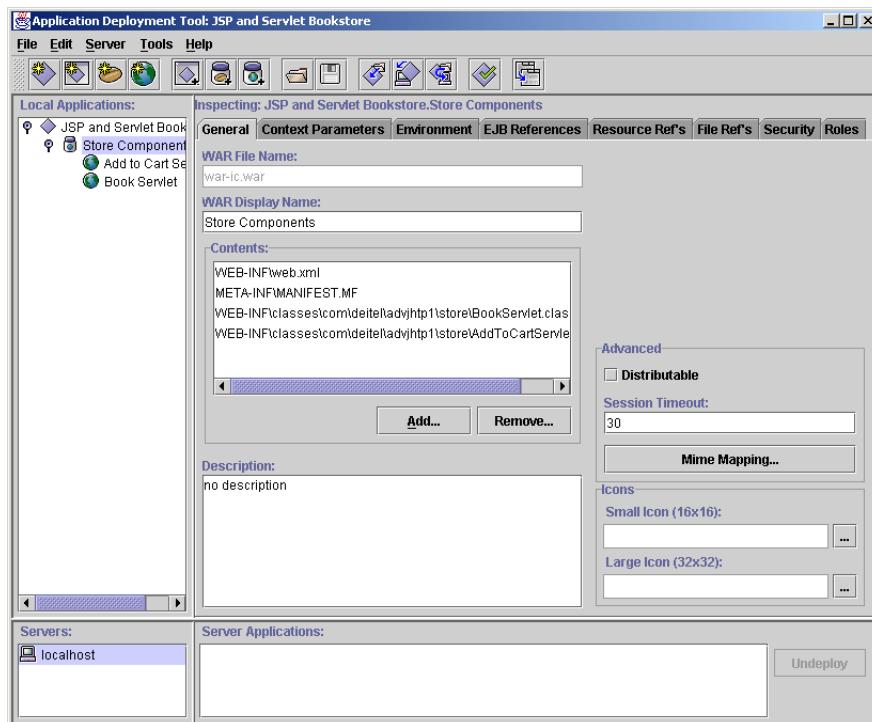


Fig. 11.28 Application Deployment Tool window after deploying **BookServlet** and **AddToCartServlet**.

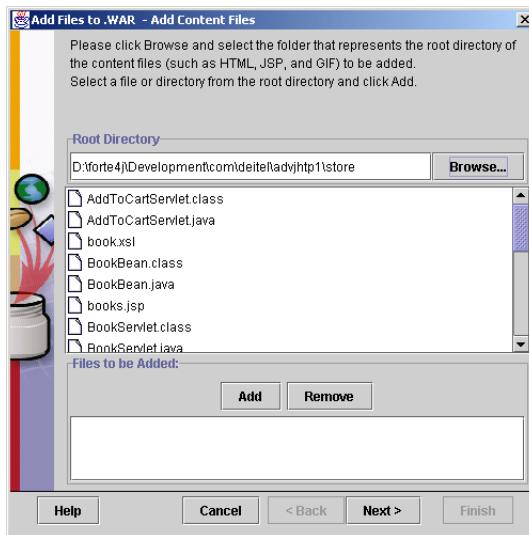


Fig. 11.29 Add Files to .WAR - Add Content Files window.

Navigate to the directory on your system that contains the files for the bookstore application. In the list box that appears in the window, locate each of the following files and directories: **book.xsl**, **books.jsp**, **images**, **index.html**, **order.html**, **process.jsp**, **styles.css** and **viewCart.jsp**. For each file or directory, click the **Add** button. You can select multiple items at one time by holding down the *<Ctrl>* key and clicking each item. All the items you add should appear in the text area at the bottom of the window. When you are done, click **Next >** to display the **Add Files to .WAR - Add Class Files** window (Fig. 11.30).

We will use this window to add the **.class** files for the non-servlet classes (i.e., our JavaBeans) to our application. Remember that the JavaBeans used in the bookstore are in a package, so their **.class** files must be added and maintained in their full package directory structure. Once again, click the **Browse...** button to display the **Choose Root Directory** window and locate the directory in which the first package directory name is found. Select that directory as the root directory. Double click the **com** directory name to expand its contents in the window. Do the same for the subdirectory **deitel**, then the sub-directory **advjhttp1** and finally, for the directory **store**. In the **store** directory, select the **.class** files for each of the JavaBeans in this bookstore example (**BookBean.class**, **CartItemBean.class** and **TitlesBean.class**), then click the **Add** button. At the bottom of the **Add Files to .WAR - Add Class Files** window, each **.class** file should be displayed with its full package directory structure. After doing this, click the **Finish** button to return to the **Application Deployment Tool** window. Note that the files selected with the **Add Files to .WAR** windows now appear in the **Contents** text area of the window. Click the **Save** button to save your work.

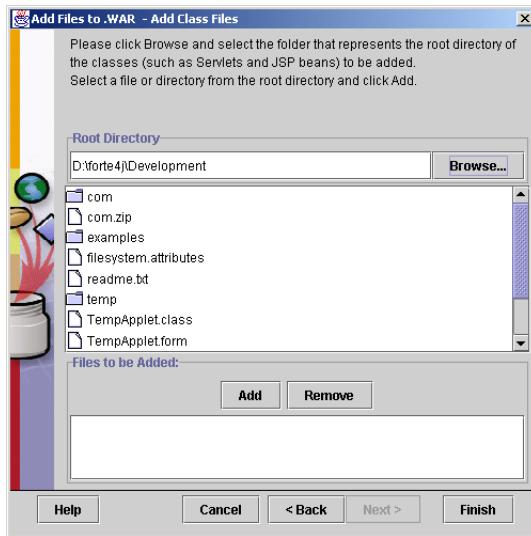


Fig. 11.30 Add Files to .WAR - Add Class Files window.

### 11.10.7 Specifying the Web Context, Resource References, JNDI Names and Welcome Files

Steps 9 through 13 of Section 11.10 perform the final configuration and deployment of the bookstore application. After performing the steps in this section, you will be able to execute the bookstore application.

We begin by specifying the Web context for our application (*Step 9* of Section 11.10). At the beginning of this chapter, we indicated that the user would enter the URL

**`http://localhost:8000/advjhttp1/store`**

in a browser to access the bookstore application. The Web context is the part of the preceding URL that enables the server to determine which application to execute when the server receives a request from a client. In this case, the Web context is **advjhttp1/store**. Once again, note that the J2EE server uses port 8000, rather than port 8080, used by Tomcat.



#### Common Programming Error 11.2

*Specifying the wrong port number in a URL that is supposed to access the J2EE server causes your Web browser to indicate that the server was not found.*



#### Testing and Debugging Tip 11.4

*When deploying an Enterprise Java application on a production application server (the J2EE server is for testing only), it is typically not necessary to specify a port number in the URL when accessing the application. See your application server's documentation for further details.*

To specify the Web context, click the **JSP and Servlet Bookstore** node in the **Local Applications** area of the **Application Deployment Tool** window. Then, click

the **Web Context** tab (Fig. 11.31). Click the white box in the **Context Root** column and type **advjhttp1/store**; then click *Enter*.

Next, we must specify the database resource referenced by the bookstore application (*Step 10* of Section 11.10). Click the **Store Components** node in the **Local Applications** area of the **Application Deployment Tool** window. Then, click the **Resource Ref's** tab (Fig. 11.32). Click the **Add** button. Under the **Coded Name** column click the white box and type **jdbc/books** (the JNDI name of our data source). Figure 11.32 shows the **Application Deployment Tool** window after creating the resource reference.

Next, we specify the JNDI name for the database in the application (*Step 11* of Section 11.10). This is used to register the name with the Java Naming and Directory Service, so the database can be located by the application at execution time.

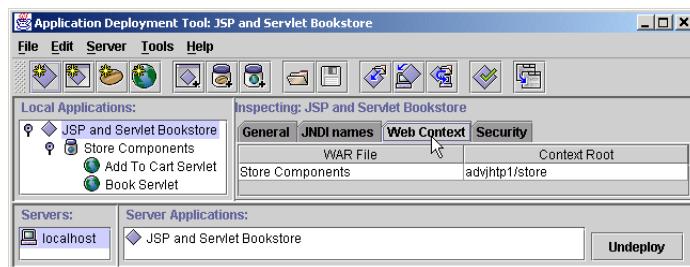


Fig. 11.31 Specifying the **Web Context** in the **Application Deployment Tool**.

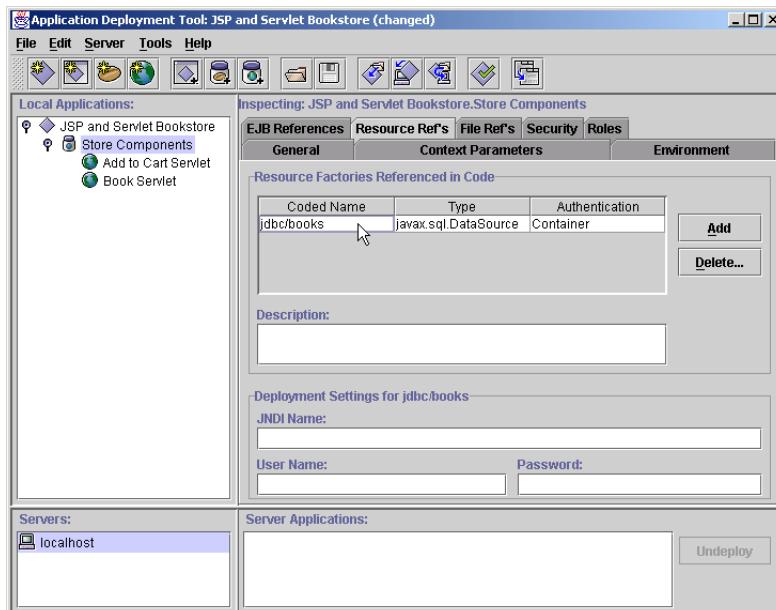


Fig. 11.32 Specifying the **Resource Ref's** in the **Application Deployment Tool**.

To specify the JNDI name for the database, click the **JSP and Servlet Bookstore** node in the **Local Applications** area of the **Application Deployment Tool** window. Then, click the **JNDI names** tab (Fig. 11.33). In the **JNDI Name** column, click the white box and type **jdbc/books**; then click **Enter**.

The last task to perform before deploying the application is specifying the welcome file that is displayed when the user first visits the bookstore. Click the **Store Components** node in the **Local Applications** area of the **Application Deployment Tool** window. Then, click the **File Ref's** tab (Fig. 11.34). Click the **Add** button. In the **Welcome Files** area click the white box and type **index.html**. Figure 11.34 shows the **Application Deployment Tool** window after specifying the welcome file. Click the **Save** button to save the application settings.

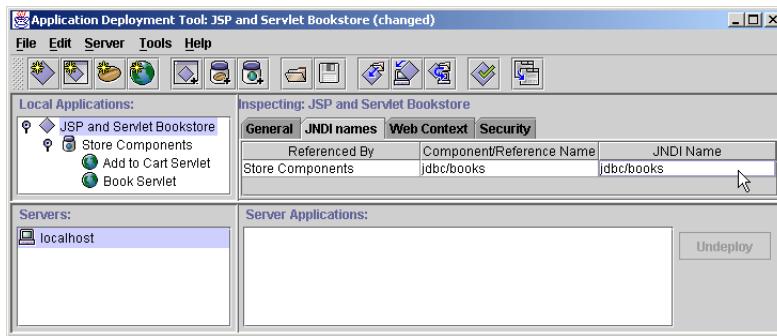


Fig. 11.33 Specifying the Resource Ref's in the Application Deployment Tool.

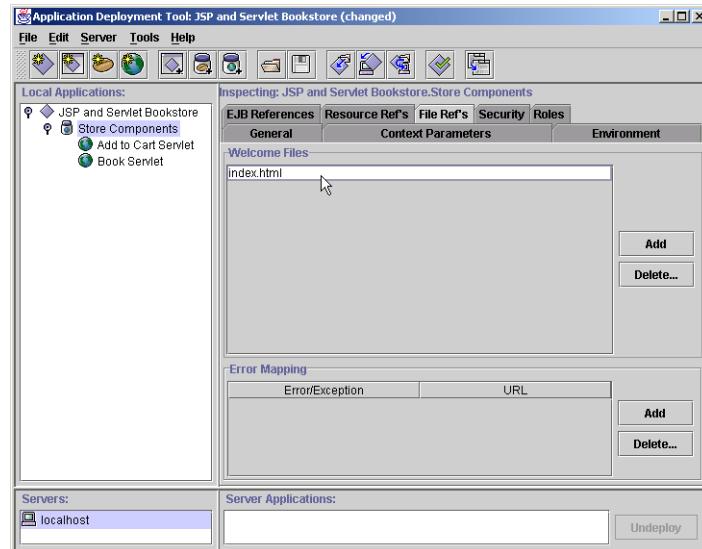


Fig. 11.34 Specifying the welcome file in the File Ref's tab of the Application Deployment Tool.

### 11.10.8 Deploying and Executing the Application

Now, you are ready to deploy the bookstore application so you can test it. Figure 11.35 shows **Application Deployment Tool** toolbar buttons for updating application files and deploying applications. The **Update Application Files** button updates the application's EAR file after changes are made to any of the files, such as recompiling classes or modifying files. The **Deploy Application** button causes the **Application Deployment Tool** to communicate with the J2EE server and deploy the application. The functionality of both these buttons is combined in the **Update and Redeploy Application** button.

Click the **Deploy Application** button to display the **Deploy JSP and Servlet Bookstore - Introduction** window (Fig. 11.36). Click the **Next >** button three times, then click the **Finish** button. A **Deployment Progress** window appears. This window will indicate when the deployment is complete. When that occurs, open a Web browser and enter the following URL to test the bookstore application:

```
http://localhost:8000/advjhtp1/store
```

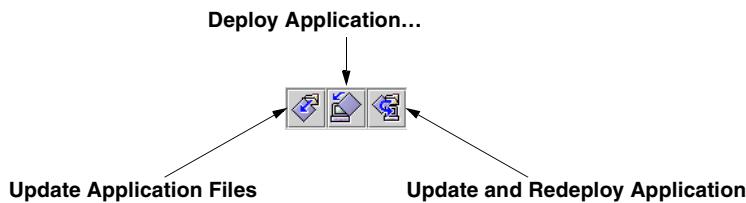


Fig. 11.35 Application Deployment Tool toolbar buttons for updating application files and deploying applications.

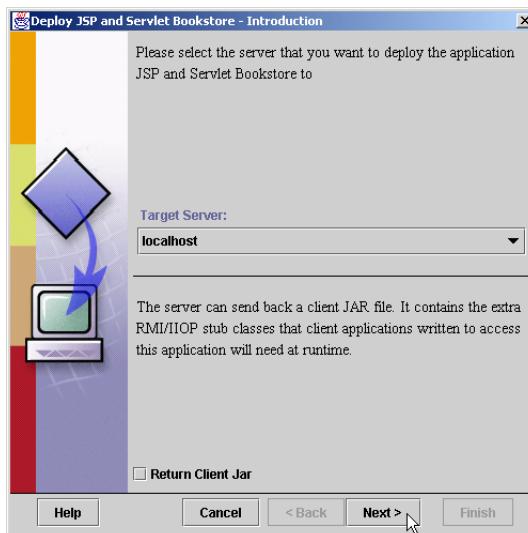


Fig. 11.36 Deploy JSP and Servlet Bookstore - Introduction window.

In this chapter, we have presented our first substantial Enterprise Java application. The steps presented in this section for deploying the bookstore application are just some of the steps required in a typical Enterprise application. For example, there were no security requirements in the bookstore application. In real Enterprise Java applications, some or all of the application components have security restrictions, such as “the user must enter a valid username and password before access is granted to a component.” Such restrictions are specified at deployment time with the **Application Deployment Tool** or some similar tool in an Enterprise Java development environment. These security restrictions are enforced by the application server. In our bookstore example, if the JSPs had security restrictions, it would be necessary to deploy each one individually, as we did with the **BookServlet** and the **AddToCartServlet**. In later chapters, we discuss more of the deployment options for application components. The *Java 2 Enterprise Edition Specification* (available at [java.sun.com/j2ee/download.html](http://java.sun.com/j2ee/download.html)) discusses the complete set of deployment options that are required in J2EE-compliant application servers.

The next chapter continues our client/server discussions. In that chapter, we use servlets and XML to create content for wireless devices, such as pagers, cell phones and personal digital assistants.

## SUMMARY

- The Java 2 Enterprise Edition 1.2.1 reference implementation includes the Apache Tomcat JSP and servlet container.
- A three-tier, distributed Web application consists of client, server and database tiers.
- The client tier in a Web application often is represented by the user's Web browser.
- The server tier in a Web application often consists of JSPs and servlets that act on behalf of the client to perform tasks.
- The database tier maintains the database accessed from the server tier.
- The Java 2 Enterprise Edition 1.2.1 reference implementation comes with an **Application Deployment Tool**. Among its many features, this tool enables us to specify the alias used to invoke a servlet.
- The **Application Deployment Tool** creates the deployment descriptor for a servlet as part of deploying an application.
- The welcome file is the default document sent as the response to a client when the client initially interacts with a J2EE application.
- Different browsers have different levels of support for Cascading Style Sheets.
- JavaServer Pages often generate XHTML that is sent to the client for rendering.
- The Java Naming and Directory Interface (JNDI) enables Enterprise Java application components to access information and resources (such as databases) that are external to an application. In some cases, those resources are distributed across a network.
- An Enterprise Java application container must provide a naming service that implements JNDI and enables the components executing in that container to perform name lookups to locate resources. The J2EE 1.2.1 reference implementation server includes such a naming service.
- When you deploy an Enterprise Java application, you specify the resources used by the application (such as databases) and the JNDI names for those resources.
- Using an **InitialContext**, an Enterprise application component can look up a resource. The **InitialContext** provides access to the application's naming environment.

- **InitialContext** method **lookup** locates a resource with a JNDI name. Method **lookup** returns an **Object** object and throws a **NamingException** if it cannot resolve the name it receives as an argument.
- A **DataSource** is used to connect to a database.
- The **org.w3c.dom** package's **Document** and **Element** interfaces are used to create an XML document tree.
- **Document** method **createElement** creates an element for an XML document.
- **Document** method **createTextNode** specifies the text for an **Element**.
- **Element** method **appendChild** appends a node to an **Element** as a child of that **Element**.
- An XML document can be transformed into an XHTML document using an XSL style sheet.
- **ServletRequest** method **getRequestDispatcher** returns a **RequestDispatcher** object that can **forward** requests to other resources or **include** other resources as part of the current servlet's response.
- When **RequestDispatcher** method **forward** is called, processing of the request by the current servlet terminates.
- **RequestDispatcher** objects can be obtained with method **getRequestDispatcher** from an object that implements interface **ServletRequest**, or from the **ServletContext** with methods **getRequestDispatcher** or **getNamedDispatcher**.
- **ServletContext** method **getNamedDispatcher** receives the name of a servlet as an argument, then searches the **ServletContext** for a servlet by that name. If no such servlet is found, the method returns **null**.
- Both the **ServletRequest** and the **ServletContext getRequestDispatcher** methods simply return the content of the specified path if the path does not represent a servlet.
- Before the XML and XSL capabilities can be used, you must download and install Sun's Java API for XML Parsing (JAXP) version 1.1 from [java.sun.com/xml/download.htm](http://java.sun.com/xml/download.htm).
- The root directory of JAXP (normally called **jaxp-1.1**) contains three JAR files that are required for compiling and running programs that use JAXP—**crimson.jar**, **jaxp.jar** and **xalan.jar**. These files must be added to the Java extension mechanism for your Java 2 Standard Edition installation.
- JAXP 1.1 is part of the forthcoming J2EE 1.3 reference implementation.
- Creating a Document Object Model (DOM) tree from an XML document requires a **DocumentBuilder** parser object. **DocumentBuilder** objects are obtained from a **DocumentBuilderFactory**.
- Classes **Document** and **Element** are located in package **org.w3c.dom**.
- A **DOMSource** represents an XML document in an XSL transformation. A **StreamSource** can be used to read a stream of bytes that represent an XSL file.
- A **StreamResult** specifies the **PrintWriter** to which the results of the XSL transformation are written.
- **TransformerFactory static** method **newInstance** creates a **TransformerFactory** object. This object enables the program to obtain a **Transformer** object that applies the XSL transformation.
- **TransformerFactory** method **newTransformer** receives a **StreamSource** argument representing the XSL that will be applied to an XML document.
- **Transformer** method **transform** performs an XSL transformation on the given **DOMSource** object and writes the result to the given **StreamResult** object.

- A **TransformerException** is thrown if a problem occurs when creating the **TransformerFactory**, creating the **Transformer** or performing the transformation.
- **HttpSession** method **invalidate** discards the session object for the current client.
- Before deploying an Enterprise Java application, you must configure your data sources and other resources, so the J2EE server can register those resources with the naming server. This enables the application to use JNDI to locate the resources at execution time.
- J2EE comes with Cloudscape—a pure-Java database application from Informix Software.
- To configure a Cloudscape data source, you must modify the J2EE default configuration file **default.properties** in the J2EE installation's **config** directory. Below the comment **JDBC URL Examples** is a line that begins with **jdbc.datasources**. Append the following text (in which *dataSource* represents your data source name) to this line:

```
| jdbc(dataSource|) | jdbc:cloudscape:rmi: dataSource;create=true
```

- Each database server typically has its own URL format that enables an application to interact with databases hosted on that database server.
- You must launch the Cloudscape database server and the J2EE server before you can deploy and execute an application.
- To ensure that the J2EE server communicates properly with the Cloudscape server (or any other database server), always launch the database server before the J2EE server.
- Always shut down the J2EE server before the Cloudscape database server, to ensure that the J2EE server does not attempt to communicate with the Cloudscape database server after the database server has been shut down.
- The J2EE reference implementation comes with a graphical application, called the **Application Deployment Tool**, that helps you deploy Enterprise Java applications.
- The **Application Deployment Tool** is nice in that it writes the deployment descriptor files for you and automatically archives the Web application's components. The tool places all Web application components and auxiliary files for a particular application into a single Enterprise Application Archive (EAR) file. This file contains deployment descriptor information, WAR files with Web application components and additional information that is discussed later in the book.
- When adding a class file for a class in a package to an application with the **Application Deployment Tool**, it is imperative that the files be added and maintained in their full package directory structure or as part of a JAR file that contains the full package directory structure.
- Not including the full package directory structure for a class in a package will prevent the application from loading the class and from executing properly.
- The Web context for an application is the part of the URL that enables the server to determine which application to execute when the server receives a request from a client.
- The J2EE server uses port 8000, rather than port 8080, used by Tomcat.
- When deploying an Enterprise Java application on a production application server, it is typically not necessary to specify a port number in the URL when accessing the application.
- Part of deploying an application is to specify the resource references for the components in the application.
- Each resource reference has a corresponding JNDI name that is used by the deployment tool to register the resource with the Java Naming and Directory Service. This enables the resource to be located by the application at execution time.

## TERMINOLOGY

<b>Application Deployment Tool</b>	Java Naming and Directory Interface (JNDI)
Cascading Style Sheets (CSS)	<b>javax.naming</b> package
component environment entries	<b>jdbc.datasources</b> J2EE
configure a data source	configuration property
create a Web component	<b>jdbc:cloudscape:rmi:books</b> JDBC URL
database resource	JNDI name
<b>DataSource</b> interface	locate a naming service
<b>default.properties</b>	<b>lookup</b> method of <b>InitialContext</b>
deploy an application	name lookup
dynamic XHTML document	name resolution
Enterprise Application Archive (EAR) file	naming service
external resource	register a data source with a naming server
<b>forward</b> method of <b>RequestDispatcher</b>	<b>RequestDispatcher</b> interface
<b>getRequestDispatcher</b> method of <b>ServletRequest</b>	server tier
include content from a resource	<b>ServletContext</b> interface
<b>include</b> method of <b>RequestDispatcher</b>	shopping cart
<b>InitialContext</b> class	style sheet
<b>invalidate</b> method of <b>HttpSession</b>	Web component
J2EE <b>config</b> directory	Web context
Java 2 Enterprise Edition 1.2.1	welcome file
reference implementation	XML
Java API for XML Parsing (JAXP)	XSL transformation

## SELF-REVIEW EXERCISES

**11.1** Fill in the blanks in each of the following statements:

- A three-tier, distributed Web application consists of \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_ tiers.
- The \_\_\_\_\_ is the default document sent as the response to a client when the client initially interacts with a J2EE application.
- The \_\_\_\_\_ enables Enterprise Java application components to access information and resources (such as databases) that are external to an application.
- An \_\_\_\_\_ object provides access to the application's naming environment.
- A **RequestDispatcher** object can \_\_\_\_\_ requests to other resources or \_\_\_\_\_ other resources as part of the current servlet's response.
- Sun's \_\_\_\_\_ provides XML and XSL capabilities in a Java program.
- Method \_\_\_\_\_ of interface \_\_\_\_\_ discards the session object for the current client.
- The \_\_\_\_\_ for an application is the part of the URL that enables the server to determine which application to execute when the server receives a request from a client.
- An Enterprise Java application container must provide a \_\_\_\_\_ that implements JNDI and enables the components executing in that container to perform name lookups to locate resources.
- The J2EE reference implementation comes with a graphical application, called the \_\_\_\_\_, that helps you deploy Enterprise Java applications.

**11.2** State whether each of the following is *true* or *false*. If *false*, explain why.

- The J2EE server uses port 8080 to await client requests.

- b) When deploying applications with the J2EE server, you can launch the Cloudscape and J2EE servers in any order.
- c) **InitialContext** method **lookup** locates a resource with a JNDI name.
- d) Method **lookup** returns a **Connection** object representing the connection to the database.
- e) The Java 2 Enterprise Edition 1.2.1 reference implementation includes the Apache Tomcat JSP and servlet container.
- f) When **RequestDispatcher** method **forward** is called, processing of the request by the current servlet is temporarily suspended to wait for a response from the resource to which the request is forwarded.
- g) Both the **ServletRequest** and the **ServletContext getRequestDispatcher** methods throw exceptions if the argument to **getRequestDispatcher** is not a servlet.
- h) Each resource reference has a corresponding JNDI name that is used by the deployment tool to register the resource with the Java Naming and Directory Service.
- i) If you do not configure your data sources and other resources before deploying an Enterprise Java application, the J2EE server will search the application to determine the resources used and register those resources with the naming server.
- j) Not including the full package directory structure for a class in a package will prevent the application from loading the class and from executing properly.

### ANSWERS TO SELF-REVIEW EXERCISES

**11.1** a) client, server, database. b) welcome file. c) Java Naming and Directory Interface (JNDI). d) **InitialContext**. e) **forward**, **include**. f) Java API for XML Parsing (JAXP). g) **invalidate**, **HttpSession**. h) Web context. i) naming service. j) **Application Deployment Tool**.

- 11.2** a) False. Port 8080 is the default port for the Tomcat server. The J2EE server uses port 8000.
- b) False. To ensure that the J2EE server communicates properly with the Cloudscape server (or any other database server), the database server must be launched before the J2EE server.
- c) True.
- d) False. Method **lookup** returns a **DataSource** object that can be used to obtain a **Connection**.
- e) True.
- f) False. When **RequestDispatcher** method **forward** is called, processing of the request by the current servlet terminates.
- g) False. Both the **ServletRequest** and the **ServletContext getRequestDispatcher** methods simply return the contents of the specified path if the path does not represent a servlet.
- h) True.
- i) False. Before deploying an Enterprise Java application, you must configure your data sources and other resources, so the J2EE server can register those resources with the naming server. Otherwise, exceptions will occur when the application attempts to access the resources.
- j) True.

### EXERCISES

**11.3** Modify the bookstore case study to enable the client to change the quantity of an item currently in the shopping cart. In **viewCart.jsp**, display the quantity in an **input** element of type

**text** in a **form**. Provide the user with a **submit** button with the value **Update Cart** that enables the user to submit the form to a servlet that updates the quantity of the items in the cart. The servlet should forward the request to **viewCart.jsp**, so the user can see the updated cart contents. Redeploy the bookstore application, and test the update capability.

**11.4** Enhance the bookstore case study's **TitlesBean** to obtain author information from the **books** database. Incorporate that author data into the **BookBean** class, and display the author information as part of the Web page users see when they select a book and view that book's information.

**11.5** Add server-side form validation to the order form in the bookstore case study. Check that the credit-card expiration date is after today's date. Make all the fields in the form required fields. When the user does not supply data for all fields, return an XHTML document containing the order form. Any fields in which the user previously entered data should contain that data. For this exercise, replace the **order.html** document with a JSP that generates the form dynamically.

**11.6** Create an **order** table and an **orderItems** table in the **books** database to store orders placed by customers. The **order** table should store an **orderId**, an **orderDate** and the **email** address of the customer who placed the order. [Note: You will need to modify the **form** in Exercise 11.6 to include the customer's e-mail address]. The **orderItems** table should store the **orderId**, **ISBN**, **price** and **quantity** of each book in the order. Modify **process.jsp** so that it stores the order information in the **order** and **orderItems** tables.

**11.7** Create a JSP that enables client to view their order history. Integrate this JSP into the bookstore case study.

**11.8** Create and deploy a single application that allows a user to test all the JSP examples in Chapter 10. The application should have a welcome file that is an XHTML document containing links to each of the examples in Chapter 10.

**11.9** Create and deploy a single application that allows a user to test all the servlets in Chapter 9. The application should have a welcome file that is an XHTML document containing links to each of the examples in Chapter 9.

# 12

## Java-Based Wireless Applications Development and J2ME

### Objectives

- To construct a three-tier, client/server application.
- To use XML and XSLT to present content for several client types.
- To understand the Java 2 Micro Edition (J2ME) Platform.
- To understand the MIDlet lifecycle.
- To be able to use J2ME CLDC and MIDP.
- To understand how our case study incorporates J2ME technology.

*One thing I know: the only ones among you who will be really happy are those who will have sought and found how to serve.*

Albert Schweitzer

*It was a miracle of rare device, ...*

Samuel Taylor Coleridge

*Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it.*

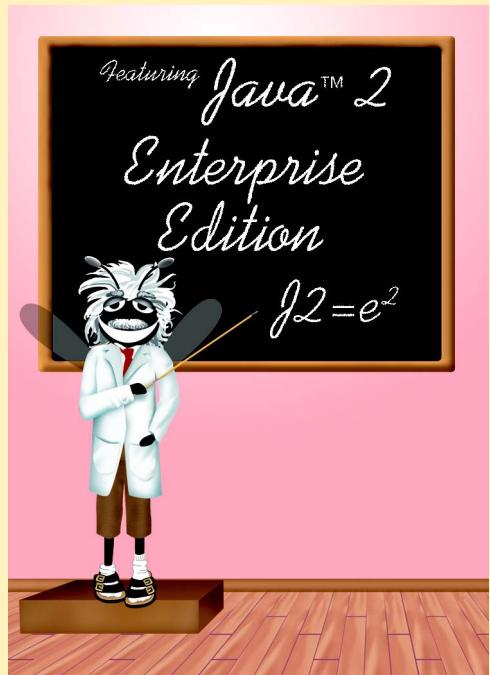
Samuel Johnson

*... all the light I can command must be concentrated on this particular web ...*

George Elliot

*When you can do the common things of life in an uncommon way, you will command the attention of the world.*

George Washington Carver



## Outline

- 12.1 Introduction**
- 12.2 `WelcomeServlet` Overview**
- 12.3 `TipTestServlet` Overview**
  - 12.3.1 Internet Explorer request**
  - 12.3.2 WAP request**
  - 12.3.3 Pixo i-mode request**
  - 12.3.4 J2ME client request**
- 12.4 Java 2 Micro Edition**
  - 12.4.1 Connected Limited Device Configuration (CLDC)**
  - 12.4.2 Mobile Information Device Profile (MIDP)**
  - 12.4.3 `TipTestMIDlet` Overview**
- 12.5 Installation Instructions**
- 12.6 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Bibliography*

### 12.1 Introduction

In this chapter, present a case study of a multiple-choice test (*Tip Test*) for users to test their knowledge of Deitel programming tips. Each question consists of a tip image and a list of four possible answers. A client downloads the test from a server. The user then selects an answer and submits it to the server, which responds with content that describes if the answer is correct or incorrect. The client then can download another question and continue playing indefinitely.

The Tip-Test application is a three-tier architecture, as shown in Fig. 12.1. The information tier consists of a database that contains a table (defined in the SQL script **tips.sql**) with seven rows and five columns. Each row contains information about a Deitel programming tip—Good Programming Practice, Software-Engineering Observation, Performance Tip, Portability Tip, Look-And-Feel Observation, Testing and Debugging Tip and Common Programming Error. The first database column stores integers that represent unique identifiers for each tip. The second column stores the names of the tips. The third column stores the tips’ descriptions—i.e., definitions of each tip and explanations of why each tip is important. The fourth column stores the image names for each tip. The fifth column stores the tips’ abbreviated names—e.g., the abbreviation for Good Programming Practice is GPP. Figure 12.2 shows the contents of **tips.sql**.

The middle tier consists of two servlets—**WelcomeServlet** and **TipTestServlet**. **WelcomeServlet** delivers a “welcome screen” that introduces the game to the user. **WelcomeServlet** then redirects the client to **TipTestServlet**. Using the database, **TipTestServlet** randomly selects a tip image and four possible answers (in the form of abbreviated tip names) and marks up this information as an XML document. **TipTestServlet** then applies an XSL transformation to the XML document and sends the resulting content to the client.

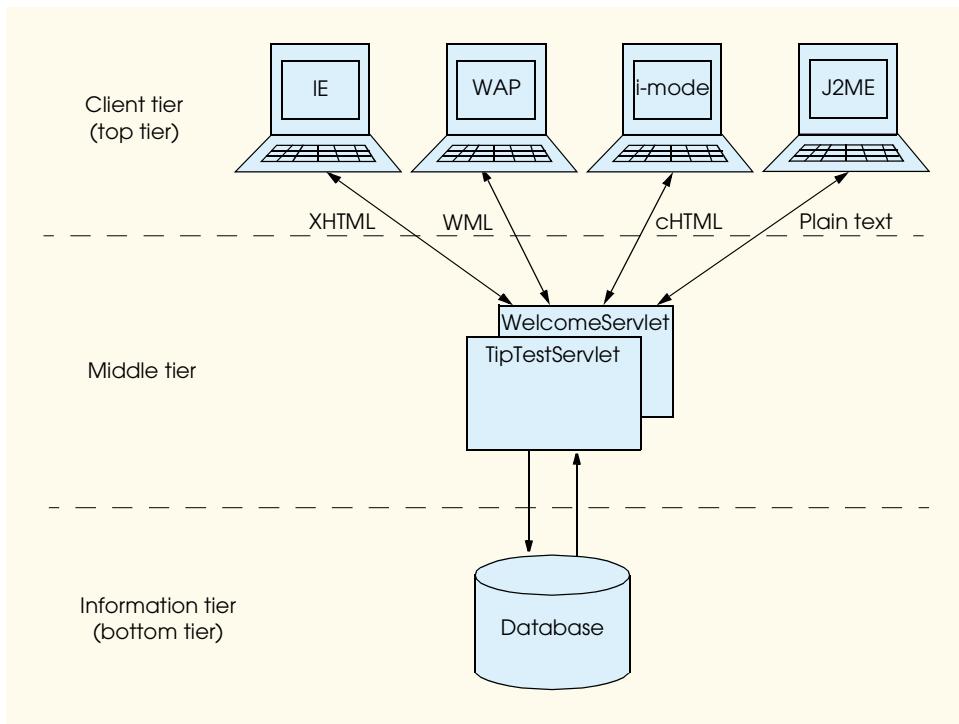


Fig. 12.1 Three-tier architecture for Tip Test.

tipID	tipName	tipDescription	tipImage	shortName
1	Good Programming Practice	Good Programming Practice call the student's attention to techniques that...	goodProgramming	GPP
2	Common Programming Error	Students learning a language tend to make certain kinds of errors...	programmingError	CPE
3	Look-and-Feel Observation	We provide Look-And-Feel Observations to highlight graphical user...	lookAndFeel	LAF
4	Performance Tip	Performance Tips highlight opportunities for improving program performance.	perf	PERF
5	Portability Tip	Organizations that develop software must often produce versions customized...	portability	PORT

Fig. 12.2 Database contents of **tips.sql** (part 1 of 2).

tipID	tipName	tipDescription	tipImage	shortName
6	Software Engineering Observation	The Software Engineering Observations highlight techniques, architectural...	softwareEngineering	SEO
7	Testing and Debugging Tip	Most of these tips tend to be observations about capabilities and features...	testingDebugging	TAD

Fig. 12.2 Database contents of `tips.sql` (part 2 of 2).

The client tier consists of four client types—Internet Explorer, WAP (Wireless Application Protocol), i-mode and J2ME. Each client can render a different content type. **TipTestServlet** handles all game logic—i.e., selecting the Tip-Test question at random and determining if the user’s answer is correct—and sends the content to each client. Microsoft Internet Explorer receives XHTML (Extensible HyperText Markup Language) content. The Openwave UP simulator is the WAP client that receives WML (Wireless Markup Language) content. WAP is a protocol that enables wireless devices to transfer information over the Internet. WML marks up content rendered on the wireless device. The Pixo Internet Microbrowser is the i-mode client that receives cHTML content—i-mode provides a popular Japanese-based wireless Internet service, and cHTML (compact HTML) is an HTML subset for resource-limited devices. The Sun MIDP-device emulator acts as the J2ME client that receives content in plain-text format. J2ME™ (Java™ 2 Micro Edition) is Sun’s newest Java platform for developing applications for various consumer devices, such as set-top boxes, Web terminals, embedded systems, mobile phones and cell pagers. MIDP (Mobile Information Device Profile) is a set of APIs that allows developers to handle mobile-device-specific issues, such as creating user interfaces, storing information locally and networking. Devices that run applications for MIDP are called *MIDP devices* (e.g., cell phones or pagers). We discuss J2ME and MIDP in much greater detail in Section 12.4.

We present this case study by discussing how each servlet sends content to each client type, then how each client type renders that content. Section 12.2 and Section 12.3 discuss how **WelcomeServlet** and **TipTestServlet** handle client requests. Sections 27.3.1–27.3.4 discuss how **TipTestServlet** responds to each client request and how each client renders the servlet-generated content. Lastly, Section 12.4 discusses Java 2 Micro Edition. Our treatment of J2ME focuses on only the client (i.e., our servlets do not use J2ME technology), so we discuss J2ME after we discuss the application’s servlets. Until we discuss Section 12.4, we recommend that you regard the J2ME client as “just another client” that receives servlet-generated content (i.e., you need not know J2ME-related topics to understand servlet behavior). In Section 12.4, we discuss how the J2ME client receives and interprets this content—e.g., how the J2ME client presents this data in a user interface. We also recommend that you follow the instructions in Section 12.5 for installing and configuring the software in this case study.

## 12.2 WelcomeServlet Overview

We begin by discussing class **WelcomeServlet** (Fig. 12.1), which redirects a client request to a static page that displays Tip-Test game instructions—this static page contains a link to the **TipTestServlet**, which enables the user to play the game.

Clients interact with servlets by making **get** or **post** requests to the servlets. Clients send **get** requests to **WelcomeServlet** to get the “welcome screen.” When a client sends a **get** request to **WelcomeServlet**, method **doGet** (lines 15–39) handles the request.

Each client type receives a different welcome screen from the servlet, because each client type supports a different content type. For example, Internet Explorer receives **index.html** as a welcome screen, because Internet Explorer can render XHTML documents. On the other hand, the Openwave UP simulator receives **index.wml**, because a WAP browser can render only WML documents. The Sun MIDP-device emulator can render only plain text, so **WelcomeServlet** sends **index.txt** to this device.<sup>1</sup> The Pixo browser for i-mode can render cHTML (compact-HTML), so the servlet sends a different **index.html** than the one for Internet Explorer.

```
1 // WelcomeServlet.java
2 // Delivers appropriate "Welcome" screen to client
3 package com.deitel.advjhtp1.wireless;
4
5 // Java core package
6 import java.io.*;
7
8 // Java extension packages
9 import javax.servlet.*;
10 import javax.servlet.http.*;
11
12 public class WelcomeServlet extends HttpServlet {
13
14     // respond to get request
15     protected void doGet( HttpServletRequest request,
16                           HttpServletResponse response )
17                           throws ServletException, IOException
18     {
19         // determine User-Agent header
20         String userAgent = request.getHeader( "User-Agent" );
21
22         // send welcome screen to appropriate client
23         if ( userAgent.indexOf(
24             ClientUserAgentHeaders.IE ) != -1 )
25             sendIEClientResponse( request, response );
26
27         else if ( userAgent.indexOf( // WAP
28             ClientUserAgentHeaders.WAP ) != -1 )
29             sendWAPClientResponse( request, response );
30     }
31 }
```

Fig. 12.3 Class **WelcomeServlet** sends an introductory screen that provides game directions to a client (part 1 of 3).

1. At the time of this writing, J2ME clients can interpret XML documents only by using proprietary software—i.e., there does not exist a standard for J2ME clients to integrate XML.

```
30
31     else if ( userAgent.indexOf( // i-mode
32             ClientUserAgentHeaders.IMODE ) != -1 )
33         sendIModeClientResponse( request, response );
34
35     else if ( userAgent.indexOf( // J2ME
36             ClientUserAgentHeaders.J2ME ) != -1 )
37         sendJ2MEClientResponse( request, response );
38
39 } // end method doGet
40
41 // send welcome screen to IE client
42 private void sendIEClientResponse(
43     HttpServletRequest request, HttpServletResponse response )
44     throws IOException, ServletException
45 {
46     redirect( "text/html", "/XHTML/index.html", request,
47             response );
48 }
49
50 // send welcome screen to Nokia WAP client
51 private void sendWAPClientResponse(
52     HttpServletRequest request, HttpServletResponse response )
53     throws IOException, ServletException
54 {
55     redirect( "text/vnd.wap.wml", "/WAP/index.wml", request,
56             response );
57 }
58
59 // send welcome screen to i-mode client
60 private void sendIModeClientResponse(
61     HttpServletRequest request, HttpServletResponse response )
62     throws IOException, ServletException
63 {
64     redirect( "text/html", "/iMode/index.html", request,
65             response );
66 }
67
68 // send welcome screen to J2ME client
69 private void sendJ2MEClientResponse(
70     HttpServletRequest request, HttpServletResponse response )
71     throws IOException
72 {
73     // send J2ME client text data
74     response.setContentType( "text/plain" );
75     PrintWriter out = response.getWriter();
76
77     // open file to send J2ME client
78     BufferedReader bufferedReader =
79         new BufferedReader( new FileReader(
80             getServletContext().getRealPath(
81                 "j2me/index.txt" ) ) );
```

Fig. 12.3 Class **WelcomeServlet** sends an introductory screen that provides game directions to a client (part 2 of 3).

```

82     String inputString = bufferedReader.readLine();
83
84     // send each line in file to J2ME client
85     while ( inputString != null ) {
86         out.println( inputString );
87         inputString = bufferedReader.readLine();
88     }
89
90
91     out.close(); // done sending data
92
93 } // end method sendJ2MEClientResponse
94
95 // redirects client request to another page
96 private void redirect( String contentType, String redirectPage,
97     HttpServletRequest request, HttpServletResponse response )
98     throws IOException, ServletException
99 {
100     // set new content type
101     response.setContentType( contentType );
102     RequestDispatcher dispatcher =
103         getServletContext().getRequestDispatcher(
104             redirectPage );
105
106     // forward user to redirectPage
107     dispatcher.forward( request, response );
108 }
109 }
```

**Fig. 12.3** Class **WelcomeServlet** sends an introductory screen that provides game directions to a client (part 3 of 3).

Before responding to a client, method **doGet** must determine what type of client made the request. Each client includes a **User-Agent header** with each request. This header contains information on the type of client requesting data from the server. Interface **ClientUserAgentHeaders** (Fig. 12.4) lists a unique **User-Agent** header substring for each client in our application. For example, a **User-Agent** header for Microsoft Internet Explorer running on Windows 2000 might be

```
Mozilla/4.0 (compatible; MSIE 5.0; Windows NT 5.0)
```

We search for the substring "**MSIE 5**" in the **User-Agent** header to recognize Internet Explorer requests from different platforms. Also, **WelcomeServlet** will recognize variance among other versions of Internet Explorer 5 (e.g., v.5.0, v.5.5, etc.). For example, the **User-Agent** header for a Windows 98 client might not be identical to the one shown, but the header will contain the "**MSIE 5**" substring.

Line 20 of class **WelcomeServlet** extracts the **User-Agent** header from the **HttpServletRequest**. Lines 23–37 determine which client made the request by matching the **User-Agent** header with the ones in interface **ClientUserAgentHeaders**. If an Internet Explorer browser made the request, line 25 invokes method **sendIEClientResponse** (lines 42–48). Lines 46–47 calls method **redirect** (lines 96–108), which redirects the request to a static page. For Internet Explorer, line 101 calls

```

1 // ClientUserAgentHeaders.java
2 // Contains all User-Agent header for clients
3 package com.deitel.advjhttp1.wireless;
4
5 public interface ClientUserAgentHeaders {
6
7     // User-Agent header for Internet Explorer browser
8     public static final String IE = "MSIE 5";
9
10    // User-Agent header for WAP browser
11    public static final String WAP = "UP";
12
13    // User-Agent header for i-mode browser
14    public static final String IMODE = "Pixo";
15
16    // User-Agent header for J2ME device
17    public static final String J2ME = "MIDP-1.0";
18 }

```

Fig. 12.4 Interface **ClientUserAgentHeaders** contains unique User-Agent header substrings for all clients.

method **setContentType** of the **HttpServletResponse** object to set the *MIME* type to **text/html**—the MIME type for XHTML clients. The *MIME type (Multipurpose Internet Mail Extensions)* helps browsers determine how to interpret data. Lines 102–107 redirect the request to **index.html** by creating a **RequestDispatcher** object with the name of the static page and invoking method **forward** of the **RequestDispatcher**. The IE browser then displays **index.html** (Fig. 12.5).

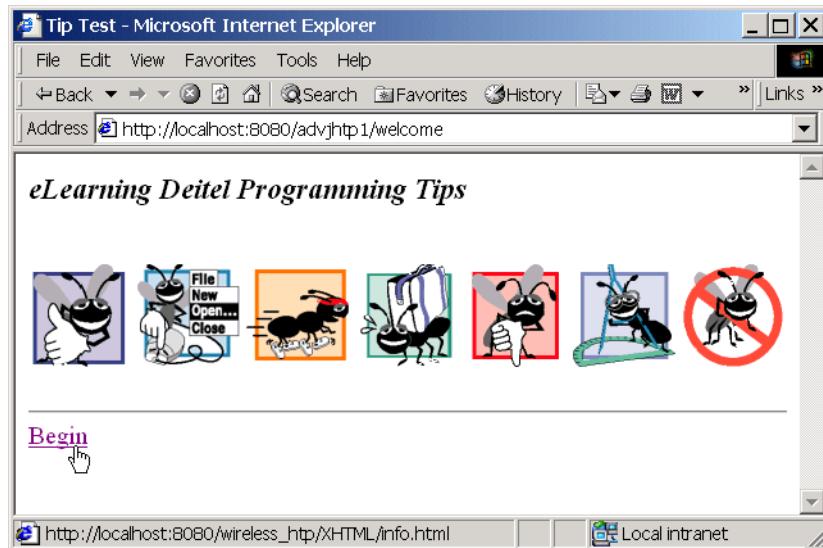


Fig. 12.5 **WelcomeServlet** output (**index.html**) for XHTML client.

If the Openwave UP simulator made the request, line 29 invokes method **sendWAPClientResponse** (lines 51–57), which invokes method **redirect** with the MIME type to **text/vnd.wap.wml**—the MIME type for WML clients—and redirects the request to **index.wml**. At this point, the simulator displays **index.wml**, as shown in Fig. 12.6.

If the Pixo i-mode browser made the request, line 33 invokes method **sendIModeClientResponse** (lines 60–66). This method also invokes method **redirect**, but sets the MIME type to **text/html**—the MIME type for cHTML clients—and redirects the request to a cHTML version of **index.html**. At this point, the Pixo browser displays **index.html**, as shown in Fig. 12.7.

If the Sun MIDP-device emulator made the request, line 37 invokes method **sendJ2MEClientResponse** (lines 69–93). To transfer **index.txt** to the J2ME client, the servlet must send **index.txt** through a stream between the servlet and the J2ME client. Line 74 sets the MIME type to **text/plain**. Line 75 invokes method **getWriter** of class **HttpServletResponse** to obtain a **PrintWriter** for sending data to the client. Lines 78–81 create a **BufferedReader** that reads **index.txt** from the **j2me** directory located in the servlet context. Lines 86–89 send each line from **BufferedReader** to the client. At this point, Sun’s emulator displays **index.txt**, as shown in Fig. 12.8.



Fig. 12.6 **WelcomeServlet** output (**index.wml**) for WAP client. (Image of UP.SDK courtesy Openwave Systems Inc. Openwave, the Openwave logo, and UP.SDK are trademarks of Openwave Systems Inc. All rights reserved.)



Fig. 12.7 **WelcomeServlet** output (**index.html**) for i-mode client.  
(Courtesy of Pixo, Inc.)



Fig. 12.8 **WelcomeServlet** output (**index.txt**) for J2ME client. (Courtesy of Sun Microsystems, Inc.)

## 12.3 TipTestServlet Overview

In this section, we discuss how the **TipTestServlet** (Fig. 12.9) generates and sends Tip-Test questions and answers to each client. Each welcome screen contains a link to an “instructions” screen—**info.html**, **info.wml** or **info.txt**, depending on the client—that provides game information. The instructions screen contains a link to **TipTestServlet**.<sup>2</sup>

If the user accesses **TipTestServlet** and the servlet has not received a previous request from a client, the servlet container calls method **init** (lines 30–67) to initialize **TipTestServlet**. This method performs operations that **TipTestServlet** need only perform once, such as loading the JDBC driver, connecting to the database and instantiating objects for creating XML documents. Lines 36–38 retrieve the class name for the JDBC-database driver from the servlet-initialization parameter in **web.xml** (which we discussed when we installed Tomcat), and line 40 loads this driver.

```

1 // TipTestServlet.java
2 // TipTestServlet sends Tip Test to clients.
3 package com.deitel.advjhtp1.wireless;
4
5 // Java core packages
6 import java.io.*;
7 import java.sql.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.*;
12 import javax.servlet.http.*;
13 import javax.xml.parsers.*;
14 import javax.xml.transform.*;
15 import javax.xml.transform.dom.*;
16 import javax.xml.transform.stream.*;
17
18 // import third-party packages
19 import org.w3c.dom.*;
20 import org.xml.sax.SAXException;
21
22 public class TipTestServlet extends HttpServlet {
23
24     private Connection connection; // database connection
25
26     private DocumentBuilderFactory factory;
27     private TransformerFactory transformerFactory;
28
29     // initialize servlet
30     public void init() throws ServletException
31     {

```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 1 of 13).

- 
2. The client is not required to access **TipTestServlet** through **WelcomeServlet**. The user can type the **TipTestServlet** URL in the browser to access **TipTestServlet** and bypass the “welcome screen” that **WelcomeServlet** generates.

```
32     // load database driver and instantiate XML factories
33     try {
34
35         // get JDBC driver from servlet container
36         String jdbcDriver =
37             getServletConfig().getInitParameter(
38                 "JDBC_DRIVER" );
39
40         Class.forName( jdbcDriver ); // load JDBC driver
41
42         // get database URL from servlet container
43         String databaseUrl =
44             getServletConfig().getInitParameter(
45                 "DATABASE_URL" );
46
47         connection = DriverManager.getConnection( databaseUrl );
48
49         // create a Factory to build XML Documents
50         factory = DocumentBuilderFactory.newInstance();
51
52         // create new TransformerFactory
53         transformerFactory = TransformerFactory.newInstance();
54
55     } // end try
56
57     // handle exception database driver class does not exist
58     catch ( ClassNotFoundException classNotFoundException ) {
59         classNotFoundException.printStackTrace();
60     }
61
62     // handle exception in making Connection
63     catch ( SQLException sqlException ) {
64         sqlException.printStackTrace();
65     }
66
67 } // end method init
68
69 // respond to get requests
70 protected void doGet( HttpServletRequest request,
71     HttpServletResponse response )
72     throws ServletException, IOException
73 {
74     // get Statement from database, then send Tip-Test Question
75     try {
76
77         // SQL query to database
78         Statement statement = connection.createStatement();
79
80         // get database information using SQL query
81         ResultSet resultSet =
82             statement.executeQuery( "SELECT * FROM tipInfo" );
83 }
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 2 of 13).

```
84      // parse and send ResultSet to client
85      if ( resultSet != null ) {
86
87          // ensure that client does not cache questions
88          response.setHeader( "Cache-Control",
89              "no-cache, must-revalidate" );
90          response.setHeader( "Pragma", "no-cache" );
91
92          sendTipTestQuestion( request, response, resultSet );
93      }
94
95      statement.close(); // close Statement
96  }
97
98      // handle exception in executing Statement
99      catch ( SQLException sqlException ) {
100         sqlException.printStackTrace();
101     }
102
103 } // end method doGet
104
105 // respond to post requests
106 protected void doPost( HttpServletRequest request,
107   HttpServletResponse response )
108   throws ServletException, IOException
109 {
110     // send ResultSet to appropriate client
111     try {
112
113         // determine User-Agent header
114         String userAgent = request.getHeader( "User-Agent" );
115
116         // if Internet Explorer is requesting client
117         if ( userAgent.indexOf(
118             ClientUserAgentHeaders.IE ) != -1 ) {
119
120             Document document =
121               createXMLTipTestAnswer( request );
122
123             // set appropriate Content-Type for client
124             response.setContentType( "text/html" );
125
126             // send XML content to client after XSLT
127             applyXSLT( "XHTML/XHTMLTipAnswer.xsl", document,
128                         response );
129         }
130
131         // if WAP client is requesting client
132         else if ( userAgent.indexOf(
133             ClientUserAgentHeaders.WAP ) != -1 ) {
134 }
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 3 of 13).

```
135         Document document =
136             createXMLTipTestAnswer( request );
137
138         // set appropriate Content-Type for client
139         response.setContentType( "text/vnd.wap.wml" );
140
141         // send XML content to client after XSLT
142         applyXSLT( "WAP/WAPTipAnswer.xsl", document,
143             response );
144     }
145
146     // if i-mode client is requesting client
147     else if ( userAgent.indexOf(
148         ClientUserAgentHeaders.IMODE ) != -1 ) {
149
150         Document document =
151             createXMLTipTestAnswer( request );
152
153         // set appropriate Content-Type for client
154         response.setContentType( "text/html" );
155
156         // send XML content to client after XSLT
157         applyXSLT( "iMode/IMODETipAnswer.xsl", document,
158             response );
159     }
160
161     // if J2ME client is requesting client
162     else if ( userAgent.indexOf(
163         ClientUserAgentHeaders.J2ME ) != -1 )
164         sendJ2MEAnswer( request, response );
165
166 } // end try
167
168 // handle exception if Document is null
169 catch ( NullPointerException nullPointerException ) {
170     nullPointerException.printStackTrace();
171 }
172
173 } // end method doPost
174
175 // send Tip-Test data to client
176 private void sendTipTestQuestion(
177     HttpServletRequest request, HttpServletResponse response,
178     ResultSet resultSet ) throws IOException
179 {
180     // send ResultSet to appropriate client
181     try {
182
183         // determine User-Agent header
184         String userAgent = request.getHeader( "User-Agent" );
185 }
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 4 of 13).

```

186         // if Internet Explorer is requesting client
187         if ( userAgent.indexOf(
188             ClientUserAgentHeaders.IE ) != -1 ) {
189
190             Document document =
191                 createXMLTipTestQuestion( resultSet, request,
192                     request.getContextPath() + "/XHTML/images/",
193                     ".gif" );
194
195             // set appropriate Content-Type for client
196             response.setContentType( "text/html" );
197             applyXSLT( "XHTML/XHTMLOpQuestion.xsl", document,
198                     response );
199
200
201         // if WAP client is requesting client
202         else if ( userAgent.indexOf(
203             ClientUserAgentHeaders.WAP ) != -1 ) {
204
205             Document document =
206                 createXMLTipTestQuestion( resultSet, request,
207                     request.getContextPath() + "/WAP/images/",
208                     ".wbmp" );
209
210             // set appropriate Content-Type for client
211             response.setContentType( "text/vnd.wap.wml" );
212             applyXSLT( "WAP/WAPTipQuestion.xsl", document,
213                     response );
214
215
216         // if i-mode client is requesting client
217         else if ( userAgent.indexOf(
218             ClientUserAgentHeaders.IMODE ) != -1 ) {
219
220             Document document =
221                 createXMLTipTestQuestion( resultSet, request,
222                     request.getContextPath() + "/iMode/images/",
223                     ".gif" );
224
225             // set appropriate Content-Type for client
226             response.setContentType( "text/html" );
227             applyXSLT( "iMode/IMODETipQuestion.xsl", document,
228                     response );
229
230
231         // if J2ME client is requesting client
232         else if ( userAgent.indexOf(
233             ClientUserAgentHeaders.J2ME ) != -1 )
234             sendJ2MEClientResponse( resultSet, request,
235                     response );
236
237     } // end try

```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 5 of 13).

```
238
239     // handle exception if Document is null
240     catch ( NullPointerException nullPointerException ) {
241         nullPointerException.printStackTrace();
242     }
243
244 } // end method sendTipTestQuestion
245
246 // send Tip Test to Internet Explorer client
247 private Document createXMLTipTestQuestion(
248     ResultSet resultSet, HttpServletRequest request,
249     String imagePrefix, String imageSuffix )
250     throws IOException
251 {
252     // convert ResultSet to two-dimensional String array
253     String resultTable[][] = getResultTable( resultSet );
254
255     // create random-number generator
256     Random random = new Random( System.currentTimeMillis() );
257
258     // create 4 random tips
259     int randomRow[] = getRandomIndices( random );
260
261     // randomly determine correct index from 4 random indices
262     int correctAnswer = Math.abs( random.nextInt() ) %
263         randomRow.length;
264
265     int correctRow = randomRow[ correctAnswer ];
266
267     // open new session
268     HttpSession session = request.getSession();
269
270     // store correct answer in session
271     session.setAttribute( "correctAnswer",
272         new Integer( correctAnswer ) );
273
274     // store correct tip name
275     session.setAttribute( "correctTipName", new String(
276         resultTable[ correctRow ][ 1 ] ) );
277
278     // store correct tip description
279     session.setAttribute( "correctTipDescription", new String(
280         resultTable[ correctRow ][ 2 ] ) );
281
282     // determine image to send client
283     String imageName = imagePrefix +
284         resultTable[ correctRow ][ 3 ] + imageSuffix;
285
286     // create XML document based on randomly determined info
287     try {
288
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 6 of 13).

```
289         // create document
290         DocumentBuilder builder = factory.newDocumentBuilder();
291         Document document = builder.newDocument();
292
293         // create question root Element
294         Element root = document.createElement( "question" );
295         document.appendChild( root );
296
297         // append Element image, which references image name
298         Element image = document.createElement( "image" );
299         image.appendChild(
300             document.createTextNode( imageName ) );
301         root.appendChild( image );
302
303         // create choices Element to hold 4 choice Elements
304         Element choices = document.createElement( "choices" );
305
306         // append 4 choice Elements that represent user choices
307         for ( int i = 0; i < randomRow.length; i++ )
308         {
309             // determine choice Elements from resultTable
310             Element choice = document.createElement( "choice" );
311             choice.appendChild( document.createTextNode(
312                 resultTable[ randomRow[ i ] ][ 4 ] ) );
313
314             // set choice Element as correct or incorrect
315             Attr attribute =
316                 document.createAttribute( "correct" );
317
318             if ( i == correctAnswer )
319                 attribute.setValue( "true" );
320             else
321                 attribute.setValue( "false" );
322
323             // append choice Element to choices Element
324             choice.setAttributeNode( attribute );
325             choices.appendChild( choice );
326         }
327
328         root.appendChild( choices );
329
330         return document;
331
332     } // end try
333
334     // handle exception building Document
335     catch ( ParserConfigurationException parserException ) {
336         parserException.printStackTrace();
337     }
338
339     return null;
340 }
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 7 of 13).

```
341     } // end method createXMLTipTestQuestion
342
343     // send tip test to J2ME client
344     private void sendJ2MEClientResponse( ResultSet resultSet,
345             HttpServletRequest request,
346             HttpServletResponse response ) throws IOException
347     {
348         // convert ResultSet to two-dimensional String array
349         String resultTable[][] = getResultTable( resultSet );
350
351         // create random-number generator
352         Random random = new Random( System.currentTimeMillis() );
353
354         // create 4 random tips
355         int randomRow[] = getRandomIndices( random );
356
357         // randomly determine correct index from 4 random indices
358         int correctAnswer = Math.abs( random.nextInt() ) %
359             randomRow.length;
360
361         int correctRow = randomRow[ correctAnswer ];
362
363         // open old session
364         HttpSession session = request.getSession();
365
366         // store correct answer in session
367         session.setAttribute( "correctAnswer",
368             new Integer( correctAnswer ) );
369
370         // store correct tip name in session
371         session.setAttribute( "correctTipName", new String(
372             resultTable[ correctRow ][ 1 ] ) );
373
374         // store correct tip description in session
375         session.setAttribute( "correctTipDescription", new String(
376             resultTable[ correctRow ][ 2 ] ) );
377
378         // send J2ME client image name
379         String imageName = "/j2me/images/" +
380             resultTable[ correctRow ][ 3 ] + ".png";
381
382         response.setContentType( "text/plain" );
383         PrintWriter out = response.getWriter();
384         out.println( imageName );
385
386         // send J2ME client test
387         for ( int i = 0; i < randomRow.length; i++ )
388             out.println( resultTable[ randomRow[ i ] ][ 4 ] );
389
390     } // end method sendJ2MEClientResponse
391
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 8 of 13).

```
392 // convert ResultSet to two-dimensional String array
393 private String[][] getResultTable( ResultSet resultSet )
394 {
395     // create table of Strings to store ResultSet
396     String resultTable[][] = new String[ 7 ][ 5 ];
397
398     for ( int i = 0; i < 7; i++ ) {
399
400         for ( int j = 0; j < 5; j++ )
401             resultTable[ i ][ j ] = "";
402     }
403
404     // store all columns in table
405     try {
406
407         // for each row in resultSet
408         for ( int row = 0; resultSet.next(); row++ ) {
409
410             // for each column in resultSet
411             for ( int column = 0; column < 5; column++ ) {
412
413                 // store resultSet element in resultTable
414                 resultTable[ row ][ column ] +=
415                     resultSet.getObject( column + 1 );
416             }
417         }
418     }
419
420     // handle exception if servlet cannot get ResultSet Object
421     catch ( SQLException sqlException ) {
422         sqlException.printStackTrace();
423         return null;
424     }
425
426     return resultTable;
427
428 } // end method getResultTable
429
430 // get 4 randomly generated indices from resultTable
431 private int[] getRandomIndices( Random random )
432 {
433     // create list containing row indices for resultTable
434     int list[] = new int[ 7 ];
435
436     for ( int i = 0; i < list.length; i++ )
437         list[ i ] = i;
438
439     int randomRow[] = new int[ 4 ];
440
441     // select 4 randomly generated indices from list
442     for ( int i = 0; i < randomRow.length; i++ )
443         randomRow[ i ] = getRandomRow( list, random );
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 9 of 13).

```
444     return randomRow; // return these indices
445
446 } // end method getRandomIndices
447
448 // get random element from list, then nullify element
449 private int getRandomRow( int list[], Random random )
450 {
451     // get random element from list
452     int randomRow = Math.abs( random.nextInt() ) % list.length;
453
454     while ( list[ randomRow ] < 0 )
455         randomRow = Math.abs( random.nextInt() ) % list.length;
456
457     list[ randomRow ] = -1; // nullify element
458
459     return randomRow;
460
461 } // end method getRandomRow
462
463
464 // apply XSLT style sheet to XML document
465 private void applyXSLT( String xslFile,
466     Document xmlDocument, HttpServletResponse response )
467     throws IOException
468 {
469     // apply XSLT
470     try {
471
472         // open InputStream for XSL document
473         InputStream xslStream =
474             getServletContext().getResourceAsStream( xslFile );
475
476         // create StreamSource for XSLT document
477         Source xslSource = new StreamSource( xslStream );
478
479         // create DOMSource for source XML document
480         Source xmlSource = new DOMSource( xmlDocument );
481
482         // get PrintWriter for writing data to client
483         PrintWriter output = response.getWriter();
484
485         // create StreamResult for transformation result
486         Result result = new StreamResult( output );
487
488         // create Transformer for XSL transformation
489         Transformer transformer =
490             transformerFactory.newTransformer( xslSource );
491
492         // transform and deliver content to client
493         transformer.transform( xmlSource, result );
494
495     } // end try
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 10 of 13).

```
496
497     // handle exception transforming content
498     catch ( TransformerException exception ) {
499         exception.printStackTrace();
500     }
501
502 } // end method applyXSLT
503
504 // create XML Document that stores Tip Test answer
505 private Document createXMLTipTestAnswer(
506     HttpServletRequest request ) throws IOException
507 {
508     // get session
509     HttpSession session = request.getSession();
510
511     // match correct answer with session answer
512     Integer integer =
513         ( Integer ) session.getAttribute( "correctAnswer" );
514     int correctAnswer = integer.intValue();
515
516     // give client correct tip name and description
517     String correctTipName =
518         ( String ) session.getAttribute( "correctTipName" );
519
520     String correctTipDescription =
521         ( String ) session.getAttribute(
522             "correctTipDescription" );
523
524     // get user selection
525     int selection = Integer.parseInt(
526         request.getParameter( "userAnswer" ) );
527
528     String answer;
529
530     // determine if user answer is correct
531     if ( correctAnswer == selection )
532         answer = "Correct";
533     else
534         answer = "Incorrect";
535
536     // get link to TipTestServlet
537     String servletName = request.getContextPath() + "/" +
538         getServletConfig().getServletName();
539
540     // create XML document based on randomly determined info
541     try {
542
543         // create document
544         DocumentBuilder builder = factory.newDocumentBuilder();
545         Document document = builder.newDocument();
546
547     }
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 11 of 13).

```
547         // create question root Element
548         Element root = document.createElement( "answer" );
549         document.appendChild( root );
550
551         // append Element that informs client of correct answer
552         Element correct = document.createElement( "correct" );
553         correct.appendChild(
554             document.createTextNode( answer ) );
555         root.appendChild( correct );
556
557         // append Element that describes tip name
558         Element name =
559             document.createElement( "correctTipName" );
560         name.appendChild(
561             document.createTextNode( correctTipName ) );
562         root.appendChild( name );
563
564         // append Element that describes tip description
565         Element description =
566             document.createElement( "correctTipDescription" );
567         description.appendChild(
568             document.createTextNode( correctTipDescription ) );
569         root.appendChild( description );
570
571         // append Element that links to TipTestServlet
572         Element servletLink =
573             document.createElement( "servletName" );
574         servletLink.appendChild(
575             document.createTextNode( servletName ) );
576         root.appendChild( servletLink );
577
578         return document;
579
580     } // end try
581
582     // handle exception building Document
583     catch ( ParserConfigurationException parserException ) {
584         parserException.printStackTrace();
585     }
586
587     return null;
588
589 } // end method createXMLTipTestAnswer
590
591 // send answer to J2ME client
592 private void sendJ2MEAnswer( HttpServletRequest request,
593     HttpServletResponse response ) throws IOException
594 {
595     // get client test response
596     BufferedReader in = request.getReader();
597     int selection = Integer.parseInt( in.readLine().trim() );
598 }
```

Fig. 12.9 **TipTestServlet** handles game logic and sends Tip Test to clients (part 12 of 13).

```

599     // send J2ME client text data
600     response.setContentType( "text/plain" );
601     PrintWriter out = response.getWriter();
602
603     // inform client whether client is correct or incorrect
604     HttpSession session = request.getSession();
605
606     // match correct answer with session answer
607     Integer integer =
608         ( Integer ) session.getAttribute( "correctAnswer" );
609     int correctAnswer = integer.intValue();
610
611     // send correct tip name and description
612     String correctTipName =
613         ( String ) session.getAttribute( "correctTipName" );
614
615     String correctTipDescription =
616         ( String ) session.getAttribute(
617             "correctTipDescription" );
618
619     // determine whether answer is correct
620     if ( selection == correctAnswer )
621         out.println( "Correct" );
622     else
623         out.println( "Incorrect" );
624
625     // give client correct tip name and description
626     out.println( correctTipName );
627     out.println( correctTipDescription );
628
629 } // end method sendJ2MEAnswer
630
631 // invoked when servlet is destroyed
632 public void destroy()
633 {
634     // close database connection
635     try {
636         connection.close();
637     }
638
639     // handle if connection cannot be closed
640     catch ( SQLException sqlException ) {
641         sqlException.printStackTrace();
642     }
643
644 } // end method destroy
645 }
```

**Fig. 12.9** **TipTestServlet** handles game logic and sends Tip Test to clients (part 13 of 13).

Using method **getInitParameter** in line 37 allows us to specify the database outside the servlet—we can change the database (e.g., change from Cloudscape to mySQL) by

modifying the `<param-value>` element in the `<init-param>` element in `web.xml`, without having to recompile the servlet. For this case study, this element contains

```
<init-param>
    <param-name>JDBC_DRIVER</param-name>
    <param-value>
        COM.cloudscape.core.RmiJdbcDriver
    </param-value>
</init-param>
```

Lines 43–45 retrieve the database URL from `web.xml`, and line 47 makes the connection to this URL—note that method `destroy` (lines 632–644) closes this connection. If we decide to change the location of the database, we need only to modify the `<param-value>` element in a separate `<init-param>` element in `web.xml`. For this case study, this element contains

```
<init-param>
    <param-name>DATABASE_URL</param-name>
    <param-value>jdbc:cloudscape:rmi:tips</param-value>
</init-param>
```

Lines 50–53 create objects that we use later to build XML **Documents** and use **Transformers** to apply XSLTs. We discuss XML-related Java packages later in this section.

**TipTestServlet** calls method `doGet` (lines 70–103) to handle the `get` request. Line 78 creates a **Statement** from the **Connection** instantiated in method `init`. Lines 81–82 obtain a **ResultSet** of all database elements from this **Statement**. As discussed in the introduction, our database (the **ResultSet**) contains seven rows and five columns—resulting in 35 **String** objects. Lines 88–90 set the **HttpServletResponse**'s header so the client will not cache the information that **TipTestServlet** sends. Line 92 calls method `sendTipTestQuestion` (lines 176–244) to perform the game logic and send the client the Tip-Test question. Line 184 extracts the **User-Agent** header from the **HttpServletRequest**. Lines 187–235 determine which client made the request by matching the **User-Agent** header with those in interface **ClientUserAgentHeaders**. This client-determination process is identical to the one in **WelcomeServlet**.

Until this point in execution, the servlet has behaved identically for all client requests. Now, **TipTestServlet** performs different operations based on the type of client making the request. These operations are almost identical among the Internet Explorer, Openwave UP simulator and the Pixo i-mode browser. The servlet's operations for the J2ME client differ from that of the other three clients, because the J2ME client cannot interpret XML documents without using non-standard software (although this is likely to change in the future). We now trace the servlet's behavior for each client type's request. We begin discussing **TipTestServlet**'s behavior for an Internet Explorer request. Next, we discuss the servlet's behavior for a Openwave UP simulator request. We then discuss the servlet's behavior for a Pixo i-mode browser request. Finally, we discuss the servlet's behavior for a Sun MIDP-device client request.

### 12.3.1 Internet Explorer request

If Internet Explorer sent the request, lines 190–193 invoke method `createXMLTipTestQuestion` (lines 247–341), which creates and returns an XML **Document** that

contains the Tip-Test question. Interface **Document** of package **org.w3c.dom** represents an XML document's top-level node, which provides access to all the document's nodes. Line 253 calls method **getResultSetTable** (lines 393–428), which converts the **ResultSet** into a two-dimensional array of **Strings**. We use this method so we have an easier time accessing individual elements of the **ResultSet** through an array. Lines 396–402 instantiate this array, and lines 408–417 transfer the **ResultSet** content to the array.

When method **getResultSetTable** returns the **String** array, line 256 creates a **Random** object that enables **TipTestServlet** to select the tip image and possible answers randomly. Line 259 passes a reference to the **Random** object to method **getRandomIndices** (lines 431–447), which returns an array of four integers. Each integer is a distinct, random index that corresponds to a tip in the two-dimensional **String** array that method **getResultSetTable** generated. Lines 434–437 create an array of seven integers called **list**—each integer represents that integer's index in the array (i.e., **list[0] = 0, list[1] = 1**, etc.). Line 439 creates an empty array of four integers that correspond to the four possible tip answers. Lines 442–443 invoke method **getRandomRow** (lines 450–462) for each element in the four-integer array. Line 453 select an integer at random from the seven-integer array. If the integer has been selected previously—indicated by a **-1** value—lines 455–456 select an integer that has not been selected. If the integer has not been selected previously, line 458 nullifies this array element by setting that element to **-1**. Nullifying this element ensures that method **getRandomRow** will not return duplicate integers. Line 460 returns the integer.

Array **randomRow** contains four distinct integers that correspond to tips in **resultTable**. Lines 262–263 randomly select an integer from **randomRow**. This integer indicates the “correct” answer in the game—specifically, this integer represents the **resultTable** row that holds the information for the correct tip (line 265). **TipTestServlet** stores this information in an **HttpSession** object (line 268), so when the client sends the user's selection back to **TipTestServlet**, **TipTestServlet** can check this selection against the correct answer stored in the **HttpSession** object. An **HttpSession** object acts like a cookie—both can store name/value pairs. In session terminology, these pairs are called *attributes*. We may store attributes in an **HttpSession** object with method **setAttribute**. Lines 271–280 store the correct answer, tip name and tip description in the **HttpSession** object. Using the correct answer and parameters **imagePrefix** and **imageSuffix** of method **createXMLTipTestQuestion**, lines 283–284 determine the proper image to send to the client.

At this point, **TipTestServlet** has determined the Tip-Test question (the image and four possible answers) to send the client. We now explain how **TipTestServlet** marks up this data as an XML **Document**, applies an XSL transformation to this **Document**, then sends the resulting document to the client.

Lines 290–328 mark up the Tip-Test question as an XML **Document**, which represents an XML document and provides a means for creating and retrieving its nodes. Line 290 creates a **DocumentBuilder** using the **DocumentBuilderFactory** instantiated in method **init**. Line 291 creates an XML **Document** using the **DocumentBuilder**.

Class **Element** represents an element node in an XML document. A **Document** creates an **Element** with method **createElement**. Lines 294–295 create **Element question** and assign it as the root **Element** in the **Document**. Lines 298–301 create **Element image** from the correct tip's image and assign **Element image** as a child of

**Element question.** Line 304 creates **Element choices**, which hold the four **choice Elements** created on lines 307–326. Each **choice Element** represents a possible answer for the question. Lines 315–324 include an attribute that specifies whether the choice is **correct** or **incorrect**—obviously, only one attribute specifies a value of **correct**. Line 325 appends the **choice Elements** to **Element choices**, and line 328 appends **choices** to root **Element question**.

When method **createXMLTipTestQuestion** returns the XML **Document**, **TipTestServlet** must apply an XSLT to this **Document** and send the result of the transformation to the client. Line 124 sets the **HttpServletResponse**'s MIME type to **text/html**, because the XSL transformation generates an XHTML document. Lines 127–128 call method **applyXSLT** (465–502) to apply **XHTMLOutputQuestion.xsl** (Fig. 12.10) to the XML **Document**. Lines 473–474 open an **InputStream** for **XHTMLOutputQuestion.xsl**. Line 477 creates a **StreamSource** from this **InputStream** for the XSL document. Line 480 creates a **DOMSource** for the XML **Document**. Line 486 creates a **Result** for the resulting transformation—in this case, an XHTML document. **TipTestServlet** uses a **PrintWriter** to create the **Result**, so **TipTestServlet** will send the resulting transformation directly to the client. Lines 489–490 create a **Transformer** using the XSL **StreamSource** and the **TransformerFactory** (instantiated in method **init**). The **Transformer** is the object that applies the XSLT to the XML document. Line 493 invokes method **transform** of class **Transformer** to apply the transformation to produce the XHTML document.

In Fig. 12.10, lines 9–11 specify the DTD and other output options using the **xsl:output** element. Line 15 specifies that **Element question** is the root **Element** in the XML **Document** that **XHTMLOutputQuestion.xsl** will transform. Line 16 begins the XHTML document with the element **html**. Lines 22–86 contain the **body** element, which contains the tip image and the four possible answers. Lines 27–29 display the image associated with the image **Element** in the XML **Document**. Lines 40–83 create a form with four possible answers. Lines 47–77 create four radio buttons associated with these answers. Line 82 creates a **Submit** button so the user can submit the selection. Figure 12.11 shows Tip Test in action after the servlet applies the XSLT to the XML **Document**. The image on the left shows the user selecting the answer, and the image on the right shows the user about to submit the answer.

```
1  <?xml version="1.0"?>
2
3  <!-- XHTMLOutputQuestion.xsl -->
4  <!-- XHTML stylesheet -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:output method = "xml" omit-xml-declaration = "no"
10         doctype-system = "DTD/xhtml1-strict.dtd"
11         doctype-public = "-//W3C//DTD XHTML 1.0 Strict//EN"/>
```

Fig. 12.10 **XHTMLOutputQuestion.xsl** transforms XML Tip-Test question to XHTML document (part 1 of 3).

```
12
13     <!-- specify the root of the XML document -->
14     <!-- that references this stylesheet          -->
15     <xsl:template match = "question">
16         <html xmlns="http://www.w3.org/1999/xhtml">
17
18             <head>
19                 <title>Tip Test</title>
20             </head>
21
22             <body>
23
24                 <p>
25
26                     <!-- display image -->
27                     <img name = "image" alt = "Tip Image"
28                         src = "{image}">
29                     </img>
30
31                 </p>
32
33                 <p>
34                     What is the name of the icon shown?
35                 </p>
36
37                 <p>
38
39                     <!-- create a form with four checkboxes -->
40                     <form method = "post"
41                         action = "/advjhttp1/tiptest">
42
43                         <!-- build a table for the options -->
44                         <table>
45                             <tr>
46                                 <td>
47                                     <input type = "radio"
48                                         name = "userAnswer" value = "0">
49                                     </input>
50                                     <xsl:value-of select =
51                                         "choices/choice[1]" />
52                                 </td>
53
54                                 <td>
55                                     <input type = "radio"
56                                         name = "userAnswer" value = "1">
57                                     </input>
58                                     <xsl:value-of select =
59                                         "choices/choice[2]" />
60                                 </td>
61                             </tr>
62                         </table>
63                     </form>
64
65             </body>
66         </html>
67     </xsl:template>
68 
```

---

Fig. 12.10 **XHTMLTipQuestion.xsl** transforms XML Tip-Test question to XHTML document (part 2 of 3).

```

63             <tr>
64                 <td>
65                     <input type = "radio"
66                         name = "userAnswer" value = "2">
67                     </input>
68                     <xsl:value-of select =
69                         "choices/choice[3]"/>
70                 </td>
71
72                 <td>
73                     <input type = "radio"
74                         name = "userAnswer" value = "3">
75                     </input>
76                     <xsl:value-of select =
77                         "choices/choice[4]"/>
78                 </td>
79             </tr>
80         </table>
81
82             <input type = "submit" value = "Submit"/>
83         </form>
84     </p>
85
86     </body>
87   </html>
88 </xsl:template>
89 </xsl:stylesheet>

```

Fig. 12.10 **XHTMLOTipQuestion.xsl** transforms XML Tip-Test question to XHTML document (part 3 of 3).

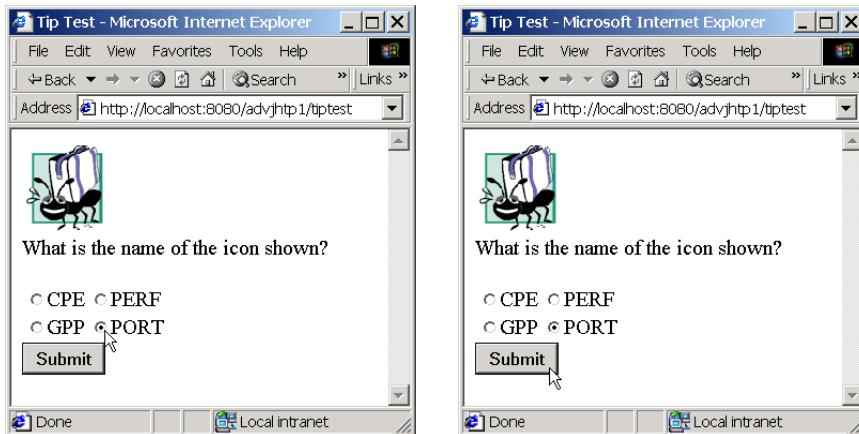


Fig. 12.11 Internet Explorer Tip-Test question output screen.

Each radio button in the XHTML document contains a unique value, so when the user presses the **Submit** button, Internet Explorer sends the selected value to **TipTest-Servlet** (as **post** data). **TipTestServlet** (Fig. 12.9) invokes method **doPost**

(lines 106–173) upon receiving **post** data. Lines 117–129 recognize that the request is from the Internet Explorer and call method **createXMLTipTestAnswer** (lines 505–589) to determine if the user's answer is correct.

Line 509 retrieves the **HttpSession**, and lines 512–522 extract the correct tip answer, name and description from the **HttpSession**. Lines 525–526 retrieve the user's selection from the **HttpServletRequest**. Lines 531–534 match the user's selection with the tip answer to determine if the user is correct. Lines 537–538 determine the **TipTestServlet**'s URL so clients can reconnect to **TipTestServlet** to receive another Tip-Test question.

Lines 544–576 mark up the **HttpSession** contents and **TipTestServlet**'s URL as an XML **Document** from the **DocumentBuilder**. Line 544 creates a **DocumentBuilder**, and line 545 creates an XML **Document**. Lines 548–549 create **Element answer** and assign it as the root **Element** in the **Document**. Lines 552–554 create **Element correct**, which stores whether the user is correct or incorrect. Line 555 assigns **Element correct** as a child of **Element answer**. Lines 558–561 and lines 565–568 create **Elements correctTipName** and **correctTipDescription**, which hold the name and description of the correct tip, respectively. Lines 562 and 569 assign these **Elements** as children of **Element answer**. Lines 572–575 create **Element servletName**, which holds **TipTestServlet**'s URL. Line 576 assigns this **Element** as a child of **Element answer**.

When method **createXMLTipTestAnswer** returns the XML **Document** (line 578), **TipTestServlet** must apply an XSLT to this **Document** and send the resulting transformation to the client. Line 124 sets the MIME type to **text/html**, and lines 127–128 call method **applyXSLT** to apply **XHTMLOTipAnswer.xsl** (Fig. 12.12) to the XML **Document**.

```
1 <?xml version="1.0"?>
2
3 <!-- XHTMLTipAnswer.xsl -->
4 <!-- XHTML stylesheet -->
5
6 <xsl:stylesheet version = "1.0"
7   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9   <xsl:output method = "xml" omit-xml-declaration = "no"
10    doctype-system = "DTD/xhtml1-strict.dtd"
11    doctype-public = "-//W3C//DTD XHTML 1.0 Strict//EN"/>
12
13  <!-- specify the root of the XML document -->
14  <!-- that references this stylesheet -->
15  <xsl:template match = "answer">
16    <html xmlns="http://www.w3.org/1999/xhtml">
17
18      <head>
19        <title>Tip Test Answer</title>
20      </head>
21
```

Fig. 12.12 **XHTMLOTipAnswer.xsl** transforms XML Tip-Test answer to XHTML document (part 1 of 2).

```

22         <body>
23
24             <p>
25                 <h1>
26                     <xsl:value-of select = "correct"/>
27                 </h1>
28             </p>
29
30             <p>
31                 <h2>Tip Name</h2>
32             </p>
33
34             <p>
35                 <h3>
36                     <xsl:value-of select = "correctTipName"/>
37                 </h3>
38             </p>
39
40             <p>
41                 <h2>Tip Description</h2>
42             </p>
43
44             <p>
45                 <h3>
46                     <xsl:value-of
47                         select = "correctTipDescription"/>
48                 </h3>
49             </p>
50
51             <p>
52                 <h2>
53                     <a href="{servletName}">Next Tip</a>
54                 </h2>
55             </p>
56
57         </body>
58     </html>
59     </xsl:template>
60 </xsl:stylesheet>
```

**Fig. 12.12** **XHTMLOTipAnswer.xsl** transforms XML Tip-Test answer to XHTML document (part 2 of 2).

In Fig. 12.12, lines 9–11 specify the DTD using the **xsl:output** element. Line 15 specifies that **Element answer** is the root **Element** in the XML **Document** that **XHTMLOTipAnswer.xsl** will transform. Line 16 begins the XHTML document. Line 26 uses **Element correct** from the XML **Document** to display whether the user's selection is the correct answer. Lines 36 and 47 use **Elements correctTipName** and **correctTipDescription** to display the name and description of the correct tip, respectively. Line 53 uses **Element servletName** to provide a link to **TipTest-Servlet** so the user can receive another Tip-Test question. Figure 12.21 shows the Tip-Test answer in Internet Explorer.

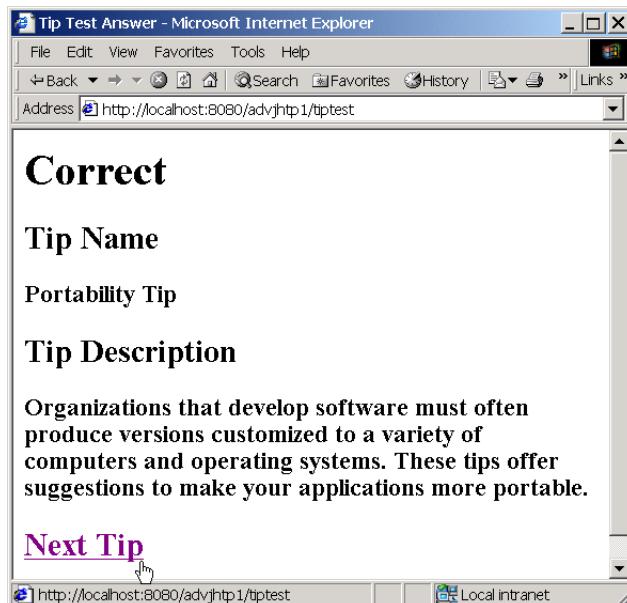


Fig. 12.13 Internet Explorer Tip-Test answer output screen.

### 12.3.2 WAP request

If the Openwave UP simulator made the original **get** request to **TipTestServlet** (Fig. 12.9), lines 202–214 determine that the requesting client is a WAP client. Lines 205–208 invoke method **createXMLTipTestQuestion** to create an **XML Document** that contains the Tip-Test question. Using the arguments for this method, we specify that the tip images are in **wbmp** format and are located in the **WAP/images** directory of the servlet-context path. Line 211 sets the MIME type to **text/vnd.wap.wml** to produce WML content. Lines 212–213 call method **applyXSLT** to apply **WAPTipQuestion.xsl** (Fig. 12.14) to the XML **Document**.

```

1  <?xml version="1.0"?>
2
3  <!-- WAPTipQuestion.xsl -->
4  <!-- WAP stylesheet      -->
5
6  <xsl:stylesheet
7      xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
8      version="1.0">
9
10    <xsl:output method = "xml" omit-xml-declaration = "no"
11        doctype-system = "http://www.wapforum.org/DTD/wml_1.1.xml"
12        doctype-public = "-//WAPFORUM//DTD WML 1.1//EN"/>
```

Fig. 12.14 **WAPTipQuestion.xsl** transforms XML Tip-Test question to WML document (part 1 of 2).

```
13      <!-- specify the root of the XML document -->
14      <!-- that references this stylesheet      -->
15      <xsl:template match = "question">
16
17          <wml>
18              <card id = "card1" title = "Tip Test">
19
20                  <do type = "accept" label = "OK">
21                      <go href = "#card2"/>
22                  </do>
23
24
25                  <p>
26                      <img src = "{image}" height = "55" width = "55"
27                          alt = "Tip Image"/>
28                  </p>
29
30              </card>
31
32              <card id = "card2" title = "Tip Test">
33                  <do type = "accept" label = "Submit">
34                      <go method = "post" href = "/advjhttp1/tiptest">
35                          <postfield name = "userAnswer"
36                              value = "${question}"/>
37                      </go>
38                  </do>
39
40                  <p>
41                      The tip shown on the previous screen is called:
42                  </p>
43
44                  <p>
45                      <select name = "question"
46                          iname = "iquestion" ivalue = "1">
47
48                          <option value = "0"><xsl:value-of
49                              select = "choices/choice[1]"/></option>
50
51                          <option value = "1"><xsl:value-of
52                              select = "choices/choice[2]"/></option>
53
54                          <option value = "2"><xsl:value-of
55                              select = "choices/choice[3]"/></option>
56
57                          <option value = "3"><xsl:value-of
58                              select = "choices/choice[4]"/></option>
59                      </select>
60                  </p>
61              </card>
62          </wml>
63      </xsl:template>
64  </xsl:stylesheet>
```

Fig. 12.14 **WAPTipQuestion.xsl** transforms XML Tip-Test question to WML document (part 2 of 2).

In Fig. 12.14, lines 10–12 specify the DTD using the **xsl:output** element. Line 16 specifies that **Element question** is the root **Element** in the XML **Document** that **WAPTipQuestion.xsl** will transform. Line 18 begins the WML document with the **wml** element. Lines 19–30 declare the first *card*—or the page that displays WML content—that the browser will display. Lines 26–27 display the image associated with the **image Element** in the XML **Document**. The **do** element (lines 21–23) informs the simulator to show the second card when the user presses the **OK** button on the simulator. Lines 32–61 declare the second card onto which the UP simulator places the four possible answers. Using the **choice Elements** in the **choices Element**, lines 45–59 create a selection list that contains the possible answers. The **do** element (lines 33–38) informs the simulator to send the user's selection to **TipTestServlet** when the user presses the **Submit** button.

Figure 12.15 shows Tip Test after **TipTestServlet** applies the XSLT to the XML **Document**. The image on the left shows the tip image, and the image on the right shows the user selecting the answer.



**Fig. 12.15** Openwave UP simulator Tip-Test question screen. (Image of UP.SDK courtesy Openwave Systems Inc. Openwave, the Openwave logo, and UP.SDK are trademarks of Openwave Systems Inc. All rights reserved.)

Each selection list item contains a unique value. When the user presses **Submit**, the UP simulator **posts** the selected value to **TipTestServlet**. **TipTestServlet** (Fig. 12.9) invokes method **doPost** when receiving **post** data. Lines 132–144 determine that the request is from the Openwave UP simulator. Lines 135–136 call method **createXML-TipTestAnswer** to create an XML **Document** that stores whether the user is correct, the name and description of the correct tip and **TipTestServlet**'s URL. Line 139 sets the MIME type to **text/vnd.wap.wml** to produce WML content and lines 157–158 call **applyXSLT** to apply **WAPTipAnswer.xsl** (Fig. 12.16) to the XML **Document**.

In Fig. 12.16, lines 10–12 specify the DTD using the **xsl:output** element. Line 16 specifies that **Element answer** is the root **Element** in the XML **Document** that **WAP-TipAnswer.xsl** will transform. Line 18 begins the WML document with the **wml** element. Lines 20–48 declare the card (the answer screen) in this WML document. Line 29 uses **Element correct** from the XML **Document** to display whether the user's selection is the correct answer. Lines 37 and 45 use **Elements correctTipName** and **correctTipDescription** to display the name and description of the correct tip, respectively. Using **Element servletName** in the XML **Document**, the **do** element (lines 22–26) provides a link to **TipTestServlet**, so the user can receive another Tip-Test question. Figure 12.17 shows the Tip-Test answer in the Openwave UP simulator.

```

1  <?xml version="1.0"?>
2
3  <!-- WAPTipAnswer.xsl -->
4  <!-- WAP stylesheet -->
5
6  <xsl:stylesheet
7      xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
8      version="1.0">
9
10     <xsl:output method = "xml" omit-xml-declaration = "no"
11         doctype-system = "http://www.wapforum.org/DTD/wml_1.1.xml"
12         doctype-public = "-//WAPFORUM//DTD WML 1.1//EN"/>
13
14     <!-- specify the root of the XML document -->
15     <!-- that references this stylesheet -->
16     <xsl:template match = "answer">
17
18         <wml>
19
20             <card id = "card1" title = "Tip Test Answer">
21
22                 <do type = "accept" label = "OK">
23                     <go method = "get"
24                         href = "/advjhtml/tiptest">
25                     </go>
26                 </do>
27
28                 <p>
29                     <xsl:value-of select = "correct"/>
30                 </p>

```

Fig. 12.16 **WAPTipAnswer.xsl** transforms answer to WML document (part 1 of 2).

```
31
32      <p>
33          Tip Name
34      </p>
35
36      <p>
37          <xsl:value-of select = "correctTipName"/>
38      </p>
39
40      <p>
41          Tip Description
42      </p>
43
44      <p>
45          <xsl:value-of select = "correctTipDescription"/>
46      </p>
47
48  </card>
49
50  </wml>
51 </xsl:template>
52 </xsl:stylesheet>
```

Fig. 12.16 WAPTipAnswer.xsl transforms answer to WML document (part 2 of 2).

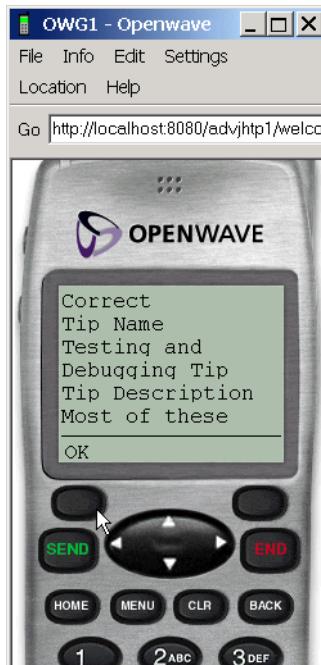


Fig. 12.17 Openwave UP simulator Tip-Test answer screen. (Image of UP.SDK courtesy Openwave Systems Inc. Openwave, the Openwave logo, and UP.SDK are trademarks of Openwave Systems Inc. All rights reserved.)

### 12.3.3 Pixo i-mode request

If the Pixo browser made the original **get** request to **TipTestServlet** (Fig. 12.9), lines 217–229 determine that the requesting client is an i-mode client. Lines 220–223 invoke method **createXMLTipTestQuestion** to create the XML **Document** that contains the Tip Test question. Using the arguments for this method, we specify that the tip images are in **gif** format and are located in the **iMode/images** directory of the servlet-context path. Line 226 sets the MIME type to **text/html** to produce cHTML content. Lines 227–228 call method **applyXSLT** to apply **IMODETipQuestion.xsl** (Fig. 12.18) to the XML **Document**.

```

1  <?xml version="1.0"?>
2
3  <!-- IMODETipQuestion.xsl -->
4  <!-- i-mode stylesheet      -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:output method = "html" omit-xml-declaration = "yes"
10         doctype-public = "-//W3C//DTD Compact HTML 1.0 Draft//EN"/>
11
12     <!-- specify the root of the XML document -->
13     <!-- that references this stylesheet      -->
14     <xsl:template match = "question">
15         <html>
16
17             <head>
18                 <title>Tip Test</title>
19             </head>
20
21             <body>
22
22             <p>
23
24                 <!-- display image -->
25                 <img name = "image" height = "40"
26                     width = "40" alt = "Tip Image"
27                     src = "{image}">
28                 </img>
29             </p>
30
31             <p>
32                 What is the name of the icon shown?
33             </p>
34
35             <p>
36
37                 <!-- create a form with four checkboxes -->
38                 <form method = "post"
39                     action = "/advjhtml/tiptest">
40

```

Fig. 12.18 **IMODETipQuestion.xsl** transforms XML Tip-Test question to cHTML document (part 1 of 2).

```

41          <!-- build a table for the options -->
42          <table>
43              <tr>
44                  <td>
45                      <input type = "radio"
46                          name = "userAnswer" value = "0">
47                      </input>
48                      <xsl:value-of select =
49                          "choices/choice[1]" />
50                  </td>
51
52                  <td>
53                      <input type = "radio"
54                          name = "userAnswer" value = "1">
55                      </input>
56                      <xsl:value-of select =
57                          "choices/choice[2]" />
58                  </td>
59              </tr>
60
61              <tr>
62                  <td>
63                      <input type = "radio"
64                          name = "userAnswer" value = "2">
65                      </input>
66                      <xsl:value-of select =
67                          "choices/choice[3]" />
68                  </td>
69
70                  <td>
71                      <input type = "radio"
72                          name = "userAnswer" value = "3">
73                      </input>
74                      <xsl:value-of select =
75                          "choices/choice[4]" />
76                  </td>
77              </tr>
78          </table>
79
80          <input type = "submit" value = "Submit"/>
81      </form>
82  </p>
83
84  </body>
85 </html>
86 </xsl:template>
87 </xsl:stylesheet>

```

Fig. 12.18 **IMODETipQuestion.xsl** transforms XML Tip-Test question to cHTML document (part 2 of 2).

In Fig. 12.18, lines 9–10 specify the DTD using the **xsl:output** element. Line 14 specifies that **Element question** is the root **Element** in the XML Document that

**IMODETipQuestion.xsl** will transform. Line 15 begins the cHTML document with the **html** element. Lines 21–85 contain the **body** element that stores the tip image and the four possible answers. Lines 26–29 display the image associated with the image **Element** in the XML **Document**. Lines 39–82 create a form for the four possible answers. Lines 46–76 create four radio buttons associated with these answers. Line 81 creates a **Submit** button so the user can submit the choice.

Figure 12.19 shows Tip Test in action after **TipTestServlet** applies the XSLT to the XML **Document**. The image on the left shows the user selecting the answer, and the image on the right shows the user about to submit the answer.

Each radio button in the cHTML document contains a unique value, so when the user presses **Submit**, the Pixo browser **posts** the selected value to **TipTestServlet**. **TipTestServlet** invokes method **doPost** upon receiving **post** data. Lines 147–159 determine that the request is from the Pixo browser. Lines 150–151 call method **createXMLTipTestAnswer** to create an XML **Document** that stores whether the user is correct, the name and description of the correct tip, and **TipTestServlet**'s URL. Line 154 sets the MIME type to **text/html** to produce cHTML content, and lines 157–158 call method **applyXSLT** to apply **IMODETipAnswer.xsl** (Fig. 12.20) to the XML **Document**.

In Fig. 12.20, lines 9–10 specify the DTD using the **xsl:output** element. Line 14 specifies that **Element answer** is the root **Element** in the XML **Document** that **IMODETipAnswer.xsl** will transform. Line 15 begins the cHTML document with the **html** element. Line 25 uses **Element correct** from the XML **Document** to display whether the user's selection is correct. Lines 35 and 45–46 use **Elements correctTipName** and **correctTipDescription** to display the name and description of the correct tip, respectively. Using **Element servletName**, line 52 provides a link to **TipTestServlet**, so the user can receive another Tip-Test question. Figure 12.21 shows the Tip-Test answer on the Pixo i-mode browser.



Fig. 12.19 Pixon i-mode browser Tip-Test question screen. (Courtesy of Pixon, Inc.)

```
1  <?xml version="1.0"?>
2
3  <!-- IMODETipAnswer.xsl -->
4  <!-- i-mode stylesheet -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:output method = "html" omit-xml-declaration = "yes"
10         doctype-public = "-//W3C//DTD Compact HTML 1.0 Draft//EN"/>
11
12     <!-- specify the root of the XML document -->
13     <!-- that references this stylesheet -->
14     <xsl:template match = "answer">
15         <html>
16
17             <head>
18                 <title>Tip Test Answer</title>
19             </head>
20
21             <body>
22
23                 <p>
24                     <h1>
25                         <xsl:value-of select = "correct"/>
26                     </h1>
27                 </p>
28
29                 <p>
30                     <h2>Tip Name</h2>
31                 </p>
32
33                 <p>
34                     <h3>
35                         <xsl:value-of select = "correctTipName"/>
36                     </h3>
37                 </p>
38
39                 <p>
40                     <h2>Tip Description</h2>
41                 </p>
42
43                 <p>
44                     <h3>
45                         <xsl:value-of
46                             select = "correctTipDescription"/>
47                     </h3>
48                 </p>
49
50                 <p>
51                     <h2>
52                         <a href="{servletName}">Next Tip</a>
```

Fig. 12.20 **IMODETipAnswer.xsl** transforms XML Tip-Test answer to cHTML document.

```

53          </h2>
54      </p>
55
56      </body>
57  </html>
58 </xsl:template>
59 </xsl:stylesheet>
```

**Fig. 12.20** **IMODETipAnswer.xsl** transforms XML Tip-Test answer to cHTML document.



**Fig. 12.21** Pixon i-mode browser Tip-Test answer screen. (Courtesy of Pixon, Inc.)

#### 12.3.4 J2ME client request

**TipTestServlet** behaves differently if a J2ME client made the **get** request. **TipTestServlet** does not use XML for the J2ME client, because currently, a J2ME client cannot interpret XML data without using proprietary software. Sun Microsystems claims that “it is not yet clear how far in the future this Java-XML nirvana is, but we can say that WAP 2.0 will use XHTML as its markup... We will see thousands, then millions, of devices using XHTML in consumers’ hands in the not too distant future.”<sup>3</sup>

3. Day, B., “Developing Wireless Applications using Java™ 2 Platform, Micro Edition (J2ME™),” developer.java.sun.com/developer/products/wireless/getstart/articles/wirelessdev/wireless-dev.pdf, June 2001.

We do not use XML for the J2ME client, so **TipTestServlet** does not send marked up data to our J2ME client. We could have used an XSLT to generate the plain text, but we chose not to for two reasons. Firstly, plain text is not well-formed and defeats the purpose of using XSLT, which should create well-formed documents. Secondly, the **ResultSet** in **TipTestServlet** already contains plain text, so converting the text to an XML **Document**, then converting the **Document** back to text, is convoluted.

In **TipTestServlet** (Fig. 12.9), lines 232–235 determine that a J2ME client made the request and invoke method **sendJ2MEClientResponse** (lines 344–390). Line 349 calls method **getResultSetTable** to convert the **ResultSet** into a two-dimensional array of **Strings**—**resultTable**, so we have instant access to database contents. Line 352 creates a **Random** object, which allows **TipTestServlet** to generate randomly the tip image and tip questions to display. Line 355 passes the **Random** object to method **getRandomIndices**, which returns an array of four integers—each integer is a distinct, randomly generated index that corresponds to a tip in **resultTable**.

Lines 358–359 randomly select an integer from **randomRow**—this integer is the “correct” answer in the game—specifically, this integer represents the row in **resultTable** that holds the information for the correct tip. Using the correct answer, line 361 determines the row in **resultTable** that contains the name and description of the correct tip. **TipTestServlet** stores this information in an **HttpSession** object (line 364), so when the J2ME client sends the user’s selection back to the server, **TipTestServlet** can check the user’s selection against the correct answer stored in the **HttpSession** object. Lines 367–376 store the correct answer and the tip name and description in the **HttpSession** object. Using the correct answer, lines 379–380 determine the proper image to send to the J2ME client. Line 382 sets the MIME type to **text/plain**, because J2ME clients interprets plain text. Line 383 creates a **PrintWriter** object through which **TipTestServlet** sends the data to the J2ME client. Line 384 sends the name of the tip image, and lines 387–388 send the four tip abbreviations to the client. Section 12.4.3 discusses in detail how the J2ME client displays the Tip Test and exchanges data between itself and **TipTestServlet**. Figure 12.22 shows a sample output after **TipTestServlet** sends the Tip-Test question to the J2ME client. The image on the left shows the tip image, and the image on the right shows the user selecting an answer.

When the client sends the user’s selection, **TipTestServlet** invokes method **doPost**. Lines 162–164 determine that the request is from the J2ME client and call method **sendJ2MEAnswer** (lines 592–629). Lines 596–597 use a **BufferedReader** object to read the user’s selection from the client. Line 600 sets the MIME type to **text/plain**, and line 601 gets a **PrintWriter** object through which **TipTestServlet** sends content. Line 604 retrieves the **HttpSession** that stores the correct tip answer, name and description—lines 607–617 extract this information from this **HttpSession**. Lines 620–623 match the user’s selection with the correct tip answer and determine if the user is correct. Using the **PrintWriter** object, lines 626–627 send the correct tip name and description to the client. Figure 12.23 shows the answer screen on the Sun MIDP-device emulator. The picture on the left shows the screen that contains the correct tip name and description. When the user scrolls down on this screen, the user will see the picture on the right, which shows the remainder of the tip description.



Fig. 12.22 J2ME client Tip-Test question screen. (Courtesy of Sun Microsystems, Inc.)



Fig. 12.23 J2ME client Tip-Test answer screen. (Courtesy of Sun Microsystems, Inc.)

## 12.4 Java 2 Micro Edition

This section introduces *Java 2 Micro Edition (J2ME™)*—a platform that enables developers to write applications for various consumer devices, such as set-top boxes, Web termi-

nals, embedded systems, mobile phones and cell pagers. We discuss the Connected Limited Device Configuration (CLDC) and the Mobile Information Device Profile (MIDP), which offer developers a set of APIs to write J2ME applications—called *MIDlets*—and deploy them across several mobile devices. We then discuss the lifecycle of a MIDlet and explain how we use J2ME in our case study.

### 12.4.1 Connected Limited Device Configuration (CLDC)

The *Connected Limited Device Configuration (CLDC)* is a set of APIs that allow developers to create applications for devices that have limited resources—i.e., limited screen size, memory, power and bandwidth. The J2ME CLDC contains both a *virtual machine*—an interpreter that runs applications—and a set of classes that developers can use to develop and run programs on resource-limited devices. The *KVM*—the virtual machine offered by the CLDC—runs J2ME applications (as the JVM runs J2SE applications). The “K” in KVM represents the word “kilo,” because J2ME applications are small enough to be measured in kilobytes.

The J2ME CLDC contains packages **java.io**, **java.lang**, **java.util** that developers use to perform such common operations as creating primitive data types, using simple data structures and sending and receiving data from networks. These packages are subsets of the J2SE packages **java.io**, **java.lang** and **java.util**—that is, the J2ME CLDC packages do not contain every class from the J2SE packages. Figure 12.24 lists the J2ME **java.io**, **java.lang** and **java.util** packages. To conserve space, we did not include exception or error classes. For the complete J2ME CLDC class list, visit [java.sun.com/j2me/docs/pdf/cldcapi.pdf](http://java.sun.com/j2me/docs/pdf/cldcapi.pdf).

Classes	<b>java.io</b>	<b>java.lang</b>	<b>java.util</b>
Interfaces	<b>DataInput</b> <b>DataOutput</b>	<b>Runnable</b>	<b>Enumeration</b>
Classes	<b>ByteArrayInputStream</b> <b>ByteArrayOutputStream</b> <b>DataInputStream</b> <b>DataOutputStream</b> <b>InputStream</b> <b>InputStreamReader</b> <b>OutputStream</b> <b>OutputStreamReader</b> <b>PrintStream</b> <b>Reader</b> <b>Writer</b>	<b>Boolean</b> <b>Byte</b> <b>Character</b> <b>Class</b> <b>Integer</b> <b>Long</b> <b>Math</b> <b>Object</b> <b>Runtime</b> <b>Short</b> <b>String</b> <b>StringBuffer</b> <b>System</b> <b>Thread</b> <b>Throwable</b>	<b>Calendar</b> <b>Data</b> <b>Hashtable</b> <b>Random</b> <b>Stack</b> <b>Timer</b> <b>TimerTask</b> <b>TimeZone</b> <b>Vector</b>

Fig. 12.24 J2ME **java.io**, **java.lang** and **java.util** packages.



### Common Programming Error 12.1

Attempting to use J2SE packages in the KVM will result in a compilation error—the KVM cannot handle the volume of classes due to KVM's limited resources.

One challenge of J2ME programming is that the API does not contain certain data types and classes that developers often “take for granted” in other Java platforms. For example, J2ME does not include floating-point operations, serializable objects, thread groups or JNI (Java Native Interface). As wireless-device technology advances, it is possible that future versions of J2ME will support those features.

#### 12.4.2 Mobile Information Device Profile (MIDP)

The *Mobile Information Device Profile (MIDP)* is a set of APIs that allow developers to handle mobile-device-specific issues, such as creating user interfaces, permitting local storage and defining the lifecycles of MIDP client applications (MIDlets). Devices that run applications using the MIDP are called *MIDP devices*. Such devices include cell phones or pagers.

MIDP contains packages `javax.microedition.lcdui`, `javax.microedition.io`, `javax.microedition.rms` and `javax.microedition.midlet`. Package `javax.microedition.lcdui` contains classes that allow developers to construct user-interfaces for MIDlets, package `javax.microedition.io` enables networking between MIDlets and other systems, package `javax.microedition.rms` contains classes that permit local storage, and package `javax.microedition.midlet` defines the MIDlet lifecycle. Figure 12.26 lists the MIDP `javax.microedition.lcdui` and `javax.microedition.io` packages. Figure 12.26 lists the MIDP `javax.microedition.rms` and `javax.microedition.midlet` packages. To conserve space, we did not include exception or error classes. For the complete J2ME MIDP class list, visit

[java.sun.com/products/midp/midp-wirelessapps-wp.pdf](http://java.sun.com/products/midp/midp-wirelessapps-wp.pdf)

Classes	<code>javax.microedition.lcdui</code>	<code>javax.microedition.io</code>
Interfaces	<code>Choice</code> <code>CommandListener</code> <code>ItemListener</code>	<code>Connection</code> <code>ContentConnection</code> <code>Datagram</code> <code>DatagramConnection</code> <code>HttpConnection</code> <code>InputConnection</code> <code>OutputConnection</code> <code>StreamConnection</code> <code>StreamConnectionNotifier</code>

Fig. 12.25 MIDP `javax.microedition.lcdui` and `javax.microedition.io` packages (part 1 of 2).

Classes	javax.microedition.lcdui	javax.microedition.io
Classes	<b>Alert</b> <b>AlertType</b> <b>Canvas</b> <b>ChoiceGroup</b> <b>Command</b> <b>DateField</b> <b>Display</b> <b>Displayable</b> <b>Font</b> <b>Form</b> <b>Gauge</b> <b>Graphics</b> <b>Image</b> <b>ImageItem</b> <b>Item</b> <b>List</b> <b>Screen</b> <b>ScreenItem</b> <b>TextBox</b> <b>TextField</b> <b>Ticker</b>	<b>Connector</b>

Fig. 12.25 MIDP **javax.microedition.lcdui** and **javax.microedition.io** packages (part 2 of 2).

Classes	javax.microedition.rms	javax.microedition.midlet
Interfaces	<b>RecordComparator</b> <b>RecordEnumeration</b> <b>RecordFilter</b> <b>RecordListener</b>	
Classes	<b>RecordStore</b>	<b>MIDlet</b>

Fig. 12.26 MIDP **javax.microedition.rms** and **javax.microedition.midlet** packages.

To run a MIDP application, a MIDP device requires a monochrome display of at least 96 pixels x 54 pixels, a two-way wireless network, some input device (such as a one-handed keypad or touch screen), at least 128 kilobytes for CLDC/MIDP classes and at least 32 kilobytes for the KVM. A MIDlet will run on any device that meets these requirements.

### 12.4.3 TipTestMIDlet Overview

In Section 12.3.4, we discussed how a servlet sends data to a J2ME client called a MIDlet. We discussed that MIDlets cannot interpret XML documents without proprietary software packages and must receive all information through streams or **PrintReader** objects. This section defines a MIDlet more specifically, discusses the MIDlet lifecycle and introduces **TipTestMIDlet**—the MIDlet in our case study.

A MIDlet is a Mobile Information Device application that runs on a MIDP device. The name is similar to the terms “applet” and “servlet,” because these applications share similar characteristics—for example, each has a lifecycle and occupies various states during program execution. Also, the developer does not invoke a constructor for objects of these classes (**Applet**, **HttpServlet** and **MIDlet**) explicitly to instantiate these objects. We discussed in Section 9.2.1 that a servlet container loads the servlet into memory—normally in response to the first request that servlet receives. MIDlets are loaded in a similar manner. MIDP developers store several MIDlets in a jar file—called a *MIDlet suite*—on a server. The MIDP device contains a program called the *application management software* (AMS), which downloads the MIDlet suite from the server, opens the MIDlet suite, then launches the user-specified MIDlet on the MIDP device.

The AMS uses an *application descriptor file* to load the MIDlet application. This file, which has a **.jad** extension, contains information such as the MIDlets in the MIDlet suite, the MIDlet suite’s size and URL, each MIDlet’s name, vendor and version, and the MIDP device’s profile and configuration. The AMS uses this information to ensure that the MIDlet application will run on the given MIDP device. Both the J2ME Wireless Toolkit and Forte create this file when creating a new MIDlet suite (see Section 12.5). The code below shows the structure of **TipTestMIDlet**’s application descriptor file.

```
MIDlet-1: TipTestMIDlet, TipTestMIDlet.png,  
          com.deitel.advjhtp1.wireless.TipTestMIDlet  
MIDlet-Jar-Size: 9577  
MIDlet-Jar-URL: TipTestMIDlet.jar  
MIDlet-Name: TipTestMIDlet  
MIDlet-Vendor: Sun Microsystems  
MIDlet-Version: 1.0  
MicroEdition-Configuration:CLDC-1.0  
MicroEdition-Profile:MIDP-1.0
```

Figure 12.27 shows the **TipTestMIDlet**. Before we discuss how **TipTestMIDlet** retrieves information from the server, we must discuss the lifecycle of a MIDlet. Every MIDlet must extend class **MIDlet** (line 13) from package **javax.microedition.midlet** (line 9). The lifecycle begins when the AMS calls the MIDlet’s constructor (lines 43–75) to launch the MIDlet. The MIDlet then enters a paused state, so it cannot accept user input or display screens created by the developer. When the constructor finishes, the AMS calls method **startApp** (lines 78–82), which places the MIDlet in the active state, allowing the MIDlet to display content and accept user input. The MIDlet then waits for user input or another notification from the AMS. If the AMS calls method **pauseApp** (line 85), the MIDlet returns to the “paused state.” When the MIDlet is paused, the AMS must call method **startApp** to enable the MIDlet to reenter the active state. If the AMS calls method **destroyApp** (line 88) to clear the device’s memory for another application, the MIDlet’s execution terminates. Methods **startApp**, **pauseApp** and

**destroyApp** are abstract methods of class **MIDlet**, so every **MIDlet** subclass must override these methods.

Line 6 imports the J2ME CLDC I/O package that enable **TipTestMIDlet** to send and receive data from the servlets. Lines 9–11 import the MIDP packages for defining the MIDlet lifecycle, creating user interfaces and networking. J2ME divides the user-interface API between low-level and high-level APIs. The low-level API allows developers to incorporate graphics and shapes at precise pixel locations and to provide animation for applications such as games. The high-level user-interface API allows developers to incorporate text-fields, lists, forms and images for programs such as e-commerce applications and basic user interfaces.

```

1 // TipTestMIDlet.java
2 // Receives TipTest from Servlet
3 package com.deitel.advjhtp1.wireless;
4
5 // J2ME Java package subset
6 import java.io.*;
7
8 // J2ME packages
9 import javax.microedition.midlet.*;
10 import javax.microedition.lcdui.*;
11 import javax.microedition.io.*;
12
13 public class TipTestMIDlet extends MIDlet {
14
15     private Display display; // display manager
16
17     // Screens displayed to user
18     private List mainScreen;
19     private List welcomeScreen;
20     private Form infoScreen;
21     private Form tipScreen;
22     private Form answerScreen;
23
24     // actions for soft-buttons
25     private Command selectCommand;
26     private Command nextCommand;
27     private Command backCommand;
28
29     private static final String servletBaseURL =
30         "http://localhost:8080/advjhtp1/";
31
32     private static final String welcomeServletName = "welcome";
33
34     // welcome servlet determines tip test servlet name
35     private String tipTestServletName;
36
37     private static final String welcomeServletURL =
38         servletBaseURL + welcomeServletName;

```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 1 of 11).

```
39
40     private String sessionID;
41
42     // constructor initializes display and main Screen
43     public TipTestMIDlet()
44     {
45         // create soft button commands
46         selectCommand = new Command( "Select", Command.OK, 0 );
47         nextCommand = new Command( "Next Tip", Command.OK, 0 );
48         backCommand = new Command( "Back", Command.BACK, 1 );
49
50         // create main screen allowing welcome servlet connection
51         mainScreen = new List( "TipTestMIDlet", List.IMPLICIT );
52         mainScreen.addCommand( selectCommand );
53
54         // allow soft button access for mainScreen
55         mainScreen.setCommandListener(
56             new CommandListener() {
57
58                 // invoked when user presses soft button
59                 public void commandAction(
60                     Command command, Displayable displayable )
61                 {
62                     // get data from welcome servlet
63                     String data = getServerData( welcomeServletURL );
64
65                     // create welcome Screen using servlet data
66                     display.setCurrent( createWelcomeScreen( data ) );
67                 }
68
69             } // end anonymous inner class
70         );
71
72         // get appropriate Display for device
73         display = Display.getDisplay( this );
74
75     } // end TipTestMIDlet constructor
76
77     // start MIDlet
78     public void startApp()
79     {
80         // set display to main Screen
81         display.setCurrent( mainScreen );
82     }
83
84     // pause MIDlet
85     public void pauseApp() {}
86
87     // destroy MIDlet
88     public void destroyApp( boolean unconditional ) {}
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 2 of 11).

```
89
90     // create "welcome" Screen introducing tip test
91     private Screen createWelcomeScreen( String data )
92     {
93         String list[] = parseData( data, ';' );
94
95         // create Screen welcoming user to tip test
96         welcomeScreen = new List( list[ 0 ], List.IMPLICIT );
97
98         welcomeScreen.append( "Take TipTest", null );
99         welcomeScreen.addCommand( selectCommand );
100        welcomeScreen.addCommand( backCommand );
101
102        // get URL of information page
103        final String url = new String( list[ 1 ].toCharArray() );
104
105        // allow soft button access for welcomeScreen
106        welcomeScreen.setCommandListener(
107            new CommandListener() {
108
109                // invoked when user presses soft button
110                public void commandAction(
111                    Command command, Displayable displayable )
112                {
113                    // soft button pressed is SELECT button
114                    if ( command.getCommandType() == Command.OK ) {
115
116                        // get data from static page
117                        String data =
118                            getServerData( servletBaseURL + url );
119
120                        // display this data
121                        display.setCurrent(
122                            createInformationScreen( data ) );
123                    }
124
125                    // soft button pressed is BACK button
126                    else if ( command.getCommandType() ==
127                        Command.BACK ) {
128                        display.setCurrent( mainScreen );
129                    }
130
131                } // end method commandAction
132
133            } // end anonymous inner class
134        );
135
136        return welcomeScreen;
137
138    } // end method createWelcomeScreen
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 3 of 11).

```
139
140 // create Screen showing servlets to which client can connect
141 private Screen createInformationScreen( String data )
142 {
143     String list[] = parseData( data, ';' );
144
145     // create Form showing available servlets
146     infoScreen = new Form( "Information" );
147
148     // create StringItem that provides directions
149     StringItem infoTitle = new StringItem( list[ 0 ], null );
150     infoScreen.append( infoTitle );
151
152     // create ChoiceGroup allowing user to select servlet
153     final ChoiceGroup choices = new ChoiceGroup( "",
154         ChoiceGroup.EXCLUSIVE );
155     choices.append( list[ 1 ], null );
156
157     // append ChoiceGroup to Form
158     infoScreen.append( choices );
159
160     infoScreen.addCommand( selectCommand );
161     infoScreen.addCommand( backCommand );
162
163     // allow soft button access for this Screen
164     infoScreen.setCommandListener(
165         new CommandListener() {
166
167             // invoked when user presses soft button
168             public void commandAction(
169                 Command command, Displayable displayable )
170             {
171                 // soft button pressed is SELECT button
172                 if ( command.getCommandType() == Command.OK ) {
173
174                     // user chooses which servlet to connect
175                     int selectedIndex = choices.getSelectedIndex();
176
177                     tipTestServletName =
178                         choices.getString( selectedIndex );
179
180                     // connect to servlet and receive data
181                     String data = getServerData( servletBaseURL +
182                         tipTestServletName );
183
184                     // display next Screen according to data
185                     display.setCurrent( createTipTestScreen(
186                         servletBaseURL + data ) );
187                 }
188             }
189         }
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 4 of 11).

```
189         // soft button pressed is BACK button
190         else if ( command.getCommandType() == Command.BACK )
191             display.setCurrent( welcomeScreen );
192
193     } // end method commandAction
194
195 } // end anonymous inner class
196 ;
197
198 return infoScreen;
199
200 } // end method createInformationScreen
201
202 // create Screen to display Tip Test
203 private Screen createTipTestScreen( String data )
204 {
205     // parse server data
206     String list[] = parseData( data, '\n' );
207
208     // create new Form to display test
209     tipScreen = new Form( "Tip Test" );
210
211     // create image from server data
212     Image serverImage = getServerImage( list[ 0 ] );
213
214     // append image to Form
215     if ( serverImage != null )
216         tipScreen.append( serverImage );
217
218     String choiceList[] = new String[ 4 ];
219
220     // construct list for ChoiceGroup from data
221     for ( int i = 0; i < choiceList.length; i++ )
222         choiceList[ i ] = list[ i + 1 ];
223
224     // create ChoiceGroup allowing user to input choice
225     final ChoiceGroup choices = new ChoiceGroup( "Tip Test",
226                                                 ChoiceGroup.EXCLUSIVE,
227                                                 choiceList,
228                                                 null );
229
230     // append ChoiceGroup to Form
231     tipScreen.append( choices );
232
233     tipScreen.addCommand( selectCommand );
234
235     // allow soft button access for this Screen
236     tipScreen.setCommandListener(
237         new CommandListener() {
238
239             // invoked when user presses soft button
240             public void commandAction(
241                 Command command, Displayable displayable )
242             {
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 5 of 11).

```
241         // send user selection to servlet
242         int selection = choices.getSelectedIndex();
243
244         String result = postData( selection );
245
246         // display results
247         display.setCurrent(
248             createAnswerScreen( result ) );
249     }
250
251 } // end anonymous inner class
252 ;
253
254 return tipScreen;
255
256 } // end method createTipTestScreen
257
258 // create Screen to display Tip Test answer and results
259 private Screen createAnswerScreen( String data )
260 {
261     // parse server data
262     String list[] = parseData( data, '\n' );
263
264     // create new Form to display test answers
265     answerScreen = new Form( list[ 0 ] );
266
267     // create StringItem showing tip name
268     StringItem tipNameItem =
269         new StringItem( "Tip Name:\n", list[ 1 ] );
270
271     // create StringItem showing tip description
272     StringItem tipDescriptionItem =
273         new StringItem( "\nTip Description:\n", list[ 2 ] );
274
275     // append StringItems to Form
276     answerScreen.append( tipNameItem );
277     answerScreen.append( tipDescriptionItem );
278
279     answerScreen.addCommand( nextCommand );
280
281     // allow soft button access for this Screen
282     answerScreen.setCommandListener(
283         new CommandListener() {
284
285             // invoked when user presses soft button
286             public void commandAction(
287                 Command command, Displayable displayable )
288             {
289                 // get next question
290                 String data = getServerData( servletBaseURL +
291                     tipTestServletName );
292             }
293         }
294     );
295 }
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 6 of 11).

```
293             // display next question
294             display.setCurrent( createTipTestScreen(
295                     servletBaseURL + data ) );
296         }
297     } // end anonymous inner class
298 };
299
300     return answerScreen;
301 }
302 } // end method createAnswerScreen
303
304 // sends user's test selection to servlet
305 private String postData( int selection )
306 {
307     // connect to server, then post data
308     try {
309
310         // connect to server sending User-Agent header
311         HttpConnection httpConnection =
312             ( HttpConnection ) Connector.open(
313                 servletBaseURL + tipTestServletName,
314                 Connector.READ_WRITE );
315
316         setUserAgentHeader( httpConnection );
317
318         // send sessionID, if one exists
319         if ( sessionID != null )
320             httpConnection.setRequestProperty(
321                 "cookie", sessionID );
322
323         // inform servlet of post request
324         httpConnection.setRequestMethod( HttpConnection.POST );
325
326         // open output stream to servlet
327         DataOutputStream out =
328             httpConnection.openDataOutputStream();
329
330         // send selection
331         out.writeUTF( Integer.toString( selection ) );
332         out.flush();
333
334         // get result from servlet
335         String data = getData( httpConnection );
336
337         httpConnection.close(); // close connection
338
339         return data;
340     } // end try
341
342 } // end postData
343
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 7 of 11).

```
344     // handle if MIDlet cannot open HTTP connection
345     catch ( IOException ioException ) {
346         ioException.printStackTrace();
347     }
348
349     return null;
350 }
351 } // end method postData
352
353 // string tokenizer parses String into sub-string array
354 private String[] parseData( String data, char delimiter )
355 {
356     int newLines = 0;
357
358     // determine number of delimiter characters in String
359     for ( int i = 0; i < data.length(); i++ )
360
361         // increase number of delimiters by one
362         if ( data.charAt( i ) == delimiter )
363             newLines++;
364
365     // create new String array
366     String list[] = new String[ newLines ];
367
368     int oldNewLineIndex = 0;
369     int currentNewLineIndex;
370
371     // store Strings into array based on demiliter
372     for ( int i = 0; i < newLines; i++ ) {
373
374         // determine index where delimiter occurs
375         currentNewLineIndex =
376             data.indexOf( delimiter, oldNewLineIndex );
377
378         // extract String within delimiter characters
379         list[ i ] = data.substring( oldNewLineIndex,
380             currentNewLineIndex - 1 );
381
382         oldNewLineIndex = currentNewLineIndex + 1;
383     }
384
385     return list;
386 }
387 } // end method parseData
388
389 // connect to server and receive data
390 private String getServerData( String serverUrl )
391 {
392     // connect to server, then get data
393     try {
394
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 8 of 11).

```
395         // connect to server sending User-Agent header
396         HttpConnection httpConnection =
397             ( HttpConnection ) Connector.open( serverUrl );
398             setUserAgentHeader( httpConnection );
399
400         // send sessionID to server
401         if ( sessionId != null )
402             httpConnection.setRequestProperty(
403                 "cookie", sessionId );
404
405         // get sessionID from server
406         String sessionIdHeaderField =
407             httpConnection.getHeaderField( "Set-cookie" );
408
409         // store sessionID from cookie
410         if ( sessionIdHeaderField != null ) {
411             int index = sessionIdHeaderField.indexOf( ';' );
412             sessionId =
413                 sessionIdHeaderField.substring( 0, index );
414         }
415
416         // receive server data
417         String data = getData( httpConnection );
418
419         httpConnection.close(); // close connection
420
421         return data;
422
423     } // end try
424
425     // handle exception communicating with HTTP server
426     catch ( IOException ioException ) {
427         ioException.printStackTrace();
428     }
429
430     return null;
431
432 } // end method getServerData
433
434 // downloads an image from a server
435 private Image getServerImage( String imageUrl )
436 {
437     // download image
438     try {
439
440         // open connection to server
441         HttpConnection httpConnection =
442             ( HttpConnection ) Connector.open( imageUrl );
443
444         int connectionSize = ( int ) httpConnection.getLength();
445         byte imageBytes[] = new byte[ connectionSize ];
446
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 9 of 11).

```
447         // read image from server
448         InputStream input = httpConnection.openInputStream();
449         input.read( imageBytes );
450
451         // create image from imageBytes
452         return
453             Image.createImage( imageBytes, 0, connectionSize );
454     }
455
456         // handle exception if InputStream cannot input bytes
457         catch ( IOException ioException ) {
458             ioException.printStackTrace();
459         }
460
461         return null;
462
463     } // end method getServerImage
464
465     // set User-Agent header to identify client to servlet
466     private void setUserAgentHeader(
467         HttpConnection httpConnection )
468     {
469         // set User-Agent header
470         try {
471
472             // use profile/configuration properties for User-Agent
473             String userAgentHeader = "Profile=" +
474                 System.getProperty( "microedition.profiles" ) +
475                 " Configuration=" +
476                 System.getProperty( "microedition.configuration" );
477
478             // set header
479             httpConnection.setRequestProperty(
480                 "User-Agent", userAgentHeader );
481         }
482
483         // handle exception getting request property
484         catch ( IOException ioException ) {
485             ioException.printStackTrace();
486         }
487
488     } // end method setUserAgentHeader
489
490     // open DataInputStream to receive data
491     private String getData( HttpConnection httpConnection )
492         throws IOException
493     {
494         String data = ""; // stores data
495 }
```

Fig. 12.27 **TipTestMIDlet** downloads Tip Test from **TipTestServlet** (part 10 of 11).

```

496     // open input stream from connection
497     DataInputStream dataInputStream =
498         new DataInputStream(
499             httpConnection.openInputStream() );
500
501     int inputCharacter = dataInputStream.read();
502
503     // read all data
504     while ( inputCharacter != -1 ) {
505         data = data + ( char ) inputCharacter;
506         inputCharacter = dataInputStream.read();
507     }
508
509     dataInputStream.close(); // close stream
510
511     return data;
512
513 } // end method getData
514 }
```

**Fig. 12.27** `TipTestMIDlet` downloads Tip Test from `TipTestServlet` (part 11 of 11).

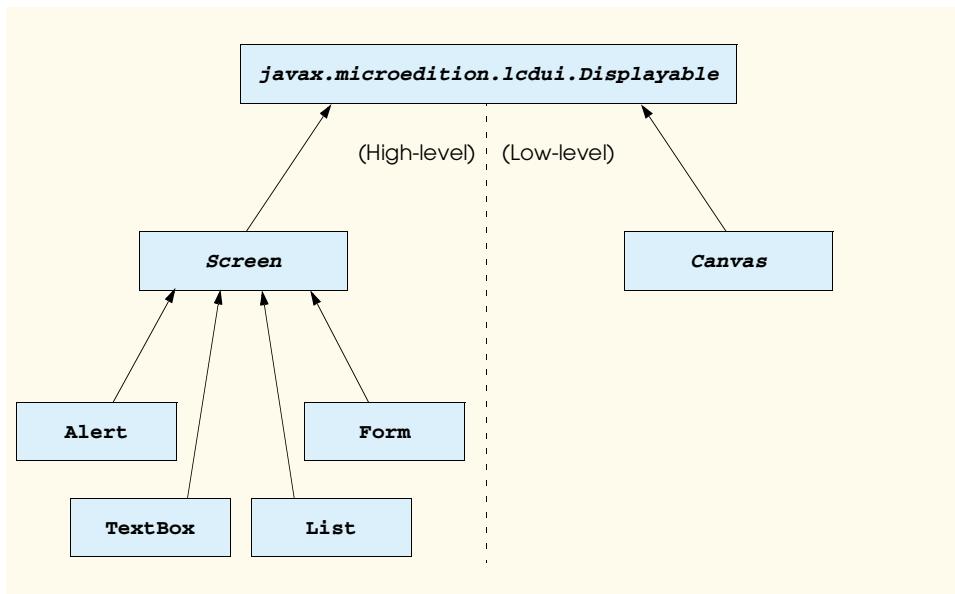
Figure 12.28 shows a portion of the J2ME user-interface API. Each rectangle represents a class in the API. Each class with its name placed in italics is abstract, and the arrows represent inheritance relationships (an arrow points to the superclass). In the J2ME user-interface API, abstract superclass **Displayable** represents content that a MIDP-device can display on screen. The abstract superclasses **Screen** and **Canvas** both inherit from class **Displayable** and represent the high-level and low-level displayable content, respectively. Classes **Alert**, **Form**, **TextBox** and **List** are concrete subclasses of class **Screen**. An **Alert** is a **Screen** that the MIDlet displays for a brief period before displaying another **Screen**. A **Form** aggregates text-fields, images and group of selectable items for the user. A **TextBox** enables the user to input and edit text. A **List** is a list of **Strings** from which the user can select using the MIDP device's keypad. Our case study uses classes **Form** and **List** to display information on screen. Class **Canvas** does not contain any subclasses. To use a **Canvas**, first create a concrete class that extends class **Canvas**, then override its **paint** method to draw graphics to the **Canvas**. Our case study incorporates only high-level user-interface classes, so we do not discuss how to use class **Canvas**.



### Portability Tip 12.1

The J2ME low-level user-interface API helps developers create more visually appealing screens than does the high-level API. However, the low-level API does not guarantee layout congruity among several devices with different screen sizes. The high-level API provides a more consistent layout among devices.

Line 15 of class **TipTestMIDlet** declares an instance of class **Display**, which acts as a display manager for a MIDlet. A MIDlet must contain exactly one **Display** to display any **Displayable** object. Class **Display** is an example of the *Singleton design pattern*, which guarantees that a system instantiates a maximum of one object of a class. Occasionally, a system should contain exactly one object of a class—that is, once the system instantiates that object, the program should not be allowed to create additional



**Fig. 12.28** J2ME user-interface API class hierarchy.

objects of that class. Because a MIDP device has only one screen, a MIDlet should contain only one display manager to display the contents on that screen—therefore, only one **Display** object can exist in each MIDlet. The **static** method **getDisplay** of class **Display** returns a reference to the only **Display** object in the system—this **Display** object is also referred to as the *singleton object*. If the **Display** object has been created, subsequent calls to method **getDisplay** merely return the same reference to the singleton **Display** object.

The **Display** object ensures that only one of the **Screens** (**Displayable** subclasses) in **TipTestMIDlet** displays at a time. Lines 18–22 declare five **Screens** for **TipTestMIDlet**. **TipTestMIDlet** contains a **List** (line 18) to represent the main screen that contains a link to **WelcomeServlet**, a **List** (line 19) to show **index.txt**, a **Form** (line 20) to show **info.txt** (which provides the link to **TipTestServlet**), a **Form** (line 21) to show Tip-Test questions and a **Form** (line 22) to show Tip-Test answers.

**Screens** also have support for *soft-buttons*—buttons that are usually located below the display (but above the keypad) on wireless devices. In Fig. 12.8, the mouse cursor is hovering over the right soft button, which is highlighted. The word **Select** on the screen above the right soft button indicates that the user will select the highlighted **List** item when the user presses this soft button—the **Display** will then show a different **Screen**. J2ME provides this functionality to MIDlets through **Command** objects, which encapsulates an action to be executed by the object that receives the **Command** object. Lines 25–27 of **TipTestMIDlet** declare three **Command** objects—**selectCommand**, **nextCommand** and **backCommand**. The **selectCommand** object—as we will see momentarily—allows the user to select **List** items on the screen. The **nextCommand** object allows the user to receive the next tip from **TipTestServlet** when playing Tip Test. The **backCommand** object enables the user to view the previous **Screen**.

Lines 46–48 instantiate these objects. The first argument to the **Command** constructor is the desired name—or label—to be displayed on the **Screen** above the soft button. The second argument is a constant that specifies how the MIDlet should respond after the user presses the soft button. For example, **Command.OK** indicates that the user has provided some input (via a text-field or via selecting a list item). **Command.BACK** indicates that the user should view the previous **Screen**. We program the logic that handles how the MIDlet behaves for each command type. The third argument indicates above which soft button the device will place the label. In a series of **Command** instantiations, the **Command** object with the lowest number has its label situated above the right soft button in the Sun MIDP-device emulator. For the object associated with the next lowest number, Sun’s device places its label above the left soft button. According to lines 46–48, the device places “**Select**” above the right soft button, “**Next Tip**” above the right soft button and “**Back**” above the left soft button.



### Portability Tip 12.2

The **Command** numbering scheme varies from device-to-device. For example, the Sun emulator’s default location for **Command** text is above the right soft button. Other devices may situate the text above the left soft button.

Line 51 instantiates **List mainScreen**, which provides a link to **WelcomeServlet**. The first argument to the **List** represents the **List** name—this text appears at the top of the MIDP-device screen. The second argument is a constant that indicates the type of **List** instantiated. The **List** type determines how the user navigates the **List** with the keypad. This argument can assume one of three constant values—**List.IMPLICIT**, **List.EXCLUSIVE** and **List.MULTIPLE**. **List.IMPLICIT** indicates that the current focused item in the **List** is the user’s selection—i.e., the user changes the selection when scrolling among **List** items. **List.EXCLUSIVE** requires the user to press the center soft button to indicate a selection among **List** items, then press the right soft button to finalize the selection—however, before finalizing the selection (but after having marked the selection), the user can scroll among **List** items. **List.MULTIPLE** enables the user to select several items in the **List**.

Line 52 adds **selectCommand** to **mainScreen**, so the user will see “**Select**” above the right soft button. Lines 55–69 allow **mainScreen** to listen for events from **selectCommand** by creating a new **CommandListener** object. When the user presses a soft button, **selectCommand** invokes method **commandAction** (lines 59–67). This method takes as arguments the **Command** object associated with the recently pressed soft button and the **Displayable** object on which this action occurred. We explain method **commandAction**’s logic momentarily.

Line 73 gets the display manager for the device. When the constructor returns, the AMS invokes method **startApp**, which informs **TipTestMIDlet** to accept user input and to display screens. Using the display manager, line 81 sets the current display to the **mainScreen**. Figure 12.29 shows the output of this operation.

**TipTestMIDlet** now waits for user input. The only events registered to **TipTestMIDlet** originate from the right soft button—when the user presses this button, **selectCommand** calls method **commandAction** of any registered **CommandListener**. Line 63 passes **WelcomeServlet**’s URL to method **getServerData** (lines 390–432), which connects to a server and receives data. Lines 396–397 open an **HttpConnection** using the URL parameter. Line 398 calls method **setUserAgentHeader** (lines 466–488), so the



Fig. 12.29 **TipTestMIDlet** main screen. (Courtesy of Sun Microsystems, Inc.)

server can identify which client is making the request. Unlike the Internet Explorer, Openwave UP browser and Pixo clients, a J2ME client does not have a well-known **User-Agent** header, so we must define our own header and store it in interface **ClientUserAgent-Headers**, so our servlets can distinguish **TipTestMIDlet** as a J2ME client. Lines 473–476 create a **User-Agent** header using **TipTestMIDlet**'s profile and configuration information. Lines 479–480 assign this header to the **HttpConnection** request.

We also require a means to track this session so the servlet can maintain state information—such as the correct answer—between sessions. Lines 406–407 store the **HttpConnection**'s **Set-cookie** header field, which provides information on this session, in **String sessionId** (line 40). The **Set-cookie** header contains information delimited by semicolons. A server stores a session identifier before the first semicolon—lines 410–413 extract the session identifier. The next time **TipTestMIDlet** connects to the server, lines 401–403 send this information to identify the session.

Line 417 calls method **getData** (lines 491–513) to receive data from the server. Lines 497–499 open a **DataInputStream** to read the server-generated data. Lines 501–507 read this data into a **String**, then return the **String**.

At this point, **TipTestMIDlet** has connected to **WelcomeServlet** and received data—which is **index.txt**—that represents the “welcome screen.” The data is

```
eLearning Deitel Programming Tips ;j2me/info.txt ;
```

Line 66 passes this **String** as an argument to method **createWelcomeScreen** (lines 91–138). Line 93 calls method **parseData** (lines 354–387), which parses the data into an array of **Strings**, so we can access individual **Strings**. Method **parseData** acts

like the J2SE class **java.util.StringTokenizer**, which the J2ME **java.util** package does not contain (due to limited resources specified by MIDP requirements). We use a semicolon as the delimiter to parse the data, so method **parseData** returns a two-element **String** array that contains “**eLearning Deitel Programming Tips**” (the screen name) and “**j2me/info.txt**” (the link to Tip-Test directions). Line 96 creates **welcomeScreen** using the first element in the **String** array as the **List** name. Line 98 appends the **String** “**Take TipTest**” to the **List**, informing the user to download the Tip Test. Figure 12.30 shows **TipTestMIDlet**’s welcome screen.

Lines 99–134 register **welcomeScreen** as a **CommandListener** for events from **selectCommand** and **backCommand**. When the user presses a soft button, either **selectCommand** or **backCommand** calls method **commandAction** (lines 110–131), depending on which button the user pressed. The **Command** is an example of the Command Design Pattern, which we discussed in Section 2.3 when we presented Swing **Actions**. In J2ME, a **Command** object can contain various commands, or instructions, such as “show the next **Screen**,” “show the previous **Screen**,” or “exit the application.” Several **Displayable** objects in the system can listen for these commands—MIDP-application developers write the operations that each **Displayable** object performs when receiving **Commands**. For example, we register **welcomeScreen** as a listener for the **selectCommand** and **backCommand** object. When each **Screen** receives a **Command** event, method **commandAction** uses the **Command** event’s method **getCommandType** to determine if the command type is **Command.OK** (“show the next **Screen**”) or **Command.BACK** (“show the previous **Screen**”). We design **TipTestMIDlet** to act according to the command type received. If the user pressed the left soft button (**Back**), line 128 sets the **Display** to display **mainScreen**. If the user pressed the right soft button (**Select**), lines 117–122 draw the “information” **Screen**. Lines 117–118 call method **getServerData**, which connects to the server and receives **j2me/info.txt** as the **String**:

```
In this exercise, we will test your knowledge of the Deitel  
programming tips ;tiptest ;
```

Lines 121–122 pass this **String** as an argument to method **createInformationScreen** (lines 141–200), which constructs a screen that provides more information on Tip Test. Line 143 calls method **parseData** to parse the server-generated data into a two-element **String** array. **String** array’s first element represents the title of the **Screen** we will create, and the second element represents the link to **TipTestServlet**. Line 146 creates **infoScreen** as a **Form**. A **Form** uses **StringItems**—components that contain **Strings**—to display several lines of text. A **List** is able to display only one line of text and therefore would display only part of the **String** array’s first element. We use a **Form** to display the **String** array’s first element in its entirety. Lines 149–150 append a **StringItem** to **infoScreen** using the **String** array’s first element. Lines 153–158 create a **ChoiceGroup**—a group of items that the user can select in a **Form**—using the **String** array’s second element, so **TipTestMIDlet** can link to **TipTestServlet**. Note that line 154 declares the **ChoiceGroup** as **EXCLUSIVE**, so the user must specify which item to select—in our example, there exists only one choice (**tiptest**), so this item is selected by default. Figure 12.31 shows **TipTestMIDlet**’s information screen.



Fig. 12.30 **TipTestMIDlet** welcome screen. (Courtesy of Sun Microsystems, Inc.)



Fig. 12.31 **TipTestMIDlet** information screen. (Courtesy of Sun Microsystems, Inc.)



## Common Programming Error 12.2

*ChoiceGroups* can be declared only as either **EXCLUSIVE** or **MULTIPLE**. Declaring a *ChoiceGroup* as **INCLUSIVE** results in an **IllegalArgumentException**.

Lines 160–196 register **infoScreen** as a **CommandListener** for events from **selectCommand** and **backCommand**. When the user presses a soft button, either **selectCommand** or **backCommand** calls method **commandAction** (lines 168–193), depending on which button the user pressed. If the user pressed the left soft button (**Back**), line 191 sets the **Display** to display **welcomeScreen**. If the user pressed the right soft button (**Select**), lines 175–186 display the “question” **Screen**. Line 175 determines which item in **ChoiceGroup** is selected—lines 177–178 assign this item to the **TipTestServlet** link. Lines 181–182 call method **getServerData**, which connects to **TipTestServlet** and receives Tip Test. **TipTestServlet** generates random information each time **TipTestMIDlet** establishes a connection; the data that **TipTestServlet** generates appears in the following format:

```
http://localhost:8080/advjhtp1/j2me/png/portability.png
PERF
CPE
TAD
PORT
```

Lines 185–186 call method **createTipTestScreen** (lines 203–256) to display the Tip-Test question. Line 206 calls method **parseData** to parse the Tip Test into a five-element **String** array. The first element contains the image file name located on the server. The remaining four elements contain the four tip abbreviations from which the user must choose the correct answer. We create a **Form**, so we can show an **Image** and a **ChoiceGroup**—no other **Displayable** subclass offers this functionality. Line 209 creates a new **Form**—**tipScreen**—to show Tip Test.

Line 212 passes the **String** array’s first element to method **getServerImage** (lines 435–463), which creates an **Image** object from the image file on the server. Lines 441–442 create an **HttpConnection** to the server, lines 448–449 read the data into an **InputStream** and lines 452–453 return an **Image** from the **InputStream** data.

Lines 215–216 append the **Image** to **tipScreen**. We now represent the four possible answers associated with this **Image** as a **ChoiceGroup**. Lines 218–222 create a **String** array to hold each of the four **String** answers. Lines 225–226 instantiate the **ChoiceGroup**, and line 229 appends this **ChoiceGroup** to **tipScreen**. Note that the **ChoiceGroup**’s constructor takes four arguments (unlike the **ChoiceGroup** constructor in method **createInformationScreen**, which took two arguments). The first argument represents the **ChoiceGroups** name, which we title “**Tip Test**.” The second argument declares this **ChoiceGroup** as **EXCLUSIVE**, so the user must indicate the selection before proceeding. The third argument is the **String** array that contains each possible **String** answer. The fourth argument represents an array of **Images** associated with the **String** array—the device places each **Image** in the **Image** array next to the respective **String** in the **String** array. We pass a **null** value for this argument, because we do not need to display any **Images** next to the four possible answers.

Figure 12.32 shows **tipScreen**. The picture on the left shows the **Image** for which the user must guess the correct name. When the user scrolls down on this screen (picture



**Fig. 12.32** **TipTestMIDlet** Tip-Test question screen. (Courtesy of Sun Microsystems, Inc.)

on the right), the user will see the four possible answers. The user must press the center soft button to indicate the selection.

Lines 231–251 register `tipScreen` as a `CommandListener` for events from `selectCommand`. When the user presses the `Select` button, `selectCommand` calls method `commandAction` (lines 238–249). Line 242 determines which item in the `ChoiceGroup` has been selected—this item represents the user's selection. Line 244 passes the selection to method `postData` (lines 306–351), which sends the selection to `TipTestServlet`. Lines 312–315 connect to `TipTestServlet` and specify that the connection is bidirectional, so `TipTestMIDlet` can send data to, and receive data from, `TipTestServlet`. Line 317 sets the `User-Agent` header so `TipTestServlet` can distinguish `TipTestMIDlet` as a J2ME client. Lines 320–322 send the session identifier that method `getServerData` stored to identify the session. Line 325 specifies that `TipTestServlet` will receive `post` data from `TipTestMIDlet`. Lines 328–329 open a `DataOutputStream`, through which line 332 sends the user selection to `TipTestServlet`. As we discussed in Section 12.3.4, `TipTestServlet` sends the correct answer to the J2ME client upon receiving this data. Line 336 calls method `getData` to receive this `String` data from the servlet. This data will have the following format:

```
Correct
Portability Tip
Organizations that develop software must often produce ver-
sions customized to a variety of computers and operating sys-
tems. These tips offer suggestions to make your applications
more portable.
```

Line 338 closes the connection between **TipTestMIDlet** and **TipTestServlet**, and line 340 returns the data that contains the correct answer. Lines 247–248 pass this **String** data to method **createAnswerScreen** (lines 259–303), which creates the **Screen** that displays the answer. Line 262 calls method **parseData** to parse the data into a three-element **String** array. The first element represents whether the user was correct or incorrect. The second and third elements hold the correct tip name and description, respectively. Line 265 instantiates **Form answerScreen** by passing the **String** array's first element to the constructor—we use a **Form** to show the tip description in its entirety. Lines 268–273 instantiate two **StringItems** to hold the tip name and description. Lines 276–277 append these **StringItems** to **answerScreen**. Figure 12.33 shows **answerScreen**. The picture on the left shows the screen that contains the correct tip name and description. When the user scrolls down on this screen, the user will see the right picture, which shows the remainder of the tip description.

Lines 279–299 register **tipScreen** as a **CommandListener** for events from **nextCommand**. The **nextCommand** object's behavior is identical to that of the **selectCommand** object; however, because we cannot alter **selectCommand**'s label to hold “**Next Tip**” as a value, we had to instantiate another **Command** object to ensure that the “**Next Tip**” text appears above the right soft button. When the user presses the right soft button, **nextCommand** calls method **commandAction** (lines 286–296), which calls method **createTipTestScreen** to generate another Tip-Test question—users can play Tip Test for as long as they desire.



Fig. 12.33 **TipTestMIDlet** Tip-Test answer screen. (Courtesy of Sun Microsystems, Inc.)

This concludes our case study of Java-based wireless application development and Java 2 Micro Edition. In this section, we created a three-tier architecture in which **TipTestServlet** (middle tier) marked up a randomly generated Tip-Test question as XML, applied an XSLT to the XML document, then sent the resulting document to clients. We then introduced J2ME by discussing the CLDC and MIDP—the fundamental J2ME APIs for building applications to run on mobile devices. We studied a MIDlet’s lifecycle and examined how to create a new MIDlet from class **MIDlet**. We created a MIDP application—**TipTestMIDlet**—then discussed how it retrieves data from **WelcomeServlet** and **TipTestServlet**. We also discussed how **TipTestMIDlet** uses this data to construct user interfaces and how, by using **Command** objects, a **TipTestMIDlet** enables the user to navigate through various **Screens**.

In Chapter 13, we continue our discussion by presenting Remote Method Invocation (RMI), which enables client objects to call methods of objects on other systems. In Chapter 14, we begin discussing Enterprise JavaBeans (EJBs), which provide a model for building business logic in enterprise Java applications.

## 12.5 Installation Instructions

This section provides installation instructions for the software in this case study.

### *Web Server Configuration*

This case study requires a web server that can run servlets. We recommend the Apache Tomcat Server. We provided directions to install Tomcat in Section 9.3.1. When you have installed Tomcat, copy the contents of the **advjhttp1** directory on the CD to the **advjhttp1** directory in the Tomcat directory on your system. The **advjhttp1** directory on the CD contains four directories—**iMode**, **j2me**, **XHTML**, **WAP**—that contain content that the servlets distribute to each client.

Next, you must copy the contents of Fig. 12.34, which we provide on the CD, in **web.xml**’s **web-app** element. The **web.xml** file should exist in the **WEB-INF** Tomcat directory. For example, on our system, **web.xml** is located in

```
C:\jakarta-tomcat-3.2.2\webapps\advjhttp1\WEB-INF\
```

---

```

1 <!-- Servlet definitions -->
2 <servlet>
3   <servlet-name>welcome</servlet-name>
4
5   <description>
6     A servlet that returns a "Welcome" screen through
7     an HTTP get request
8   </description>
9
10  <servlet-class>
11    com.deitel.advjhttp1.wireless.WelcomeServlet
12  </servlet-class>
13 </servlet>
14
```

---

Fig. 12.34 Deployment descriptor to run **WelcomeServlet** and **TipTestServlet** (part 1 of 2).

```
15 <servlet>
16   <servlet-name>tiptest</servlet-name>
17
18   <description>
19     A servlet that accesses a database to generate tests for
20     Deitel programming tips
21   </description>
22
23   <init-param>
24     <param-name>DATABASE_URL</param-name>
25     <param-value>jdbc:cloudscape:rmi:tips</param-value>
26   </init-param>
27
28   <init-param>
29     <param-name>JDBC_DRIVER</param-name>
30     <param-value>
31       COM.cloudscape.core.RmiJdbcDriver
32     </param-value>
33   </init-param>
34
35   <servlet-class>
36     com.deitel.advjhttp1.wireless.TipTestServlet
37   </servlet-class>
38 </servlet>
39
40 <!-- Servlet mappings -->
41 <servlet-mapping>
42   <servlet-name>welcome</servlet-name>
43   <url-pattern>/welcome</url-pattern>
44 </servlet-mapping>
45
46 <servlet-mapping>
47   <servlet-name>tiptest</servlet-name>
48   <url-pattern>/tiptest</url-pattern>
49 </servlet-mapping>
50
51 <mime-mapping> <!-- WML Source -->
52   <extension>wml</extension>
53   <mime-type>text/vnd.wap.wml</mime-type>
54 </mime-mapping>
55
56 <mime-mapping> <!-- Wireless Bitmap -->
57   <extension>wbmp</extension>
58   <mime-type>image/vnd.wap.wbmp</mime-type>
59 </mime-mapping>
```

---

Fig. 12.34 Deployment descriptor to run **WelcomeServlet** and **TipTestServlet** (part 2 of 2).

In Fig. 12.34, lines 2–13 describe **WelcomeServlet**, and line 15–38 describe **TipTestServlet**. Lines 23–33 declare two **init-param** elements that enable us to change the database that **TipTestServlet** uses, without having to modify **TipTestServlet.java**. Lines 41–49 map the two servlets to specified URLs. Lines 51–59 con-

figure Tomcat to serve WML content with correct MIME types—if we do not specify these MIME types, the WAP clients will not receive content.

The last step for configuring Tomcat to run the case study involves specifying those classes that Tomcat uses to run the servlets. Create the directory structure **com/deitel/advjhttp1/wireless** in the **WEB-INF/classes** directory. For example, on our system, the directory structure is

```
C:\jakarta-tomcat-3.2.2\webapps\advjhttp1\WEB-INF\classes\com\deitel\advjhttp1\wireless\
```

Copy **WelcomeServlet.class** and **TipTestServlet.class** into this directory.

### **Database Configuration**

This case study also requires a database from which the servlet can extract tip information. We recommend the Cloudscape database, which we provide installation instructions in Sections 8.1 and 8.5. Copy the **tips.sql** file and the **tips** directory from our CD to the **frameworks/RmiJdbc/bin** directory where you have installed Cloudscape on your system. For example, **c:\cloudscape\_3.6** is the directory that contains Cloudscape on our system, so

```
C:\cloudscape_3.6\frameworks\RmiJdbc\bin\
```

should contain **tips.sql** and the **tips** directory. Next, copy **cloudscape.jar** and **RmiJdbc.jar** (located on the CD) into the **WEB-INF/lib** Tomcat directory. For example, on our system, this directory is

```
C:\jakarta-tomcat-3.2.2\webapps\advjhttp1\WEB-INF\lib\
```

Placing **cloudscape.jar** and **RmiJdbc.jar** in this directory enable **TipTest-Servlet** to connect to, and extract from, a Cloudscape database.

### **J2ME Wireless Toolkit Installation and Configuration**

To use the Sun MIDP-device emulator and develop MIDP applications, you must use the J2ME Wireless Toolkit. We include this toolkit on the CD, or you may download the toolkit from

```
java.sun.com/products/j2mewtoolkit/
```

At the time of this writing, Release 1.0.2 is available for download. In the installation procedure, you can specify whether you want to integrate the J2ME Wireless Toolkit with Forte—which facilitates developing MIDP applications in Forte—or to run the toolkit as a “stand-alone” application. We recommend that you integrate the toolkit in Forte.

If you integrate the toolkit in Forte, create the directory structure **com/deitel/advjhttp1/wireless** in your system’s Forte development directory. For example, **c:\forte4j\Development** is the Forte development directory on our system, so we create the directory structure

```
C:\forte4j\Development\com\deitel\advjhttp1\wireless\
```

Next, copy **TipTestMIDlet.java** and **TipTestMIDlet.jar** from our CD to this directory. When you expand this directory structure in Forte, you should see

```
TipTestMIDlet.java  
TipTestMIDlet.jar
```

**TipTestMIDlet.jar** is the MIDlet suite that contains class **TipTestMIDlet**. To run class **TipTestMIDlet**, right-click on the **TipTestMIDlet.jar** icon, then select execute.

If you prefer to use the Wireless Toolkit (or if you had installed the toolkit as a stand-alone application), first open the Wireless Toolkit by selecting **KToolbar** in the directory where you installed the toolkit. Next, press the **New Project** button. In the **Project Name** text field, type

```
TipTestMIDlet
```

In the **MIDlet Class Name** text field, type

```
com.deitel.advjhttp1.wireless.TipTestMIDlet
```

then press the **Create Project** button. When the **Settings** frame appears, press the **OK** button. Next, copy **TipTestMIDlet.java** from our CD to the **apps/TipTestMIDlet/src** directory in the directory where you installed the toolkit. For example, **C:\J2mewtk** is the directory where we installed the toolkit on our system, so we copy **TipTestMIDlet.java** to

```
C:\J2mewtk\apps\TipTestMIDlet\src\
```

Return to the Wireless toolkit, and press the **Build** button. When **TipTestMIDlet** has finished compiling and preverifying, press the **Run** button to execute **TipTestMIDlet**. The **Device** menu—located on the toolkit's right side—enables you to select from among several devices to run **TipTestMIDlet**. Although the default device is the Sun grayscale MIDP-device emulator, you can specify to run **TipTestMIDlet** on other devices, such as RIM's Blackberry-957<sup>TM</sup> and the Motorola i85s<sup>TM</sup>.

#### *Other clients*

Figure 12.35 lists the URLs to download the browsers used in this case study.

Browser	URL
Microsoft Internet Explorer	<a href="http://www.microsoft.com/downloads/search.asp?">www.microsoft.com/downloads/search.asp?</a>
Openwave UP simulator	<a href="http://developer.openwave.com/download/license_41.html">developer.openwave.com/download/license_41.html</a>
Pixo Internet Microbrowser	<a href="http://www.pixo.com/products/products001.htm">www.pixo.com/products/products001.htm</a>

Fig. 12.35 Case-study browser URLs.

## 12.6 Internet and World Wide Web Resources

### **[www.java.sun.com/j2me](http://www.java.sun.com/j2me)**

This site contains Sun's Java 2 Micro Edition available for download.

### **[www.onjava.com/pub/a/onjava/2001/03/08/J2ME.html](http://www.onjava.com/pub/a/onjava/2001/03/08/J2ME.html)**

This site contains a J2ME article.

### **[www.jguru.com/faq/home.jsp?topic=J2ME](http://www.jguru.com/faq/home.jsp?topic=J2ME)**

This site presents the J2ME FAQ.

### **[www.wirelessdevnet.com/channels/java/features/j2me\\_http.phtml](http://www.wirelessdevnet.com/channels/java/features/j2me_http.phtml)**

This site discusses network programming with J2ME devices.

### **[www.ericgiguere.com/microjava/fallacies.html](http://www.ericgiguere.com/microjava/fallacies.html)**

This site lists some common misconceptions of J2ME.

### **[www.motorola.com/java](http://www.motorola.com/java)**

This site discusses J2ME integration in new Motorola's wireless devices.

### **[www.internetnews.com/wd-news/article/0,,10\\_533091,00.html](http://www.internetnews.com/wd-news/article/0,,10_533091,00.html)**

This site discusses J2ME integration in the Palm devices.

### **[www.mot.com/java/devices.html](http://www.mot.com/java/devices.html)**

This site lists several wireless devices that use J2ME technology in the market.

### **[www.nttdocomo.com/i/index.html](http://www.nttdocomo.com/i/index.html)**

This is the Web site of NTT DoCoMo—the creators of i-mode.

### **[www.anywheredyougo.com/imode/Index.po](http://www.anywheredyougo.com/imode/Index.po)**

This site presents news about i-mode development.

### **[www.i-modesales.com](http://www.i-modesales.com)**

This site offers information on i-mode phones and services.

### **[www.wap.com](http://www.wap.com)**

This site offers news about WAP development.

### **[www.wapforum.org/](http://www.wapforum.org/)**

This site discusses advancements in the WAP field.

## SUMMARY

- This case study is a three-tier architecture of a multiple choice test (Tip Test) that allows users to test their knowledge of Deitel programming tips.
- Developers can use Java technology to develop wireless and server-side applications that developers can also develop with ASP.
- The information tier consists of a database. The middle tier consists of two servlets—**WelcomeServlet** and **TipTestServlet**—that generate content to clients of various types. The client tier consists of four client types—Internet Explorer, WAP, i-mode and J2ME. Each client type renders content differently.
- Microsoft Internet Explorer receives XHTML content.
- The Openwave UP simulator is the WAP client that receives WML content.
- The Pixo Internet Microbrowser is the i-mode client that receives cHTML content.
- The Sun MIDP-device emulator displays a J2ME client that receives content in plain-text format.
- J2ME™ (Java™ 2 Micro Edition) is Sun's newest Java platform for developing applications for various consumer devices, such as set-top boxes, Web terminals, embedded systems, mobile phones and cell pagers.

- MIDP (Mobile Information Device Profile) is a set of APIs that allow developers to handle mobile-device-specific issues, such as creating user interfaces, storing information locally and networking.)
- Devices that run applications for MIDP are called MIDP devices (e.g., cell phones or pagers).
- Clients interact with servlets by making a series of **get** and **post** request to the servlets. When a client sends a **get** request to an **HttpServlet**, method **doGet** handles the request. When a client sends a **post** request to an **HttpServlet**, method **doPost** handles the request.
- All clients contain a unique **User-Agent** header, which contains information on what type of client is requesting data from the server.
- Method **getInitParameter** of **HttpServlet** allows us to specify information (such as database locations or drivers) declared in **web.xml**. We need only to modify the **<param-value>** element in the **<init-param>** element in **web.xml** to change this information.
- **org.w3c.dom.Element** objects element nodes in XML documents.
- We can apply an XSLT to an XML **Document** to produce different content for each different client type. Each client type renders this content accordingly.
- We did not use XML for our J2ME client, because at the time of this writing, J2ME cannot support XML without using non-standard XML-based software.
- J2ME uses the Connected Limited Device Configuration (CLDC) and the Mobile Information Device Profile (MIDP), which offer developers a set of APIs to write J2ME applications and deploy them across several mobile devices.
- The CLDC is a set of APIs that allow developers to create applications for devices that have limited resources—i.e., limited screen size, memory, power and bandwidth.
- Currently, the CLDC does not contain certain features that developers often “take for granted” in other Java platforms—e.g., floating-point operations, serializable objects and thread groups.
- The MIDP is a set of APIs that allow developers to handle mobile-device-specific issues, such as creating user interfaces, permitting local storage and defining the lifecycles of MIDP-client applications.
- A MIDlet is a type of MIDP-client application. All MIDlets must extend class **javax.microedition.midlet.MIDlet**.
- MIDP developers store several MIDlets in a jar file—called a MIDlet suite—on a server.
- The application management software (AMS) on the MIDP device downloads the MIDlet suite from the server, opens the MIDlet suite, then launches the user-specified MIDlet on the MIDP device.
- The AMS uses an application descriptor file to load the MIDlet application. This file contains various information on the MIDlet suite and the MIDP device.
- The MIDlet lifecycle consists of methods **startApp**, **pauseApp** and **destroyApp**.
- J2ME divides the user-interface API between low-level and high-level APIs. The low-level API allows developers to incorporate graphics and provide animation, whereas the high-level user-interface API allows developers to incorporate text fields, lists and forms.
- Class **Displayable** represents content that a MIDP-device can display on screen. Classes **Screen** (high-level) and **Canvas** (low-level) extend class **Displayable**.
- Class **Display** acts as a display manager for a MIDlet. Exactly one **Display** object can exist in a MIDlet.
- J2ME provides “soft-button support” in MIDlets through **Command** objects, which encapsulates an action to be executed by the object that receives the **Command** object.
- **Lists** and **Forms** are two high-level user-interface classes that extend class **Screen**.
- A **Form** can include **ChoiceGroups**—groups of items the user can select in a **Form**.

## TERMINOLOGY

application management software (AMS)	J2ME low-level user-interface API
cHTML (compact HTML)	Java application descriptor file
class <b>Alert</b>	KVM
class <b>Canvas</b>	Openwave UP simulator
class <b>ChoiceGroup</b>	method <b>commandAction</b> of class <b>CommandListener</b>
class <b>Command</b>	method <b>doGet</b> of class <b>HttpServlet</b>
class <b>CommandListener</b>	method <b>doPost</b> of class <b>HttpServlet</b>
class <b>Display</b>	method <b>destroyApp</b> of class MIDlet
class <b>Displayable</b>	method <b>pauseApp</b> of class MIDlet
class <b>DocumentBuilder</b>	method <b>startApp</b> of class MIDlet
class <b>DocumentBuilderFactory</b>	middle tier
class <b>DOMSource</b>	MIDlet
class <b>Element</b>	MIDlet lifecycle
class <b>Form</b>	MIDlet suite
class <b>HttpServletRequest</b>	MIDP application
class <b>HttpServletResponse</b>	MIDP devices
class <b>HttpRequest</b>	MIDP package <b>javax.microedition.io</b>
class <b>HttpSession</b>	MIDP package
class <b>InputStream</b>	<b>javax.microedition.lcdui</b>
class <b>List</b>	MIDP package
class <b>Screen</b>	<b>javax.microedition.midlet</b>
class <b>StreamSource</b>	MIDP package <b>javax.microedition.rms</b>
class <b>StringItem</b>	mobile device
class <b>TextBox</b>	Mobile Information Device Profile (MIDP)
class <b>Transformer</b>	namespace
class <b>TransformerFactory</b>	Pixo Internet Microbrowser
client	server
CLDC packages <b>java.io</b> , <b>java.lang</b> and <b>java.util</b>	Sun MIDP-device emulator
Connected Limited Device Configuration (CLDC)	three-tier architecture
database	<b>User-Agent</b> header
Extensible HyperText Markup Language (XHTML)	servlet
<b>get</b> and <b>post</b> data	Wireless Application Protocol (WAP)
i-mode	Wireless Markup Language (WML)
information tier	XML
Java 2 Micro Edition (J2ME)	<b>XML Document</b>
J2ME high-level user-interface API	XSLT

## SELF-REVIEW EXERCISES

### 12.1 Fill in the blanks in each of the following statements:

- Typically, a three-tier architecture contains a \_\_\_\_\_ layer, a \_\_\_\_\_ layer and a \_\_\_\_\_ layer.
- The servlets in our case study generated \_\_\_\_\_ content to Internet Explorer, \_\_\_\_\_ content to the WAP client, \_\_\_\_\_ content to the i-mode client and \_\_\_\_\_ content to the J2ME client.
- TipTestServlet** used a \_\_\_\_\_ object to store the correct tip name and description.

- d) CLDC stands for \_\_\_\_\_.
- e) MIDP stands for \_\_\_\_\_.
- f) Developers can package several MIDlets in a jar file called a \_\_\_\_\_.
- g) The application descriptor file contains the \_\_\_\_\_ extension.
- h) The MIDlet lifecycle consists of methods \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- i) In package **javax.microedition.lcdui**, class \_\_\_\_\_ represents content that a MIDP device can display on screen.
- j) Class **javax.microedition.Display** is an example of the \_\_\_\_\_ design pattern.

- 12.2** State whether each of the following statements is *true* or *false*. If *false*, explain why.
- a) An **HttpServlet**'s calls method **doGet** upon receiving a **get** request and method **doPost** upon receiving a **post** request. (true/false).
  - b) A User-Agent header contains information about the server. (true/false).
  - c) **DocumentBuilder**'s **static** method **newDocumentBuilder** creates a new **DocumentBuilder**. (true/false).
  - d) In this case study, **TipTestServlet** uses XSLT to transform XML Tip Test **Documents** to well formed content for all clients. (true/false).
  - e) The J2ME CLDC package consist of **java.io**, **java.lang** and **java.net**. (true/false).
  - f) The application management software loads a MIDlet on a MIDP device. (true/false).
  - g) The application description file specifies such information as the MIDP device's configuration and the MIDlet's name. (true/false).
  - h) Classes **Alert**, **Form**, **Screen**, and **List** are the concrete classes of the MIDP high-level user-interface package. (true/false).
  - i) A **javax.microedition.lcdui.Command** object encapsulates an action to be executed by the object that received the **Command**. (true/false).
  - j) An **HttpSession**'s **Set-Cookie** header field contains session information. (true/false).

## ANSWERS TO SELF-REVIEW EXERCISES

- 12.1** a) client (top), middle, information (bottom). b) XHTML, WAP, cHTML, plain text. c) **HttpSession**. d) Connected Limited Device Configuration. e) Mobile Information Device Profile. f) MIDlet suite. g) **.jad**. h) **startApp**, **pauseApp**, **destroyApp**. i) **Displayable**. j) Singleton.

- 12.2** a) True. b) False. A User-Agent header contains information on what client type is requesting data from a server. c) False. **DocumentBuilderFactory**'s **static** method **newDocumentBuilder** creates a new **DocumentBuilder**. Class **DocumentBuilder** creates new **Documents**. d) False. **TipTestServlet** uses XSLT to transform XML Tip Test **Documents** to well-formed content for only Internet-Explorer, WAP and i-mode clients. e) False. The J2ME CLDC package consist of **java.io**, **java.lang** and **java.util**. f) True. g) True. h) Classes **Alert**, **Form**, **TextBox**, and **List** are the concrete classes of the MIDP high-level user-interface package. Class **Screen** is an abstract class these classes extend. i) True. j) True.

## EXERCISES

- 12.3** To make **TipTestServlet** more manageable and extendable, we stored the database driver name and URL in the **<init-param>** element in **web.xml**. List 3 other constants that we could have stored from **WelcomeServlet** and **TipTestServlet** in the **<init-param>** element.

- 12.4** Extend the list of possible answers in the Tip-Test question from four to five.

**12.5** Method `getResultSet` of **TipTestServlet** creates a two-dimensional **String**-array **ResultSet** representation. However, because these dimensions are pre-defined (seven rows by five columns), the **String** array cannot store additional rows if we append another tip to the database. Modify **TipTestServlet** so that it can handle any number of tips from the database. Use techniques shown in Chapter 8, Java Database Connectivity (JDBC), to create a scrollable **ResultSet** so that you can determine the number of rows in the **ResultSet** and size the **String** array accordingly.

**12.6** Lines 29–38 of class **TipTestMIDlet** specify the servlet URL and the **WelcomeServlet** URL. This approach can be problematic if a network administrator changes either URL. In practice, we would like the application descriptor file to contain the servlet URL and the MIDP-device user to specify the **WelcomeServlet** URL with the MIDP-device keypad.

- a) Encode the servlet URL—**http://localhost:8080/advjhttp1/**—in the **TipTestMIDlet** application descriptor file by typing

```
Servlet-URL: http://localhost:8080/advjhttp1/
```

at the end of **TipTestMIDlet**'s **.jad** file. In **TipTestMIDlet**, use method `getAppProperty` of class **MIDlet** to return the servlet URL. (Method `getAppProperty` takes a property-tag **String**—e.g., **"Servlet-URL"**—as an argument and returns the **String** associated with that property.)

- b) Enable the user to specify the **WelcomeServlet** URL. Modify the class **TipTestMIDlet** constructor to create **mainScreen** (line 51) as a **TextBox**—a **Screen** subclass that enables the user to input text. A **TextBox** constructor takes four arguments: 1) a **String** that represents the **TextBox**'s title; 2) a **String** that represents the **TextBox**'s initial contents; 3) an **int** that represents the maximum number of characters allowed in the **TextBox**; 4) an input constraint **int** that specifies the required input format—e.g., if you want the user to enter a phone number, the constraint is **TextField.PHONENUMBER**. We want the user to enter a URL, so the constraint is **TextField.URL**. Use method `getString` of class **TextBox** to return the **TextBox**'s contents (user input) to store the **WelcomeServlet** URL when the user presses the Select soft button.

**12.7** Modify **TipTestMIDlet** to enable the user to exit the application in the Tip-Test answer screen in addition to receiving the next Tip-Test question. Create a new **Command** object that uses **Command.EXIT** and register **answerScreen** as a listener for this **Command**. (Hint: override method `destroyApp` to call method `notifyDestroy` of class **javax.microedition.midlet.MIDlet**.

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# 13

## Remote Method Invocation

### Objectives

- To understand the distributed computing concepts.
- To understand the architecture of RMI.
- To be able to use activatable RMI objects to build resilient distributed systems.
- To understand how to use RMI callbacks.
- To be able to build RMI clients that download necessary classes dynamically.
- To be able to build activatable RMI objects.

*Dealing with more than one client at a time is the business world's equivalent of bigamy. It's so awkward to tell one client that you're working on someone else's business that you inevitably start lying.*

Andrew Frothingham

*They also serve who only stand and wait.*

John Milton

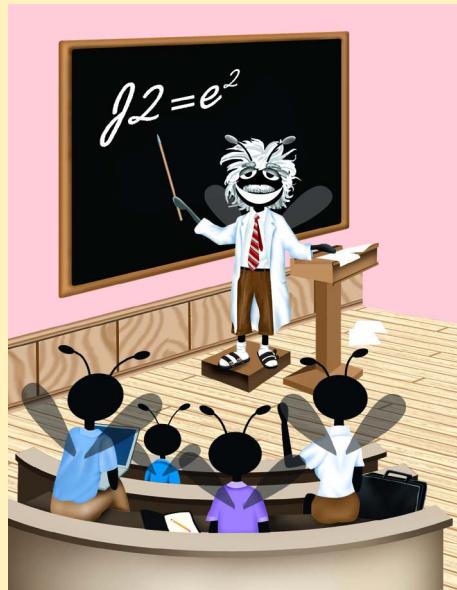
*Rule 1: The client is always right.*

*Rule 2: If you think the client is wrong, see Rule 1.*

Sign seen in shops

*I love being a writer. What I can't stand is the paperwork.*

Peter De Vries



## Outline

- 13.1 Introduction
- 13.2 Case Study: Creating a Distributed System with RMI
- 13.3 Defining the Remote Interface
- 13.4 Implementing the Remote Interface
- 13.5 Compiling and Executing the Server and the Client
- 13.6 Case Study: Deitel Messenger with Activatable Server
  - 13.6.1 Activatable Deitel Messenger ChatServer
  - 13.6.2 Deitel Messenger Client Architecture and Implementation
  - 13.6.3 Running the Deitel Messenger Server and Client Applications
- 13.7 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 13.1 Introduction

In this chapter, we introduce Java’s distributed computing capabilities with *Remote Method Invocation (RMI)*. RMI allows Java objects running on separate computers or in separate processes to communicate with one another via *remote method calls*. Such method calls appear to the programmer the same as those operating on objects in the same program.

RMI is based on a similar, earlier technology for procedural programming called *remote procedure calls (RPCs)* developed in the 1980s. RPC allows a procedural program (i.e., a program written in C or another procedural programming language) to call a function residing on another computer as conveniently as if that function were part of the same program running on the same computer. A goal of RPC was to allow programmers to concentrate on the required tasks of an application by calling functions, while making the mechanism that allows the application’s parts to communicate over a network transparent to the programmer. RPC performs all the networking and *marshaling of data* (i.e., packaging of function arguments and return values for transmission over a network). A disadvantage of RPC is that it supports a limited set of simple data types. Therefore, RPC is not suitable for passing and returning Java objects. Another disadvantage of RPC is that it requires the programmer to learn a special *interface definition language (IDL)* to describe the functions that can be invoked remotely.

RMI is Java’s implementation of RPC for Java-object-to-Java-object distributed communication. Once a Java object registers as being remotely accessible (i.e., it is a *remote object*), a client can obtain a remote reference to that object, which allows the client to use that object remotely. The method call syntax is identical to the syntax for calling methods of other objects in the same program. As with RPC, RMI handles the marshaling of data across the network. However, RMI also enables Java programs to transfer complete Java objects using Java’s object-serialization mechanism. The programmer need not be concerned with the transmission of the data over the network. RMI does not require the programmer to learn an IDL, because the J2SE SDK includes tools for generating all the

networking code from the program's interface definitions. Also, because RMI supports only Java, no language-neutral IDL is required; Java's own interfaces are sufficient.

We present two substantial RMI examples and discuss the key concepts of RMI as we encounter them throughout the examples. After studying these examples, you should have an understanding of the RMI networking model and should be able to take advantage of advanced RMI features for building Java-to-Java distributed applications.

[*Note:* For Java-to-non-Java communication, you can use Java IDL (introduced in Java 1.2) or RMI-IIOP. Java IDL and RMI-IIOP enable applications and applets written in Java to communicate with objects written in any language that supports CORBA (Common Object Request Broker Architecture). Please see Chapter 26, CORBA: Part 1 and Chapter 27, CORBA: Part 2 for our discussion of CORBA and RMI-IIOP.]

## 13.2 Case Study: Creating a Distributed System with RMI

In the next several sections, we present an RMI example that downloads the *Traveler's Forecast* weather information from the National Weather Service Web site:

`http://iwin.nws.noaa.gov/iwin/us/traveler.html`

[*Note:* As we developed this example, the format of the *Traveler's Forecast* Web page changed several times (a common occurrence with today's dynamic Web pages). The information we use in this example depends directly on the format of the *Traveler's Forecast* Web page. If you have trouble running this example, please refer to the FAQ page on our Web site, [www.deitel.com](http://www.deitel.com).]

We store the *Traveler's Forecast* information in an RMI remote object that accepts requests for weather information through remote method calls.

The four major steps in this example include:

1. Defining a *remote interface* that declares methods that clients can invoke on the remote object.
2. Defining the *remote object implementation* for the remote interface. [*Note:* By convention, the remote object implementation class has the same name as the remote interface and ends with `Impl`.]
3. Defining the client application that uses a *remote reference* to interact with the interface implementation (i.e., an object of the class that implements the remote interface).
4. Compiling and executing the remote object and the client.

## 13.3 Defining the Remote Interface

The first step in creating a distributed application with RMI is to define the remote interface that describes the *remote methods* through which the client interacts with the remote object using RMI. To create a remote interface, define an interface that extends interface `java.rmi.Remote`. Interface `Remote` is a *tagging interface*—it does not declare any methods, and therefore places no burden on the implementing class. An object of a class that implements interface `Remote` directly or indirectly is a *remote object* and can be accessed—with appropriate security permissions—from any Java virtual machine that has a connection to the computer on which the remote object executes.



### Software Engineering Observation 13.1

*Every remote method must be declared in an interface that extends `java.rmi.Remote`.*



### Software Engineering Observation 13.2

*An RMI distributed application must export an object of a class that implements the `Remote` interface to make that remote object available to receive remote method calls.*

Interface **WeatherService** (Fig. 13.1)—which extends interface **Remote** (line 10)—is the remote interface for our remote object. Line 13 declares method **getWeatherInformation**, which clients can invoke to retrieve weather information from the remote object. Note that although the **WeatherService** remote interface defines only one method, remote interfaces can declare multiple methods. A remote object must implement all methods declared in its remote interface.

When computers communicate over networks, there exists the potential for communication problems. For example, a server computer could malfunction, or a network resource could malfunction. If a communication problem occurs during a remote method call, the remote method throws a **RemoteException**, which is a checked exception.



### Software Engineering Observation 13.3

*Each method in a `Remote` interface must have a `throws` clause that indicates that the method can throw `RemoteExceptions`.*



### Software Engineering Observation 13.4

*RMI uses Java's default serialization mechanism to transfer method arguments and return values across the network. Therefore, all method arguments and return values must be `Serializable` or primitive types.*

## 13.4 Implementing the Remote Interface

The next step is to define the remote object implementation. Class **WeatherServiceImpl** (Fig. 13.2) is the remote object class that implements the **WeatherService** remote interface. The client interacts with an object of class **WeatherServiceImpl** by invoking

```
1 // WeatherService.java
2 // WeatherService interface declares a method for obtaining
3 // weather information.
4 package com.deitel.advjhttp1.rmi.weather;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.util.*;
9
10 public interface WeatherService extends Remote {
11
12     // obtain List of WeatherBean objects from server
13     public List getWeatherInformation() throws RemoteException;
14
15 }
```

Fig. 13.1 **WeatherService** interface.

method `getWeatherInformation` of interface `WeatherService` to obtain weather information. Class `WeatherServiceImpl` stores weather data in a `List` of `WeatherBean` (Fig. 13.3) objects. When a client invokes remote method `getWeatherInformation`, the `WeatherServiceImpl` returns a reference to the `List` of `WeatherBeans`. The RMI system returns a serialized copy of the `List` to the client. The RMI system then de-serializes the `List` on the receiving end and provides the caller with a reference to the `List`.

The National Weather Service updates the Web page from which we retrieve information twice a day. However, class `WeatherServiceImpl` downloads this information only once, when the server starts. The exercises ask you to modify the server to update the data twice a day. [Note: `WeatherServiceImpl` is the class affected if the National Weather Service changes the format of the *Traveler's Forecast* Web page. If you encounter problems with this example, visit the FAQ page at our Web site [www.deitel.com](http://www.deitel.com).]

```
1 // WeatherServiceImpl.java
2 // WeatherServiceImpl implements the WeatherService remote
3 // interface to provide a WeatherService remote object.
4 package com.deitel.advjhtp1.rmi.weather;
5
6 // Java core packages
7 import java.io.*;
8 import java.net.URL;
9 import java.rmi.*;
10 import java.rmi.server.*;
11 import java.util.*;
12
13 public class WeatherServiceImpl extends UnicastRemoteObject
14     implements WeatherService {
15
16     private List weatherInformation; // WeatherBean object List
17
18     // initialize server
19     public WeatherServiceImpl() throws RemoteException
20     {
21         super();
22         updateWeatherConditions();
23     }
24
25     // get weather information from NWS
26     private void updateWeatherConditions()
27     {
28         try {
29             System.out.println( "Update weather information..." );
30
31             // National Weather Service Traveler's Forecast page
32             URL url = new URL(
33                 "http://iwin.nws.noaa.gov/iwin/us/traveler.html" );
34     }
```

Fig. 13.2 `WeatherServiceImpl` class implements remote interface `WeatherService` (part 1 of 3).

```
35      // create BufferedReader for reading Web page contents
36      BufferedReader in = new BufferedReader(
37          new InputStreamReader( url.openStream() ) );
38
39      // separator for starting point of data on Web page
40      String separator = "TAV12";
41
42      // locate separator string in Web page
43      while ( !in.readLine().startsWith( separator ) )
44          ;      // do nothing
45
46      // strings representing headers on Traveler's Forecast
47      // Web page for daytime and nighttime weather
48      String dayHeader =
49          "CITY           WEA     HI/LO    WEA     HI/LO";
50      String nightHeader =
51          "CITY           WEA     LO/HI    WEA     LO/HI";
52
53      String inputLine = "";
54
55      // locate header that begins weather information
56      do {
57          inputLine = in.readLine();
58      } while ( !inputLine.equals( dayHeader ) &&
59                  !inputLine.equals( nightHeader ) );
60
61      weatherInformation = new ArrayList(); // create List
62
63      // create WeatherBeans containing weather data and
64      // store in weatherInformation List
65      inputLine = in.readLine(); // get first city's info
66
67      // The portion of inputLine containing relevant data is
68      // 28 characters long. If the line length is not at
69      // least 28 characters long, done processing data.
70      while ( inputLine.length() > 28 ) {
71
72          // Create WeatherBean object for city. First 16
73          // characters are city name. Next, six characters
74          // are weather description. Next six characters
75          // are HI/LO or LO/HI temperature.
76          WeatherBean weather = new WeatherBean(
77              inputLine.substring( 0, 16 ),
78              inputLine.substring( 16, 22 ),
79              inputLine.substring( 23, 29 ) );
80
81          // add WeatherBean to List
82          weatherInformation.add( weather );
83
84          inputLine = in.readLine(); // get next city's info
85      }
86
```

Fig. 13.2 `WeatherServiceImpl` class implements remote interface `WeatherService` (part 2 of 3).

```
87         in.close(); // close connection to NWS Web server
88
89         System.out.println( "Weather information updated." );
90
91     } // end method updateWeatherConditions
92
93     // handle exception connecting to National Weather Service
94     catch( java.net.ConnectException connectException ) {
95         connectException.printStackTrace();
96         System.exit( 1 );
97     }
98
99     // process other exceptions
100    catch( Exception exception ) {
101        exception.printStackTrace();
102        System.exit( 1 );
103    }
104 }
105
106 // implementation for WeatherService interface remote method
107 public List getWeatherInformation() throws RemoteException
108 {
109     return weatherInformation;
110 }
111
112 // launch WeatherService remote object
113 public static void main( String args[] ) throws Exception
114 {
115     System.out.println( "Initializing WeatherService..." );
116
117     // create remote object
118     WeatherService service = new WeatherServiceImpl();
119
120     // specify remote object name
121     String serverObjectName = "rmi://localhost/WeatherService";
122
123     // bind WeatherService remote object in RMI registry
124     Naming.rebind( serverObjectName, service );
125
126     System.out.println( "WeatherService running." );
127 }
128 }
```

Fig. 13.2 `WeatherServiceImpl` class implements remote interface `WeatherService` (part 3 of 3).

Class `WeatherServiceImpl` extends class `UnicastRemoteObject` (package `java.rmi.server`) and implements `Remote` interface `WeatherService` (lines 13–14). Class `UnicastRemoteObject` provides the basic functionality required for all remote objects. In particular, its constructor *exports* the object to make it available to receive remote calls. Exporting the object enables the remote object to wait for client connections on an *anonymous port number* (i.e., one chosen by the computer on which the remote object executes). This enables the object to perform *unicast communication* (point-

to-point communication between two objects via method calls) using standard streams-based socket connections. RMI abstracts away these communication details so the programmer can work with simple method calls. The `WeatherServiceImpl` constructor (lines 19–23) invokes the default constructor for class `UnicastRemoteObject` (line 21) and calls `private` method `updateWeatherConditions` (line 22). Overloaded constructors for class `UnicastRemoteObject` allow the programmer to specify additional information, such as an explicit port number on which to export the remote object. All `UnicastRemoteObject` constructors throw `RemoteExceptions`.



#### Software Engineering Observation 13.5

Class `UnicastRemoteObject` constructors and methods throw checked `RemoteExceptions`, so `UnicastRemoteObject` subclasses must define constructors that also throw `RemoteExceptions`.



#### Software Engineering Observation 13.6

Class `UnicastRemoteObject` provides basic functionality that remote objects require to handle remote requests. Remote object classes need not extend this class if those remote object classes use `static` method `exportObject` of class `UnicastRemoteObject` to export remote objects.

Method `updateWeatherConditions` (lines 26–91) reads weather information from the *Traveler's Forecast* Web page and stores this information in a `List` of `WeatherBean` objects. Lines 32–33 create a `URL` object for the *Traveler's Forecast* Web page. Lines 36–37 invoke method `openStream` of class `URL` to open a connection to the specified `URL` and wrap that connection with a `BufferedReader`.

Lines 40–87 perform *HTML scraping* (i.e., extracting data from a Web page) to retrieve the weather forecast information. Line 40 defines a separator `String`—`"TAV12"`—that determines the starting point from which to locate the appropriate weather information. Lines 43–44 read through the *Traveler's Forecast* Web page until reaching the sentinel. This process skips over information not needed for this application.

Lines 48–51 define two `Strings` that represent the column heads for the weather information. Depending on the time of day, the column headers are either

`"CITY`

`WEA`

`HI/LO`

`WEA`

`HI/LO"`

after the morning update (normally around 10:30 AM Eastern Standard Time) or

`"CITY`

`WEA`

`LO/HI`

`WEA`

`LO/HI"`

after the evening update (normally around 10:30 PM Eastern Standard Time).

Lines 65–85 read each city's weather information and place this information in `WeatherBean` objects. Each `WeatherBean` contains the city's name, the temperature and a description of the weather. Line 61 creates a `List` for storing the `WeatherBean` objects. Lines 76–79 construct a `WeatherBean` object for the current city. The first 16 characters of `inputLine` are the city name, the next 6 characters of `inputLine` are the description (i.e., weather forecast) and the next 6 characters of `inputLine` are the high and low temperatures. The last two columns of data represent the next day's weather forecast, which we ignore in this example. Line 82 adds the `WeatherBean` object to the `List`. Line 87 closes the `BufferedReader` and its associated `InputStream`.

Method `getWeatherInformation` (lines 107–110) is the method from interface `WeatherService` that `WeatherServiceImpl` must implement to respond to remote

requests. The method returns a serialized copy of the **weatherInformation** List. Clients invoke this remote method to obtain the weather information.

Method **main** (lines 113–127) creates the **WeatherServiceImpl** remote object. When the constructor executes, it exports the remote object so the object can listen for remote requests. Line 106 defines the URL that a client can use to obtain a *remote reference* to the server object. The client uses this remote reference to invoke methods on the remote object. The URL normally is of the form

```
rmi://host:port/remoteObjectName
```

where *host* represents the computer that is running the *registry for remote objects* (this also is the computer on which the remote object executes), *port* represents the port number on which the registry is running on the *host* and *remoteObjectName* is the name the client will supply when it attempts to locate the remote object in the registry. The **rmiregistry** utility program manages the registry for remote objects and is part of the J2SE SDK. The default port number for the RMI registry is **1099**.

#### Software Engineering Observation 13.7



*RMI clients assume that they should connect to port 1099 when attempting to locate a remote object through the RMI registry (unless specified otherwise with an explicit port number in the URL for the remote object).*



#### Software Engineering Observation 13.8

*A client must specify a port number only if the RMI registry is running on a port other than the default port, 1099.*

In this program, the remote object URL is

```
rmi://localhost/WeatherService
```

indicating that the RMI registry is running on the **localhost** (i.e., the local computer) and that the name the client must use to locate the service is **WeatherService**. The name **localhost** is synonymous with the IP address **127.0.0.1**, so the preceding URL is equivalent to

```
rmi://127.0.0.1/WeatherService
```

Line 124 invokes **static** method **rebind** of class **Naming** (package **java.rmi**) to bind the remote **WeatherServiceImpl** object **service** to the RMI registry with the URL **rmi://localhost/WeatherService**. There also is a **bind** method for binding a remote object to the registry. Programmers use method **rebind** more commonly, because method **rebind** guarantees that if an object already has registered under the given name, the new remote object will replace the previously registered object. This could be important when registering a new version of an existing remote object.

Class **WeatherBean** (Fig. 13.3) stores data that class **WeatherServiceImpl** retrieves from the National Weather Service Web site. This class stores the city, temperature and weather descriptions as **Strings**. Lines 64–85 provide *get* methods for each piece of information. Lines 25–45 load a property file that contains image names for displaying the weather information. This **static** block ensures that the image names are available as soon as the virtual machine loads the **WeatherBean** class into memory.

```
1 // WeatherBean.java
2 // WeatherBean maintains weather information for one city.
3 package com.deitel.advjhttp1.rmi.weather;
4
5 // Java core packages
6 import java.awt.*;
7 import java.io.*;
8 import java.net.*;
9 import java.util.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 public class WeatherBean implements Serializable {
15
16     private String cityName;           // name of city
17     private String temperature;        // city's temperature
18     private String description;       // weather description
19     private ImageIcon image;          // weather image
20
21     private static Properties imageNames;
22
23     // initialize imageNames when class WeatherBean
24     // is loaded into memory
25     static {
26         imageNames = new Properties(); // create properties table
27
28         // load weather descriptions and image names from
29         // properties file
30         try {
31
32             // obtain URL for properties file
33             URL url = WeatherBean.class.getResource(
34                 "imenames.properties" );
35
36             // load properties file contents
37             imageNames.load( new FileInputStream( url.getFile() ) );
38         }
39
40         // process exceptions from opening file
41         catch ( IOException ioException ) {
42             ioException.printStackTrace();
43         }
44
45     } // end static block
46
47     // WeatherBean constructor
48     public WeatherBean( String city, String weatherDescription,
49                         String cityTemperature )
50     {
51         cityName = city;
52         temperature = cityTemperature;
53         description = weatherDescription.trim();
```

Fig. 13.3 WeatherBean stores weather forecast for one city (part 1 of 2).

```
54
55     URL url = WeatherBean.class.getResource( "images/" +
56         imageNames.getProperty( description, "noinfo.jpg" ) );
57
58     // get weather image name or noinfo.jpg if weather
59     // description not found
60     image = new ImageIcon( url );
61 }
62
63 // get city name
64 public String getCityName()
65 {
66     return cityName;
67 }
68
69 // get temperature
70 public String getTemperature()
71 {
72     return temperature;
73 }
74
75 // get weather description
76 public String getDescription()
77 {
78     return description;
79 }
80
81 // get weather image
82 public ImageIcon getImage()
83 {
84     return image;
85 }
86 }
```

Fig. 13.3 **WeatherBean** stores weather forecast for one city (part 2 of 2).

Next, we define the client application that will obtain weather information from the **WeatherServiceImpl**. Class **WeatherServiceClient** (Fig. 13.4) is the client application that invokes remote method **getWeatherInformation** of interface **WeatherService** to obtain weather information through RMI. Class **WeatherServiceClient** uses a **JList** with a custom **ListCellRenderer** to display the weather information for each city.

The **WeatherServiceClient** constructor (lines 16–58) takes as an argument the name of computer on which the **WeatherService** remote object is running. Line 24 creates a **String** that contains the URL for this remote object. Lines 27–28 invoke **Naming's static** method **lookup** to obtain a remote reference to the **WeatherService** remote object at the specified URL. Method **lookup** connects to the RMI registry and returns a **Remote** reference to the remote object, so line 28 casts this reference to type **WeatherService**. Note that the **WeatherServiceClient** refers to the remote object only through interface **WeatherService**—the remote interface for the **WeatherServiceImpl** remote object implementation. The client can use this remote reference as if it referred to a local object running in the same virtual machine. This remote reference

refers to a *stub* object on the client. Stubs allow clients to invoke remote objects' methods. Stub objects receive each remote method call and pass those calls to the RMI system, which performs the networking that allows clients to interact with the remote object. In this case, the `WeatherServiceImpl` stub will handle the communication between `WeatherServiceClient` and `WeatherServiceImpl`. The RMI layer is responsible for network connections to the remote object, so referencing remote objects is transparent to the client. RMI handles the underlying communication with the remote object and the transfer of arguments and return values between the objects.

Lines 31–32 invoke remote method `getWeatherInformation` on the `weatherService` remote reference. This method call returns a copy of the `List` of `WeatherBeans`, which contains information from the *Traveler's Forecast* Web page. It is important to note that RMI returns a copy of the `List`, because returning a reference from a remote method call is different from returning a reference from a local method call. RMI uses object serialization to send the `List` of `WeatherBean` objects to the client. Therefore, the argument and return types for remote methods must be `Serializable`.

```
1 // WeatherServiceClient.java
2 // WeatherServiceClient uses the WeatherService remote object
3 // to retrieve weather information.
4 package com.deitel.advjhttp1.rmi.weather;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class WeatherServiceClient extends JFrame
14 {
15     // WeatherServiceClient constructor
16     public WeatherServiceClient( String server )
17     {
18         super( "RMI WeatherService Client" );
19
20         // connect to server and get weather information
21         try {
22
23             // name of remote server object bound to rmi registry
24             String remoteName = "rmi://" + server + "/WeatherService";
25
26             // lookup WeatherServiceImpl remote object
27             WeatherService weatherService =
28                 ( WeatherService ) Naming.lookup( remoteName );
29
30             // get weather information from server
31             List weatherInformation =
32                 weatherService.getWeatherInformation();
33     }
```

Fig. 13.4 `WeatherServiceClient` client for `WeatherService` remote object (part 1 of 2).

```
34         // create WeatherListModel for weather information
35         ListModel weatherListModel =
36             new WeatherListModel( weatherInformation );
37
38         // create JList, set ListCellRenderer and add to layout
39         JList weatherJList = new JList( weatherListModel );
40         weatherJList.setCellRenderer( new WeatherCellRenderer() );
41         getContentPane().add( new JScrollPane( weatherJList ) );
42
43     } // end try
44
45     // handle exception connecting to remote server
46     catch ( ConnectException connectionException ) {
47         System.err.println( "Connection to server failed. " +
48             "Server may be temporarily unavailable." );
49
50         connectionException.printStackTrace();
51     }
52
53     // handle exceptions communicating with remote object
54     catch ( Exception exception ) {
55         exception.printStackTrace();
56     }
57
58 } // end WeatherServiceClient constructor
59
60 // execute WeatherServiceClient
61 public static void main( String args[] )
62 {
63     WeatherServiceClient client = null;
64
65     // if no sever IP address or host name specified,
66     // use "localhost"; otherwise use specified host
67     if ( args.length == 0 )
68         client = new WeatherServiceClient( "localhost" );
69     else
70         client = new WeatherServiceClient( args[ 0 ] );
71
72     // configure and display application window
73     client.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
74     client.pack();
75     client.setResizable( false );
76     client.setVisible( true );
77 }
78 }
```

Fig. 13.4 WeatherServiceClient client for WeatherService remote object (part 2 of 2).

Lines 35–36 create a **WeatherListModel** (Fig. 13.5) to facilitate displaying the weather information in a **JList** (line 39). Line 40 sets a **ListCellRenderer** for the **JList**. Class **WeatherCellRenderer** (Fig. 13.6) is a **ListCellRenderer** that uses **WeatherItem** objects to display weather information stored in **WeatherBeans**.

Method **main** (lines 61–77) checks the command-line arguments for a user-provided hostname. If the user did not provide a hostname, line 68 creates a new **WeatherServiceClient** that connects to an RMI registry running on **localhost**. If the user did provide a hostname, line 70 creates a **WeatherServiceClient** using the given hostname.

Class **WeatherListModel** (Fig. 13.5) is a **ListModel** that contains **WeatherBeans** to be displayed in a **JList**. This example continues our design patterns discussion by introducing the *Adapter design pattern*, which enables two objects with incompatible interfaces to communicate with each other.<sup>1</sup> The Adapter design pattern has many parallels in the real world. For example, the electrical plugs on appliances in the United States are not compatible with European electrical sockets. Using an American electrical appliance in Europe requires the user to place an adapter between the electrical plug and the electrical socket. On one side, this adapter provides an interface compatible with the American electrical plug. On the other side, this adapter provides an interface compatible with the European electrical socket. Class **WeatherListModel** plays the role of the *Adapter* in the Adapter design pattern. In Java, interface **List** is not compatible with class **JList**'s interface—a **JList** can retrieve elements only from a **ListModel**. Therefore, we provide class **WeatherListModel**, which adapts interface **List** to make it compatible with **JList**'s interface. When the **JList** invokes **WeatherListModel** method **getSize**, **WeatherListModel** invokes method **size** of interface **List**. When the **JList** invokes **WeatherListModel** method **getElementAt**, **WeatherListModel** invokes **JList** method **get**, etc. Class **WeatherListModel** also plays the role of the model in Swing's delegate-model architecture, as we discussed in Chapter 3, Model-View-Controller.

```
1 // WeatherListModel.java
2 // WeatherListModel extends AbstractListModel to provide a
3 // ListModel for storing a List of WeatherBeans.
4 package com.deitel.advjhttp1.rmi.weather;
5
6 // Java core packages
7 import java.util.*;
8
9 // Java extension packages
10 import javax.swing.AbstractListModel;
11
12 public class WeatherListModel extends AbstractListModel {
13
14     // List of elements in ListModel
15     private List list;
16
17     // no-argument WeatherListModel constructor
18     public WeatherListModel()
19     {
20         // create new List for WeatherBeans
21         list = new ArrayList();
22     }
23 }
```

Fig. 13.5 **WeatherListModel** is a **ListModel** implementation for storing weather information (part 1 of 2).

1. Gamma, Erich, Richard Helm, Ralph Johnson, and John Vlissides. *Design Patterns; Elements of Reusable Object-Oriented Software*. (Reading, MA: Addison-Wesley, 1995): p. 139.

```
23
24 // WeatherListModel constructor
25 public WeatherListModel( List elementList )
26 {
27     list = elementList;
28 }
29
30 // get size of List
31 public int getSize()
32 {
33     return list.size();
34 }
35
36 // get Object reference to element at given index
37 public Object getElementAt( int index )
38 {
39     return list.get( index );
40 }
41
42 // add element to WeatherListModel
43 public void add( Object element )
44 {
45     list.add( element );
46     fireIntervalAdded( this, list.size(), list.size() );
47 }
48
49 // remove element from WeatherListModel
50 public void remove( Object element )
51 {
52     int index = list.indexOf( element );
53
54     if ( index != -1 ) {
55         list.remove( element );
56         fireIntervalRemoved( this, index, index );
57     }
58
59 } // end method remove
60
61 // remove all elements from WeatherListModel
62 public void clear()
63 {
64     // get original size of List
65     int size = list.size();
66
67     // clear all elements from List
68     list.clear();
69
70     // notify listeners that content changed
71     fireContentsChanged( this, 0, size );
72 }
73 }
```

Fig. 13.5 **WeatherListModel** is a **ListModel** implementation for storing weather information (part 2 of 2).

Class **JList** uses a **ListCellRenderer** to render each element in that **JList**'s **ListModel**. Class **WeatherCellRenderer** (Fig. 13.6) is a **DefaultListCellRenderer** subclass for rendering **WeatherBeans** in a **JList**. Method **getListCellRendererComponent** creates and returns a **WeatherItem** (Fig. 13.7) for the given **WeatherBean**.

Class **WeatherItem** (Fig. 13.7) is a **JPanel** subclass for displaying weather information stored in a **WeatherBean**. Class **WeatherCellRenderer** uses instances of class **WeatherItem** to display weather information in a **JList**. The **static** block (lines 22–29) loads the **ImageIcon backgroundImage** into memory when the virtual machine loads the **WeatherItem** class itself. This ensures that **backgroundImage** is available to all instances of class **WeatherItem**. Method **paintComponent** (lines 38–56) draws the **backgroundImage** (line 43), the city name (line 50), the temperature (line 51) and the **WeatherBean**'s **ImageIcon**, which describes the weather conditions (line 54).

```
1 // WeatherCellRenderer.java
2 // WeatherCellRenderer is a custom ListCellRenderer for
3 // WeatherBeans in a JList.
4 package com.deitel.advjhttp1.rmi.weather;
5
6 // Java core packages
7 import java.awt.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class WeatherCellRenderer extends DefaultListCellRenderer {
13
14     // returns a WeatherItem object that displays city's weather
15     public Component getListCellRendererComponent( JList list,
16         Object value, int index, boolean isSelected, boolean focus )
17     {
18         return new WeatherItem( ( WeatherBean ) value );
19     }
20 }
```

Fig. 13.6 **WeatherCellRenderer** is a custom **ListCellRenderer** for displaying **WeatherBeans** in a **JList**.

```
1 // WeatherItem.java
2 // WeatherItem displays a city's weather information in a JPanel.
3 package com.deitel.advjhttp1.rmi.weather;
4
5 // Java core packages
6 import java.awt.*;
7 import java.net.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
```

Fig. 13.7 **WeatherItem** displays weather information for one city (part 1 of 2).

```
13 public class WeatherItem extends JPanel {
14
15     private WeatherBean weatherBean; // weather information
16
17     // background ImageIcon
18     private static ImageIcon backgroundImage;
19
20     // static initializer block loads background image when class
21     // WeatherItem is loaded into memory
22     static {
23
24         // get URL for background image
25         URL url = WeatherItem.class.getResource( "images/back.jpg" );
26
27         // background image for each city's weather info
28         backgroundImage = new ImageIcon( url );
29     }
30
31     // initialize a WeatherItem
32     public WeatherItem( WeatherBean bean )
33     {
34         weatherBean = bean;
35     }
36
37     // display information for city's weather
38     public void paintComponent( Graphics g )
39     {
40         super.paintComponent( g );
41
42         // draw background
43         backgroundImage.paintIcon( this, g, 0, 0 );
44
45         // set font and drawing color,
46         // then display city name and temperature
47         Font font = new Font( "SansSerif", Font.BOLD, 12 );
48         g.setFont( font );
49         g.setColor( Color.white );
50         g.drawString( weatherBean.getCityName(), 10, 19 );
51         g.drawString( weatherBean.getTemperature(), 130, 19 );
52
53         // display weather image
54         weatherBean.getImage().paintIcon( this, g, 253, 1 );
55     } // end method paintComponent
56
57     // make WeatherItem's preferred size the width and height of
58     // the background image
59     public Dimension getPreferredSize()
60     {
61         return new Dimension( backgroundImage.getIconWidth(),
62                             backgroundImage.getIconHeight() );
63     }
64 }
65 }
```

Fig. 13.7 **WeatherItem** displays weather information for one city (part 2 of 2).

The images in this example are available with the example code from this text on the CD that accompanies the text and from our Web site ([www.deitel.com](http://www.deitel.com)). Click the **Downloads** link and download the examples for *Advanced Java 2 Platform How to Program*.

## 13.5 Compiling and Executing the Server and the Client

Now that the pieces are in place, we can build and execute our distributed application; this requires several steps. First, we must compile the classes. Next, we must compile the remote object class (**WeatherServiceImpl**), using the **rmic compiler** (a utility supplied with the J2SE SDK) to produce a *stub class*. As we discussed in Section 13.4, a stub class forwards method invocations to the RMI layer, which performs the network communication necessary to invoke the method call on the remote object. The command line

```
rmic -v1.2 com.deitel.advjhttp1.rmi.weather.WeatherServiceImpl
```

generates the file **WeatherServiceImpl\_Stub.class**. This class must be available to the client (either locally or via download) to enable remote communication with the server object. Depending on the command line options passed to **rmic**, this may generate several files. In Java 1.1, **rmic** produced two classes—a stub class and a *skeleton class*. Java 2 no longer requires the skeleton class. The command-line option **-v1.2** indicates that **rmic** should create only the stub class.

The next step is to start the RMI registry with which the **WeatherServiceImpl** object will register. The command line

```
rmiregistry
```

launches the RMI registry on the local machine. The command line window (Fig. 13.8) will not show any text in response to this command.



### Common Programming Error 13.1

*Not starting the RMI registry before attempting to bind the remote object to the registry results in a **java.rmi.ConnectException**, which indicates that the program cannot connect to the registry.*

To make the remote object available to receive remote method calls, we bind the object to a name in the RMI registry. Run the **WeatherServiceImpl** application from the command line as follows:

```
java com.deitel.advjhttp1.rmi.weather.WeatherServiceImpl
```

Figure 13.9 shows the **WeatherServiceImpl** application output. Class **WeatherServiceImpl** retrieves the data from the *Traveler's Forecast* Web page and displays a message indicating that the service is running.

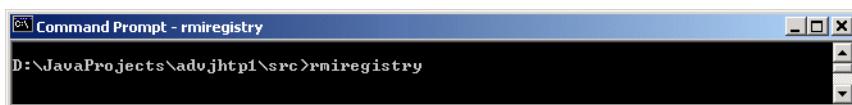


Fig. 13.8 Running the **rmiregistry**.

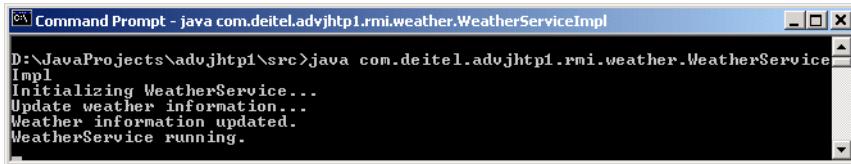


Fig. 13.9 Executing the **WeatherServiceImpl** remote object.

The **WeatherServiceClient** program now can connect with the **WeatherServiceImpl** running on **localhost** with the command

```
java com.deitel.advjhttp1.rmi.weather.WeatherServiceClient
```

Figure 13.10 shows the **WeatherServiceClient** application window. When the program executes, the **WeatherServiceClient** connects to the remote server object and displays the current weather information.

If the **WeatherServiceImpl** is running on a different machine from the client, you can specify the IP address or host name of the server computer as a command-line argument when executing the client. For example, to access a computer with IP address **192.168.0.150**, enter the command

```
java com.deitel.advjhttp1.rmi.weather.WeatherServiceClient
192.168.0.150
```

In the first part of this chapter, we built a simple distributed system that demonstrated the basics of RMI. In the following case study, we build a more sophisticated RMI distributed system that takes advantage of some advanced RMI features.



Fig. 13.10 **WeatherServiceClient** application window.

## 13.6 Case Study: Deitel Messenger with Activatable Server

In this section, we present a case study that implements an online chat system using RMI and an *activatable* chat server. This case study—the Deitel Messenger—uses several advanced RMI features and a modular architecture that promotes reusability. Figure 13.11 lists the classes and interfaces that make up the case study and brief descriptions of each. Interfaces are shown in italic font.

Standard RMI objects exported as **UnicastRemoteObjects** must run continuously on the server to handle client requests. RMI objects that extend class **java.rmi.activation.Activatable** are able to *activate*, or start running, when a client invokes one of the remote object's methods. This can conserve resources on the server because a remote object's processes are put to sleep and release memory when there are no clients using that particular remote object. The *RMI activation daemon* (**rmid**) is a server process that enables activatable remote objects to become active when clients invoke remote methods on these objects.

Name	Role
<b>ChatServer</b>	Remote interface through which clients register for a chat, leave a chat, and post chat messages.
<b>StoppableChatServer</b>	Administrative remote interface for terminating the chat server.
<b>ChatServerImpl</b>	Implementation of the ChatServer remote interface that provides an RMI-based chat server.
<b>ChatServerAdministrator</b>	Utility program for launching and terminating the activatable <b>ChatServer</b> .
<b>ChatClient</b>	Remote interface through which the ChatServer communicates with clients.
<b>ChatMessage</b>	<b>Serializable</b> object for sending messages between <b>ChatServer</b> and <b>ChatClients</b> .
<b>MessageManager</b>	Interface that defines methods for managing communication between the client's user interface and the <b>ChatServer</b> .
<b>RMIMessageManager</b>	<b>ChatClient</b> and <b>MessageManager</b> implementation for managing communication between the client and the <b>ChatServer</b> .
<b>MessageListener</b>	Interface for classes that wish to receive new chat messages.
<b>DisconnectListener</b>	Interface for classes that wish to receive notifications when the server disconnects.
<b>ClientGUI</b>	GUI for sending and receiving chat messages using a <b>MessageManager</b> .
<b>DeitelMessenger</b>	Application launcher for Deitel Messenger client.

Fig. 13.11 Participants of DeitelMessenger case study.

Activatable remote objects also are able to recover from server crashes, because remote references to activatable objects are persistent—when the server restarts, the RMI activation daemon maintains the remote reference, so clients can continue to use the remote object. We discuss the details of implementing **Activatable** remote objects when we present the chat server implementation.

### 13.6.1 Activatable Deitel Messenger ChatServer

Like every RMI remote object, an **Activatable** remote object must implement a remote interface. Interface **ChatServer** (Fig. 13.12) is the remote interface for the Deitel Messenger server. Clients interact with the Deitel Messenger server through the **ChatServer** remote interface. Remote interfaces for an **Activatable** RMI have the same requirements as standard RMI remote interfaces.

Line 13 declares that interface **ChatServer** extends interface **Remote**, which RMI requires for all remote interfaces. Method **registerClient** (lines 16–17) enables a **ChatClient** (Fig. 13.17) to register with the **ChatServer** and take part in the chat session. Method **registerClient** takes as an argument the **ChatClient** to register. Interface **ChatClient** is itself a remote interface, so both the server and client are remote objects in this application. This enables the server to communicate with clients by invoking remote methods on those clients. We discuss this communication—called an RMI callback—in more detail when we present the **ChatClient** implementation.

---

```
1 // ChatServer.java
2 // ChatServer is a remote interface that defines how a client
3 // registers for a chat, leaves a chat and posts chat messages.
4 package com.deitel.messenger.rmi.server;
5
6 // Java core packages
7 import java.rmi.*;
8
9 // Deitel packages
10 import com.deitel.messenger.rmi.ChatMessage;
11 import com.deitel.messenger.rmi.client.ChatClient;
12
13 public interface ChatServer extends Remote {
14
15     // register new ChatClient with ChatServer
16     public void registerClient( ChatClient client )
17         throws RemoteException;
18
19     // unregister ChatClient with ChatServer
20     public void unregisterClient( ChatClient client )
21         throws RemoteException;
22
23     // post new message to ChatServer
24     public void postMessage( ChatMessage message )
25         throws RemoteException;
26 }
```

---

Fig. 13.12 **ChatServer** remote interface for Deitel Messenger chat server.

Method **unregisterClient** (lines 20–21) enables clients to remove themselves from the chat session. Method **postMessage** enables clients to post new messages to the chat session. Method **postMessage** takes as an argument a reference to a **ChatMessage**. A **ChatMessage** (Fig. 13.18) is a **Serializable** object that contains the name of the sender and the message body. We discuss this class in more detail shortly.

The server side of the Deitel Messenger application includes a program for managing the **Activatable** remote object. Interface **StoppableChatServer** (Fig. 13.13) declares method **stopServer**. The program that manages the Deitel Messenger server invokes method **stopServer** to terminate the server.

Class **ChatServerImpl** (Fig. 13.14) is an **Activatable** RMI object that implements the **ChatServer** and **StoppableChatServer** remote interfaces. Line 23 creates a **Set** for maintaining remote references to registered **ChatClients**. The **ChatServerImpl** constructor (lines 29–34) takes as arguments an **ActivationID** and a **MarshallledObject**. The RMI activation mechanism requires that **Activatable** objects provide this constructor. When the activation daemon activates a remote object of this class, it invokes this *activation constructor*. The **ActivationID** argument specifies a unique identifier for the remote object. Class **MarshallledObject** is a wrapper class that contains a serialized object for transmission over RMI. In this case, the **MarshallledObject** argument contains application-specific initialization information, such as the name under which the activation daemon registered the remote object. Line 33 invokes the superclass constructor to complete activation. The second argument to the superclass constructor (**0**) specifies that the activation daemon should export the object on an anonymous port.

```
1 // StoppableChatServer.java
2 // StoppableChatServer is a remote interface that provides a
3 // mechanism to terminate the chat server.
4 package com.deitel.messenger.rmi.server;
5
6 // Java core packages
7 import java.rmi.*;
8
9 public interface StoppableChatServer extends Remote {
10
11     // stop ChatServer
12     public void stopServer() throws RemoteException;
13 }
```

Fig. 13.13 **StoppableChatServer** remote interface for stopping a **ChatServer** remote object.

```
1 // ChatServerImpl.java
2 // ChatServerImpl implements the ChatServer remote interface
3 // to provide an RMI-based chat server.
4 package com.deitel.messenger.rmi.server;
5
```

Fig. 13.14 **ChatServerImpl** implementation of remote interfaces **ChatServer** and **StoppableChatServer** as **Activatable** remote objects (part 1 of 5).

```
6 // Java core packages
7 import java.io.*;
8 import java.net.*;
9 import java.rmi.*;
10 import java.rmi.activation.*;
11 import java.rmi.server.*;
12 import java.rmi.registry.*;
13 import java.util.*;
14
15 // Deitel packages
16 import com.deitel.messenger.rmi.ChatMessage;
17 import com.deitel.messenger.rmi.client.ChatClient;
18
19 public class ChatServerImpl extends Activatable
20     implements ChatServer, StoppableChatServer {
21
22     // Set of ChatClient references
23     private Set clients = new HashSet();
24
25     // server object's name
26     private String serverObjectName;
27
28     // ChatServerImpl constructor
29     public ChatServerImpl( ActivationID id, MarshalledObject data )
30         throws RemoteException {
31
32         // register activatable object and export on anonymous port
33         super( id, 0 );
34     }
35
36     // register ChatServerImpl object with RMI registry.
37     public void register( String rmiName ) throws RemoteException,
38         IllegalArgumentException, MalformedURLException
39     {
40         // ensure registration name was provided
41         if ( rmiName == null )
42             throw new IllegalArgumentException(
43                 "Registration name cannot be null" );
44
45         serverObjectName = rmiName;
46
47         // bind ChatServerImpl object to RMI registry
48         try {
49
50             // create RMI registry
51             System.out.println( "Creating registry ..." );
52             Registry registry =
53                 LocateRegistry.createRegistry( 1099 );
54
55             // bind RMI object to default RMI registry
56             System.out.println( "Binding server to registry ..." );
```

Fig. 13.14 ChatServerImpl implementation of remote interfaces ChatServer and StoppableChatServer as Activatable remote objects (part 2 of 5).

```
57         registry.rebind( serverObjectName, this );
58     }
59
60     // if registry already exists, bind to existing registry
61     catch ( RemoteException remoteException ) {
62         System.err.println( "Registry already exists. " +
63             "Binding to existing registry ..." );
64         Naming.rebind( serverObjectName, this );
65     }
66
67     System.out.println( "Server bound to registry" );
68
69 } // end method register
70
71 // register new ChatClient with ChatServer
72 public void registerClient( ChatClient client )
73     throws RemoteException
74 {
75     // add client to Set of registered clients
76     synchronized ( clients ) {
77         clients.add( client );
78     }
79
80     System.out.println( "Registered Client: " + client );
81
82 } // end method registerClient
83
84 // unregister client with ChatServer
85 public void unregisterClient( ChatClient client )
86     throws RemoteException
87 {
88     // remove client from Set of registered clients
89     synchronized( clients ) {
90         clients.remove( client );
91     }
92
93     System.out.println( "Unregistered Client: " + client );
94
95 } // end method unregisterClient
96
97 // post new message to chat server
98 public void postMessage( ChatMessage message )
99     throws RemoteException
100 {
101     Iterator iterator = null;
102
103     // get Iterator for Set of registered clients
104     synchronized( clients ) {
105         iterator = new HashSet( clients ).iterator();
106     }
107 }
```

Fig. 13.14 ChatServerImpl implementation of remote interfaces ChatServer and StoppableChatServer as Activatable remote objects (part 3 of 5).

```
108     // send message to every ChatClient
109     while ( iterator.hasNext() ) {
110
111         // attempt to send message to client
112         ChatClient client = ( ChatClient ) iterator.next();
113
114         try {
115             client.deliverMessage( message );
116         }
117
118         // unregister client if exception is thrown
119         catch( Exception exception ) {
120             System.err.println( "Unregistering absent client." );
121             unregisterClient( client );
122         }
123
124     } // end while loop
125
126 } // end method postMessage
127
128 // notify each client that server is shutting down and
129 // terminate server application
130 public void stopServer() throws RemoteException
131 {
132     System.out.println( "Terminating server ..." );
133
134     Iterator iterator = null;
135
136     // get Iterator for Set of registered clients
137     synchronized( clients ) {
138         iterator = new HashSet( clients ).iterator();
139     }
140
141     // send message to every ChatClient
142     while ( iterator.hasNext() ) {
143         ChatClient client = ( ChatClient ) iterator.next();
144         client.serverStopping();
145     }
146
147     // create Thread to terminate application after
148     // stopServer method returns to caller
149     Thread terminator = new Thread(
150         new Runnable() {
151
152             // sleep for 5 seconds, print message and terminate
153             public void run()
154             {
155                 // sleep
156                 try {
157                     Thread.sleep( 5000 );
158                 }
```

Fig. 13.14 ChatServerImpl implementation of remote interfaces ChatServer and StoppableChatServer as Activatable remote objects (part 4 of 5).

```
159                     // ignore InterruptedExceptions
160             catch ( InterruptedException exception ) {
161                 }
162
163             System.err.println( "Server terminated" );
164             System.exit( 0 );
165         }
166     }
167 }
168
169 terminator.start(); // start termination thread
170
171 } // end method stopServer
172
173 }
```

Fig. 13.14 ChatServerImpl implementation of remote interfaces ChatServer and StoppableChatServer as Activatable remote objects (part 5 of 5).

Method **register** (lines 37–69) registers a **ChatServerImpl** remote object with the RMI registry. If the provided name for the remote object is **null**, lines 42–43 throw an **IllegalArgumentException**, indicating that the caller must specify a name for the remote object. Lines 52–53 use **static** method **createRegistry** of class **LocateRegistry** to create a new **Registry** on the local machine at port **1099**, which is the default port. This is equivalent to executing the **rmiregistry** utility to start a new RMI registry. Line 57 invokes method **rebind** of class **Registry** to bind the activatable object to the **Registry**. If creating or binding to the **Registry** fails, we assume that an RMI registry already is running on the local machine. Line 64 invokes **static** method **rebind** of class **Naming** to bind the remote object to the existing RMI registry.

Method **registerClient** (lines 72–82) enables **ChatClient** remote objects to register with the **ChatServer** to participate in the chat session. The **ChatClient** argument to method **registerClient** is a remote reference to the registering client, which is itself a remote object. Line 77 adds the **ChatClient** remote reference to the **Set** of **ChatClients** participating in the chat session. Method **unregisterClient** (lines 85–95) enables **ChatClients** to leave the chat session. Line 90 removes the given **ChatClient** remote reference from the **Set** of **ChatClient** references.

**ChatClients** invoke method **postMessage** (lines 98–124) to post new **ChatMessages** to the chat session. Each **ChatMessage** (Fig. 13.18) instance is a **Serializable** object that contains as properties the message sender and the message body. Lines 109–123 iterate through the **Set** of **ChatClient** references and invoke remote method **deliverMessage** of interface **ChatClient** to deliver the new **ChatMessage** to each client. If delivering a message to a client throws an exception, we assume that the client is no longer available. Line 121 therefore unregisters the absent client from the server.

Interface **StoppableChatServer** requires that class **ChatServerImpl** implements method **stopServer** (lines 128–170). Lines 140–143 iterate through the **Set** of **ChatClient** references and invoke method **serverStopping** of interface **ChatClient** to notify each **ChatClient** that the server is shutting down. Lines 147–168

create and start a new **Thread** to ensure that the **ChatServerAdministrator** (Fig. 13.15) can unbind the remote object from the RMI **Registry** before the remote object terminates.

Class **ChatServerAdministrator** (Fig. 13.15) is a utility program for registering and unregistering the activatable **ChatServer** remote object. Method **startServer** (lines 14–52) launches the activatable **ChatServer**. Activatable RMI objects execute as part of an **ActivationGroup** (package `java.rmi.activation`). The RMI activation daemon starts a new virtual machine for each **ActivationGroup**. Lines 21–22 create a **Properties** object and add a property that specifies the policy file under which the **ActivationGroup**'s JVM should run. This policy file (Fig. 13.16) allows **Activatable** objects in this **ActivationGroup** to terminate the virtual machine for this activation group. Recall that **ChatServerImpl** invokes **static** method **exit** of class **System** in method **stopServer**, which terminates the **ActivationGroup**'s virtual machine along with all of its executing remote objects.

```
1 // ChatServerAdministrator.java
2 // ChatServerAdministrator is a utility program for launching
3 // and terminating the Activatable ChatServer.
4 package com.deitel.messenger.rmi.server;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.rmi.activation.*;
9 import java.util.*;
10
11 public class ChatServerAdministrator {
12
13     // set up activatable server object
14     private static void startServer( String policy,
15         String codebase ) throws Exception
16     {
17         // set up RMI security manager
18         System.setSecurityManager( new RMISecurityManager() );
19
20         // set security policy for ActivationGroup JVM
21         Properties properties = new Properties();
22         properties.put( "java.security.policy", policy );
23
24         // create ActivationGroupDesc for activatable object
25         ActivationGroupDesc groupDesc =
26             new ActivationGroupDesc( properties, null );
27
28         // register activation group with RMI activation system
29         ActivationGroupID groupID =
30             ActivationGroup.getSystem().registerGroup( groupDesc );
31
32         // create activation group
33         ActivationGroup.createGroup( groupID, groupDesc , 0 );
34 }
```

Fig. 13.15 **ChatServerAdministrator** application for starting and stopping the **ChatServer** remote object (part 1 of 3).

```
35     // activation description for ChatServerImpl
36     ActivationDesc description = new ActivationDesc(
37         "com.deitel.messenger.rmi.server.ChatServerImpl",
38         codebase, null );
39
40     // register description with rmid
41     ChatServer server =
42         ( ChatServer ) Activatable.register( description );
43     System.out.println( "Obtained ChatServerImpl stub" );
44
45     // bind ChatServer in registry
46     Naming.rebind( "ChatServer", server );
47     System.out.println( "Bound object to registry" );
48
49     // terminate setup program
50     System.exit( 0 );
51
52 } // end method startServer
53
54 // terminate server
55 private static void terminateServer( String hostname )
56     throws Exception
57 {
58     // lookup ChatServer in RMI registry
59     System.out.println( "Locating server ...." );
60     StoppableChatServer server = ( StoppableChatServer )
61         Naming.lookup( "rmi://" + hostname + "/ChatServer" );
62
63     // terminate server
64     System.out.println( "Stopping server ...." );
65     server.stopServer();
66
67     // remove ChatServer from RMI registry
68     System.out.println( "Server stopped" );
69     Naming.unbind( "rmi://" + hostname + "/ChatServer" );
70
71 } // end method terminateServer
72
73 // launch ChatServerAdministrator application
74 public static void main( String args[] ) throws Exception
75 {
76     // check for stop server argument
77     if ( args.length == 2 ) {
78
79         if ( args[ 0 ].equals( "stop" ) )
80             terminateServer( args[ 1 ] );
81
82         else printUsageInstructions();
83     }
84 }
```

Fig. 13.15 ChatServerAdministrator application for starting and stopping the ChatServer remote object (part 2 of 3).

```

85      // check for start server argument
86      else if ( args.length == 3 ) {
87
88          // start server with user-provided policy, codebase
89          // and Registry hostname
90          if ( args[ 0 ].equals( "start" ) )
91              startServer( args[ 1 ], args[ 2 ] );
92
93          else printUsageInstructions();
94      }
95
96      // wrong number of arguments provided, so print instructions
97      else printUsageInstructions();
98
99  } // end method main
100
101 // print instructions for running ChatServerAdministrator
102 private static void printUsageInstructions()
103 {
104     System.err.println( "\nUsage:\n" +
105         "\tjava com.deitel.messenger.rmi.server." +
106         "ChatServerAdministrator start <policy> <codebase>\n" +
107         "\tjava com.deitel.messenger.rmi.server." +
108         "ChatServerAdministrator stop <registry hostname>" );
109 }
110 }
```

Fig. 13.15 ChatServerAdministrator application for starting and stopping the ChatServer remote object (part 3 of 3).

```

1 // allow ActivationGroup to terminate the virtual machine
2 grant {
3     permission java.lang.RuntimePermission "exitVM";
4 };
```

Fig. 13.16 Policy file for ChatServer's ActivationGroup.

Lines 25–26 create an **ActivationGroupDesc** object, which is an *activation group descriptor*. The activation group descriptor specifies configuration information for the **ActivationGroup**. The first argument to the **ActivationGroupDesc** constructor is a **Properties** reference that contains replacement values for system properties in the **ActivationGroup**'s virtual machine. In this example, we override the **java.security.policy** system property to provide an appropriate security policy for the **ActivationGroup**'s virtual machine. The second argument is a reference to an **ActivationGroupDesc.CommandEnvironment** object. This object enables the **ActivationGroup** to customize the commands that the activation daemon executes when starting the **ActivationGroup**'s virtual machine. This example requires no such customization, so we pass a **null** reference for the second argument.

Lines 29–30 obtain an **ActivationSystem** by invoking **static** method **getSystem** of class **ActivationGroup**. Line 30 invokes method **registerGroup** of interface **ActivationSystem** and passes as an argument the **groupDesc** activation

group descriptor. Method `registerGroup` returns the `ActivationGroupID` for the newly registered `ActivationGroup`. Line 33 invokes `static` method `createGroup` of class `ActivationGroup` to create the `ActivationGroup`. This method takes as arguments the `ActivationGroupID`, the `ActivationGroupDesc` and the *incarnation number* for the `ActivationGroup`. The incarnation number identifies different instances of the same `ActivationGroup`. Each time the activation daemon activates the `ActivationGroup`, the daemon increments the incarnation number.

Lines 36–38 create an `ActivationDesc` object for the `ChatServer` remote object. This *activation descriptor* specifies configuration information for a particular `Activatable` remote object. The first argument to the `ActivationDesc` constructor specifies the name of the class that implements the `Activatable` remote object. The second argument specifies the codebase that contains the remote object's class files. The final argument is a `MarshalledObject` reference, whose object specifies initialization information for the remote object. Recall that the `ChatServerImpl` activation constructor takes as its second argument a `MarshalledObject` reference. Our `ChatServer` remote object requires no special initialization information, so line 38 passes a `null` reference for the `MarshalledObject` argument.

Line 42 invokes `static` method `register` of class `Activatable` to register the `Activatable` remote object. Method `register` takes as an argument the `ActivationDesc` for the `Activatable` object and returns a reference to the remote object's stub. Line 46 invokes `static` method `rebind` of class `Naming` to bind the `ChatServer` in the RMI `Registry`.

Method `terminateServer` (lines 55–71) provides a means to shut down the activatable `ChatServer` remote object. Line 61 invokes `static` method `lookup` of class `Naming` to obtain a remote reference to the `ChatServer`. Line 60 casts the reference to type `StoppableChatServer`, which declares method `stopServer`. Line 65 invokes method `stopServer` to notify clients that the `ChatServer` is shutting down. Recall that method `stopServer` of class `ChatServerImpl` starts a `Thread` that waits five seconds before invoking `static` method `exit` of class `System`. This `Thread` keeps the `ChatServer` remote object running after method `stopServer` returns, allowing the `ChatServerAdministrator` to remove the remote object from the RMI `Registry`. Line 69 invokes `static` method `unbind` of class `Naming` to remove the `ChatServer` remote object from the RMI `Registry`. The `Thread` in class `ChatServerImpl` then terminates the virtual machine in which the `ChatServer` remote object ran.

Method `main` (lines 74–99) checks the command-line arguments to determine whether to start or stop the `ChatServer` remote object. When stopping the server, the user must provide as the second argument the hostname of the computer on which the server is running. When starting the server, the user must provide as arguments the location of the policy file for the `ActivationGroup` and the codebase for the remote object. If the user passes argument "`stop`", line 80 invokes method `terminateServer` to shut down the `ChatServer` on the specified host. If the user passes argument "`start`", line 91 invokes method `startServer` with the given policy file location and codebase. If the user provides an invalid number or type of arguments, lines 82, 93 and 97 invoke method `printUsageInstructions` (lines 102–109) to display information about the required command-line arguments.

### 13.6.2 Deitel Messenger Client Architecture and Implementation

Throughout this book, we present several versions of the Deitel Messenger case study. Each version implements the underlying communications using a different technology. For example, in Chapter 26, Common Object Request Broker Architecture (CORBA): Part 1, we present an implementation that uses CORBA as the underlying communication mechanism. The client for the Deitel Messenger application uses a modularized architecture to optimize code reuse in the several versions of this case study.

#### *Communication Interfaces and Implementation*

The client for the Deitel Messenger system separates the application GUI and the network communication into separate objects that interact through a set of interfaces. This enables us to use the same client-side GUI for different versions of the Deitel Messenger application. In this section, we present these interfaces and implementations with RMI.

Interface **ChatClient** (Fig. 13.17) is an RMI remote interface that enables the **ChatServer** to communicate with the **ChatClient** through *RMI callbacks*—remote method calls from the **ChatServer** back to the client. Recall that when a client connects to the **ChatServer**, the client invokes **ChatServer** method **registerClient** and passes as an argument a **ChatClient** remote reference. The server then uses this **ChatClient** remote reference to invoke RMI callbacks on the **ChatClient** (e.g., to deliver **ChatMessages** to that client). Method **deliverMessage** (lines 16–17) enables the **ChatServer** to send new **ChatMessages** to the **ChatClient**. Method **serverStopping** (line 20) enables the **ChatServer** to notify the **ChatClient** when the **ChatServer** is shutting down.

```
1 // ChatClient.java
2 // ChatClient is a remote interface that defines methods for a
3 // chat client to receive messages and status information from
4 // a ChatServer.
5 package com.deitel.messenger.rmi.client;
6
7 // Java core packages
8 import java.rmi.*;
9
10 // Deitel packages
11 import com.deitel.messenger.rmi.ChatMessage;
12
13 public interface ChatClient extends Remote {
14
15     // method called by server to deliver message to client
16     public void deliverMessage( ChatMessage message )
17         throws RemoteException;
18
19     // method called when server shutting down
20     public void serverStopping() throws RemoteException;
21 }
```

Fig. 13.17 **ChatClient** remote interface to enable RMI callbacks.

Class **ChatMessage** (Fig. 13.18) is a **Serializable** class that represents a message in the Deitel Messenger system. Instance variables **sender** and **message** contain the name of the person who sent the message and the message body, respectively. Class **ChatMessage** provides *set* and *get* methods for the **sender** and **message** and method **toString** for producing a **String** representation of a **ChatMessage**.

Interface **MessageManager** (Fig. 13.19) declares methods for classes that implement communication logic for a **ChatClient**. The methods that this interface declares are not specific to any underlying communication implementation. The chat client GUI uses a **MessageManager** implementation to connect to and disconnect from the **ChatServer**, and to send messages. Method **connect** (lines 10–11) connects to the **ChatServer** and takes as an argument the **MessageListener** to which the **MessageManager** should deliver new incoming messages. We discuss interface **MessageListener** in detail when we present the client user interface. Method **disconnect** (lines 15–16) disconnects the **MessageManager** from the **ChatServer** and stops routing messages to the given **MessageListener**. Method **sendMessage** (lines 19–20) takes as **String** arguments a user name (**from**) and a **message** to send to the **ChatServer**. Method **setDisconnectListener** registers a **DisconnectListener** to be notified when the **ChatServer** disconnects the client. We discuss interface **DisconnectListener** in detail when we present the client user interface.

```
1 // ChatMessage.java
2 // ChatMessage is a Serializable object for messages in the RMI
3 // ChatClient and ChatServer.
4 package com.deitel.messenger.rmi;
5
6 // Java core packages
7 import java.io.*;
8
9 public class ChatMessage implements Serializable {
10
11     private String sender;    // person sending message
12     private String message;   // message being sent
13
14     // construct empty ChatMessage
15     public ChatMessage()
16     {
17         this( "", "" );
18     }
19
20     // construct ChatMessage with sender and message values
21     public ChatMessage( String sender, String message )
22     {
23         setSender( sender );
24         setMessage( message );
25     }
26 }
```

Fig. 13.18 **ChatMessage** is a serializable class for transmitting messages over RMI (part 1 of 2).

---

```
27 // set name of person sending message
28 public void setSender( String name )
29 {
30     sender = name;
31 }
32
33 // get name of person sending message
34 public String getSender()
35 {
36     return sender;
37 }
38
39 // set message being sent
40 public void setMessage( String messageBody )
41 {
42     message = messageBody;
43 }
44
45 // get message being sent
46 public String getMessage()
47 {
48     return message;
49 }
50
51 // String representation of ChatMessage
52 public String toString()
53 {
54     return getSender() + "> " + getMessage();
55 }
56 }
```

Fig. 13.18 **ChatMessage** is a serializable class for transmitting messages over RMI (part 2 of 2).

---

```
1 // MessageManager.java
2 // MessageManger is an interface for objects capable of managing
3 // communications with a message server.
4 package com.deitel.messenger;
5
6 public interface MessageManager {
7
8     // connect to message server and route incoming messages
9     // to given MessageListener
10    public void connect( MessageListener listener )
11        throws Exception;
12
13    // disconnect from message server and stop routing
14    // incoming messages to given MessageListener
15    public void disconnect( MessageListener listener )
16        throws Exception;
17}
```

Fig. 13.19 **MessageManager** interface for classes that implement communication logic for a **ChatClient** (part 1 of 2).

```
18 // send message to message server
19 public void sendMessage( String from, String message )
20     throws Exception;
21
22 // set listener for disconnect notifications
23 public void setDisconnectListener(
24     DisconnectListener listener );
25 }
```

Fig. 13.19 **MessageManager** interface for classes that implement communication logic for a **ChatClient** (part 2 of 2).

Class **RMIMessageManager** (Fig. 13.20) handles all communication between the client and the **ChatServer**. Class **RMIMessageManager** is an RMI remote object that extends class **UnicastRemoteObject** and implements the **ChatClient** remote interface (lines 18–19). Class **RMIMessageManager** also implements interface **MessageManager**, enabling the client user interface to use an **RMIMessageManager** object to communicate with the **ChatServer**.

The **RMIMessageManager** constructor takes as a **String** argument the hostname of the computer running the RMI registry with which the **ChatServer** has registered. Note that because class **RMIMessenger** is itself an RMI remote object, the **RMIMessageManager** constructor throws **RemoteException**, which RMI requires of all **UnicastRemoteObject** subclasses. Line 31 assigns the given server name to instance variable **serverAddress**.

```
1 // RMIMessageManager.java
2 // RMIMessageManager implements the ChatClient remote interface
3 // and manages incoming and outgoing chat messages using RMI.
4 package com.deitel.messenger.rmi.client;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.rmi.*;
10 import java.rmi.server.*;
11 import java.util.*;
12
13 // Deitel packages
14 import com.deitel.messenger.*;
15 import com.deitel.messenger.rmi.*;
16 import com.deitel.messenger.rmi.server.ChatServer;
17
18 public class RMIMessageManager extends UnicastRemoteObject
19     implements ChatClient, MessageManager {
20
21     // listeners for incoming messages and disconnect notifications
22     private MessageListener messageListener;
23     private DisconnectListener disconnectListener;
24 }
```

Fig. 13.20 **RMIMessageManager** remote object and **MessageManager** implementation for managing **ChatClient** communication (part 1 of 3).

```
25  private String serverAddress;
26  private ChatServer chatServer;
27
28  // RMIMessageManager constructor
29  public RMIMessageManager( String server ) throws RemoteException
30  {
31      serverAddress = server;
32  }
33
34  // connect to ChatServer
35  public void connect( MessageListener listener )
36      throws Exception
37  {
38      // look up ChatServer remote object
39      chatServer = ( ChatServer ) Naming.lookup(
40          "://" + serverAddress + "/ChatServer" );
41
42      // register with ChatServer to receive messages
43      chatServer.registerClient( this );
44
45      // set listener for incoming messages
46      messageListener = listener;
47
48 } // end method connect
49
50 // disconnect from ChatServer
51 public void disconnect( MessageListener listener )
52     throws Exception
53 {
54     if ( chatServer == null )
55         return;
56
57     // unregister with ChatServer
58     chatServer.unregisterClient( this );
59
60     // remove references to ChatServer and MessageListener
61     chatServer = null;
62     messageListener = null;
63
64 } // end method disconnect
65
66 // send ChatMessage to ChatServer
67 public void sendMessage( String fromUser, String message )
68     throws Exception
69 {
70     if ( chatServer == null )
71         return;
72
73     // create ChatMessage with message text and userName
74     ChatMessage chatMessage =
75         new ChatMessage( fromUser, message );
76 }
```

Fig. 13.20 RMIMessageManager remote object and MessageManager implementation for managing ChatClient communication (part 2 of 3).

```
77      // post message to ChatServer
78      chatServer.postMessage( chatMessage );
79
80  } // end method sendMessage
81
82  // process delivery of ChatMessage from ChatServer
83  public void deliverMessage( ChatMessage message )
84  throws RemoteException
85  {
86      if ( messageListener != null )
87          messageListener.messageReceived( message.getSender(),
88          message.getMessage() );
89  }
90
91  // method called when server shutting down
92  public void serverStopping() throws RemoteException
93  {
94      chatServer = null;
95      fireServerDisconnected( "Server shut down." );
96  }
97
98  // register listener for disconnect notifications
99  public void setDisconnectListener(
100     DisconnectListener listener )
101  {
102      disconnectListener = listener;
103  }
104
105  // send disconnect notification
106  private void fireServerDisconnected( String message )
107  {
108      if ( disconnectListener != null )
109          disconnectListener.serverDisconnected( message );
110  }
111 }
```

Fig. 13.20 **RMIMessageManager** remote object and **MessageManager** implementation for managing **ChatClient** communication (part 3 of 3).

Method **connect** (lines 35–48)—declared in interface **MessageManager**—connects the **RMIMessageManager** to the **ChatServer**. Lines 39–40 invoke **static** method **lookup** of class **Naming** to retrieve a remote reference to the **ChatServer**. Line 43 invokes method **registerClient** of interface **ChatServer** to register the **RMIMessageManager** for RMI callbacks from the **ChatServer**. Note that line 43 passes the **this** reference as the argument to method **registerClient**. Recall that class **RMIMessageManager** is a remote object, therefore the **this** reference can serve as a remote **ChatClient** reference to the **RMIMessageManager** remote object.

Method **disconnect** (lines 51–64) disconnects the **RMIMessageManager** from the **ChatServer**. If remote **ChatServer** reference **chatServer** is **null**, line 55 returns immediately, because the **RMIMessageManager** is disconnected already. Line 58 invokes method **unregisterClient** of remote interface **ChatServer** to unregister the **RMIMessageManager** from the **ChatServer**. Line 58 passes the **this** reference as an

argument to method `unregisterClient`, specifying that the `ChatServer` should `unregister` this `RMIMessageManager` remote object. Line 62 sets `MessageListener` reference `messageListener` to `null`.

Method `sendMessage` (lines 67–80) delivers a message from the client to the `ChatServer`. Line 71 returns immediately if the `chatServer` remote reference is `null`. Lines 74–75 create a new `ChatMessage` object to contain the user name from whom the message came and the message body. Line 78 invokes method `postMessage` of remote interface `ChatServer` to post the new `ChatMessage` to the `ChatServer`. The `ChatServer` will use RMI callbacks to deliver this message to each registered `ChatClient`.

Method `deliverMessage` (lines 83–89)—defined in remote interface `ChatClient`—enables the `ChatServer` to use RMI callbacks to deliver incoming `ChatMessages` to the `ChatClient`. If there is a `MessageListener` registered with the `RMIMessageManager` (line 86), lines 87–88 invoke method `messageReceived` of interface `MessageListener` to notify the `MessageListener` of the incoming `ChatMessage`. Lines 87–88 invoke methods `getSender` and `getMessage` of class `ChatMessage` to retrieve the message sender and message body, respectively.

Method `serverStopping` (lines 92–96)—defined in remote interface `ChatClient`—enables the `ChatServer` to use RMI callbacks to notify the `ChatClient` that the `ChatServer` is shutting down so the `ChatClient` can disconnect and notify the `DisconnectListener`. Line 95 invokes method `fireServerDisconnected` of class `RMIMessageManager` to notify the registered `DisconnectListener` that the `ChatServer` has disconnected the `ChatClient`.

Method `setDisconnectListener` (lines 99–103)—defined in interface `MessageManager`—enables a `DisconnectListener` to register for notifications when the `ChatServer` disconnects the client. For example, the client user interface could register for these notifications to notify the user that the server has disconnected. Method `fireServerDisconnected` (lines 106–110) is a utility method for sending `serverDisconnected` messages to the `DisconnectListener`. If there is a registered `DisconnectListener`, line 109 invokes method `serverDisconnected` of interface `DisconnectListener` to notify the listener that the server disconnected. We discuss interface `DisconnectListener` in detail when we present the client user interface.

### *Client GUI Interfaces and Implementation*

We uncouple the client user interface from the `MessageManager` implementation through interfaces `MessageListener` and `DisconnectListener` (Fig. 13.19 and 13.20). Class `ClientGUI` uses implementations of interfaces `MessageListener` and `DisconnectListener` to interact with the `MessageManager` and provides a graphical user interface for the client.

Interface `MessageListener` (Fig. 13.21) enables objects of an implementing class to receive incoming messages from a `MessageManager`. Line 9 defines method `messageReceived`, which takes as arguments the user name `from` whom the message came and the `message` body.

Interface `DisconnectListener` (Fig. 13.22) enables implementing objects to receive notifications when the server disconnects the `MessageManager`. Line 9 defines method `serverDisconnected`, which takes as a `String` argument a `message` that indicates why the server disconnected.

```
1 // MessageListener.java
2 // MessageListener is an interface for classes that wish to
3 // receive new chat messages.
4 package com.deitel.messenger;
5
6 public interface MessageListener {
7
8     // receive new chat message
9     public void messageReceived( String from, String message );
10 }
```

Fig. 13.21 **MessageListener** interface for receiving new messages.

```
1 // DisconnectListener.java
2 // DisconnectListener defines method serverDisconnected, which
3 // indicates that the server has disconnected the client.
4 package com.deitel.messenger;
5
6 public interface DisconnectListener {
7
8     // receive notification that server disconnected
9     public void serverDisconnected( String message );
10 }
```

Fig. 13.22 **DisconnectListener** interface for receiving server disconnect notifications.

Class **ClientGUI** (Fig. 13.23) provides a user interface for the Deitel Messenger client. The GUI consists of a menu and a toolbar with **Actions** for connecting to and disconnecting from a **ChatServer**, a **JTextArea** for displaying incoming **ChatMessages** and a **JTextArea** and **JButton** for sending new messages to the **ChatServer**. Lines 27–29 declare **Action** references for connecting to and disconnecting from the **ChatServer** and for sending **ChatMessages**. Line 35 declares a **MessageManager** reference for the **MessageManager** implementation that provides the network communication. Line 38 declares a **MessageListener** reference for receiving new **ChatMessages** from the **ChatServer** through the **MessageManager**.

```
1 // ClientGUI.java
2 // ClientGUI provides a GUI for sending and receiving
3 // chat messages using a MessageManager.
4 package com.deitel.messenger;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.util.*;
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 1 of 9).

```
10 // Java extension packages
11 import javax.swing.*;
12 import javax.swing.border.*;
13 import javax.swing.text.*;
14
15 public class ClientGUI extends JFrame {
16
17     // JLabel for displaying connection status
18     private JLabel statusBar;
19
20     // JTextAreas for displaying and inputting messages
21     private JTextArea messageArea;
22     private JTextArea inputArea;
23
24     // Actions for connecting and disconnecting MessageManager
25     // and sending messages
26     private Action connectAction;
27     private Action disconnectAction;
28     private Action sendAction;
29
30     // userName to add to outgoing messages
31     private String userName = "";
32
33     // MessageManager for communicating with server
34     MessageManager messageManager;
35
36     // MessageListener for receiving new messages
37     MessageListener messageListener;
38
39     // ClientGUI constructor
40     public ClientGUI( MessageManager manager )
41     {
42         super( "Deitel Messenger" );
43
44         messageManager = manager;
45
46         messageListener = new MyMessageListener();
47
48         // create Actions
49         connectAction = new ConnectAction();
50         disconnectAction = new DisconnectAction();
51         disconnectAction.setEnabled( false );
52         sendAction = new SendAction();
53         sendAction.setEnabled( false );
54
55         // set up File menu
56         JMenu fileMenu = new JMenu( "File" );
57         fileMenu.setMnemonic( 'F' );
58         fileMenu.add( connectAction );
59         fileMenu.add( disconnectAction );
60
61 }
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 2 of 9).

```
62      // set up JMenuBar and attach File menu
63      JMenuBar menuBar = new JMenuBar();
64      menuBar.add( fileMenu );
65      setJMenuBar( menuBar );
66
67      // set up JToolBar
68      JToolBar toolBar = new JToolBar();
69      toolBar.add( connectAction );
70      toolBar.add( disconnectAction );
71
72      // create JTextArea for displaying messages
73      messageArea = new JTextArea( 15, 15 );
74
75      // disable editing and wrap words at end of line
76      messageArea.setEditable( false );
77      messageArea.setLineWrap( true );
78      messageArea.setWrapStyleWord( true );
79
80      JPanel panel = new JPanel();
81      panel.setLayout( new BorderLayout( 5, 5 ) );
82      panel.add( new JScrollPane( messageArea ),
83                 BorderLayout.CENTER );
84
85      // create JTextArea for entering new messages
86      inputArea = new JTextArea( 3, 15 );
87      inputArea.setLineWrap( true );
88      inputArea.setWrapStyleWord( true );
89      inputArea.setEditable( false );
90
91      // map Enter key in inputArea to sendAction
92      Keymap keyMap = inputArea.getKeymap();
93      KeyStroke enterKey = KeyStroke.getKeyStroke(
94          KeyEvent.VK_ENTER, 0 );
95      keyMap.addActionForKeyStroke( enterKey, sendAction );
96
97      // lay out inputArea and sendAction JButton in BoxLayout
98      // and add Box to messagePanel
99      Box box = new Box( BoxLayout.X_AXIS );
100     box.add( new JScrollPane( inputArea ) );
101     box.add( new JButton( sendAction ) );
102
103    panel.add( box, BorderLayout.SOUTH );
104
105    // create statusBar JLabel with recessed border
106    statusBar = new JLabel( "Not Connected" );
107    statusBar.setBorder(
108        new BevelBorder( BevelBorder.LOWERED ) );
109
110    // lay out components
111    Container container = getContentPane();
112    container.add( toolBar, BorderLayout.NORTH );
113    container.add( panel, BorderLayout.CENTER );
```

Fig. 13.23 ClientGUI provides a graphical user interface for the Deitel Messenger client (part 3 of 9).

```
114     container.add( statusBar, BorderLayout.SOUTH );
115
116     // disconnect and exit if user closes window
117     addWindowListener(
118
119         new WindowAdapter() {
120
121             // disconnect MessageManager when window closes
122             public void windowClosing( WindowEvent event )
123             {
124                 // disconnect from chat server
125                 try {
126                     messageManager.disconnect( messageListener );
127                 }
128
129                 // handle exception disconnecting from server
130                 catch ( Exception exception ) {
131                     exception.printStackTrace();
132                 }
133
134                 System.exit( 0 );
135
136             } // end method windowClosing
137
138         } // end WindowAdapter inner class
139     );
140
141 } // end ClientGUI constructor
142
143 // Action for connecting to server
144 private class ConnectAction extends AbstractAction {
145
146     // configure ConnectAction
147     public ConnectAction()
148     {
149         putValue( Action.NAME, "Connect" );
150         putValue( Action.SMALL_ICON, new ImageIcon(
151             ClientGUI.class.getResource(
152                 "images/Connect.gif" ) ) );
153         putValue( Action.SHORT_DESCRIPTION,
154                 "Connect to Server" );
155         putValue( Action.LONG_DESCRIPTION,
156                 "Connect to server to send Instant Messages" );
157         putValue( Action.MNEMONIC_KEY, new Integer( 'C' ) );
158     }
159
160     // connect to server
161     public void actionPerformed( ActionEvent event )
162     {
163         // connect MessageManager to server
164         try {
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 4 of 9).

```
166         // clear messageArea
167         messageArea.setText( "" );
168
169         // connect MessageManager and register MessageListener
170         messageManager.connect( messageListener );
171
172         // listen for disconnect notifications
173         messageManager.setDisconnectListener(
174             new DisconnectHandler() );
175
176         // get desired userName
177        (userName = JOptionPane.showInputDialog(
178             ClientGUI.this, "Please enter your name: " );
179
180         // update Actions, inputArea and statusBar
181         connectAction.setEnabled( false );
182         disconnectAction.setEnabled( true );
183         sendAction.setEnabled( true );
184         inputArea.setEditable( true );
185         inputArea.requestFocus();
186         statusBar.setText( "Connected: " + userName );
187
188         // send message indicating user connected
189         messageManager.sendMessage( userName, userName +
190             " joined chat" );
191
192     } // end try
193
194     // handle exception connecting to server
195     catch ( Exception exception ) {
196         JOptionPane.showMessageDialog( ClientGUI.this,
197             "Unable to connect to server.", "Error Connecting",
198             JOptionPane.ERROR_MESSAGE );
199
200         exception.printStackTrace();
201     }
202
203 } // end method actionPerformed
204
205 } // end ConnectAction inner class
206
207 // Action for disconnecting from server
208 private class DisconnectAction extends AbstractAction {
209
210     // configure DisconnectAction
211     public DisconnectAction()
212     {
213         putValue( Action.NAME, "Disconnect" );
214         putValue( Action.SMALL_ICON, new ImageIcon(
215             ClientGUI.class.getResource(
216                 "images/Disconnect.gif" ) ) );
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 5 of 9).

```
217     putValue( Action.SHORT_DESCRIPTION,
218             "Disconnect from Server" );
219     putValue( Action.LONG_DESCRIPTION,
220             "Disconnect to end Instant Messaging session" );
221     putValue( Action.MNEMONIC_KEY, new Integer( 'D' ) );
222 }
223
224 // disconnect from server
225 public void actionPerformed( ActionEvent event )
226 {
227     // disconnect MessageManager from server
228     try {
229
230         // send message indicating user disconnected
231         messageManager.sendMessage( userName, userName +
232             " exited chat" );
233
234         // disconnect from server and unregister
235         // MessageListener
236         messageManager.disconnect( messageListener );
237
238         // update Actions, inputArea and statusBar
239         sendAction.setEnabled( false );
240         disconnectAction.setEnabled( false );
241         inputArea.setEditable( false );
242         connectAction.setEnabled( true );
243         statusBar.setText( "Not Connected" );
244
245     } // end try
246
247     // handle exception disconnecting from server
248     catch ( Exception exception ) {
249         JOptionPane.showMessageDialog( ClientGUI.this,
250             "Unable to disconnect from server.",
251             "Error Disconnecting", JOptionPane.ERROR_MESSAGE );
252
253         exception.printStackTrace();
254     }
255
256 } // end method actionPerformed
257
258 } // end DisconnectAction inner class
259
260 // Action for sending messages
261 private class SendAction extends AbstractAction {
262
263     // configure SendAction
264     public SendAction()
265     {
266         putValue( Action.NAME, "Send" );
267         putValue( Action.SMALL_ICON, new ImageIcon(
268             ClientGUI.class.getResource( "images/Send.gif" ) ) );
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 6 of 9).

```
269         putValue( Action.SHORT_DESCRIPTION, "Send Message" );
270         putValue( Action.LONG_DESCRIPTION,
271             "Send an Instant Message" );
272         putValue( Action.MNEMONIC_KEY, new Integer( 'S' ) );
273     }
274
275     // send message and clear inputArea
276     public void actionPerformed( ActionEvent event )
277     {
278         // send message to server
279         try {
280
281             // send userName and text in inputArea
282             messageManager.sendMessage( userName,
283                 inputArea.getText() );
284
285             inputArea.setText( "" );
286         }
287
288         // handle exception sending message
289         catch ( Exception exception ) {
290             JOptionPane.showMessageDialog( ClientGUI.this,
291                 "Unable to send message.", "Error Sending Message",
292                 JOptionPane.ERROR_MESSAGE );
293
294             exception.printStackTrace();
295         }
296
297     } // end method actionPerformed
298
299 } // end SendAction inner class
300
301 // MyMessageListener listens for new messages from the
302 // MessageManager and displays the messages in messageArea
303 // using a MessageDisplayer.
304 private class MyMessageListener implements MessageListener {
305
306     // when new message received, display in messageArea
307     public void messageReceived( String from, String message )
308     {
309         // append message using MessageDisplayer and invokeLater
310         // to ensure thread-safe access to messageArea
311         SwingUtilities.invokeLater(
312             new MessageDisplayer( from, message ) );
313     }
314
315 } // end MyMessageListener inner class
316
317 // MessageDisplayer displays a new message by appending
318 // the message to the messageArea JTextArea. This Runnable
319 // object should be executed only on the event-dispatch
320 // thread, as it modifies a live Swing component.
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 7 of 9).

```
321     private class MessageDisplayer implements Runnable {
322
323         private String fromUser;
324         private String messageBody;
325
326         // MessageDisplayer constructor
327         public MessageDisplayer( String from, String body )
328         {
329             fromUser = from;
330             messageBody = body;
331         }
332
333         // display new message in messageArea
334         public void run()
335         {
336             // append new message
337             messageArea.append( "\n" + fromUser + "> " +
338                 messageBody );
339
340             // move caret to end of messageArea to ensure new
341             // message is visible on screen
342             messageArea.setCaretPosition(
343                 messageArea.getText().length() );
344         }
345
346     } // end MessageDisplayer inner class
347
348     // DisconnectHandler listens for serverDisconnected messages
349     // from the MessageManager and updates the user interface.
350     private class DisconnectHandler implements DisconnectListener {
351
352         // receive disconnect notification
353         public void serverDisconnected( final String message )
354         {
355             // update GUI in thread-safe manner
356             SwingUtilities.invokeLater(
357
358                 new Runnable() {
359
360                     // update Actions, inputs and status bar
361                     public void run()
362                     {
363                         sendAction.setEnabled( false );
364                         disconnectAction.setEnabled( false );
365                         inputArea.setEditable( false );
366                         connectAction.setEnabled( true );
367                         statusBar.setText( message );
368                     }
369
370                 } // end Runnable inner class
371             );
372         }
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 8 of 9).

```
373         } // end method serverDisconnected  
374     } // end DisconnectHandler inner class  
375 }  
376 }
```

Fig. 13.23 **ClientGUI** provides a graphical user interface for the Deitel Messenger client (part 9 of 9).

The **ClientGUI** constructor (lines 41–141) creates and lays out the various user-interface components. The constructor takes as an argument the **MessageManager** that implements the underlying network communications. A **WindowAdapter** inner class (lines 119–138) ensures that the **MessageManager** disconnects from the **ChatServer** (line 126) when the user closes the application window.

The **ConnectAction** inner class (lines 144–205) is an **Action** implementation for connecting to the Deitel Messenger server. Lines 170–174 invoke method **connect** of interface **MessageManager** and register a **DisconnectListener** for receiving **serverDisconnected** notifications. Lines 177–186 prompt the user for a name to use in the chat session and update the user-interface components to allow the user to send messages and disconnect from the Deitel Messenger server. Lines 188–189 invoke method **sendMessage** of interface **MessageManager** to send a **ChatMessage** that announces the user's arrival in the chat session.

The **DisconnectAction** inner class (lines 211–258) is an **Action** implementation for disconnecting the **MessageManager** from the Deitel Messenger server. Lines 231–232 send a **ChatMessage** to announce the user's departure from the chat session. Line 236 invokes method **disconnect** of interface **MessageManager** to disconnect from the server. Lines 239–243 update the user-interface components to disable the message **inputArea** and display a message in the status bar.

The **SendAction** inner class (lines 261–299) is an **Action** implementation for sending messages to the server. Lines 282–283 invoke method **sendMessage** of interface **MessageManager** and pass the contents of **inputArea** and the user's **userName** as arguments.

An instance of inner class **MyMessageListener** (lines 304–315) listens for incoming **ChatMessages**. When the **MessageManager** receives a new **ChatMessage** from the server, the **MessageManager** invokes method **messageReceived** (lines 307–313). Lines 311–312 invoke **static** method **invokeLater** of class **SwingUtilities** with a **MessageDisplayer** argument to display the new message.

Inner class **MessageDisplayer** (lines 321–346) is a **Runnable** implementation that appends a new message to the **messageArea JTextArea** to display that message to the user. Lines 337–338 append the message text and sender's user name to **messageArea**, and lines 342–343 move the cursor to the end of **messageArea**.

An instance of inner class **DisconnectHandler** (lines 350–375) receives **serverDisconnected** notifications from the **MessageManager** when the server disconnects. Lines 356–371 update the user-interface components to indicate that the server disconnected.

Class **DeitelMessenger** (Fig. 13.24) launches the client application using a **ClientGUI** and **RMIManager**. Line 18 invokes method **setSecurityManager** of class **System** to install an **RMISecurityManager** for the client application.

The client requires this **SecurityManager** for downloading the **ChatServer**'s stub dynamically. We discuss dynamic class downloading in Section 13.6.3. If the user does not specify a hostname for the **ChatServer**, line 24 creates an **RMIMessageManager** that connects to the server running on **localhost**. Line 26 creates an **RMIMessageManager** that connects to the user-provided hostname. Lines 29–32 create a **ClientGUI** for the **RMIMessageManager** and display that GUI to the user.

### 13.6.3 Running the Deitel Messenger Server and Client Applications

Running the Deitel Messenger case study server and clients requires several steps. In addition to the RMI registry, RMI applications that use **Activatable** objects require the RMI activation daemon (**rmid**). The RMI activation daemon is a server process that manages the registration, activation and deactivation of **Activatable** remote objects.\

```
1 // DeitelMessenger.java
2 // DeitelMessenger uses a ClientGUI and RMIMessageManager to
3 // implement an RMI-based chat client.
4 package com.deitel.messenger.rmi.client;
5
6 // Java core packages
7 import java.rmi.RMISecurityManager;
8
9 // Deitel packages
10 import com.deitel.messenger.*;
11
12 public class DeitelMessenger {
13
14     // launch DeitelMessenger application
15     public static void main ( String args[] ) throws Exception
16     {
17         // install RMISecurityManager
18         System.setSecurityManager( new RMISecurityManager() );
19
20         MessageManager messageManager;
21
22         // create new DeitelMessenger
23         if ( args.length == 0 )
24             messageManager = new RMIMessageManager( "localhost" );
25         else
26             messageManager = new RMIMessageManager( args[ 0 ] );
27
28         // finish configuring window and display it
29         ClientGUI clientGUI = new ClientGUI( messageManager );
30         clientGUI.pack();
31         clientGUI.setResizable( false );
32         clientGUI.setVisible( true );
33     }
34 }
```

Fig. 13.24 **DeitelMessenger** launches a chat client using classes **ClientGUI** and **RMIMessageManager**.

To begin, start the RMI registry by executing the command

```
rmiregistry
```

at a command prompt. Be sure that the stub file for the **ChatServer** remote object (**ChatServerImpl\_Stub.class**) is not in the RMI registry's **CLASSPATH**, as this will disable dynamic class downloading. Next, start the RMI activation daemon by executing the command

```
rmid -J-Djava.security.policy=rmid.policy
```

where **rmid.policy** is the complete path to the policy file of Fig. 13.25. This policy file allows the **ActivationGroup** in which the **ChatServer** runs to specify **C:\activationGroup.policy** as the policy file for the **ActivationGroup**'s virtual machine. If you place **activationGroup.policy** in a location other than the **C:\** directory, be sure to modify **rmid.policy** to specify the appropriate location.

*Dynamic class downloading* enables Java programs to download classes not available in the local **CLASSPATH**. This is particularly useful in RMI applications for enabling clients to download stub files dynamically. When an RMI object specifies the **java.rmi.server.codebase** system property, the RMI registry adds an *annotation* to that object's remote references. This annotation specifies the codebase from which clients can download any necessary classes. These classes might include the stub for the remote object and other classes. These **.class** files must be available for download from an HTTP server. Sun provides a basic HTTP server suitable for testing purposes, which is downloadable from

```
java.sun.com/products/jdk/rmi/class-server.zip
```

Extract the files from **class-server.zip** and read the included instructions for running the HTTP server. Figure 13.26 lists the files to include in the HTTP server's download directory. For example, if the HTTP server's download directory is **C:\classes**, copy the directory structure and **.class** files listed in Fig. 13.26 to **C:\classes**. Be sure to start the HTTP server before continuing.

Next, run the **ChatServerAdministrator** application to launch the **Activatable** remote object by using the command

```
java -Djava.security.policy=administrator.policy
      -Djava.rmi.server.codebase=http://hostname:port/
      com.deitel.messenger.rmi.server.ChatServerAdministrator
      start
```

```
1 // allow ActivationGroup to specify C:\activationGroup.policy
2 // as its VM's security policy
3 grant {
4     permission com.sun.rmi.rmid.ExecOptionPermission
5         "-Djava.security.policy=file:///C:/activationGroup.policy";
6 };
```

Fig. 13.25 Policy file for the RMI activation daemon.

Directory	File Name
com\deitel\messenger\rmi\server\	
	ChatServer.class
	ChatServerImpl.class
	ChatServerImpl\$1.class
	ChatServerImpl_Stub.class
	StopableChatServer.class
com\deitel\messenger\rmi\client\	
	ChatClient.class
	RMIMessageManager_Stub.class
com\deitel\messenger\rmi\	
	ChatMessage.class

Fig. 13.26 File listing for the HTTP server's download directory.

where **administrator.policy** is the complete path to the policy file of Fig. 13.27, *hostname* is the name of the computer running the HTTP server and *port* is the port number on which that HTTP server is running. The RMI registry will annotate each remote reference it returns with this codebase. The policy file must permit **ChatServerAdministrator** to connect to port 1098 on the local machine, which is the port for the RMI activation daemon. The policy file also must allow the **ChatServerAdministrator** to access the port on which the Web server is running. Lines 4–5 of Fig. 13.27 specify that the **ChatServerAdministrator** can access all ports above and including **1024** on *hostname*. Be sure to replace *hostname* with the appropriate name or IP address of the machine running the Web server and RMI activation daemon. The **ChatServerAdministrator** also requires the permission **setFactory** of type **java.lang.RuntimePermission**, which permits the **ActivationGroup** to set a **SecurityManager**.

The **ChatServerAdministrator** application registers the **ActivationGroup** for the **Activatable ChatServer**, then exits. Clients then may access the **ChatServer** by obtaining a remote reference to the **ChatServer** from the RMI registry and invoking methods on that remote reference. Note that the **ChatServer** does not begin executing until the first client invokes a method on the **ChatServer** remote object.

```

1 // allow ChatServerAdministrator to connect to
2 // activation daemon
3 grant {
4     permission java.net.SocketPermission "hostname:1024-",
5         "connect, accept, resolve";
6
7     permission java.lang.RuntimePermission "setFactory";
8 };

```

Fig. 13.27 Policy file for **ChatServerAdministrator**.

At that time, the activation system activates the **ChatServer**'s **ActivationGroup**. To launch a client for the **ChatServer**, type the following at a command prompt:

```
java -Djava.security.policy=client.policy  
com.deitel.messenger.rmi.client.DeitelMessenger
```

where **client.policy** is the policy file of Fig. 13.28. This policy file enables the client to connect, accept and resolve connections to the specified hostname on ports above and including **1024**. Recall that the client is itself a remote object, so the client must be able to accept incoming network connections from the **ChatServer**. Be sure to replace **hostname** with the hostname or IP address of the computer on which the **ChatServer** is running.

Figure 13.29 shows a sample conversation in Deitel Messenger. Notice that the GUI elements properly reflect the current connection state—when the client is disconnected, only the **ConnectAction** is enabled. After the client connects, the **DisconnectAction**, input **JTextArea** and **SendAction** become enabled. Note also that the bottom of each window displays the message **Java Applet Window**. The virtual machine places this message in the windows because the application is running under security restrictions.

```
1 // allow client to connect to network resources on hostname  
2 // at ports above 1024  
3 grant {  
4     permission java.net.SocketPermission "hostname:1024-",  
5         "connect, accept, resolve";  
6 };
```

Fig. 13.28 Policy file for the **DeitelMessenger** client.

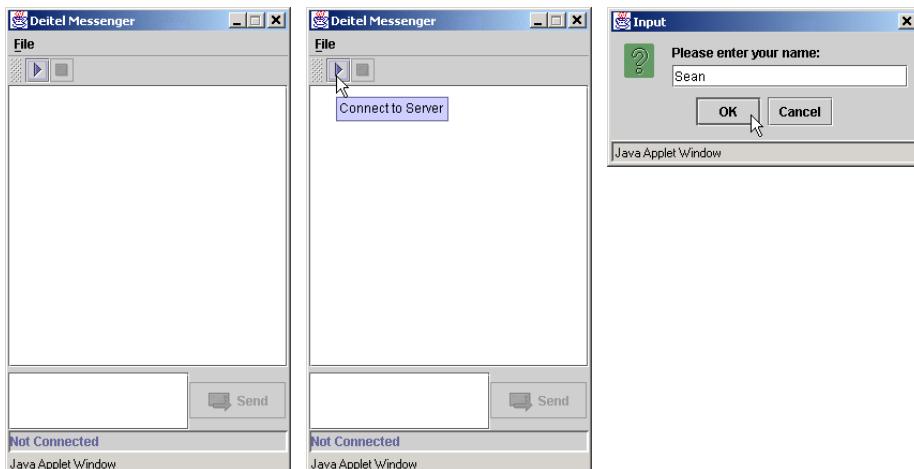


Fig. 13.29 Sample conversation using Deitel Messenger.

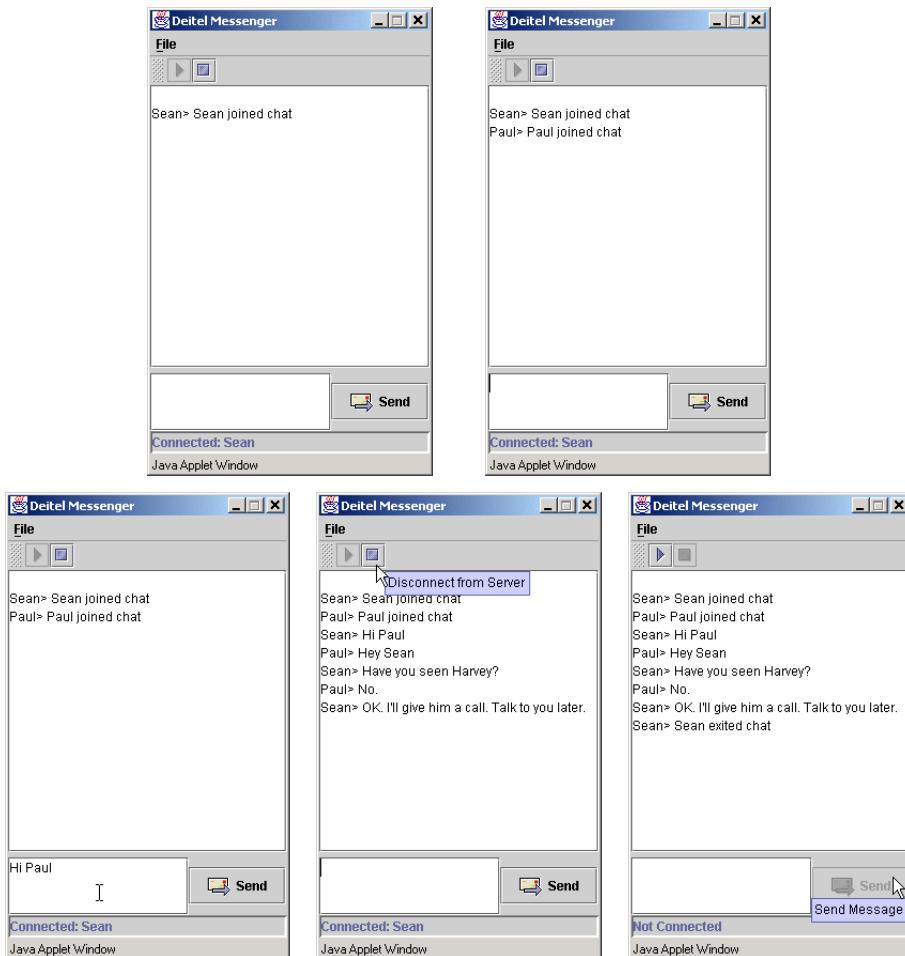


Fig. 13.29 Sample conversation using Deitel Messenger.

## 13.7 Internet and World Wide Web Resources

[java.sun.com/products/jdk/rmi/index.html](http://java.sun.com/products/jdk/rmi/index.html)

Sun's Remote Method Invocation (RMI) home page, which provides links to technical articles, documentation and other resources.

[java.sun.com/j2se/1.3/docs/guide/rmi/index.html](http://java.sun.com/j2se/1.3/docs/guide/rmi/index.html)

Sun's RMI guide, which includes links to tutorials on building activatable remote objects and other useful resources.

[www.jguru.com/faq/home.jsp?topic=RMI](http://www.jguru.com/faq/home.jsp?topic=RMI)

jGuru's RMI Frequently Asked Questions with answers, which provides tips and answers to many common questions that developer's ask about RMI.

[www.javaworld.com/javaworld/topicalindex/jw-ti-rmi.html](http://www.javaworld.com/javaworld/topicalindex/jw-ti-rmi.html)

JavaWorld's list of articles related to RMI. Articles include discussions of activatable RMI objects, integrating RMI with CORBA and RMI-related technologies, such as Jini.

## SUMMARY

- RMI allows Java objects running on separate computers or in separate processes to communicate with one another via remote method calls. Such method calls appear to the programmer the same as those operating on objects in the same program.
- RMI is based on a similar, earlier technology for procedural programming called remote procedure calls (RPCs) developed in the 1980s.
- RMI enables Java programs to transfer complete Java objects using Java's object-serialization mechanism. The programmer need not be concerned with the transmission of the data over the network.
- For Java-to-non-Java communication, you can use Java IDL (introduced in Java 1.2) or RMI-IIOP. Java IDL and RMI-IIOP enable applications and applets written in Java to communicate with objects written in any language that supports CORBA (Common Object Request Broker Architecture).
- The four major steps for building an RMI distributed system are 1) defining the remote interface, 2) defining the remote object implementation, 3) defining the client application that uses the remote object and 4) compiling and executing the remote object and the client.
- To create a remote interface, define an interface that extends interface **java.rmi.Remote**. Interface **Remote** is a tagging interface—it does not declare any methods, and therefore places no burden on the implementing class.
- An object of a class that implements interface **Remote** directly or indirectly is a remote object and can be accessed—with appropriate security permissions—from any Java virtual machine that has a connection to the computer on which the remote object executes.
- Every remote method must be declared in an interface that extends **java.rmi.Remote**. A remote object must implement all methods declared in its remote interface.
- An RMI distributed application must export an object of a class that implements the **Remote** interface to make that remote object available to receive remote method calls.
- Each method in a **Remote** interface must have a **throws** clause that indicates that the method can throw **RemoteExceptions**. A **RemoteException** indicates a problem communicating with the remote object.
- RMI uses Java's default serialization mechanism to transfer method arguments and return values across the network. Therefore, all method arguments and return values must be **Serializable** or primitive types.
- Class **UnicastRemoteObject** provides the basic functionality required for all remote objects. In particular, its constructor exports the object to make it available to receive remote calls.
- Exporting a remote object enables that object to wait for client connections on an anonymous port number (i.e., one chosen by the computer on which the remote object executes). RMI abstracts away communication details so the programmer can work with simple method calls.
- Constructors for class **UnicastRemoteObject** allow the programmer to specify information about the remote object, such as an explicit port number on which to export the remote object. All **UnicastRemoteObject** constructors throw **RemoteExceptions**.
- The **rmiregistry** utility program manages the registry for remote objects and is part of the J2SE SDK. The default port number for the RMI registry is **1099**.
- Method **lookup** connects to the RMI registry and returns a **Remote** reference to the remote object. Note that clients refer to remote objects only through those object's remote interfaces.
- A remote reference refers to a stub object on the client. Stubs allow clients to invoke remote objects' methods. Stub objects receive each remote method call and pass those calls to the RMI system, which performs the networking that allows clients to interact with the remote object.

- The RMI layer is responsible for network connections to the remote object, so referencing remote objects is transparent to the client. RMI handles the underlying communication with the remote object and the transfer of arguments and return values between the objects. Argument and return types for remote methods must be **Serializable**.
- The **rmic** utility compiles the remote object class to produce a stub class. A stub class forwards method invocations to the RMI layer, which performs the network communication necessary to invoke the method call on the remote object.
- Standard RMI objects exported as **UnicastRemoteObjects** must run continuously on the server to handle client requests. RMI objects that extend class **java.rmi.activation.Activatable** are able to activate, or start running, when a client invokes one of the remote object's methods.
- The RMI activation daemon (**rmid**) is a server process that enables activatable remote objects to become active when clients invoke remote methods on these objects.
- Activatable remote objects also are able to recover from server crashes, because remote references to activatable objects are persistent—when the server restarts, the RMI activation daemon maintains the remote reference, so clients can continue to use the remote object.
- The RMI activation mechanism requires that **Activatable** objects provide a constructor that takes as arguments an **ActivationID** and a **MarshalledObject**. When the activation daemon activates a remote object of this class, it invokes this activation constructor. The **ActivationID** argument specifies a unique identifier for the remote object.
- Class **MarshalledObject** is a wrapper class that contains a serialized object for transmission over RMI. The **MarshalledObject** passed to the activation constructor can contain application-specific initialization information, such as the name under which the activation daemon registered the remote object.
- Activatable RMI objects execute as part of an **ActivationGroup** (package **java.rmi.activation**). The RMI activation daemon—a server-side process that manages activatable objects—starts a new virtual machine for each **ActivationGroup**.
- Class **ActivationGroupDesc** specifies configuration information for an **ActivationGroup**. The first argument to the **ActivationGroupDesc** constructor is a **Properties** reference that contains replacement values for system properties in the **ActivationGroup**'s virtual machine. The second argument is a reference to an **ActivationGroupDesc.CommandEnvironment** object, which enables the **ActivationGroup** to customize the commands that the activation daemon executes when starting the **ActivationGroup**'s virtual machine.
- The incarnation number of an **ActivationGroup** identifies different instances of the same **ActivationGroup**. Each time the activation daemon activates the **ActivationGroup**, the daemon increments the incarnation number.
- Class **ActivationDesc** specifies configuration information for a particular **Activatable** remote object. The first argument to the **ActivationDesc** constructor specifies the name of the class that implements the **Activatable** remote object. The second argument specifies the codebase that contains the remote object's class files. The final argument is a **MarshalledObject** reference, whose object specifies initialization information for the remote object.
- Method **register** of class **Activatable** takes as an argument the **ActivationDesc** for the **Activatable** object and returns a reference to the remote object's stub.
- Dynamic class downloading enables Java programs to download classes not available in the local **CLASSPATH**. This is particularly useful in RMI applications for enabling clients to download stub files dynamically.
- When an RMI object specifies the **java.rmi.server.codebase** system property, the RMI registry adds an annotation to that object's remote references, which specifies the codebase from

which clients can download necessary classes. Downloadable **.class** files must be available from an HTTP server.

## TERMINOLOGY

<b>Activatable</b> class (package <b>java.rmi.activation</b> )	marshaling of data
activatable remote object	<b>MarshalledObject</b> class
activation daemon	<b>rebind</b> method of class <b>Naming</b>
activation descriptor	<b>Registry</b> class
activation group descriptor	remote interface
<b>ActivationGroup</b> class	<b>Remote</b> interface (package <b>java.rmi</b> )
<b>ActivationGroupDesc</b> class	remote method
<b>ActivationGroupDescd.Command-Environment</b> class	remote method call
<b>ActivationID</b> class	Remote Method Invocation (RMI)
<b>ActivationSystem</b> interface	remote object
Adapter design pattern	remote object implementation
anonymous port number	Remote Procedure Call (RPC)
<b>bind</b> method of class <b>Naming</b>	remote reference
<b>createRegistry</b> method of class <b>LocateRegistry</b>	<b>RemoteException</b> class (package <b>java.rmi</b> )
distributed computing	RMI registry
export	<b>rmic</b> compiler
<b>exportObject</b> method of class <b>UnicastRemoteObject</b>	<b>rmid</b> utility
HTML scraping	<b>rmiregistry</b> utility
Interface Definition Language (IDL)	<b>RMISecurityManager</b> class
<b>ListCellRenderer</b> interface	stub class
<b>LocateRegistry</b> class	tagging interface
	<b>UnicastRemoteObject</b> class (package <b>java.rmi.server</b> )

## SELF-REVIEW EXERCISES

### 13.1 Fill in the blanks in each of the following statements:

- a) The remote object class must be compiled using the \_\_\_\_\_ to produce a stub class.
- b) RMI is based on a similar technology for procedural programming called \_\_\_\_\_.
- c) Clients use method \_\_\_\_\_ of class **Naming** to obtain a remote reference to a remote object.
- d) To create a remote interface, define an interface that extends interface \_\_\_\_\_ of package \_\_\_\_\_.
- e) Method \_\_\_\_\_ or \_\_\_\_\_ of class **Naming** binds a remote object to the RMI registry.
- f) Remote objects normally extend class \_\_\_\_\_, which provides the basic functionality required for all remote objects.
- g) Remote objects use the \_\_\_\_\_ and \_\_\_\_\_ to locate the RMI registry so they can register themselves as remote services. Clients use these to locate a service.
- h) The default port number for the RMI registry is \_\_\_\_\_.
- i) Interface **Remote** is a \_\_\_\_\_.
- j) \_\_\_\_\_ allows Java objects running on separate computers (or possibly the same computer) to communicate with one another via remote method calls.

- 13.2** State whether each of the following is true or false. If false, explain why.
- a) Not starting the RMI registry before attempting to bind the remote object to the registry results in a **RuntimeException** refusing connection to the registry.
  - b) Every remote method must be part of an interface that extends **java.rmi.Remote**.
  - c) The **stubcompiler** creates a stub class that performs the networking which allows the client to connect to the server and use the remote object's methods.
  - d) Class **UnicastRemoteObject** provides basic functionality required by remote objects.
  - e) An object of a class that implements interface **Serializable** can be registered as a remote object and receive a remote method call.
  - f) All methods in a **Remote** interface must have a **throws** clause indicating the potential for a **RemoteException**.
  - g) RMI clients assume that they should connect to port 80 on a server computer when attempting to locate a remote object through the RMI registry.
  - h) Once a remote object is bound to the RMI registry with method **bind** or **rebind** of class **Naming**, the client can look up the remote object with **Naming** method **lookup**.
  - i) Method **find** of class **Naming** interacts with the RMI registry to help the client obtain a reference to a remote object so the client can use the remote object's services.

## ANSWERS TO SELF-REVIEW EXERCISES

- 13.1** a) **rmic** compiler. b) RPC. c) **lookup**. d) **Remote**, **java.rmi**. e) **bind**, **rebind**. f) **UnicastRemoteObject**. g) host, port. h) 1099. i) tagging interface. j) RMI.
- 13.2** a) False. This results in a **java.rmi.ConnectException**.  
b) True.  
c) False. The **rmic** compiler creates a stub class.  
d) True.  
e) False. An object of a class that implements a subinterface of **java.rmi.Remote** can be registered as a remote object and receive remote method calls.  
f) True.  
g) False. RMI clients assume port 1099 by default. Web browser clients assume port 80.  
h) True.  
i) False. Method **lookup** interacts with the RMI registry to help the client obtain a reference to a remote object.

## EXERCISES

**13.3** The current implementation of class **WeatherServiceImpl** downloads the weather information only once. Modify class **WeatherServiceImpl** to obtain weather information from the National Weather Service twice a day.

**13.4** Modify interface **WeatherService** to include support for obtaining the current day's forecast and the next day's forecast. Study the Traveler's Forecast Web page

<http://iwin.nws.noaa.gov/iwin/us/traveler.html>

**13.5** Visit the NWS Web site for the format of each line of information. Next, modify class **WeatherServiceImpl** to implement the new features of the interface. Finally, modify class **WeatherServiceClient** to allow the user to select the weather forecast for either day. Modify the support classes **WeatherBean** and **WeatherItem** as necessary to support the changes to classes **WeatherServiceImpl** and **WeatherServiceClient**.

**13.6** (Project: Weather for Your State) There is a wealth of weather information on the National Weather Service Web site. Study the following Web pages:

```
http://iwin.nws.noaa.gov/  
http://iwin.nws.noaa.gov/iwin/textversion/main.html
```

and create a complete weather forecast server for your state. Design your classes for reusability.

**13.7** (Project: Weather for Your State) Modify the Exercise 13.6 project solution to allow the user to select the weather forecast for any state. [Note: For some states, the format of the weather forecast differs from the standard format. Your solution should allow the user to select only from those states whose forecasts are in the standard format.]

**13.8** (*For International Readers*) If there is a similar World Wide Web-based weather service in your own country, provide a different **WeatherServiceImpl** implementation with the same remote interface **WeatherService** (Fig. 13.1). The server should return weather information for major cities in your country.

**13.9** (*Remote Phone Book Server*) Create a remote phone book server that maintains a file of names and phone numbers. Define interface **PhoneBookServer** with the following methods:

```
public PhoneBookEntry[] getPhoneBook()  
public void addEntry( PhoneBookEntry entry )  
public void modifyEntry( PhoneBookEntry entry )  
public void deleteEntry( PhoneBookEntry entry )
```

Create **Activatable** remote object class **PhoneBookServerImpl**, which implements interface **PhoneBookServer**. Class **PhoneBookEntry** should contain **String** instance variables that represent the first name, last name and phone number for one person. The class should also provide appropriate *set/get* methods and perform validation on the phone number format. Remember that class **PhoneBookEntry** also must implement **Serializable**, so that RMI can serialize objects of this class.

**13.10** Class **PhoneBookClient** should provide a user interface that allows the user to scroll through entries, add a new entry, modify an existing entry and delete an existing entry. The client and the server should provide proper error handling (e.g., the client cannot modify an entry that does not exist).

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# Session EJBs and Distributed Transactions

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## Objectives

- To understand EJBs as business-logic components.
- To understand the advantages and disadvantages of stateful and stateless session EJBs.
- To understand JNDI's role in enterprise Java applications.
- To understand distributed transactions.
- To understand the advantages and disadvantages of container-managed and bean-managed transaction demarcation.

*Only the traveling is good which reveals to me the value of home and enables me to enjoy it better.*

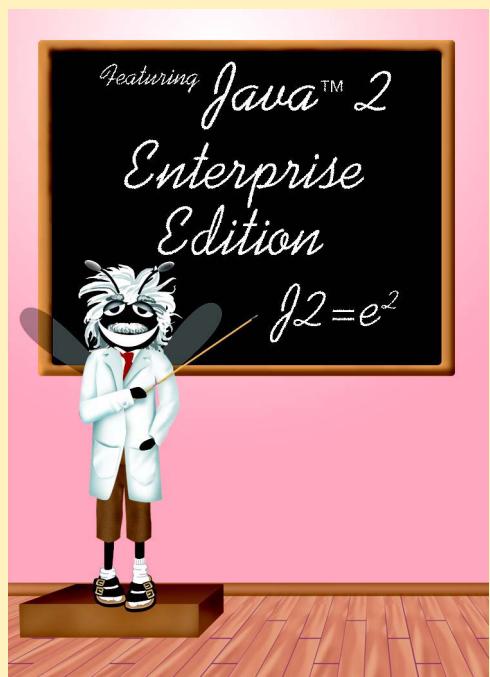
Henry David Thoreau

*Youth would be an ideal state if it came a little later in life.*

Herbert Henry Asquith

*We cannot make events. Our business is wisely to improve them.*

Samuel Adams



## Outline

- 14.1 Introduction
- 14.2 EJB Overview
  - 14.2.1 Remote Interface
  - 14.2.2 Home Interface
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  - 14.2.4 EJB Container
- 14.3 Session Beans
  - 14.3.1 Stateful Session EJBs
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  - 14.3.2 Deploying Session EJBs
- 14.4 EJB Transactions
  - 14.4.1 MoneyTransfer EJB Home and Remote Interfaces
  - 14.4.2 Bean-Managed Transaction Demarcation
  - 14.4.3 Container-Managed Transaction Demarcation
  - 14.4.4 MoneyTransfer EJB Client
  - 14.4.5 Deploying the MoneyTransfer EJB
- 14.5 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

## 14.1 Introduction

In previous chapters, we presented Java servlets and JavaServer Pages for implementing business and presentation logic in multi-tier applications. In this chapter, we introduce *Enterprise JavaBeans (EJBs)*, which provide a component model for building business logic in enterprise Java applications.

In this chapter, we introduce *session EJBs* in their two forms: *stateful* and *stateless*. We also introduce EJB support for *distributed transactions*, which help to ensure data integrity across databases and across application servers. After reading this chapter, you will be able to develop stateless and stateful session EJBs. You also will be able to build EJBs that take advantage of J2EE's distributed transaction support to update data across multiple databases atomically.

## 14.2 EJB Overview

Every EJB consists of a *remote interface*, a *home interface* and an *EJB implementation*. The remote interface declares *business methods* that clients of the EJB may invoke. The home interface provides **create** methods for creating new EJB instances, **finder** methods for finding EJB instances and **remove** methods for removing EJB instances. The EJB implementation defines the business methods declared in the remote interface and the **create**, **remove** and **finder** methods of the home interface. An *EJB container* provides the EJB's runtime environment and life-cycle management.

The J2EE specification defines six *roles* for people implementing enterprise systems. Each role is responsible for producing some part of an enterprise application. The *enterprise bean provider* implements the Java classes for EJBs. The *application assembler* constructs application components from EJBs implemented by the enterprise bean provider. The *deployer* takes application components provided by the application assembler and deploys the application to an EJB container, ensuring that all dependencies are met. The *EJB server provider* and *EJB container provider* implement an *application server* suitable for the deployment of J2EE applications. An application server typically includes an EJB container and a servlet container and provides services such as JNDI directories, database connection pooling, integration with distributed systems and resource management. The same developer or team of developers can play more than one role in the construction and deployment of an enterprise application. For more information on the various roles in building J2EE applications, please see the resources listed in Section 14.5.

### 14.2.1 Remote Interface

The EJB remote interface declares business methods that EJB clients can invoke. The remote interface must extend interface **javax.ejb.EJBObject**. The EJB container generates a class that implements the remote interface. This generated class implements interface **EJBObject** methods and delegates business method invocations to the EJB implementation (Section 14.2.3). Figure 14.1 describes interface **EJBObject** methods.

Each remote-interface method is required to declare that it throws **RemoteException**. Each method also may throw application-specific exceptions—for example, an **IllegalArgumentException** if a provided argument does not meet certain criteria.

### 14.2.2 Home Interface

The EJB home interface declares methods for creating, removing and finding EJB instances. The home interface must extend interface **javax.ejb.EJBHome**. The EJB container provides an implementation of the home interface. Depending on the type of EJB (i.e., session or entity), the container will invoke EJB implementation methods that correspond to methods **create** and **remove** and *finder* methods of the home interface. These *finder* methods enable clients to locate a particular instance of an EJB. Figure 14.2 describes interface **EJBHome** methods.

Method	Description
<b>getEJBHome</b>	Returns the <b>EJBHome</b> interface for the <b>EJBObject</b> .
<b>getHandle</b>	Returns a <b>Handle</b> for the <b>EJBObject</b> . A <b>Handle</b> is a persistent, <b>Serializable</b> reference to an <b>EJBObject</b> .
<b>getPrimaryKey</b>	Returns the <b>EJBObject</b> 's primary key if <b>EJBObject</b> is an entity bean.
<b>isIdentical</b>	Returns a <b>boolean</b> indicating if the <b>EJBObject</b> argument is identical to the current <b>EJBObject</b> .
<b>remove</b>	Removes the <b>EJBObject</b> .

Fig. 14.1 Methods of interface **javax.ejb.EJBObject**.

Method	Description
<code>getEJBMetaData</code>	Returns an <code>EJBMetaData</code> object that provides information about the EJB, such as its home interface class and whether it is a session EJB.
<code>getHomeHandle</code>	Returns a <code>Handle</code> for the <code>EJBHome</code> interface.
<code>remove</code>	Removes the <code>EJBObject</code> identified by the given <code>Handle</code> or primary key <code>Object</code> .

Fig. 14.2 Methods of interface `javax.ejb.EJBHome`.

### 14.2.3 EJB Implementation

The EJB implementation defines the business methods declared in the EJB remote interface and the `create`, `remove` and `finder` methods declared in the EJB home interface. Session EJBs also must implement interface `javax.ejb.SessionBean`. We discuss interface `SessionBean` in detail in Section 14.3.

### 14.2.4 EJB Container

The EJB container manages an EJB's client interactions, method invocations, transactions, security, exceptions, etc. Clients of an EJB do not interact directly with the EJB. Clients access the EJB container to obtain remote references to EJB instances. When a client invokes an EJB business method, the invocation goes first to the EJB container, which then delegates the business method invocation to the EJB implementation.

The EJB container also manages the life cycles of its EJBs. EJB containers typically perform *pooling* of EJB instances to enhance performance. By maintaining a pool of inactive EJB instances, the EJB container can increase performance by avoiding the overhead associated with creating new EJB instances for each client request. The EJB container simply activates a pooled instance and performs any necessary initialization. The EJB container also can create new EJB instances and remove existing instances. In addition, the EJB container provides more advanced services for entity EJBs (Chapter 15, Entity EJBs).

## 14.3 Session Beans

A session EJB instance performs business logic processing for a particular client. Session EJBs can manipulate data in a database, but unlike entity EJBs (Chapter 15), session EJBs are not persistent and do not represent database data directly. Session EJB instances are lost if the EJB container crashes. There are two session EJB types: *stateful* and *stateless*. Section 14.3.1 presents stateful session EJBs and Section 14.3.3 presents stateless session EJBs. Section 14.3.2 discusses deploying session EJBs to the J2EE 1.2.1 reference implementation.

### 14.3.1 Stateful Session EJBs

*Stateful session EJBs* maintain state information between business method invocations. For example, a stateful session EJB could maintain information about a customer's shopping cart while the customer browses an on-line store. The stateful session EJB would provide business methods for adding and removing items from the shopping cart. Each time the customer added an item to the shopping cart, information about the item, such as its price and

quantity, would be stored in the stateful session EJB. If the customer left the site or otherwise terminated the session, the shopping-cart information would be lost.

**InterestCalculator** (Fig. 14.3) is the remote interface for a stateful session EJB that calculates simple interest. Methods **setPrincipal** (lines 15–16), **setInterestRate** (lines 19–20) and **setTerm** (lines 23–24) set the principal, rate and term values needed to calculate simple interest. Method **getBalance** (line 27) calculates the total balance after interest accrues for the given term. Method **getInterestEarned** (line 30) calculates the amount of interest earned.

Clients of the **InterestCalculator** EJB can invoke only those methods declared in the **InterestCalculator** remote interface. The EJB container for the **InterestCalculator** EJB will create a class that implements the **InterestCalculator** remote interface, including methods declared in interface **javax.ejb.EJBObject**. When a client invokes an **InterestCalculator** remote-interface method, the EJB container will invoke the corresponding method in EJB implementation **InterestCalculatorEJB** (Fig. 14.5). When a client invokes a method declared in interface **javax.ejb.EJBObject**, the container will invoke the corresponding method in the class generated by the EJB container.

```
1 // InterestCalculator.java
2 // InterestCalculator is the remote interface for the
3 // InterestCalculator EJB.
4 package com.deitel.advjhtp1.ejb.session.stateful.ejb;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
9 // Java standard extensions
10 import javax.ejb.EJBObject;
11
12 public interface InterestCalculator extends EJBObject {
13
14     // set principal amount
15     public void setPrincipal( double amount )
16         throws RemoteException;
17
18     // set interest rate
19     public void setInterestRate( double rate )
20         throws RemoteException;
21
22     // set loan length in years
23     public void setTerm( int years )
24         throws RemoteException;
25
26     // get loan balance
27     public double getBalance() throws RemoteException;
28
29     // get amount of interest earned
30     public double getInterestEarned() throws RemoteException;
31 }
```

Fig. 14.3 **InterestCalculator** remote interface for calculating simple interest.

**InterestCalculatorHome** (Fig. 14.4) is the home interface for the **InterestCalculator** EJB. **InterestCalculatorHome** provides method **create** (lines 15–16) for creating instances of the **InterestCalculator** EJB. When a client invokes **InterestCalculatorHome** method **create**, the EJB container invokes method **ejbCreate** of class **InterestCalculatorEJB** (Fig. 14.5). The home interface may declare zero or more **create** methods. For example, we could declare an additional **create** method that takes a **double** argument that initializes the principal amount to use in the simple interest calculation.

**InterestCalculatorEJB** (Fig. 14.5) implements the business methods declared in the **InterestCalculator** remote interface. On line 12, **InterestCalculatorEJB** implements interface **SessionBean**. This indicates that the **InterestCalculatorEJB** is a session EJB. Lines 17–19 declare variables that maintain the state of the EJB between business method invocations. The state information consists of the **principal** amount, the **interestRate** and the **term**. Method **setPrincipal** (lines 22–25) sets the **principal** amount and stores the value in the **principal** state variable. Method **setInterestRate** (lines 28–31) sets the **interestRate** state variable for the calculation. Method **setTerm** (lines 34–37) sets the **term** for which interest will accrue. Method **getBalance** (lines 40–44) uses the formula

$$a = p (1 + r)^n$$

where

- p** is the principal amount
- r** is the annual interest rate (e.g., .05 for 5%)
- n** is the number of years
- a** is the amount on deposit at the end of the **n**th year

to calculate the balance (i.e., amount on deposit). Method **getInterestEarned** (lines 47–50) calculates the amount of interest earned by subtracting the **principal** amount from the balance—calculated by method **getBalance**.

```
1 // InterestCalculatorHome.java
2 // InterestCalculatorHome is the home interface for the
3 // InterestCalculator EJB.
4 package com.deitel.advjhtp1.ejb.session.stateful.ejb;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public interface InterestCalculatorHome extends EJBHome {
13
14     // create InterestCalculator EJB
15     public InterestCalculator create() throws RemoteException,
16             CreateException;
16 }
```

Fig. 14.4 **InterestCalculatorHome** interface for creating **InterestCalculator** EJBs.

```
1 // InterestCalculatorEJB.java
2 // InterestCalculator is a stateful session EJB for calculating
3 // simple interest.
4 package com.deitel.advjhtp1.ejb.session.stateful.ejb;
5
6 // Java core libraries
7 import java.util.*;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public class InterestCalculatorEJB implements SessionBean {
13
14     private SessionContext sessionContext;
15
16     // state variables
17     private double principal;
18     private double interestRate;
19     private int term;
20
21     // set principal amount
22     public void setPrincipal( double amount )
23     {
24         principal = amount;
25     }
26
27     // set interest rate
28     public void setInterestRate( double rate )
29     {
30         interestRate = rate;
31     }
32
33     // set loan length in years
34     public void setTerm( int years )
35     {
36         term = years;
37     }
38
39     // get loan balance
40     public double getBalance()
41     {
42         // calculate simple interest
43         return principal * Math.pow( 1.0 + interestRate, term );
44     }
45
46     // get amount of interest earned
47     public double getInterestEarned()
48     {
49         return getBalance() - principal;
50     }
51
```

Fig. 14.5 InterestCalculatorEJB implementation of InterestCalculator remote interface (part 1 of 2).

```
52     // set SessionContext
53     public void setSessionContext( SessionContext context )
54     {
55         sessionContext = context;
56     }
57
58     // create InterestCalculator instance
59     public void ejbCreate() {}
60
61     // remove InterestCalculator instance
62     public void ejbRemove() {}
63
64     // passivate InterestCalculator instance
65     public void ejbPassivate() {}
66
67     // activate InterestCalculator instance
68     public void ejbActivate() {}
69 }
```

Fig. 14.5 **InterestCalculatorEJB** implementation of **InterestCalculator** remote interface (part 2 of 2).

Method **setSessionContext** (lines 53–56) is a callback method defined in interface **SessionBean**. The EJB container invokes method **setSessionContext** after creating the EJB instance. Interface **SessionContext** extends interface **EJBContext**, which provides methods for obtaining information about the EJB container.



### Common Programming Error 14.1

Returning the **this** reference from a method or passing the **this** reference as an argument is not allowed in an EJB. Instead, use **SessionContext** or **EntityContext** method **getEJBObject** to obtain a reference to the current **EJBObject**.

When a client invokes a **create** method in the home interface, the EJB container invokes method **ejbCreate** (line 59). The EJB implementation must provide an **ejbCreate** method for each **create** method declared in the home interface. The **ejbCreate** methods must have the same number and types of arguments as their corresponding **create** methods. The **ejbCreate** methods also must return **void**. For example, if the **InterestCalculatorHome** interface declares a **create** method that takes a **double** argument for the **principal** amount, the EJB implementation must define an **ejbCreate** method that takes a **double** argument. The **InterestCalculator** EJB has an empty implementation of method **ejbCreate**, because no initialization is necessary for this EJB.

The EJB container invokes method **ejbRemove** (line 62) in response to an invocation of method **remove** in the home interface. The EJB container also may invoke method **ejbRemove** if the session expires due to lengthy inactivity. Method **ejbRemove** should free resources the EJB has used.

The EJB container invokes method **ejbPassivate** (line 65) when the container determines that the EJB is no longer needed in memory. The algorithm that the EJB container uses to determine when it should passivate an EJB is application-server dependent. Many application servers enforce a *least recently used policy*, which passivates EJBs that

clients have not accessed recently. When the EJB container passivates an EJB, the container serializes the state of the EJB and removes the EJB from memory.

The EJB container invokes method **ejbActivate** (line 68) to restore an EJB instance that the container passivated previously. The EJB container activates an EJB instance if the client associated with the EJB instance invokes a business method of that EJB instance. The EJB container reads the state information that it saved during passivation and restores the EJB instance in memory.



### Software Engineering Observation 14.1

Use the **transient** keyword to mark instance variables that the EJB container should not save and restore during passivation and activation.

**InterestCalculatorClient** (Fig. 14.6) is an application that uses the **InterestCalculator** EJB to calculate simple interest. Line 25 declares an **InterestCalculator** reference, which **InterestCalculatorClient** uses to calculate simple interest. Method **createInterestCalculator** (lines 71–108) creates an **InterestCalculator** EJB instance to use throughout the application. A client application must use a JNDI directory to *look up* the home interface for an EJB. Line 77 creates an **InitialContext**, which is an interface into a JNDI directory. The **InitialContext** represents a *naming context*, which maps names (e.g., "**InterestCalculator**") to objects, such as EJBs. Lines 80–81 use method **lookup** of class **InitialContext** to retrieve an **Object** remote reference to the **InterestCalculatorHome** interface. The **String** argument passed to method **lookup** is the name to which the EJB is mapped in the JNDI directory.

```
1 // InterestCalculatorClient.java
2 // InterestCalculatorClient is a GUI for interacting with the
3 // InterestCalculator EJB.
4 package com.deitel.advjhttp1.ejb.session.stateful.client;
5
6 // Java core libraries
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.rmi.*;
10 import java.text.*;
11 import java.util.*;
12
13 // Java standard extensions
14 import javax.swing.*;
15 import javax.rmi.*;
16 import javax.naming.*;
17 import javax.ejb.*;
18
19 // Deitel libraries
20 import com.deitel.advjhttp1.ejb.session.stateful.ejb.*;
21
22 public class InterestCalculatorClient extends JFrame {
```

Fig. 14.6 **InterestCalculatorClient** for interacting with **InterestCalculator** EJB (part 1 of 7).

```
24 // InterestCalculator remote reference
25 private InterestCalculator calculator;
26
27 private JTextField principalTextField;
28 private JTextField rateTextField;
29 private JTextField termTextField;
30 private JTextField balanceTextField;
31 private JTextField interestEarnedTextField;
32
33 // InterestCalculatorClient constructor
34 public InterestCalculatorClient()
35 {
36     super( "Stateful Session EJB Example" );
37
38     // create InterestCalculator for calculating interest
39     createInterestCalculator();
40
41     // create JTextField for entering principal amount
42     createPrincipalTextField();
43
44     // create JTextField for entering interest rate
45     createRateTextField();
46
47     // create JTextField for entering loan term
48     createTermTextField();
49
50     // create uneditable JTextFields for displaying balance
51     // and interest earned
52     balanceTextField = new JTextField( 10 );
53     balanceTextField.setEditable( false );
54
55     interestEarnedTextField = new JTextField( 10 );
56     interestEarnedTextField.setEditable( false );
57
58     // layout components for GUI
59     layoutGUI();
60
61     // add WindowListener to remove EJB instances when user
62     // closes window
63     addWindowListener( getWindowListener() );
64
65     setSize( 425, 200 );
66     setVisible( true );
67
68 } // end InterestCalculatorClient constructor
69
70 // create InterestCalculator EJB instance
71 public void createInterestCalculator()
72 {
73     // lookup InterestCalculatorHome and create
74     // InterestCalculator EJB
75     try {
```

Fig. 14.6 **InterestCalculatorClient** for interacting with **InterestCalculator** EJB (part 2 of 7).

```
76
77     InitialContext initialContext = new InitialContext();
78
79     // lookup InterestCalculator EJB
80     Object homeObject =
81         initialContext.lookup( "InterestCalculator" );
82
83     // get InterestCalculatorHome interface
84     InterestCalculatorHome calculatorHome =
85         ( InterestCalculatorHome )
86         PortableRemoteObject.narrow( homeObject,
87             InterestCalculatorHome.class );
88
89     // create InterestCalculator EJB instance
90     calculator = calculatorHome.create();
91
92 } // end try
93
94 // handle exception if InterestCalculator EJB not found
95 catch ( NamingException namingException ) {
96     namingException.printStackTrace();
97 }
98
99 // handle exception when creating InterestCalculator EJB
100 catch ( RemoteException remoteException ) {
101     remoteException.printStackTrace();
102 }
103
104 // handle exception when creating InterestCalculator EJB
105 catch ( CreateException createException ) {
106     createException.printStackTrace();
107 }
108 } // end method createInterestCalculator
109
110 // create JTextField for entering principal amount
111 public void createPrincipalTextField()
112 {
113     principalTextField = new JTextField( 10 );
114
115     principalTextField.addActionListener(
116         new ActionListener() {
117
118         public void actionPerformed( ActionEvent event )
119         {
120             // set principal amount in InterestCalculator
121             try {
122                 double principal = Double.parseDouble(
123                     principalTextField.getText() );
124
125                 calculator.setPrincipal( principal );
126             }
127         }
128     });
129 }
```

Fig. 14.6 **InterestCalculatorClient** for interacting with **InterestCalculator** EJB (part 3 of 7).

```
128         // handle exception setting principal amount
129         catch ( RemoteException remoteException ) {
130             remoteException.printStackTrace();
131         }
132
133         // handle wrong number format
134         catch ( NumberFormatException
135             numberFormatException ) {
136             numberFormatException.printStackTrace();
137         }
138     }
139 }
140 ); // end addActionListener
141 } // end method createPrincipalTextField
142
143 // create JTextField for entering interest rate
144 public void createRateTextField()
145 {
146     rateTextField = new JTextField( 10 );
147
148     rateTextField.addActionListener(
149         new ActionListener() {
150
151         public void actionPerformed( ActionEvent event )
152         {
153             // set interest rate in InterestCalculator
154             try {
155                 double rate = Double.parseDouble(
156                     rateTextField.getText() );
157
158                 // convert from percentage
159                 calculator.setInterestRate( rate / 100.0 );
160             }
161
162             // handle exception when setting interest rate
163             catch ( RemoteException remoteException ) {
164                 remoteException.printStackTrace();
165             }
166         }
167     }
168 ); // end addActionListener
169 } // end method createRateTextField
170
171 // create JTextField for entering loan term
172 public void createTermTextField()
173 {
174     termTextField = new JTextField( 10 );
175
176     termTextField.addActionListener(
177         new ActionListener() {
178 }
```

Fig. 14.6 **InterestCalculatorClient** for interacting with **InterestCalculator** EJB (part 4 of 7).

```
179     public void actionPerformed( ActionEvent event )
180     {
181         // set loan term in InterestCalculator
182         try {
183             int term = Integer.parseInt(
184                 termTextField.getText() );
185
186             calculator.setTerm( term );
187         }
188
189         // handle exception when setting loan term
190         catch ( RemoteException remoteException ) {
191             remoteException.printStackTrace();
192         }
193     }
194 }
195 ); // end addActionListener
196 } // end method getTermTextField
197
198 // get JButton for starting calculation
199 public JButton getCalculateButton()
200 {
201     JButton calculateButton = new JButton( "Calculate" );
202
203     calculateButton.addActionListener(
204         new ActionListener() {
205
206         public void actionPerformed( ActionEvent event )
207         {
208             // use InterestCalculator to calculate interest
209             try {
210
211                 // get balance and interest earned
212                 double balance = calculator.getBalance();
213                 double interest =
214                     calculator.getInterestEarned();
215
216                 NumberFormat dollarFormatter =
217                     NumberFormat.getCurrencyInstance(
218                         Locale.US );
219
220                 balanceTextField.setText(
221                     dollarFormatter.format( balance ) );
222
223                 interestEarnedTextField.setText(
224                     dollarFormatter.format( interest ) );
225             }
226
227             // handle exception when calculating interest
228             catch ( RemoteException remoteException ) {
229                 remoteException.printStackTrace();
230             }
231         }
232     });
233 }
```

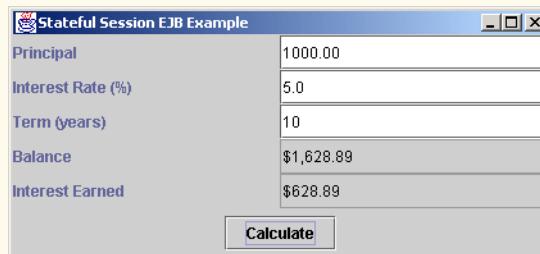
Fig. 14.6 **InterestCalculatorClient** for interacting with **InterestCalculator** EJB (part 5 of 7).

```
231             } // end method actionPerformed
232         }
233     ); // end addActionListener
234 
235     return calculateButton;
236 }
237 } // end method getCalculateButton
238 
239 // lay out GUI components in JFrame
240 public void layoutGUI()
241 {
242     Container contentPane = getContentPane();
243 
244     // layout user interface components
245     JPanel inputPanel = new JPanel( new GridLayout( 5, 2 ) );
246 
247     inputPanel.add( new JLabel( "Principal" ) );
248     inputPanel.add( principalTextField );
249 
250     inputPanel.add( new JLabel( "Interest Rate (%)" ) );
251     inputPanel.add( rateTextField );
252 
253     inputPanel.add( new JLabel( "Term (years)" ) );
254     inputPanel.add( termTextField );
255 
256     inputPanel.add( new JLabel( "Balance" ) );
257     inputPanel.add( balanceTextField );
258 
259     inputPanel.add( new JLabel( "Interest Earned" ) );
260     inputPanel.add( interestEarnedTextField );
261 
262     // add inputPanel to contentPane
263     contentPane.add( inputPanel, BorderLayout.CENTER );
264 
265     // create JPanel for calculateButton
266     JPanel controlPanel = new JPanel( new FlowLayout() );
267     controlPanel.add( getCalculateButton() );
268     contentPane.add( controlPanel, BorderLayout.SOUTH );
269 }
270 
271 // get WindowListener for exiting application
272 public WindowListener getWindowListener()
273 {
274     return new WindowAdapter() {
275 
276         public void windowClosing( WindowEvent event )
277         {
278             // check to see if calculator is null
279             if ( calculator.equals( null ) ) {
280                 System.exit( -1 );
281             }
282         }
283     };
284 }
```

Fig. 14.6 InterestCalculatorClient for interacting with InterestCalculator EJB (part 6 of 7).

```

283         else {
284             // remove InterestCalculator instance
285             try {
286                 calculator.remove();
287             }
288
289             // handle exception removing InterestCalculator
290             catch ( RemoveException removeException ) {
291                 removeException.printStackTrace();
292                 System.exit( -1 );
293             }
294
295             // handle exception removing InterestCalculator
296             catch ( RemoteException remoteException ) {
297                 remoteException.printStackTrace();
298                 System.exit( -1 );
299             }
300
301             System.exit( 0 );
302         }
303     }
304 }
305 } // end method getWindowListener
306
307 // execute the application
308 public static void main( String[] args )
309 {
310     new InterestCalculatorClient();
311 }
312 }
```



**Fig. 14.6** `InterestCalculatorClient` for interacting with `InterestCalculator` EJB (part 7 of 7).

Lines 84–87 use class `PortableRemoteObject` method `narrow` to convert the remote reference to an `InterestCalculatorHome` remote reference. This is the standard method for casting a remote reference to the proper interface type when using *RMI-IIOP*. RMI-IIOP allows RMI objects to interact with CORBA components, which communicate using the *Internet Inter-Orb Protocol* (IIOP). CORBA is a language-independent framework for building distributed systems. To enable interoperability among EJBs and CORBA components, EJBs communicate using RMI-IIOP. We discuss CORBA and RMI-IIOP in Chapters 26 and 27.

Line 90 invokes method `create` of interface `InterestCalculatorHome` to create a new instance of the `InterestCalculator` EJB. This `InterestCalculator` EJB instance is exclusive to the client that creates it, because it is a session EJB. The `InterestCalculator` EJB instance will maintain state information, because it is a stateful session EJB. Method `create` returns a remote reference to the newly created `InterestCalculator` EJB instance. Line 90 assigns this remote reference to the `calculator` member variable. Instances of class `InterestCalculatorClient` can use this remote reference to invoke the business methods defined in the `InterestCalculator` remote interface.

Lines 95–97 catch a `NamingException`, which indicates a problem accessing the JNDI directory. If the `InitialContext` cannot be created, the `InitialContext` constructor throws a `NamingException`. Method `lookup` also throws a `NamingException` if the name passed as an argument cannot be found in the JNDI directory.

Lines 100–102 `catch` a `RemoteException`. If there is an error communicating with the EJB container, method `create` throws a `RemoteException`. Lines 105–107 `catch` a `CreateException`. Method `create` throws a `CreateException` if there is an error creating the EJB instance.

Method `createPrincipalTextField` (lines 111–141) creates a `JTextField` for the user to input the `principal` amount. An `ActionListener` anonymous inner class (lines 116–139) uses `static` method `parseDouble` of class `Double` to get the `principal` entered by the user (lines 122–123). Line 125 sets the `principal` in the `InterestCalculator` EJB by invoking method `setPrincipal`. Note that `JTextFields` generate `ActionEvents` when the user presses the *Enter* key in the `JTextField`. Therefore, the user must press the *Enter* key after entering each piece of data to cause the `ActionListener`'s `actionPerformed` method to invoke the appropriate `InterestCalculator` business method.

Method `createRateTextField` (lines 144–169) creates a `JTextField` for inputting an interest rate for the calculation. Lines 149–167 create an `ActionListener` anonymous inner class to parse the input from the user (lines 155–156) and invoke `InterestCalculator` method `setInterestRate` to set the interest rate (line 159).

Method `createTermTextField` (lines 172–196) creates a `JTextField` for inputting the number of years for which interest will accrue. An `ActionListener` anonymous inner class (lines 177–194) parses the input from the user (lines 183–184) and sets the term in the `InterestCalculator` by invoking method `setTerm` (line 186) of the `InterestCalculator` remote interface.

Method `getCalculateButton` (lines 199–237) creates a `JButton` that, when clicked, invokes `InterestCalculator` methods `getBalance` and `getInterestEarned`. Lines 220–224 set the text in `balanceTextField` and `interestEarnedTextField` to display the calculation results to the user.

The `InterestCalculatorClient` constructor (lines 34–68) invokes method `createInterestCalculator` to create a new `InterestCalculator` EJB instance (line 39). Lines 42–56 create the application's user-interface components and invoke method `layoutGUI` (line 59), which creates a `JLabel` for each `JTextField` and lays out the components (lines 240–269).

Method `getWindowListener` (lines 272–305) creates a `WindowAdapter` anonymous inner class that provides method `windowClosing` to perform cleanup tasks when

the user closes the application window. Line 279 checks to see if `calculator` is `null`. If calculator is `null`, the program exits with an error code (line 280). Otherwise, line 286 invokes method `remove` of the `InterestCalculator` remote interface to remove the EJB instance that the application used. If there is an error when removing the EJB instance, lines 290–293 `catch` a `RemoveException`. If there is an error communicating with the EJB container, lines 296–299 `catch` a `RemoteException`.

### 14.3.2 Deploying Session EJBs

Enterprise JavaBeans execute in the context of an EJB container, which is a fundamental part of a J2EE-compliant application server. This section details the steps necessary to deploy the `InterestCalculator` session EJB in the Java 2 Enterprise Edition version 1.2.1 reference implementation from Sun Microsystems. If you have not yet installed and configured the J2EE SDK, please see Appendix E for instructions.

Create a new enterprise application by selecting **New Application** from the **File** menu (Fig. 14.7). Specify the file name for the EAR file and the name of the application in the **New Application** dialog box and click **OK** (Fig. 14.8).

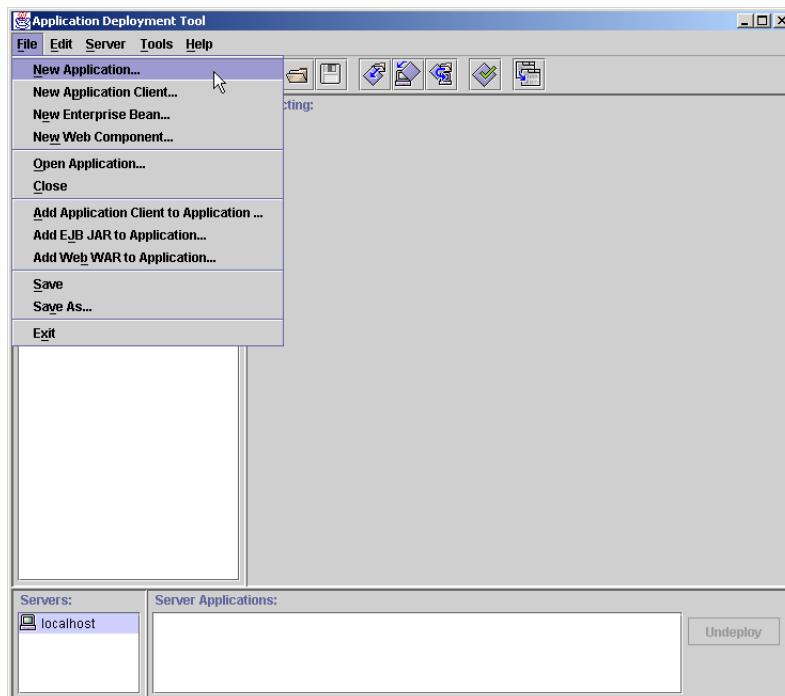


Fig. 14.7 Creating New Application in Application Deployment Tool.

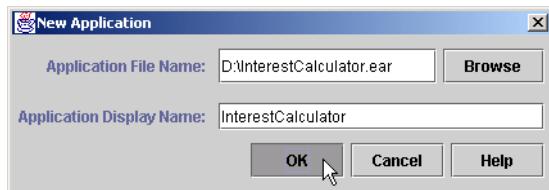


Fig. 14.8 Specifying EAR file for **New Application**.

Select **New Enterprise Bean** from the **File** menu to begin deploying the EJB (Fig. 14.9). Click **Next**, provide a **JAR Display Name** and click **Add** to add the class files for the **InterestCalculator** EJB (Fig. 14.10).

Specify the **Root Directory** for the classes that make up the **InterestCalculator** EJB (Fig. 14.11). The **InterestCalculator** classes are in package **com.deitel.advjhttp1.ejb.session.stateful.ejb**, so select as the **Root Directory** the directory that contains the **com** directory. Select the **InterestCalculator** class files—**InterestCalculator.class**, **InterestCalculatorHome.class** and **InterestCalculatorEJB.class**—and click **Add** and **OK**. After adding the class files, they will appear in the **Contents** of the **EJB JAR** (Fig. 14.12). Click **Next** to begin adding class files to the **EJB JAR**.

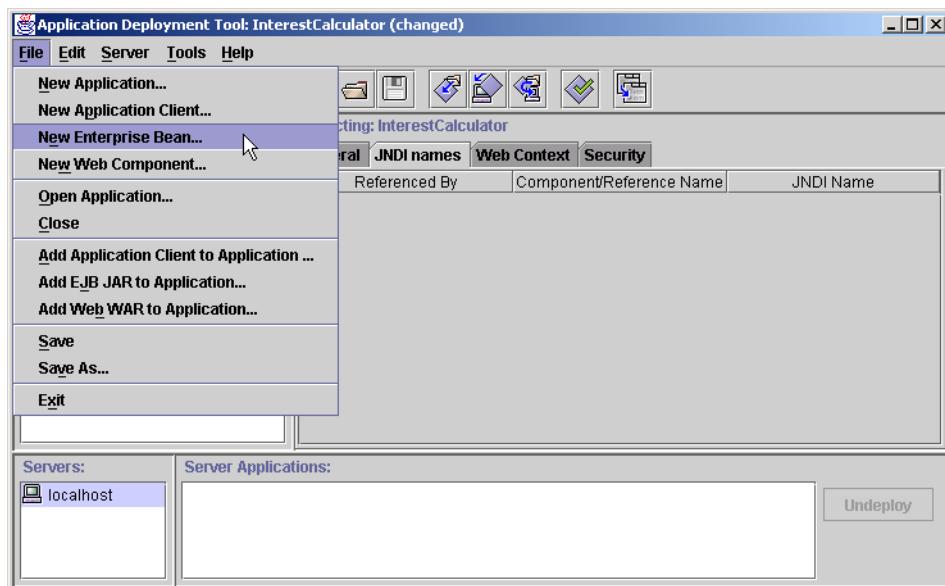


Fig. 14.9 Creating a New Enterprise Bean.

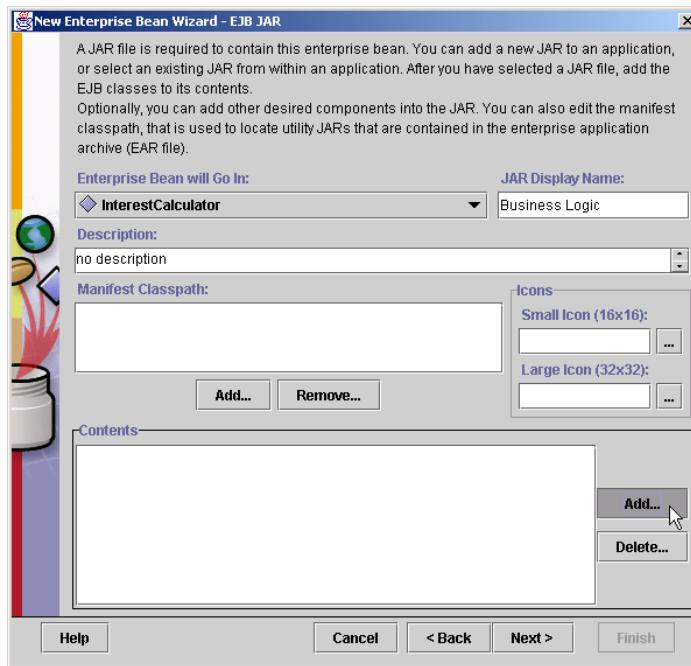


Fig. 14.10 Adding **InterestCalculator** EJB classes.

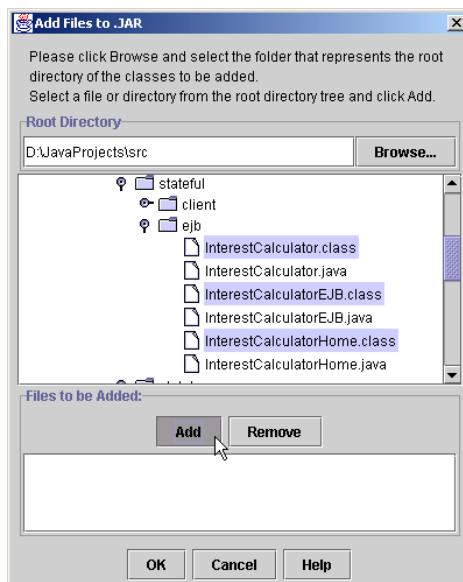
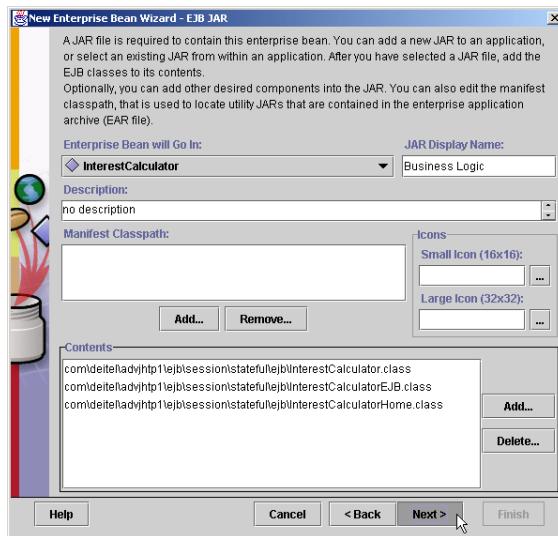
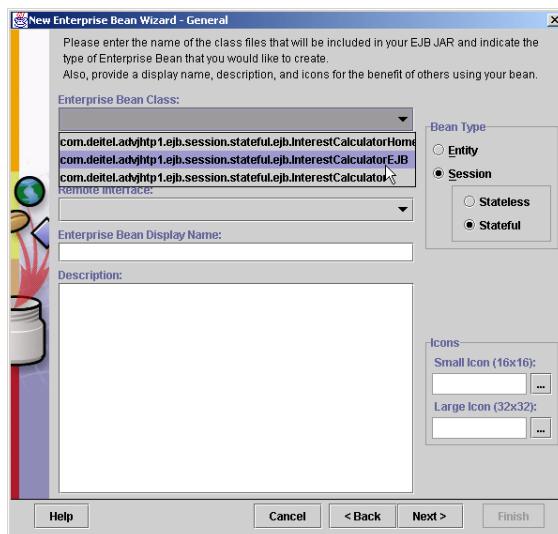


Fig. 14.11 Selecting **InterestCalculator** EJB classes to add.

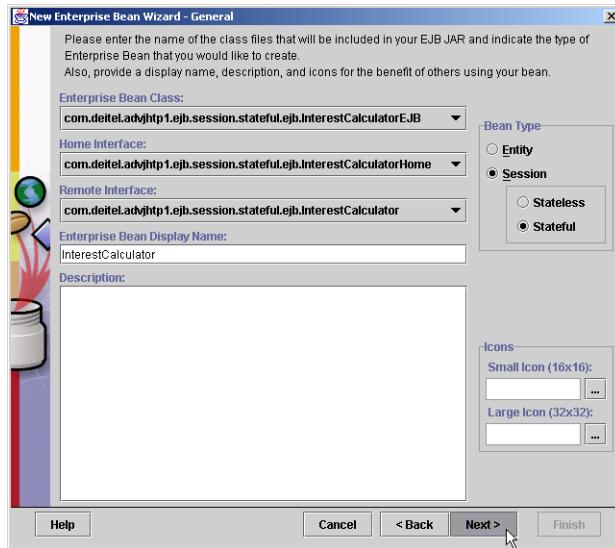


**Fig. 14.12** Result of adding **InterestCalculator** EJB classes.

Specify the **Enterprise Bean Class**, **Home Interface** and **Remote Interface** by selecting the appropriate classes from the drop-down lists (Fig. 14.13). Specify an **Enterprise Bean Display Name** to be displayed in the **Application Deployment Tool** and select the **Bean Type**. The **InterestCalculator** EJB is a stateful session bean, so select the **Session** and **Stateful** radio buttons and click **Next** (Fig. 14.14). When deploying the **MathToolEJB**, specify **Stateless** instead of **Stateful** for the **Bean Type**.

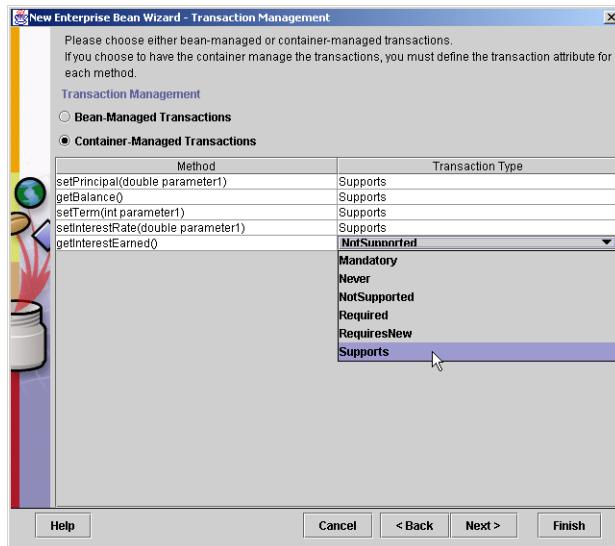


**Fig. 14.13** Specifying Enterprise Bean Class for **InterestCalculator** EJB.



**Fig. 14.14** Specifying **InterestCalculator** EJB classes and **Stateful Session Bean Type**.

Specify **Container-Managed Transactions** in the **Transaction Management** dialog (Fig. 14.15). For each **Method**, specify the **Supports** Transaction Type, and click **Next**. We discuss the details of transactions in Section 14.4.



**Fig. 14.15** Specifying **Container Managed Transactions** for **InterestCalculator** EJB.

Figure 14.16 shows the XML deployment descriptor generated for the **InterestCalculator** EJB. The application server uses this XML descriptor to configure the **InterestCalculator** EJB.

You must specify a **JNDI Name** for the **InterestCalculator**, so that clients may obtain references to the EJB. For this example, specify the **JNDI Name InterestCalculator** (Fig. 14.17). The **JNDI Name** need not be the same as the EJB name.



### Good Programming Practice 14.1

*Use an EJB's remote interface name as the EJB's JNDI name. This makes your code more readable and makes the JNDI name easier to remember.*

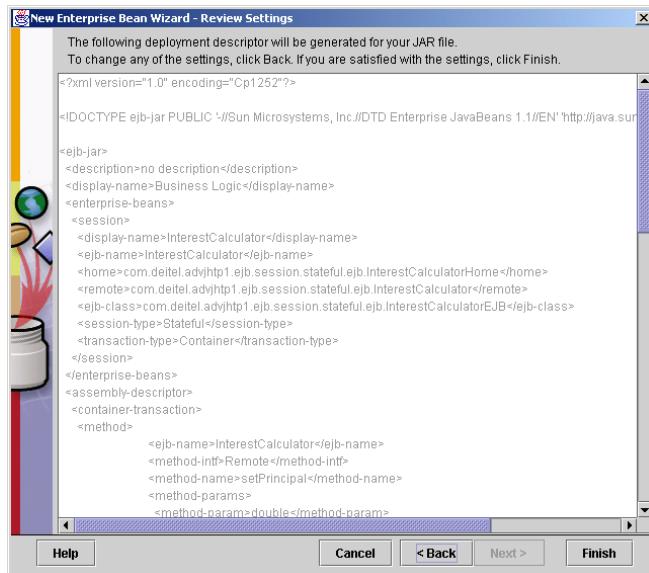


Fig. 14.16 XML deployment descriptor for **InterestCalculator** EJB.

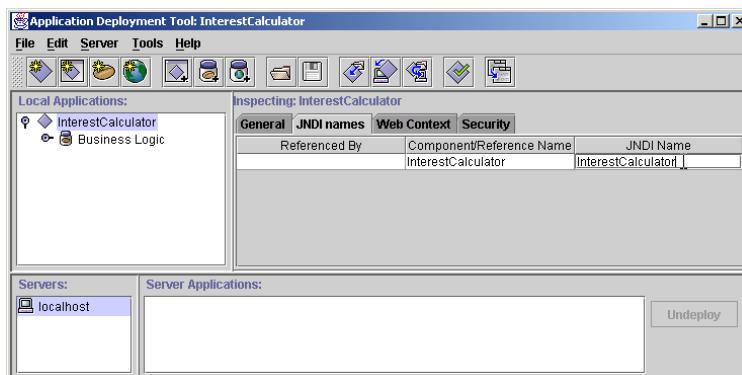
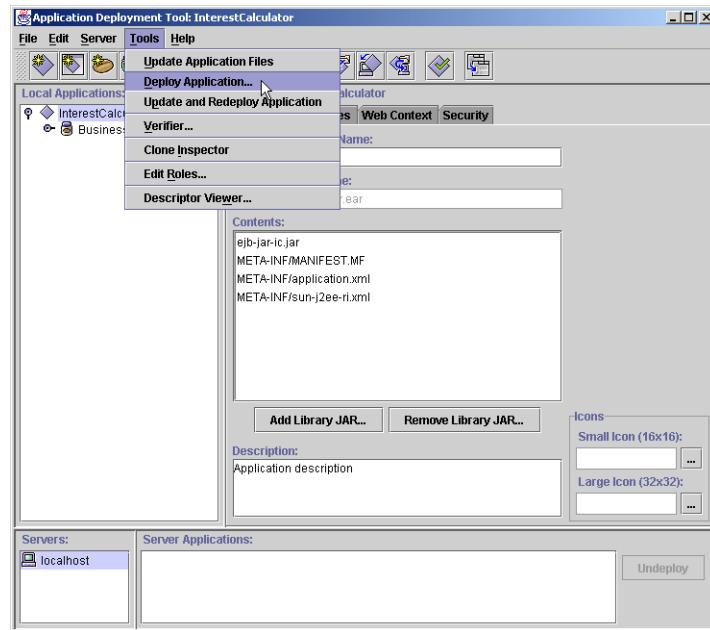


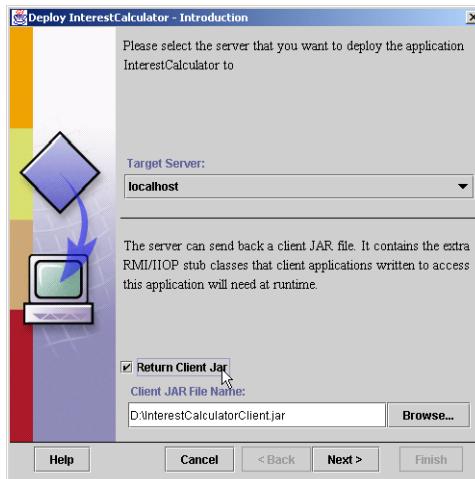
Fig. 14.17 Specifying JNDI Name for **InterestCalculator** EJB.

Deploy the application to the J2EE server by selecting **Deploy Application** from the **Tools** menu, or by clicking the **Deploy Application** button on the toolbar (Fig. 14.18).

Specify **localhost** as the **Target Server** and select the checkbox **Return Client Jar** (Fig. 14.19). The client JAR contains the stub classes the client will use to communicate with the EJB.



**Fig. 14.18** Deploying enterprise application to **localhost**.



**Fig. 14.19** Specifying the **Application Deployment Tool** should **Return Client Jar**.

After deploying the **InterestCalculator** EJB (Fig. 14.20), execute the **InterestCalculatorClient** to test the **InterestCalculator**. The **InterestCalculatorClient.jar** and the **j2ee.jar** must be in the CLASSPATH when executing the **InterestCalculatorClient**. For example, from the command line, type

```
java -classpath D:\j2sdkee1.2.1\lib\j2ee.jar;D:\Interest-
CalculatorClient.jar;. com.deitel.advjhttp1.ejb.session.state-
ful.client.InterestCalculatorClient
```

### 14.3.3 Stateless Session EJBs

*Stateless session EJBs* maintain no state information between business method invocations. As a result, the EJB container can use any stateless session EJB instance to respond to any client's request.



#### Performance Tip 14.1

*Stateless session EJBs may perform better than stateful session EJBs, because a single stateless session EJB instance can be shared among many clients, reducing memory, processor and other resource requirements on the server.*

Figure 14.21 shows the **MathTool** remote interface. **MathTool** is a stateless session EJB with business methods for generating a Fibonacci series and calculating factorials. Method **getFibonacciSeries** (lines 14–15) generates a Fibonacci series of the length supplied in integer argument **howMany**. Method **getFactorial** (lines 18–19) calculates the factorial of the provided integer.

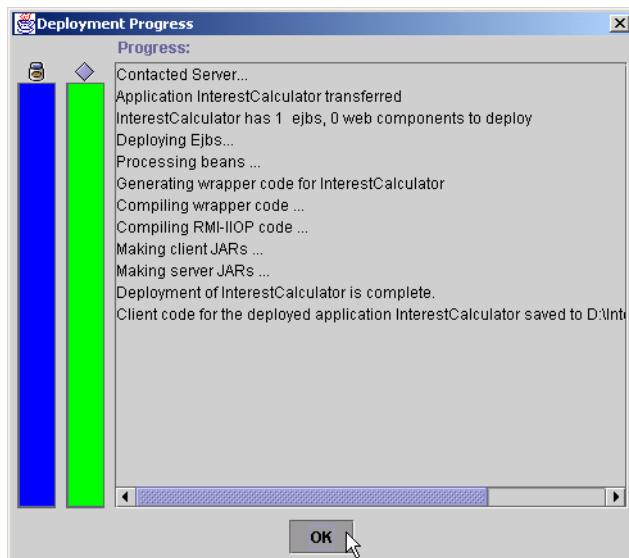


Fig. 14.20 Successful completion of deployment process.

```
1 // MathTool.java
2 // MathTool is the remote interface for the MathTool EJB.
3 package com.deitel.advjhttp1.ejb.session.stateless.ejb;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7
8 // Java standard extensions
9 import javax.ejb.EJBObject;
10
11 public interface MathTool extends EJBObject
12 {
13     // get Fibonacci series
14     public int[] getFibonacciSeries( int howMany )
15         throws RemoteException, IllegalArgumentException;
16
17     // get factorial of given integer
18     public int getFactorial( int number )
19         throws RemoteException, IllegalArgumentException;
20 }
```

Fig. 14.21 **MathTool** remote interface for calculating factorials and generating Fibonacci series.

**MathToolEJB** (Fig. 14.22) provides implementations of the business methods declared in the **MathTool** remote interface. **MathToolEJB** implements the **Session-Bean** interface (line 9), indicating **MathTool** is a session EJB. Method **getFibonacciSeries** (lines 14–48) generates a Fibonacci series. The Fibonacci series

0, 1, 1, 2, 3, 5, 8, 13, 21, ...

begins with **0** and **1** and has the property that each subsequent Fibonacci number is the sum of the previous two Fibonacci numbers. The **MathTool** EJB calculates the Fibonacci series on lines 25–44. Each number in the series is placed in the integer array **series** (line 29). Lines 32–33 set the zeroth number in the series to **0** and the first number in the series to **1**. Line 39 sets the next number in the series to the sum of the previous two numbers.

```
1 // MathToolEJB.java
2 // MathToolEJB is a stateless session EJB with methods for
3 // calculating Fibonacci series and factorials.
4 package com.deitel.advjhttp1.ejb.session.stateless.ejb;
5
6 // Java standard extensions
7 import javax.ejb.*;
8
9 public class MathToolEJB implements SessionBean {
10
11     private SessionContext sessionContext;
```

Fig. 14.22 **MathToolEJB** implementation of **MathTool** remote interface (part 1 of 3).

```
13 // get Fibonacci series
14 public int[] getFibonacciSeries( int howMany )
15     throws IllegalArgumentException
16 {
17     // throw IllegalArgumentException if series length
18     // is less than zero
19     if ( howMany < 2 )
20         throw new IllegalArgumentException(
21             "Cannot generate Fibonacci series of " +
22             "length less than two." );
23
24     // starting points
25     int startPoint1 = 0;
26     int startPoint2 = 1;
27
28     // array to contain Fibonacci sequence
29     int[] series = new int[ howMany ];
30
31     // set base cases
32     series[ 0 ] = 0;
33     series[ 1 ] = 1;
34
35     // generate Fibonacci series
36     for ( int i = 2; i < howMany; i++ ) {
37
38         // calculate next number in series
39         series[ i ] = startPoint1 + startPoint2;
40
41         // set start points for next iteration
42         startPoint1 = startPoint2;
43         startPoint2 = series[ i ];
44     }
45
46     return series;
47
48 } // end method getFibonacciSeries
49
50 // get factorial of given integer
51 public int getFactorial( int number )
52     throws IllegalArgumentException
53 {
54     // throw IllegalArgumentException if number less than zero
55     if ( number < 0 )
56         throw new IllegalArgumentException(
57             "Cannot calculate factorial of negative numbers." );
58
59     // base case for recursion, return 1
60     if ( number == 0 )
61         return 1;
62 }
```

Fig. 14.22 **MathToolEJB** implementation of **MathTool** remote interface (part 2 of 3).

```

63      // call getFactorial recursively to calculate factorial
64      else
65          return number * getFactorial( number - 1 );
66
67 } // end method getFactorial
68
69 // set SessionContext
70 public void setSessionContext( SessionContext context )
71 {
72     sessionContext = context;
73 }
74
75 // create new MathTool instance
76 public void ejbCreate() {}
77
78 // remove MathTool instance
79 public void ejbRemove() {}
80
81 // activate MathTool instance
82 public void ejbActivate() {}
83
84 // passivate MathTool instance
85 public void ejbPassivate() {}
86 }
```

Fig. 14.22 **MathToolEJB** implementation of **MathTool** remote interface (part 3 of 3).

Method **getFactorial** (lines 51–67) calculates the factorial of a nonnegative integer, which is defined to be the product

$$n \cdot (n - 1) \cdot (n - 2) \cdot \dots \cdot 1$$

Lines 56–57 throw an **IllegalArgumentException** if the integer argument **number** is less than 0. Lines 60–61 implement the base case for the recursive calculation. Line 65 calculates the factorial with a recursive call to **getFactorial**.

The EJB container invokes method **setSessionContext** (lines 70–73) when the EJB instance is activated and a remote reference is given to a client. The **SessionContext** argument implements method **getEJBObject**, which the EJB can use to retrieve a reference to the current EJB instance.

When a client invokes method **create** of interface **MathToolHome** (Fig. 14.23), the EJB container invokes method **ejbCreate** (line 76). Method **ejbCreate** performs initialization of the EJB. **MathToolEJB** method **ejbCreate** has an empty implementation, because this EJB requires no initialization. The EJB container invokes method **ejbRemove** (line 79) to remove a **MathTool** EJB instance.

The EJB container invokes method **ejbActivate** (line 82) when the EJB instance is taken out of the EJB container's pool and associated with a particular client. The EJB container invokes method **ejbPassivate** (line 85) when the EJB instance is no longer needed and can be returned to the ready pool.

**MathToolHome** (Fig. 14.23) is the home interface for the **MathTool** EJB. Method **create** (lines 15–16) creates a new **MathTool** EJB. The EJB container invokes **MathToolEJB** method **ejbCreate** when a client invokes **MathToolHome** method **create**.

```
1 // MathToolHome.java
2 // MathToolHome is the home interface for the MathTool EJB.
3 package com.deitel.advjhttp1.ejb.session.stateless.ejb;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7
8 // Java standard extensions
9 import javax.ejb.EJBHome;
10 import javax.ejb.CreateException;
11
12 public interface MathToolHome extends EJBHome {
13
14     // create new MathTool EJB
15     public MathTool create() throws RemoteException,
16         CreateException;
16 }
17 }
```

Fig. 14.23 MathToolHome interface for creating MathTool EJBs.

Please refer to Section 14.3.2 for deployment instructions. Recall that **MathTool** is a stateless session EJB, so you must specify this in the deployment process. Also, be sure to specify an appropriate JNDI name (e.g., **MathTool**) for the **MathTool** EJB.

**MathToolClient** (Fig. 14.24) is an application client for the **MathTool** EJB. The user interface consists of a **JTextField** into which the user can enter an integer, a **JButton** to invoke **MathTool** method **getFactorial** and a **JButton** to invoke **MathTool** method **getFibonacciSeries**. The calculation results are displayed in a **JTextArea**.

The **MathToolClient** constructor (lines 29–45) invokes method **createMathTool** (line 35) to create a new instance of the **MathTool** EJB. Line 38 invokes method **createGUI** to create and lay out GUI components for the application's user interface. Method **createMathTool** (lines 48–83) uses an **InitialContext** (line 53) to look up the **MathToolHome** interface in the JNDI Directory (lines 56–57). Line 65 invokes **MathToolHome** method **create** to create a **MathTool** EJB instance.

Method **getFactorialButton** (lines 86–122) creates a **JButton** that, when pressed, invokes **MathTool** EJB method **getFactorial**. Lines 100–104 parse the number entered in **numberTextField** and invoke method **getFactorial** of the **MathTool** remote interface. Lines 107–108 display the factorial in **resultsTextArea**. Lines 113–115 catch a **RemoteException** if there is an error invoking method **getFactorial**.

Method **getFibonacciButton** (lines 125–182) creates a **JButton** that, when clicked, invokes **MathTool** EJB method **getFibonacciSeries**. Lines 140–145 parse the number entered in **numberTextField** and invoke method **getFibonacciSeries** of the **MathTool** remote interface. Method **getFibonacciSeries** returns an array of integers containing a Fibonacci series of the length specified by the integer argument **howMany**. Lines 148–168 build a **StringBuffer** containing the Fibonacci series and display the series in **resultsTextArea**.

```
1 // MathToolClient.java
2 // MathToolClient is a GUI for calculating factorials and
3 // Fibonacci series using the MathTool EJB.
4 package com.deitel.advjhttp1.ejb.session.stateless.client;
5
6 // Java core libraries
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.rmi.*;
10
11 // Java standard extensions
12 import javax.swing.*;
13 import javax.rmi.*;
14 import javax.naming.*;
15 import javax.ejb.*;
16
17 // Deitel libraries
18 import com.deitel.advjhttp1.ejb.session.stateless.ejb.*;
19
20 public class MathToolClient extends JFrame {
21
22     private MathToolHome mathToolHome;
23     private MathTool mathTool;
24
25     private JTextArea resultsTextArea;
26     private JTextField numberTextField;
27
28     // MathToolClient constructor
29     public MathToolClient()
30     {
31         super( "Stateless Session EJB Example" );
32
33         // create MathTool for calculating factorials
34         // and Fibonacci series
35         createMathTool();
36
37         // create and lay out GUI components
38         createGUI();
39
40         addWindowListener( getWindowListener() );
41
42         setSize( 425, 200 );
43         setVisible( true );
44
45     } // end MathToolClient constructor
46
47     // create MathTool EJB instance
48     private void createMathTool()
49     {
50         // lookup MathToolHome and create MathTool EJB
51         try {
52             InitialContext initialContext = new InitialContext();
```

Fig. 14.24 MathToolClient for interacting with MathTool EJB (part 1 of 6).

```
54
55      // lookup MathTool EJB
56      Object homeObject =
57          initialContext.lookup( "MathTool" );
58
59      // get MathToolHome interface
60      mathToolHome = ( MathToolHome )
61          PortableRemoteObject.narrow( homeObject,
62              MathToolHome.class );
63
64      // create MathTool EJB instance
65      mathTool = mathToolHome.create();
66
67 } // end try
68
69 // handle exception if MathTool EJB is not found
70 catch ( NamingException namingException ) {
71     namingException.printStackTrace();
72 }
73
74 // handle exception when creating MathTool EJB
75 catch ( RemoteException remoteException ) {
76     remoteException.printStackTrace();
77 }
78
79 // handle exception when creating MathTool EJB
80 catch ( CreateException createException ) {
81     createException.printStackTrace();
82 }
83 } // end method createMathTool
84
85 // create JButton for calculating factorial
86 private JButton getFactorialButton()
87 {
88     JButton factorialButton =
89         new JButton( "Calculate Factorial" );
90
91     // add ActionListener for factorial button
92     factorialButton.addActionListener(
93         new ActionListener() {
94
95             public void actionPerformed( ActionEvent event )
96             {
97                 // use MathTool EJB to calculate factorial
98                 try {
99
100                     int number = Integer.parseInt(
101                         numberTextField.getText() );
102
103                     // get Factorial of number input by user
104                     int result = mathTool.getFactorial( number );
105
106                 }
107             }
108         }
109     );
110 }
```

Fig. 14.24 MathToolClient for interacting with MathTool EJB (part 2 of 6).

```
106             // display results in resultsTextArea
107             resultsTextArea.setText( number + " ! = " +
108                         result );
109
110         } // end try
111
112         // handle exception calculating factorial
113         catch ( RemoteException remoteException ) {
114             remoteException.printStackTrace();
115         }
116     } // end method actionPerformed
117 }
118 ); // end addActionListener
119
120     return factorialButton;
121
122 } // end method getFactorialButton
123
124 // create JButton for generating Fibonacci series
125 private JButton getFibonacciButton()
126 {
127     JButton fibonacciButton =
128         new JButton( "Fibonacci Series" );
129
130     // add ActionListener for generating Fibonacci series
131     fibonacciButton.addActionListener(
132         new ActionListener() {
133
134             public void actionPerformed( ActionEvent event )
135             {
136                 // generate Fibonacci series using MathTool EJB
137                 try {
138
139                     // get number entered by user
140                     int number = Integer.parseInt(
141                         numberTextField.getText() );
142
143                     // get Fibonacci series
144                     int[] series = mathTool.getFibonacciSeries(
145                         number );
146
147                     // create StringBuffer to store series
148                     StringBuffer buffer =
149                         new StringBuffer( "The first " );
150
151                     buffer.append( number );
152
153                     buffer.append( " Fibonacci number(s): \n" );
154
155                     // append each number in series to buffer
156                     for ( int i = 0; i < series.length; i++ ) {
157
158                         buffer.append( series[i] );
159
160                     }
161
162                     // display results in resultsTextArea
163                     resultsTextArea.setText( buffer.toString() );
164
165                 } // end try
166                 catch ( RemoteException remoteException ) {
167                     remoteException.printStackTrace();
168                 }
169             }
170
171         } // end ActionListener
172     );
173
174     return fibonacciButton;
175 }
```

Fig. 14.24 **MathToolClient** for interacting with **MathTool** EJB (part 3 of 6).

```
158          // do not add comma before first number
159          if ( i != 0 )
160              buffer.append( ", " );
161
162          // append next number in series to buffer
163          buffer.append( String.valueOf(
164              series[ i ] ) );
165      }
166
167      // display series in resultsTextArea
168      resultsTextArea.setText( buffer.toString() );
169
170  } // end try
171
172      // handle exception calculating series
173      catch ( RemoteException remoteException ) {
174          remoteException.printStackTrace();
175      }
176  } // end method actionPerformed
177 }
178 ); // end addActionListener
179
180 return fibonacciButton;
181
182 } // end method getFibonacciButton
183
184 // create lay out GUI components
185 public void createGUI()
186 {
187     // create JTextArea to show results
188     resultsTextArea = new JTextArea();
189     resultsTextArea.setLineWrap( true );
190     resultsTextArea.setWrapStyleWord( true );
191     resultsTextArea.setEditable( false );
192
193     // create JTextField for user input
194     numberTextField = new JTextField( 10 );
195
196     // create JButton for calculating factorial
197     JButton factorialButton = getFactorialButton();
198
199     // create JButton for generating Fibonacci series
200     JButton fibonacciButton = getFibonacciButton();
201
202     Container contentPane = getContentPane();
203
204     // put resultsTextArea in a JScrollPane
205     JScrollPane resultsScrollPane =
206         new JScrollPane( resultsTextArea );
207
208     contentPane.add( resultsScrollPane,
209                     BorderLayout.CENTER );
210 }
```

Fig. 14.24 **MathToolClient** for interacting with **MathTool** EJB (part 4 of 6).

```
211     // add input components to new JPanel
212     JPanel inputPanel = new JPanel( new FlowLayout() );
213     inputPanel.add( new JLabel( "Enter an integer: " ) );
214     inputPanel.add( numberTextField );
215
216     // add JButton components to new JPanel
217     JPanel buttonPanel = new JPanel( new FlowLayout() );
218     buttonPanel.add( factorialButton );
219     buttonPanel.add( fibonacciButton );
220
221     // add inputPanel and buttonPanel to new JPanel
222     JPanel controlPanel =
223         new JPanel( new GridLayout( 2, 2 ) );
224
225     controlPanel.add( inputPanel );
226     controlPanel.add( buttonPanel );
227
228     contentPane.add( controlPanel, BorderLayout.NORTH );
229
230 } // end method createGUI
231
232 // get WindowListener for exiting application
233 private WindowListener getWindowListener()
234 {
235     return new WindowAdapter() {
236
237         public void windowClosing( WindowEvent event )
238         {
239             // remove MathTool instance
240             try {
241                 mathTool.remove();
242             }
243
244             // handle exception when removing MathTool EJB
245             catch ( RemoveException removeException ) {
246                 removeException.printStackTrace();
247                 System.exit( -1 );
248             }
249
250             // handle exception when removing MathTool EJB
251             catch ( RemoteException remoteException ) {
252                 remoteException.printStackTrace();
253                 System.exit( -1 );
254             }
255
256             System.exit( 0 );
257         } // end method windowClosing
258     };
259 } // end method getWindowListener
260
261 // execute application
262 public static void main( String[] args )
263 {
```

Fig. 14.24 MathToolClient for interacting with MathTool EJB (part 5 of 6).

```
264     MathToolClient client = new MathToolClient();  
265 }  
266 }
```

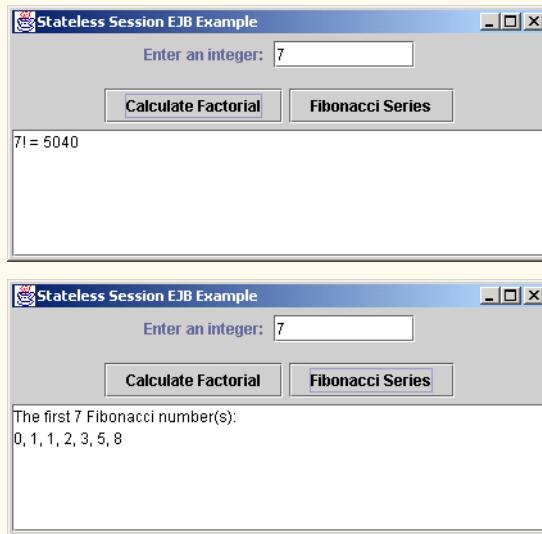


Fig. 14.24 **MathToolClient** for interacting with **MathTool** EJB (part 6 of 6).

## 14.4 EJB Transactions

The Java 2 Enterprise Edition supports *distributed transactions*. A distributed transaction is a transaction that includes multiple databases or multiple application servers. For example, a distributed transaction could transfer funds from an account at one bank into an account at another bank atomically.

J2EE supports two methods for defining transaction boundaries: *bean-managed transaction demarcation* and *container-managed transaction demarcation*. Bean-managed transaction demarcation requires the EJB developer to code the transaction boundaries manually in the EJBs using the *Java Transaction API (JTA)*. Container-managed transaction demarcation allows the EJB deployer to specify transaction boundaries declaratively when deploying EJBs.



### Software Engineering Observation 14.2

Entity EJBs may use only container-managed transaction demarcation.

#### 14.4.1 MoneyTransfer EJB Home and Remote Interfaces

The **MoneyTransfer** EJB demonstrates the need for distributed transactions and their implementation using bean-managed and container-managed transaction demarcation. In this example, we transfer money from an account at **BankABC** to an account at **BankXYZ**. We first withdraw money from an account at **BankABC** and then deposit the same amount at **BankXYZ**. Transactions are needed to ensure that the money is “put back” in the **Bank-**

**ABC** account if the deposit at **BankXYZ** fails. We also need to ensure that if the withdrawal from **BankABC** fails, the money is not deposited at **BankXYZ**.

The **MoneyTransfer** remote interface (Fig. 14.25) provides methods for transferring money between accounts and for getting the balances of accounts at two different banks. Method **transfer** (line 15) transfers the given amount of money from an account at **BankABC** to an account at **BankXYZ**. Method **getBankABCBalance** (line 18) returns the account balance at **BankABC**. Method **getBankXYZBalance** (line 21) returns the account balance at **BankXYZ**. Interface **MoneyTransferHome** (Fig. 14.26) provides method **create** (lines 15–16) for creating **MoneyTransfer** EJB instances.

---

```

1 // MoneyTransfer.java
2 // MoneyTransfer is the remote interface for the MoneyTransfer
3 // EJB.
4 package com.deitel.advjhtp1.ejb.transactions;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
9 // Java standard extensions
10 import javax.ejb.EJBObject;
11
12 public interface MoneyTransfer extends EJBObject {
13
14     // transfer amount from BankABC to BankXYZ
15     public void transfer( double amount ) throws RemoteException;
16
17     // get BankABC account balance
18     public double getBankABCBalance() throws RemoteException;
19
20     // get BankXYZ account balance
21     public double getBankXYZBalance() throws RemoteException;
22 }
```

---

Fig. 14.25 **MoneyTransfer** remote interface for transferring money and getting account balances.

---

```

1 // MoneyTransferHome.java
2 // MoneyTransferHome is the home interface for the
3 // MoneyTransferHome EJB.
4 package com.deitel.advjhtp1.ejb.transactions;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public interface MoneyTransferHome extends EJBHome {
13 }
```

---

Fig. 14.26 **MoneyTransferHome** interface for creating **MoneyTransfer** EJBs (part 1 of 2).

```
14 // create MoneyTransfer EJB
15 public MoneyTransfer create() throws RemoteException,
16     CreateException;
17 }
```

Fig. 14.26 **MoneyTransferHome** interface for creating **MoneyTransfer** EJBs (part 2 of 2).

#### 14.4.2 Bean-Managed Transaction Demarcation

*Bean-managed transaction demarcation* requires the EJB developer to code the transaction boundaries manually in the EJBs. Bean-managed transaction demarcation may be used only with session EJBs.

**MoneyTransferEJB** (Fig. 14.27) implements the **MoneyTransfer** remote interface using bean-managed transaction demarcation to ensure atomicity of the database updates in method **transfer** (lines 26–81). Lines 29–30 create a **UserTransaction**. Line 34 begins the **transaction** by invoking **UserTransaction** method **begin**. All statements after the **transaction** begins are part of the **transaction** until the **transaction** is committed or rolled back.

```
1 // MoneyTransferEJB.java
2 // MoneyTransferEJB is a stateless session EJB for transferring
3 // funds from an Account at BankABC to an Account at BankXYZ
4 // using bean-managed transaction demarcation.
5 package com.deitel.advjhtp1.ejb.transactions.beanmanaged;
6
7 // Java core libraries
8 import java.util.*;
9 import java.sql.*;
10
11 // Java standard extensions
12 import javax.ejb.*;
13 import javax.naming.*;
14 import javax.transaction.*;
15 import javax.sql.*;
16
17 public class MoneyTransferEJB implements SessionBean {
18
19     private SessionContext sessionContext;
20     private Connection bankOneConnection;
21     private Connection bankTwoConnection;
22     private PreparedStatement withdrawalStatement;
23     private PreparedStatement depositStatement;
24
25     // transfer funds from BankABC to BankXYZ
26     public void transfer( double amount ) throws EJBException
27     {
28         // create transaction for transferring funds
29         UserTransaction transaction =
30             sessionContext.getUserTransaction();
```

Fig. 14.27 **MoneyTransferEJB** implementation of **MoneyTransfer** remote interface using bean-managed transaction demarcation (part 1 of 6).

```
31      // begin bean-managed transaction demarcation
32      try {
33          transaction.begin();
34      }
35
36      // catch exception if method begin fails
37      catch ( Exception exception ) {
38
39          // throw EJBException indicating transaction failed
40          throw new EJBException( exception );
41      }
42
43
44      // transfer funds from account in BankABC to account
45      // in BankXYZ using bean-managed transaction demarcation
46      try {
47
48          withdrawalStatement.setDouble( 1, amount );
49
50          // withdraw funds from account at BankABC
51          withdrawalStatement.executeUpdate();
52
53          depositStatement.setDouble( 1, amount );
54
55          // deposit funds in account at BankXYZ
56          depositStatement.executeUpdate();
57
58          // commit transaction
59          transaction.commit();
60
61      } // end try
62
63      // handle exceptions when withdrawing, depositing and
64      // committing transaction
65      catch ( Exception exception ) {
66
67          // attempt rollback of transaction
68          try {
69              transaction.rollback();
70          }
71
72          // handle exception when rolling back transaction
73          catch ( SystemException systemException ) {
74              throw new EJBException( systemException );
75          }
76
77          // throw EJBException indicating transaction failed
78          throw new EJBException( exception );
79      }
80
81  } // end method transfer
82
```

Fig. 14.27 MoneyTransferEJB implementation of MoneyTransfer remote interface using bean-managed transaction demarcation (part 2 of 6).

```
83     // get balance of Account at BankABC
84     public double getBankABCBalance() throws EJBException
85     {
86         // get balance of Account at BankABC
87         try {
88
89             // select balance for Account # 12345
90             String select = "SELECT balance FROM Account " +
91                 "WHERE accountID = 12345";
92
93             PreparedStatement selectStatement =
94                 bankOneConnection.prepareStatement( select );
95
96             ResultSet resultSet = selectStatement.executeQuery();
97
98             // get first record in ResultSet and return balance
99             if ( resultSet.next() )
100                 return resultSet.getDouble( "balance" );
101             else
102                 throw new EJBException( "Account not found" );
103
104         } // end try
105
106         // handle exception when getting Account balance
107         catch ( SQLException sqlException ) {
108             throw new EJBException( sqlException );
109         }
110
111     } // end method getBankABCBalance
112
113     // get balance of Account at BankXYZ
114     public double getBankXYZBalance() throws EJBException
115     {
116         // get balance of Account at BankXYZ
117         try {
118
119             // select balance for Account # 54321
120             String select = "SELECT balance FROM Account " +
121                 "WHERE accountID = 54321";
122
123             PreparedStatement selectStatement =
124                 bankTwoConnection.prepareStatement( select );
125
126             ResultSet resultSet = selectStatement.executeQuery();
127
128             // get first record in ResultSet and return balance
129             if ( resultSet.next() )
130                 return resultSet.getDouble( "balance" );
131             else
132                 throw new EJBException( "Account not found" );
133
134         } // end try
```

Fig. 14.27 MoneyTransferEJB implementation of MoneyTransfer remote interface using bean-managed transaction demarcation (part 3 of 6).

```
135
136      // handle exception when getting Account balance
137      catch ( SQLException sqlException ) {
138          throw new EJBException( sqlException );
139      }
140
141  } // end method getBankXYZBalance
142
143  // set SessionContext
144  public void setSessionContext( SessionContext context )
145      throws EJBException
146  {
147      sessionContext = context;
148
149      openDatabaseResources();
150  }
151
152  // create MoneyTransfer instance
153  public void ejbCreate() {}
154
155  // remove MoneyTransfer instance
156  public void ejbRemove() throws EJBException
157  {
158      closeDatabaseResources();
159  }
160
161  // passivate MoneyTransfer instance
162  public void ejbPassivate() throws EJBException
163  {
164      closeDatabaseResources();
165  }
166
167  // activate MoneyTransfer instance
168  public void ejbActivate() throws EJBException
169  {
170      openDatabaseResources();
171  }
172
173  // close database Connections and PreparedStatements
174  private void closeDatabaseResources() throws EJBException
175  {
176      // close database resources
177      try {
178
179          // close PreparedStatements
180          depositStatement.close();
181          depositStatement = null;
182
183          withdrawalStatement.close();
184          withdrawalStatement = null;
185      }
```

Fig. 14.27 **MoneyTransferEJB** implementation of **MoneyTransfer** remote interface using bean-managed transaction demarcation (part 4 of 6).

```
186         // close database Connections
187         bankOneConnection.close();
188         bankOneConnection = null;
189
190         bankTwoConnection.close();
191         bankTwoConnection = null;
192     }
193
194     // handle exception closing database connections
195     catch ( SQLException sqlException ) {
196         throw new EJBException( sqlException );
197     }
198
199 } // end method closeDatabaseResources
200
201 // open database Connections and create PreparedStatements
202 private void openDatabaseResources() throws EJBException
203 {
204     // look up the BankABC and BankXYZ DataSources and create
205     // Connections for each
206     try {
207         Context initialContext = new InitialContext();
208
209         // get DataSource reference from JNDI directory
210         DataSource dataSource = ( DataSource )
211             initialContext.lookup(
212                 "java:comp/env/jdbc/BankABC" );
213
214         // get Connection from DataSource
215         bankOneConnection = dataSource.getConnection();
216
217         dataSource = ( DataSource ) initialContext.lookup(
218             "java:comp/env/jdbc/BankXYZ" );
219
220         bankTwoConnection = dataSource.getConnection();
221
222         // prepare withdraw statement for account #12345 at
223         // BankABC
224         String withdrawal = "UPDATE Account SET balance = " +
225             "balance - ? WHERE accountID = 12345";
226
227         withdrawalStatement =
228             bankOneConnection.prepareStatement( withdrawal );
229
230         // prepare deposit statement for account #54321 at
231         // BankXYZ
232         String deposit = "UPDATE Account SET balance = " +
233             "balance + ? WHERE accountID = 54321";
234
235         depositStatement =
236             bankTwoConnection.prepareStatement( deposit );
237 }
```

Fig. 14.27 MoneyTransferEJB implementation of MoneyTransfer remote interface using bean-managed transaction demarcation (part 5 of 6).

```

238         } // end try
239
240         // handle exception if DataSource not found in directory
241         catch ( NamingException namingException ) {
242             throw new EJBException( namingException );
243         }
244
245         // handle exception getting Connection to DataSource
246         catch ( SQLException sqlException ) {
247             throw new EJBException( sqlException );
248         }
249
250     } // end method openDatabaseResources
251 }
```

Fig. 14.27 **MoneyTransferEJB** implementation of **MoneyTransfer** remote interface using bean-managed transaction demarcation (part 6 of 6).

Lines 48–51 withdraw the given transfer **amount** from an account in the **BankABC** database. Lines 53–56 deposit the given transfer **amount** in an account in the **BankXYZ** database. Both of these updates are part of the **transaction** begun on line 34 even though they are in separate databases. Line 59 commits the **transaction** to save the updates to each database.

Lines 65–79 catch any **Exceptions** thrown from lines 46–61. Line 69 invokes **UserTransaction** method **rollback** to undo any updates that were made within the **transaction** boundaries. This **rollback** ensures that if any critical part of method **transfer** failed, all of the changes made in both databases are undone to ensure the integrity of the data. Lines 73–75 catch a **SystemException**, which is thrown by **UserTransaction** method **rollback** if the **rollback** fails. Lines 74 and 78 throw **EJBExceptions** to aid in debugging the application.

Methods **getBankABCBalance** (lines 84–111) and **getBankXYZBalance** (lines 114–141) execute simple SQL **SELECT** statements to retrieve the balances of the accounts at each bank. Methods **setSessionContext** (lines 144–150) and **ejbActivate** (lines 168–171) invoke method **openDatabaseResources** (lines 202–250) to create **Connections** and **PreparedStatement**s for each database for use throughout the lifetime of the **MoneyTransfer** EJB instance. Methods **ejbRemove** (lines 156–159) and **ejbPassivate** (lines 162–165) invoke method **closeDatabaseResources** (lines 174–199) to close the **Connections** and **PreparedStatement**s.

### 14.4.3 Container-Managed Transaction Demarcation

*Container-managed transaction demarcation* allows the EJB developer to implement an EJB without specifying transaction boundaries. The EJB deployer provides transaction demarcation semantics declaratively when deploying the application.

**MoneyTransferEJB** (Fig. 14.28) implements the **MoneyTransfer** remote interface using container-managed transaction demarcation. Method **transfer** (lines 25–51) is similar to method **transfer** in Fig. 14.27. Note, however, that this version of method **transfer** does not declare any transaction boundaries, as this is now the responsibility

of the EJB deployer. The EJB deployer specifies the transaction semantics using one of the six transaction types listed in Fig. 14.29.

```
1 // MoneyTransferEJB.java
2 // MoneyTransferEJB is a stateless session EJB for transferring
3 // funds from an Account at BankABC to an Account at BankXYZ
4 // using container-managed transaction demarcation.
5 package com.deitel.advjhtp1.ejb.transactions.containermanaged;
6
7 // Java core libraries
8 import java.util.*;
9 import java.sql.*;
10
11 // Java standard extensions
12 import javax.ejb.*;
13 import javax.naming.*;
14 import javax.sql.*;
15
16 public class MoneyTransferEJB implements SessionBean {
17
18     private SessionContext sessionContext;
19     private Connection bankOneConnection;
20     private Connection bankTwoConnection;
21     private PreparedStatement withdrawalStatement;
22     private PreparedStatement depositStatement;
23
24     // transfer funds from BankABC to BankXYZ
25     public void transfer( double amount ) throws EJBException
26     {
27         // transfer funds from account in BankABC to account in
28         // BankXYZ using container-managed transaction demarcation
29         try {
30
31             withdrawalStatement.setDouble( 1, amount );
32
33             // withdraw funds from account at BankABC
34             withdrawalStatement.executeUpdate();
35
36             depositStatement.setDouble( 1, amount );
37
38             // deposit funds in account at BankXYZ
39             depositStatement.executeUpdate();
40
41         } // end try
42
43         // handle exception withdrawing and depositing
44         catch ( SQLException sqlException ) {
45
```

Fig. 14.28 MoneyTransferEJB implementation of MoneyTransfer remote interface using container-managed transaction demarcation (part 1 of 5).

```
46          // throw EJBException to indicate transfer failed
47          // and roll back container-managed transaction
48          throw new EJBException( sqlException );
49      }
50
51  } // end method transfer
52
53 // get balance of Account at BankABC
54 public double getBankABCBalance() throws EJBException
55 {
56     // get balance of Account at BankABC
57     try {
58
59         // select balance for Account # 12345
60         String select = "SELECT balance FROM Account " +
61             "WHERE accountID = 12345";
62
63         PreparedStatement selectStatement =
64             bankOneConnection.prepareStatement( select );
65
66         ResultSet resultSet = selectStatement.executeQuery();
67
68         // get first record in ResultSet and return balance
69         if ( resultSet.next() )
70             return resultSet.getDouble( "balance" );
71         else
72             throw new EJBException( "Account not found" );
73
74     } // end try
75
76     // handle exception when getting Account balance
77     catch ( SQLException sqlException ) {
78         throw new EJBException( sqlException );
79     }
80
81 } // end method getBankABCBalance
82
83 // get balance of Account at BankXYZ
84 public double getBankXYZBalance() throws EJBException
85 {
86     // get balance of Account at BankXYZ
87     try {
88
89         // select balance for Account # 54321
90         String select = "SELECT balance FROM Account " +
91             "WHERE accountID = 54321";
92
93         PreparedStatement selectStatement =
94             bankTwoConnection.prepareStatement( select );
95
96         ResultSet resultSet = selectStatement.executeQuery();
97 }
```

Fig. 14.28 MoneyTransferEJB implementation of MoneyTransfer remote interface using container-managed transaction demarcation (part 2 of 5).

```
98         // get first record in ResultSet and return balance
99         if ( resultSet.next() )
100             return resultSet.getDouble( "balance" );
101         else
102             throw new EJBException( "Account not found" );
103     } // end try
104
105     // handle exception when getting Account balance
106     catch ( SQLException sqlException ) {
107         throw new EJBException( sqlException );
108     }
109 }
110
111 } // end method getBankXYZBalance
112
113 // set SessionContext
114 public void setSessionContext( SessionContext context )
115     throws EJBException
116 {
117     sessionContext = context;
118
119     openDatabaseResources();
120 }
121
122 // create MoneyTransfer instance
123 public void ejbCreate()
124
125 // remove MoneyTransfer instance
126 public void ejbRemove() throws EJBException
127 {
128     closeDatabaseResources();
129 }
130
131 // passivate MoneyTransfer instance
132 public void ejbPassivate() throws EJBException
133 {
134     closeDatabaseResources();
135 }
136
137 // activate MoneyTransfer instance
138 public void ejbActivate() throws EJBException
139 {
140     openDatabaseResources();
141 }
142
143 // close database Connections and PreparedStatements
144 private void closeDatabaseResources() throws EJBException
145 {
146     // close database resources
147     try {
148
```

Fig. 14.28 MoneyTransferEJB implementation of MoneyTransfer remote interface using container-managed transaction demarcation (part 3 of 5).

```
149         // close PreparedStatements
150         depositStatement.close();
151         depositStatement = null;
152
153         withdrawalStatement.close();
154         withdrawalStatement = null;
155
156         // close database Connections
157         bankOneConnection.close();
158         bankOneConnection = null;
159
160         bankTwoConnection.close();
161         bankTwoConnection = null;
162     }
163
164     // handle exception closing database connections
165     catch ( SQLException sqlException ) {
166         throw new EJBException( sqlException );
167     }
168
169 } // end method closeDatabaseConnections
170
171 // open database Connections and create PreparedStatements
172 private void openDatabaseResources() throws EJBException
173 {
174     // look up the BankABC and BankXYZ DataSources and create
175     // Connections for each
176     try {
177         Context initialContext = new InitialContext();
178
179         // get DataSource reference from JNDI directory
180         DataSource dataSource = ( DataSource )
181             initialContext.lookup(
182                 "java:comp/env/jdbc/BankABC" );
183
184         // get Connection from DataSource
185         bankOneConnection = dataSource.getConnection();
186
187         dataSource = ( DataSource ) initialContext.lookup(
188             "java:comp/env/jdbc/BankXYZ" );
189
190         bankTwoConnection = dataSource.getConnection();
191
192         // prepare withdraw statement for account #12345 at
193         // BankABC
194         String withdrawal = "UPDATE Account SET balance = " +
195             "balance - ? WHERE accountID = 12345";
196
197         withdrawalStatement =
198             bankOneConnection.prepareStatement( withdrawal );
199 }
```

Fig. 14.28 MoneyTransferEJB implementation of MoneyTransfer remote interface using container-managed transaction demarcation (part 4 of 5).

```

200      // prepare deposit statement for account #54321 at
201      // BankXYZ
202      String deposit = "UPDATE Account SET balance = " +
203          "balance + ? WHERE accountID = 54321";
204
205      depositStatement =
206          bankTwoConnection.prepareStatement( deposit );
207
208    } // end try
209
210    // handle exception if DataSource not found in directory
211    catch ( NamingException namingException ) {
212        throw new EJBException( namingException );
213    }
214
215    // handle exception getting Connection to DataSource
216    catch ( SQLException sqlException ) {
217        throw new EJBException( sqlException );
218    }
219
220 } // end method openDatabaseConnections
221 }
```

**Fig. 14.28** **MoneyTransferEJB** implementation of **MoneyTransfer** remote interface using container-managed transaction demarcation (part 5 of 5).

Line 66 throws an **EJBException** in response to any **SQLException** thrown from lines 29–41. The **EJBContainer** rolls back the current **transaction** when method **transfer** throws an **EJBException** (line 48).

Figure 14.29 lists the available transaction types for container-managed persistence. The deployer specifies the transaction type for each business method when deploying the application.

Transaction Type	Description
<b>NotSupported</b>	Method does not support transactions. The EJB container suspends the existing transaction context if the method is invoked within a transaction context.
<b>Required</b>	Method requires a transaction. The EJB container creates a new transaction if the method is invoked without an existing transaction context and commits the transaction at the end of the method.
<b>Supports</b>	Method supports transactions. The EJB container will not create a new transaction if the method is invoked without an existing transaction context, but will execute the method as part of an existing transaction context if one is available.
<b>RequiresNew</b>	Method requires a new transaction. The EJB container suspends the existing transaction context and starts a new transaction if the method is invoked as part of another transaction.

**Fig. 14.29** Transaction types for container-managed transaction demarcation (part 1 of 2).

Transaction Type	Description
<b>Mandatory</b>	The method must execute in an existing transaction context. The EJB container throws a <b>TransactionRequiredException</b> if the method is invoked without a valid transaction context.
<b>Never</b>	The method must not execute in a transaction context. The EJB container throws a <b>RemoteException</b> if the method is invoked inside a transaction context.

**Fig. 14.29** Transaction types for container-managed transaction demarcation (part 2 of 2).

#### 14.4.4 MoneyTransfer EJB Client

**MoneyTransferEJBClient** (Fig. 14.30) provides a user interface for interacting with the **MoneyTransfer** EJB. Lines 24–26 declare **JTextFields** to display the account balances and accept a user-input **transfer amount**. Line 34 invokes method **create-MoneyTransfer** to create a new **MoneyTransfer** EJB instance. Line 37 invokes method **createGUI** to create and lay out GUI components for the application. The GUI consists of **JTextFields** for displaying account balances and inputting the transfer amount and a **JButton** for transferring funds. Line 40 invokes method **displayBalances** to display the current account balances at **BankABC** and **BankXYZ**.

Method **createMoneyTransfer** (lines 47–80) uses the **MoneyTransferHome** interface to create a **MoneyTransfer** EJB instance. Line 51 creates an **InitialContext** for locating the **MoneyTransfer** EJB in the JNDI directory. Lines 54–59 invoke **InitialContext** method **lookup** to get a remote reference to the **MoneyTransferHome** interface. Line 62 creates a new **MoneyTransfer** EJB instance by invoking **MoneyTransferHome** method **create**.

Method **getTransferButton** (lines 108–142) creates a **JButton** to transfer funds from **BankABC** to **BankXYZ**. Lines 120–124 read the **transfer amount** from the user and invoke **MoneyTransfer** method **transfer**. Line 127 invokes method **displayBalances** to update the display with the new account balances.

```

1 // MoneyTransferEJBClient.java
2 // MoneyTransferEJBClient is a client for interacting with
3 // the MoneyTransfer EJB.
4 package com.deitel.advjhtp1.ejb.transactions.client;
5
6 // Java core libraries
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.rmi.*;
10
11 // Java standard extensions
12 import javax.swing.*;
```

**Fig. 14.30** **MoneyTransferEJBClient** for interacting with **MoneyTransfer** EJB (part 1 of 6).

```
13 import javax.ejb.*;
14 import javax.rmi.*;
15 import javax.naming.*;
16
17 // Deitel libraries
18 import com.deitel.advjhtp1.ejb.transactions.*;
19
20 public class MoneyTransferEJBCClient extends JFrame {
21
22     private MoneyTransfer moneyTransfer;
23
24     private JTextField bankABCBalanceTextField;
25     private JTextField bankXYZBalanceTextField;
26     private JTextField transferAmountTextField;
27
28     // MoneyTransferEJBCClient constructor
29     public MoneyTransferEJBCClient( String JNDIName )
30     {
31         super( "MoneyTransferEJBCClient" );
32
33         // create MoneyTransfer EJB for transferring money
34         createMoneyTransfer( JNDIName );
35
36         // create and lay out GUI components
37         createGUI();
38
39         // display current balances at BankABC and BankXYZ
40         displayBalances();
41
42         setSize( 400, 300 );
43         setVisible( true );
44     }
45
46     // create MoneyTransferEJB for transferring money
47     private void createMoneyTransfer( String JNDIName )
48     {
49         // look up MoneyTransfer EJB using given JNDIName
50         try {
51             InitialContext context = new InitialContext();
52
53             // lookup MoneyTransfer EJB
54             Object homeObject = context.lookup( JNDIName );
55
56             // get MoneyTransfer interface
57             MoneyTransferHome moneyTransferHome =
58                 ( MoneyTransferHome ) PortableRemoteObject.narrow(
59                     homeObject, MoneyTransferHome.class );
60
61             // create MathTool EJB instance
62             moneyTransfer = moneyTransferHome.create();
63
64         } // end try
```

Fig. 14.30 **MoneyTransferEJBCClient** for interacting with **MoneyTransfer** EJB (part 2 of 6).

```
65
66      // handle exception when looking up MoneyTransfer EJB
67      catch ( NamingException namingException ) {
68          namingException.printStackTrace();
69      }
70
71      // handle exception when looking up MoneyTransfer EJB
72      catch ( CreateException createException ) {
73          createException.printStackTrace();
74      }
75
76      // handle exception when looking up MoneyTransfer EJB
77      catch ( RemoteException remoteException ) {
78          remoteException.printStackTrace();
79      }
80  } // end method createMoneyTransfer
81
82  // display balance in account at BankABC
83  private void displayBalances()
84  {
85      try {
86
87          // get and display BankABC Account balance
88          double balance = moneyTransfer.getBankABCBalance();
89
90          bankABCBalanceTextField.setText(
91              String.valueOf( balance ) );
92
93          // get and display BankXYZ Account balance
94          balance = moneyTransfer.getBankXYZBalance();
95
96          bankXYZBalanceTextField.setText(
97              String.valueOf( balance ) );
98      }
99
100     // handle exception when invoke MoneyTransfer EJB methods
101     catch ( RemoteException remoteException ) {
102         JOptionPane.showMessageDialog( this,
103             remoteException.getMessage() );
104     }
105 } // end method displayBalances
106
107 // create button to transfer funds between accounts
108 private JButton getTransferButton()
109 {
110     JButton transferButton = new JButton( "Transfer" );
111
112     transferButton.addActionListener(
113         new ActionListener() {
114
115             public void actionPerformed( ActionEvent event )
116             {
```

Fig. 14.30 **MoneyTransferEJBClient** for interacting with **MoneyTransfer** EJB (part 3 of 6).

```
117         try {
118
119             // get transfer amount from JTextField
120             double amount = Double.parseDouble(
121                 transferAmountTextField.getText() );
122
123             // transfer money
124             moneyTransfer.transfer( amount );
125
126             // display new balances
127             displayBalances();
128         }
129
130         // handle exception when transferring money
131         catch ( RemoteException remoteException ) {
132             JOptionPane.showMessageDialog(
133                 MoneyTransferEJBCClient.this,
134                 remoteException.getMessage() );
135         }
136     } // end method actionPerformed
137 }
138 ); // end addActionListener
139
140     return transferButton;
141
142 } // end method getTransferButton
143
144 // create and lay out GUI components
145 private void createGUI()
146 {
147     // create JTextFields for user input and display
148     bankABCBalanceTextField = new JTextField( 10 );
149     bankABCBalanceTextField.setEditable( false );
150
151     bankXYZBalanceTextField = new JTextField( 10 );
152     bankXYZBalanceTextField.setEditable( false );
153
154     transferAmountTextField = new JTextField( 10 );
155
156     // create button to transfer between accounts
157     JButton transferButton = getTransferButton();
158
159     // layout user interface
160     Container contentPane = getContentPane();
161     contentPane.setLayout( new GridLayout( 3, 2 ) );
162
163     contentPane.add( transferButton );
164     contentPane.add( transferAmountTextField );
165
166     contentPane.add( new JLabel( "Bank ABC Balance: " ) );
167     contentPane.add( bankABCBalanceTextField );
```

Fig. 14.30 **MoneyTransferEJBCClient** for interacting with **MoneyTransfer** EJB (part 4 of 6).

```
168     contentPane.add( new JLabel( "Bank XYZ Balance: " ) );
169     contentPane.add( bankXYZBalanceTextField );
170
171 } // end method createGUI
172
173 // get WindowListener for exiting application
174 private WindowListener getWindowListener()
175 {
176     // remove MoneyTransfer EJB when user exits application
177     return new WindowAdapter() {
178
179         public void windowClosing( WindowEvent event ) {
180
181             // remove MoneyTransfer EJB
182             try {
183                 moneyTransfer.remove();
184             }
185
186             // handle exception removing MoneyTransfer EJB
187             catch ( RemoveException removeException ) {
188                 removeException.printStackTrace();
189                 System.exit( 1 );
190             }
191
192             // handle exception removing MoneyTransfer EJB
193             catch ( RemoteException remoteException ) {
194                 remoteException.printStackTrace();
195                 System.exit( 1 );
196             }
197
198             System.exit( 0 );
199
200         } // end method windowClosing
201     };
202 }
203 } // end method getWindowListener
204
205 // execute application
206 public static void main( String[] args )
207 {
208     // ensure user provided JNDI name for MoneyTransfer EJB
209     if ( args.length != 1 )
210         System.err.println(
211             "Usage: java MoneyTransferEJBClient <JNDI Name>" );
212
213     // start application using provided JNDI name
214     else
215         new MoneyTransferEJBClient( args[ 0 ] );
216     }
217 }
```

Fig. 14.30 **MoneyTransferEJBClient** for interacting with **MoneyTransfer** EJB (part 5 of 6).

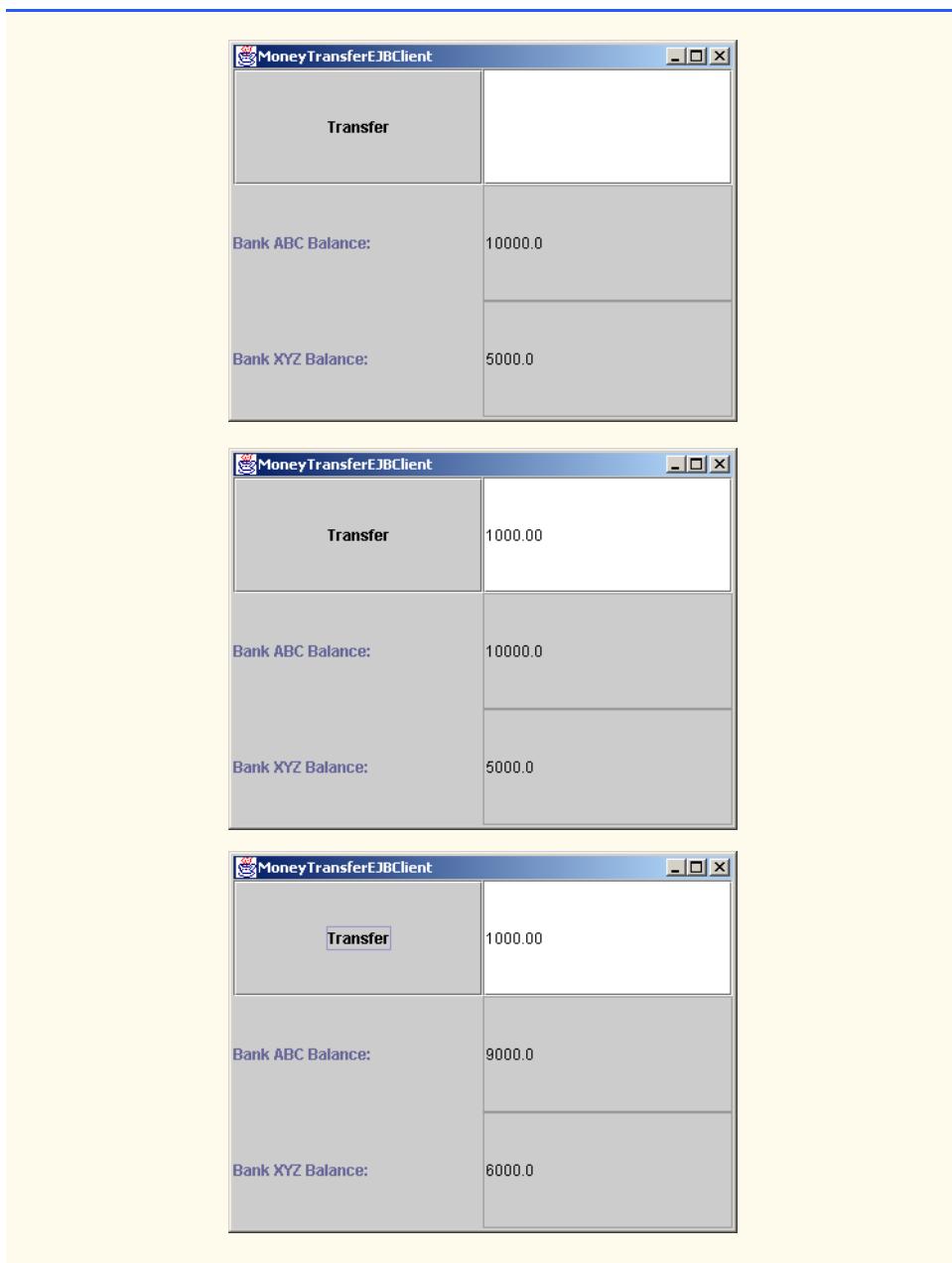


Fig. 14.30 **MoneyTransferEJBClient** for interacting with **MoneyTransfer** EJB (part 6 of 6).

Figure 14.30 shows three screen captures of **MoneyTransferEJBClient**. Enter any legal value in the text field and press the **Transfer** button. This causes the EJB to update the database entries. The client then updates its GUI to reflect the new account balances.

#### 14.4.5 Deploying the MoneyTransfer EJB

The **MoneyTransfer** EJB accesses two databases that store account information. The examples use the Cloudscape DBMS introduced in Chapter 8, JDBC. Follow the directions in Section 8.5 to set up the databases for the **MoneyTransfer** EJB. The SQL script for the databases, **transactions.sql**, is on the CD-ROM that accompanies this book. If you have not already done so, please see Appendix E for instructions on integrating Cloudscape with the J2EE 1.2.1 reference implementation. Add the following

```
| jdbc/BankABC | jdbc:cloudscape:rmi:BankABC;create=true; | jdbc/
BankXYZ | jdbc:cloudscape:rmi:BankXYZ;create=true;
```

to the **jdbc.datasources** property in the file **C:\j2sdkee1.2.1\config\default.properties**.

Deploying each versions of the **MoneyTransfer** EJB is very similar to deploying the other session EJBs. When deploying the **MoneyTransfer** EJB, we must create resource references to the two databases in the **New Enterprise Bean Wizard** (Fig. 14.31). Click the **Add** button to add a new resource reference. Fill in the **Coded Name** and **JNDI Name** fields with **jdbc/BankABC** for the BankABC database (Fig. 14.32) and **jdbc/BankXYZ** for the BankXYZ database (Fig. 14.33). In the **Transaction Management** dialog of the **New Enterprise Bean Wizard** select **Bean-Managed Transactions** for the bean-managed version of **MoneyTransferEJB** (Fig. 14.34) or **Container-Managed Transactions** for the container-managed version of **MoneyTransferEJB** (Fig. 14.35). For the container-managed EJB, select a transaction type for each method (see Section 14.4.3 for information about transaction types). The rest of the deployment is the same as the deployment of the other session EJBs. Be sure to run the Cloudscape server before executing **MoneyTransferEJBClient**.

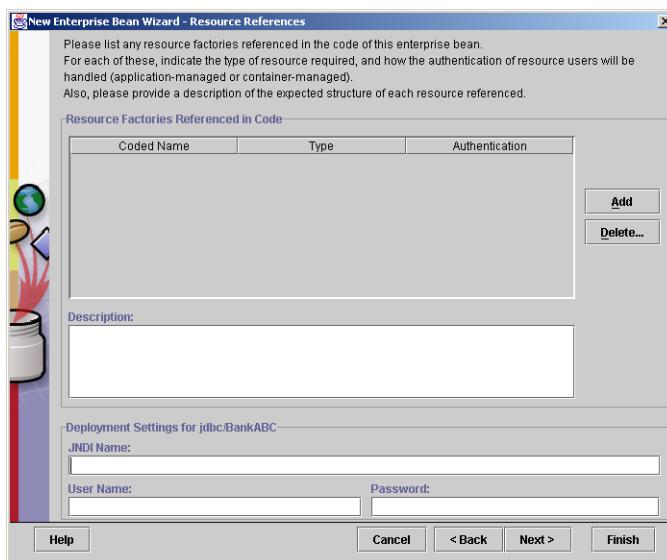


Fig. 14.31 Resource References dialog of New Enterprise Bean Wizard.

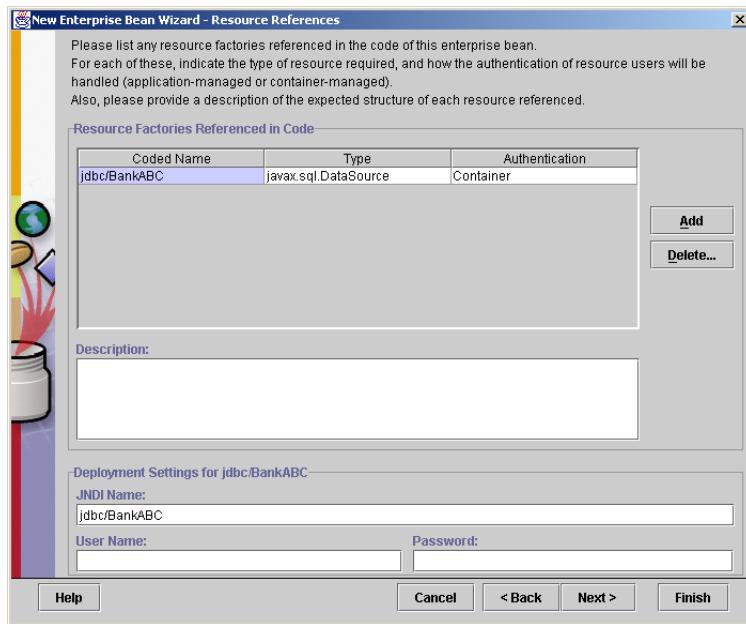


Fig. 14.32 Add Resource Reference for BankABC.

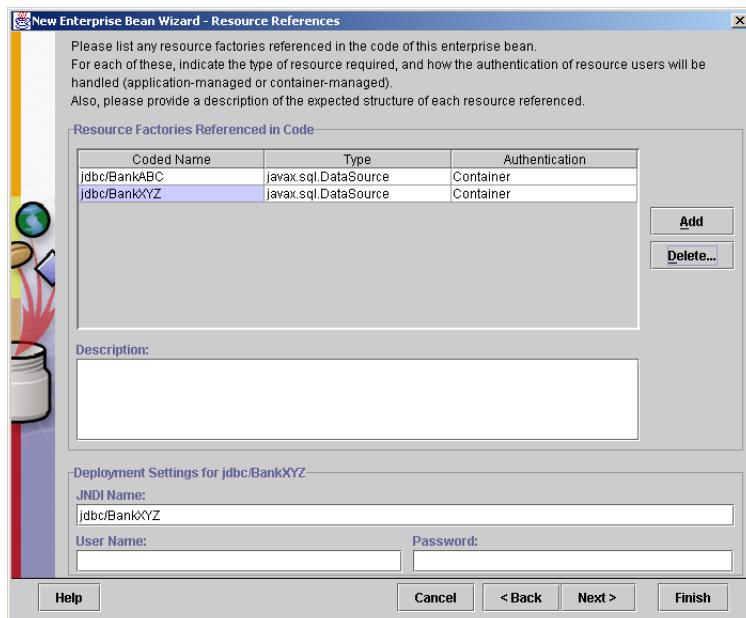


Fig. 14.33 Add Resource Reference for BankXYZ.



Fig. 14.34 Selecting Bean-Managed Transactions.

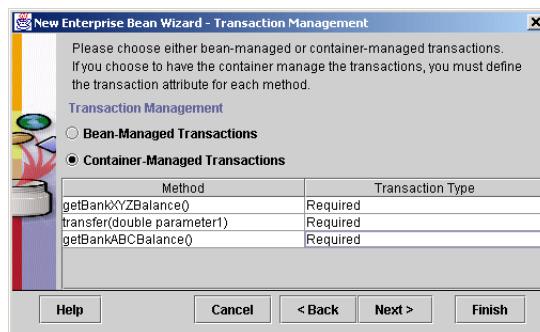


Fig. 14.35 Selecting Container-Managed Transactions.

## 14.5 Internet and World Wide Web Resources

[java.sun.com/products/ejb](http://java.sun.com/products/ejb)

Sun's Enterprise Java Bean home page. Contains articles, documentation and examples.

[www.javaworld.com/javaworld/topicalindex/jw-ti-ejb.html](http://www.javaworld.com/javaworld/topicalindex/jw-ti-ejb.html)

List of EJB-related articles from JavaWorld.

[www.jguru.com/faq/home.jsp?topic=EJB](http://www.jguru.com/faq/home.jsp?topic=EJB)

List of frequently asked questions on EJBs at [jguru.com](http://www.jguru.com).

[www.theserverside.com](http://www.theserverside.com)

[TheServerSide.com](http://www.theserverside.com) is an online community for J2EE developers. There are forums, articles and other resources for building applications with J2EE.

### SUMMARY

- Every EJB consists of a remote interface, a home interface and an EJB implementation.
- The remote interface declares business methods that clients of the EJB may invoke. The home interface provides **create** methods for creating new instances of the EJB, **finder** methods for finding instances of the EJB and **remove** methods for removing instances of the EJB. The EJB implementation defines the business methods declared in the remote interface and the **create**, **remove** and **finder** methods of the home interface.

- EJBs have a complex life cycle that is managed by an EJB container. The EJB container creates classes that implement the home and remote interfaces.
- The J2EE specification defines six roles for implementing enterprise systems. Each role is responsible for producing some part of an enterprise application.
- The remote interface for an EJB declares the business methods that clients of the EJB may invoke. The remote interface must extend interface **javax.ejb.EJBObject**.
- Each method of the remote interface is required to declare that it throws **java.rmi.RemoteException**. Each method also may throw application-specific exceptions—for example, an **IllegalArgumentException** if a provided argument does not meet certain criteria.
- The home interface for an EJB declares methods for creating, removing and finding EJB instances. The home interface must extend interface **javax.ejb.EJBHome**.
- Depending on the EJB type (i.e., session or entity), the container invokes EJB implementation methods that correspond to methods **create** and **remove** and **finder** methods of the home interface.
- The EJB implementation defines the business methods declared in the EJB remote interface and the **create**, **remove** and **finder** methods declared in the EJB home interface. The EJB implementation must also implement the methods of interface **javax.ejb.SessionBean** for session EJBs, or interface **javax.ejb.EntityBean** for entity EJBs.
- The EJB container manages the life cycle, client interactions and method invocations, transactions, security and exceptions of an EJB. Clients of an EJB do not interact directly with the EJB. When a client invokes a business method of the EJB's remote interface, the invocation goes first to the EJB container, which then delegates the business method invocation to the EJB implementation.
- Session EJBs exist for the duration of a client's session. Each session EJB instance is associated with a single client. Session EJBs can manipulate data in a database, but unlike entity EJBs, session EJBs are not persistent and do not represent database data directly.
- Stateful session EJBs maintain state information between business method invocations. For example, a stateful session EJB could maintain information about a customer's shopping cart while the customer browses an on-line store.
- Interface **SessionContext** extends interface **EJBContext**, which provides methods for obtaining information about the EJB container.
- The EJB container invokes method **ejbCreate** when a client invokes a **create** method in the home interface. The EJB implementation must provide an **ejbCreate** method for each **create** method declared in the home interface. The **ejbCreate** methods must have the same number and types of arguments as their corresponding **create** methods.
- The EJB container invokes method **ejbRemove** in response to an invocation of method **remove** in the home interface.
- The EJB container invokes method **ejbPassivate** when it determines that the EJB is no longer needed in memory.
- The EJB container invokes method **ejbActivate** to restore an EJB instance that the container passivated previously. The EJB container activates an EJB instance if a client invokes a business method of that EJB instance.
- RMI-IIOP allows RMI objects to interact with CORBA components, which communicate using the *Internet Inter-Orb Protocol* (IIOP). CORBA is a language-independent framework for building distributed systems. To enable interoperability among EJBs and CORBA components, EJBs communicate using RMI-IIOP. We discuss CORBA and RMI-IIOP in detail in Chapter 22.
- Stateless session EJBs maintain no state information between business method invocations. As a result, any stateless session EJB instance can be used to respond to any client's request. This improves the performance of stateless session EJBs over stateful session EJBs.

- The Java 2 Enterprise Edition supports distributed transactions. A distributed transaction is a transaction that is applied across multiple databases or across multiple EJB servers.
- J2EE supports two methods for defining transaction boundaries: bean-managed transaction demarcation and container-managed transaction demarcation. Bean-managed transaction demarcation requires the EJB developer to code the transaction boundaries manually in the EJBs, using the Java Transaction Services. Container-managed transaction demarcation allows the EJB deployer to specify transaction boundaries declaratively when deploying EJBs.
- Bean-managed transaction demarcation requires the EJB developer to code the transaction boundaries manually in the EJBs. Bean-managed transaction demarcation may be used only with session EJBs.
- Container-managed transaction demarcation allows the EJB developer to implement an EJB without specifying transaction boundaries. The EJB deployer provides transaction demarcation semantics declaratively when deploying the application.

## TERMINOLOGY

application server	Internet Inter-Orb Protocol (IIOP)
bean-managed transaction demarcation	J2EE (Java 2 Enterprise Edition)
business methods	Java Transaction Services (JTS)
container-managed transaction demarcation	<b>java.rmi.RemoteException</b>
CORBA (Common Object Request Broker Architecture)	<b>java:comp/env</b> naming context
<b>create</b> methods	<b>javax.ejb.EJBHome</b>
distributed transaction	<b>javax.ejb.EJBObject</b>
EJB container	<b>javax.ejb.SessionBean</b>
EJB implementation	JNDI (Java Naming and Directory Interface) directory
EJB server	least recently used
<b>ejbActivate</b> method	naming context
<b>EJBContext</b> interface	remote interface of an EJB
<b>ejbCreate</b> methods	<b>remove</b> methods
<b>ejbPassivate</b> method	RMI-IIOP
<b>ejbRemove</b> method	session EJB
Enterprise JavaBeans (EJBs)	<b>SessionContext</b> interface
entity EJB	stateful session EJB
home interface	stateless session EJB
<b>IllegalArgumentException</b>	

## SELF-REVIEW EXERCISES

- 14.1 What are the two main types of session EJBs? What is the primary difference between them?
- 14.2 What three Java objects must the EJB developer provide for each EJB?
- 14.3 What are the responsibilities of the EJB container?
- 14.4 How does a client get a remote reference to an EJB instance?
- 14.5 What types of transaction demarcation can EJBs use? What are the benefits of each type?

## ANSWERS TO SELF-REVIEW EXERCISES

- 14.1 There are stateful session EJBs and stateless session EJBs. Stateful session EJBs maintain state information between business method invocations in a client's session. Stateless session EJBs maintain no state information between business method invocations.

**14.2** The EJB developer must provide a remote interface, a home interface and the EJB implementation.

**14.3** The EJB container is responsible for managing the life cycle of the EJB. The EJB container creates classes to implement the home and remote interfaces, and delegates business method invocations to the developer-supplied EJB implementation. The EJB container also provides runtime resources, such as database connections and transactions, as well as life-cycle management.

**14.4** A client looks up the EJB's home interface in a JNDI directory. For session EJBs, the client then invokes one of the home interface's **create** methods. For entity EJBs, the client can invoke one of the home interface's **create** methods or *finder* methods.

**14.5** EJBs can use either bean-managed or container-managed transaction demarcation. Bean-managed transaction demarcation allows the developer to have fine-grained control over transaction boundaries. Container-managed transaction demarcation simplifies the EJB implementation by allowing the EJB deployer to specify transaction boundaries declaratively at deployment time.

## EXERCISES

**14.1** Stateless session EJBs offer a performance advantage over stateful session beans. Convert the example of Fig. 14.3, Fig. 14.4, Fig. 14.5 and Fig. 14.6 from a stateful session EJB to a stateless session EJB.

**14.2** Add a new recursive business method **power( base, exponent )** to the **MathTool** EJB (Fig. 14.21, Fig. 14.22, Fig. 14.23) that, when invoked, returns

```
base exponent
```

For example, **power( 3, 4 ) = 3 \* 3 \* 3 \* 3**. If the **exponent** is not an integer greater than or equal to **1**, **throw** an **IllegalArgumentException**. [Hint: The recursion step would use the relationship

```
base exponent = base . base exponent - 1
```

and the terminating condition occurs when exponent is equal to 1 because

```
base1 = base
```

Modify the client in Fig. 14.24 to enable the user to enter the **base** and **exponent**.]

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# Entity EJBs

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## Objectives

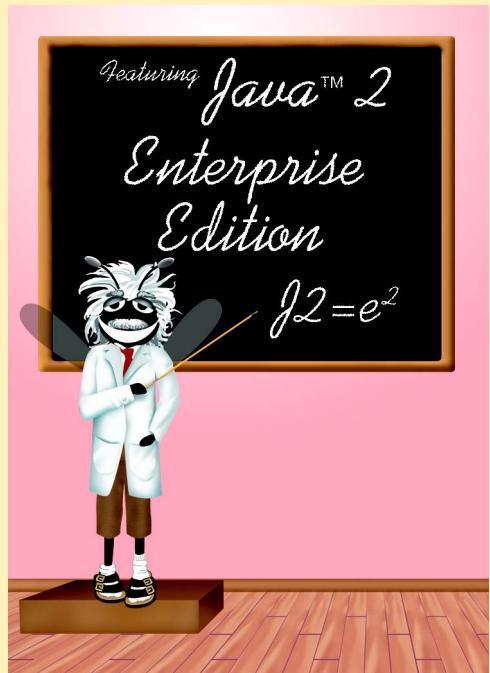
- To understand how entity EJBs represent persistent data.
- To understand synchronization issues between EJBs and database data.
- To understand the life-cycle of an entity EJB.
- To understand the advantages and disadvantages of container-managed and bean-managed persistence.

*There is nothing more requisite in business than dispatch.*  
Joseph Addison

*All meanings, we know, depend on the key of interpretation.*  
George Eliot

*Event that are predestined require but little management.  
They manage themselves. They slip into place while we sleep,  
and suddenly we are aware that the thing we fear to attempt,  
is already accomplished.*

Amelia Barr



## Outline

- 
- 15.1 Introduction**
  - 15.2 Entity EJB Overview**
  - 15.3 Employee Entity EJB**
  - 15.4 Employee EJB Home and Remote Interfaces**
  - 15.5 Employee EJB with Bean-Managed Persistence**
    - 15.5.1 Employee EJB Implementation**
    - 15.5.2 Employee EJB Deployment**
  - 15.6 Employee EJB with Container-Managed Persistence**
  - 15.7 Employee EJB Client**
  - 15.8 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 15.1 Introduction

A fundamental part of an enterprise application is the information tier, which maintains data for the application. In this chapter, we introduce *entity EJBs*, which enable developers to build object-based representations of information-tier data, such as data stored in a relational database. EJB containers provide advanced features that simplify developing entity EJBs. For example, based on information provided at deployment time (e.g., SQL queries), an entity EJB’s container can generate code automatically for storing and retrieving data represented by the EJB. For entity EJBs that represent more complex data (e.g., data stored in multiple database tables), the programmer can implement code for storing and retrieving the data manually.

In this chapter, we present two versions of an entity EJB that represents a company employee. The first version demonstrates an entity EJB that uses JDBC to persist data to a relational database. The second version takes advantage of the container’s ability to manage data storage and retrieval to simplify the EJB implementation. After completing this chapter, you will be able to build and deploy entity EJBs through which business-logic components, such as session EJBs (Chapter 14), can access data in the information tier.

### 15.2 Entity EJB Overview

Each entity EJB instance represents a particular unit of data, such as a record in a database table. There are two types of entity EJBs—those that use *bean-managed persistence* and those that use *container-managed persistence*. Entity EJBs that use bean-managed persistence must implement code for storing and retrieving data from the persistent data sources they represent. For example, an entity EJB that uses bean-managed persistence might use the JDBC API to store and retrieve data in a relational database. Entity EJBs that use container-managed persistence rely on the EJB container to implement the data-access calls to their persistent data sources. The deployer must supply information about the persistent data source when deploying the EJB.

Entity EJBs provide **create** methods for creating new EJB instances, **remove** methods for removing EJB instances and *finder* methods for finding EJB instances. For entity EJBs that represent information in a database, each **create** method performs **INSERT** operations to create new records in the database, and each **remove** method performs **DELETE** operations to remove records from the database. Each *finder* method locates entity EJB instances that conform to certain search criteria (e.g. using **SELECT** operations). We discuss each of these method types throughout the chapter.

### 15.3 Employee Entity EJB

In the following sections, we build an entity EJB that represents an **Employee**. We provide two implementations of the **Employee** EJB. The first implementation (Section 15.5) uses bean-managed persistence to store and retrieve **Employee** information in an underlying database. The second implementation (Section 15.6) uses container-managed persistence. Both of these implementations use the same **Employee** remote interface and **EmployeeHome** interface, which we present in Section 15.4.

We use the Cloudscape database for storing **Employee** data. To create the **Employee** database, run the SQL script **employee.sql** that is on the CD-ROM that accompanies the book. Please see Chapter 8, JDBC, for instructions on running SQL scripts in Cloudscape. To configure the J2EE reference implementation to use the **Employee** database, append the text

```
| jdbc/Employee|jdbc:cloudscape:rmi:Employee;create=true
```

to the end of the **jdbc.datasources** property in the J2EE **default.properties** configuration file.

### 15.4 Employee EJB Home and Remote Interfaces

The **Employee** remote interface (Fig. 15.1) provides methods for setting and getting **Employee** information. Note that interface **Employee** extends interface **EJBObject** (line 11). This is a requirement for all EJB remote interfaces. The **Employee** remote interface provides *set* and *get* methods for each **Employee** property, including the **socialSecurityNumber**, **firstName**, **lastName**, **title** and **salary**. There is no *set* method for property **employeeID** because **employeeID** is the primary key. Each *set* and *get* method throws a **RemoteException**. This is required of all methods in the remote interface.

```
1 // Employee.java
2 // Employee is the remote interface for the Address EJB.
3 package com.deitel.advjhtp1.ejb.entity;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7
8 // Java standard extensions
9 import javax.ejb.EJBObject;
10
11 public interface Employee extends EJBObject {
```

Fig. 15.1 **Employee** remote interface for setting and getting **Employee** information (part 1 of 2).

```
12      // get Employee ID
13  public Integer getEmployeeID() throws RemoteException;
14
15      // set social security number
16  public void setSocialSecurityNumber( String number )
17      throws RemoteException;
18
19      // get social security number
20  public String getSocialSecurityNumber()
21      throws RemoteException;
22
23      // set first name
24  public void setFirstName( String name )
25      throws RemoteException;
26
27      // get first name
28  public String getFirstName() throws RemoteException;
29
30      // set last name
31  public void setLastName( String name )
32      throws RemoteException;
33
34      // get last name
35  public String getLastname() throws RemoteException;
36
37      // set title
38  public void setTitle( String title )
39      throws RemoteException;
40
41      // get title
42  public String getTitle() throws RemoteException;
43
44      // set salary
45  public void setSalary( Double salary ) throws RemoteException;
46
47      // get salary
48  public Double getSalary() throws RemoteException;
49
50 }
```

Fig. 15.1 **Employee** remote interface for setting and getting **Employee** information (part 2 of 2).

An EJB instance represents a particular row in the corresponding database table. The home interface for an entity EJB represents the table as a whole. The home interface provides *finder* methods for locating particular rows in the table and *create* methods for inserting new records. Interface **EmployeeHome** (Fig. 15.2) provides *finder* method **findByPrimaryKey** (lines 15–16) to locate instances of the **Employee** EJB based on a primary key. The primary key for the **Employee** EJB is the **employeeID**. Method **findByPrimaryKey** throws a **FinderException** if the **Employee** with the given **primaryKey** cannot be found. Method **create** (lines 19–20) creates new instances of the **Employee** EJB. Method **create throws** a **CreateException** if there is a problem with creating the EJB instance.

```
1 // EmployeeHome.java
2 // EmployeeHome is the home interface for the Employee EJB.
3 package com.deitel.advjhtp1.ejb.entity;
4
5 // Java core libraries
6 import java.rmi.*;
7 import java.util.*;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public interface EmployeeHome extends EJBHome {
13
14     // find Employee with given primary key
15     public Employee findByPrimaryKey( Integer primaryKey )
16         throws RemoteException, FinderException;
17
18     // create new Employee EJB
19     public Employee create( Integer primaryKey )
20         throws RemoteException, CreateException;
21 }
```

Fig. 15.2 `EmployeeHome` interface for finding and creating `Employee` EJBs.

Method `findByPrimaryKey` is one type of *finder* method for entity EJBs. Every entity EJB must have a `findByPrimaryKey` method that takes the entity EJB's primary-key class as an argument. Entity EJBs also can define additional *finder* methods. A *finder* method name must begin with `findBy` and should end with the name of property to be used as the search criteria. For example, a *finder* method for finding `Employees` based on the `title` property would be named `findByTitle`. A *finder* method for finding `Employees` within a certain salary range would be named `findBySalaryRange`.

## 15.5 Employee EJB with Bean-Managed Persistence

This section describes the `Employee` EJB with bean-managed persistence and deploying the EJB. This bean-managed implementation uses JDBC to store `Employee` data in an underlying database.

### 15.5.1 Employee EJB Implementation

Figure 15.3 shows the `Employee` EJB implementation using bean-managed persistence. Class `EmployeeEJB` implements interface `EntityBean` (line 15). All entity EJB implementations must implement interface `EntityBean`. Line 17 declares an `EntityContext` reference for the EJB's `EntityContext`. The `EntityContext` provides the EJB with information about the container in which the EJB is deployed. The `Connection` object (line 18) is the EJB's `Connection` to the `Employee` database. Lines 20–25 declare `private` member variables that cache data retrieved from the database and updates from the client.

```
1 // EmployeeEJB.java
2 // EmployeeEJB is an entity EJB that uses bean-managed
3 // persistence to persist Employee data in a database.
4 package com.deitel.advjhttp1.ejb.entity.bmp;
5
6 // Java core libraries
7 import java.sql.*;
8 import java.rmi.RemoteException;
9
10 // Java standard extensions
11 import javax.ejb.*;
12 import javax.sql.*;
13 import javax.naming.*;
14
15 public class EmployeeEJB implements EntityBean {
16
17     private EntityContext entityContext;
18     private Connection connection;
19
20     private Integer employeeID;
21     private String socialSecurityNumber;
22     private String firstName;
23     private String lastName;
24     private String title;
25     private Double salary;
26
27     // get Employee ID
28     public Integer getEmployeeID()
29     {
30         return employeeID;
31     }
32
33     // set social security number
34     public void setSocialSecurityNumber( String number )
35     {
36         socialSecurityNumber = number;
37     }
38
39     // get social security number
40     public String getSocialSecurityNumber()
41     {
42         return socialSecurityNumber;
43     }
44
45     // set first name
46     public void setFirstName( String name )
47     {
48         firstName = name;
49     }
50
```

Fig. 15.3 EmployeeEJB implementation of Employee remote interface using bean-managed persistence (part 1 of 8).

```
51     // get first name
52     public String getFirstName()
53     {
54         return firstName;
55     }
56
57     // set last name
58     public void setLastName( String name )
59     {
60         lastName = name;
61     }
62
63     // get last name
64     public String getLastNames()
65     {
66         return lastName;
67     }
68
69     // set title
70     public void setTitle( String jobTitle )
71     {
72         title = jobTitle;
73     }
74
75     // get title
76     public String getTitle()
77     {
78         return title;
79     }
80
81     // set salary
82     public void setSalary( Double amount )
83     {
84         salary = amount;
85     }
86
87     // get salary
88     public Double getSalary()
89     {
90         return salary;
91     }
92
93     // create new Employee
94     public Integer ejbCreate( Integer primaryKey )
95         throws CreateException
96     {
97         employeeID = primaryKey;
98
99         // INSERT new Employee in database
100        try {
```

Fig. 15.3 **EmployeeEJB** implementation of **Employee** remote interface using bean-managed persistence (part 2 of 8).

```
102     // create INSERT statement
103     String insert = "INSERT INTO Employee " +
104         "( employeeID ) VALUES ( ? )";
105
106     // create PreparedStatement to perform INSERT
107     PreparedStatement insertStatement =
108         connection.prepareStatement( insert );
109
110     // set values for PreparedStatement
111     insertStatement.setInt( 1, employeeID.intValue() );
112
113     // execute INSERT and close PreparedStatement
114     insertStatement.executeUpdate();
115     insertStatement.close();
116
117     return employeeID;
118 }
119
120     // throw EJBException if INSERT fails
121     catch ( SQLException sqlException ) {
122         throw new CreateException( sqlException.getMessage() );
123     }
124 } // end method ejbCreate
125
126 // do post-creation tasks when creating new Employee
127 public void ejbPostCreate( Integer primaryKey ) {}
128
129 // remove Employee information from database
130 public void ejbRemove() throws RemoveException
131 {
132     // DELETE Employee record
133     try {
134
135         // get primary key of Employee to be removed
136         Integer primaryKey =
137             ( Integer ) entityContext.getPrimaryKey();
138
139         // create DELETE statement
140         String delete = "DELETE FROM Employee WHERE " +
141             "employeeID = ?";
142
143         // create PreparedStatement to perform DELETE
144         PreparedStatement deleteStatement =
145             connection.prepareStatement( delete );
146
147         // set values for PreparedStatement
148         deleteStatement.setInt( 1, primaryKey.intValue() );
149
150         // execute DELETE and close PreparedStatement
151         deleteStatement.executeUpdate();
152         deleteStatement.close();
153     }
```

Fig. 15.3 EmployeeEJB implementation of Employee remote interface using bean-managed persistence (part 3 of 8).

```
154
155      // throw new EJBException if DELETE fails
156      catch ( SQLException sqlException ) {
157          throw new RemoveException( sqlException.getMessage() );
158      }
159  } // end method ejbRemove
160
161  // store Employee information in database
162  public void ejbStore() throws EJBException
163  {
164      // UPDATE Employee record
165      try {
166
167          // get primary key for Employee to be updated
168          Integer primaryKey =
169              ( Integer ) entityContext.getPrimaryKey();
170
171          // create UPDATE statement
172          String update = "UPDATE Employee SET " +
173              "socialSecurityNumber = ?, firstName = ?, " +
174              "lastName = ?, title = ?, salary = ? " +
175              "WHERE employeeID = ?";
176
177          // create PreparedStatement to perform UPDATE
178          PreparedStatement updateStatement =
179              connection.prepareStatement( update );
180
181          // set values in PreparedStatement
182          updateStatement.setString( 1,socialSecurityNumber );
183          updateStatement.setString( 2,firstName );
184          updateStatement.setString( 3,lastName );
185          updateStatement.setString( 4,title );
186          updateStatement.setDouble( 5,salary.doubleValue() );
187          updateStatement.setInt( 6, primaryKey.intValue() );
188
189          // execute UPDATE and close PreparedStatement
190          updateStatement.executeUpdate();
191          updateStatement.close();
192      }
193
194      // throw EJBException if UPDATE fails
195      catch ( SQLException sqlException ) {
196          throw new EJBException( sqlException );
197      }
198  } // end method ejbStore
199
200  // load Employee information from database
201  public void ejbLoad() throws EJBException
202  {
203      // get Employee record from Employee database table
204      try {
```

Fig. 15.3 **EmployeeEJB** implementation of **Employee** remote interface using bean-managed persistence (part 4 of 8).

```
206      // get primary key for Employee to be loaded
207      Integer primaryKey =
208          ( Integer ) entityContext.getPrimaryKey();
209
210      // create SELECT statement
211      String select = "SELECT * FROM Employee WHERE " +
212          "employeeID = ?";
213
214      // create PreparedStatement for SELECT
215      PreparedStatement selectStatement =
216          connection.prepareStatement( select );
217
218      // set employeeID value in PreparedStatement
219      selectStatement.setInt( 1, primaryKey.intValue() );
220
221      // execute selectStatement
222      ResultSet resultSet = selectStatement.executeQuery();
223
224      // get Employee information from ResultSet and update
225      // local member variables to cache data
226      if ( resultSet.next() ) {
227
228          // get employeeID
229          employeeID = new Integer( resultSet.getInt(
230              "employeeID" ) );
231
232          // get social-security number
233          socialSecurityNumber = resultSet.getString(
234              "socialSecurityNumber" );
235
236          // get first name
237          firstName = resultSet.getString( "firstName" );
238
239          // get last name
240          lastName = resultSet.getString( "lastName" );
241
242          // get job title
243          title = resultSet.getString( "title" );
244
245          // get salary
246          salary = new Double( resultSet.getDouble(
247              "salary" ) );
248
249      } // end if
250
251      else
252          throw new EJBException( "No such employee." );
253
254      // close PreparedStatement
255      selectStatement.close();
256
257  } // end try
```

Fig. 15.3 EmployeeEJB implementation of Employee remote interface using bean-managed persistence (part 5 of 8).

```
258
259      // throw EJBException if SELECT fails
260      catch ( SQLException sqlException ) {
261          throw new EJBException( sqlException );
262      }
263  } // end method ejbLoad
264
265  // find Employee using its primary key
266  public Integer ejbFindByPrimaryKey( Integer primaryKey )
267      throws FinderException, EJBException
268  {
269      // find Employee in database
270      try {
271
272          // create SELECT statement
273          String select = "SELECT employeeID FROM Employee " +
274              "WHERE employeeID = ?";
275
276          // create PreparedStatement for SELECT
277          PreparedStatement selectStatement =
278              connection.prepareStatement( select );
279
280          // set employeeID value in PreparedStatement
281          selectStatement.setInt( 1, primaryKey.intValue() );
282
283          // execute selectStatement
284          ResultSet resultSet = selectStatement.executeQuery();
285
286          // return primary key if SELECT returns a record
287          if ( resultSet.next() ) {
288
289              // close resultSet and selectStatement
290              resultSet.close();
291              selectStatement.close();
292
293              return primaryKey;
294          }
295
296          // throw ObjectNotFoundException if SELECT produces
297          // no records
298          else
299              throw new ObjectNotFoundException();
300      }
301
302      // throw EJBException if SELECT fails
303      catch ( SQLException sqlException ) {
304          throw new EJBException( sqlException );
305      }
306  } // end method ejbFindByPrimaryKey
307
```

Fig. 15.3 **EmployeeEJB** implementation of **Employee** remote interface using bean-managed persistence (part 6 of 8).

```
308 // set EntityContext and create DataSource Connection
309 public void setEntityContext( EntityContext context )
310     throws EJBException
311 {
312     // set entityContext
313     entityContext = context;
314
315     // look up the Employee DataSource and create Connection
316     try {
317         InitialContext initialContext = new InitialContext();
318
319         // get DataSource reference from JNDI directory
320         DataSource dataSource = ( DataSource )
321             initialContext.lookup(
322                 "java:comp/env/jdbc/Employee" );
323
324         // get Connection from DataSource
325         connection = dataSource.getConnection();
326     }
327
328     // handle exception if DataSource not found in directory
329     catch ( NamingException namingException ) {
330         throw new EJBException( namingException );
331     }
332
333     // handle exception when getting Connection to DataSource
334     catch ( SQLException sqlException ) {
335         throw new EJBException( sqlException );
336     }
337 } // end method setEntityContext
338
339 // unset EntityContext
340 public void unsetEntityContext() throws EJBException
341 {
342     entityContext = null;
343
344     // close DataSource Connection
345     try {
346         connection.close();
347     }
348
349     // throw EJBException if closing Connection fails
350     catch ( SQLException sqlException ) {
351         throw new EJBException( sqlException );
352     }
353
354     // prepare connection for reuse
355     finally {
356         connection = null;
357     }
358 }
359 }
```

Fig. 15.3 **EmployeeEJB** implementation of **Employee** remote interface using bean-managed persistence (part 7 of 8).

```

360    // set employeeID to null when container passivates EJB
361    public void ejbPassivate()
362    {
363        employeeID = null;
364    }
365
366    // get primary key value when container activates EJB
367    public void ejbActivate()
368    {
369        employeeID = ( Integer ) entityContext.getPrimaryKey();
370    }
371 }

```

Fig. 15.3 EmployeeEJB implementation of Employee remote interface using bean-managed persistence (part 8 of 8).

Lines 28–91 provide implementations of the *set* and *get* business methods declared in the **Employee** remote interface. When a client invokes interface **EmployeeHome** method **create**, the EJB container invokes method **ejbCreate** (lines 94–126). This EJB uses bean-managed persistence, so method **ejbCreate** must implement the appropriate logic to create a new **Employee** in the underlying database. Line 97 sets the **employeeID** member variable to the value of the **primaryKey** argument. Lines 103–111 create a **PreparedStatement** to **INSERT** the new **Employee** in the database. Line 111 sets the **employeeID** in the **PreparedStatement**, and line 114 inserts the new record by invoking **PreparedStatement** method **executeUpdate**. Line 115 closes the **PreparedStatement**, and line 117 returns the **employeeID** primary key. Lines 121–122 **catch** the **SQLException** that could be thrown when creating, executing or closing the **PreparedStatement**. An **SQLException** would indicate a problem inserting the record, so line 122 throws a **CreateException** to indicate that method **ejbCreate** could not create the **Employee** EJB instance.

Method **ejbCreate** declares an **Integer** return type. All **ejbCreate** methods in entity EJBs are required to return the EJB's *primary-key class*. The primary key for the **Employee** table is an integer, so the primary-key class for the **Employee** EJB is **java.lang.Integer**. Most EJBs use a standard Java class (e.g., **Integer** or **String**) as their primary-key class. If a database table has a *complex primary key* (i.e., a primary key that consists of more than one field), the developer must define a custom primary-key class. For an example of a custom primary-key class, please see the **Order-Product** EJB example in Chapter 19.

The EJB container invokes method **ejbPostCreate** (line 127) after invoking method **ejbCreate** to perform any required tasks after creating the EJB instance. For example, method **ejbPostCreate** could change the format of the **socialSecurityNumber** to include dashes. No additional work is needed in this EJB, so line 127 is an empty implementation of method **ejbPostCreate**.

When a client invokes method **remove** in either the **Employee** remote interface or interface **EmployeeHome**, the EJB container invokes method **ejbRemove** (lines 130–159). To **remove** an entity EJB instance means to **DELETE** the associated database record. Lines 136–137 get the primary key for the current EJB instance from the **entityContext** object associated with the EJB. Lines 140–145 create a **PreparedStatement** to **DELETE** the **Employee** record from the database. Line 148 sets the **employeeID** primary key in

the **PreparedStatement**. Lines 151–152 execute and close the **PreparedStatement**. Lines 156–158 catch the **SQLException** that could be thrown when creating, executing or closing the **PreparedStatement**. If an **SQLException** is thrown, line 157 throws a **RemoveException** to indicate that removing the **Employee** EJB failed.

The EJB container invokes method **ejbStore** to save **Employee** data in the database. The EJB container determines the best time to update the database, so method **ejbStore** is only called by the container. Lines 168–169 get the primary key for the current EJB instance from the **entityContext**. Lines 172–187 create a **PreparedStatement** to **UPDATE** the **Employee** record in the database. Lines 190–191 execute and close the **PreparedStatement**. Lines 195–196 catch the **SQLException** that could be thrown when creating, executing or closing the **PreparedStatement**. Line 196 throws an **EJBException** to indicate the **ejbStore** method failed to update the data properly. Line 196 passes the **SQLException** to the **EJBException** constructor to aid in debugging the application.

The EJB container invokes method **ejbLoad** to load **Employee** data from the database and store the data in the EJB instance's member variables. The EJB container determines the best time to load from the database, so method **ejbLoad** is only called by the container. Lines 207–208 get the primary key for the current **Employee** EJB instance from the EJB's **EntityContext**. Lines 211–219 create a **PreparedStatement** to **SELECT** the **Employee** data from the database. Line 226 ensures that the **ResultSet** contains data, and lines 229–247 update the **private** member variables with the data from the **ResultSet**. Line 252 throws a new **EJBException** if the **ResultSet** is empty. Lines 260–262 catch an **SQLException** and throw an **EJBException** to indicate the **ejbLoad** method failed to load the **Employee** information from the database.

When a client invokes **EmployeeHome** method **findByPrimaryKey**, the EJB container invokes method **ejbFindByPrimaryKey** (lines 266–306). Method **findByPrimaryKey** must take a single argument whose type is the EJB's primary-key class. Lines 273–281 create a **PreparedStatement** to **SELECT** data from the database for the **Employee** with the given **employeeID** primary key. Lines 287–294 check on whether the **Employee** was found and return its primary key. If the **Employee** with the given primary key was not found in the database, lines 298–299 **throw** an **ObjectNotFound****Exception**. If there was an error in searching for the **Employee**, lines 303–305 catch an **SQLException** and throw a new **EJBException**.

The EJB container invokes method **setEntityContext** after the EJB instance is first created, but before the EJB instance is associated with a particular database record. The **EntityContext** argument provides methods for obtaining information about the EJB container in which the EJB instance executes. Line 313 sets the **entityContext** member variable so other methods can use the given **EntityContext** to discover information about the EJB container. There are some restrictions on what can be done in method **setEntityContext**, because when this method is invoked, the EJB instance is not yet associated with a particular database record. For example, the EJB must not invoke **EntityContext** method **getPrimaryKey**, because there is no primary key associated with the current EJB instance. Invoking **EntityContext** method **getPrimaryKey** would cause an **IllegalStateException**.

Method **setEntityContext** should allocate resources the EJB instance will need throughout its lifetime. This **Employee** EJB implementation uses bean-managed persis-

tence and therefore needs a database **Connection** to exchange data with the database throughout the EJB's lifetime. Line 317 creates a new **InitialContext** that the EJB will use to look up the **Employee** database in the JNDI directory. Lines 320–322 invoke **InitialContext** method **lookup** to obtain a **DataSource** reference to the **Employee** database. J2EE applications use a special JNDI naming context called **java:comp/env**, which stands for “component environment.” There are subcontexts in the **java:comp/env** naming context for different types of objects. For example, EJBs are found in the **ejb** subcontext and databases are found in the **jdbc** subcontext. Line 322 uses the JNDI name **java:comp/env/jdbc/Employee** to locate the **Employee** database in the JNDI directory. Line 325 sets the **connection** member variable to a newly created database **Connection**. If the database with the given name cannot be found, lines 329–331 catch a **NamingException**, which is thrown by the **InitialContext** constructor or by method **lookup**.



### Common Programming Error 15.1

The **java:comp/env** naming context is available only within a J2EE application (e.g., in a servlet, JSP or EJB). Using this naming context in a Java application or applet will result in a **javax.naming.NamingException**.

The EJB container invokes method **unsetEntityContext** (lines 340–358) when the EJB instance is no longer needed. Method **unsetEntityContext** should deallocate any resources the EJB instance used throughout its lifetime. Line 346 closes the **Connection** to the database. If there was an error closing the database **Connection**, lines 350–352 catch an **SQLException** and throw an **EJBException**. Lines 355–357 set the **Connection** to **null** for later reuse.

The EJB container maintains a pool of inactive EJB instances that the container can associate with particular database records when needed. This pooling prevents the EJB container from incurring the overhead required to create a new EJB instance each time an EJB instance is needed. The EJB container invokes method **ejbPassivate** (lines 361–364) to place an active EJB back in the inactive pool. Line 363 sets the **employeeID** to **null** because a passivated EJB is no longer associated with any particular database record.

The EJB container invokes method **ejbActivate** (lines 367–371) to activate an EJB instance taken from the pool of inactive EJB instances. Line 369 sets the **employeeID** to the **primaryKey** value retrieved from the EJB's **entityContext** to associate the EJB with the appropriate database record.

#### 15.5.2 Employee EJB Deployment

Deploying entity EJBs is similar to deploying session EJBs (Chapter 14), but with the following changes. In the **General** dialog of the **New Enterprise Bean Wizard**, select the **Entity** radio button in the **Bean Type** field (Fig. 15.4). Next, select the type of persistence in the **Entity Settings** dialog. Click the **Bean-Managed Persistence** radio button for bean-managed persistence and enter the class name for the primary key in the **Primary Key Class** text field (Fig. 15.5). Finally, in the **Resource References** dialog, add a reference to the **Employee** database. The information for the reference must match that in Fig. 15.6. The rest of the deployment is the same as deploying a session EJB. For the Employee EJB's JNDI name, we recommend you specify **BMPEmployee** for the bean-managed persistence version.

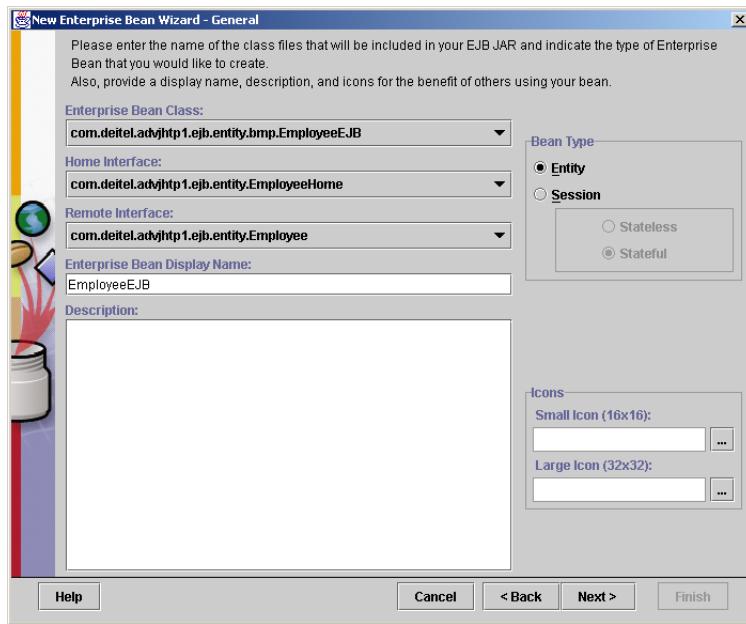


Fig. 15.4 General dialog of New Enterprise Bean Wizard.

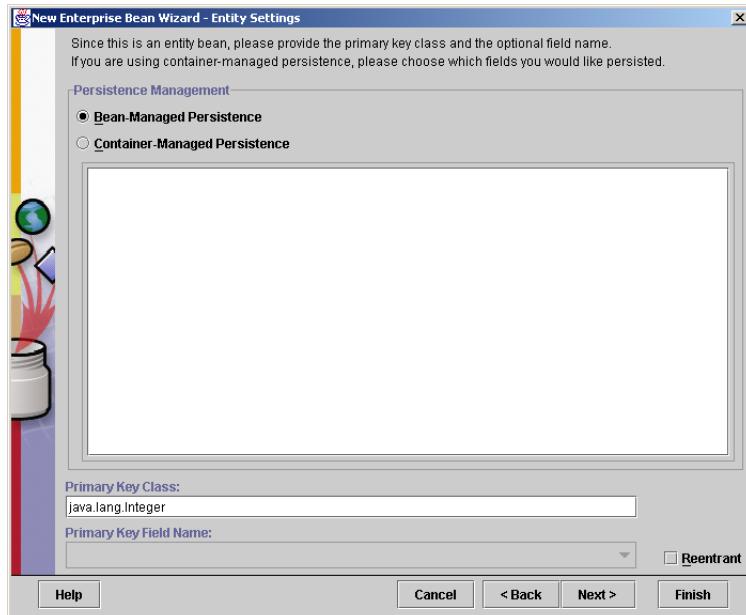


Fig. 15.5 Bean-Managed Persistence selected in Entity Settings dialog.

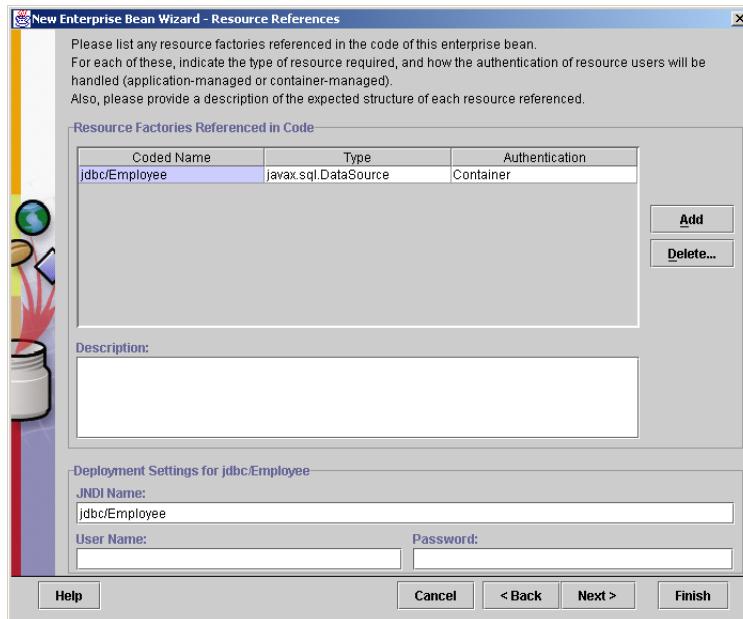


Fig. 15.6 Resource References dialog in New Enterprise Bean Wizard.

## 15.6 Employee EJB with Container-Managed Persistence

Figure 15.7 shows an **Employee** EJB implementation that uses container-managed persistence to simplify the EJB implementation. Class **EmployeeEJB** implements interface **EntityBean** (line 12), indicating that this is an entity EJB. Line 14 declares an **EntityContext** reference to store the **EntityContext** associated with the EJB instance.

Lines 17–22 declare the *container-managed fields* for the **Employee** EJB. Container-managed fields are member variables that a container-managed persistence EJB instance uses to cache data retrieved from the database. The container-managed fields must have the same names as the fields in the corresponding database table. The container-managed fields also must be marked **public** so the EJB container can access them directly. The EJB container is responsible for synchronizing the container-managed fields with the database. When deploying the EJB, the deployer must provide the SQL statements for updating, inserting, deleting and retrieving data from the database. Lines 25–88 provide implementations of the methods declared in the **Employee** remote interface.

Method **ejbCreate** (lines 91–96) takes an **Integer primaryKey** argument and stores this **primaryKey** in the **employeeID** member variable (line 93). The EJB container executes the SQL **INSERT** statement (supplied by the deployer) after method **ejbCreate** completes. This SQL **INSERT** statement takes the current values of the container-managed fields in the EJB and inserts their values into the database. Note that, although method **ejbCreate** specifies **Integer** as its return type (line 91), line 95 returns **null**. According to the EJB specification, method **ejbCreate** must return the primary-key class type, which for the **Employee** EJB is **Integer**. However, the EJB container ignores the return value from **ejbCreate** when using container-managed per-

sistence, so we return **null**. The EJB specification requires an **ejbPostCreate** method for each **ejbCreate** method. Line 99 provides an empty implementation of method **ejbPostCreate** because this EJB requires no further initialization.

Methods **setEntityContext** (lines 102–105) and **unsetEntityContext** (lines 108–111) manage the **EntityContext** member variable. This EJB implementation does not have any resources it needs throughout the EJB lifetime, so no other work is done in either method.

```
1 // EmployeeEJB.java
2 // EmployeeEJB is an entity EJB that uses container-managed
3 // persistence to persist Employee data in a database.
4 package com.deitel.advjhttp1.ejb.entity.cmp;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public class EmployeeEJB implements EntityBean {
13
14     private EntityContext entityContext;
15
16     // container-managed fields
17     public Integer employeeID;
18     public String socialSecurityNumber;
19     public String firstName;
20     public String lastName;
21     public String title;
22     public Double salary;
23
24     // get Employee ID
25     public Integer getEmployeeID()
26     {
27         return employeeID;
28     }
29
30     // set social security number
31     public void setSocialSecurityNumber( String number )
32     {
33         socialSecurityNumber = number;
34     }
35
36     // get social security number
37     public String getSocialSecurityNumber()
38     {
39         return socialSecurityNumber;
40     }
41
```

Fig. 15.7 EmployeeEJB implementation of Employee remote interface using container-managed persistence (part 1 of 3).

```
42 // set first name
43 public void setFirstName( String name )
44 {
45     firstName = name;
46 }
47
48 // get first name
49 public String getFirstName()
50 {
51     return firstName;
52 }
53
54 // set last name
55 public void setLastName( String name )
56 {
57     lastName = name;
58 }
59
60 // get last name
61 public String getLastname()
62 {
63     return lastName;
64 }
65
66 // set title
67 public void setTitle( String jobTitle )
68 {
69     title = jobTitle;
70 }
71
72 // get title
73 public String getTitle()
74 {
75     return title;
76 }
77
78 // set salary
79 public void setSalary( Double amount )
80 {
81     salary = amount;
82 }
83
84 // get salary
85 public Double getSalary()
86 {
87     return salary;
88 }
89
90 // create new Employee instance
91 public Integer ejbCreate( Integer primaryKey )
92 {
93     employeeID = primaryKey;
```

Fig. 15.7 EmployeeEJB implementation of Employee remote interface using container-managed persistence (part 2 of 3).

```
94         return null;
95     }
96
97     // do post-creation tasks when creating new Employee
98     public void ejbPostCreate( Integer primaryKey ) {}
99
100    // set EntityContext
101    public void setEntityContext( EntityContext context )
102    {
103        entityContext = context;
104    }
105
106    // unset EntityContext
107    public void unsetEntityContext()
108    {
109        entityContext = null;
110    }
111
112    // activate Employee instance
113    public void ejbActivate()
114    {
115        employeeID = ( Integer ) entityContext.getPrimaryKey();
116    }
117
118    // passivate Employee instance
119    public void ejbPassivate()
120    {
121        employeeID = null;
122    }
123
124    // load Employee instance in database
125    public void ejbLoad() {}
126
127    // store Employee instance in database
128    public void ejbStore() {}
129
130    // remove Employee instance from database
131    public void ejbRemove() {}
132
133 }
```

Fig. 15.7 **EmployeeEJB** implementation of **Employee** remote interface using container-managed persistence (part 3 of 3).

Methods **ejbActivate** (lines 114–117) and **ejbPassivate** (lines 120–123) perform the same functions they did in the bean-managed persistence version of the **Employee** EJB. Method **ejbActivate** associates an EJB instance taken from the inactive pool with a particular database record, and method **ejbPassivate** disassociates the EJB instance from its database record.

Methods **ejbLoad** (line 126), **ejbStore** (line 129) and **ejbRemove** (line 132) also perform the same functions they did in the bean-managed persistence version of the **Employee** EJB. However with container-managed persistence, the deployer specifies the necessary **SELECT**, **UPDATE** and **DELETE** statements when deploying the application.

The EJB container executes these statements at runtime. These methods could perform further processing on the data if necessary. No further processing is necessary in this **Employee** EJB, so these methods are given empty implementations.



### Common Programming Error 15.2

*For entity EJBs using container-managed persistence, the EJB container loads database data and invokes method `ejbLoad` when the client first invokes a business method. However, the business method must be invoked in a transaction context.*



### Performance Tip 15.1

*Entity EJBs using container-managed persistence might not perform as well as their bean-managed persistence counterparts, because all database data is loaded before the EJB container invokes method `ejbLoad`. Entity EJBs using bean-managed persistence can defer the loading of data from the database until the data is needed, which may enhance performance for EJBs with large amounts of data.*

To deploy the container-managed persistence version of the Employee EJB, follow the instructions in Section 15.5.2. We recommend you use the JNDI Name **CMPEmployee** for the container-managed persistence version of the **Employee** EJB. In the **Persistence Management** dialog (Fig. 15.8), click the **Container-Managed Persistence** radio button and place check marks next to each container-managed field. Enter the class name of the primary key in the **Primary Key Class** text field and select the primary key field name from the **Primary Key Field Name** drop-down menu.

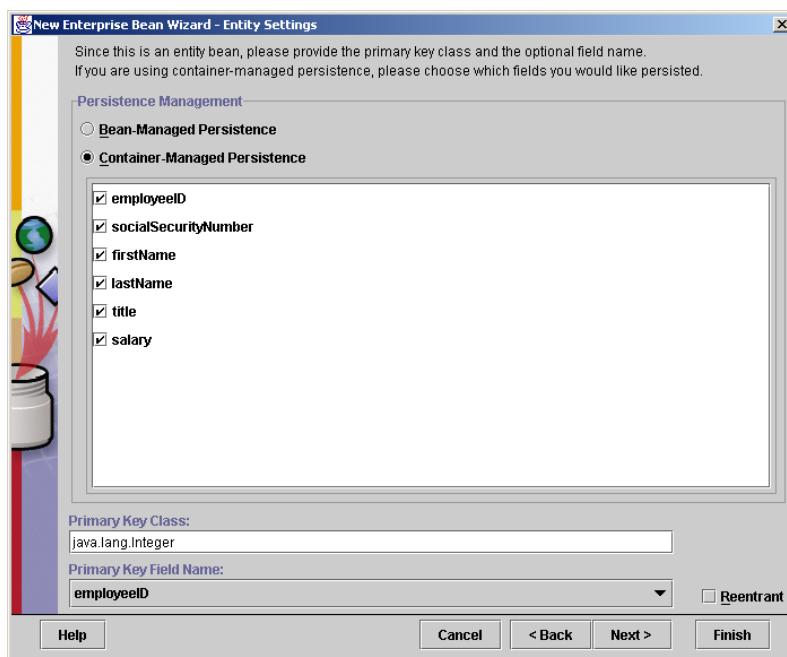


Fig. 15.8 Container-Managed Persistence selected in Entity Settings dialog.

## 15.7 Employee EJB Client

Figure 15.9 shows class **EmployeeEJBClient** for interacting with entity EJB **Employee**. The GUI provides buttons for finding, adding, updating and deleting **Employee** EJBs, and **JTextFields** for displaying **Employee** information. Lines 26–27 declare an **EmployeeHome** reference and an **Employee** reference for accessing the **Employee** EJB. The **EmployeeEJBClient** constructor takes a **String** argument containing the JNDI Name of the **Employee** EJB to load. This client works with both the bean-managed and container-managed persistence versions of the **Employee** EJB, because both versions use the same home and remote interfaces. The constructor uses the **JNDIName** argument to determine which version of the **Employee** EJB to use.

Line 47 creates a new **InitialContext** to look up the **Employee** EJB using the **JNDIName** argument. Lines 50–51 look up the **EmployeeHome** interface using **InitialContext** method **lookup**. Lines 54–56 use **PortableRemoteObject** method **narrow** to convert the **Object** reference returned by method **lookup** to an **EmployeeHome** reference. We will use this **EmployeeHome** reference throughout the program to create, find and remove **Employee** EJBs. If there is an error creating the **InitialContext** or looking up the **EmployeeHome** interface, lines 60–62 **catch** a **NamingException**.

Method **getEmployeeID** (lines 74–85) displays a **JOptionPane** to prompt the user for an **employeeID**. This **employeeID** can be used to find an existing **Employee** EJB instance or to create a new **Employee** EJB instance.

Method **getEmployee** (lines 88–119) uses method **getEmployeeID** on line 91 to prompt the user for the **employeeID** of the **Employee** the user would like to find. Lines 99–100 use **EmployeeHome** method **findByPrimaryKey** to locate the **Employee** EJB instance for the **Employee** with the given **employeeID**. Method **findByPrimaryKey** returns a remote reference to the **Employee** EJB instance. Line 103 invokes method **setCurrentEmployee** to display the **Employee**'s information to the user. If there was an error communicating with the **Employee** EJB, lines 107–111 **catch** a **RemoteException**. If there is no **Employee** with the given **employeeID**, lines 114–118 catch a **FinderException**.

Method **addEmployee** (lines 122–150) adds a new **Employee** to the database by creating a new **Employee** EJB. Line 126 invokes method **getEmployeeID** to prompt the user for an **employeeID**. Line 133 invokes **EmployeeHome** method **create** to create a new **Employee** EJB instance with the given **employeeID**. Line 136 invokes method **setCurrentEmployee** to display the **Employee**'s information to the user. Lines 140–143 **catch** a **CreateException**, which is thrown if there is an error creating the **Employee** EJB. For example, if the **employeeID** entered by the user is already in use by another **Employee** EJB, the EJB container will throw a **DuplicateKeyException**, which is a subclass of **CreateException**. If there is an error communicating with the **Employee** EJB, lines 146–149 catch a **RemoteException**.

Method **updateEmployee** (lines 153–184) uses the values provided in the **JTextFields** to update the current **Employee**'s information. Lines 159–175 invoke the **Employee** EJB **set** methods with values from each **JTextField**. If there is an error communicating with the **Employee** EJB, lines 180–183 catch a **RemoteException**.

Method **deleteEmployee** (lines 187–214) deletes the current **Employee** from the database by invoking **Employee** EJB method **remove** (line 191). Lines 194–199 set the

**JTextFields** in the user interface to the empty string. If there is an error communicating with the **Employee** EJB, lines 204–207 **catch** a **RemoteException**. If there is an error removing the **Employee** EJB, lines 210–213 **catch** a **RemoveException**.

Method **setCurrentEmployee** (lines 217–266) takes an **Employee** remote reference argument and updates the user interface with the information from this **Employee** EJB. Lines 224–258 retrieve values for each of the **Employee** EJB properties and update the **JTextFields** in the user interface. If there is an error communicating with the **Employee** EJB, lines 262–265 catch a **RemoteException**.

```
1 // EmployeeEJBClient.java
2 // EmployeeEJBClient is a user interface for interacting with
3 // bean- and container-managed persistence Employee EJBs.
4 package com.deitel.advjhtp1.ejb.entity.client;
5
6 // Java core libraries
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.text.*;
10 import java.util.*;
11 import java.rmi.RemoteException;
12
13 // Java standard extensions
14 import javax.swing.*;
15 import javax.ejb.*;
16 import javax.naming.*;
17 import javax.rmi.*;
18
19 // Deitel libraries
20 import com.deitel.advjhtp1.ejb.entity.*;
21
22 public class EmployeeEJBClient extends JFrame {
23
24     // variables for accessing EJBs
25     private InitialContext initialContext;
26     private EmployeeHome employeeHome;
27     private Employee currentEmployee;
28
29     // JTextFields for user input
30     private JTextField employeeIDTextField;
31     private JTextField socialSecurityTextField;
32     private JTextField firstNameTextField;
33     private JTextField lastNameTextField;
34     private JTextField titleTextField;
35     private JTextField salaryTextField;
36
37     // BMPEmployeeEJBClient constructor
38     public EmployeeEJBClient( String JNDIName )
39     {
40         super( "Employee EJB Client" );
41     }
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 1 of 9).

```
42     // create user interface
43     createGUI();
44
45     // get EmployeeHome reference for Employee EJB
46     try {
47         initialContext = new InitialContext();
48
49         // look up Employee EJB using given JNDI name
50         Object homeObject =
51             initialContext.lookup( JNDIName );
52
53         // get EmployeeHome interface
54         employeeHome = ( EmployeeHome )
55             PortableRemoteObject.narrow(
56                 homeObject, EmployeeHome.class );
57     }
58
59     // handle exception when looking up Employee EJB
60     catch ( NamingException namingException ) {
61         namingException.printStackTrace( System.err );
62     }
63
64     // close application when user closes window
65     setDefaultCloseOperation( EXIT_ON_CLOSE );
66
67     // set size of application window and make it visible
68     setSize( 600, 300 );
69     setVisible( true );
70
71 } // end EmployeeEJBClient constructor
72
73 // prompt user for employeeID
74 private Integer getEmployeeID()
75 {
76     String primaryKeyString = JOptionPane.showInputDialog(
77         this, "Please enter an employeeID" );
78
79     // check if primaryKeyString is null, else return
80     // Integer
81     if ( primaryKeyString == null )
82         return null;
83     else
84         return new Integer( primaryKeyString );
85 }
86
87 // get Employee reference for user-supplied employeeID
88 private void getEmployee()
89 {
90     // prompt user for employeeID and get Employee reference
91     Integer employeeID = getEmployeeID();
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 2 of 9).

```
93     // return if employeeID is null
94     if ( employeeID == null )
95         return;
96
97     try {
98         // find Employee with given employeeID
99         Employee employee =
100             employeeHome.findByPrimaryKey( employeeID );
101
102         // update display with current Employee
103         setCurrentEmployee( employee );
104     }
105
106     // handle exception when finding Employee
107     catch ( RemoteException remoteException ) {
108         JOptionPane.showMessageDialog(
109             EmployeeEJBClient.this,
110             remoteException.getMessage() );
111     }
112
113     // handle exception when finding Employee
114     catch ( FinderException finderException ) {
115         JOptionPane.showMessageDialog(
116             EmployeeEJBClient.this, "Employee not " +
117             "found: " + finderException.getMessage() );
118     }
119 } // end method getEmployee
120
121 // add new Employee by creating new Employee EJB instance
122 private void addEmployee()
123 {
124     // prompt user for employeeID and create Employee
125     try {
126         Integer employeeID = getEmployeeID();
127
128         // return if employeeID null
129         if ( employeeID == null )
130             return;
131
132         // create new Employee
133         Employee employee = employeeHome.create( employeeID );
134
135         // update display with new Employee
136         setCurrentEmployee( employee );
137     }
138
139     // handle exception when creating Employee
140     catch ( CreateException createException ) {
141         JOptionPane.showMessageDialog( this,
142             createException.getMessage() );
143     }
144 }
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 3 of 9).

```
145     // handle exception when creating Employee
146     catch ( RemoteException remoteException ) {
147         JOptionPane.showMessageDialog( this,
148             remoteException.getMessage() );
149     }
150 } // end method addEmployee
151
152 // update current Employee with user-supplied information
153 private void updateEmployee()
154 {
155     // get information from JTextFields and update Employee
156     try {
157
158         // set Employee socialSecurityNumber
159         currentEmployee.setSocialSecurityNumber(
160             socialSecurityTextField.getText() );
161
162         // set Employee firstName
163         currentEmployee.setFirstName(
164             firstNameTextField.getText() );
165
166         // set Employee lastName
167         currentEmployee.setLastName(
168             lastNameTextField.getText() );
169
170         // set Employee title
171         currentEmployee.setTitle( titleTextField.getText() );
172
173         // set Employee salary
174         Double salary = new Double( salaryTextField.getText() );
175         currentEmployee.setSalary( salary );
176
177     } // end try
178
179     // handle exception invoking Employee business methods
180     catch ( RemoteException remoteException ) {
181         JOptionPane.showMessageDialog( this,
182             remoteException.getMessage() );
183     }
184 } // end method updateEmployee
185
186 // delete current Employee
187 private void deleteEmployee()
188 {
189     // remove current Employee EJB
190     try {
191         currentEmployee.remove();
192
193         // clear JTextFields
194         employeeIDTextField.setText( "" );
195         socialSecurityTextField.setText( "" );
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 4 of 9).

```
196         firstNameTextField.setText( "" );
197         lastNameTextField.setText( "" );
198         titleTextField.setText( "" );
199         salaryTextField.setText( "" );
200
201     } // end try
202
203     // handle exception when removing Employee
204     catch ( RemoteException remoteException ) {
205         JOptionPane.showMessageDialog( this,
206             remoteException.getMessage() );
207     }
208
209     // handle exception when removing Employee
210     catch ( RemoveException removeException ) {
211         JOptionPane.showMessageDialog( this,
212             removeException.getMessage() );
213     }
214 } // end method deleteEmployee
215
216 // update display with current Employee information
217 private void setCurrentEmployee( Employee employee )
218 {
219     // get information for currentEmployee and update display
220     try {
221         currentEmployee = employee;
222
223         // get the employeeID
224         Integer employeeID = ( Integer )
225             currentEmployee.getEmployeeID();
226
227         // update display
228         employeeIDTextField.setText( employeeID.toString() );
229
230         // set socialSecurityNumber in display
231         socialSecurityTextField.setText(
232             currentEmployee.getSocialSecurityNumber() );
233
234         // set firstName in display
235         firstNameTextField.setText(
236             currentEmployee.getFirstName() );
237
238         // set lastName in display
239         lastNameTextField.setText(
240             currentEmployee.getLastName() );
241
242         // set title in display
243         titleTextField.setText( currentEmployee.getTitle() );
244
245         // get Employee salary
246         Double salary = (Double) currentEmployee.getSalary();
247     }
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 5 of 9).

```
248         // ensure salary is not null and update display
249         if ( salary != null ) {
250             NumberFormat dollarFormatter =
251                 NumberFormat.getCurrencyInstance(
252                     Locale.US );
253
254             salaryTextField.setText( dollarFormatter.format(
255                 salary ) );
256         }
257         else
258             salaryTextField.setText( "" );
259     } // end try
260
261     // handle exception invoking Employee business methods
262     catch ( RemoteException remoteException ) {
263         JOptionPane.showMessageDialog( this,
264             remoteException.getMessage() );
265     }
266 } // end method setCurrentEmployee
267
268 // create the application GUI
269 private void createGUI()
270 {
271     // create JPanel for Employee form components
272     JPanel formPanel = new JPanel( new GridLayout( 6, 2 ) );
273
274     // create read-only JTextField for employeeID
275     employeeIDTextField = new JTextField();
276     employeeIDTextField.setEditable( false );
277     formPanel.add( new JLabel( "Employee ID" ) );
278     formPanel.add( employeeIDTextField );
279
280     // create JTextField and JLabel for social security #
281     socialSecurityTextField = new JTextField();
282     formPanel.add( new JLabel( "Social Security #" ) );
283     formPanel.add( socialSecurityTextField );
284
285     // create JTextField and JLabel for first name
286     firstNameTextField = new JTextField();
287     formPanel.add( new JLabel( "First Name" ) );
288     formPanel.add( firstNameTextField );
289
290     // create JTextField and JLabel for last name
291     lastNameTextField = new JTextField();
292     formPanel.add( new JLabel( "Last Name" ) );
293     formPanel.add( lastNameTextField );
294
295     // create JTextField and JLabel for job title
296     titleTextField = new JTextField();
297     formPanel.add( new JLabel( "Title" ) );
298     formPanel.add( titleTextField );
299 }
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 6 of 9).

```
300     // create JTextField and JLabel for salary
301     salaryTextField = new JTextField();
302     formPanel.add( new JLabel( "Salary" ) );
303     formPanel.add( salaryTextField );
304
305     // add formPanel to the JFrame's contentPane
306     Container contentPane = getContentPane();
307     contentPane.add( formPanel, BorderLayout.CENTER );
308
309     // create JPanel for JButtons
310     JPanel employeeButtonPanel =
311         new JPanel( new FlowLayout() );
312
313     // create JButton for adding Employees
314     JButton addButton = new JButton( "Add Employee" );
315     addButton.addActionListener(
316         new ActionListener() {
317
318             public void actionPerformed( ActionEvent event )
319             {
320                 addEmployee();
321             }
322         }
323     );
324     employeeButtonPanel.add( addButton );
325
326     // create JButton for saving Employee information
327     JButton saveButton = new JButton( "Save Changes" );
328     saveButton.addActionListener(
329         new ActionListener() {
330
331             public void actionPerformed( ActionEvent event )
332             {
333                 updateEmployee();
334             }
335         }
336     );
337     employeeButtonPanel.add( saveButton );
338
339     // create JButton for deleting Employees
340     JButton deleteButton = new JButton( "Delete Employee" );
341     deleteButton.addActionListener(
342         new ActionListener() {
343
344             public void actionPerformed( ActionEvent event )
345             {
346                 deleteEmployee();
347             }
348         }
349     );
350     employeeButtonPanel.add( deleteButton );
351
```

Fig. 15.9 **EmployeeEJBClient** for interacting with **Employee** EJB (part 7 of 9).

```
352     // create JButton for finding existing Employees
353     JButton findButton = new JButton( "Find Employee" );
354     findButton.addActionListener(
355         new ActionListener() {
356
357             public void actionPerformed( ActionEvent event )
358             {
359                 getEmployee();
360             }
361         }
362     );
363     employeeButtonPanel.add( findButton );
364
365     // add employeeButtonPanel to JFrame's contentPane
366     contentPane.add( employeeButtonPanel,
367                     BorderLayout.NORTH );
368
369 } // end method createGUI
370
371 // execute application
372 public static void main( String[] args )
373 {
374     // ensure user provided JNDI name for Employee EJB
375     if ( args.length != 1 ) {
376         System.err.println(
377             "Usage: java EmployeeEJBClient <JNDI Name>" );
378         System.exit( 1 );
379     }
380
381     // start application using provided JNDI name
382     else
383         new EmployeeEJBClient( args[ 0 ] );
384 }
385 }
```

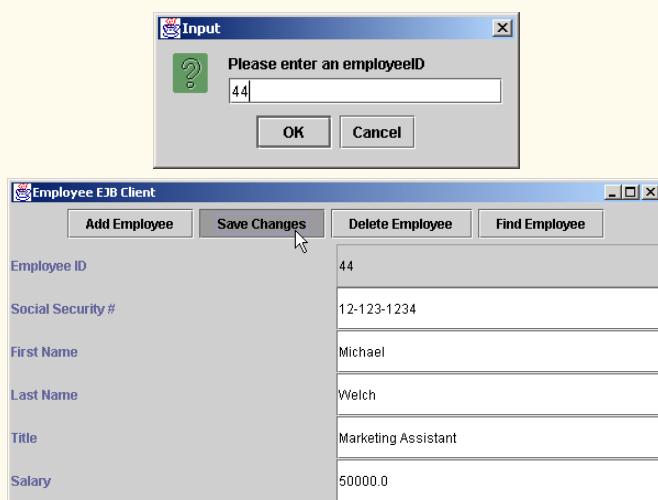
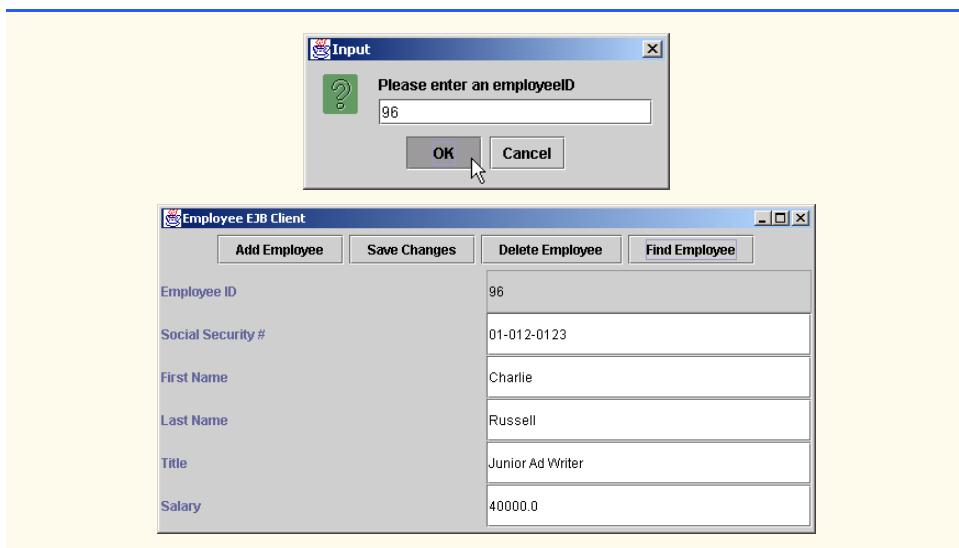


Fig. 15.9 EmployeeEJBClient for interacting with Employee EJB (part 8 of 9).



**Fig. 15.9 EmployeeEJBClient** for interacting with **Employee** EJB (part 9 of 9).

Method **createGUI** (lines 269–369) builds the user interface for the **EmployeeEJBClient**. Lines 275–303 create **JTextFields** and **JLabels** for each **Employee** property. Lines 314–363 create **JButtons** and associated **ActionListeners** to allow the user to add, update, delete and find **Employees**.

Method **main** (lines 372–384) requires that the user provide a command-line argument containing the JNDI name of the **Employee** EJB to use in the application. This command-line argument enables the user to specify the JNDI name of either the bean- or container-managed persistence version of the **Employee** EJB (i.e., **BMPEmployee** or **CMPEmployee**). Lines 376–377 print instructions to the user if a JNDI name is not provided. Line 383 creates a new instance of the **EmployeeEJBClient** using the given JNDI name argument. When executing the **EmployeeEJBClient**, be sure that the client JAR for the **Employee** EJB is in the **EmployeeEJBClient**'s CLASSPATH.

## 15.8 Internet and World Wide Web Resources

[java.sun.com/products/ejb/news.html](http://java.sun.com/products/ejb/news.html)

This site provides articles and news related to Enterprise JavaBeans.

[www.theserverside.com/resources/pdf/ejbmatrix11.pdf](http://www.theserverside.com/resources/pdf/ejbmatrix11.pdf)

This document (in PDF format) provides a quick reference for EJB interfaces, classes and methods.

[java.sun.com/products/ejb/docs.html](http://java.sun.com/products/ejb/docs.html)

The Enterprise JavaBeans specification home page provides documentation and specifications for EJBs.

[developer.java.sun.com/developer/technicalArticles/J2EE/build](http://developer.java.sun.com/developer/technicalArticles/J2EE/build)

This article at the Java Developer Connection (requires free registration) discusses techniques for ensuring J2EE applications are portable across application servers from different vendors.

[java.sun.com/j2ee/blueprints](http://java.sun.com/j2ee/blueprints)

The J2EE Blueprints discuss proven strategies for building enterprise applications with J2EE. Included are technical articles that discuss the blueprints and code examples that implement the blueprints in real systems.

## SUMMARY

- Entity EJBs provide an object-oriented representation of persistent data, such as data stored in a relational database.
- Entity EJBs that use bean-managed persistence require the developer to implement code for storing and retrieving data from the persistent data sources the EJB represents.
- Entity EJBs use container-managed persistence rely on the EJB container to implement the data-access calls to their persistent data sources. The deployer must supply information about the persistent data source when deploying the EJB.
- Entity EJBs provide **create** methods for creating new EJB instances, **remove** methods for removing EJB instances and *finder* methods for finding EJB instances. Each **create** method performs **INSERT** operations to create new records in the database. Each **remove** method performs **DELETE** operations to remove records from the database. Each *finder* method locates entity EJB instances that match certain criteria.
- Method **findByPrimaryKey** is one type of *finder* method for entity EJBs. Every entity EJB must have a **findByPrimaryKey** method that takes the entity EJB's primary-key class as an argument. Entity EJBs can also define other *finder* methods. A *finder* method name must begin with **findBy** and should end with the name of property to be used as the search criteria.
- All entity EJB implementations must implement interface **EntityBean**.
- An **EntityContext** provides the EJB with information about the container in which the EJB is deployed.
- All **ejbCreate** methods in entity EJBs are required to return the EJB's primary-key class. Most EJBs use a standard Java class (e.g., **Integer** or **String**) as their primary-key class.
- If a database table has a complex primary key (i.e., a primary key that consists of more than one field), the developer must define a custom primary-key class.
- The EJB container invokes method **ejbPostCreate** after invoking method **ejbCreate** to perform any required tasks after creating the EJB instance.
- To **remove** an entity EJB instance means to **DELETE** the associated database record. A **RemoveException** indicates that removing the EJB instance failed.
- There are some restrictions on what can be done in method **setEntityContext**, because when this method is invoked, the EJB instance is not yet associated with a particular database record. For example, the EJB must not invoke **EntityContext** method **getPrimaryKey**, because there is no primary key associated with the current EJB instance.
- Method **setEntityContext** should allocate resources the EJB instance will need throughout its lifetime (e.g., a database connection).
- J2EE applications use a special JNDI naming context called **java:comp/env**, which stands for “component environment.” EJBs are found in the **ejb** subcontext and databases are found in the **jdbc** subcontext.
- Container-managed fields are member variables that a container-managed persistence EJB instance uses to cache data retrieved from the database. The container-managed fields must have the same names as the fields in the corresponding database table. The container-managed fields also must be marked **public** so the EJB container can access them directly.

## TERMINOLOGY

application server

complex primary key

bean-managed persistence

container-managed field

business methods

container-managed persistence

<b>EntityBean</b> interface	<i>finder</i> methods
<b>EntityContext</b> interface	home interface
<b>findByPrimaryKey</b> method	<b>javax.ejb.EntityBean</b> interface
<b>ejbCreate</b> methods	primary-key class
<b>ejbPassivate</b> method	<b>remove</b> methods
<b>ejbRemove</b> method	<b>setEntityContext</b> method
entity EJB	<b>unsetEntityContext</b> method

## SELF-REVIEW EXERCISES

**15.1** State which of the following are *true* and which are *false*. If *false*, explain why.

- Data associated with an entity EJB typically is stored in a relational database.
- The remote interface for an entity EJB represents the database table with which the EJB is associated.
- Entity EJBs that use bean-managed persistence require the deployer to specify SQL queries for inserting, updating, deleting and querying data from the database.
- The *create* methods in the home interface for an entity EJB insert new records into the underlying database.
- Entity EJBs should obtain necessary resources in method **ejbCreate**.
- Entity EJBs that use container-managed persistence must implement interface **CMPEntityBean**, whereas those that use bean-managed persistence must implement interface **EntityBean**.

**15.2** Fill in the blanks in each of the following:

- For entity EJBs that use \_\_\_\_\_ persistence to represent data in a relational database, the \_\_\_\_\_ must specify SQL queries when deploying the EJB.
- For entity EJBs that use \_\_\_\_\_ persistence to represent data in a relational database, the \_\_\_\_\_ must implement code that synchronizes data with the database.
- Each create method in the home interface must have a corresponding \_\_\_\_\_ method in the EJB implementation.
- If an entity EJB has a complex primary key, the developer must provide a custom \_\_\_\_\_ that represents the complex primary key.

## ANSWERS TO SELF-REVIEW EXERCISES

**15.1** a) True. b) False. The remote interface specifies the business methods for the EJB. The home interface represents the database table. c) False. The developer must provide code for managing synchronization with the underlying database. d) True. e) False. Entity EJBs should obtain necessary resources in method **setEntityContext**. f) False. All entity EJBs must implement interface **EntityBean**.

**15.2** a) container-managed, deployer. b) bean-managed persistence, developer. c) **ejbCreate**. d) primary-key class.

## EXERCISES

**15.3** What types of persistence can entity EJBs use? What are the benefits of each?

**15.4** Create an entity EJB for the **Titles** table in the **books** database of Chapter 8. The entity EJB should use bean-managed persistence to synchronize its data members with the values in the database. Provide *set* and *get* methods for each field in the **Titles** table. Provide a *create* method that takes the **ISBN** and **Title** as arguments.

**15.5** Modify the entity EJB you created in Exercise 15.4 to use container-managed persistence instead of bean-managed persistence.

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# Messaging with JMS

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## Objectives

- To understand message-oriented middleware.
- To understand the point-to-point messaging model.
- To understand the publish/subscribe messaging model.
- To understand the difference between the two messaging models and when it is appropriate to use each.
- To understand how to use the Java Message Service (JMS) API to build messaging applications in Java.
- To introduce message-driven EJBs.

*The next thing most like living one's life over again seems to be a recollection of that life, and to make that recollection as durable as possible by putting it down in writing.*

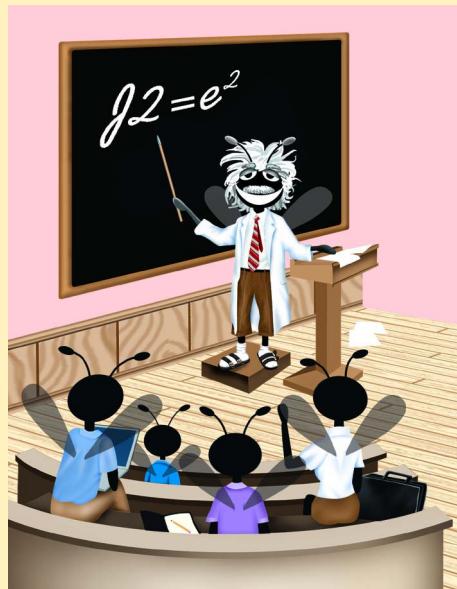
Benjamin Franklin

*Sow good services: sweet remembrances will grow from them.*

Anne Louise Germaine de Staél

*... And many a message from the skies, ...*

Robert Burns



## Outline

- 16.1 Introduction**
- 16.2 Installation and Configuration of J2EE 1.3**
- 16.3 Point-To-Point Messaging**
  - 16.3.1 Voter Application: Overview**
  - 16.3.2 Voter Application: Sender Side**
  - 16.3.3 Voter Application: Receiver Side**
  - 16.3.4 Voter Application: Configuring and Running**
- 16.4 Publish/Subscribe Messaging**
  - 16.4.1 Weather Application: Overview**
  - 16.4.2 Weather Application: Publisher Side**
  - 16.4.3 Weather Application: Subscriber Side**
  - 16.4.4 Weather Application: Configuring and Running**
- 16.5 Message-Driven Enterprise JavaBeans**
  - 16.5.1 Voter Application: Overview**
  - 16.5.2 Voter Application: Receiver Side**
  - 16.5.3 Voter Application: Configuring and Running**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

## 16.1 Introduction

When creating enterprise applications, it often is useful for ordinarily uncoupled components of the applications to "talk" to each other. For instance, a book supplier's clients need to communicate book orders to the supplier. One solution is to loosely couple the client's buying application with the supplier's ordering application through a *messaging system*, sometimes called *message-oriented middleware (MOM)*. Messaging systems allow components to post *messages* for other components to read. There are two basic messaging-system models—*point-to-point* and *publish/subscribe*.

The *point-to-point messaging model* allows components to send messages to a *message queue*. In this model, the sender intends the messages for one *message consumer*—a target component that processes the received messages. When this target component connects to the queue to receive messages, the target component receives any messages not yet consumed. A message is consumed once the server sends the message to the target component. Note that in the point-to-point model, exactly one client consumes a message.

The *publish/subscribe messaging model* allows components to *publish* messages to a *topic* on a server. The server maintains various topics to which components can connect. Components interested in messages published to a particular topic can *subscribe* to that topic. When a publisher publishes a message to a given topic, current subscribers receive that message. Note that in the publish/subscribe model, unlike in the point-to-point model, zero or more subscribers consume each published message.

In both messaging models, a message consists of a *header*, *properties* (optional) and a *body* (also optional). The message header contains information, such as the message destination and the sending time. Message properties allow message receivers to select which types of messages they would like to receive; the sender of a message can set these properties. Message receivers use *message selectors* to filter out messages. Filtering is done on the server side; the server does not send those messages to the receiver.

*Message-driven beans* are Enterprise JavaBeans that support messaging. Like an EJB container can use any instance of a stateless session EJB to handle client requests, the EJB container for message-driven beans can use any instance of a message-driven bean to process incoming messages for a given queue or topic. Since the container may use any instance, message-driven beans cannot maintain state for a specific client. Using message-driven beans, a component can receive messages asynchronously, without tying up resources waiting for a message to arrive.

In this chapter, we explore the *Java Message Service (JMS)* API. JMS standardizes the API for enterprise messaging, and supports both the point-to-point and publish/subscribe messaging models. JMS provides five types of messages—**BytesMessages**, **MapMessages**, **ObjectMessages**, **StreamMessages** and **TextMessages**. There are several implementations of JMS available from various vendors. For more information on these vendors and JMS, please visit [java.sun.com/jms](http://java.sun.com/jms).

## 16.2 Installation and Configuration of J2EE 1.3

The Java 2 Enterprise Edition version 1.3 reference implementation provides support for the Java Message Service API. At the time of this writing, the beta 2 release of the J2EE 1.3 reference implementation was available. Note that J2EE 1.3 beta 2 supports only the Windows 2000, Windows NT 4.0, Solaris SPARC 7, Solaris SPARC 8 and RedHat Linux v. 6.1 operating systems. Also note that J2SE 1.3.1 is required for J2EE 1.3 beta 2. To install the J2EE 1.3 reference implementation, follow these steps:

1. Download and unpack the appropriate software bundle from [java.sun.com/j2ee/j2sdkee-beta/index.html](http://java.sun.com/j2ee/j2sdkee-beta/index.html).
2. Set the environment variables according to the values in Fig. 16.1.

Environment variable	Value
<b>J2EE_HOME</b>	Directory in which J2EE 1.3 is installed (e.g., <b>C:\j2sdkee1.3</b> ).
<b>JAVA_HOME</b>	Directory in which J2SE 1.3.1 is installed (e.g., <b>C:\jdk1.3.1</b> ).
<b>PATH</b>	The existing <b>PATH</b> plus the J2EE 1.3 <b>bin</b> directory (e.g., <b>C:\j2sdkee1.3\bin</b> ).

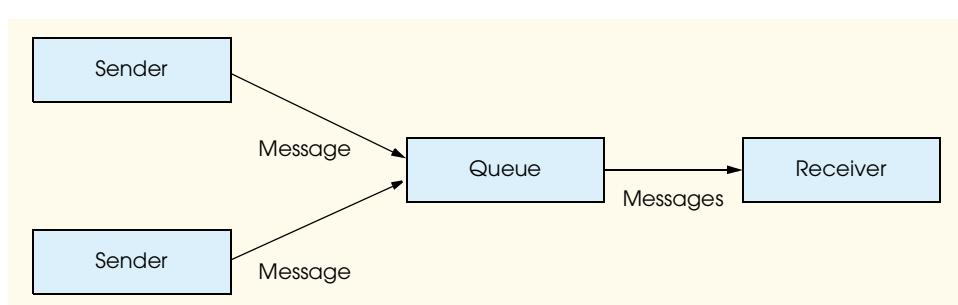
Fig. 16.1 Setting environment variables for J2EE 1.3 installation.

## 16.3 Point-To-Point Messaging

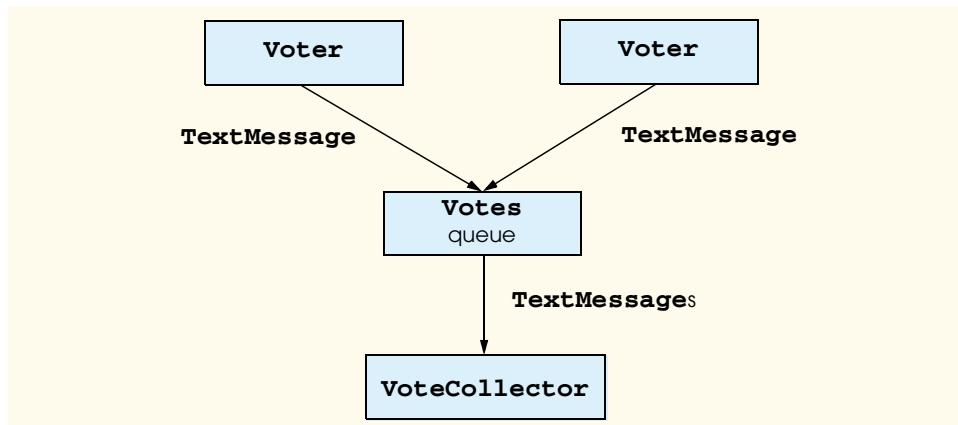
The point-to-point messaging model (Fig. 16.2) allows clients to send messages to a message queue. A receiver connects to the queue to consume messages that have not been consumed. In general, messages in a queue are intended for exactly one client, so only one client connects as the receiver. If there is no receiver, the server maintains messages sent to the queue until a receiver connects and consumes those messages.

### 16.3.1 Voter Application: Overview

To demonstrate point-to-point messaging, we present an application that tallies votes for the voters' favorite programming language. Class **Voter** (Section 16.3.2) sends votes as messages to the **Votes** queue. These messages are simple **TextMessage** objects (package **javax.jms**). The message body contains the candidate name. Class **VoteCollector** (Section 16.3.3) consumes the messages and tallies the votes. Class **VoteCollector** can connect to the **Votes** queue before or after messages have been sent. As additional votes arrive in the queue, the **VoteCollector** updates the tallies and displays the totals. Figure 16.3 provides a diagram overview of the application.



**Fig. 16.2** Point-to-point messaging model.



**Fig. 16.3** **Voter** application overview.

### 16.3.2 Voter Application: Sender Side

The sender side of the application consists of a single class—**voter** (Fig. 16.4). Class **Voter** allows the user to select a programming language and sends a vote for the selected language to the **Votes** queue as a **TextMessage**.

```
1 // Voter.java
2 // Voter is the GUI that allows the client to vote
3 // for a programming language. Voter sends the vote
4 // to the "Votes" queue as a TextMessage.
5 package com.deitel.advjhttp1.jms.voter;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.jms.*;
14 import javax.naming.*;
15
16 public class Voter extends JFrame {
17
18     private String selectedLanguage;
19
20     // JMS variables
21     private QueueConnection queueConnection;
22     private QueueSession queueSession;
23     private QueueSender queueSender;
24
25     // Voter constructor
26     public Voter()
27     {
28         // lay out user interface
29         super( "Voter" );
30
31         Container container = getContentPane();
32         container.setLayout( new BorderLayout() );
33
34         JTextArea voteArea =
35             new JTextArea( "Please vote for your\n" +
36                 "favorite programming language" );
37         voteArea.setEditable( false );
38         container.add( voteArea, BorderLayout.NORTH );
39
40         JPanel languagesPanel = new JPanel();
41         languagesPanel.setLayout( new GridLayout( 0, 1 ) );
42
43         // add each language as its own JCheckBox
44         // ButtonGroup ensures exactly one language selected
45         ButtonGroup languagesGroup = new ButtonGroup();
46         CheckBoxHandler checkBoxHandler = new CheckBoxHandler();
```

Fig. 16.4 **Voter** class submits votes as messages to queue (part 1 of 4).

```
47     String languages[] =
48     { "C", "C++", "Java", "Lisp", "Python" };
49     selectedLanguage = "";
50
51     // create JCheckBox for each language
52     // and add to ButtonGroup and JPanel
53     for ( int i = 0; i < languages.length; i++ ) {
54         JCheckBox checkBox = new JCheckBox( languages[ i ] );
55         checkBox.addItemListener( checkBoxHandler );
56         languagesPanel.add( checkBox );
57         languagesGroup.add( checkBox );
58     }
59
60     container.add( languagesPanel, BorderLayout.CENTER );
61
62     // create button to submit vote
63     JButton submitButton = new JButton( "Submit vote!" );
64     container.add( submitButton, BorderLayout.SOUTH );
65
66     // invoke method submitVote when submitButton clicked
67     submitButton.addActionListener(
68
69         new ActionListener() {
70
71             public void actionPerformed ( ActionEvent event ) {
72                 submitVote();
73             }
74         }
75     );
76
77     // invoke method quit when window closed
78     addWindowListener(
79
80         new WindowAdapter() {
81
82             public void windowClosing( WindowEvent event ) {
83                 quit();
84             }
85         }
86     );
87
88     // connect to message queue
89     try {
90
91         // create JNDI context
92         Context jndiContext = new InitialContext();
93
94         // retrieve queue connection factory and
95         // queue from JNDI context
96         QueueConnectionFactory queueConnectionFactory =
97             ( QueueConnectionFactory )
98             jndiContext.lookup( "VOTE_FACTORY" );
99         Queue queue = ( Queue ) jndiContext.lookup( "Votes" );
```

Fig. 16.4 Voter class submits votes as messages to queue (part 2 of 4).

```
100
101     // create connection, session and sender
102     queueConnection =
103         queueConnectionFactory.createQueueConnection();
104     queueSession =
105         queueConnection.createQueueSession( false,
106             Session.AUTO_ACKNOWLEDGE );
107     queueSender = queueSession.createSender( queue );
108 }
109
110 // process Naming exception from JNDI context
111 catch ( NamingException namingException ) {
112     namingException.printStackTrace();
113     System.exit( 1 );
114 }
115
116 // process JMS exception from queue connection or session
117 catch ( JMSEException jmsException ) {
118     jmsException.printStackTrace();
119     System.exit( 1 );
120 }
121
122 } // end Voter constructor
123
124 // submit selected vote to "Votes" queue as TextMessage
125 public void submitVote()
126 {
127     if ( selectedLanguage != "" ) {
128
129         // create text message containing selected language
130         try {
131             TextMessage voteMessage =
132                 queueSession.createTextMessage();
133             voteMessage.setText( selectedLanguage );
134
135             // send the message to the queue
136             queueSender.send( voteMessage );
137         }
138
139         // process JMS exception
140         catch ( JMSEException jmsException ) {
141             jmsException.printStackTrace();
142         }
143     }
144
145 } // end method submitVote
146
147 // close client application
148 public void quit()
149 {
150     if ( queueConnection != null ) {
151 }
```

Fig. 16.4 **Voter** class submits votes as messages to queue (part 3 of 4).

```
152         // close queue connection if it exists
153         try {
154             queueConnection.close();
155         }
156
157         // process JMS exception
158         catch ( JMSEException jmsException ) {
159             jmsException.printStackTrace();
160         }
161     }
162
163     System.exit( 0 );
164
165 } // end method quit
166
167 // launch Voter application
168 public static void main( String args[] )
169 {
170     Voter voter = new Voter();
171     voter.pack();
172     voter.setVisible( true );
173 }
174
175 // CheckBoxHandler handles event when checkbox checked
176 private class CheckBoxHandler implements ItemListener {
177
178     // checkbox event
179     public void itemStateChanged( ItemEvent event )
180     {
181         // update selectedLanguage
182         JCheckBox source = ( JCheckBox ) event.getSource();
183         selectedLanguage = source.getText();
184     }
185 }
186 }
```

Fig. 16.4 **Voter** class submits votes as messages to queue (part 4 of 4).

Line 13 imports package **javax.jms**, which contains JMS API classes and interfaces. Lines 29–86 set up the GUI for the **Voter** client. Lines 53–58 create **JCheckBox** objects to allow the client to vote. Note that these are added to a **ButtonGroup** (lines 45–58) so that the user can select only one candidate.

Lines 89–120 set up JMS connections. Line 92 creates the JNDI context, from which the program retrieves a **QueueConnectionFactory** and **Queue**, identified by **VOICE\_FACTORY** and **Votes**, respectively. Note that the server administrator must create the queue connection factory and queue (Section 16.3.4). A queue connection factory allows the client to create a **QueueConnection** (lines 102–103). The **QueueConnection** creates a **QueueSession** (lines 104–106). Finally, the **QueueSession** creates either a **QueueSender** or a **QueueReceiver**. Here, the **QueueSession** creates a **QueueSender** for the **Votes** queue (line 107); the **QueueSender** now can post messages to the queue.

When the user selects a language and clicks the **Submit vote** button (Fig. 16.5), method **submitVote** creates a **TextMessage** object and sets the text of the message to **selectedLanguage** (lines 131–133). Line 136 sends the message to the **Votes** queue.

The program invokes method **quit** (lines 148–165) when the user closes the application window. Lines 150–161 close the connection to the queue.

### 16.3.3 Voter Application: Receiver Side

In the Voter application example, a **VoteCollector** (Fig. 16.6) is the intended receiver of messages sent to the **Votes** queue. Class **VoteCollector** tallies and displays votes it receives from the queue. Note that the **Voter** can send messages to the queue before the **VoteCollector** has connected; once connected, the **VoteCollector** will receive these messages.



Fig. 16.5 Voter application votes for favorite programming language

```
1 // VoteCollector.java
2 // VoteCollector tallies and displays the votes
3 // posted as TextMessages to the "Votes" queue.
4 package com.deitel.advjhttp1.jms.voter;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.util.*;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.jms.*;
14 import javax.naming.*;
15
16 public class VoteCollector extends JFrame {
17
18     private JPanel displayPanel;
19     private Map tallies = new HashMap();
20
21     // JMS variables
22     private QueueConnection queueConnection;
```

Fig. 16.6 VoteCollector class retrieves and tallies votes (part 1 of 4).

```
23
24     // VoteCollector constructor
25     public VoteCollector()
26     {
27         super( "Vote Tallyies" );
28
29         Container container = getContentPane();
30
31         // displayPanel will display tally results
32         displayPanel = new JPanel();
33         displayPanel.setLayout( new GridLayout( 0, 1 ) );
34         container.add( new JScrollPane( displayPanel ) );
35
36         // invoke method quit when window closed
37         addWindowListener(
38
39             new WindowAdapter() {
40
41                 public void windowClosing( WindowEvent event ) {
42                     quit();
43                 }
44             }
45         );
46
47         // connect to "Votes" queue
48         try {
49
50             // create JNDI context
51             Context jndiContext = new InitialContext();
52
53             // retrieve queue connection factory
54             // and queue from JNDI context
55             QueueConnectionFactory queueConnectionFactory =
56                 ( QueueConnectionFactory )
57                 jndiContext.lookup( "VOTE_FACTORY" );
58             Queue queue = ( Queue ) jndiContext.lookup( "Votes" );
59
60             // create connection, session and receiver
61             queueConnection =
62                 queueConnectionFactory.createQueueConnection();
63             QueueSession queueSession =
64                 queueConnection.createQueueSession( false,
65                     Session.AUTO_ACKNOWLEDGE );
66             QueueReceiver queueReceiver =
67                 queueSession.createReceiver( queue );
68
69             // initialize and set message listener
70             queueReceiver.setMessageListener(
71                 new VoteListener( this ) );
72
73             // start connection
74             queueConnection.start();
75         }
```

Fig. 16.6 **VoteCollector** class retrieves and tallies votes (part 2 of 4).

```
76      // process Naming exception from JNDI context
77      catch ( NamingException namingException ) {
78          namingException.printStackTrace();
79          System.exit( 1 );
80      }
81
82      // process JMS exception from queue connection or session
83      catch ( JMSException jmsException ) {
84          jmsException.printStackTrace();
85          System.exit( 1 );
86      }
87  }
88
89 } // end VoteCollector constructor
90
91 // add vote to corresponding tally
92 public void addVote( String vote )
93 {
94     if ( tallies.containsKey( vote ) ) {
95
96         // if vote already has corresponding tally
97         TallyPanel tallyPanel =
98             ( TallyPanel ) tallies.get( vote );
99         tallyPanel.updateTally();
100    }
101
102    // add to GUI and tallies
103    else {
104        TallyPanel tallyPanel = new TallyPanel( vote, 1 );
105        displayPanel.add( tallyPanel );
106        tallies.put( vote, tallyPanel );
107        validate();
108    }
109 }
110
111 // quit application
112 public void quit()
113 {
114     if ( queueConnection != null ) {
115
116         // close the queue connection if it exists
117         try {
118             queueConnection.close();
119         }
120
121         // process JMS exception
122         catch ( JMSException jmsException ) {
123             jmsException.printStackTrace();
124             System.exit( 1 );
125         }
126     }
127 }
128 }
```

Fig. 16.6 **VoteCollector** class retrieves and tallies votes (part 3 of 4).

```

129     System.exit( 0 );
130 }
131 } // end method quit
132
133 // launch VoteCollector
134 public static void main( String args[] )
135 {
136     VoteCollector voteCollector = new VoteCollector();
137     voteCollector.setSize( 200, 200 );
138     voteCollector.setVisible( true );
139 }
140 }
```

Fig. 16.6 **VoteCollector** class retrieves and tallies votes (part 4 of 4).

Class **VoteCollector** collects and tallies votes retrieved from the **Votes** queue. Variable **tallies** (line 19) is a **Map** from candidate names to corresponding **TallyPanel** objects (Fig. 16.9); it updates tallies when a new vote is received. Lines 27–45 lay out the GUI. Note that the GUI initially displays nothing as the **VoteCollector** has received no votes.

Lines 48–87 establish a connection to the **Votes** queue. Line 51 creates a JNDI context for retrieving the **QueueConnectionFactory** and **Queue** (lines 55–58). The **QueueConnectionFactory** allows the program to create the **QueueConnection** (lines 61–62). The **QueueConnection** creates the **QueueSession** (lines 63–65). The **QueueSession**, in turn, creates the **QueueReceiver** (lines 66–67), which receives votes from the **Queue**. Lines 70–71 create a new **VoteListener** (Fig. 16.8) and set the **VoteListener** as the message listener for the **QueueReceiver**. Line 74 starts the **queueConnection**; at this point, the **VoteListener** will process messages received from the **queue**.

Method **addVote** (lines 92–109) updates the tallies and display (Fig. 16.7). If there is a **TallyPanel** corresponding to the **vote**'s candidate, lines 97–99 increment the tally by invoking method **updateTally**. If there is no corresponding **TallyPanel**, lines 104–106 add a new entry to the **tallies Map**. The program invokes method **quit** (lines 112–131) when the client closes the application window. Lines 114–127 close the **queueConnection**.

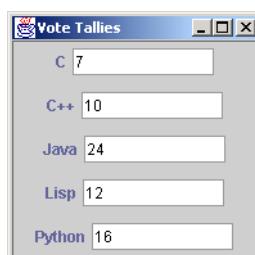


Fig. 16.7 **VoteCollector** tallies and displays votes.

Class **VoteListener** (Fig. 16.8) implements interface **MessageListener**. When the **QueueReceiver** receives a message, the **QueueReceiver**'s *message listener* processes the message. Interface **MessageListener** specifies the single method **onMessage** (lines 22–49), which the program invokes when a new message arrives. Line 29 checks that the message is of type **TextMessage**. If so, lines 30–31 retrieve the text of the message; line 32 then invokes method **addVote** of class **VoteCollector** to update the tallies.

```
1 // VoteListener.java
2 // VoteListener is the message listener for the
3 // receiver of the "Votes" queue. It implements
4 // the specified onMessage method to update the
5 // GUI with the received vote.
6 package com.deitel.advjhttp1.jms.voter;
7
8 // Java extension packages
9 import javax.jms.*;
10
11 public class VoteListener implements MessageListener {
12
13     private VoteCollector voteCollector;
14
15     // VoteListener constructor
16     public VoteListener( VoteCollector collector )
17     {
18         voteCollector = collector;
19     }
20
21     // receive new message
22     public void onMessage( Message message )
23     {
24         TextMessage voteMessage;
25
26         // retrieve and process message
27         try {
28
29             if ( message instanceof TextMessage ) {
30                 voteMessage = ( TextMessage ) message;
31                 String vote = voteMessage.getText();
32                 voteCollector.addVote( vote );
33
34                 System.out.println( "Received vote: " + vote );
35             }
36
37             else {
38                 System.out.println( "Expecting " +
39                         "TextMessage object, received " +
40                         message.getClass().getName() );
41             }
42         }
43     }
}
```

Fig. 16.8 **VoteListener** class receives messages from the queue (part 1 of 2).

```
44     // process JMS exception from message
45     catch ( JMSException jmsException ) {
46         jmsException.printStackTrace();
47     }
48
49 } // end method onMessage
50 }
```

Fig. 16.8 **VoteListener** class receives messages from the queue (part 2 of 2).

Class **TallyPanel** (Fig. 16.9) maintains and displays the **tally** for a vote candidate. Method **updateTally** (lines 37–41) increments the **tally** by one.

```
1 // TallyPanel.java
2 // TallyPanel is the GUI component which displays
3 // the name and tally for a vote candidate.
4 package com.deitel.advjhtp1.jms.voter;
5
6 // Java core packages
7 import java.awt.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class TallyPanel extends JPanel {
13
14     private JLabel nameLabel;
15     private JTextField tallyField;
16     private String name;
17     private int tally;
18
19     // TallyPanel constructor
20     public TallyPanel( String voteName, int voteTally )
21     {
22         name = voteName;
23         tally = voteTally;
24
25         nameLabel = new JLabel( name );
26         tallyField =
27             new JTextField( Integer.toString( tally ), 10 );
28         tallyField.setEditable( false );
29         tallyField.setBackground( Color.white );
30
31         add( nameLabel );
32         add( tallyField );
33
34     } // end TallyPanel constructor
35
36     // update tally by one vote
37     public void updateTally()
38     {
39         tally++;
40     }
41 }
```

Fig. 16.9 **TallyPanel** class displays candidate name and tally (part 1 of 2).

```
40     tallyField.setText( Integer.toString( tally ) );
41 }
42 }
```

Fig. 16.9 **TallyPanel** class displays candidate name and tally (part 2 of 2).

### 16.3.4 Voter Application: Configuring and Running

To run the application, issue the following commands at a command prompt:

1. Start J2EE server in a command window:

```
j2ee -verbose
```

2. In a new command window, create the **Votes** queue:

```
j2eeadmin -addJmsDestination Votes queue
```

3. Verify that the queue was created:

```
j2eeadmin -listJmsDestination
```

4. Create the connection factory:

```
j2eeadmin -addJmsFactory VOTE_FACTORY queue
```

5. Start **VoteCollector**:

```
java -classpath %J2EE_HOME%\lib\j2ee.jar;.
-Djms.properties=%J2EE_HOME%\config\jms_client.properties
com.deitel.advjhttp1.jms.voter.VoteCollector
```

6. Start **Voter** in a new command window:

```
java -classpath %J2EE_HOME%\lib\j2ee.jar;.
-Djms.properties=%J2EE_HOME%\config\jms_client.properties
com.deitel.advjhttp1.jms.voter.Voter
```

Once you have finished running the application, you can remove the connection factory with the command:

```
j2eeadmin -removeJmsFactory VOTE_FACTORY
```

To remove the topic, use the command:

```
j2eeadmin -removeJmsDestination Votes
```

To stop J2EE server, use the command:

```
j2ee -stop
```

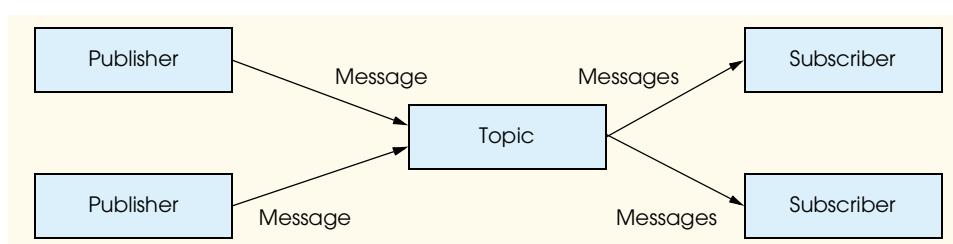
## 16.4 Publish/Subscribe Messaging

The publish/subscribe messaging model (Fig. 16.10) allows multiple clients to connect to a topic on the server and send and receive messages. Once connected, the client may publish messages or subscribe to the topic. When a client publishes a message, the server sends the message to those clients that subscribe to the topic. A client may obtain two types of subscriptions—*nondurable* and *durable*. Nondurable subscriptions receive messages only while the subscriptions are active. Durable subscriptions, however, can receive messages

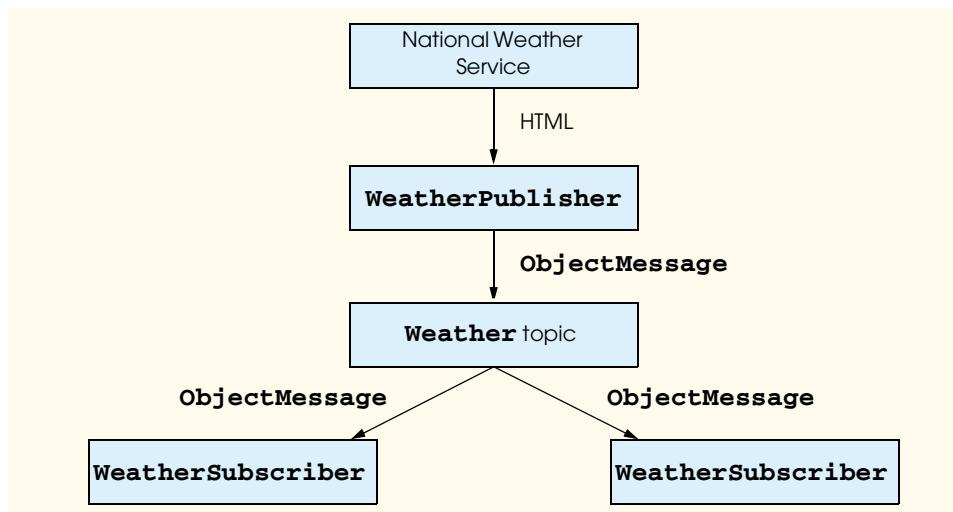
while inactive—the server maintains messages sent to the topic while the subscription is inactive and sends those messages to the client when the client reactivates the subscription. Note that if a client specifies a message selector to filter the messages, the server maintains only those messages that satisfy the selector.

### 16.4.1 Weather Application: Overview

We present an example of publish/subscribe messaging that uses a nondurable subscription. The following application publishes messages to a **Weather** topic on the server. These messages contain weather information for various U. S. cities retrieved from the National Weather Service Travelers Forecast page ([iwin.nws.noaa.gov/iwin/us/traveler.html](http://iwin.nws.noaa.gov/iwin/us/traveler.html)). Class **WeatherPublisher** (Section 16.4.2) retrieves weather updates and publishes them as messages to the topic. Class **WeatherSubscriber** (Section 16.4.3), presents a graphical user interface that allows the user to select cities for which to display weather updates. Class **WeatherSubscriber** subscribes to the **Weather** topic and receives messages corresponding to the selected cities, using a message selector. Figure 16.11 provides an overview of the application.



**Fig. 16.10** Publish/subscribe messaging model.



**Fig. 16.11** Weather application overview.

### 16.4.2 Weather Application: Publisher Side

Class **WeatherPublisher** (Fig. 16.12) retrieves weather updates from the National Weather Service and publishes those updates as messages to the **Weather** topic. An **ObjectMessage** contains each city's weather conditions. The **ObjectMessage**'s **String** property **City** specifies the corresponding city. The **WeatherSubscriber** uses the **City** property in its message selector.

```
1 // WeatherPublisher.java
2 // WeatherPublisher retrieves weather conditions from the National
3 // Weather Service and publishes them to the Weather topic
4 // as ObjectMessages containing WeatherBeans. The city name is
5 // used in a String property "City" in the message header.
6 package com.deitel.advjhttp1.jms.weather;
7 \
8 // Java core packages
9 import java.io.*;
10 import java.net.*;
11 import java.util.*;
12
13 // Java extension packages
14 import javax.jms.*;
15 import javax.naming.*;
16
17 // Deitel packages
18 import com.deitel.advjhttp1.rmi.weather.WeatherBean;
19
20 public class WeatherPublisher extends TimerTask {
21
22     private BufferedReader in;
23     private TopicConnection topicConnection;
24
25     // WeatherPublisher constructor
26     public WeatherPublisher()
27     {
28         // update weather conditions every minute
29         Timer timer = new Timer();
30         timer.scheduleAtFixedRate( this, 0, 60000 );
31
32         // allow user to quit
33         InputStreamReader inputStreamReader =
34             new InputStreamReader( System.in );
35         char answer = '\0';
36
37         // loop until user enters q or Q
38         while ( !( ( answer == 'q' ) || ( answer == 'Q' ) ) ) {
39
40             // read in character
41             try {
42                 answer = ( char ) inputStreamReader.read();
43             }
```

Fig. 16.12 **WeatherPublisher** class publishes messages to **Weather** topic (part 1 of 5).

```
44      // process IO exception
45      catch ( IOException ioException ) {
46          ioException.printStackTrace();
47          System.exit( 1 );
48      }
49
50  } // end while
51
52  // close connections
53  try {
54
55      // close topicConnection if it exists
56      if ( topicConnection != null ) {
57          topicConnection.close();
58      }
59
60      in.close(); // close connection to NWS Web server
61      timer.cancel(); // stop timer
62  }
63
64
65  // process JMS exception from closing topic connection
66  catch ( JMSException jmsException ) {
67      jmsException.printStackTrace();
68      System.exit( 1 );
69  }
70
71  // process IO exception from closing connection
72  // to NWS Web server
73  catch ( IOException ioException ) {
74      ioException.printStackTrace();
75      System.exit( 1 );
76  }
77
78  System.exit( 0 );
79
80 } // end WeatherPublisher constructor
81
82 // get weather information from NWS
83 public void run()
84 {
85     // connect to topic "Weather"
86     try {
87         System.out.println( "Update weather information..." );
88
89         // create JNDI context
90         Context jndiContext = new InitialContext();
91         String topicName = "Weather";
92 }
```

Fig. 16.12 **WeatherPublisher** class publishes messages to **Weather** topic (part 2 of 5).

```
93      // retrieve topic connection factory and topic
94      // from JNDI context
95      TopicConnectionFactory topicConnectionFactory =
96          ( TopicConnectionFactory )
97          jndiContext.lookup( "WEATHER_FACTORY" );
98
99      Topic topic =
100         ( Topic ) jndiContext.lookup( topicName );
101
102     // create connection, session, publisher and message
103     topicConnection =
104         topicConnectionFactory.createTopicConnection();
105
106    TopicSession topicSession =
107        topicConnection.createTopicSession( false,
108            Session.AUTO_ACKNOWLEDGE );
109
110    TopicPublisher topicPublisher =
111        topicSession.createPublisher( topic );
112
113    ObjectMessage message =
114        topicSession.createObjectMessage();
115
116    // connect to National Weather Service
117    // and publish conditions to topic
118
119    // National Weather Service Travelers Forecast page
120    URL url = new URL(
121        "http://iwin.nws.noaa.gov/iwin/us/traveler.html" );
122
123    // set up text input stream to read Web page contents
124    in = new BufferedReader(
125        new InputStreamReader( url.openStream() ) );
126
127    // helps determine starting point of data on Web page
128    String separator = "TAV12";
129
130    // locate separator string in Web page
131    while ( !in.readLine().startsWith( separator ) )
132        ;      // do nothing
133
134    // strings representing headers on Travelers Forecast
135    // Web page for daytime and nighttime weather
136    String dayHeader =
137        "CITY           WEA      HI/LO    WEA      HI/LO";
138
139    String nightHeader =
140        "CITY           WEA      LO/HI    WEA      LO/HI";
141
142    String inputLine = "";
143
```

Fig. 16.12 **WeatherPublisher** class publishes messages to **Weather** topic (part 3 of 5).

```
144      // locate header that begins weather information
145      do {
146          inputLine = in.readLine();
147      }
148
149      while ( !inputLine.equals( dayHeader ) &&
150             !inputLine.equals( nightHeader ) );
151
152      // create WeatherBean objects for each city's data
153      // publish to Weather topic using city as message's type
154      inputLine = in.readLine(); // get first city's info
155
156      // the portion of inputLine containing relevant data is
157      // 28 characters long. If the line length is not at
158      // least 28 characters long, done processing data.
159      while ( inputLine.length() > 28 ) {
160
161          // create WeatherBean object for city
162          // first 16 characters are city name
163          // next six characters are weather description
164          // next six characters are HI/LO temperature
165          WeatherBean weather = new WeatherBean(
166              inputLine.substring( 0, 16 ).trim(),
167              inputLine.substring( 16, 22 ).trim(),
168              inputLine.substring( 23, 29 ).trim() );
169
170          // publish WeatherBean object with city name
171          // as a message property,
172          // used for selection by clients
173          message.setObject( weather );
174          message.setStringProperty( "City",
175              weather.getCityName() );
176          topicPublisher.publish( message );
177
178          System.out.println( "published message for city: "
179                  + weather.getCityName() );
180
181          inputLine = in.readLine(); // get next city's info
182      }
183
184      System.out.println( "Weather information updated." );
185
186  } // end try
187
188  // process Naming exception from JNDI context
189  catch ( NamingException namingException ) {
190      namingException.printStackTrace();
191      System.exit( 1 );
192  }
193
```

Fig. 16.12 **WeatherPublisher** class publishes messages to **Weather** topic (part 4 of 5).

```
194     // process JMS exception from connection,
195     // session, publisher or message
196     catch ( JMSException jmsException ) {
197         jmsException.printStackTrace();
198         System.exit( 1 );
199     }
200
201     // process failure to connect to National Weather Service
202     catch ( java.net.ConnectException connectException ) {
203         connectException.printStackTrace();
204         System.exit( 1 );
205     }
206
207     // process other exceptions
208     catch ( Exception exception ) {
209         exception.printStackTrace();
210         System.exit( 1 );
211     }
212
213 } // end method run
214
215 // launch WeatherPublisher
216 public static void main( String args[] )
217 {
218     System.err.println( "Initializing server...\n" +
219                         "Enter 'q' or 'Q' to quit" );
220
221     WeatherPublisher publisher = new WeatherPublisher();
222 }
223 }
```

Fig. 16.12 **WeatherPublisher** class publishes messages to **Weather** topic (part 5 of 5).

Class **WeatherPublisher** publishes weather information for U.S. cities to the **Weather** topic on the server. Every minute, the **WeatherPublisher** obtains the weather information from the National Weather Service and publishes an individual message for each city's weather. Figure 16.13 shows the server in progress. Method **run** (lines 83–213)—specified by class **TimerTask**—connects to the topic and publishes the messages. Line 90 creates the JNDI context, in which the WeatherPublisher looks up the **TopicConnectionFactory** and **Topic** (lines 95–100). The **TopicConnectionFactory**—which the server administrator must create—creates a **TopicConnection** (lines 103–104). The **TopicConnection** then creates a **TopicSession** (lines 106–108). Lines 110–111 obtain the **TopicPublisher** from the **TopicSession**. The **TopicSession** also creates an **ObjectMessage** (lines 113–114); the **ObjectMessage** will contain **WeatherBean** objects (see Fig. 13.3 in Chapter 13, Remote Method Invocation) that maintain the weather information for a given city. Lines 165–168 create the **WeatherBean** object with data from the National Weather Service. Method **setObject** of class **ObjectMessage** stores the **WeatherBean** object in the message. Lines 174–175 use the **setStringProperty** of class **Message** to set **String** prop-

erty **City** to the city name. The subscriber can use this property to filter the messages. Finally, the **topicPublisher** publishes the message to the **topic** (line 176).

### 16.4.3 Weather Application: Subscriber Side

Class **WeatherSubscriber** (Fig. 16.14) subscribes to the **Weather** topic to receive weather updates for selected cities. Class **WeatherSubscriber** creates a graphical user interface, which allows the user to choose cities, and displays the resulting weather conditions.

As with the **WeatherPublisher**, the **WeatherSubscriber** uses a JNDI context to obtain the **TopicConnectionFactory** and **Topic** (lines 55–65). The **TopicConnectionFactory** creates a **TopicConnection** (lines 68–69), which creates a **TopicSession** (lines 72–73). Line 76 initializes the message listener for the topic receiver (created in method **getWeather**) to a new instance of the **WeatherListener** class (Fig. 16.17). Lines 90–135 set up the user interface; the weather conditions are displayed in a **WeatherDisplay** (Fig. 16.18). Figure 16.15 shows the client GUI.

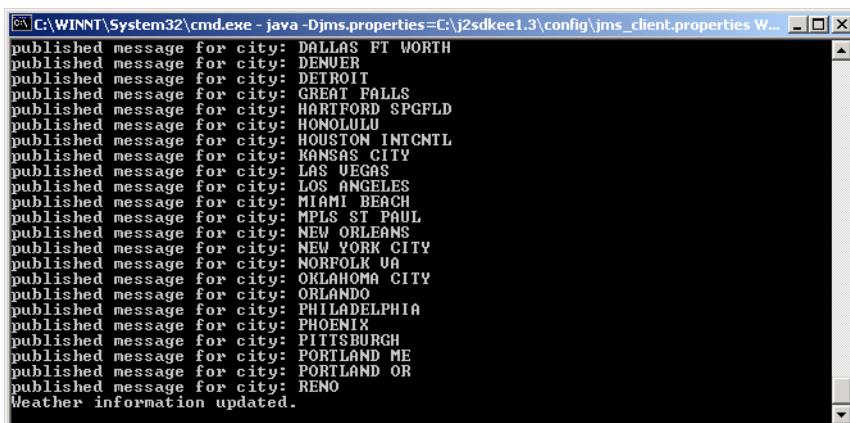


Fig. 16.13 **WeatherPublisher** publishing weather update messages.

```

1 // WeatherSubscriber.java
2 // WeatherSubscriber presents a GUI for the client to request
3 // weather conditions for various cities. The WeatherSubscriber
4 // retrieves the weather conditions from the Weather topic;
5 // each message body contains a WeatherBean object. The message
6 // header contains a String property "City," which allows
7 // the client to select the desired cities.
8 package com.deitel.advjhtp1.jms.weather;
9
10 // Java core packages
11 import java.awt.*;
12 import java.awt.event.*;

```

Fig. 16.14 **WeatherSubscriber** class allows user to receive weather updates (part 1 of 6).

```
13 // Java extension packages
14 import javax.swing.*;
15 import javax.naming.*;
16 import javax.jms.*;
17
18
19 public class WeatherSubscriber extends JFrame {
20
21     // GUI variables
22     private WeatherDisplay weatherDisplay;
23     private JList citiesList;
24
25     // cities contains cities for which weather
26     // updates are available on "Weather" topic
27     private String cities[] = { "ALBANY NY", "ANCHORAGE",
28         "ATLANTA", "ATLANTIC CITY", "BOSTON", "BUFFALO",
29         "BURLINGTON VT", "CHARLESTON WV", "CHARLOTTE", "CHICAGO",
30         "CLEVELAND", "DALLAS FT WORTH", "DENVER", "DETROIT",
31         "GREAT FALLS", "HARTFORD SPGFLD", "HONOLULU",
32         "HOUSTON INT_CNTL", "KANSAS CITY", "LAS VEGAS",
33         "LOS ANGELES", "MIAMI BEACH", "MPLS ST PAUL", "NEW ORLEANS",
34         "NEW YORK CITY", "NORFOLK VA", "OKLAHOMA CITY", "ORLANDO",
35         "PHILADELPHIA", "PHOENIX", "PITTSBURGH", "PORTLAND ME",
36         "PORTLAND OR", "RENO" };
37
38     // JMS variables
39     private TopicConnection topicConnection;
40     private TopicSession topicSession;
41     private Topic topic;
42     private TopicSubscriber topicSubscriber;
43     private WeatherListener topicListener;
44
45     // WeatherSubscriber constructor
46     public WeatherSubscriber()
47     {
48         super( "JMS WeatherSubscriber..." );
49         weatherDisplay = new WeatherDisplay();
50
51         // set up JNDI context and JMS connections
52         try {
53
54             // create JNDI context
55             Context jndiContext = new InitialContext();
56
57             // retrieve topic connection factory
58             // from JNDI context
59             TopicConnectionFactory topicConnectionFactory =
60                 ( TopicConnectionFactory ) jndiContext.lookup(
61                     "WEATHER_FACTORY" );
62
63             // retrieve topic from JNDI context
64             String topicName = "Weather";
```

Fig. 16.14 **WeatherSubscriber** class allows user to receive weather updates  
(part 2 of 6).

```
65         topic = ( Topic ) jndiContext.lookup( topicName );
66
67         // create topic connection
68         topicConnection =
69             topicConnectionFactory.createTopicConnection();
70
71         // create topic session
72         topicSession = topicConnection.createTopicSession( false,
73             Session.AUTO_ACKNOWLEDGE );
74
75         // initialize listener
76         topicListener = new WeatherListener( weatherDisplay );
77     }
78
79     // process Naming exception from JNDI context
80     catch ( NamingException namingException ) {
81         namingException.printStackTrace();
82     }
83
84     // process JMS exceptions from topic connection or session
85     catch ( JMSEException jmsException ) {
86         jmsException.printStackTrace();
87     }
88
89     // lay out user interface
90     Container container = getContentPane();
91     container.setLayout( new BorderLayout() );
92
93     JPanel selectionPanel = new JPanel();
94     selectionPanel.setLayout( new BorderLayout() );
95
96     JLabel selectionLabel = new JLabel( "Select Cities" );
97     selectionPanel.add( selectionLabel, BorderLayout.NORTH );
98
99     // create list of cities for which users
100    // can request weather updates
101    citiesList = new JList( cities );
102    selectionPanel.add( new JScrollPane( citiesList ),
103        BorderLayout.CENTER );
104
105   JButton getWeatherButton = new JButton( "Get Weather..." );
106   selectionPanel.add( getWeatherButton, BorderLayout.SOUTH );
107
108   // invoke method getWeather when getWeatherButton clicked
109   getWeatherButton.addActionListener(
110
111       new ActionListener() {
112
113           public void actionPerformed ( ActionEvent event )
114           {
115               getWeather();
116           }
117       }
118   );
119 }
```

Fig. 16.14 **WeatherSubscriber** class allows user to receive weather updates  
(part 3 of 6).

```
117         }
118     ); // end call to addActionListener
119
120     container.add( selectionPanel, BorderLayout.WEST );
121     container.add( weatherDisplay, BorderLayout.CENTER );
122
123     // invoke method quit when window closed
124     addWindowListener(
125
126         new WindowAdapter() {
127
128             public void windowClosing( WindowEvent event ) {
129                 {
130                     quit();
131                 }
132             }
133         }
134     ); // end call to addWindowListener
135
136 } // end WeatherSubscriber constructor
137
138 // get weather information for selected cities
139 public void getWeather()
140 {
141
142     // retrieve selected indices
143     int selectedIndices[] = citiesList.getSelectedIndices();
144
145     if ( selectedIndices.length > 0 ) {
146
147         // if topic subscriber exists, method has
148         // been called before
149         if ( topicSubscriber != null ) {
150
151             // close previous topic subscriber
152             try {
153                 topicSubscriber.close();
154             }
155
156             // process JMS exception
157             catch ( JMSException jmsException ) {
158                 jmsException.printStackTrace();
159             }
160
161             // clear previous cities from display
162             weatherDisplay.clearCities();
163         }
164
165         // create message selector to retrieve specified cities
166         StringBuffer messageSelector = new StringBuffer();
167         messageSelector.append(
168             "City = '" + cities[ selectedIndices[ 0 ] ] + "'");
```

Fig. 16.14 **WeatherSubscriber** class allows user to receive weather updates  
(part 4 of 6).

```
169
170     for ( int i = 1; i < selectedIndices.length; i++ ) {
171         messageSelector.append( " OR City = '" +
172             cities[ selectedIndices[ i ] ] + "'" );
173     }
174
175     // create topic subscriber and subscription
176     try {
177         topicSubscriber = topicSession.createSubscriber(
178             topic, messageSelector.toString(), false );
179         topicSubscriber.setMessageListener( topicListener );
180         topicConnection.start();
181
182         JOptionPane.showMessageDialog( this,
183             "A weather update should be arriving soon..." );
184     }
185
186     // process JMS exception
187     catch ( JMSEException jmsException ) {
188         jmsException.printStackTrace();
189     }
190
191 } // end if
192
193 } // end method getWeather
194
195 // quit WeatherSubscriber application
196 public void quit()
197 {
198     // close connection and subscription to topic
199     try {
200
201         // close topic subscriber
202         if ( topicSubscriber != null ) {
203             topicSubscriber.close();
204         }
205
206         // close topic connection
207         topicConnection.close();
208     }
209
210     // process JMS exception
211     catch ( JMSEException jmsException ) {
212         jmsException.printStackTrace();
213         System.exit( 1 );
214     }
215
216     System.exit( 0 );
217
218 } // end method quit
219
```

Fig. 16.14 **WeatherSubscriber** class allows user to receive weather updates  
(part 5 of 6).

```

220 // launch WeatherSubscriber application
221 public static void main( String args [] )
222 {
223     WeatherSubscriber subscriber = new WeatherSubscriber();
224     subscriber.pack();
225     subscriber.setVisible( true );
226 }
227 }
```

Fig. 16.14 **WeatherSubscriber** class allows user to receive weather updates (part 6 of 6).



Fig. 16.15 **WeatherSubscriber** selecting cities for weather updates.

The program invokes method **getWeather** (lines 140–193) when the user clicks the **Get Weather** button. If the method has been called previously (i.e., the user has clicked the button before), lines 149–163 close the previous **TopicSubscriber** so that a new subscriber can filter in the selected cities with a message selector. When a client specifies a message selector for a subscription, the server will only send messages satisfying that filter to the client. Lines 166–173 create a **messageSelector** so that the weather conditions for the selected cities will be displayed. The **messageSelector** syntax is based on SQL92 (see the **Message** javadoc for more details). Lines 177–178 create the **TopicSubscriber** from **TopicSession**, passing the **Topic** and **messageSelector** as parameters. The third parameter, with value **false**, indicates that the subscriber can receive messages published by its own connection. Line 179 sets the message listener for the **TopicSubscriber** to **topicListener**. A **TopicSubscriber**'s message listener handles new messages when they arrive. Finally, line 180 starts the **TopicConnection**; once the connection has started, the **TopicSubscriber** will receive messages published to the topic. Figure 16.16 shows the application after receiving messages.

When the user closes the application window, lines 202–204 close the **TopicSubscriber** if it exists. Line 207 closes the **topicConnection**.

Class **WeatherListener** (Fig. 16.17) implements interface **MessageListener**. It therefore defines method **onMessage** (lines 26–57) to receive incoming messages. When a new message arrives, line 32 checks that it is of the appropriate message type—**ObjectMessage**. If so, method **getObject** gets the **WeatherBean** from the **ObjectMessage**. The **WeatherBean** object is then passed to the **WeatherDisplay**, which displays the corresponding information for the user. Figure 16.16 shows the application window once it has received a weather update.



Fig. 16.16 **WeatherSubscriber** having received updated weather conditions.

```

1 // WeatherListener.java
2 // WeatherListener is the MessageListener for a subscription
3 // to the Weather topic. It implements the specified onMessage
4 // method to update the GUI with the corresponding city's
5 // weather.
6 package com.deitel.advjhttp1.jms.weather;
7
8 // Java extension packages
9 import javax.jms.*;
10 import javax.swing.*;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.rmi.weather.WeatherBean;
14
15 public class WeatherListener implements MessageListener {
16
17     private WeatherDisplay weatherDisplay;
18
19     // WeatherListener constructor
20     public WeatherListener( WeatherDisplay display )
21     {
22         weatherDisplay = display;
23     }
24
25     // receive new message
26     public void onMessage( Message message )
27     {
28         // retrieve and process message
29         try {
30
31             // ensure Message is an ObjectMessage
32             if ( message instanceof ObjectMessage ) {
33
34                 // get WeatherBean from ObjectMessage
35                 ObjectMessage objectMessage =
36                     ( ObjectMessage ) message;

```

Fig. 16.17 **WeatherListener** class subscribes to **Weather** topic to receive weather forecasts (part 1 of 2).

```
37         WeatherBean weatherBean =
38             ( WeatherBean ) objectMessage.getObject() ;
39
40         // add WeatherBean to display
41         weatherDisplay.addItem( weatherBean ) ;
42
43     } // end if
44
45     else {
46         System.out.println( "Expected ObjectMessage," +
47             " but received " + message.getClass().getName() ) ;
48     }
49
50 } // end try
51
52 // process JMS exception from message
53 catch ( JMSEException jmsException ) {
54     jmsException.printStackTrace();
55 }
56
57 } // end method onMessage
58 }
```

Fig. 16.17 **WeatherListener** class subscribes to **Weather** topic to receive weather forecasts (part 2 of 2).

Class **WeatherDisplay** (Fig. 16.18) displays **WeatherBean** objects in **JList** **weatherList**. The **weatherList** uses classes **WeatherListModel** and **WeatherCellRenderer** (see Fig. 13.5 and Fig. 13.6 in Chapter 13, Remote Method Invocation) to display **WeatherBean** objects. Method **addItem** (lines 47–65) adds the specified **WeatherBean** item to the display if the corresponding city is not displayed currently. If the city is in the display already, lines 56–58 remove the city's previous **WeatherBean** object and add the updated **WeatherBean** object.

```
1 // WeatherDisplay.java
2 // WeatherDisplay extends JPanel to display results
3 // of client's request for weather conditions.
4 package com.deitel.advjhttp1.jms.weather;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.util.*;
10
11 // Java extension packages
12 import javax.swing.*;
13
14 // Deitel packages
15 import com.deitel.advjhttp1.rmi.weather.*;
```

Fig. 16.18 **WeatherDisplay** displays **WeatherBeans** in a **JList** using a **WeatherCellRenderer** (part 1 of 3).

```
16
17 public class WeatherDisplay extends JPanel {
18
19     // WeatherListModel and Map for storing WeatherBeans
20     private WeatherListModel weatherListModel;
21     private Map weatherItems;
22
23     // WeatherDisplay constructor
24     public WeatherDisplay()
25     {
26         setLayout( new BorderLayout() );
27
28         ImageIcon headerImage = new ImageIcon(
29             WeatherDisplay.class.getResource(
30                 "images/header.jpg" ) );
31         add( new JLabel( headerImage ), BorderLayout.NORTH );
32
33         // use JList to display updated weather conditions
34         // for requested cities
35         weatherListModel = new WeatherListModel();
36         JList weatherJList = new JList( weatherListModel );
37         weatherJList.setCellRenderer( new WeatherCellRenderer() );
38
39         add( new JScrollPane( weatherJList ), BorderLayout.CENTER );
40
41         // maintain WeatherBean items in HashMap
42         weatherItems = new HashMap();
43
44     } // end WeatherDisplay constructor
45
46     // add WeatherBean item to display
47     public void addItem( WeatherBean weather )
48     {
49         String city = weather.getCityName();
50
51         // check whether city is already in display
52         if ( weatherItems.containsKey( city ) ) {
53
54             // if city is in Map, and therefore in display
55             // remove previous WeatherBean object
56             WeatherBean previousWeather =
57                 ( WeatherBean ) weatherItems.remove( city );
58             weatherListModel.remove( previousWeather );
59         }
60
61         // add WeatherBean to Map and WeatherListModel
62         weatherListModel.add( weather );
63         weatherItems.put( city, weather );
64
65     } // end method addItem
66
```

Fig. 16.18 `WeatherDisplay` displays `WeatherBeans` in a `JList` using a `WeatherCellRenderer` (part 2 of 3).

```
67 // clear all cities from display
68 public void clearCities()
69 {
70     weatherItems.clear();
71     weatherListModel.clear();
72 }
73 }
```

Fig. 16.18 `WeatherDisplay` displays `WeatherBeans` in a `JList` using a `WeatherCellRenderer` (part 3 of 3).

#### 16.4.4 Weather Application: Configuring and Running

To run the application, issue the following commands at a command prompt:

1. Start J2EE server in a command window:

```
j2ee -verbose
```

2. In a new command window, create the `Weather` topic:

```
j2eeadmin -addJmsDestination Weather topic
```

3. Verify that the topic was created:

```
j2eeadmin -listJmsDestination
```

4. Create the connection factory:

```
j2eeadmin -addJmsFactory WEATHER_FACTORY topic
```

5. Start `WeatherPublisher`:

```
java -classpath %J2EE_HOME%\lib\j2ee.jar;.
-Djms.properties=%J2EE_HOME%\config\jms_client.properties
com.deitel.advjhttp1.jms.weather.WeatherPublisher
```

6. Start `WeatherSubscriber` in a new command window:

```
java -classpath %J2EE_HOME%\lib\j2ee.jar;.
-Djms.properties=%J2EE_HOME%\config\jms_client.properties
com.deitel.advjhttp1.jms.weather.WeatherSubscriber
```

Once you have finished running the application, you can remove the connection factory with the command:

```
j2eeadmin -removeJmsFactory WEATHER_FACTORY
```

To remove the topic, use the command:

```
j2eeadmin -removeJmsDestination Weather
```

To stop J2EE server, use the command:

```
j2ee -stop
```

## 16.5 Message-Driven Enterprise JavaBeans

*Message-driven EJBs*, or *message-driven beans*, are a new type of Enterprise JavaBean available in Enterprise JavaBeans version 2.0, which is part of the Java 2 Enterprise Edition version 1.3.<sup>1</sup> Message-driven beans are capable of processing JMS messages posted to a queue or topic. When a message is received, the EJB container uses any available instance of a particular message-driven bean to process the message. This is similar to the way an EJB container will use any instance of a stateless session EJB to handle a client request. Since any message-driven EJB instance may be used, message-driven beans are not specific to particular client and must not maintain client state information. Note that any given EJB instance may process messages from multiple clients. Unlike session and entity beans (which require developers to provide home and remote interfaces), message-driven beans require that developers to provide only the bean implementation class.

### 16.5.1 Voter Application: Overview

This section presents an implementation of the Voter application from Section 16.3 using a message-driven bean to tally the votes posted to the **Votes** queue. Class **Voter** (Fig. 16.4), which posts the vote messages to the queue, remains exactly the same—a benefit of loosely-coupled applications. The sender simply sends messages to the queue regardless of the receiver’s implementation. The receiving end of the application (Section 16.5.2) is now a message-driven bean. Entity bean **Candidate** (Fig. 16.20, Fig. 16.21 and Fig. 16.22) represents a particular candidate for which users can vote. Entity bean **Candidate** stores the vote tallies in database **Voting**. Message-driven bean **VoteCollectorEJB** (Fig. 16.23) uses the **Candidate** EJB to update the tallies when the **Votes** queue receives a new vote message. Class **TallyDisplay** (Fig. 16.24) accesses the **Candidate** EJB to present a GUI with the current tallies from the database. Figure 16.19 provides an overview of the application.

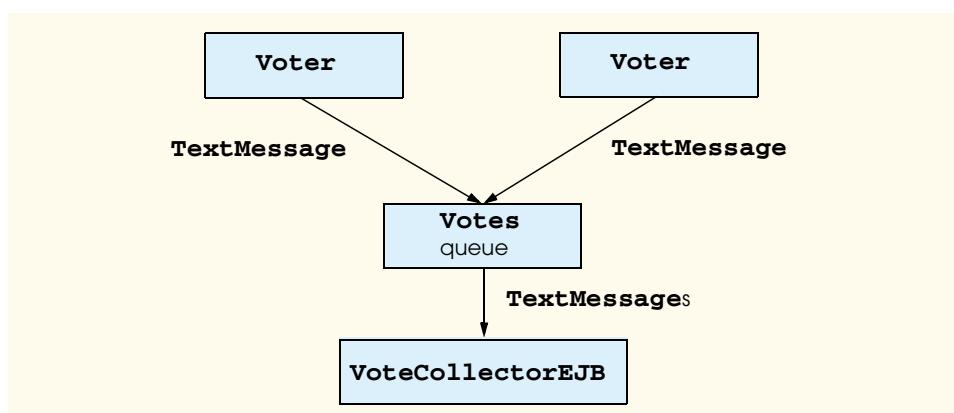


Fig. 16.19 **Voter** application overview.

1. At the time of this writing, the Java 2 Enterprise Edition Specification, version 1.3, was a Proposed Final Draft in the Java Community Process.

### 16.5.2 Voter Application: Receiver Side

The **Candidate** entity EJB represents a particular candidate for which users can vote and the total number of votes the **Candidate** has received. Home interface **CandidateHome** (Fig. 16.20) provides methods **findByPrimaryKey** (lines 15–16) and **findAllCandidates** (lines 19–20) to locate a particular **Candidate** or a **Collection** of all **Candidates**, respectively. Method **create** (lines 23–24) creates a new **Candidate** EJB with the given **candidateName** and zero votes.

Remote interface **Candidate** (Fig. 16.21) provides method **incrementVoteCount** to add a new vote for the **Candidate**. Method **getVoteCount** (line 18) returns the current vote tally for the **Candidate**. Method **getCandidateName** (line 21) returns the **Candidate**'s name.

```
1 // CandidateHome.java
2 // CandidateHome is the home interface for the Candidate EJB.
3 package com.deitel.advjhttp1.jms.mdb;
4
5 // Java core libraries
6 import java.rmi.*;
7 import java.util.*;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public interface CandidateHome extends EJBHome {
13
14     // find Candidate with given name
15     public Candidate findByPrimaryKey( String candidateName )
16         throws RemoteException, FinderException;
17
18     // find all Candidates
19     public Collection findAllCandidates()
20         throws RemoteException, FinderException;
21
22     // create new Candidate EJB
23     public Candidate create( String candidateName )
24         throws RemoteException, CreateException;
25 }
```

Fig. 16.20 CandidateHome interface for Candidate EJB.

```
1 // Candidate.java
2 // Candidate is the remote interface for the Candidate
3 // EJB, which maintains a tally of votes.
4 package com.deitel.advjhttp1.jms.mdb;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
```

Fig. 16.21 Candidate remote interface for Candidate EJB (part 1 of 2).

---

```

9 // Java standard extensions
10 import javax.ejb.EJBObject;
11
12 public interface Candidate extends EJBObject {
13
14     // place vote for this Candidate
15     public void incrementVoteCount() throws RemoteException;
16
17     // get total vote count for this Candidate
18     public Integer getVoteCount() throws RemoteException;
19
20     // get Candidate's name
21     public String getCandidateName() throws RemoteException;
22 }
```

Fig. 16.21 Candidate remote interface for **Candidate** EJB (part 2 of 2).

Class **CandidateEJB** (Fig. 16.22) implements the **Candidate** entity EJB. The **Candidate** EJB uses container-managed persistence for storing **Candidate** information in a database. Lines 17–18 declare container-managed fields **voteCount** and **name** for storing the **Candidate**'s total vote tally and name, respectively. Method **incrementVoteCount** (lines 21–25) increments the **Candidate**'s vote tally. Method **getName** (lines 34–37) returns the **Candidate**'s name. Method **ejbCreate** (lines 40–47) creates a new **Candidate** EJB, sets the **Candidate**'s **name** and initializes the **voteCount** to zero.

---

```

1 // CandidateEJB.java
2 // CandidateEJB is an entity EJB that uses container-managed
3 // persistence to persist its Candidate and its vote tally.
4 package com.deitel.advjhttp1.jms.mdb;
5
6 // Java core libraries
7 import java.rmi.RemoteException;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 public class CandidateEJB implements EntityBean {
13
14     private EntityContext entityContext;
15
16     // container-managed fields
17     public Integer voteCount;
18     public String name;
19
20     // place vote for this Candidate
21     public void incrementVoteCount()
22     {
23         int newVoteCount = voteCount.intValue() + 1;
24         voteCount = new Integer( newVoteCount );
25     }
}
```

Fig. 16.22 CandidateEJB class to maintain candidate tallies (part 1 of 3).

```
26
27     // get total vote count for this Candidate
28     public Integer getVoteCount()
29     {
30         return voteCount;
31     }
32
33     // get Candidate's name
34     public String getCandidateName()
35     {
36         return name;
37     }
38
39     // create new Candidate
40     public String ejbCreate( String candidateName )
41         throws CreateException
42     {
43         name = candidateName;
44         voteCount = new Integer( 0 );
45
46         return null;
47     }
48
49     // do post-creation tasks when creating new Candidate
50     public void ejbPostCreate( String candidateName ) {}
51
52     // set EntityContext
53     public void setEntityContext( EntityContext context )
54     {
55         entityContext = context;
56     }
57
58     // unset EntityContext
59     public void unsetEntityContext()
60     {
61         entityContext = null;
62     }
63
64     // activate Candidate instance
65     public void ejbActivate()
66     {
67         name = ( String ) entityContext.getPrimaryKey();
68     }
69
70     // passivate Candidate instance
71     public void ejbPassivate()
72     {
73         name = null;
74     }
75
76     // load Candidate from database
77     public void ejbLoad() {}
78
```

Fig. 16.22 **CandidateEJB** class to maintain candidate tallies (part 2 of 3).

```
79 // store Candidate in database
80 public void ejbStore() {}
81
82 // remove Candidate from database
83 public void ejbRemove() {}
84 }
```

Fig. 16.22 **CandidateEJB** class to maintain candidate tallies (part 3 of 3).

To handle incoming messages from the **Votes** queue, the container uses message-driven bean class **VoteCollectorEJB** (Fig. 16.23). When **VoteCollectorEJB** receives a new vote, the container invokes method **onMessage** (lines 21–48).

```
1 // VoteCollectorEJB.java
2 // VoteCollectorEJB is a MessageDriven EJB that tallies votes.
3 package com.deitel.advjhtp1.jms.mdb;
4
5 // Java core packages
6 import java.util.*;
7 import java.rmi.*;
8
9 // Java extension packages
10 import javax.ejb.*;
11 import javax.rmi.*;
12 import javax.jms.*;
13 import javax.naming.*;
14
15 public class VoteCollectorEJB
16     implements MessageDrivenBean, MessageListener {
17
18     private MessageDrivenContext messageDrivenContext;
19
20     // receive new message
21     public void onMessage( Message message )
22     {
23         TextMessage voteMessage;
24
25         // retrieve and process message
26         try {
27
28             if ( message instanceof TextMessage ) {
29                 voteMessage = ( TextMessage ) message;
30                 String vote = voteMessage.getText();
31                 countVote( vote );
32
33                 System.out.println( "Received vote: " + vote );
34             } // end if
35         }
```

Fig. 16.23 **VoteCollectorEJB** class tallies votes from **Votes** queue (part 1 of 3).

```
36         else {
37             System.out.println( "Expecting " +
38                 "TextMessage object, received " +
39                 message.getClass().getName() );
40         }
41     } // end try
42
43     // process JMS exception from message
44     catch ( JMSEException jmsException ) {
45         jmsException.printStackTrace();
46     }
47 }
48 }
49
50 // add vote to corresponding tally
51 private void countVote( String vote )
52 {
53     // CandidateHome reference for finding/creating Candidates
54     CandidateHome candidateHome = null;
55
56     // find Candidate and increment vote count
57     try {
58
59         // look up Candidate EJB
60         Context initialContext = new InitialContext();
61
62         Object object = initialContext.lookup(
63             "java:comp/env/ejb/Candidate" );
64
65         candidateHome =
66             ( CandidateHome ) PortableRemoteObject.narrow(
67                 object, CandidateHome.class );
68
69         // find Candidate for whom the user voted
70         Candidate candidate =
71             candidateHome.findByPrimaryKey( vote );
72
73         // increment Candidate's vote count
74         candidate.incrementVoteCount();
75
76     } // end try
77
78     // if Candidate not found, create new Candidate
79     catch ( FinderException finderException ) {
80
81         // create new Candidate and increment its vote count
82         try {
83             Candidate newCandidate = candidateHome.create( vote );
84             newCandidate.incrementVoteCount();
85         }
86     }
```

Fig. 16.23 **VoteCollectorEJB** class tallies votes from **Votes** queue (part 2 of 3).

```

87          // handle exceptions creating new Candidate
88          catch ( Exception exception ) {
89              throw new EJBException( exception );
90          }
91      } // end FinderException catch
92
93      // handle exception when looking up OrderProducts EJB
94      catch ( NamingException namingException ) {
95          throw new EJBException( namingException );
96      }
97
98      // handle exception when invoking OrderProducts methods
99      catch ( RemoteException remoteException ) {
100         throw new EJBException( remoteException );
101     }
102
103 } // end method countVote
104
105 // set message driven context
106 public void setMessageDrivenContext(
107     MessageDrivenContext context )
108 {
109     messageDrivenContext = context;
110 }
111
112 // create bean instance
113 public void ejbCreate() {}
114
115 // remove bean instance
116 public void ejbRemove() {}
117
118 }
```

Fig. 16.23 **VoteCollectorEJB** class tallies votes from **Votes** queue (part 3 of 3).

Class **VoteCollectorEJB** implements interfaces **MessageDrivenBean** and **MessageListener**. The container invokes method **ejbCreate** following instantiation of a new bean instance and method **ejbRemove** just before the instance is destroyed. Interface **MessageDrivenBean** specifies method **setMessageDrivenContext**. Note that interface **MessageDrivenBean** also specifies that the message-driven context should be stored as an instance variable (**messageDrivenContext**).

Upon receiving a message, the container invokes method **onMessage**, specified by interface **MessageListener**. Line 28 checks that the received **Message** is of type **TextMessage**. If so, line 31 invokes method **countVote** to count the received vote. Method **countVote** (lines 51–104) looks up the **Candidate** EJB (lines 60–67) and invokes method **findByPrimaryKey** of interface **CandidateHome** to locate the **Candidate** for which the user voted. If the **Candidate** is found, line 74 invokes method **incrementVoteCount** of interface **Candidate** to add a vote for the **Candidate**. If the **Candidate** is not found, lines 79–92 catch a **FinderException**.

Class **TallyDisplay** (Fig. 16.24) displays a snapshot of the candidates and corresponding tallies. Class **TallyDisplay** uses the **Candidate** EJB to retrieve the voting data. Lines 36–46 look up the **Candidate** EJB and retrieve a Collection of all Candidates.

For each **Candidate**, lines 51–58 create and add a new **TallyPanel** (Fig. 16.26), passing the candidate name and vote count as parameters to the **TallyPanel** constructor.

```
1 // TallyDisplay.java
2 // TallyDisplay displays the votes from database.
3 package com.deitel.advjhtp1.jms.mdb;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.event.*;
8 import java.rmi.*;
9 import java.util.*;
10 import java.util.List;
11
12 // Java extension packages
13 import javax.swing.*;
14 import javax.ejb.*;
15 import javax.rmi.*;
16 import javax.naming.*;
17
18 public class TallyDisplay extends JFrame {
19
20     // TallyDisplay constructor
21     public TallyDisplay()
22     {
23         super( "Vote Tallies" );
24
25         Container container = getContentPane();
26
27         // displayPanel displays tally results
28         JPanel displayPanel = new JPanel();
29         displayPanel.setLayout( new GridLayout( 0, 1 ) );
30         container.add( new JScrollPane( displayPanel ) );
31
32         // find Candidates and display tallies
33         try {
34
35             // look up Candidate EJB
36             Context initialContext = new InitialContext();
37
38             Object object = initialContext.lookup(
39                 "Candidate" );
40             CandidateHome candidateHome =
41                 ( CandidateHome ) PortableRemoteObject.narrow(
42                     object, CandidateHome.class );
43
44             // find all Candidates
45             Collection candidates =
46                 candidateHome.findAllCandidates();
```

Fig. 16.24 **TallyDisplay** displays candidate tallies from database (part 1 of 2).

```
47         // add TallyPanel with candidate name and
48         // vote count for each candidate
49         Iterator iterator = candidates.iterator();
50         while ( iterator.hasNext() ) {
51             Candidate candidate = ( Candidate ) iterator.next();
52
53             // create TallyPanel for Candidate
54             TallyPanel tallyPanel =
55                 new TallyPanel( candidate.getCandidateName(),
56                               candidate.getVoteCount().intValue() );
56             displayPanel.add( tallyPanel );
57         }
58     }
59 }
60 }
61 } // end try
62
63 // handle exception finding Candidates
64 catch ( FinderException finderException ) {
65     finderException.printStackTrace();
66 }
67 // handle exception looking up Candidate EJB
68 catch ( NamingException namingException ) {
69     namingException.printStackTrace();
70 }
71
72 // handle exception communicating with Candidate
73 catch ( RemoteException remoteException ) {
74     remoteException.printStackTrace();
75 }
76
77 } // end TallyDisplay constructor
78
79 // launch TallyDisplay application
80 public static void main( String args[] )
81 {
82     TallyDisplay tallyDisplay = new TallyDisplay();
83     tallyDisplay.setDefaultCloseOperation( EXIT_ON_CLOSE );
84     tallyDisplay.pack();
85     tallyDisplay.setVisible( true );
86 }
87 }
```

Fig. 16.24 **TallyDisplay** displays candidate tallies from database (part 2 of 2).

Figure 16.25 demonstrates the **TallyDisplay**. Note that the **TallyDisplay** displays only those votes already registered; the **TallyDisplay** does not update as new votes are received.

Class **TallyPanel** (Fig. 16.26) displays the name and tally for an individual candidate in a **JPanel**.

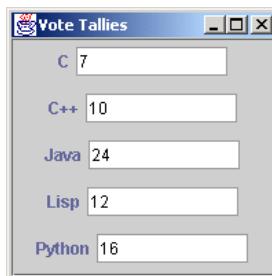


Fig. 16.25 **TallyDisplay** displays candidate tallies from database.

```
1 // TallyPanel.java
2 // TallyPanel is the GUI component which displays
3 // the name and tally for a vote candidate.
4 package com.deitel.advjhtp1.jms.mdb;
5
6 // Java core packages
7 import java.awt.*;
8
9 // Java extension packages
10 import javax.swing.*;
11
12 public class TallyPanel extends JPanel {
13
14     private JLabel nameLabel;
15     private JTextField tallyField;
16     private String name;
17     private int tally;
18
19     // TallyPanel constructor
20     public TallyPanel( String voteName, int voteTally )
21     {
22         name = voteName;
23         tally = voteTally;
24
25         nameLabel = new JLabel( name );
26         tallyField =
27             new JTextField( Integer.toString( tally ), 10 );
28         tallyField.setEditable( false );
29         tallyField.setBackground( Color.white );
30
31         add( nameLabel );
32         add( tallyField );
33
34     } // end TallyPanel constructor
35
36 }
```

Fig. 16.26 **TallyPanel** class displays the name and tally for a candidate.

### 16.5.3 Voter Application: Configuring and Running

This section presents the steps needed to deploy and run the message-driven bean **Voter** application. Since the application relies on the Cloudscape database, the following lines must be added to the file **resource.properties** within the **config** directory under the main J2EE directory (e.g., **C:\j2sdkee1.3\config\resource.properties**):

```
jdbcDataSource.5.name=jdbc/Voting  
jdbcDataSource.5.url=jdbc:cloudscape:rmi:VotingDB;create=true
```

Note that there may be several **jdbcDataSource** entries in this properties file. In the above examples, you should replace the **5** with the number of the last **jdbcDataSource** entry plus **1**. For example, if the last **jdbcDataSource** entry is number **3**, you would specify **jdbcDataSource.4.name** and **jdbcDataSource.4.url**. Once you have added these lines, start Cloudscape. Then start the J2EE server, using the command

```
j2ee -verbose
```

In a new command window, create the queue and connection factory (note that these might still exist, if created in Section 16.3.4):

```
j2eeadmin -addJmsDestination Votes queue  
j2eeadmin -listJmsDestination  
j2eeadmin -addJmsFactory VOTE_FACTORY queue
```

To deploy the **VoteCollector** application, start

```
deploytool
```

Create a new application by selecting **File -> New Application** from the menu bar. In the dialog, click **Browse** and navigate to the directory above the **com** directory. Enter **VoteCollectorApp.ear** as the **File** name and click **New Application**. Then click **OK**.

Now, add the Candidate EJB by selecting **New Enterprise Bean** from the **File** menu. In the **EJB JAR** dialog, select the **Create new EJB File in Application** radio button, highlighting **VoteCollectorApp** from the resulting pull-down menu. Enter **VoteCollectorJAR** as the **EJB Display Name**. See Fig. 16.27 for details. Click the **Edit** button to add the class files. Inside the **Edit** dialog, specify the directory that contains the **com.deitel.advjhttp1** packages structure as the **Starting Directory**. Navigate down the tree to the **mdb** directory (**com/deitel/advjhttp1/jms/mdb**) and **Add Candidate.class**, **CandidateEJB.class** and **CandidateHome.class** (Fig. 16.28). Click **OK** to exit the **Edit** dialog. Click **Next** to proceed to the **General** dialog.

In the **General** dialog, select the **Entity** radio button as the **Bean Type**. Select **com.deitel.advjhttp1.jms.mdb.CandidateEJB** from the pull-down menu for the **Enterprise Bean Class**. Enter **Candidate** as the **Enterprise Bean Name**. In the **Remote Interfaces** section, select **com.deitel.advjhttp1.jms.mdb.CandidateHome** and **com.deitel.advjhttp1.jms.mdb.Candidate** as the **Remote Home Interface** and **Remote Interface**, respectively. (See Fig. 16.29 for details.) Click **Next** to proceed to the **Entity Settings** dialog.

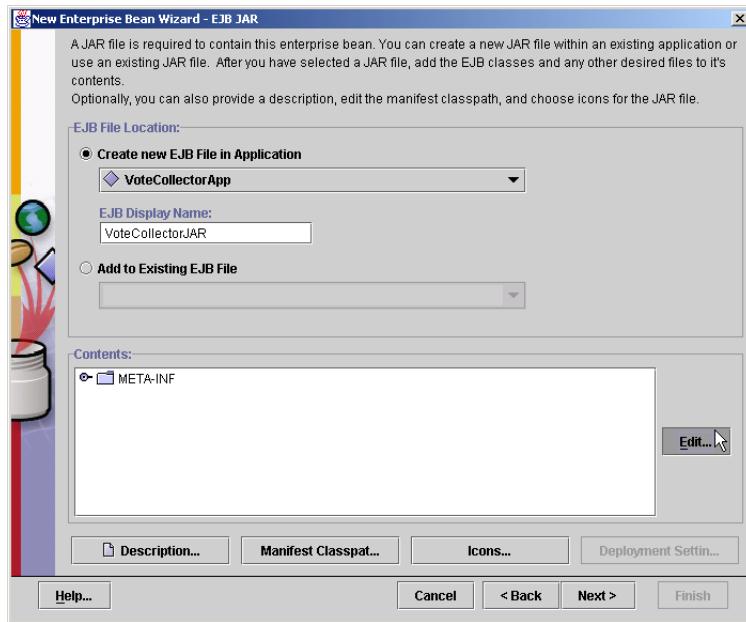


Fig. 16.27 EJB JAR settings for **VoteCollectorApp** application.

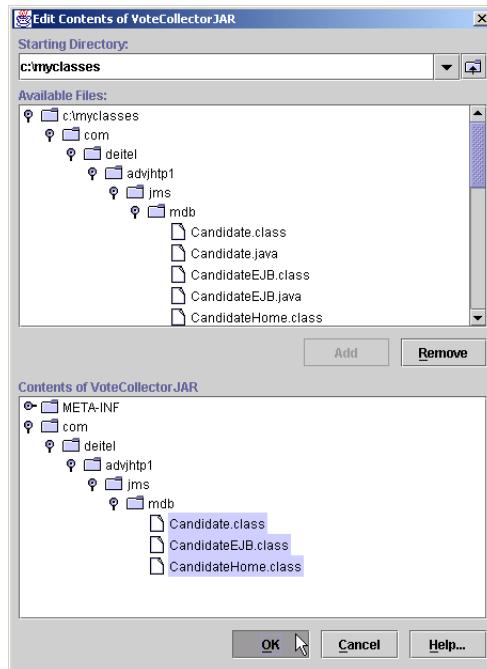


Fig. 16.28 Add class files for **Candidate** EJB.

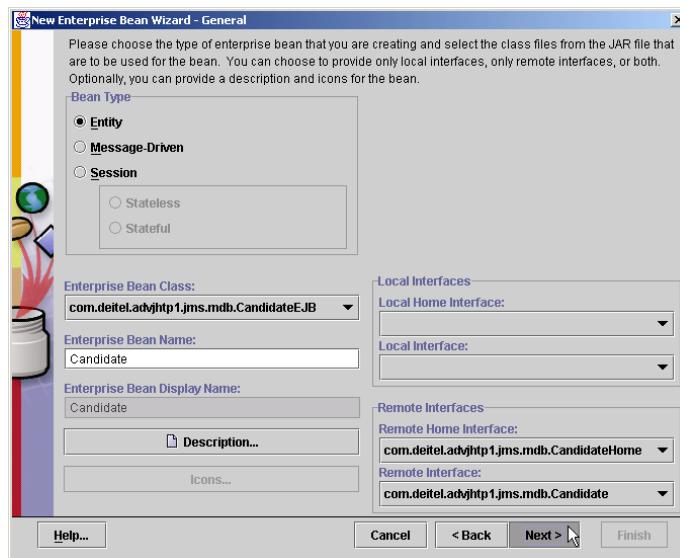


Fig. 16.29 General settings for **Candidate** EJB.

In the **Entity Settings** dialog, select radio button **Container managed persistence(1.0)**. Check both **voteCount** and **name**. Enter **java.lang.String** as the **Primary Key Class**, and select **name** from the pull-down menu under the **Primary Key Field**. See Fig. 16.30 for details. Click **Finish**.

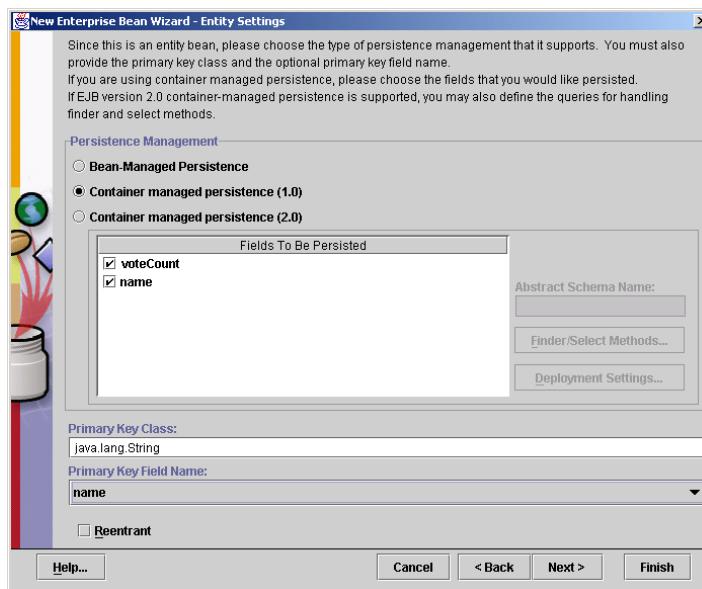


Fig. 16.30 Entity settings for **Candidate** EJB.

In the main **deploytool** window, select **Candidate** and click the **Entity** tab (Fig. 16.31). Click **Deployment Settings**. In the resulting dialog, click **Database Settings**. Enter **jdbc/Voting** as the **Database JNDI Name** (Fig. 16.32). Click **OK**. In the **Deployment Settings** dialog, click **Generate Default SQL**. A dialog will pop up, indicating **SQL Generation complete**; click **OK** (Fig. 16.33). In the **Deployment Settings** dialog, click **OK**. A warning dialog will appear that indicates there is no **WHERE** clause for method **findAllCandidates**; click **OK** to ignore the warning (Fig. 16.34).

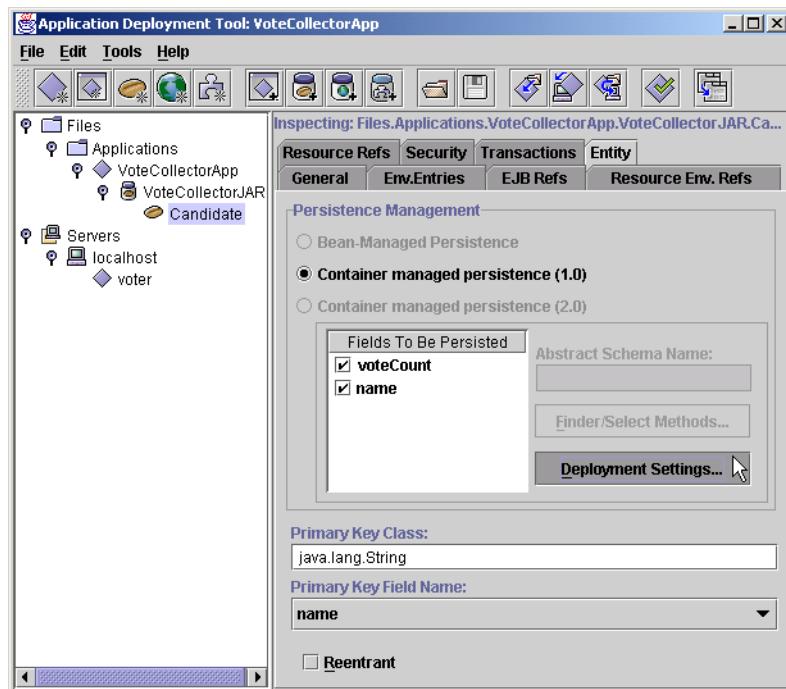


Fig. 16.31 Entity tab for **Candidate** EJB.

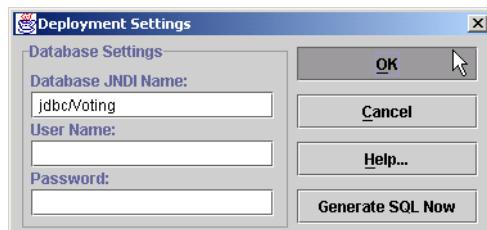


Fig. 16.32 Database settings for **Candidate** EJB.

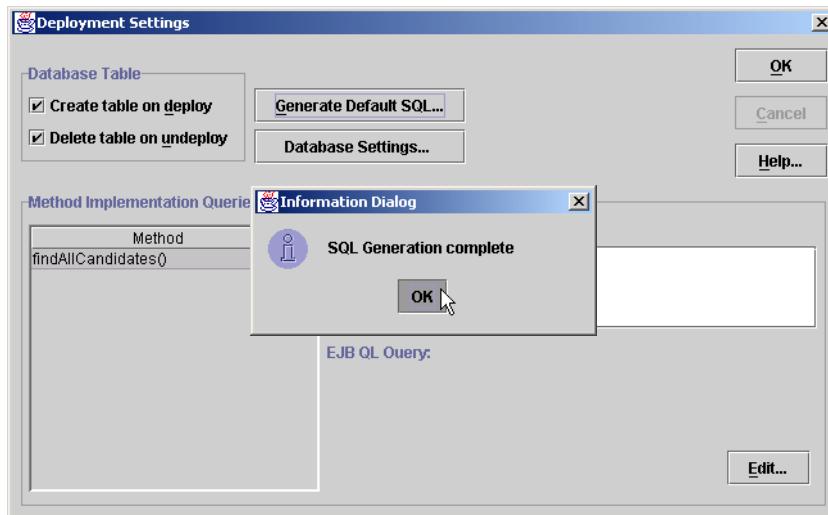


Fig. 16.33 SQL generation for **Candidate** EJB.



Fig. 16.34 SQL warning for **Candidate** EJB.

Now create the **VoteCollector** EJB by selecting **File -> New Enterprise Bean** from the menu bar. Click radio button **Add to Existing EJB File** and select **VoteCollectorJAR(VoteCollectorApp)** from the resulting pull-down menu (Fig. 16.35). Click **Edit** and **Add VoteCollectorEJB.class** from tree structure **com/deitel/advjhttp1/jms/mdb** (Fig. 16.36). Click **OK** to exit the **Edit** dialog. Click **Next** to proceed to the **General** dialog.

In the **General** dialog (Fig. 16.37), select **Message-Driven Bean** as the **Bean Type**. Select **com.deitel.advjhttp1.jms.mdb.VoteCollectorEJB** as the **Enterprise Bean Class**. Enter **VoteCollector** as the **Enterprise Bean Name**. Click **Next** to proceed to the **Transaction Management** dialog.

In the **Transaction Management** dialog (Fig. 16.38), select **Container-Managed**. Verify **Transaction Attribute Required** for method **onMessage**. Click **Next** to proceed to the **Message-Driven Bean Settings** dialog.

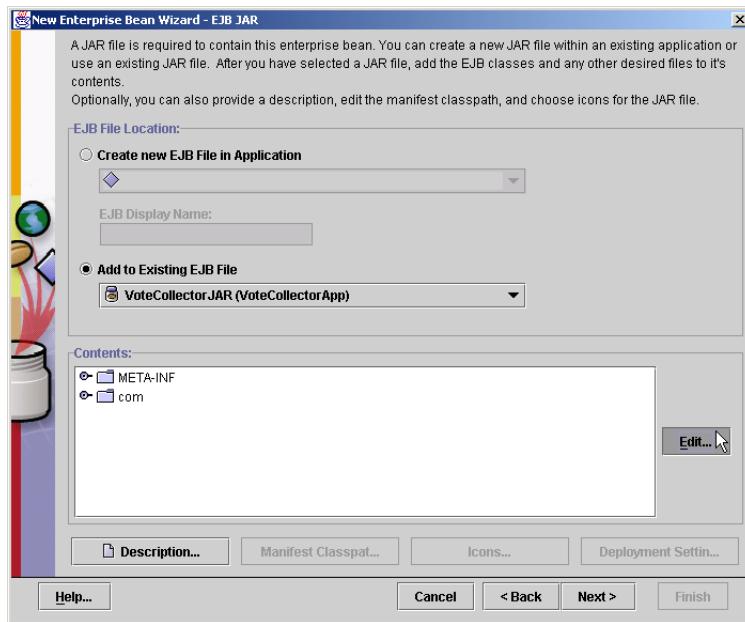


Fig. 16.35 EJB JAR settings for **VoteCollector** EJB.

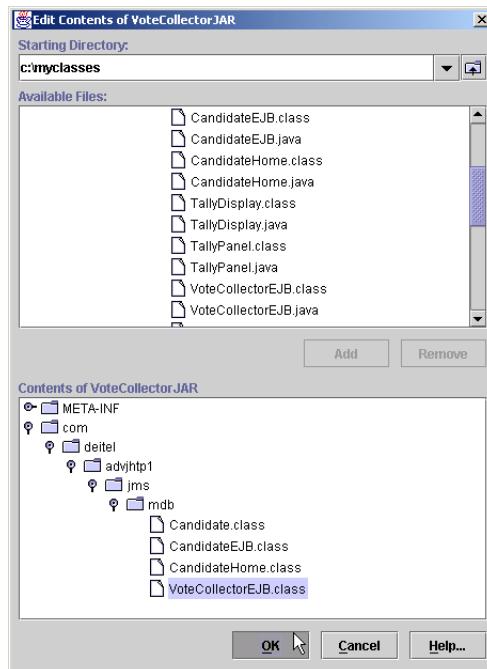


Fig. 16.36 Add class file for **VoteCollector** EJB.

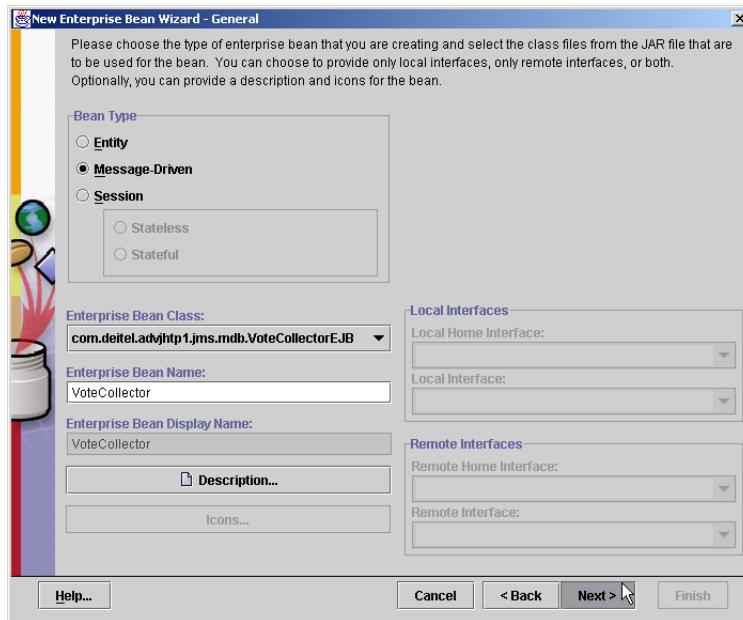


Fig. 16.37 General settings for **VoteCollector** EJB.

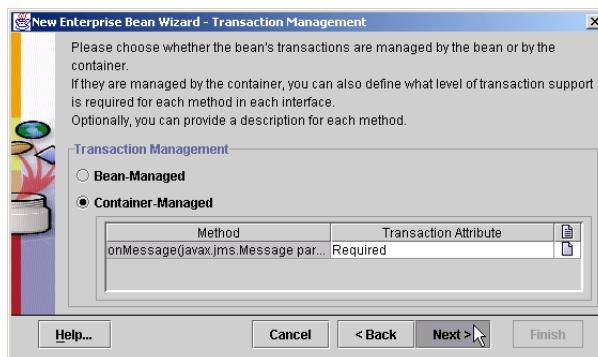


Fig. 16.38 Transaction management settings for the **VoteCollector** EJB.

In the **Message-Driven Bean** dialog, select **Queue** as the **Destination Type** (Fig. 16.39). Select **Votes** and **VOTE\_FACTORY** from the pull-down menus for **Destination** and **Connection Factory**, respectively. Click **Next** to proceed to the **Environment Entries** dialog. Do not enter anything in this dialog; click **Next** again to proceed to the **Enterprise Bean References** dialog.

In the **Enterprise Bean References** dialog (Fig. 16.40), click **Add**. For the **Coded Name**, enter **ejb/Candidate**. Select **Entity** for **Type** and **Remote** for **Interfaces**. Enter **com.deitel.advjhttp1.jms.mdb.CandidateHome** and **com.deitel.advjhttp1.jms.mdb.Candidate** as the **Home Interface** and

**Local/Remote Interface**, respectively. Select radio button **JNDI Name** and enter **Candidate** in the corresponding text field. Click **Finish**.

In the main **deploytool** window, select **VoteCollectorApp** from the tree, and click the **JNDI Names** tab. Enter **Candidate** as the **JNDI Name** for **Candidate**. Verify that **Votes** is the **JNDI Name** for **VoteCollector** (Fig. 16.41).

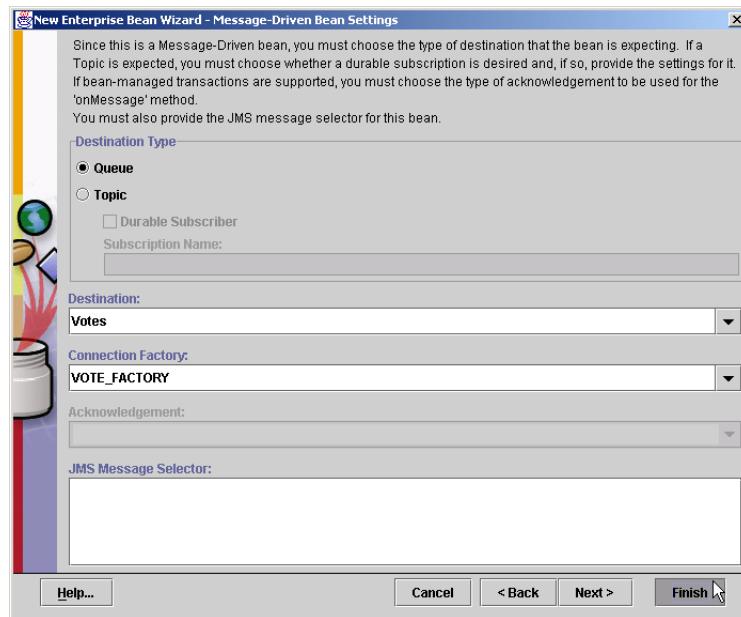


Fig. 16.39 Message-Driven Bean settings for **VoteCollector** EJB.

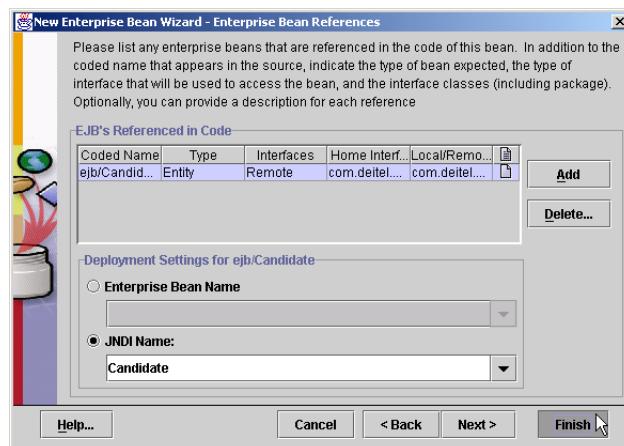


Fig. 16.40 Enterprise Bean References for **VoteCollector** EJB.

Finally, deploy the application by selecting **Deploy** from the **Tools** menu. Select **VoteCollectorApp** as the **Object to Deploy**. In the dialog, check **Return Client JAR** (Fig. 16.42). Click **Next** and verify the JNDI names. Click **Next**, then **Finish**.

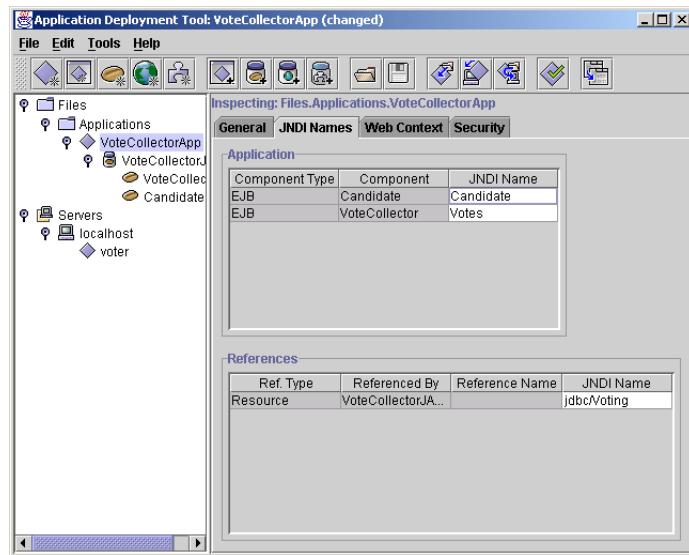


Fig. 16.41 Setting JNDI names for **VoteCollectorApp**.

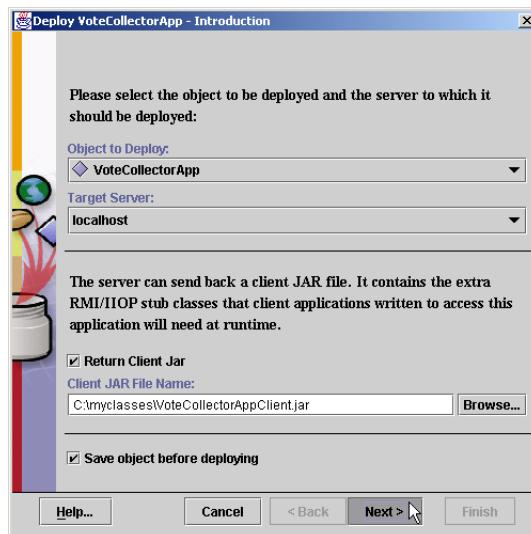


Fig. 16.42 Deploying the **VoteCollector** application.

After deploying the **VoteCollector** application, run the **Voter** client application:

```
java -classpath %J2EE_HOME%\lib\j2ee.jar;.
-Djms.properties=%J2EE_HOME%\config\jms_client.properties
com.deitel.advjhttp1.jms.mdb.Voter
```

To view the current vote tallies, run **TallyDisplay** (note that the client JAR must be included in the classpath)

```
java -classpath
%J2EE_HOME%\lib\j2ee.jar;VoteCollectorAppClient.jar;.
com.deitel.advjhttp1.jms.mdb.TallyDisplay
```

## SUMMARY

- A messaging system loosely couples components.
- Messaging systems allow components to post messages for other components to read.
- There are two basic messaging system models—point-to-point and publish/subscribe. The point-to-point messaging model allows components to send messages to a message queue. A message consumer is a target component that processes the received messages.
- In the point-to-point model, exactly one client consumes a message; the server maintains messages that have not been consumed.
- The publish/subscribe messaging model allows components to publish messages to a topic. Components interested in messages published to a particular topic can subscribe to that topic.
- When a publisher publishes a message to a given topic, current subscribers receive that message.
- In the publish/subscribe model, zero or more subscribers consume a published message.
- A message consists of a header, properties (optional) and a body (also optional). The message header contains information, such as the message destination and the sending time.
- Message properties allow message receivers to select which types of messages they would like to receive; the sender of a message can set these properties. Message receivers use message selectors to filter out messages; filtering is done on the server side.
- Message-driven beans are a type of enterprise bean that integrate nicely with MOM.
- The EJB container can use any instance of a message-driven bean to process incoming messages to a given queue or topic. Using message-driven beans, a component can receive messages asynchronously.
- The Java Message Service (JMS) API. JMS standardizes enterprise messaging, providing APIs for both the point-to-point and publish/subscribe models.
- JMS provides five types of messages—**BytesMessages**, **MapMessages**, **ObjectMessages**, **StreamMessages** and **TextMessages**.
- The server administrator creates the connection factories, queues and topics.
- A **QueueConnectionFactory** allows the client to create a **QueueConnection**.
- A **QueueConnection** creates a **QueueSession**. A **QueueSession** creates either a **QueueSender** or a **QueueReceiver**.
- When the queue receiver or topic subscriber receives a message, the message listener processes the message.
- Interface **MessageListener** declares method **onMessage** that is invoked when a new message arrives.
- A client may obtain two types of subscriptions—nondurable and durable. Nondurable subscriptions receive messages only while the subscriptions are active.

- Durable subscriptions can receive messages while inactive—the server maintains messages sent to the topic while the subscription is inactive and sends them to the client when the subscription is reactivated. Note that, if a message selector is specified for the subscription to filter the messages, the server maintains only the messages that satisfy the selector.
- A **TopicConnectionFactory**, which the server has created, creates a **TopicConnection**. A **TopicConnection** creates a **TopicSession**. A **TopicSession** creates a **TopicPublisher** or **TopicSubscriber**.
- A topic subscriber (or queue receiver) can filter messages with a message selector. When a client specifies a message selector, the server will only send messages satisfying that filter to the client. The message selector syntax is based on SQL92.
- Message-driven EJBs, or message-driven beans, are a new type of Enterprise JavaBean available in Enterprise JavaBeans version 2.0, which is part of the Java 2 Enterprise Edition version 1.3.
- Message-driven beans are capable of processing JMS messages posted to a queue or topic.
- When a message is received, the EJB container uses any available instance of a particular message-driven bean to process the message.
- Since any message-driven EJB instance may be used, message-driven beans are not specific to particular client and must not maintain client state information.
- Any given EJB instance may process messages from multiple clients.
- Unlike session and entity beans (which require interfaces), message-driven beans require only that developers to provide the bean implementation class.
- Interface **MessageDrivenBean** declares **setMessageDrivenContext** and specifies that the message-driven context should be stored as instance variable **messageDrivenContext**.

## TERMINOLOGY

<b>BytesMessage</b> interface	queue
durable subscription	<b>QueueConnection</b> interface
Java Message Service (JMS)	<b>QueueConnectionFactory</b> interface
<b>MapMessage</b> interface	<b>QueueReceiver</b> interface
message	<b>QueueSender</b> interface
message body	<b>QueueSession</b> interface
message consumer	receiver
message-driven bean	sender
message header	<b>StreamMessage</b> interface
message-oriented middleware (MOM)	subscribe
message property	subscriber
message selector	subscription
messaging system	<b>TextMessage</b> interface
nondurable subscription	topic
<b>ObjectMessage</b> interface	<b>TopicConnection</b> interface
point-to-point messaging model	<b>TopicConnectionFactory</b> interface
publish	<b>TopicPublisher</b> interface
publish/subscribe messaging model	<b>TopicSession</b> interface
publisher	<b>TopicSubscriber</b> interface

## SELF-REVIEW EXERCISES

16.1 State which of the following are *true* and which are *false*. If *false*, explain why.

- a) Messages in the point-to-point messaging model are intended for zero or more recipients.
- b) Messages in the publish/subscribe messaging model are intended for zero or one recipient.

- c) When a message selector is specified, filtering is done on the server side.
- d) The server maintains messages published to a topic while there are no subscriptions until a subscription is created.
- e) The server maintains messages sent to a queue while there is no receiver until a receiver connects.
- f) Message-driven beans maintain state for a specific client.

**16.2** Fill in the blanks in each of the following:

- a) The two messaging models are \_\_\_\_\_ and \_\_\_\_\_.
- b) In the \_\_\_\_\_ messaging model, the client sends a message a \_\_\_\_\_ and intends that message for exactly one recipient.
- c) In the \_\_\_\_\_ messaging model, the client sends a message to a \_\_\_\_\_ and intends that message for zero or more recipients.
- d) The server will maintain messages for a \_\_\_\_\_ subscription while the subscription is inactive.
- e) A \_\_\_\_\_ bean is a type of enterprise bean, which integrates well with MOM.

## ANSWERS TO SELF-REVIEW EXERCISES

**16.1** a) False. Messages in the point-to-point messaging model are intended for exactly one recipient.  
b) False. Messages in the publish/subscribe messaging model are intended for zero or more recipients.  
c) True. d) False. If there are no current subscriptions, the server will not maintain an incoming message; note that if there is a durable subscription that is inactive, however, the server will maintain messages for that subscription. e) True. f) False. A message-driven bean instance may process messages from multiple clients; message-driven beans cannot maintain client-specific state.

**16.2** a) Point-to-point, Publish/subscribe. b) Point-to-point, Queue. c) Publish/subscribe, Topic.  
d) Durable. e) Message-driven.

## EXERCISES

**16.3** What is the purpose of a messaging system?

**16.4** Compare and contrast the point-to-point messaging model and the publish/subscribe messaging model. When would it be appropriate to use one over the other?

**16.5** Using the point-to-point messaging model, create an application that allows a seller to receive bids on an item. The offering message should include the bidder's email address and bid price. (*Hint:* The seller should be the receiver of the offering messages, and the bidders should be the senders of the offering messages.)

**16.6** Modify your solution to Exercise 16.5 to allow the seller to filter out offers lower than a certain bid price. (*Hint:* Set the bid price as a **double** property of the offering messages and use this property in a message selector.)

**16.7** Create an application using the publish/subscribe messaging model that accepts orders from a client. The order should be published as a message to a **Domestic\_orders** topic if the client's shipping address is domestic or an **International\_orders** topic if the client's shipping address is international.

**16.8** Modify your solution to Exercise 16.7 to allow subscribers of the **Domestic\_orders** and **International\_orders** topics to filter out product orders by category. For instance, suppose a component is responsible for book orders—allow that component to filter out all orders not of the "book" category. (*Hint:* Use a **String** property to set the order category and a message selector to filter by that property.)

---

# Enterprise Java Case Study: Architectural Overview

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## Objectives

- To understand the Deitel Bookstore Enterprise Java case study architecture.
- To understand the decisions made in designing the Deitel Bookstore.
- To understand the Model-View-Controller (MVC) architecture in an Enterprise Java application context.
- To understand how XML and XSLT can generate content for many different client types.
- To understand the roles that servlets and EJBs play in enterprise applications.
- To understand multi-tier application design within the J2EE framework.

*It is easier to go down a hill than up,  
but the view is from the top.*

Arnold Bennett

*The universe is wider than our views of it.*

Henry David Thoreau

*Don't bother looking at the view—I have already composed it.*

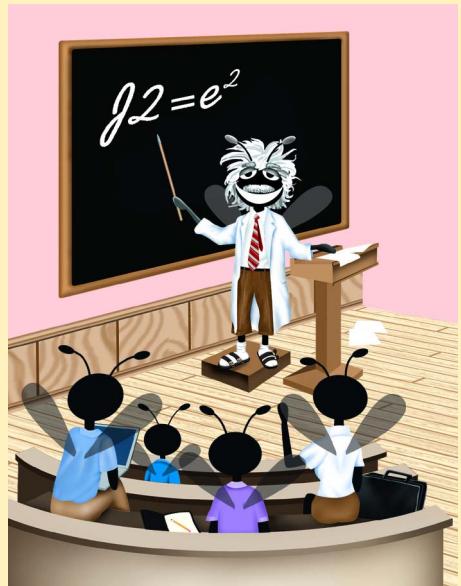
Gustav Mahler

*A whole is that which has a beginning, middle and end.*

Aristotle

*The life of the law has not been logic: it has been experience.*

Oliver Wendell Holmes, Jr.



## Outline

- 17.1 Introduction
- 17.2 Deitel Bookstore
- 17.3 System Architecture
- 17.4 Enterprise JavaBeans
  - 17.4.1 Entity EJBs
  - 17.4.2 Stateful Session EJBs
- 17.5 Servlet Controller Logic
- 17.6 XSLT Presentation Logic

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises*

### 17.1 Introduction

The technologies that comprise the Java 2 Enterprise Edition (J2EE) enable developers to build robust, scalable enterprise applications. In this case study, we build an online bookstore e-business application using several features of J2EE, including servlets and Enterprise JavaBeans, and other technologies, such as XML, XSLT, XHTML, WML and cHTML.

We used the Model-View-Controller (MVC) architecture in Chapter 5 to build a substantial drawing application. The Deitel Drawing application used MVC to separate the underlying representation of a drawing (a **Collection** of **MyShapes**) from views of that drawing (rendered using Java 2D) and input-processing logic (**MyShapeControllers** and a **DragAndDropController**). In this case study, we employ the MVC architecture to separate data and business logic from presentation logic and controller logic in a Java 2 Enterprise Edition application. A relational database and entity EJBs comprise the applications model. Java servlets implement controller logic for processing user input, and XSL transformations implement the application’s presentation logic.

XSLT presentation logic enables our application to present content to several client types. XSL transformations process application data (marked up with XML) to generate XHTML, WML and other presentations dynamically. We can extend the application to support additional client types and customize output for certain client types by implementing additional XSL transformations. For example, we could develop a J2ME MIDlet for handheld devices and implement a set of XSL transformations that produce output suitable for that MIDlet.

In this chapter, we present an overview of the Deitel Bookstore case study architecture. In the following chapters, we present the controller logic implementation with servlets (Chapter 18) and the business logic and data abstraction implementations with EJBs (Chapters 19 and 20). In Chapter 20, we also provide instructions for deploying the Deitel Bookstore case study on Sun Microsystems’ J2EE reference implementation application server. In Chapter 21, Application Servers, we introduce three of the top J2EE-compliant commercial application servers—BEA’s WebLogic, IBM’s WebSphere and the iPlanet Application Server. We discuss the features of each application server, then deploy the Deitel Bookstore case study on BEA’s WebLogic and IBM’s WebSphere.

## 17.2 Deitel Bookstore

The application we develop in this case study implements a subset of the functionality that customers expect of commercial on-line stores. We provide a product catalog that customers can search or browse for available books. We also provide a shopping cart to which customers can add products to be purchased. The customer can view the shopping cart, remove products, change the quantity of any product or purchase the products.

We provide customer registration, in which customers enter billing and shipping information. We also allow customers to view the details of previous orders and recover lost passwords. Customers can access the on-line store, using standard Web browsers, Wireless Markup Language (WML) browsers and cHTML (i-mode) browsers.

## 17.3 System Architecture

The Deitel Bookstore is a multi-tier application. Multi-tier applications—sometimes referred to as *n*-tier applications—divide functionality into separate tiers. Each tier may be located on a separate physical computer. We use a three-tier architecture in the Deitel Bookstore. Figure 17.1 presents the basic structure of three-tier applications.

The *information tier* (also called the *data tier* or the *bottom tier*) maintains data for the application. The information tier of an enterprise application typically stores data in a relational database management system (RDBMS). In the Deitel Bookstore case study, the database contains product information, such as a description, price and quantity in stock, and customer information, such as a user name, billing address and credit-card number.

The *middle tier* implements business logic and controller logic that control interactions between application clients and application data. The middle tier acts as an intermediary between the data in the information tier and the application clients. The middle-tier controller logic processes client requests (e.g., a request to view the product catalog) and retrieves data from the database. The middle-tier presentation logic then processes data from the information tier and presents the content to the client.



### Software Engineering Observation 17.1

*The Web server in a multi-tier application could be considered to be a separate tier, resulting in a four-tier application. We consider the Web server to be part of the middle tier in this case study, because the Web server simply delegates requests to the application server and forwards responses to the client tier.*

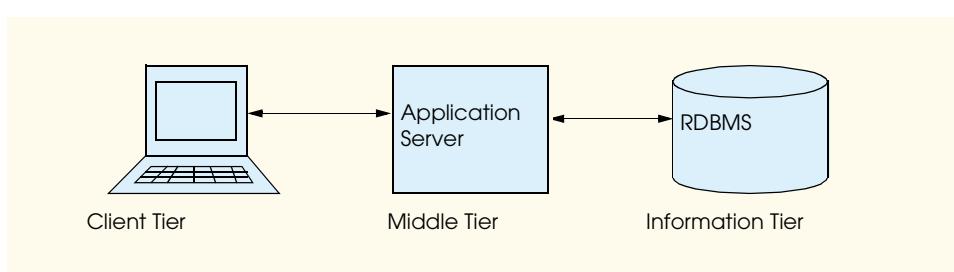


Fig. 17.1 Three-tier application model in Deitel Bookstore.

Business logic enforces *business rules* and ensures that data are reliable before updating the database or presenting data to the user. Business rules dictate how clients of the application can and cannot access data, and how data are processed within the application. For example, an on-line store could have a business rule requiring that a customer's credit-card issuer verify the customer's credit card before the warehouse can ship the customer's order. Business logic might implement this business rule by obtaining the credit-card number, expiration date and billing address from the customer and performing the verification. If the verification is successful, the business logic would update the database to indicate that the warehouse can ship the customer's order.

The middle tier also implements the application's presentation logic. Web applications typically present information to clients as XHTML documents. With recent advances in wireless technologies, many Web applications also present information to wireless clients as WML and cHTML documents. The middle tier of the Deitel Bookstore uses XML and XSLT to generate content for different client types dynamically, enabling support for Web browsers (XHTML), WAP browsers (WML) and i-mode browsers (cHTML).

The *client tier*, or top tier, is the application's user interface. For Web applications, the client tier typically consists of a Web browser. Users view application output in the Web browser and click hyperlinks and form buttons to interact with the application. The Web browser then communicates with the middle tier to make requests and retrieve data from the information tier. The Deitel Bookstore supports Web, WML and cHTML browsers in the client tier. Developers can add support for other clients by providing XSL transformations for those other clients. Figure 17.2 presents a detailed diagram of the Deitel Bookstore enterprise application architecture. We discuss each portion of the diagram in the following sections.

## 17.4 Enterprise JavaBeans

Enterprise JavaBeans (EJBs) implement the Deitel Bookstore's business logic and database abstraction layer. The primary business logic component is a stateful session EJB that represents a customer's shopping cart. The entity EJBs in the Deitel Bookstore, which provide an object-based interface to the information tier, implement the Deitel Bookstore application's model. Any program that can communicate using RMI-IIOP can use the EJB business logic. For example, an administrative tool could be developed as a stand-alone Java application that uses EJB business logic to modify application data. Servlets use the EJB business logic in the Deitel Bookstore application to create an on-line store.

### 17.4.1 Entity EJBs

Entity EJBs provide an object-based abstraction of the application's information tier. Each entity EJB represents a particular object stored in the application's relational database. Instances of each entity EJB represent individual rows in the database. For example, a **Customer** EJB instance represents a store customer. The database stores each customer's first name, last name, billing address, shipping address and credit-card information. Each **Customer** EJB instance represents a particular customer and provides methods for retrieving and storing the customer's information.

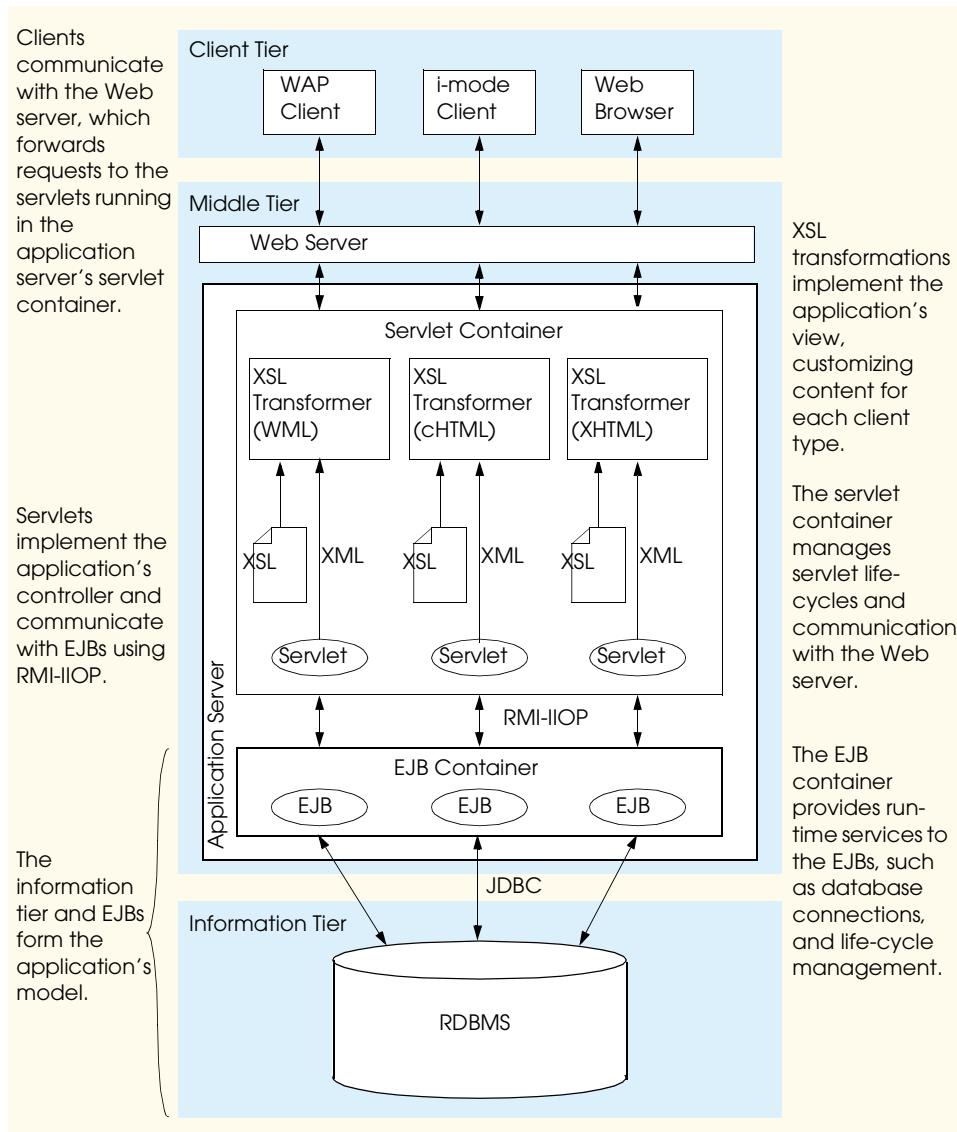


Fig. 17.2 Detailed architecture of Deitel Bookstore Enterprise Java case study.

To facilitate transmitting data through the application, each entity EJB has a corresponding *model class* that has properties for each entity EJB property. For example, the **Product** EJB, which represents a product in the database, has a corresponding **ProductModel** class with properties for the product's ISBN, price, author, etc. Each model class implements interface **Serializable** and therefore is suitable for transmission over RMI-IIOP. Encapsulating data into model classes relieves network congestions by reducing the number of remote method calls required to obtain information from an entity EJB. For example, a servlet can invoke method **getProductModel** to obtain informa-

tion about a **Product**, instead of invoking separate methods such as **getISBN**, **getPrice**, **getAuthor**, etc. Each model class also implements interface **XMLGenerator**, which declares method **getXML** for retrieving an XML representation of a particular model class instance. The servlets in the Deitel Bookstore use these XML elements to build XML documents, such as the product catalog and order history.

### 17.4.2 Stateful Session EJBs

The **ShoppingCart** stateful session EJB, which manages the customer's shopping cart, is the primary business-logic component in the Deitel Bookstore. Sometimes, customers browse online stores and add products to their shopping carts, then decide not to purchase those products. Such shopping carts are said to be *abandoned*. Rather than store an abandoned shopping cart in the database, the Deitel Bookstore uses a stateful session EJB to parallel more closely a user's experience in brick-and-mortar stores. When a customer abandons a shopping cart, the EJB container removes the **ShoppingCart** EJB instance.

## 17.5 Servlet Controller Logic

Servlets provide the middle-tier interface between the client and the EJB business logic. The servlets in the Deitel Bookstore implement the controller in the application's MVC architecture. Servlets handle client requests (via HTTP and WAP) and interact with the EJB business-logic components to fulfill those requests. The servlets then process data retrieved from the EJBs and generate XML documents that represent those data. These XML documents act as intermediate models of application data. The servlets then pass those XML documents through XSL transformations, which produce presentations for each client type.

## 17.6 XSLT Presentation Logic

Each servlet in the Deitel Bookstore employs an XSL **Transformer** and XSL transformations to generate appropriate presentations for each client type. The application requires a separate set of XSL transformations for each supported client type. For example, we provide one set of XSL transformations for producing XHTML, a second set for producing WML and a third set for producing cHTML. The servlets use a configuration file to determine the appropriate XSL transformation to apply for a particular client type.

**GetProductServlet** obtains an XML description of a product from that product's **ProductModel**. An XSL **Transformer** uses an XSL transformation to extract data from the XML document and create a presentation for the client. If the client is a Web browser, the XSL **Transformer** uses an XSL transformation that produces XHTML. If the client is a WAP browser (e.g., running on a cell phone), the XSL **Transformer** uses an XSL transformation that produces WML.

Figure 17.3 shows a sample XML document generated by **GetProductServlet**. This XML document marks up a product, including the product's ISBN, title, author, publisher, price, etc.

The XSL document of Fig. 17.4 transforms **GetProductServlet**'s XML document into XHTML, which is rendered in a Web browser in Fig. 17.5. The transformation simply extracts the relevant pieces of information from the XML document and creates an appropriate XHTML representation. We discuss the structures of these XSL transformations in Chapter 18.

---

```

1 <?xml version="1.0" encoding="UTF-8"?>
2 <catalog>
3   <product>
4     <isbn>0130284173</isbn>
5     <publisher>Prentice Hall</publisher>
6     <author>Deitel, Deitel, Nieto, Lin &amp; Sadhu</author>
7     <title>XML How to Program</title>
8     <price>$69.95</price>
9      <pages>1200</pages>
10    <image>images/xmlhttp1.jpg</image>
11    <media>CD</media>
12    <quantity>500</quantity>
13  </product>
14 </catalog>

```

---

Fig. 17.3 XML file generated by **GetProductServlet**.

---

```

1 <?xml version = "1.0"?>
2
3 <!-- ProductDetails.xsl -->
4 <!-- XSLT stylesheet for transforming content generated by -->
5 <!-- GetProductServlet into XHTML. -->
6
7 <xsl:stylesheet version = "1.0"
8   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
9
10  <xsl:output method = "xml" omit-xml-declaration = "no"
11    indent = "yes" doctype-system = "DTD/xhtml1-strict.dtd"
12    doctype-public = "-//W3C//DTD XHTML 1.0 Strict//EN"/>
13
14  <!-- include template for processing error elements -->
15  <xsl:include href = "/XSLT/XHTML/error.xsl"/>
16
17  <!-- template for product element -->
18  <xsl:template match = "product">
19    <html xmlns = "http://www.w3.org/1999/xhtml"
20      xml:lang = "en" lang = "en">
21
22    <head>
23      <title>
24        <xsl:value-of select = "title"/> -- Description
25      </title>
26
27      <link rel = "StyleSheet" href = "styles/default.css"/>
28    </head>
29
30    <body>
31
32      <!-- copy navigation header into XHTML document -->
33      <xsl:for-each select =
34        "document( '/XSLT/XHTML/navigation.xml' )">

```

---

Fig. 17.4 XSL transformation for generating XHTML from **GetProductServlet** (part 1 of 3).

```
35             <xsl:copy-of select = ".\"/>
36         </xsl:for-each>
37
38         <div class = "header">
39             <xsl:value-of select = "title"/>
40         </div>
41
42         <div class = "author">
43             by <xsl:value-of select = "author"/>
44         </div>
45
46         <!-- create div element with details of Product -->
47         <div class = "productDetails">
48             <table style = "width: 100%;">
49                 <tr>
50                     <td style = "text-align: center;">
51                         <img class = "bookCover"
52                             src = "images/{image}"
53                             alt = "{title} cover image."/>
54                     </td>
55
56                     <td>
57                         <p style = "text-align: right;">
58                             Price: <xsl:value-of select = "price"/>
59                         </p>
60
61                         <p style = "text-align: right;">
62                             ISBN: <xsl:value-of select = "ISBN"/>
63                         </p>
64
65                         <p style = "text-align: right;">
66                             Pages: <xsl:value-of select = "pages"/>
67                         </p>
68
69                         <p style = "text-align: right;">
70                             Publisher:
71                             <xsl:value-of select = "publisher"/>
72                         </p>
73
74             <!-- AddToCart button -->
75             <form method = "post" action = "AddToCart">
76                 <p style = "text-align: center;">
77                     <input type = "submit"
78                         value = "Add to cart"/>
79
80                     <input type = "hidden" name = "ISBN"
81                         value = "{ISBN}" />
82                 </p>
83             </form>
84         </td>
85     </tr>
86 </table>
```

Fig. 17.4 XSL transformation for generating XHTML from **GetProductServlet** (part 2 of 3).

```
87         </div>
88
89     </body>
90
91 </html>
92 </xsl:template>
93 </xsl:stylesheet>
```

Fig. 17.4 XSL transformation for generating XHTML from **GetProductServlet** (part 3 of 3).

```
1 <?xml version="1.0" encoding="UTF-8"?>
2 <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
3   "DTD/xhtml1-strict.dtd">
4 <html xmlns="http://www.w3.org/1999/xhtml"
5   lang="en" xml:lang="en">
6 <head>
7   <title>XML How to Program -- Description</title>
8   <link href="styles/default.css" rel="StyleSheet" />
9 </head>
10 <body>
11   <div>
12     <div class="logo">
13       <table style="width: 100%;">
14         <tr>
15           <td style="text-align: left;">
16             
18           </td>
19
20           <td style="text-align: right;">
21             <div style=
22               "position: relative; bottom: -50px;">
23               <form action="ProductSearch" method="get">
24                 <p><input type="text" size="15"
25                   name="searchString" />
26                   <input type="submit" value="Search" />
27                 </p>
28               </form>
29             </div>
30           </td>
31         </tr>
32       </table>
33     </div>
34
35     <div class="navigation">
36       <table class="menu">
37         <tr>
38           <td class="menu">
39             <a href="GetAllProducts">Product Catalog</a>
40           </td>
41     </div>
```

Fig. 17.5 XHTML document generated by XSLT in **GetProductServlet** (part 1 of 3).

```
42         <td class="menu">
43             <a href="registration.html">Create Account</a>
44         </td>
45
46         <td class="menu">
47             <a href="login.html">Log in</a>
48         </td>
49
50         <td class="menu">
51             <a href="ViewCart">Shopping Cart</a>
52         </td>
53
54         <td class="menu">
55             <a href="ViewOrderHistory">Order History</a>
56         </td>
57     </tr>
58   </table>
59 </div>
60
61 </div>
62 <div class="header">XML How to Program</div>
63 <div class="author">
64     by Deitel, Deitel, Nieto, Lin & Sadhu</div>
65 <div class="productDetails">
66     <table style="width: 100%;">
67         <tr>
68             <td style="text-align: center;">
69                 </td>
72             <td>
73                 <p style="text-align: right;">
74                     Price: $69.95</p>
75                 <p style="text-align: right;">
76                     ISBN: 0130284173</p>
77                 <p style="text-align: right;">
78                     Pages: 1100</p>
79                 <p style="text-align: right;">
80                     Publisher: Prentice Hall</p>
81
82             <form action="AddToCart" method="post">
83                 <p style="text-align: center;">
84                     <input value="Add to cart"
85                         type="submit" />
86                     <input value="0130284173"
87                         name="ISBN" type="hidden" /></p>
88             </form>
89         </td>
90     </tr>
91   </table>
92 </div>
93 </body>
```

Fig. 17.5 XHTML document generated by XSLT in **GetProductServlet** (part 2 of 3).

94 </html>

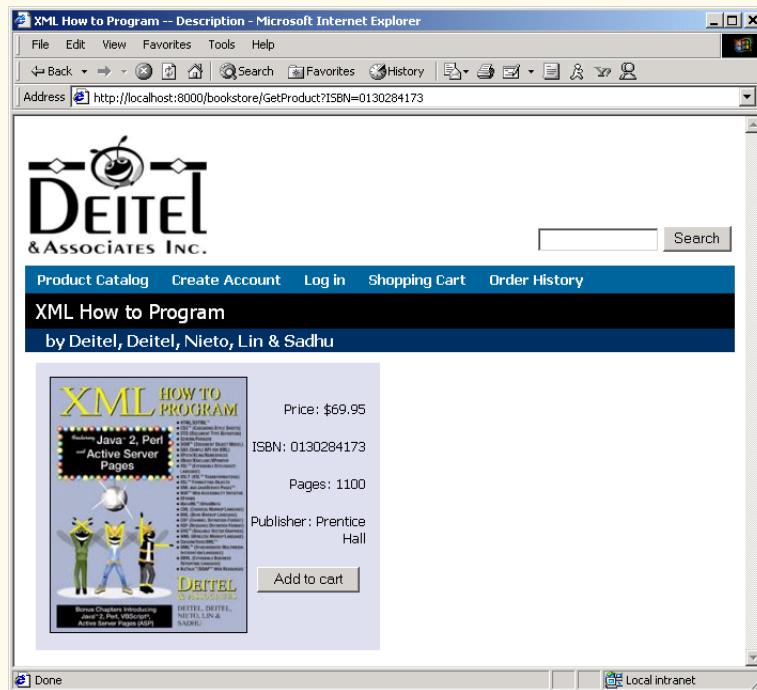


Fig. 17.5 XHTML document generated by XSLT in **GetProductServlet** (part 3 of 3).

The XSL transformation of Fig. 17.6 transforms **GetProductServlet**'s XML document into WML, which appears in a WML browser in Fig. 17.7. Note that in the WML document there is little formatting information. WML is rendered on small devices, such as cell phones, so display capabilities are limited. These devices also have limited network connections, so the amount of data sent should be kept to a minimum. For example, the WML document does not contain an image of the books cover, which would be cumbersome to download over a wireless connection.

```

1  <?xml version = "1.0"?>
2
3  <xsl:stylesheet version = "1.0"
4      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
5
6      <xsl:output method = "xml" omit-xml-declaration = "no"
7          doctype-system = "http://www.wapforum.org/DTD/wml_1.1.xml"
8          doctype-public = "-//WAPFORUM//DTD WML 1.1//EN"/>
9
10     <xsl:include href = "/XSLT/WML/error.xsl"/>

```

Fig. 17.6 XSL transformation for generating WML from **GetProductServlet** (part 1 of 2).

```
11      <xsl:template match = "product">
12          <wml>
13
14
15          <card id = "product" title = "{title}">
16              <do type = "accept" label = "Add To Cart">
17                  <go href = "AddToCart" method = "post">
18                      <postfield name = "ISBN" value = "{ISBN}" />
19                  </go>
20              </do>
21
22              <do type = "prev" label = "Back">
23                  <prev/>
24              </do>
25
26              <p>Description:</p>
27              <p><xsl:value-of select = "title"/></p>
28              <p>by <xsl:value-of select = "author"/></p>
29
30              <p>
31                  <table columns = "2" title = "info">
32                      <tr>
33                          <td>ISBN:
34                              <xsl:value-of select = "ISBN"/>
35                          </td>
36                          <td>Price:
37                              $<xsl:value-of select = "price"/>
38                          </td>
39                      </tr>
40                      <tr>
41                          <td>Publisher:
42                              <xsl:value-of select = "publisher"/>
43                          </td>
44                          <td>Pages:
45                              <xsl:value-of select = "pages"/>
46                          </td>
47                      </tr>
48                  </table>
49              </p>
50          </card>
51
52      </wml>
53  </xsl:template>
54 </xsl:stylesheet>
```

Fig. 17.6 XSL transformation for generating WML from **GetProductServlet** (part 2 of 2).

```
1  <?xml version="1.0"?>
2  <!DOCTYPE wml PUBLIC "-//WAPFORUM//DTD WML 1.1//EN"
3      "http://www.wapforum.org/DTD/wml_1.1.xml">
```

Fig. 17.7 WML document generated by XSLT in **GetProductServlet** (part 1 of 2). (Image © 2001 Nokia Mobile Phones.)

```
4
5  <wml>
6      <card title="XML How to Program" id="product">
7          <do label="Add To Cart" type="accept">
8              <go method="post" href="AddToCart">
9                  <postfield value="0130284173" name="ISBN"/></go>
10         </do>
11         <do label="Back" type="prev"><prev/></do>
12
13         <p>Description:</p>
14         <p>XML How to Program</p>
15         <p>by Deitel, Deitel, Nieto, Lin & Sadhu</p>
16         <p>
17             <table title="info" columns="2">
18                 <tr>
19                     <td>ISBN: 0130284173</td>
20                     <td>Price: $$69.95</td>
21                 </tr>
22                 <tr>
23                     <td>Publisher: Prentice Hall</td>
24                     <td>Pages: 1100</td>
25                 </tr>
26             </table>
27         </p>
28     </card>
29 </wml>
```

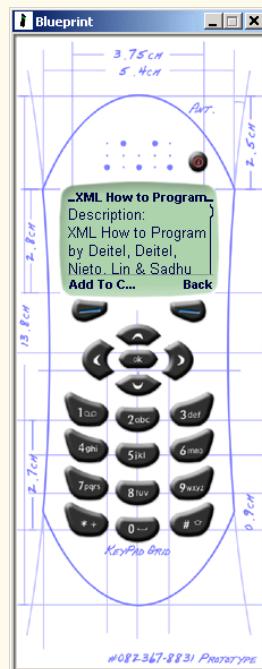


Fig. 17.7 WML document generated by XSLT in **GetProductServlet** (part 2 of 2). (Image © 2001 Nokia Mobile Phones.)

The XSL document of Fig. 17.8 transforms **GetProductServlet**'s XML document into cHTML, which appears in a cHTML browser in Fig. 17.9.

```
1  <?xml version = "1.0"?>
2
3  <xsl:stylesheet version = "1.0"
4      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
5
6      <xsl:output method = "html"
7          omit-xml-declaration = "yes"
8          indent = "yes"
9          doctype-system =
10             "http://www.w3.org/MarkUp/html-spec/html-spec_toc.html"
11             doctype-public = "-//W3C//DTD HTML 2.0//EN"/>
12
13      <xsl:include href = "/XSLT/cHTML/error.xsl"/>
14
15      <xsl:template match = "product">
16          <html>
17
18              <head>
19                  <title>
20                      <xsl:value-of select = "title"/> -- Description
21                  </title>
22              </head>
23
24              <body>
25                  <div class = "header">
26                      <xsl:value-of select = "title"/>
27                  </div>
28
29                  <div class = "author">
30                      by <xsl:value-of select = "author"/>
31                  </div>
32
33                  <!-- create div element with details of Product -->
34                  <div class = "productDetails">
35                      <table>
36                          <tr>
37                              <td style = "text-align: center;">
38                                  <img class = "bookCover"
39                                      src = "images/{image}"/>
40                              </td>
41
42                              <td>
43                                  <p style = "text-align: right;">
44                                      Price: <xsl:value-of select = "price"/>
45                                  </p>
46
47                                  <p style = "text-align: right;">
48                                      ISBN: <xsl:value-of select = "ISBN"/>
49                                  </p>
```

Fig. 17.8 XSL transformation for generating cHTML from **GetProductServlet** (part 1 of 2).

```

50          <p style = "text-align: right;">
51              Pages: <xsl:value-of select = "pages"/>
52          </p>
53
54          <p style = "text-align: right;">
55              Publisher:
56                  <xsl:value-of select = "publisher"/>
57          </p>
58
59          <!-- AddToCart button -->
60          <form method="post" action="AddToCart">
61              <p style = "text-align: center;">
62                  <input type = "submit"
63                      value = "Add to cart"/>
64              </p>
65
66              <input type = "hidden" name = "ISBN"
67                  value = "{ISBN}"/>
68          </form>
69      </td>
70  </tr>
71 </table>
72 </div>
73 </body>
74
75     </html>
76 </xsl:template>
77 </xsl:stylesheet>

```

**Fig. 17.8** XSL transformation for generating cHTML from **GetProductServlet** (part 2 of 2).

```

1  <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 2.0//EN"
2      "http://www.w3.org/MarkUp/html-spec/html-spec_toc.html">
3  <html>
4      <head>
5          <META http-equiv="Content-Type"
6              content="text/html; charset=UTF-8">
7          <title>XML How to Program -- Description</title>
8      </head>
9      <body>
10         <div class="header">XML How to Program</div>
11         <div class="author">
12             by Deitel, Deitel, Nieto, Lin & Sadhu</div>
13         <div class="productDetails">
14             <table>
15                 <tr>
16                     <td style="text-align: center;">
17                         
18                     </td>

```

**Fig. 17.9** cHTML document generated by XSLT in **GetProductServlet** (part 1 of 2). (Image courtesy of Pixo, Inc.)

```
19      <td>
20          <p style="text-align: right;">Price: $69.95</p>
21
22          <p style="text-align: right;">ISBN: 0130284173</p>
23
24          <p style="text-align: right;">Pages: 1100</p>
25
26          <p style="text-align: right;">
27              Publisher: Prentice Hall</p>
28
29          <form action="AddToCart" method="post">
30              <p style="text-align: center;">
31                  <input value="Add to cart" type="submit">
32              </p>
33                  <input value="0130284173" name="ISBN"
34                      type="hidden">
35          </form>
36      </td>
37  </tr>
38 </table>
39 </div>
40 </body>
41 </html>
```



Fig. 17.9 cHTML document generated by XSLT in **GetProductServlet** (part 2 of 2). (Image courtesy of Pixo, Inc.)

This chapter overviewed the Deitel Bookstore case study architecture, which uses powerful enterprise Java capabilities, including servlets, EJBs, RMI, XML and XSLT. Chapters 18, 19 and 20 present the implementations of each tier. In Chapters 20–21, we provide instructions for deploying the Deitel Bookstore using the J2EE reference implementation, BEA's WebLogic and IBM's WebSphere.

## SUMMARY

- The MVC design pattern, as applied in this enterprise application case study, separates data and business logic from presentation logic and controller logic.
- Multi-tier applications—sometimes referred to as *n*-tier applications—are divided into modular parts called tiers. Each tier may be located on a separate physical computer.
- The information tier, or data tier, maintains data for the application. The information tier typically stores data in a relational database management system (RDBMS). The database could contain product information, such as a description, price and quantity in stock, and customer information, such as a user name, billing address and credit-card number.
- The middle tier implements business logic and presentation logic to control interactions between application clients and application data. The middle tier acts as an intermediary between the data in the information tier and application clients.
- Middle-tier controller logic processes client requests (e.g., a request to view the product catalog) and retrieves data from the database. The middle-tier presentation logic then processes data from the information tier and presents the content to the client.
- Business logic enforces business rules and ensures that data are reliable before updating the database or presenting data to the user. Business rules dictate how clients of the application can and cannot access data and how data are processed within the application.
- The middle tier also implements the application's presentation logic. The middle tier accepts client requests, retrieves data from the information tier and presents content to clients.
- Web applications typically present information to clients as XHTML documents. Many Web applications present information to wireless clients as Wireless Markup Language (WML) documents or Compact HyperText Markup Language (cHTML) documents.
- The middle tier of the Deitel Bookstore uses XML and XSLT to generate content for different client types dynamically, enabling support for XHTML, WML, cHTML and virtually any other client type.
- The client tier is the application's user interface. Users interact directly with the application through the user interface. The client interacts with the middle tier to make requests and retrieve data from the application. The client then displays data retrieved from the middle tier to the user.
- Enterprise JavaBeans (EJBs) implement the Deitel Bookstore's business rules. The entity EJBs in the Deitel Bookstore, along with the database they represent, are the model for the Deitel Bookstore application.
- Any program that can communicate using RMI-IIOP can use EJB business logic and database abstraction objects. For example, an administrative tool could be developed as a stand-alone Java application that uses the EJB business logic to process orders.
- Entity EJBs provide an object-based representation of the application's information tier. Each entity EJB represents a particular object stored in the database. Instances of each entity EJB represent individual rows in the database.
- On-line store customers often browse the store catalog and add products to their shopping carts, but decide not to purchase the products. The shopping cart is therefore abandoned. Rather than

store the abandoned shopping cart in the database, we use session EJBs to parallel more closely a user's experience in brick-and-mortar stores.

- Servlets provide the middle-tier interface between the client and the EJB business logic. The servlets in the Deitel Bookstore implement the controller of the MVC architecture. Servlets handle user requests (via HTTP and WAP) and interact with the EJB business logic.
- Servlets process data retrieved from EJBs and generate XML representations, which act as intermediate models of application data.
- XSL transformations act as the application view by transforming the XML model to appropriate formats for various client types.
- Each servlet in the Deitel Bookstore employs an XSL **Transformer** and XSL transformations to generate appropriate content for each client type. A separate set of XSL transformations generates content for each client type.
- The servlets produce XML documents to which the XSL **Transformer** applies XSL transformations to generate the appropriate content. To support additional client types, the developer can create additional sets of XSL transformations.

## TERMINOLOGY

abandoned shopping cart	Enterprise JavaBean (EJB)
application server	entity EJB
bottom tier	four-tier application
brick-and-mortar store	information tier
business logic	middle tier
business rules	model-view-controller (MVC)
business-logic component	multi-tier application
client tier	<i>n</i> -tier application
Compact HyperText Markup Language (cHTML)	presentation logic
container-managed persistence	shopping cart e-commerce model
controller logic	three-tier architecture
controller-logic component	top tier
data tier	Wireless Access Protocol (WAP)
delegate	Wireless Markup Language (WML)
design patterns	XHTML
e-business	XML
e-business application	XSL transformation
e-commerce	XSL <b>Transformer</b>
e-commerce application	XSLT

## SELF-REVIEW EXERCISES

**17.1** What architectural pattern plays a major role in the Deitel Bookstore application architecture? What benefits does this design pattern provide?

**17.2** Which part of the Deitel Bookstore application architecture could be separated into an additional tier? Why?

**17.3** Section 17.3 describes a hypothetical business rule requiring credit-card verification. Describe an additional business rule appropriate for the Deitel Bookstore.

**17.4** What are the controller-logic components in the Deitel Bookstore? What are the business-logic components? How do the controller-logic components in the application server communicate with the business-logic components?

- 17.5** What type of EJB in the Deitel Bookstore closely parallels customer experiences in brick-and-mortar stores?
- 17.6** How is the Deitel Bookstore application able to present content to clients of virtually any type?
- 17.7** How could a B2B partner (e.g., a corporate client) communicate with the Deitel Bookstore application? For example, a B2B partner may wish to order, on a periodic basis, large numbers of copies of a particular book used for training new employees. How could this B2B partner order the books programmatically?

## ANSWERS TO SELF-REVIEW EXERCISES

**17.1** The Deitel Bookstore application architecture uses the Model-View-Controller (MVC) architecture. MVC separates business logic from controller logic and presentation logic. Implementations of the business logic, controller logic and presentation logic can change independently of one another without requiring changes in the other components.

**17.2** The Web server could be separated into a fourth tier. Separating the Web server into a fourth tier would provide a more modular design for applications that support clients using other protocols, in addition to HTTP.

**17.3** An additional business rule could require customers to provide their e-mail addresses in the registration. Business logic could process the registration forms and reject registrations that do not include e-mail addresses.

**17.4** Servlets are the controller-logic components in the Deitel Bookstore. Enterprise JavaBeans are the business-logic components. The servlets communicate with the EJBs through the EJB container using RMI-IIOP.

**17.5** The **ShoppingCart** EJB is implemented as a stateful session EJB to simulate a shopping cart in a brick-and-mortar store.

**17.6** The Deitel Bookstore application uses XSL transformations to present content for each client type. The servlets generate XML documents, and the developer supplies XSL transformations to transform the servlet XML documents for each client type.

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# Enterprise Java Case Study: Presentation and Controller Logic

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## Objectives

- To understand the role of presentation logic in a multitier application.
- To understand the role of controller logic in a multitier application.
- To understand the use of servlets in the middle tier of an Enterprise Java application.
- To understand how XML and XSLT can enable support for a variety of client types in a Web application.
- To understand how servlet initialization parameters can make servlets more flexible.

*First come, first served.*

Traditional Proverb

*'Tis distance lends enchantment to the view...*

Thomas Campbell

*Invention is nothing more than a fine deviation from, or enlargement on a fine model...*

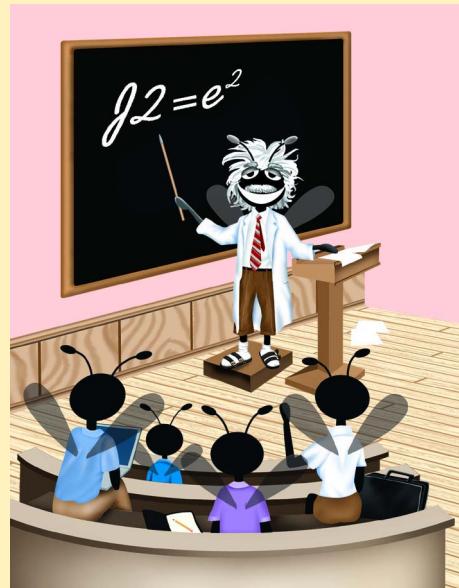
Edward G. Bulwer-Lytton

*Do not become the slave of your model.*

Vincent Van Gogh

*While Genius was thus wasting his strength in eccentric flights, I saw a person of a very different appearance, named Application.*

Anna Letitia Barbauld



## Outline

- 18.1 Introduction**
- 18.2 XMLServlet Base Class**
- 18.3 Shopping Cart Servlets**
  - 18.3.1 AddToCartServlet**
  - 18.3.2 ViewCartServlet**
  - 18.3.3 RemoveFromCartServlet**
  - 18.3.4 UpdateCartServlet**
  - 18.3.5 CheckoutServlet**
- 18.4 Product Catalog Servlets**
  - 18.4.1 GetAllProductsServlet**
  - 18.4.2 GetProductServlet**
  - 18.4.3 ProductSearchServlet**
- 18.5 Customer Management Servlets**
  - 18.5.1 RegisterServlet**
  - 18.5.2 LoginServlet**
  - 18.5.3 ViewOrderHistoryServlet**
  - 18.5.4 ViewOrderServlet**
  - 18.5.5 GetPasswordHintServlet**

*Self-Review Exercises • Answers to Self-Review Exercises*

## 18.1 Introduction

In this chapter, we present the controller and presentation logic for the Deitel Bookstore. Controller logic in an application is responsible for processing user requests. For example, when a customer makes a request to add a book to a shopping cart, controller logic handles the request and invokes the appropriate business-logic methods to perform the requested action. The presentation logic then shows the output from the request to the user.

Java servlets implement the Deitel Bookstore's controller logic. After invoking business-logic methods to process client requests, the servlets generate XML documents that contain content presented to the client. These XML documents are not specific to any particular type of client (e.g., Web browser, cell phone, etc.); they simply mark up the data that the business logic supplies. XSL transformations implement the application's presentation logic—the view in the MVC architecture—by transforming the XML documents into output suitable for each client type. For example, an XSL transformation might generate an XHTML document to present to a Web browser on a desktop computer, or a WML document to present to a WAP browser in a cell phone.

Using XSL transformations as presentation logic enable developers to extend the set of client types that the application supports without modifying the controller logic or business logic. To support a new client type, the developer simply supplies an additional set of

XSL transformations that produce appropriate output for the new client type. The developer then modifies an XML configuration file to install support for the new client type. [Note: The Deitel Bookstore requires the Apache Software Foundation's Xalan XSL transformer. Download Xalan version 2.1 from [xml.apache.org/dist/xalan-j](http://xml.apache.org/dist/xalan-j) and copy **xalan.jar** and **xerces.jar** to your J2SE SDK's **jre/lib/ext** directory.]

This chapter is the first of three chapters that present the implementation of the Deitel Bookstore case study. In Chapters 19 and 20 we present the business logic and entity EJB components required for processing orders and working with the database.

## 18.2 XMLServlet Base Class

Each servlet in the Deitel Bookstore case study extends class **XMLServlet** (Fig. 18.1), which provides common initialization and utility methods. To enable support for multiple client types, each servlet in the Deitel Bookstore creates an XML document that represents raw application data retrieved from the application's business logic and information tier. An XSLT transformation processes this XML document and presents the output to the client. Class **XMLServlet** implements this common functionality.

Method **init** (lines 41–85) initializes the servlet. The servlet container provides the **ServletConfig** argument when the container initializes the servlet. Line 49 retrieves the name of the XSL transformation that will transform the servlet's content for each client type. This file name is provided as a servlet-initialization parameter, so the deployer must define this parameter when deploying the servlet. Line 52 creates a **DocumentBuilderFactory** instance, which will be used to create **DocumentBuilders** for building XML documents. Line 55 creates a **TransformerFactory**, with which instances of **XMLServlet** perform XSL transformations. Lines 58–81 set a **URIResolver** for the **TransformerFactory** to enable its **Transformers** to resolve relative URIs in XSL documents. For example, if an XSL document references another XSL document using element **xsl:include** with a relative URI (e.g., `/XSLT/XHTML/error.xsl`), the **Transformer** invokes method **resolve** of interface **URIResolver** to determine from where the **Transformer** should load the included XSL. Line 67 resolves the relative URI by invoking **ServletContext** method **getResource**, which returns a **URL**. Line 71 returns a **StreamSource** for the **URLs InputStream**. The **Transformer** uses this **StreamSource** to read the contents of the included XSL document.

```
1 // XMLServlet.java
2 // XMLServlet is a base class for servlets that generate
3 // XML documents and perform XSL transformations.
4 package com.deitel.advjhtp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.net.URL;
10
11 // Java extension packages
12 import javax.servlet.*;
13 import javax.servlet.http.*;
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 1 of 8).

```
14 import javax.xml.parsers.*;
15 import javax.xml.transform.*;
16 import javax.xml.transform.dom.*;
17 import javax.xml.transform.stream.*;
18
19 // third-party packages
20 import org.w3c.dom.*;
21 import org.xml.sax.SAXException;
22
23 // Deitel packages
24 import com.deitel.advjhttp1.bookstore.model.*;
25
26 public class XMLServlet extends HttpServlet {
27
28     // factory for creating DocumentBuilders
29     private DocumentBuilderFactory builderFactory;
30
31     // factory for creating Transformers
32     private TransformerFactory transformerFactory;
33
34     // XSL file that presents servlet's content
35     private String XSLFileName;
36
37     // ClientModel List for determining client type
38     private List clientList;
39
40     // initialize servlet
41     public void init( ServletConfig config )
42         throws ServletException
43     {
44         // call superclass's init method for initialization
45         super.init( config );
46
47         // use InitParameter to set XSL file for transforming
48         // generated content
49         setXSLFileName( config.getInitParameter( "XSL_FILE" ) );
50
51         // create new DocumentBuilderFactory
52         builderFactory = DocumentBuilderFactory.newInstance();
53
54         // create new TransformerFactory
55         transformerFactory = TransformerFactory.newInstance();
56
57         // set URIResolver for resolving relative paths in XSLT
58         transformerFactory.setURIResolver(
59
60             new URIResolver() {
61
62                 // resolve href as relative to ServletContext
63                 public Source resolve( String href, String base )
64                 {
65                     try {
66                         ServletContext context = getServletContext();
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 2 of 8).

```
67             URL url = context.getResource( href );
68
69             // create StreamSource to read document from URL
70             return new StreamSource( url.openStream() );
71         }
72
73         // handle exceptions obtaining referenced document
74         catch ( Exception exception ) {
75             exception.printStackTrace();
76
77             return null;
78         }
79     }
80 }
81 ); // end call to setURIResolver
82
83 // create ClientModel ArrayList
84 clientList = buildClientList();
85 }
86
87 // get DocumentBuilder instance for building XML documents
88 public DocumentBuilder getDocumentBuilder( boolean validating )
89 {
90     // create new DocumentBuilder
91     try {
92
93         // set validation mode
94         builderFactory.setValidating( validating );
95
96         // return new DocumentBuilder to the caller
97         return builderFactory.newDocumentBuilder();
98     }
99
100    // handle exception when creating DocumentBuilder
101    catch ( ParserConfigurationException parserException ) {
102        parserException.printStackTrace();
103
104        return null;
105    }
106
107 } // end method getDocumentBuilder
108
109 // get non-validating parser
110 public DocumentBuilder getDocumentBuilder()
111 {
112     return getDocumentBuilder( false );
113 }
114
115 // set XSL file name for transforming servlet's content
116 public void setXSLFileName( String fileName )
117 {
118     xSLFileName = fileName;
119 }
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 3 of 8).

```
120
121 // get XSL file name for transforming servlet's content
122 public String getXSLFileName()
123 {
124     return XSLFileName;
125 }
126
127 // write XML document to client using provided response
128 // Object after transforming XML document with
129 // client-specific XSLT document
130 public void writeXML( HttpServletRequest request,
131     HttpServletResponse response, Document document )
132     throws IOException
133 {
134     // get current session, create if not extant
135     HttpSession session = request.getSession( true );
136
137     // get ClientModel from session Object
138     ClientModel client = ( ClientModel )
139         session.getAttribute( "clientModel" );
140
141     // if client is null, get new ClientModel for this
142     // User-Agent and store in session
143     if ( client == null ) {
144         String userAgent = request.getHeader( "User-Agent" );
145         client = getClientModel( userAgent );
146         session.setAttribute( "clientModel", client );
147     }
148
149     // set appropriate Content-Type for client
150     response.setContentType( client.getContentType() );
151
152     // get PrintWriter for writing data to client
153     PrintWriter output = response.getWriter();
154
155     // build file name for XSLT document
156     String xslFile = client.getXSLPath() + getXSLFileName();
157
158     // open InputStream for XSL document
159     InputStream xslStream =
160         getServletContext().getResourceAsStream( xslFile );
161
162     // transform XML document using XSLT
163     transform( document, xslStream, output );
164
165     // flush and close PrintWriter
166     output.close();
167
168 } // end method writeXML
169
170 // transform XML document using provided XSLT InputStream
171 // and write resulting document to provided PrintWriter
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 4 of 8).

```
172     public void transform( Document document,
173                           InputStream xslStream, PrintWriter output )
174     {
175         // create Transformer and apply XSL transformation
176         try {
177
178             // create DOMSource for source XML document
179             Source xmlSource = new DOMSource( document );
180
181             // create StreamSource for XSLT document
182             Source xslSource =
183                 new StreamSource( xslStream );
184
185             // create StreamResult for transformation result
186             Result result = new StreamResult( output );
187
188             // create Transformer for XSL transformation
189             Transformer transformer =
190                 transformerFactory.newTransformer( xslSource );
191
192             // transform and deliver content to client
193             transformer.transform( xmlSource, result );
194
195         } // end try
196
197         // handle exception when transforming XML document
198         catch ( TransformerException transformerException ) {
199             transformerException.printStackTrace();
200         }
201
202     } // end method transform
203
204     // build error element containing error message
205     public Node buildErrorMessage( Document document,
206                                   String message)
207     {
208         // create error element
209         Element error = document.createElement( "error" );
210
211         // create message element
212         Element errorMessage =
213             document.createElement( "message" );
214
215         // create message text and append to message element
216         errorMessage.appendChild(
217             document.createTextNode( message ) );
218
219         // append message element to error element
220         error.appendChild( errorMessage );
221
222         return error;
223     }
224 }
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 5 of 8).

```
225 // build list of ClientModel Objects for delivering
226 // appropriate content to each client
227 private List buildClientList()
228 {
229     // get validating DocumentBuilder for client XML document
230     DocumentBuilder builder = getDocumentBuilder( true );
231
232     // create client ArrayList
233     List clientList = new ArrayList();
234
235     // get name of XML document containing client
236     // information from ServletContext
237     String clientXML = getServletContext().getInitParameter(
238         "CLIENT_LIST" );
239
240     // read clients from XML document and build ClientModels
241     try {
242
243         // open InputStream to XML document
244         InputStream clientXMLStream =
245             getServletContext().getResourceAsStream(
246                 clientXML );
247
248         // parse XML document
249         Document clientsDocument =
250             builder.parse( clientXMLStream );
251
252         // get NodeList of client elements
253         NodeList clientElements =
254             clientsDocument.getElementsByTagName( "client" );
255
256         // get length of client NodeList
257         int listLength = clientElements.getLength();
258
259         // process NodeList of client Elements
260         for ( int i = 0; i < listLength; i++ ) {
261
262             // get next client Element
263             Element client =
264                 ( Element ) clientElements.item( i );
265
266             // get agent Element from client Element
267             Element agentElement = ( Element )
268                 client.getElementsByTagName(
269                     "userAgent" ).item( 0 );
270
271             // get agent Element's child text node
272             Text agentText =
273                 ( Text ) agentElement.getFirstChild();
274
275             // get value of agent Text node
276             String agent = agentText.getNodeValue();
277 }
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 6 of 8).

```

278         // get contentType Element
279         Element typeElement = ( Element )
280             client.getElementsByTagName(
281                 "contentType" ).item( 0 );
282
283         // get contentType Element's child text node
284         Text typeText =
285             ( Text ) typeElement.getFirstChild();
286
287         // get value of contentType text node
288         String type = typeText.getNodeValue();
289
290         // get XPath element
291         Element pathElement = ( Element )
292             client.getElementsByTagName(
293                 "XPath" ).item( 0 );
294
295         // get Text node child of XPath
296         Text pathText =
297             ( Text ) pathElement.getFirstChild();
298
299         // get value of XPath text node
300         String path = pathText.getNodeValue();
301
302         // add new ClientModel with userAgent, contentType
303         // and XPath for this client Element
304         clientList.add(
305             new ClientModel( agent, type, path ) );
306     }
307
308 } // end try
309
310 // handle SAXException when parsing XML document
311 catch ( SAXException saxException ) {
312     saxException.printStackTrace();
313 }
314
315 // catch IO exception when reading XML document
316 catch ( IOException ioException ) {
317     ioException.printStackTrace();
318 }
319
320 // return newly creating list of ClientModels
321 return clientList;
322
323 } // end method buildClientList
324
325 // get ClientModel for given User-Agent HTTP header
326 private ClientModel getClientModel( String header )
327 {
328     // get Iterator for clientList
329     Iterator iterator = clientList.iterator();
330

```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 7 of 8).

```

331     // find ClientModel whose userAgent property is a
332     // substring of given User-Agent HTTP header
333     while ( iterator.hasNext() ) {
334         ClientModel client = ( ClientModel ) iterator.next();
335
336         // if this ClientModel's userAgent property is a
337         // substring of the User-Agent HTTP header, return
338         // a reference to the ClientModel
339         if ( header.indexOf( client.getUserAgent() ) > -1 )
340             return client;
341     }
342
343     // return default ClientModel if no others match
344     return new ClientModel(
345         "DEFAULT CLIENT", "text/html", "/XHTML/" );
346
347 } // end method getClientModel
348 }
```

Fig. 18.1 **XMLServlet** base class for servlets in the Deitel Bookstore (part 8 of 8).

Line 84 invokes method **buildClientList**, which reads the **clients.xml** configuration file and produces a **List** of **ClientModels** (Fig. 18.4). Instances of **XMLServlet** use these **ClientModels** to determine which XSL transformation to apply for each client type.

Method **getDocumentBuilder** (lines 88–107) creates a **DocumentBuilder** object for parsing and creating XML documents. The **boolean** argument specifies whether method **getDocumentBuilder** should create a validating XML parser. Class **XMLServlet** stores a **DocumentBuilderFactory** in an instance variable (line 29), which prevents the need to create a new **DocumentBuilderFactory** each time a **DocumentBuilder** is needed. The overloaded **getDocumentBuilder** (lines 110–113) invokes method **getDocumentBuilder** with a **false** argument to create a non-validating XML parser.

Methods **setXSLFileName** and **getXSLFileName** (lines 116–125) are *set* and *get* methods for the **XSLFileName** property of class **XMLServlet**. The **XSLFileName** property specifies the name of the XSLT document that transforms the servlet's content for a particular client type. The Deitel Bookstore application separates the XSL transformations for the various client types into separate directories. For example, the file **products.xsl** in directory **/XSLT/XHTML** produces XHTML output, whereas the version of **products.xsl** in directory **/XSLT/WML** produces WML output. The **XSLFileName** property specifies only the filename (e.g., **products.xsl**); each **ClientModel** specifies the appropriate directory for a particular client type.

Method **writeXML** (lines 130–168) determines which type of client is accessing the servlet and invokes method **transform** to perform an XSL transformation. Lines 138–139 attempt to obtain a **ClientModel** from the **HttpSession**. If the **HttpSession** does not contain a **ClientModel**, line 144 obtains the client's **User-Agent** header, which uniquely identifies the client type. Line 145 invokes method **getClientModel** to get an appropriate **ClientModel** for the given client type. Line 146 places the **ClientModel** in the **HttpSession** for later use. Line 150 obtains the content type for the client

from the **ClientModel** and configure the **HttpServletResponse** object. Line 156 constructs the complete relative path for the XSL transformation by concatenating the **ClientModel**'s **XSLPath** property with the servlet's **XSLFileName** property. Lines 159–160 open an **InputStream** for the XSL transformation. Line 163 invokes method **transform** to perform the transformation and send the result to the client.

Method **transform** (lines 172–202) performs the given XSL transformation on the given XML document, and writes the result of the transformation to the given **PrintWriter**. Line 179 creates a **DOMSource** for the XML document. Lines 182–183 create a **StreamSource** for the XSL document. Line 159 creates a **StreamResult** for the **PrintWriter** to which the **Transformer** will write the results of the XSL transformation. Lines 189–190 create a **Transformer** by invoking **TransformerFactory** method **newTransformer**. Line 193 invokes **Transformer** method **transform** to perform the XSL transformation on the given **Source** object and writes the result to the given **Result** object.

Method **buildErrorMessage** (lines 205–223) is a utility method for constructing XML **Element** that contains an error message. Line 209 creates an **error Element** using the provided **document**. Lines 212–213 create a **errorMessage Element** that will contain the actual error message. Lines 189–190 create a **Text** node that contains the text of the error message and append this **Text** node to the **errorMessage Element**. Line 220 appends the **errorMessage Element** to the **error Element**, and line 223 returns the complete **error Element**.

Method **buildClientList** (lines 227–323) constructs a **List** of **ClientModels** by reading client information from an XML configuration file (Fig. 18.2). Lines 237–238 retrieve the name of the configuration file from an initialization parameter in the servlet's **ServletContext**. The deployer must specify the value of this parameter when deploying the application. Lines 244–246 open an **InputStream** to the configuration file. Lines 249–50 parse the XML configuration file and build a **Document** object in memory. Lines 253–254 get a **NodeList** of **client Elements** from the document. Each **client Element** has a **name Attribute** and three child **Elements**—**user-Agent**, **contentType** and **XSLPath**—each of which corresponds to a **ClientModel** property. Lines 260–306 construct a **ClientModel** for each **client Element** in the XML configuration file and add those **ClientModels** to the **List**.

Method **getClientModel** (lines 326–347) returns a **ClientModel** that matches the given **User-Agent** header. The **UserAgent** property of class **ClientModel** contains a substring of the **User-Agent** header that uniquely identifies a particular client type. For example, the **User-Agent** substring **Mozilla/4.0 (compatible; MSIE 5** uniquely identifies the Microsoft Internet Explorer version 5 client. Lines 333–341 compare the **UserAgent** property of each **ClientModel** with the given **User-Agent** header. If the **UserAgent** property is a substring of the **User-Agent** header, the **ClientModel** is a match and line 340 returns it to the caller. Lines 344–345 construct a generic XHTML **ClientModel** as a default if no others match the given **User-Agent** header.

Figure 18.2 presents a sample configuration file that enables application support for several popular client types. Figure 18.3 presents the DTD for this configuration file.

Class **ClientModel** (Fig. 18.4) represents a particular client type. Lines 18–23 define the **ClientModel** constructor. Lines 26–59 provide *set* and *get* methods for the **UserAgent**, **ContentType** and **XSLPath** properties.

```
1 <?xml version = "1.0" encoding = "UTF-8"?>
2 <!DOCTYPE clients SYSTEM
3   "http://www.deitel.com/advjhttp1/clients.dtd">
4
5 <!-- Client configuration file for the Deitel Bookstore -->
6
7 <clients>
8
9   <!-- Microsoft Internet Explorer version 5 client -->
10  <client name = "Microsoft Internet Explorer 5">
11    <userAgent>Mozilla/4.0 (compatible; MSIE 5</userAgent>
12    <contentType>text/html</contentType>
13    <XSLPath>/XSLT/XHTML/</XSLPath>
14  </client>
15
16  <!-- Microsoft Internet Explorer version 6 client -->
17  <client name = "Microsoft Internet Explorer 6">
18    <userAgent>Mozilla/4.0 (compatible; MSIE 6</userAgent>
19    <contentType>text/html</contentType>
20    <XSLPath>/XSLT/XHTML/</XSLPath>
21  </client>
22
23  <!-- Netscape version 4.7x client -->
24  <client name = "Netscape 4.7">
25    <userAgent>Mozilla/4.7</userAgent>
26    <contentType>text/html</contentType>
27    <XSLPath>/XSLT/XHTML/</XSLPath>
28  </client>
29
30  <!-- Mozilla/Netscape version 6 client -->
31  <client name = "Mozilla/Netscape 6">
32    <userAgent>Gecko</userAgent>
33    <contentType>text/html</contentType>
34    <XSLPath>/XSLT/XHTML/</XSLPath>
35  </client>
36
37  <!-- Phone.com WML browser client -->
38  <client name = "Openwave SDK Browser">
39    <userAgent>UP.Browser/4</userAgent>
40    <contentType>text/vnd.wap.wml</contentType>
41    <XSLPath>/XSLT/WML/</XSLPath>
42  </client>
43
44  <!-- Nokia WML browser client -->
45  <client name = "Nokia WAP Toolkit Browser">
46    <userAgent>Nokia-WAP</userAgent>
47    <contentType>text/vnd.wap.wml</contentType>
48    <XSLPath>/XSLT/WML/</XSLPath>
49  </client>
50
51  <!-- Pixo iMode browser client -->
52  <client name = "Pixo Browser">
```

Fig. 18.2 Configuration file for enabling support for various client types (**clients.xml**) (part 1 of 2).

```

53      <userAgent>Pixo-Browser</userAgent>
54      <contentType>text/html</contentType>
55      <xslPath>/XSLT/cHTML/</xslPath>
56    </client>
57
58  </clients>

```

Fig. 18.2 Configuration file for enabling support for various client types (**clients.xml**) (part 2 of 2).

```

1  <!-- clients.dtd                                -->
2  <!-- DTD for specifying Bookstore client types -->
3
4  <!ELEMENT clients ( client+ )>
5
6  <!ELEMENT client ( userAgent, contentType, xslPath )>
7  <!ATTLIST client name CDATA #REQUIRED>
8
9  <!ELEMENT userAgent ( #PCDATA )>
10 <!ELEMENT contentType ( #PCDATA )>
11 <!ELEMENT xslPath ( #PCDATA )>

```

Fig. 18.3 DTD for **clients.xml**.

```

1 // ClientModel.java
2 // ClientModel is a utility class for determining the proper
3 // Content-Type and path for XSL files for each type of client
4 // supported by the Bookstore application.
5 package com.deitel.advjhtp1.bookstore.model;
6
7 // Java core packages
8 import java.io.*;
9
10 public class ClientModel implements Serializable {
11
12     // ClientModel properties
13     private String userAgent;
14     private String contentType;
15     private String xslPath;
16
17     // ClientModel constructor for initializing data members
18     public ClientModel( String agent, String type, String path )
19     {
20         setUserAgent( agent );
21         setContentType( type );
22         setXSLPath( path );
23     }
24

```

Fig. 18.4 **ClientModel** for representing supported clients (part 1 of 2).

```

25 // set UserAgent substring
26 public void setUserAgent( String agent )
27 {
28     userAgent = agent;
29 }
30
31 // get UserAgent substring
32 public String getUserAgent()
33 {
34     return userAgent;
35 }
36
37 // set ContentType
38 public void setContentType( String type )
39 {
40     contentType = type;
41 }
42
43 // get ContentType
44 public String getContentType()
45 {
46     return contentType;
47 }
48
49 // set XSL path
50 public void setXSLPath( String path )
51 {
52     xslPath = path;
53 }
54
55 // get XSL path
56 public String getXSLPath()
57 {
58     return xslPath;
59 }
60 }

```

Fig. 18.4 **ClientModel** for representing supported clients (part 2 of 2).

### 18.3 Shopping Cart Servlets

Several e-commerce models have become common for shopping on the Web. These models include auction sites, bargain shoppers, bartering and name your own price. Our application uses the familiar shopping-cart model, in which a customer browses through the store and selects items for purchase. Each of these items is placed in a virtual shopping cart. When the customer is finished shopping, a checkout process gathers the person's billing and shipping information to complete the transaction. Maintaining the shopping cart is part of the business logic implemented in the application's EJBs.

Figure 18.5 shows the flow of client requests and responses for a new customer who orders multiple copies of a book using a Web browser. The customer enters the site at **index.html**. The customer then selects a link to view the product catalog, which is generated by **GetAllProductsServlet**. The customer then chooses a product from the

product catalog, and **GetProductServlet** shows the details of the product, including a picture of the cover, the price and the author(s). The customer adds the product to the shopping cart through **AddToCartServlet**, and **ViewCartServlet** shows the shopping cart contents. The customer updates the quantity to be purchased through **UpdateCartServlet**, and **ViewCartServlet** again shows the shopping cart contents to the customer. The customer then selects a link to register as a new customer and fills out the registration form in **register.html**. The customer submits the form to **RegisterServlet**, which then invokes **LoginServlet** to log the customer into the store. The customer then selects a link to invoke **CheckoutServlet**. **CheckoutServlet** places the order and forwards the customer to **ViewOrderServlet**, which shows the details of the customer's order.

### 18.3.1 AddToCartServlet

As customers browse through our on-line store, they add products they wish to purchase to their shopping carts. Servlet **AddToCartServlet** (Fig. 18.6) handles each customer request to add a product to the shopping cart. Class **AddToCartServlet** extends class **XMLServlet**, which implements functionality common to all servlets in the Deitel Bookstore, such as initialization and XSL transformations.

Line 41 retrieves from the **HttpServletRequest** object the ISBN of the product the customer would like purchase. Lines 37–38 retrieve a reference to the customer's **ShoppingCart** from the servlet's **HttpSession** object. It is possible that the customer does not yet have a shopping cart, in which case the **ShoppingCart** reference will be **null**. If this is the case, line 59 creates a new **ShoppingCart** using the **ShoppingCart** home interface, and stores its reference in the servlet's **HttpSession** object (line 62) for later use. The **ShoppingCart** EJB is a stateful session bean and will therefore maintain the contents of the customer's **ShoppingCart** throughout the browsing session.

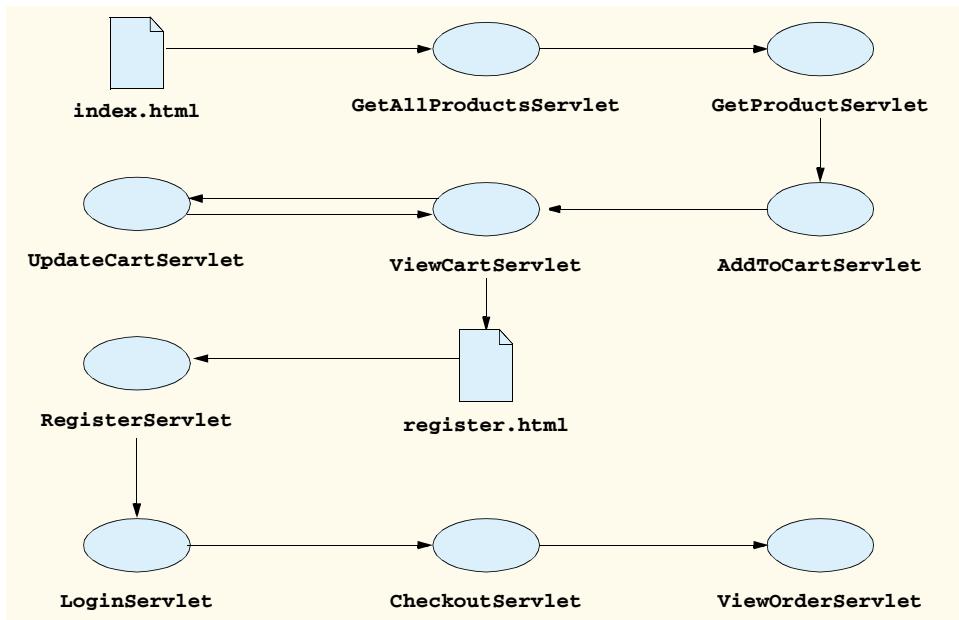
Once the servlet has a valid **ShoppingCart** reference, line 66 invokes the **ShoppingCart**'s **addProduct** business method with the product's ISBN as an argument. Line 70 invokes method **sendRedirect** of class **HttpServletResponse** to redirect the client to **ViewCartServlet**, which displays a list of products in the shopping cart.

There are three checked exceptions that could be thrown from the **try** block on lines 44–72. Lines 75–86 **catch** a **NamingException** if the **ShoppingCart** EJB is not found in the JNDI directory. Lines 89–99 **catch** a **CreateException** if there is an error creating the customer's shopping cart. Lines 102–110 **catch** a **ProductNotFoundException**, which is an application-specific exception that we present in detail in Chapter 19. A **ProductNotFoundException** indicates that a product with the given ISBN could not be found in the database.

Each of these exception handlers uses **XMLServlet** method **buildErrorMessage** to create an XML error message to present to the client. In each case, we provide a message to inform the user of the error, and print a stack trace of the exception to aid the developer in debugging the application. Invoking **XMLServlet** method **writeXML** (lines 85, 98 and 109) sends the content to the client.

### 18.3.2 ViewCartServlet

Once the customer has added an item to the shopping cart, **ViewCartServlet** (Fig. 18.7) displays the shopping cart's contents. This servlet is a subclass of **XMLServlet**.



**Fig. 18.5** Flow of client requests and data returned in the Deitel Bookstore for XHTML clients.

```

1 // AddToCartServlet.java
2 // AddToCartServlet adds a Product to the Customer's
3 // ShoppingCart.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.servlet.*;
11 import javax.servlet.http.*;
12 import javax.naming.*;
13 import javax.rmi.*;
14 import javax.ejb.*;
15
16 // third-party packages
17 import org.w3c.dom.*;
18
19 // Deitel packages
20 import com.deitel.advjhttp1.bookstore.model.*;
21 import com.deitel.advjhttp1.bookstore.ejb.*;
22 import com.deitel.advjhttp1.bookstore.exceptions.*;
23

```

**Fig. 18.6** **AddToCartServlet** for adding products to a shopping cart (part 1 of 3).

```

24  public class AddToCartServlet extends XMLServlet {
25
26      // respond to HTTP post requests
27      public void doPost( HttpServletRequest request,
28                          HttpServletResponse response )
29          throws ServletException, IOException
30      {
31          Document document = getDocumentBuilder().newDocument();
32
33          // get HttpSession Object for this user
34          HttpSession session = request.getSession();
35
36          // get Customer's ShoppingCart
37          ShoppingCart shoppingCart =
38              ( ShoppingCart ) session.getAttribute( "cart" );
39
40          // get ISBN parameter from request Object
41          String isbn = request.getParameter( "ISBN" );
42
43          // get ShoppingCart and add Product to be purchased
44          try {
45              InitialContext context = new InitialContext();
46
47              // create ShoppingCart if Customer does not have one
48              if ( shoppingCart == null ) {
49                  Object object = context.lookup(
50                      "java:comp/env/ejb/ShoppingCart" );
51
52                  // cast Object reference to ShoppingCartHome
53                  ShoppingCartHome shoppingCartHome =
54                      ( ShoppingCartHome )
55                      PortableRemoteObject.narrow(
56                          object, ShoppingCartHome.class );
57
58                  // create ShoppingCart using ShoppingCartHome
59                  shoppingCart = shoppingCartHome.create();
60
61                  // store ShoppingCart in session
62                  session.setAttribute( "cart", shoppingCart );
63              }
64
65              // add Product to Customer's ShoppingCart
66              shoppingCart.addProduct( isbn );
67
68              // redirect Customer to ViewCartServlet to view
69              // contents of ShoppingCart
70              response.sendRedirect( "ViewCart" );
71
72          } // end try
73
74          // handle exception when looking up ShoppingCart EJB
75          catch ( NamingException namingException ) {

```

Fig. 18.6 **AddToCartServlet** for adding products to a shopping cart (part 2 of 3).

```

76         namingException.printStackTrace();
77
78         String error = "The ShoppingCart EJB was not " +
79             "found in the JNDI directory.";
80
81         // append error message to XML document
82         document.appendChild( buildErrorMessage(
83             document, error ) );
84
85         writeXML( request, response, document );
86     }
87
88     // handle exception when creating ShoppingCart EJB
89     catch ( CreateException createException ) {
90         createException.printStackTrace();
91
92         String error = "ShoppingCart could not be created";
93
94         // append error message to XML document
95         document.appendChild( buildErrorMessage(
96             document, error ) );
97
98         writeXML( request, response, document );
99     }
100
101    // handle exception when Product is not found
102    catch ( ProductNotFoundException productException ) {
103        productException.printStackTrace();
104
105        // append error message to XML document
106        document.appendChild( buildErrorMessage(
107            document, productException.getMessage() ) );
108
109        writeXML( request, response, document );
110    }
111
112 } // end method doGet
113 }
```

Fig. 18.6 **AddToCartServlet** for adding products to a shopping cart  
(part 3 of 3).

```

1 // ViewCartServlet.java
2 // ViewCartServlet presents the contents of the Customer's
3 // ShoppingCart.
4 package com.deitel.advjhtp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.text.*;
10
```

Fig. 18.7 **ViewCartServlet** for viewing contents of shopping cart (part 1 of 3).

```
11 // Java extension packages
12 import javax.servlet.*;
13 import javax.servlet.http.*;
14 import javax.rmi.*;
15
16 // third-party packages
17 import org.w3c.dom.*;
18
19 // Deitel packages
20 import com.deitel.advjhttp1.bookstore.model.*;
21 import com.deitel.advjhttp1.bookstore.ejb.*;
22
23 public class ViewCartServlet extends XMLServlet {
24
25     // respond to HTTP get requests
26     public void doGet( HttpServletRequest request,
27                         HttpServletResponse response )
28         throws ServletException, IOException
29     {
30         Document document = getDocumentBuilder().newDocument();
31         HttpSession session = request.getSession();
32
33         // get Customer's ShoppingCart from session
34         ShoppingCart shoppingCart =
35             ( ShoppingCart ) session.getAttribute( "cart" );
36
37         // build XML document with contents of ShoppingCart
38         if ( shoppingCart != null ) {
39
40             // create cart element in XML document
41             Element root = ( Element ) document.appendChild(
42                 document.createElement( "cart" ) );
43
44             // get total cost of Products in ShoppingCart
45             double total = shoppingCart.getTotal();
46
47             // create NumberFormat for local currency
48             NumberFormat priceFormatter =
49                 NumberFormat.getCurrencyInstance();
50
51             // format total price for ShoppingCart and add it
52             // as an attribute of element cart
53             root.setAttribute( "total",
54                 priceFormatter.format( total ) );
55
56             // get contents of ShoppingCart
57             Iterator orderProducts =
58                 shoppingCart.getContents().iterator();
59
60             // add an element for each Product in ShoppingCart
61             // to XML document
62             while ( orderProducts.hasNext() ) {
63                 OrderProductModel orderProductModel =
```

Fig. 18.7 **ViewCartServlet** for viewing contents of shopping cart (part 2 of 3).

```

64             ( OrderProductModel ) orderProducts.next();
65
66         root.appendChild(
67             orderProductModel.getXML( document ) );
68     }
69
70 } // end if
71
72 else {
73     String error = "Your ShoppingCart is empty.";
74
75     // append error message to XML document
76     document.appendChild( buildErrorMessage(
77         document, error ) );
78 }
79
80 // write content to client
81 writeXML( request, response, document );
82
83 } // end method doGet
84 }

```

Fig. 18.7 **ViewCartServlet** for viewing contents of shopping cart (part 3 of 3).

A remote reference to the customer's **ShoppingCart** is stored in the **HttpSession** object. Lines 34–35 retrieve this remote reference. After ensuring the **ShoppingCart** remote reference is not **null**, lines 41–42 begin building the XML document that describes the customer's shopping cart by creating element **cart**. Line 45 obtains the total price for the items in the shopping cart by invoking **ShoppingCart** method **getTotal**. Lines 48–49 format the **total** using a **NumberFormat** and append the formatted **total** to the XML document.

Lines 62–68 iterate through the **Collection** of **OrderProductModels** in the shopping cart. Each **OrderProductModel** represents a product and the quantity of that product in the shopping cart. Line 67 invokes **OrderProductModel** method **getXML** to obtain an XML element that describes the **OrderProductModel**, including the product's ISBN and quantity. Lines 66–67 append this description to the servlet's XML document.

If the **ShoppingCart** remote reference stored in the **HttpSession** object was **null**, lines 72–78 generate an error message. Line 81 invokes method **writeXML** to transforms the XML content using XSLT and present that content to the client.

The XSL transformation of Fig. 18.8 produces XHTML for **ViewCartServlet**. Lines 6–8 set the output parameters for the transformation. Line 10 includes templates from **error.xsl** for transforming error messages. Lines 23–27 load a navigation header from an external XML document. Note that we refer to the **error.xsl** and **navigation.xml** documents with relative URIs. Recall that class **XMLServlet** creates a custom **URIResolver** that enables the XSL transformer to resolve these relative URIs. Had we not provided a custom **URIResolver**, each XSL transformation would have to specify the complete URI for these documents, which would make the application less portable. This header contains links for viewing the product catalog, creating an online

account, viewing the shopping cart, etc. Lines 42–43 apply a template that populates a table with product information, including the title, author, ISBN price and quantity. The **form** on lines 51–54 enables the customer to check out from the online store to place the order. The **xsl:template** on lines 61–91 extracts each product's information from the **ViewCartServlet**'s XML document and creates a table row. The **form** on lines 75–80 enables the user to change the quantity of the product in the shopping cart. The **form** on lines 84–88 enables the user to remove the product from the shopping cart.

The XSL transformation of Fig. 18.9 produces cHTML for **ViewCartServlet**. Lines 28–29 display the total cost of products in the cart. Lines 38–41 apply the **xsl:template** for **orderProduct** elements to produce an unordered list of product information. The **form** on lines 44–47 enables the customer to check out of the online store to place the order. The **form** on lines 64–69 enables the customer to update the quantity of a particular product in the shopping cart. The **form** on lines 72–76 enables the customer to remove a product from the shopping cart.

```

1  <?xml version = "1.0"?>
2
3  <xsl:stylesheet version = "1.0"
4      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
5
6      <xsl:output method = "xml" omit-xml-declaration = "no"
7          indent = "yes" doctype-system = "DTD/xhtml1-strict.dtd"
8          doctype-public = "-//W3C//DTD XHTML 1.0 Strict//EN"/>
9
10     <xsl:include href = "/XSLT/XHTML/error.xsl"/>
11
12     <xsl:template match = "cart">
13         <html xmlns = "http://www.w3.org/1999/xhtml"
14             xml:lang = "en" lang = "en">
15
16         <head>
17             <title>Your Online Shopping Cart</title>
18             <link rel = "StyleSheet" href = "styles/default.css"/>
19         </head>
20
21         <body>
22
23             <xsl:for-each select =
24                 "document( '/XSLT/XHTML/navigation.xml' )">
25
26                 <xsl:copy-of select = "."/>
27             </xsl:for-each>
28
29             <div class = "header">Your Shopping Cart:</div>
30
31             <table class = "cart">
32                 <tr>
33                     <th>Title</th>
34                     <th>Author(s)</th>
```

Fig. 18.8 **ViewCartServlet** XSL transformation for XHTML browsers (**XHTML/viewCart.xsl**) (part 1 of 3).

```
35             <th>ISBN</th>
36             <th>Price</th>
37             <th>Quantity</th>
38         </tr>
39
40         <xsl:apply-templates
41             select = "orderProduct"/>
42
43     </table>
44
45     <p>
46         Your total:
47         <xsl:value-of select = "@total"/>
48     </p>
49
50     <p>
51         <form action = "Checkout" method = "post">
52             <input name = "submit" type = "submit"
53                 value = "Check Out"/>
54         </form>
55     </p>
56
57     </body>
58   </html>
59 </xsl:template>
60
61 <xsl:template match = "orderProduct">
62     <tr>
63         <td>
64             <a href = "GetProduct?ISBN={product/ISBN}">
65                 <xsl:value-of select = "product/title"/></a>
66             </td>
67
68             <td><xsl:value-of select = "product/author"/></td>
69
70             <td><xsl:value-of select = "product/ISBN"/></td>
71
72             <td><xsl:value-of select = "product/price"/></td>
73
74         <td>
75             <form action = "UpdateCart" method = "post">
76                 <input type = "text" size = "2"
77                     name = "{product/ISBN}"
78                     value = "{quantity}"/>
79                 <input type = "submit" value = "Update"/>
80             </form>
81         </td>
82
83         <td align = "center">
84             <form action = "RemoveFromCart" method = "post">
85                 <input name = "ISBN" type = "hidden"
86                     value = "{product/ISBN}"/>
```

Fig. 18.8 **ViewCartServlet** XSL transformation for XHTML browsers (**XHTML/viewCart.xsl**) (part 2 of 3).

```

87          <input type = "submit" value = "Remove"/>
88      </form>
89  </td>
90 </tr>
91 </xsl:template>
92 </xsl:stylesheet>
```

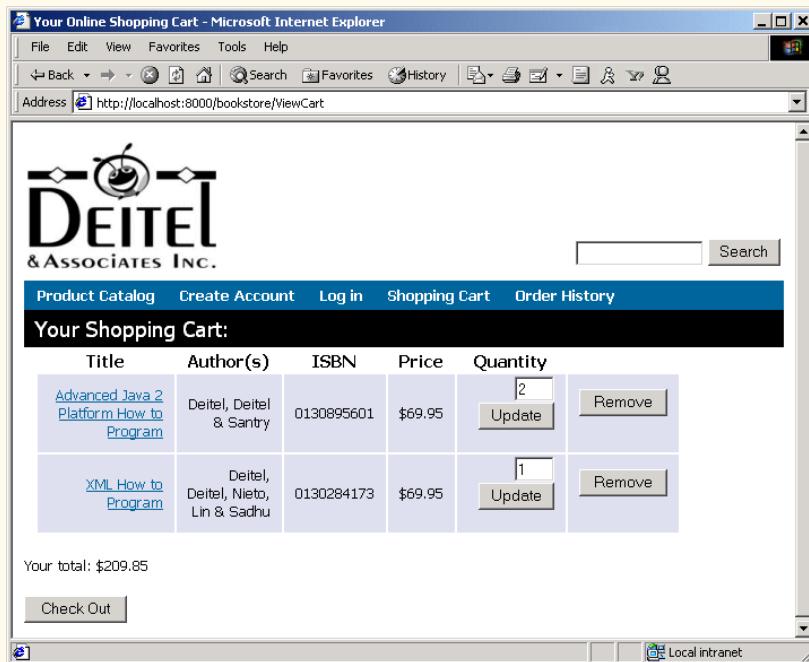


Fig. 18.8 ViewCartServlet XSL transformation for XHTML browsers (**XHTML/viewCart.xsl**) (part 3 of 3).

```

1 <?xml version = "1.0"?>
2
3 <xsl:stylesheet version = "1.0"
4   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
5
6   <xsl:output method = "html"
7     omit-xml-declaration = "yes"
8     indent = "yes"
9     doctype-system =
10    "http://www.w3.org/MarkUp/html-spec/html-spec_toc.html"
11    doctype-public = "-//W3C//DTD HTML 2.0//EN"/>
12
13   <xsl:include href = "/XSLT/cHTML/error.xsl"/>
14
```

Fig. 18.9 ViewCartServlet XSL transformation for i-mode browsers (**cHTML/viewCart.xsl**) (part 1 of 3). (Image courtesy of Pixo, Inc.)

```
15    <xsl:template match = "cart">
16        <html>
17
18            <head>
19                <title>Your Online Shopping Cart</title>
20            </head>
21
22            <body>
23                <div class = "header">
24                    Your Shopping Cart:
25                </div>
26
27                <p>
28                    Your total:
29                        <xsl:value-of select = "@total"/>
30                </p>
31
32                <p>Title</p>
33                <p>Author(s) </p>
34                <p>ISBN</p>
35                <p>Price</p>
36                <p>Quantity</p>
37
38                <ul>
39                    <xsl:apply-templates
40                        select = "orderProduct"/>
41                </ul>
42
43                <p>
44                    <form method = "post" action = "Checkout">
45                        <input type = "submit" name = "Checkout"
46                            value = "Checkout"/>
47                    </form>
48                </p>
49
50            </body>
51
52        </html>
53    </xsl:template>
54
55    <xsl:template match = "orderProduct">
56        <li>
57            <a href = "GetProduct?ISBN={product/ISBN}">
58                <xsl:value-of select = "product/title"/></a>
59            <br/>
60            <p><xsl:value-of select = "product/author"/></p>
61            <p><xsl:value-of select = "product/ISBN"/></p>
62            <p><xsl:value-of select = "product/price"/></p>
63            <p>
64                <form method = "post" action = "UpdateCart">
65                    <input type = "text" size = "2"
66                        name = "{product/ISBN}"
```

Fig. 18.9 **ViewCartServlet** XSL transformation for i-mode browsers (**cHTML/viewCart.xsl**) (part 2 of 3). (Image courtesy of Pixo, Inc.)

```

67             value = "{quantity}" />
68         <input type = "submit" value = "Update" />
69     </form>
70   </p>
71   <p>
72     <form method = "post" action = "RemoveFromCart">
73       <input type = "hidden" name = "ISBN"
74         value = "{product/ISBN}" />
75       <input type = "submit" value = "Remove" />
76     </form>
77   </p>
78   <br/>
79   </li>
80 </xsl:template>
81 </xsl:stylesheet>

```



**Fig. 18.9** **ViewCartServlet** XSL transformation for i-mode browsers (**cHTML/viewCart.xsl**) (part 3 of 3). (Image courtesy of Pixo, Inc.)

The XSL transformation of Fig. 18.10 produces WML for **ViewCartServlet**. The **do** element on lines 21–23 enables the user to check out of the online store to place the order. Lines 25–49 mark up the list of products in the shopping cart. The **card** element on lines 55–64 displays information about a single product. The **card** element on lines 66–81 provides an interface for changing the quantity of a particular product in the shopping cart. [Note: To download the Nokia WAP Toolkit WML browser, please visit [www.nokia.com/corporate/wap/downloads.html](http://www.nokia.com/corporate/wap/downloads.html).]

### 18.3.3 RemoveFromCartServlet

Once a customer has added a product to the shopping cart, the customer may wish to remove that product. **RemoveFromCartServlet** (Fig. 18.11) processes requests to remove products from shopping carts. Line 34 retrieves from the **HttpSession** the ISBN of the product that the customer would like to remove from the shopping cart. Lines 39–40 obtain the **ShoppingCart** remote reference from the **HttpSession** object. After ensuring that the **ShoppingCart** reference is not **null**, line 44 invokes **ShoppingCart** method **removeProduct**, providing the ISBN as an argument. Line 48 redirects the client to **ViewCartServlet** to display the results of removing the product from the shopping cart. Method **removeProduct** throws a **ProductNotFoundException** if a product with the given ISBN is not found in the shopping cart. Lines 53–61 **catch** this exception and generate an error message to inform the user of the problem.

### 18.3.4 UpdateCartServlet

Products in a customer's shopping cart each have an associated quantity. **UpdateCartServlet** (Fig. 18.12) enables customers to change the quantities of products in their shopping carts. Lines 37–38 retrieve the customer's **ShoppingCart** from the **HttpSession** object. Line 44 retrieves an **Enumeration** of parameter names from the **HttpServletRequest** object. Each parameter name is the ISBN of a product in the customer's shopping cart. The value of each parameter is the desired quantity of the product in the shopping cart. For each product in the shopping cart, lines 50–51 obtain the **newQuantity** for that product from the **request** parameter. Lines 55–56 set the quantity for each product in the shopping cart by invoking **ShoppingCart** method **setProductQuantity**. Once all of the quantities have been updated, line 61 redirects the client to **ViewCartServlet** to show the updates to the shopping cart.

```

1 <?xml version = "1.0"?>
2
3 <xsl:stylesheet version = "1.0"
4   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
5
6   <xsl:output method = "xml" omit-xml-declaration = "no"
7     doctype-system = "http://www.wapforum.org/DTD/wml_1.1.xml"
8     doctype-public = "-//WAPFORUM//DTD WML 1.1//EN"/>
9
10  <xsl:include href = "/XSLT/WML/error.xsl"/>
11
12  <xsl:template match = "cart">
13    <wml>
14
15      <card title = "Shopping Cart">
16        <do type = "prev">
17          <prev/>
18        </do>
19

```

Fig. 18.10 **ViewCartServlet** XSL transformation for WML browsers (**WML/viewCart.xsl**) (part 1 of 3). (Image © 2001 Nokia Mobile Phones.)

```

20          <do type = "accept" label = "Check Out">
21              <go href = "Checkout" method = "post"/>
22          </do>
23
24          <p><em>Shopping Cart</em></p>
25
26          <p>
27              Your total: $<xsl:value-of select = "@total"/>
28
29              <table columns = "2">
30                  <tr>
31                      <td>Title</td>
32                      <td>Price</td>
33                  </tr>
34
35                  <xsl:for-each select = "orderProduct">
36                      <tr>
37                          <td>
38                              <a href = "#ISBN{product/ISBN}">
39                                  <xsl:value-of select = "product/title"/>
40                              </a>
41                          </td>
42                          <td>
43                              $<xsl:value-of select = "product/price"/>
44                          </td>
45                      </tr>
46                  </xsl:for-each>
47
48              </table>
49          </p>
50
51      </card>
52
53      <xsl:for-each select = "orderProduct" >
54          <card id = "ISBN{product/ISBN}">
55              <do label = "OK" type = "prev"><prev/></do>
56              <do label = "Change Quant" type = "options">
57                  <go href = "#quant{product/ISBN}" />
58              </do>
59              <p><xsl:value-of select = "product/title"/></p>
60              <p>Quantity: <xsl:value-of select = "quantity"/></p>
61              <p><xsl:value-of select = "product/author"/></p>
62              <p><xsl:value-of select = "product/ISBN"/></p>
63          </card>
64
65          <card id = "quant{product/ISBN}">
66              <p>Enter new quantity
67                  <input name = "quantity" emptyok = "false"
68                      type = "text" format = "*n"/>
69              </p>
70

```

Fig. 18.10 **ViewCartServlet** XSL transformation for WML browsers (**WML/viewCart.xsl**) (part 2 of 3). (Image © 2001 Nokia Mobile Phones.)

```

71      <do type = "accept" label = "Update Quantity">
72          <go href = "UpdateCart" method = "post">
73              <postfield name = "{product/ISBN}"
74                  value = "$quantity"/>
75      </go>
76  </do>
77
78      <do type = "prev" label = "Cancel"><prev/></do>
79
80      </card>
81  </xsl:for-each>
82
83      </wml>
84  </xsl:template>
85 </xsl:stylesheet>

```



Fig. 18.10 **ViewCartServlet** XSL transformation for WML browsers ([WML / viewCart.xsl](#)) (part 3 of 3). (Image © 2001 Nokia Mobile Phones.)

```

1 // RemoveFromCartServlet.java
2 // RemoveFromCartServlet removes a Product from the Customer's
3 // ShoppingCart.
4 package com.deitel.advjhtp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;

```

Fig. 18.11 **RemoveFromCartServlet** for removing products from shopping cart (part 1 of 3).

```
8 // Java extension packages
9 import javax.servlet.*;
10 import javax.servlet.http.*;
11
12
13 // third-party packages
14 import org.w3c.dom.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.bookstore.model.*;
18 import com.deitel.advjhttp1.bookstore.ejb.*;
19 import com.deitel.advjhttp1.bookstore.exceptions.*;
20
21 public class RemoveFromCartServlet extends XMLServlet {
22
23     // respond to HTTP post requests
24     public void doPost( HttpServletRequest request,
25                         HttpServletResponse response )
26             throws ServletException, IOException
27     {
28         Document document = getDocumentBuilder().newDocument();
29
30         // remove Product from ShoppingCart
31         try {
32
33             // get ISBN of Product to be removed
34             String isbn = request.getParameter( "ISBN" );
35
36             // get Customer's ShoppingCart from session
37             HttpSession session = request.getSession();
38
39             ShoppingCart shoppingCart =
40                 ( ShoppingCart ) session.getAttribute( "cart" );
41
42             // if ShoppingCart is not null, remove Product
43             if ( shoppingCart != null )
44                 shoppingCart.removeProduct( isbn );
45
46             // redirect Customer to ViewCartServlet to view
47             // the contents of ShoppingCart
48             response.sendRedirect( "ViewCart" );
49
50         } // end try
51
52         // handle exception if Product not found in ShoppingCart
53         catch ( ProductNotFoundException productException ) {
54             productException.printStackTrace();
55
56             // append error message to XML document
57             document.appendChild( buildErrorMessage(
58                 document, productException.getMessage() ) );
59     }
```

Fig. 18.11 RemoveFromCartServlet for removing products from shopping cart (part 2 of 3).

```

60         writeXML( request, response, document );
61     }
62
63 } // end method doGet
64 }
```

Fig. 18.11 **RemoveFromCartServlet** for removing products from shopping cart (part 3 of 3).

```

1 // UpdateCartServlet.java
2 // UpdateCartServlet updates the quantity of a Product in the
3 // Customer's ShoppingCart.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.*;
12 import javax.servlet.http.*;
13
14 // third-party packages
15 import org.w3c.dom.*;
16
17 // Deitel packages
18 import com.deitel.advjhttp1.bookstore.model.*;
19 import com.deitel.advjhttp1.bookstore.ejb.*;
20 import com.deitel.advjhttp1.bookstore.exceptions.*;
21
22 public class UpdateCartServlet extends XMLServlet {
23
24     // respond to HTTP post requests
25     public void doPost( HttpServletRequest request,
26                         HttpServletResponse response )
27             throws ServletException, IOException
28     {
29         Document document = getDocumentBuilder().newDocument();
30
31         // update quantity of given Product in ShoppingCart
32         try {
33
34             // get Customer's ShoppingCart from session
35             HttpSession session = request.getSession( false );
36
37             ShoppingCart shoppingCart = ( ShoppingCart )
38                 session.getAttribute( "cart" );
39
40             // get Enumeration of parameter names
41             Enumeration parameters = request.getParameterNames();
```

Fig. 18.12 **UpdateCartServlet** for updating quantities of products in shopping cart (part 1 of 2).

```

42         // update quantity for each ISBN parameter
43         while ( parameters.hasMoreElements() ) {
44
45             // get ISBN of Product to be updated
46             String ISBN = ( String ) parameters.nextElement();
47
48             // get new quantity for Product
49             int newQuantity = Integer.parseInt(
50                 request.getParameter( ISBN ) );
51
52             // set quantity in ShoppingCart for Product
53             // with given ISBN
54             shoppingCart.setProductQuantity( ISBN,
55                 newQuantity );
56
57         }
58
59         // redirect Customer to ViewCartServlet to view
60         // contents of ShoppingCart
61         response.sendRedirect( "ViewCart" );
62
63     } // end try
64
65     // handle exception if Product not found in ShoppingCart
66     catch ( ProductNotFoundException productException ) {
67         productException.printStackTrace();
68
69         document.appendChild( buildErrorMessage(
70             document, productException.getMessage() ) );
71
72         writeXML( request, response, document );
73     }
74
75 } // end method doGet
76 }
```

Fig. 18.12 **UpdateCartServlet** for updating quantities of products in shopping cart (part 2 of 2).

Method **setProductQuantity** throws a **ProductNotFoundException** if the product with the given ISBN is not found in the shopping cart. Lines 66–73 handle this exception and generate an XML error message using method **buildErrorMessage**. The Method **writeXML** presents the error message to the client (line 72).

### 18.3.5 CheckoutServlet

Once the customer has finished browsing through the store and adding products to the shopping cart, **CheckOutServlet** (Fig. 18.13) completes the customer's **Order**.

A customer must log into the on-line store before checking out. Lines 32–33 retrieve the customer's **userID** from the **HttpSession**. Lines 39–40 then obtain a remote reference to the customer's **ShoppingCart** from the **session** object. After ensuring that neither the **ShoppingCart** nor the **userID** is **null**, line 51 invokes **ShoppingCart**

method **checkout** to place the order. Method **checkout** returns a remote reference to an **Order** EJB instance, which represents the customer's order. Line 54 gets the **orderId** for the **Order** by invoking method **getPrimaryKey**. Lines 57–58 redirect the client to **ViewOrderServlet**, which displays the details of the order that was placed.

If the **userID** is **null**, lines 60–70 generates an error message indicating that the customer is not logged in. Lines 75–83 catch a **ProductNotFoundException**, which method **checkout** throws if the shopping cart is empty (i.e., contains no products).

## 18.4 Product Catalog Servlets

Servlets **GetAllProductsServlet** and **ProductSearchServlet** provide an online catalog. These servlets retrieve a list of products and present the list to the customer. **GetProductServlet** shows the details of a given product.

### 18.4.1 GetAllProductsServlet

**GetAllProductsServlet** (Fig. 18.14) provides a list of products available at our online store. Lines 35–44 retrieve a remote reference to the **Product** EJB, which represents a product in the store. Method **findAllProducts** of interface **ProductHome** returns a **Collection** of **Product** EJBs, each of which represents a single product (lines 47–48). Lines 58–70 iterate through the **Collection** of products to build an XML document that contains information about each product. Lines 64–65 obtain a **ProductModel** for each product and lines 68–69 retrieve each product's XML description.

---

```

1 // CheckoutServlet.java
2 // CheckoutServlet allows a Customer to checkout of the online
3 // store to purchase the Products in the ShoppingCart.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.servlet.*;
11 import javax.servlet.http.*;
12
13 // third-party packages
14 import org.w3c.dom.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.bookstore.model.*;
18 import com.deitel.advjhttp1.bookstore.ejb.*;
19 import com.deitel.advjhttp1.bookstore.exceptions.*;
20
21 public class CheckoutServlet extends XMLServlet {
22
23     // respond to HTTP post requests
24     public void doPost( HttpServletRequest request,
25                         HttpServletResponse response )

```

---

Fig. 18.13 **CheckoutServlet** for placing **Orders** (part 1 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```

26     throws ServletException, IOException
27 {
28     Document document = getDocumentBuilder().newDocument();
29     HttpSession session = request.getSession();
30
31     // get Customer's userID from session
32     String userID = ( String )
33         session.getAttribute( "userID" );
34
35     // get ShoppingCart and check out
36     try {
37
38         // get Customer's ShoppingCart from session
39         ShoppingCart shoppingCart = ( ShoppingCart )
40             session.getAttribute( "cart" );
41
42         // ensure Customer has a ShoppingCart
43         if ( shoppingCart == null )
44             throw new ProductNotFoundException( "Your " +
45                 "ShoppingCart is empty." );
46
47         // ensure userID is neither null nor empty
48         if ( !( userID == null || userID.equals( "" ) ) ) {
49
50             // invoke checkout method to place Order
51             Order order = shoppingCart.checkout( userID );
52
53             // get orderID for Customer's Order
54             Integer orderID = ( Integer ) order.getPrimaryKey();
55
56             // go to ViewOrder to show completed order
57             response.sendRedirect( "ViewOrder?orderID=" +
58                 orderID );
59         }
60     else {
61         // userID was null, indicating Customer is
62         // not logged in
63         String error = "You are not logged in.";
64
65         // append error message to XML document
66         document.appendChild( buildErrorMessage( document,
67             error ) );
68
69         writeXML( request, response, document );
70     }
71
72 } // end try
73
74 // handle exception if Product not found in ShoppingCart
75 catch ( ProductNotFoundException productException ) {
76     productException.printStackTrace();
77 }
```

Fig. 18.13 **CheckoutServlet** for placing Orders (part 2 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```

78         // append error message to XML document
79         document.appendChild( buildErrorMessage(
80             document, productException.getMessage() ) );
81
82         writeXML( request, response, document );
83     }
84
85 } // end method doPost
86 }
```

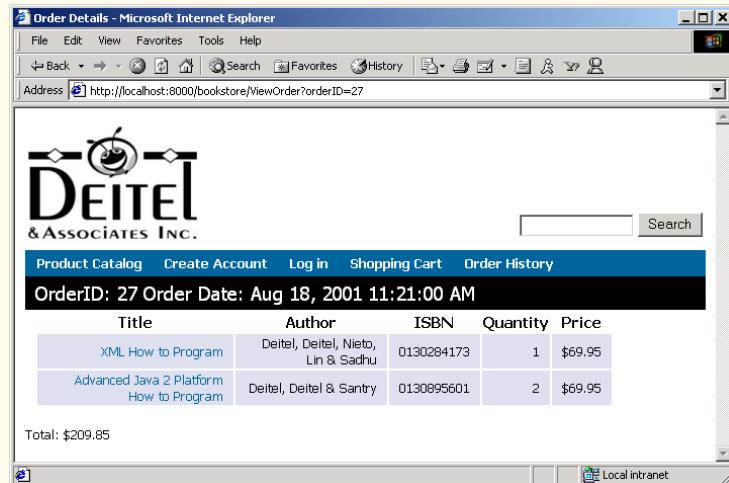


Fig. 18.13 **CheckoutServlet** for placing Orders (part 3 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
1 // GetAllProductsServlet.java
2 // GetAllProductsServlet retrieves a list of all Products
3 // available in the store and presents the list to the client.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.*;
12 import javax.servlet.http.*;
13 import javax.rmi.*;
14 import javax.naming.*;
15 import javax.ejb.*;
16
17 // third-party packages
18 import org.w3c.dom.*;
19
20 // Deitel packages
21 import com.deitel.advjhttp1.bookstore.model.*;
22 import com.deitel.advjhttp1.bookstore.ejb.*;
23
24 public class GetAllProductsServlet extends XMLServlet {
25
26     // respond to HTTP get requests
27     public void doGet( HttpServletRequest request,
28                         HttpServletResponse response )
29         throws ServletException, IOException
30     {
31         Document document = getDocumentBuilder().newDocument();
32
33         // generate Product catalog
34         try {
35             InitialContext context = new InitialContext();
36
37             // look up Product EJB
38             Object object =
39                 context.lookup( "java:comp/env/ejb/Product" );
40
41             // get ProductHome interface to find all Products
42             ProductHome productHome = ( ProductHome )
43                 PortableRemoteObject.narrow( object,
44                     ProductHome.class );
45
46             // get Iterator for Product list
47             Iterator products =
48                 productHome.findAllProducts().iterator();
49
50             // create root of XML document
51             Element rootElement =
52                 document.createElement( "catalog" );
```

Fig. 18.14 **GetAllProductsServlet** for viewing the product catalog (part 1 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
53      // append catalog Element to XML document
54      document.appendChild( rootElement );
55
56
57      // add each Product to the XML document
58      while ( products.hasNext() ) {
59          Product product = ( Product )
60              PortableRemoteObject.narrow( products.next(),
61                  Product.class );
62
63          // get ProductModel for current Product
64          ProductModel productModel =
65              product.getProductModel();
66
67          // add an XML element to document for Product
68          rootElement.appendChild(
69              productModel.getXML( document ) );
70      }
71
72  } // end try
73
74  // handle exception when looking up Product EJB
75  catch ( NamingException namingException ) {
76      namingException.printStackTrace();
77
78      String error = "The Product EJB was not found in " +
79          "the JNDI directory.";
80
81      // append error message to XML document
82      document.appendChild( buildErrorMessage(
83          document, error ) );
84  }
85
86  // handle exception when a Product cannot be found
87  catch ( FinderException finderException ) {
88      finderException.printStackTrace();
89
90      String error = "No Products found in the store.";
91
92      // append error message to XML document
93      document.appendChild( buildErrorMessage(
94          document, error ) );
95  }
96
97  // ensure content is written to client
98  finally {
99      writeXML( request, response, document );
100  }
101
102 } // end method doGet
103 }
```

Fig. 18.14 **GetAllProductsServlet** for viewing the product catalog (part 2 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

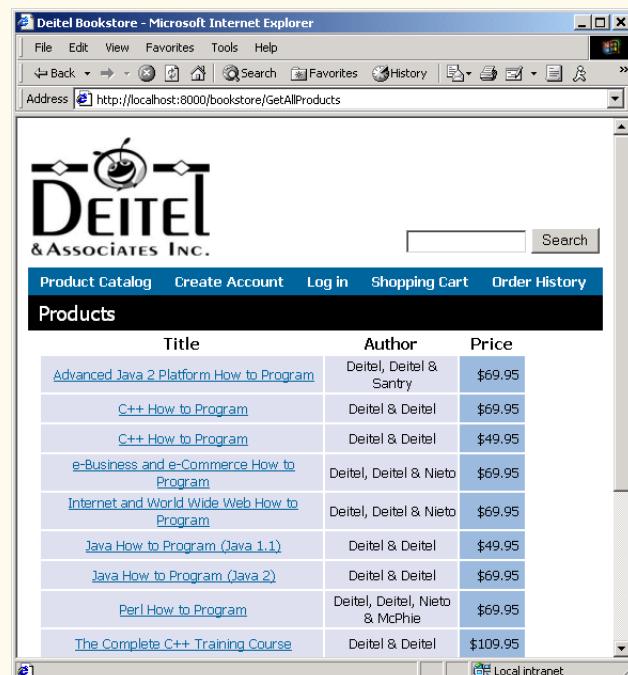


Fig. 18.14 **GetAllProductsServlet** for viewing the product catalog (part 3 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

Method `lookup` (line 39) throws a `NamingException` if the `Product` EJB cannot be found in the JNDI directory. The corresponding `catch` block (lines 75–84) produces an XML error message indicating that the JNDI lookup of the `Product` EJB failed. Method `findAllProducts` (line 48) throws a `FinderException` if no `Products` are found. Lines 87–95 `catch` this exception and build an XML error message that indicates there were no products found in the database. The `finally` block (lines 98–100) presents the content to the client using method `writeXML`.

### 18.4.2 GetProductServlet

`GetAllProductsServlet` presents a list of all `Products` in the store. To view the details of a given product, the customer invokes `GetProductServlet` (Fig. 18.15). This servlet uses the application's business logic to retrieve detailed information about a given product for the customer.

```

1 // GetProductServlet.java
2 // GetProductServlet retrieves the details of a Product and
3 // presents them to the customer.
4 package com.deitel.advjhtp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.servlet.*;
11 import javax.servlet.http.*;
12 import javax.naming.*;
13 import javax.ejb.*;
14 import javax.rmi.*;
15
16 // third-party packages
17 import org.w3c.dom.*;
18
19 // Deitel packages
20 import com.deitel.advjhtp1.bookstore.model.*;
21 import com.deitel.advjhtp1.bookstore.ejb.*;
22
23 public class GetProductServlet extends XMLServlet {
24
25     public void doGet( HttpServletRequest request,
26                         HttpServletResponse response )
27         throws ServletException, IOException
28     {
29         Document document = getDocumentBuilder().newDocument();
30
31         // get ISBN from request object
32         String isbn = request.getParameter( "ISBN" );
33
34         // generate XML document with Product details

```

Fig. 18.15 `GetProductServlet` for viewing product details (part 1 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
35     try {
36         InitialContext context = new InitialContext();
37
38         // look up Product EJB
39         Object object =
40             context.lookup( "java:comp/env/ejb/Product" );
41
42         // get ProductHome interface to find Product
43         ProductHome productHome = ( ProductHome )
44             PortableRemoteObject.narrow(
45                 object, ProductHome.class );
46
47         // find Product with given ISBN
48         Product product =
49             productHome.findByPrimaryKey( isbn );
50
51         // create XML document root Element
52         Node rootNode =
53             document.createElement( "bookstore" );
54
55         // append root Element to XML document
56         document.appendChild( rootNode );
57
58         // get Product details as a ProductModel
59         ProductModel productModel =
60             product.getProductModel();
61
62         // build an XML document with Product details
63         rootNode.appendChild(
64             productModel.getXML( document ) );
65
66     } // end try
67
68     // handle exception when looking up Product EJB
69     catch ( NamingException namingException ) {
70         namingException.printStackTrace();
71
72         String error = "The Product EJB was not found in " +
73             "the JNDI directory.";
74
75         document.appendChild( buildErrorMessage(
76             document, error ) );
77     }
78
79     // handle exception when Product is not found
80     catch ( FinderException finderException ) {
81         finderException.printStackTrace();
82
83         String error = "The Product with ISBN " + isbn +
84             " was not found in our store.";
85     }
```

Fig. 18.15 **GetProductServlet** for viewing product details (part 2 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
86         document.appendChild( buildErrorMessage(
87             document, error ) );
88     }
89
90     // ensure content is written to client
91     finally {
92         writeXML( request, response, document );
93     }
94
95 } // end method doGet
96 }
```

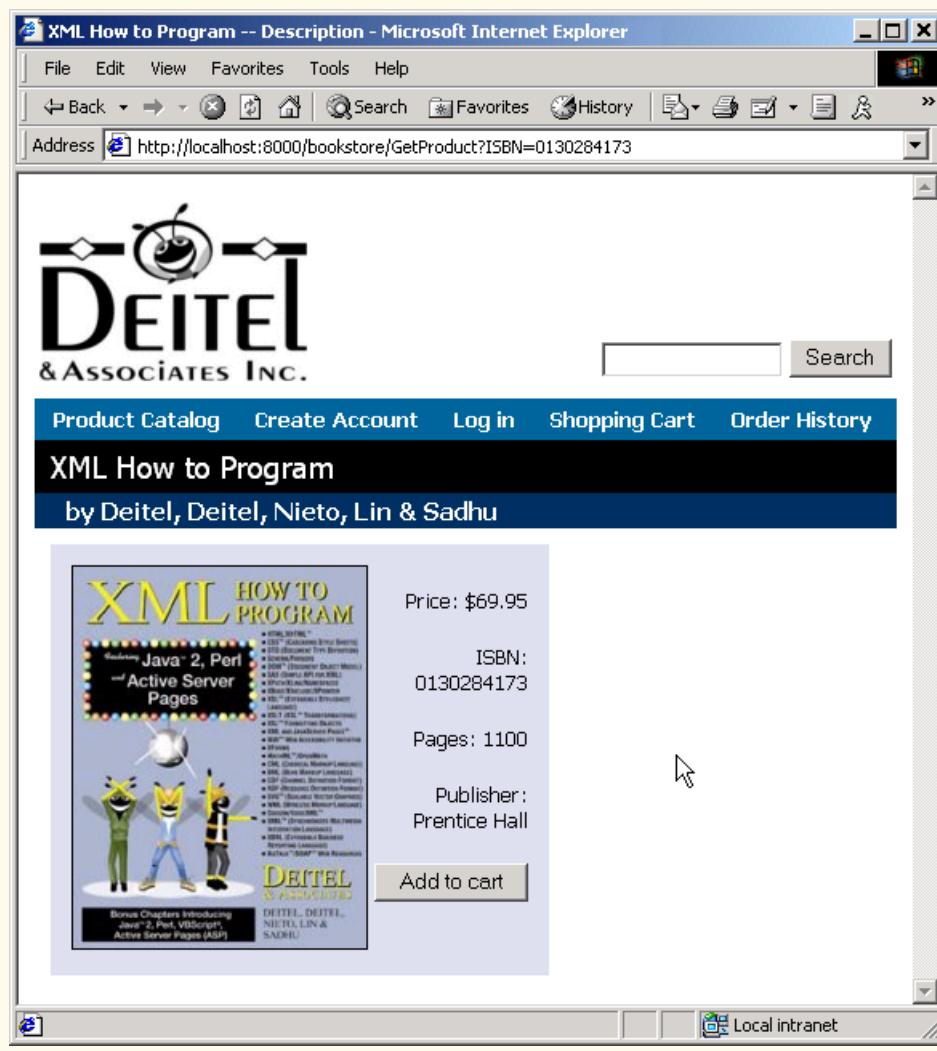


Fig. 18.15 **GetProductServlet** for viewing product details (part 3 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)



Fig. 18.15 **GetProductServlet** for viewing product details (part 4 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

The **Product** EJB provides the details of a given product as a **ProductModel**. Lines 39–45 retrieve a reference to the **ProductHome** interface. Lines 48–49 invoke **ProductHome** interface method **findByPrimaryKey** to obtain the **Product** EJB for the given **ISBN**. Lines 59–64 obtain the details of the product as a **ProductModel** and use method **getXML** to generate the XML content for the client.

Lines 69–77 **catch** a **NamingException** if the **lookup** of the **ProductHome** interface fails. Lines 80–88 **catch** a **FinderException**, which is generated by the call to **findByPrimaryKey** on line 49 if a product with the given **ISBN** is not found in the database. In each **catch** block, we create an XML error message to inform the user of the error. The **finally** block on lines 91–93 ensures that the content is presented to the client, regardless of any exceptions that may be thrown.

#### 18.4.3 ProductSearchServlet

**ProductSearchServlet** (Fig. 18.16) searches the database for products whose titles contain a particular keyword. Method **findByTitle** of the **Product** EJB's home interface takes a **String** as an argument and finds a product whose title contains the provided keyword. Because a search of this type may match many different products, method **findByTitle** returns an **Collection** of **Product** EJB remote references.

Lines 34–35 get the **searchString** parameter from the request object and place a wildcard character (%) before and after the **searchString**. The database uses this wildcard character to match titles that contain the given **searchString**. Lines 50–51 create an **Iterator** to iterate through the list of products returned by the search. Lines 58–69 add an XML representation to the XML document for each product found.

```

1 // ProductSearchServlet.java
2 // ProductSearchServlet allows a Customer to search through
3 // the store for a particular Product.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.*;
12 import javax.servlet.http.*;
13 import javax.naming.*;
14 import javax.ejb.*;
15 import javax.rmi.PortableRemoteObject;
16
17 // third-party packages
18 import org.w3c.dom.*;
19
20 // Deitel packages
21 import com.deitel.advjhttp1.bookstore.model.*;
22 import com.deitel.advjhttp1.bookstore.ejb.*;
23
24 public class ProductSearchServlet extends XMLServlet {
25
26     // respond to HTTP get requests
27     public void doGet( HttpServletRequest request,
28                         HttpServletResponse response )
29         throws ServletException, IOException
30     {
31         Document document = getDocumentBuilder().newDocument();
32
33         // get the searchString from the request object
34         String searchString = "%" +
35             request.getParameter( "searchString" ) + "%";
36
37         // find Product using Product EJB
38         try {
39             InitialContext context = new InitialContext();
40
41             // look up Product EJB
42             Object object =
43                 context.lookup( "java:comp/env/ejb/Product" );
44
45             ProductHome productHome = ( ProductHome )

```

**Fig. 18.16 ProductSearchServlet** for searching product catalog (part 1 of 3).  
 (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
46         PortableRemoteObject.narrow(
47             object, ProductHome.class );
48
49     // find Products that match searchString
50     Iterator products = productHome.findByTitle(
51         searchString ).iterator();
52
53     // create catalog document element
54     Node rootNode = document.appendChild(
55         document.createElement( "catalog" ) );
56
57     // generate list of matching products
58     while ( products.hasNext() ) {
59         Product product = ( Product )
60             PortableRemoteObject.narrow( products.next(),
61                 Product.class );
62
63         ProductModel productModel = product.getProductModel();
64
65         // append XML element to the document for the
66         // current Product
67         rootNode.appendChild(
68             productModel.getXML( document ) );
69     }
70
71 } // end try
72
73 // handle exception when looking up Product EJB
74 catch ( NamingException namingException ) {
75     namingException.printStackTrace();
76
77     String error = "The Product EJB was not found in " +
78         "the JNDI directory.";
79
80     document.appendChild( buildErrorMessage(
81         document, error ) );
82 }
83
84 // handle exception when Product is not found
85 catch ( FinderException finderException ) {
86     finderException.printStackTrace();
87
88     String error = "No Products match your search.";
89
90     document.appendChild( buildErrorMessage(
91         document, error ) );
92 }
93
94 // ensure content is written to client
95 finally {
96     writeXML( request, response, document );
97 }
```

Fig. 18.16 **ProductSearchServlet** for searching product catalog (part 2 of 3).  
(Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```

98
99 } // end method doGet
100 }

```

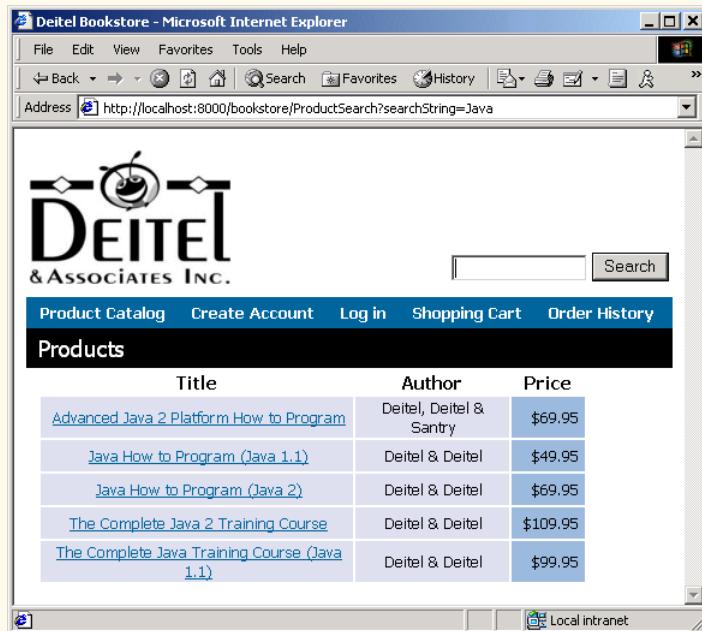


Fig. 18.16 **ProductSearchServlet** for searching product catalog (part 3 of 3).  
(Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

## 18.5 Customer Management Servlets

Online stores typically allow customers to register personal information (e.g., name, e-mail address and shipping address) with the store, for a number of purposes. Primarily, the store needs the information provided in a customer registration to bill the customer and ship products from the store. By registering, a customer will need to enter this information only once. Later, a customer can return to the store and log-in with a user name and password to retrieve previously entered billing and shipping information. Customer registrations also allow on-line stores to provide customers with personalized content and order-tracking information. Some on-line stores also can use customer registration information to help target advertisements to customers with certain preferences or within particular demographics.

**RegisterServlet** (Section 18.5.1) handles customer registrations for the Deitel Bookstore. Once a customer registers, **LoginServlet** allows the customer to log into the site with a user name and password. **ViewOrderHistoryServlet** allows customers to see information about orders they already have placed. **GetLostPasswordServlet** provides **Customers** with a hint to remind them of forgotten passwords.

### 18.5.1 RegisterServlet

**RegisterServlet** (Fig. 18.17) processes the registration forms submitted by new customers. The servlet creates a **CustomerModel** instance (line 34) and uses the parameter values received from the client to populate the model with details about the customer (lines 38–125). Once the **CustomerModel** has been populated with data, line 133 looks up the **Customer** EJB, which represents a customer in the database. Lines 141–142 create a new customer registration in the database by invoking **Customer** EJB method **create** with the newly created **CustomerModel** object as an argument. After registering the customer, lines 147–157 forward the customer to **LoginServlet** to log into the store.

```
1 // RegisterServlet.java
2 // RegisterServlet processes the Customer registration form
3 // to register a new Customer.
4 package com.deitel.advjhtp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.*;
12 import javax.servlet.http.*;
13 import javax.ejb.*;
14 import javax.naming.*;
15 import javax.rmi.*;
16
17 // third-party packages
18 import org.w3c.dom.*;
```

Fig. 18.17 **RegisterServlet** for registering new **Customers** (part 1 of 5).

```
20 // Deitel packages
21 import com.deitel.advjhttp1.bookstore.model.*;
22 import com.deitel.advjhttp1.bookstore.ejb.*;
23
24 public class RegisterServlet extends XMLServlet {
25
26     // respond to HTTP post requests
27     public void doPost( HttpServletRequest request,
28                         HttpServletResponse response )
29             throws ServletException, IOException
30     {
31         Document document = getDocumentBuilder().newDocument();
32
33         // create CustomerModel to store registration data
34         CustomerModel customerModel = new CustomerModel();
35
36         // set properties of CustomerModel using values
37         // passed through request object
38         customerModel.setUserID( request.getParameter(
39             "userID" ) );
40
41         customerModel.setPassword( request.getParameter(
42             "password" ) );
43
44         customerModel.setPasswordHint( request.getParameter(
45             "passwordHint" ) );
46
47         customerModel.setFirstName( request.getParameter(
48             "firstName" ) );
49
50         customerModel.setLastName( request.getParameter(
51             "lastName" ) );
52
53         // set credit card information
54         customerModel.setCreditCardName( request.getParameter(
55             "creditCardName" ) );
56
57         customerModel.setCreditCardNumber( request.getParameter(
58             "creditCardNumber" ) );
59
60         customerModel.setCreditCardExpirationDate(
61             request.getParameter( "creditCardExpirationDate" ) );
62
63         // create AddressModel for billing address
64         AddressModel billingAddress = new AddressModel();
65
66         billingAddress.setFirstName( request.getParameter(
67             "billingAddressFirstName" ) );
68
69         billingAddress.setLastName( request.getParameter(
70             "billingAddressLastName" ) );
71
72         billingAddress.setStreetAddressLine1(
```

Fig. 18.17 RegisterServlet for registering new **Customers** (part 2 of 5).

```
73         request.getParameter( "billingAddressStreet1" ) );
74
75     billingAddress.setStreetAddressLine2(
76         request.getParameter( "billingAddressStreet2" ) );
77
78     billingAddress.setCity( request.getParameter(
79         "billingAddressCity" ) );
80
81     billingAddress.setState( request.getParameter(
82         "billingAddressState" ) );
83
84     billingAddress.setZipCode( request.getParameter(
85         "billingAddressZipCode" ) );
86
87     billingAddress.setCountry( request.getParameter(
88         "billingAddressCountry" ) );
89
90     billingAddress.setPhoneNumber( request.getParameter(
91         "billingAddressPhoneNumber" ) );
92
93     customerModel.setBillingAddress( billingAddress );
94
95     // create AddressModel for shipping address
96     AddressModel shippingAddress = new AddressModel();
97
98     shippingAddress.setFirstName( request.getParameter(
99         "shippingAddressFirstName" ) );
100
101    shippingAddress.setLastName( request.getParameter(
102        "shippingAddressLastName" ) );
103
104    shippingAddress.setStreetAddressLine1(
105        request.getParameter( "shippingAddressStreet1" ) );
106
107    shippingAddress.setStreetAddressLine2(
108        request.getParameter( "shippingAddressStreet2" ) );
109
110    shippingAddress.setCity( request.getParameter(
111        "shippingAddressCity" ) );
112
113    shippingAddress.setState( request.getParameter(
114        "shippingAddressState" ) );
115
116    shippingAddress.setZipCode( request.getParameter(
117        "shippingAddressZipCode" ) );
118
119    shippingAddress.setCountry( request.getParameter(
120        "shippingAddressCountry" ) );
121
122    shippingAddress.setPhoneNumber( request.getParameter(
123        "shippingAddressPhoneNumber" ) );
124
125    customerModel.setShippingAddress( shippingAddress );
```

Fig. 18.17 RegisterServlet for registering new Customers (part 3 of 5).

```
126 // look up Customer EJB and create new Customer
127 try {
128     InitialContext context = new InitialContext();
129
130     // look up Customer EJB
131     Object object =
132         context.lookup( "java:comp/env/ejb/Customer" );
133
134     CustomerHome customerHome = ( CustomerHome )
135         PortableRemoteObject.narrow( object,
136             CustomerHome.class );
137
138     // create new Customer using the CustomerModel with
139     // Customer's registration information
140     Customer customer =
141         customerHome.create( customerModel );
142
143     customerModel = customer.getCustomerModel();
144
145     // get RequestDispatcher for Login servlet
146     RequestDispatcher dispatcher =
147         getServletContext().getRequestDispatcher( "/Login" );
148
149     // set userID and password for Login servlet
150     request.setAttribute( "userID",
151         customerModel.getUserID() );
152     request.setAttribute( "password",
153         customerModel.getPassword() );
154
155     // forward user to LoginServlet
156     dispatcher.forward( request, response );
157
158 } // end try
159
160 // handle exception when looking up Customer EJB
161 catch ( NamingException namingException ) {
162     namingException.printStackTrace();
163
164     String error = "The Customer EJB was not " +
165         "found in the JNDI directory.";
166
167     document.appendChild( buildErrorMessage(
168         document, error ) );
169
170     writeXML( request, response, document );
171 }
172
173 // handle exception when creating Customer
174 catch ( CreateException createException ) {
175     createException.printStackTrace();
176
177     String error = "The Customer could not be created";
178 }
```

Fig. 18.17 RegisterServlet for registering new **Customers** (part 4 of 5).

```

179         document.appendChild( buildErrorMessage(
180             document, error ) );
181
182         writeXML( request, response, document );
183     }
184 }
185
186 } // end method doPost
187 }
```

Fig. 18.17 RegisterServlet for registering new **Customers** (part 5 of 5).

Lines 162–172 **catch** a **NamingException**, which indicates that the **CustomerHome** interface could not be found in the JNDI directory. Because **RegisterServlet** creates a new **Customer**, lines 175–184 **catch** a **CreateException** in case the **Customer** EJB could not be created. Each **catch** block builds an XML error message using method **buildErrorMessage** and invokes method **writeXML** to display the error message to the customer.

### 18.5.2 LoginServlet

To log into the store, a registered customer must provide a valid **userID** and **password**, which the client submits to **LoginServlet**. **LoginServlet** (Fig. 18.18) checks the **userID** and **password** against the **userIDs** and **passwords** stored in the database.

```

1 // LoginServlet.java
2 // LoginServlet that logs an existing Customer into the site.
3 package com.deitel.advjhttp1.bookstore.servlets;
4
5 // Java core packages
6 import java.io.*;
7
8 // Java extension packages
9 import javax.servlet.*;
10 import javax.servlet.http.*;
11 import javax.naming.*;
12 import javax.ejb.*;
13 import javax.rmi.*;
14
15 // third-party packages
16 import org.w3c.dom.*;
17
18 // Deitel packages
19 import com.deitel.advjhttp1.bookstore.model.*;
20 import com.deitel.advjhttp1.bookstore.ejb.*;
21
22 public class LoginServlet extends XMLServlet {
23 }
```

Fig. 18.18 LoginServlet for authenticating registered **Customers** (part 1 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
24     // respond to HTTP post requests
25     public void doPost( HttpServletRequest request,
26                         HttpServletResponse response )
27         throws ServletException, IOException
28     {
29         Document document = getDocumentBuilder().newDocument();
30
31         String userID = request.getParameter( "userID" );
32         String password = request.getParameter( "password" );
33
34         // use Customer EJB to authenticate user
35         try {
36             InitialContext context = new InitialContext();
37
38             // look up Customer EJB
39             Object object =
40                 context.lookup( "java:comp/env/ejb/Customer" );
41
42             CustomerHome customerHome = ( CustomerHome )
43                 PortableRemoteObject.narrow( object,
44                     CustomerHome.class );
45
46             // find Customer with given userID and password
47             Customer customer =
48                 customerHome.findByLogin( userID, password );
49
50             // get CustomerModel for Customer
51             CustomerModel customerModel =
52                 customer.getCustomerModel();
53
54             // set userID in Customer's session
55             request.getSession().setAttribute( "userID",
56                 customerModel.getUserID() );
57
58             // create login XML element
59             Element login = document.createElement( "login" );
60             document.appendChild( login );
61
62             // add Customer's first name to XML document
63             Element firstName =
64                 document.createElement( "firstName" );
65
66             firstName.appendChild( document.createTextNode(
67                 customerModel.getFirstName() ) );
68
69             login.appendChild( firstName );
70
71         } // end try
72
73         // handle exception when looking up Customer EJB
74         catch ( NamingException namingException ) {
75             namingException.printStackTrace();
```

Fig. 18.18 **LoginServlet** for authenticating registered **Customers** (part 2 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
76      String error = "The Customer EJB was not found in " +
77          "the JNDI directory.";
78
79      document.appendChild( buildErrorMessage(
80          document, error ) );
81  }
82
83
84 // handle exception when Customer is not found
85 catch ( FinderException finderException ) {
86     finderException.printStackTrace();
87
88     String error = "The userID and password entered " +
89         "were not found.";
90
91     document.appendChild( buildErrorMessage(
92         document, error ) );
93  }
94
95 // ensure content is written to client
96 finally {
97     writeXML( request, response, document );
98  }
99
100 } // end method doPost
101 }
```

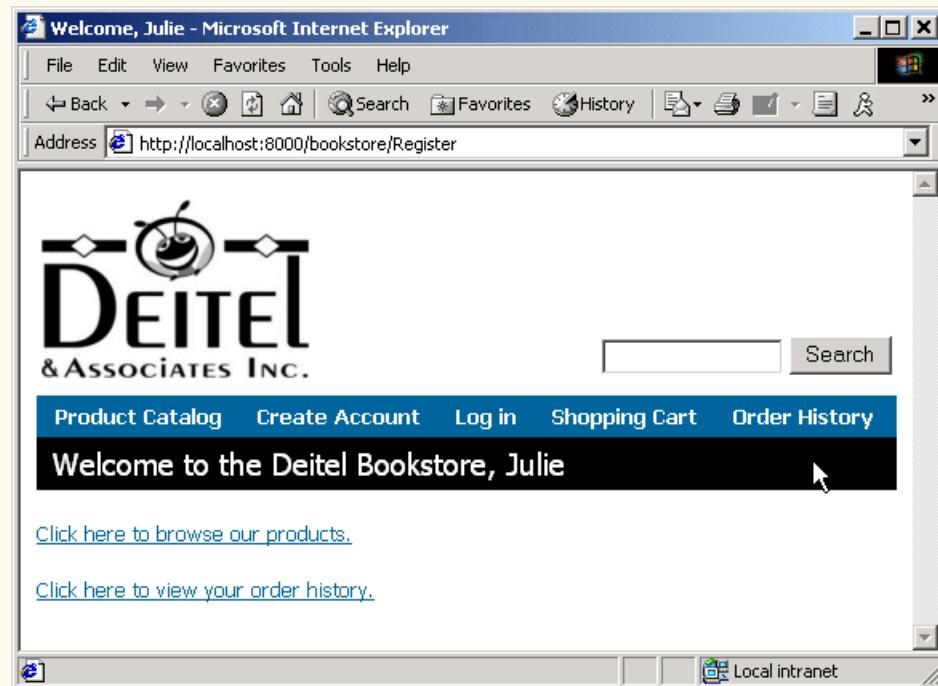


Fig. 18.18 **LoginServlet** for authenticating registered **Customers** (part 3 of 4). (Images courtesy Pixon, Inc. or © 2001 Nokia Mobile Phones.)



**Fig. 18.18 LoginServlet** for authenticating registered **Customers** (part 4 of 4). (Images courtesy Pixon, Inc. or © 2001 Nokia Mobile Phones.)

**LoginServlet** uses the **Customer** EJB to validate the **userID** and password that the customer entered. Lines 39–44 obtain a reference to the **CustomerHome** interface. Lines 47–48 invoke **CustomerHome** method **findByLogin**, which returns a remote reference to the **Customer** with the **userID** and **password** that the user provided. Once the **Customer** is found, lines 59–69 build a simple XML document that indicates the customer has successfully logged into the store.

Lines 74–82 **catch a NamingException** if the **Customer** EJB cannot be found in the JNDI directory. If no **Customer** is found that matches the **userID** and **password** the user entered, lines 85–93 **catch a FinderException**. Each **catch** block builds an XML error message for the client to display. Lines 96–98 present the content to the client.

### 18.5.3 ViewOrderHistoryServlet

Registered customers may want to see information about orders they have placed in the past. **ViewOrderHistoryServlet** (Fig. 18.19) allows customers to see orders they have placed, along with the dates the orders were taken, the total costs of the orders and whether or not the orders were shipped from the warehouse.

```
1 // ViewOrderHistoryServlet.java
2 // ViewOrderHistoryServlet presents a list of previous Orders
3 // to the Customer.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.servlet.*;
12 import javax.servlet.http.*;
13 import javax.naming.*;
14 import javax.rmi.*;
15 import javax.ejb.*;
16
17 // third-party packages
18 import org.w3c.dom.*;
19
20 // Deitel packages
21 import com.deitel.advjhttp1.bookstore.model.*;
22 import com.deitel.advjhttp1.bookstore.ejb.*;
23 import com.deitel.advjhttp1.bookstore.exceptions.*;
24
25 public class ViewOrderHistoryServlet extends XMLServlet {
26
27     // respond to HTTP get requests
28     public void doGet( HttpServletRequest request,
29                         HttpServletResponse response )
30         throws ServletException, IOException
31     {
32         Document document = getDocumentBuilder().newDocument();
33
34         HttpSession session = request.getSession();
35         String userID = ( String )
36             session.getAttribute( "userID" );
37
38         // build order history using Customer EJB
39         try {
40             InitialContext context = new InitialContext();
41
42             // look up Customer EJB
43             Object object =
44                 context.lookup( "java:comp/env/ejb/Customer" );
45
46             CustomerHome customerHome = ( CustomerHome )
47                 PortableRemoteObject.narrow(
48                 object, CustomerHome.class );
49
50             // find Customer with given userID
51             Customer customer =
```

Fig. 18.19 **ViewOrderHistoryServlet** for viewing customer's previously placed **Orders** (part 1 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
52         customerHome.findByUserID( userID );
53
54     // create orderHistory element
55     Element rootNode = ( Element ) document.appendChild(
56         document.createElement( "orderHistory" ) );
57
58     // get Customer's Order history
59     Iterator orderHistory =
60         customer.getOrderHistory().iterator();
61
62     // loop through Order history and add XML elements
63     // to XML document for each Order
64     while ( orderHistory.hasNext() ) {
65         OrderModel orderModel =
66             ( OrderModel ) orderHistory.next();
67
68         rootNode.appendChild(
69             orderModel.getXML( document ) );
70     }
71 } // end try
72
73 // handle exception when Customer has no Order history
74 catch ( NoOrderHistoryException historyException ) {
75     historyException.printStackTrace();
76
77     document.appendChild( buildErrorMessage( document,
78         historyException.getMessage() ) );
79 }
80
81 // handle exception when looking up Customer EJB
82 catch ( NamingException namingException ) {
83     namingException.printStackTrace();
84
85     String error = "The Customer EJB was not found in " +
86         "the JNDI directory.";
87
88     document.appendChild( buildErrorMessage(
89         document, error ) );
90 }
91
92 // handle exception when Customer is not found
93 catch ( FinderException finderException ) {
94     finderException.printStackTrace();
95
96     String error = "The Customer with userID " + userID +
97         " was not found.";
98
99     document.appendChild( buildErrorMessage(
100        document, error ) );
101 }
102 }
```

Fig. 18.19 **ViewOrderHistoryServlet** for viewing customer's previously placed **Orders** (part 2 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```

103     // ensure content is written to client
104     finally {
105         writeXML( request, response, document );
106     }
107 }
108 } // end method doGet
109 }

```

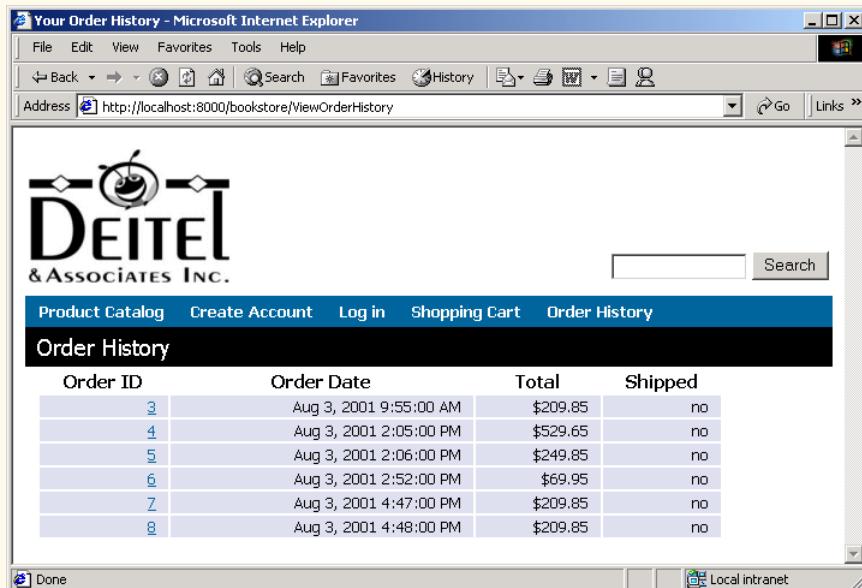
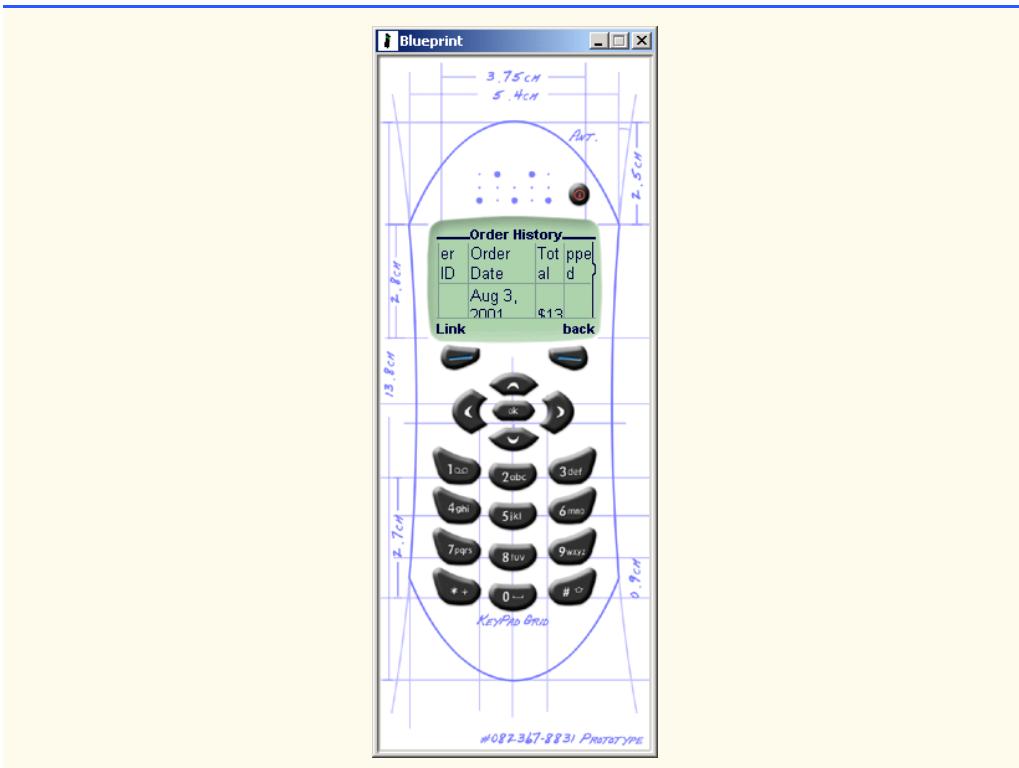


Fig. 18.19 **ViewOrderHistoryServlet** for viewing customer's previously placed **Orders** (part 3 of 4). (Images courtesy Pixon, Inc. or © 2001 Nokia Mobile Phones.)



**Fig. 18.19 ViewOrderHistoryServlet** for viewing customer's previously placed **Orders** (part 4 of 4). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

**Customer** EJB method **getOrderHistory** returns a **Collection** of the customer's previous orders. Lines 51–52 obtain the **Customer** EJB for the **Customer**, who must be logged into the bookstore. Lines 59–60 retrieve an **Iterator** for the customer's order history. Lines 64–70 loop through the order history and build the XML document to present to the client.

If the customer has not placed any orders in our on-line store, method **getOrderHistory** throws a **NoOrderHistoryException**. Lines 74–79 **catch** this exception and build an error message to display to the customer. If the **CustomerHome** interface could not be found or the **Customer** could not be found in the database, a **NamingException** or **FinderException** is thrown, respectively. Lines 82–101 **catch** each of these exceptions and construct an error message, using method **buildErrorMessage**. Line 105 presents the content to the client, using method **writeXML**.

#### 18.5.4 ViewOrderServlet

**ViewOrderServlet** (Fig. 18.20) displays the details of an order. **CheckoutServlet** forwards clients to **ViewOrderServlet** when a customer places an order. **ViewOrderHistoryServlet** forwards clients to **ViewOrderServlet** to present the details of an order that has already been placed.

Lines 39–44 obtain a reference to interface **OrderHome**. Lines 47–48 retrieve the **orderID** parameter from the **request** object. Line 51 invokes **OrderHome** method **findByPrimaryKey** to obtain a remote reference to the **Order** with the given **orderID**. Lines 54–58 get the **OrderModel** for the **Order** and append its XML representation to the XML document.

Lines 63–71 **catch** a **NamingException**, which is thrown from method **lookup** if the **Order** EJB cannot be found in the JNDI directory. Lines 74–82 **catch** a **FinderException**, which is thrown by method **findByPrimaryKey** if an **Order** with the given **orderID** is not found. Line 86 presents the XML document to the client, using method **writeXML**.

```

1 // ViewOrderServlet.java
2 // ViewOrderServlet presents the contents of a Customer's
3 // Order.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.servlet.*;
11 import javax.servlet.http.*;
12 import javax.naming.*;
13 import javax.ejb.*;
14 import javax.rmi.*;
15
16 // third-party packages
17 import org.w3c.dom.*;
18
19 // Deitel packages
20 import com.deitel.advjhttp1.bookstore.model.*;
21 import com.deitel.advjhttp1.bookstore.ejb.*;
22
23 public class ViewOrderServlet extends XMLServlet {
24
25     // respond to HTTP get requests
26     public void doGet( HttpServletRequest request,
27                         HttpServletResponse response )
28         throws ServletException, IOException
29     {
30         Document document = getDocumentBuilder().newDocument();
31         Integer orderID = null;
32
33         // look up Order EJB and get details of Order with
34         // given orderID
35         try {
36             InitialContext context = new InitialContext();
37
38             // look up Order EJB

```

Fig. 18.20 **ViewOrderServlet** for viewing details of an order (part 1 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```
39         Object object =
40             context.lookup( "java:comp/env/ejb/Order" );
41
42         OrderHome orderHome = ( OrderHome )
43             PortableRemoteObject.narrow(
44                 object, OrderHome.class );
45
46         // get orderID from request object
47         orderID = new Integer(
48             request.getParameter( "orderID" ) );
49
50         // find Order with given orderID
51         Order order = orderHome.findByPrimaryKey( orderID );
52
53         // get Order details as an OrderModel
54         OrderModel orderModel = order.getOrderModel();
55
56         // add Order details to XML document
57         document.appendChild(
58             orderModel.getXML( document ) );
59
60     } // end try
61
62     // handle exception when looking up Order EJB
63     catch ( NamingException namingException ) {
64         namingException.printStackTrace();
65
66         String error = "The Order EJB was not found in " +
67             "the JNDI directory.";
68
69         document.appendChild( buildErrorMessage(
70             document, error ) );
71     }
72
73     // handle exception when Order is not found
74     catch ( FinderException finderException ) {
75         finderException.printStackTrace();
76
77         String error = "An Order with orderID " + orderID +
78             " was not found.";
79
80         document.appendChild( buildErrorMessage(
81             document, error ) );
82     }
83
84     // ensure content is written to client
85     finally {
86         writeXML( request, response, document );
87     }
88
89 } // end method doGet
90 }
```

Fig. 18.20 **ViewOrderServlet** for viewing details of an order (part 2 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)



Fig. 18.20 **ViewOrderServlet** for viewing details of an order (part 3 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

### 18.5.5 GetPasswordHintServlet

Registered **Customers** occasionally forget their passwords. **GetPasswordHint-Servlet** (Fig. 18.21) provides hints to help **Customers** remember their passwords. The customer supplies the password hint as part of the registration process.

The hint is stored with other customer registration information in the **Customer** EJB. Lines 38–47 look up the **CustomerHome** interface and retrieve the **Customer** EJB remote reference. **Customer** EJB method **getPasswordHint** (line 55) returns the hint the user entered when registering on the site. Line 58 adds the hint to the XML document.

In this chapter, we presented the controller and presentation logic for the Deitel Bookstore. This controller logic provides an HTTP interface to the business logic objects we present in Chapters 18 and 19. Java servlets provide a robust and flexible controller logic implementation. XSLT presentation logic allows the Deitel Bookstore application to support many different client types without a need for changes in controller logic implementations. In Chapters 19 and 20, we present the business logic for the Deitel Bookstore, using Enterprise JavaBeans.

```

1 // GetPasswordHintServlet.java
2 // GetPasswordHintServlet allows a customer to retrieve a
3 // lost password.
4 package com.deitel.advjhttp1.bookstore.servlets;
5
6 // Java core packages
7 import java.io.*;
8
9 // Java extension packages
10 import javax.servlet.*;
11 import javax.servlet.http.*;
12 import javax.naming.*;
13 import javax.ejb.*;
14 import javax.rmi.*;
15
16 // third-party packages
17 import org.w3c.dom.*;
18
19 // Deitel packages
20 import com.deitel.advjhttp1.bookstore.model.*;
21 import com.deitel.advjhttp1.bookstore.ejb.*;
22
23 public class GetPasswordHintServlet extends XMLServlet {
24
25     // respond to HTTP get requests
26     public void doGet( HttpServletRequest request,
27                         HttpServletResponse response )
28         throws ServletException, IOException
29     {
30         Document document = getDocumentBuilder().newDocument();
31         String userID = request.getParameter( "userID" );
32
33         // get password hint from Customer EJB
34         try {
35             InitialContext context = new InitialContext();
36
37             // look up Customer EJB
38             Object object =

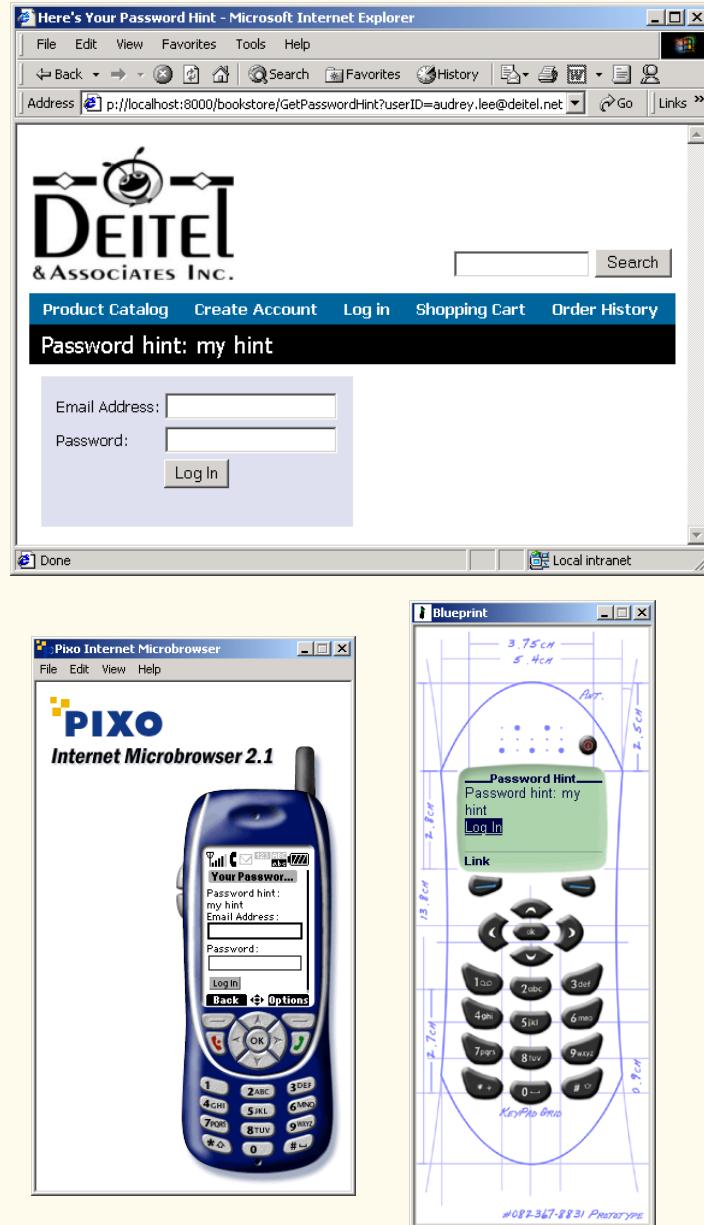
```

Fig. 18.21 **GetPasswordHintServlet** for viewing a **Customer**'s password hint (part 1 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

```

39         context.lookup( "java:comp/env/ejb/Customer" );
40
41     CustomerHome customerHome = ( CustomerHome )
42         PortableRemoteObject.narrow( object,
43             CustomerHome.class );
44
45     // find Customer with given userID
46     Customer customer =
47         customerHome.findByUserID( userID );
48
49     // create passwordHint element in XML document
50     Element hintElement =
51         document.createElement( "passwordHint" );
52
53     // add text of passwordHint to XML element
54     hintElement.appendChild( document.createTextNode(
55         customer.getPasswordHint() ) );
56
57     // append passwordHint element to XML document
58     document.appendChild( hintElement );
59
60 } // end try
61
62 // handle exception when looking up Customer EJB
63 catch ( NamingException namingException ) {
64     namingException.printStackTrace();
65
66     String error = "The Customer EJB was not found in " +
67         "the JNDI directory.";
68
69     document.appendChild( buildErrorMessage(
70         document, error ) );
71 }
72
73 // handle exception when Customer is not found
74 catch ( FinderException finderException ) {
75     finderException.printStackTrace();
76
77     String error = "No customer was found with userID " +
78         userID + ".";
79
80     document.appendChild( buildErrorMessage(
81         document, error ) );
82 }
83
84 // ensure content is written to client
85 finally {
86     writeXML( request, response, document );
87 }
88
89 } // end method doGet
90 }
```

Fig. 18.21 **GetPasswordHintServlet** for viewing a **Customer**'s password hint (part 2 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)



**Fig. 18.21** `GetPasswordHintServlet` for viewing a `Customer`'s password hint (part 3 of 3). (Images courtesy Pixo, Inc. or © 2001 Nokia Mobile Phones.)

### SELF-REVIEW EXERCISES

- 18.1** Which part of the MVC architecture do the servlets in the Deitel Bookstore implement? Which part of the MVC architecture do the XSL transformations implement?

**18.2** Write a code snippet for looking up the **ShoppingCart** EJB in the JNDI directory and creating a new instance using interface **ShoppingCartHome**. Be sure to catch any exceptions thrown when looking up the EJB or creating a new instance.

**18.3** How does **ViewOrderServlet** (Fig. 18.20) locate the **Order** that the user requested to view?

**18.4** What common functionality does class **XMLErrorServlet** (Fig. 18.1) provide for the servlets in the Deitel Bookstore? Describe the purposes of the main methods of class **XMLErrorServlet**.

**18.5** How does class **XMLErrorServlet** determine the name of the XSLT stylesheet to use when transforming content generated by the servlet? What benefit does this strategy provide?

**18.6** How does class **XMLErrorServlet** determine the particular XSLT stylesheet to use when transforming content generated by the servlet for a particular type of client? What benefit does this strategy provide?

## ANSWERS TO SELF-REVIEW EXERCISES

**18.1** The servlets implement the controller in the MVC architecture, because they handle all user requests and process user input. The XSL transformations implement the view in the MVC design pattern because they produce presentations of application data.

**18.2** The following code snippet looks up the **ShoppingCart** EJB in the JNDI directory and creates a new instance using interface **ShoppingCartHome**:

```
try {
    InitialContext context = new InitialContext;

    Object object = context.lookup(
        "java:comp/env/ejb/ShoppingCart" );

    ShoppingCartHome shoppingCartHome =
        ( ShoppingCartHome ) PortableRemoteObject.narrow(
            object, ShoppingCartHome.class );
}

ShoppingCart shoppingCart = shoppingCartHome.create();
}

catch ( NamingException namingException ) {
    namingException.printStackTrace();
}

catch ( CreateException createException ) {
    createException.printStackTrace();
}
```

**18.3** **ViewOrderServlet** uses **OrderHome** method **findByIdPrimaryKey** to locate the **Order**, with the **orderID** passed as a parameter to the **HttpServletRequest** object.

**18.4** Class **XMLErrorServlet** provides a common **init** method for initializing the **DocumentBuilderFactory**, **TransformerFactory** and properties each servlet uses. Class **XMLErrorServlet** provides method **buildErrorMessage**, which creates an XML element to describe an error message. Class **XMLErrorServlet** also provides method **writeXML**, which uses method **transform** to transform the XML content generated by each servlet using client-specific XSL transformations.

**18.5** Class **XMLServlet** has property **XSLFileName** that specifies the name of the XSL file to use when transforming the servlet's content. Class **XMLServlet**'s **init** method sets the **XSL-FileName** property to the value specified in the **XSL\_FILE** servlet initialization parameter. Determining the file name from an initialization parameter enables the deployer to specify the file name when deploying the application. The file name can be changed later without the need to recompile the servlet.

**18.6** Class **XMLServlet** uses a **ClientModel** to determine which directory contains the XSL transformation for XML content generated by the servlet. Class **XMLServlet** creates a list of **ClientModels** from an XML configuration file when the servlet is first initialized. Each **ClientModel** specifies a **User-Agent** header that uniquely identifies the client, the **Content-Type** for sending data to the client and the directory in which the XSL transformations can be found for generating content specific to the client. This enables the developer to add support for new client types without modifying any servlet code. The developer simply provides a set of XSL transformations for the new client type and includes information about the new client type in **clients.xml**.

---

# Enterprise Java Case Study: Business Logic

## Part 1

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### Objectives

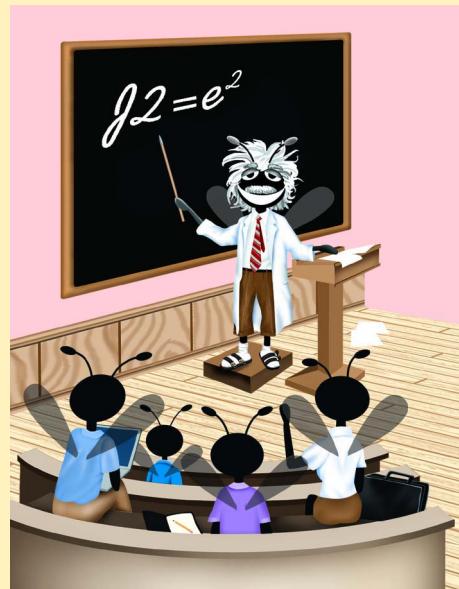
- To understand the EJB data model for the Deitel Bookstore case study.
- To understand the business logic used in the Deitel Bookstore case study.
- To understand performance issues involved in transmitting objects over RMI-IIOP.
- To understand the benefits of EJBs that use container-managed persistence for database storage.
- To understand the usage of primary-key classes that represent complex primary keys.

*Drive thy business, or it will drive thee.*

Benjamin Franklin

*Everybody's business is nobody's business, and nobody's business is my business.*

Clara Barton



## Outline

- 19.1 Introduction
- 19.2 EJB Architecture
- 19.3 ShoppingCart Implementation
  - 19.3.1 ShoppingCart Remote Interface
  - 19.3.2 ShoppingCartEJB Implementation
  - 19.3.3 ShoppingCartHome Interface
- 19.4 Product Implementation
  - 19.4.1 Product Remote Interface
  - 19.4.2 ProductEJB Implementation
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- 19.5 Order Implementation
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- 19.6 OrderProduct Implementation
  - 19.6.1 OrderProduct Remote Interface
  - 19.6.2 OrderProductEJB Implementation
  - 19.6.3 OrderProductHome Interface
  - 19.6.4 OrderProductPK Primary-Key Class
  - 19.6.5 OrderProductModel

## 19.1 Introduction

In this chapter, we present the EJB business logic for the shopping-cart e-commerce model, and entity EJBs that provide an object-based interface to the store's product catalog. After reading this chapter, you will understand the use of EJBs in an e-commerce application context, as well as more advanced EJB topics, such as custom primary-key classes and many-to-many relationships.

## 19.2 EJB Architecture

EJBs implement the business logic of the Deitel Bookstore case study. Servlet controller logic communicates with EJB business logic to process user requests and retrieve data from the database. For example, **GetProductServlet** handles **Customer** requests to view **Product** details. **GetProductServlet** uses the JNDI directory to locate the **Product** EJB's home interface. **GetProductServlet** invokes **ProductHome** method **findByIdPrimarykey** to retrieve a remote reference to the **Product** with the requested

**ISBN.GetProductServlet** must then use methods in the **Product** remote interface to retrieve information about the **Product**. Each method call on the **Product** remote interface incurs network traffic, because communication with the EJB is performed over RMI-IIOP (discussed in Chapter 27). If separate method calls were required to retrieve the **Product's title, author, price** and other properties, the network overhead would severely limit the performance and scalability of the application.

The entity EJBs in the Deitel Bookstore case study alleviate this network congestion by using *models* to transmit EJB data. A model is a **Serializable** class that contains all the data for a given EJB. These classes are called models because each model class implements a piece of the model in the MVC architecture. Each entity EJB provides a *get* method that returns its model representation. For example, the **Product** EJB has method **getProductModel**, which returns a **ProductModel** containing the **ISBN, author, price** and other properties of a **Product**. Many of the entity EJBs also provide *create* methods that accept models as arguments. These *create* methods create new EJB instances and set the data in the EJB, using property values provided in the model.



### Performance Tip 19.1

Aggregating entity EJB data into a model class and returning instances of this model class from EJB business methods can improve EJB performance by reducing the network traffic associated with multiple method calls over RMI-IIOP.

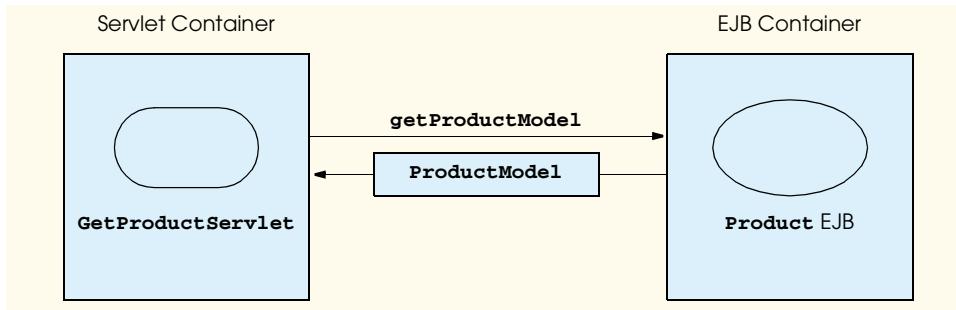
Figure 19.1 shows a sample communication between servlet **GetProductServlet** and the **Product** EJB. To get the details of a given **Product**, **GetProductServlet** invokes **Product** method **getProductModel**. Method **getProductModel** returns a **ProductModel** object containing data for a given **Product** and serializes the **ProductModel** over RMI-IIOP. **GetProductServlet** retrieves the **ProductModel**'s property values to build the output for the user.

## 19.3 ShoppingCart Implementation

Stateful session EJB **ShoppingCart** implements business logic for managing each Customer's shopping cart. The **ShoppingCart** EJB consists of a remote interface, an EJB implementation and a home interface. We implement **ShoppingCart** as a stateful session EJB so each **ShoppingCart** instance will persist throughout a customer's shopping session. Just as customers of brick-and-mortar stores use shopping carts to gather products, customers of our on-line store use **ShoppingCart** EJBs to gather products while they browse through our store.

### 19.3.1 ShoppingCart Remote Interface

Remote interface **ShoppingCart** (Fig. 19.2) defines business logic methods available in the **ShoppingCart** EJB. Each remote interface method must declare that it **throws** **RemoteException**. Each method also must declare any application-specific exceptions that may be thrown from the implementation. Method **getContents** (line 20) returns an **Collection** of **Products** in the **ShoppingCart**. Method **addProduct** (lines 23–24) takes as a **String** argument the **ISBN** of a **Product** to add to the **ShoppingCart**. Method **addProduct** throws **ProductNotFoundException**, which is an application-specific exception that indicates the **Product** with the given **ISBN** is not in the database and therefore could not be added to the **ShoppingCart**.



**Fig. 19.1** Communication between **GetProductServlet** and **Product EJB**.

Method **removeProduct** (lines 27–28) removes the **Product** with the given **ISBN** from the **ShoppingCart**. If the **Product** with the given **ISBN** is not found in the **ShoppingCart**, method **removeProduct** throws a **ProductNotFoundException**.

Method **setProductQuantity** (lines 32–34) updates the quantity of the **Product** with the given **ISBN** in the **ShoppingCart**. For example, if there were one copy of *Advanced Java 2 Platform How to Program* in the **Customer's ShoppingCart**, **setProductQuantity** could be called with the **ISBN** of *Advanced Java How to Program* and the integer **5** to purchase five copies of the book. If the **Product** with the given **ISBN** is not in the **ShoppingCart**, method **setProductQuantity** throws the application-specific **ProductNotFoundException**.

Method **checkout** (lines 37–38) places an **Order** for the **Products** in the **Customer's ShoppingCart**. Method **checkout** takes as a **String** argument the **userID** of the customer placing the **Order**. Only registered customers may place **Orders**. Method **getTotal** (line 41) returns the total cost of the **Products** in the **Customer's ShoppingCart**.

```

1 // ShoppingCart.java
2 // ShoppingCart is the remote interface for stateful session
3 // EJB ShoppingCart.
4 package com.deitel.advjhttp1.bookstore.ejb;
5
6 // Java core packages
7 import java.rmi.RemoteException;
8 import java.util.ArrayList;
9
10 // Java extension packages
11 import javax.ejb.EJBObject;
12
13 // Deitel packages
14 import com.deitel.advjhttp1.bookstore.model.*;
15 import com.deitel.advjhttp1.bookstore.exceptions.*;

```

**Fig. 19.2** **ShoppingCart** remote interface for adding, removing and updating **Products**, checking out and calculating the **Order's** total cost (part 1 of 2).

```
16 public interface ShoppingCart extends EJBObject {  
17     // get contents of ShoppingCart  
18     public Collection getContents() throws RemoteException;  
19     // add Product with given ISBN to ShoppingCart  
20     public void addProduct( String isbn )  
21         throws RemoteException, ProductNotFoundException;  
22     // remove Product with given ISBN from ShoppingCart  
23     public void removeProduct( String isbn )  
24         throws RemoteException, ProductNotFoundException;  
25     // change quantity of Product in ShoppingCart with  
26     // given ISBN to given quantity  
27     public void setProductQuantity( String isbn, int quantity )  
28         throws RemoteException, ProductNotFoundException,  
29             IllegalArgumentException;  
30     // checkout ShoppingCart (i.e., create new Order)  
31     public Order checkout( String userID )  
32         throws RemoteException, ProductNotFoundException;  
33     // get total cost for Products in ShoppingCart  
34     public double getTotal() throws RemoteException;  
35 }  
36 }
```

Fig. 19.2 **ShoppingCart** remote interface for adding, removing and updating **Products**, checking out and calculating the **Order**'s total cost (part 2 of 2).

### 19.3.2 ShoppingCartEJB Implementation

**ShoppingCart** remote interface implementation **ShoppingCartEJB** (Fig. 19.3) contains an **Collection** of **OrderProductModels** (line 24). An **OrderProductModel** (Fig. 19.25) represents an item in the **ShoppingCart**. Each **OrderProductModel** contains a **Product** and that **Product**'s quantity in the **ShoppingCart**. Method **ejbCreate** (lines 27–30) initializes the **Collection** (line 29). Method **getContents** (line 33–36) returns the contents of the **ShoppingCart** as a **Collection** of **OrderProductModels**.

```
1 // ShoppingCartEJB.java  
2 // Stateful session EJB ShoppingCart represents a Customer's  
3 // shopping cart.  
4 package com.deitel.advjhtp1.bookstore.ejb;  
5  
6 // Java core packages  
7 import java.util.*;  
8 import java.rmi.RemoteException;
```

Fig. 19.3 **ShoppingCartEJB** implementation of **ShoppingCart** remote interface (part 1 of 7).

```
9 import java.text.DateFormat;
10 // Java extension packages
11 import javax.ejb.*;
12 import javax.naming.*;
13 import javax.rmi.PortableRemoteObject;
14
15 // Deitel packages
16 import com.deitel.advjhttp1.bookstore.model.*;
17 import com.deitel.advjhttp1.bookstore.exceptions.*;
18
19 public class ShoppingCartEJB implements SessionBean {
20     private SessionContext sessionContext;
21
22     // OrderProductModels (Products & quantities) in ShoppingCart
23     private Collection orderProductModels;
24
25     // create new ShoppingCart
26     public void ejbCreate()
27     {
28         orderProductModels = new ArrayList();
29     }
30
31     // get contents of ShoppingCart
32     public Collection getContents()
33     {
34         return orderProductModels;
35     }
36
37     // add Product with given ISBN to ShoppingCart
38     public void addProduct( String isbn )
39         throws ProductNotFoundException, EJBException
40     {
41         // check if Product with given ISBN is already
42         // in ShoppingCart
43         Iterator iterator = orderProductModels.iterator();
44
45         while ( iterator.hasNext() ) {
46             OrderProductModel orderProductModel =
47                 ( OrderProductModel ) iterator.next();
48
49             ProductModel productModel =
50                 orderProductModel.getProductModel();
51
52             // if Product is in ShoppingCart, increment quantity
53             if ( productModel.getISBN().equals( isbn ) ) {
54
55                 orderProductModel.setQuantity(
56                     orderProductModel.getQuantity() + 1 );
57
58             }
59         }
60     }
```

Fig. 19.3 ShoppingCartEJB implementation of ShoppingCart remote interface (part 2 of 7).

```
61      } // end while
62
63
64      // if Product is not in ShoppingCart, find Product with
65      // given ISBN and add OrderProductModel to ShoppingCart
66      try {
67          InitialContext context = new InitialContext();
68
69          Object object = context.lookup(
70              "java:comp/env/ejb/Product" );
71
72          ProductHome productHome = ( ProductHome )
73              PortableRemoteObject.narrow( object,
74                  ProductHome.class );
75
76          // find Product with given ISBN
77          Product product = productHome.findByPrimaryKey( isbn );
78
79          // get ProductModel
80          ProductModel productModel = product.getProductModel();
81
82          // create OrderProductModel for ProductModel and set
83          // its quantity
84          OrderProductModel orderProductModel =
85              new OrderProductModel();
86
87          orderProductModel.setProductModel( productModel );
88          orderProductModel.setQuantity( 1 );
89
90          // add OrderProductModel to ShoppingCart
91          orderProductModels.add( orderProductModel );
92
93      } // end try
94
95      // handle exception when finding Product record
96      catch ( FinderException finderException ) {
97          finderException.printStackTrace();
98
99          throw new ProductNotFoundException( "The Product " +
100              "with ISBN " + isbn + " was not found." );
101      }
102
103     // handle exception when invoking Product EJB methods
104     catch ( Exception exception ) {
105         throw new EJBException( exception );
106     }
107
108 } // end method addProduct
109
110 // remove Product with given ISBN from ShoppingCart
111 public void removeProduct( String isbn )
112     throws ProductNotFoundException
```

Fig. 19.3 ShoppingCartEJB implementation of ShoppingCart remote interface (part 3 of 7).

```
113     {
114         Iterator iterator = orderProductModels.iterator();
115
116         while ( iterator.hasNext() ) {
117
118             // get next OrderProduct in ShoppingCart
119             OrderProductModel orderProductModel =
120                 ( OrderProductModel ) iterator.next();
121
122             ProductModel productModel =
123                 orderProductModel.getProductModel();
124
125             // remove Product with given ISBN from ShoppingCart
126             if ( productModel.getISBN().equals( isbn ) ) {
127                 orderProductModels.remove( orderProductModel );
128
129                 return;
130             }
131
132         } // end while
133
134         // throw exception if Product not found in ShoppingCart
135         throw new ProductNotFoundException( "The Product " +
136             "with ISBN " + isbn + " was not found in your " +
137             "ShoppingCart." );
138
139     } // end method removeProduct
140
141     // set quantity of Product in ShoppingCart
142     public void setProductQuantity( String isbn,
143         int productQuantity ) throws ProductNotFoundException
144     {
145         // throw IllegalArgumentException if uantity not valid
146         if ( productQuantity < 0 )
147             throw new IllegalArgumentException(
148                 "Quantity cannot be less than zero." );
149
150         // remove Product if productQuantity less than 1
151         if ( productQuantity == 0 ) {
152             removeProduct( isbn );
153             return;
154         }
155
156         Iterator iterator = orderProductModels.iterator();
157
158         while ( iterator.hasNext() ) {
159
160             // get next OrderProduct in ShoppingCart
161             OrderProductModel orderProductModel =
162                 ( OrderProductModel ) iterator.next();
163
164             ProductModel productModel =
```

Fig. 19.3 ShoppingCartEJB implementation of ShoppingCart remote interface (part 4 of 7).

```
165         orderProductModel.getProductModel();
166
167         // set quantity for Product with given ISBN
168         if ( productModel.getISBN().equals( isbn ) ) {
169             orderProductModel.setQuantity( productQuantity );
170             return;
171         }
172     } // end while
173
174     // throw exception if Product not found in ShoppingCart
175     throw new ProductNotFoundException( "The Product " +
176         "with ISBN " + isbn + " was not found in your " +
177         "ShoppingCart." );
178
179 } // end method setProductQuantity
180
181 // checkout of store (i.e., create new Order)
182 public Order checkout( String userID )
183     throws ProductNotFoundException, EJBException
184 {
185     // throw exception if ShoppingCart is empty
186     if ( orderProductModels.isEmpty() )
187         throw new ProductNotFoundException( "There were " +
188             "no Products found in your ShoppingCart." );
189
190     // create OrderModel for Order details
191     OrderModel orderModel = new OrderModel();
192
193     // set OrderModel's date to today's Date
194     orderModel.setOrderDate( new Date() );
195
196     // set list of OrderProduct in OrderModel
197     orderModel.setOrderProductModels( orderProductModels );
198
199     // set OrderModel's shipped flag to false
200     orderModel.setShipped( false );
201
202     // use OrderHome interface to create new Order
203     try {
204         InitialContext context = new InitialContext();
205
206         // look up Order EJB
207         Object object = context.lookup(
208             "java:comp/env/ejb/Order" );
209
210         OrderHome orderHome = ( OrderHome )
211             PortableRemoteObject.narrow( object,
212                 OrderHome.class );
213
214         // create new Order using OrderModel and
215         // Customer's userID
```

Fig. 19.3 **ShoppingCartEJB** implementation of **ShoppingCart** remote interface (part 5 of 7).

```
217     Order order = orderHome.create( orderModel, userID );
218
219     // empty ShoppingCart for further shopping
220     orderProductModels = new ArrayList();
221
222     // return Order EJB that was created
223     return order;
224
225 } // end try
226
227 // handle exception when looking up Order EJB
228 catch ( Exception exception ) {
229     throw new EJBException( exception );
230 }
231
232 } // end method checkout
233
234 // get total cost for Products in ShoppingCart
235 public double getTotal()
236 {
237     double total = 0.0;
238     Iterator iterator = orderProductModels.iterator();
239
240     // calculate Order's total cost
241     while ( iterator.hasNext() ) {
242
243         // get next OrderProduct in ShoppingCart
244         OrderProductModel orderProductModel =
245             ( OrderProductModel ) iterator.next();
246
247         ProductModel productModel =
248             orderProductModel.getProductModel();
249
250         // add OrderProduct extended price to total
251         total += ( productModel.getPrice() *
252             orderProductModel.getQuantity() );
253     }
254
255     return total;
256 }
257 } // end method getTotal
258
259 // set SessionContext
260 public void setSessionContext( SessionContext context )
261 {
262     sessionContext = context;
263 }
264
265 // activate ShoppingCart EJB instance
266 public void ejbActivate() {}
267
```

Fig. 19.3 **ShoppingCartEJB** implementation of **ShoppingCart** remote interface (part 6 of 7).

```
268     // passivate ShoppingCart EJB instance
269     public void ejbPassivate() {}
270
271     // remove ShoppingCart EJB instance
272     public void ejbRemove() {}
273 }
```

Fig. 19.3 ShoppingCartEJB implementation of ShoppingCart remote interface (part 7 of 7).

Method **addProduct** (lines 39–108) adds a **Product** to the **ShoppingCart**. Lines 46–62 determine if the **ShoppingCart** already contains the given **Product**. If the **Product** is found in the **ShoppingCart**, lines 56–57 increment the associated **OrderProductModel**'s **quantity**. Otherwise, method **findByPrimaryKey** of interface **ProductHome** locates the **Product** with the given **ISBN** (line 77). Lines 84–85 create an **OrderProductModel** to store the **Product** in the **ShoppingCart**. Line 87 adds the **ProductModel** to the **OrderProductModel**, and line 88 sets the **OrderProductModel**'s **quantity** to 1. Line 91 adds the **OrderProductModel** to the **Collection**, which completes the addition of the **Product** to the **ShoppingCart**.

If method **findByPrimaryKey** of interface **ProductHome** does not find the **Product** with the given primary key, lines 96–101 catch a **FinderException**. Lines 99–100 throw a **ProductNotFoundException** to indicate that a **Product** with the given **ISBN** could not be found.

Method **removeProduct** (lines 111–139) compares the **ISBN** of each **Product** in the **ShoppingCart**'s **OrderProductModel Collection** with the **ISBN** of the **Product** to be removed. If the **Product** with the given **ISBN** is found, line 127 removes the associated **OrderProductModel** from the **Collection**. If the **Product** is not found in the **ShoppingCart**, lines 135–137 throw a **ProductNotFoundException**.

Method **setProductQuantity** (lines 142–180) sets the **quantity** of an **OrderProductModel** in the **ShoppingCart**. If argument **productQuantity** is less than 0, lines 147–148 throw an **IllegalArgumentException**. If the **productQuantity** equals 0, line 152 removes the **Product** from the **ShoppingCart**. Lines 158–173 compare the **ISBN** of each **Product** in the **OrderProductModel Collection** with the given **ISBN**. Line 169 updates the matching **OrderProductModel**'s **quantity** by invoking **OrderProductModel** method **setQuantity**. If the **Product** with the given **ISBN** is not found in the **ShoppingCart**, lines 176–178 throw a **ProductNotFoundException**.

Method **checkout** (lines 183–232) places an **Order** for the **Products** in the **ShoppingCart**. Each **Order** must have an associated **Customer**, so method **checkout** takes the **Customer**'s **userID** as an argument. Lines 192–201 create an **OrderModel** to represent the **Order**'s details. Each **Order** has an **orderDate**, a **shipped** flag and a **Collection** of **OrderProductModels**. Line 195 sets the date in the **OrderModel**. Line 198 invokes method **setOrderProductModels** of class **OrderModel** to add the **OrderProductModels** list to the **Order**. Line 201 sets the **shipped** flag to **false**, to indicate that the **Order** has not shipped from the warehouse. We discuss entity EJB **Order** in detail in Section 19.5.

Line 217 invokes method **create** of interface **OrderHome** to create a new **Order**. Method **create** takes as arguments an **OrderModel** containing the details of the **Order** to be created and a **String** containing the **Customer's userID**. Line 220 empties the **ShoppingCart** by creating assigning a new **ArrayList** to **Collection** reference **orderProductModels**. Line 223 returns a remote reference to the newly created **Order**. Lines 228–230 catch any exceptions that occur.

Method **getTotal** (lines 235–257) iterates through the **Collection** of **OrderProductModels** and calculates the total cost of items in the **ShoppingCart**.

### 19.3.3 ShoppingCartHome Interface

Interface **ShoppingCartHome** (Fig. 19.4) defines a single **create** method (lines 15–16) that creates new **ShoppingCart** EJB instances. The EJB container provides the implementation for method **create**.

Figure 19.5 and Figure 19.6 show the deployment settings for stateful session EJB **ShoppingCart**. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods.

```

1 // ShoppingCartHome.java
2 // ShoppingCartHome is the home interface for stateful session
3 // EJB ShoppingCart.
4 package com.deitel.advjhtp1.bookstore.ejb;
5
6 // Java core packages
7 import java.rmi.RemoteException;
8
9 // Java extension packages
10 import javax.ejb.*;
11
12 public interface ShoppingCartHome extends EJBHome {
13
14     // create new ShoppingCart EJB
15     public ShoppingCart create()
16         throws RemoteException, CreateException;
17 }
```

Fig. 19.4 **ShoppingCartHome** interface for creating **ShoppingCart** EJB instances.

#### ShoppingCart General Deployment Settings

<b>Bean Type</b>	<b>Stateful Session</b>
<b>Enterprise Bean Class</b>	<b>com.deitel.advjhtp1.bookstore.ejb.ShoppingCartEJB</b>
<b>Bean Class</b>	

Fig. 19.5 **ShoppingCart** general deployment settings (part 1 of 2).

**ShoppingCart General Deployment Settings**

Home Interface	com.deitel.advjhttp1.bookstore.ejb.ShoppingCartHome
Remote Interface	com.deitel.advjhttp1.bookstore.ejb.ShoppingCart

Fig. 19.5 ShoppingCart general deployment settings (part 2 of 2).

**ShoppingCart EJB References**

Coded Name	ejb/Product
Type	Entity
Home	com.deitel.advjhttp1.bookstore.ejb.ProductHome
Remote	com.deitel.advjhttp1.bookstore.ejb.Product
JNDI Name	Product
Coded Name	ejb/Order
Type	Entity
Home	com.deitel.advjhttp1.bookstore.ejb.OrderHome
Remote	com.deitel.advjhttp1.bookstore.ejb.Order
JNDI Name	Order

Fig. 19.6 ShoppingCart EJB references.

## 19.4 Product Implementation

Entity EJB **Product** uses container-managed persistence to represent a **Product** in the Deitel Bookstore. The EJB container implements methods that select, insert, update and delete database data. The deployer must provide information about how the database table should be created and the SQL queries to be used for the **create**, **remove** and **finder** methods at deployment time.

### 19.4.1 Product Remote Interface

Remote interface **Product** (Fig. 19.7) declares method **getProductModel** (line 17–18), which returns a **ProductModel** that contains the **Product**'s details.

```
1 // Product.java
2 // Product is the remote interface for entity EJB Product.
3 package com.deitel.advjhttp1.bookstore.ejb;
```

Fig. 19.7 Product remote interface for modifying details of Product EJB instances (part 1 of 2).

```
4 // Java core packages
5 import java.rmi.RemoteException;
6
7 // Java extension packages
8 import javax.ejb.*;
9
10 // Deitel packages
11 import com.deitel.advjhttp1.bookstore.model.*;
12
13 public interface Product extends EJBObject {
14
15     // get Product details as ProductModel
16     public ProductModel getProductModel()
17         throws RemoteException;
18 }
19 }
```

Fig. 19.7 **Product** remote interface for modifying details of **Product** EJB instances (part 2 of 2).

#### 19.4.2 ProductEJB Implementation

**Product** remote interface implementation **ProductEJB** (Fig. 19.8) uses container-managed persistence. The EJB container manages the synchronization of the **public** data members declared on lines 18–24 with the database. Method **getProductModel** (lines 27–43) creates a **ProductModel** that contains the **Product**'s details. Line 30 creates the **ProductModel** instance, and lines 33–39 invoke *set* methods to initialize the **ProductModel**'s data members.

```
1 // ProductEJB.java
2 // Entity EJB Product represents a Product, including the
3 // ISBN, publisher, author, title, price number of pages
4 // and cover image.
5 package com.deitel.advjhttp1.bookstore.ejb;
6
7 // Java extension packages
8 import javax.ejb.*;
9
10 // Deitel packages
11 import com.deitel.advjhttp1.bookstore.model.*;
12 import com.deitel.advjhttp1.bookstore.*;
13
14 public class ProductEJB implements EntityBean {
15     private EntityContext entityContext;
16
17     // container-managed fields
18     public String ISBN;
19     public String publisher;
20     public String author;
21     public String title;
22     public double price;
```

Fig. 19.8 **ProductEJB** implementation of **Product** remote interface (part 1 of 3).

```
23     public int pages;
24     public String image;
25
26     // get Product details as ProductModel
27     public ProductModel getProductModel()
28     {
29         // construct new ProductModel
30         ProductModel productModel = new ProductModel();
31
32         // initialize ProductModel with data from Product
33         productModel.setISBN( ISBN );
34         productModel.setPublisher( publisher );
35         productModel.setAuthor( author );
36         productModel.setTitle( title );
37         productModel.setPrice( price );
38         productModel.setPages( pages );
39         productModel.setImage( image );
40
41         return productModel;
42     }
43
44     // set Product details using ProductModel
45     private void setProductModel( ProductModel productModel )
46     {
47
48         // populate Product's data members with data in
49         // provided ProductModel
50         ISBN = productModel.getISBN();
51         publisher = productModel.getPublisher();
52         author = productModel.getAuthor();
53         title = productModel.getTitle();
54         price = productModel.getPrice();
55         pages = productModel.getPages();
56         image = productModel.getImage();
57
58     } // end method setProductModel
59
60     // create instance of Product EJB using given ProductModel
61     public String ejbCreate( ProductModel productModel )
62     {
63         setProductModel( productModel );
64         return null;
65     }
66
67     // perform any necessary post-creation tasks
68     public void ejbPostCreate( ProductModel productmodel ) {}
69
70     // set EntityContext
71     public void setEntityContext( EntityContext context )
72     {
73         entityContext = context;
74     }
75
```

Fig. 19.8 **ProductEJB** implementation of **Product** remote interface (part 2 of 3).

```

76     // unset EntityContext
77     public void unsetEntityContext()
78     {
79         entityContext = null;
80     }
81
82     // activate Product EJB instance
83     public void ejbActivate()
84     {
85         ISBN = ( String ) entityContext.getPrimaryKey();
86     }
87
88     // passivate Product EJB instance
89     public void ejbPassivate()
90     {
91         ISBN = null;
92     }
93
94     // remove Product EJB instance
95     public void ejbRemove() {}
96
97     // store Product EJB data in database
98     public void ejbStore() {}
99
100    // load Product EJB data from database
101    public void ejbLoad() {}
102 }
```

Fig. 19.8 **ProductEJB** implementation of **Product** remote interface (part 3 of 3).

Method **setProductModel** (lines 46–58) sets the **Product**'s details, using values in the given **ProductModel**. Line 50 sets the value of the **ISBN** data member to the value of the **ISBN** contained in the **ProductModel** argument. Lines 51–56 set the values of the other **ProductEJB** data members. Method **ejbCreate** (lines 61–65) accepts a **ProductModel** argument. Method **ejbCreate** invokes method **setProductModel** with the provided **ProductModel** to initialize the **Product** EJB instance (line 63).

### 19.4.3 **ProductHome** Interface

Interface **ProductHome** (Fig. 19.9) creates new **ProductEJB** instances and declares *finder* methods for finding existing **Products**. Method **create** (lines 18–19) corresponds to method **ejbCreate** of Fig. 19.8, and provides an interface for creating a **ProductEJB** instance. Method **findByPrimaryKey** (lines 22–23) takes as a **String** argument the ISBN for a particular **Product** in the database. Method **findAllProducts** (lines 26–27) returns a **Collection** of all **Products** in the database. Method **findByTitle** (lines 30–31) searches for **Products** whose titles contain the given **searchString** and returns a **Collection** of **Product** remote references. The EJB container implements each *finder* method, using SQL queries the deployer must provide at deployment time.

```
1 // ProductHome.java
2 // ProductHome is the home interface for entity EJB Product.
3 package com.deitel.advjhtp1.bookstore.ejb;
4
5 // Java core packages
6 import java.rmi.RemoteException;
7 import java.util.Collection;
8
9 // Java extension packages
10 import javax.ejb.*;
11
12 // Deitel packages
13 import com.deitel.advjhtp1.bookstore.model.*;
14
15 public interface ProductHome extends EJBHome {
16
17     // create Product EJB using given ProductModel
18     public Product create( ProductModel productModel )
19         throws RemoteException, CreateException;
20
21     // find Product with given ISBN
22     public Product findByPrimaryKey( String isbn )
23         throws RemoteException, FinderException;
24
25     // find all Products
26     public Collection findAllProducts()
27         throws RemoteException, FinderException;
28
29     // find Products with given title
30     public Collection findByTitle( String title )
31         throws RemoteException, FinderException;
32 }
```

Fig. 19.9 **ProductHome** interface for finding and creating **Product** EJB instances.

#### 19.4.4 ProductModel

Class **ProductModel** (Fig. 19.10) implements interface **Serializable**, so that instances may be serialized over RMI-IIOP. **ProductModel** has a **private** data member (lines 18–25) and *set* and *get* methods (lines 28–109) for each **Product** EJB property.

```
1 // ProductModel.java
2 // ProductModel represents a Product in the Deitel Bookstore,
3 // including ISBN, author, title and a picture of the cover.
4 package com.deitel.advjhtp1.bookstore.model;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.text.*;
10
```

Fig. 19.10 **ProductModel** class for serializing **Product** data (part 1 of 4).

```
11 // third-party packages
12 import org.w3c.dom.*;
13
14 public class ProductModel implements Serializable,
15     XMLGenerator {
16
17     // ProductModel properties
18     private String ISBN;
19     private String publisher;
20     private String author;
21     private String title;
22     private double price;
23     private int pages;
24     private String image;
25     private int quantity;
26
27     // set ISBN
28     public void setISBN( String productISBN )
29     {
30         ISBN = productISBN;
31     }
32
33     // get ISBN
34     public String getISBN()
35     {
36         return ISBN;
37     }
38
39     // set publisher
40     public void setPublisher( String productPublisher )
41     {
42         publisher = productPublisher;
43     }
44
45     // get publisher
46     public String getPublisher()
47     {
48         return publisher;
49     }
50
51     // set author
52     public void setAuthor( String productAuthor )
53     {
54         author = productAuthor;
55     }
56
57     // get author
58     public String getAuthor()
59     {
60         return author;
61     }
62
```

Fig. 19.10 **ProductModel** class for serializing **Product** data (part 2 of 4).

```
63     // set title
64     public void setTitle( String productTitle )
65     {
66         title = productTitle;
67     }
68
69     // get title
70     public String getTitle()
71     {
72         return title;
73     }
74
75     // set price
76     public void setPrice( double productPrice )
77     {
78         price = productPrice;
79     }
80
81     // get price
82     public double getPrice()
83     {
84         return price;
85     }
86
87     // set number of pages
88     public void setPages( int pageCount )
89     {
90         pages = pageCount;
91     }
92
93     // get number of pages
94     public int getPages()
95     {
96         return pages;
97     }
98
99     // set URL of cover image
100    public void setImage( String productImage )
101    {
102        image = productImage;
103    }
104
105    // get URL of cover image
106    public String getImage()
107    {
108        return image;
109    }
110
111    // get XML representation of Product
112    public Element getXML( Document document )
113    {
114        // create product Element
115        Element product = document.createElement( "product" );
```

Fig. 19.10 **ProductModel** class for serializing **Product** data (part 3 of 4).

```

116     // create ISBN Element
117     Element temp = document.createElement( "ISBN" );
118     temp.appendChild(
119         document.createTextNode( getISBN() ) );
120     product.appendChild( temp );
121
122     // create publisher Element
123     temp = document.createElement( "publisher" );
124     temp.appendChild(
125         document.createTextNode( getPublisher() ) );
126     product.appendChild( temp );
127
128     // create author Element
129     temp = document.createElement( "author" );
130     temp.appendChild(
131         document.createTextNode( getAuthor() ) );
132     product.appendChild( temp );
133
134     // create title Element
135     temp = document.createElement( "title" );
136     temp.appendChild(
137         document.createTextNode( getTitle() ) );
138     product.appendChild( temp );
139
140     NumberFormat priceFormatter =
141         NumberFormat.getCurrencyInstance( Locale.US );
142
143     // create price Element
144     temp = document.createElement( "price" );
145     temp.appendChild( document.createTextNode(
146         priceFormatter.format( getPrice() ) ) );
147     product.appendChild( temp );
148
149     // create pages Element
150     temp = document.createElement( "pages" );
151     temp.appendChild( document.createTextNode(
152         String.valueOf( getPAGES() ) ) );
153     product.appendChild( temp );
154
155     // create image Element
156     temp = document.createElement( "image" );
157     temp.appendChild(
158         document.createTextNode( getImage() ) );
159     product.appendChild( temp );
160
161     return product;
162
163 }
164 } // end method getXML
165 }
```

Fig. 19.10 **ProductModel** class for serializing **Product** data (part 4 of 4).

**ProductModel** also implements interface **XMLGenerator** (Fig. 19.11), which defines a single method, **getXML**. Method **getXML** of class **ProductModel** (lines 112–

164) generates an XML **Element** for the data contained in the **ProductModel**. This method uses the **Document** argument to create XML elements for each **ProductModel** data member. However, method **getXML** does not modify the **Document**. Line 162 returns the newly created **product** element.

Figure 19.12 and Fig. 19.13 show the deployment settings for entity EJB **Product**. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods.

```
1 // XMLGenerator.java
2 // XMLGenerator is an interface for classes that can generate
3 // XML Elements. The XML element returned by method getXML
4 // should contain Elements for each public property.
5 package com.deitel.advjhttp1.bookstore.model;
6
7 // third-party packages
8 import org.w3c.dom.*;
9
10 public interface XMLGenerator {
11
12     // build an XML element for this Object
13     public Element getXML( Document document );
14 }
```

Fig. 19.11 **XMLGenerator** interface for generating XML **Elements** for **public** properties.

#### Product General Deployment Settings

Bean Type	Entity
Enterprise Bean Class	com.deitel.advjhttp1.bookstore.ejb.ProductEJB
Home Interface	com.deitel.advjhttp1.bookstore.ejb.ProductHome
Remote Interface	com.deitel.advjhttp1.bookstore.ejb.Product

Fig. 19.12 **Product** general deployment settings.

#### Product Entity and Deployment Settings

Persistence Management	Container-Managed Persistence
------------------------	-------------------------------

Fig. 19.13 **Product Entity** and deployment settings (part 1 of 2).

### Product Entity and Deployment Settings

<b>Primary Key Class</b>	<code>java.lang.String</code>
<b>Primary Key Field Name</b>	<code>ISBN</code>
<b>Database JNDI Name</b>	<code>jdbc/Bookstore</code>
<b>Method findByTitle SQL Statement</b>	<code>SELECT ISBN FROM Product WHERE title LIKE ?1</code>
<b>Method findAllProducts SQL Statement</b>	<code>SELECT ISBN FROM Product WHERE 1 = 1</code>
<b>Method ejb-Store SQL Statement</b>	<code>UPDATE Product SET author = ?, image = ?, pages = ?, price = ?, publisher = ?, title = ? WHERE ISBN = ?</code>
<b>Method ejb-Create SQL Statement</b>	<code>INSERT INTO Product ( ISBN, author, image, pages, price, publisher, title ) VALUES ( ?, ?, ?, ?, ?, ? )</code>
<b>Method ejb-Remove SQL Statement</b>	<code>DELETE FROM Product WHERE ISBN = ?</code>
<b>Method find-ByPrimaryKey SQL Statement</b>	<code>SELECT ISBN FROM Product WHERE ISBN = ?</code>
<b>Method ejb-Load SQL Statement</b>	<code>SELECT author, image, pages, price, publisher, title FROM Product WHERE ISBN = ?</code>
<b>Table Create SQL Statement</b>	<code>CREATE TABLE Product ( ISBN VARCHAR( 255 ), author VARCHAR( 255 ), image VARCHAR( 255 ), pages INTEGER NOT NULL, price DOUBLE PRECISION NOT NULL, publisher VARCHAR( 255 ), title VARCHAR( 255 ), CONSTRAINT pk_Product PRIMARY KEY ( ISBN ) )</code>
<b>Table Delete SQL Statement</b>	<code>DROP TABLE Product</code>

Fig. 19.13 **Product Entity** and deployment settings (part 2 of 2).

## 19.5 Order Implementation

Entity EJB **Order** represents an **Order** placed at the Deitel Bookstore. Each **Order** consists of a list of **Products** and their associated quantities, as well as the **customerID** of the **Customer** who placed the **Order**.

### 19.5.1 Order Remote Interface

The **Order** EJB remote interface (Fig. 19.14) defines the business methods available in the **Order** EJB. Method **getOrderModel** (line 17) returns an **OrderModel** containing **Order** details. Method **setShipped** (lines 20–21) marks an **Order** as having been shipped from the warehouse. Method **isShipped** (line 24) returns a **boolean** that indicates whether the **Order** has been shipped.

### 19.5.2 OrderEJB Implementation

**Order** remote interface implementation **OrderEJB** (Fig. 19.15) declares **public** data members for container-manage persistence (lines 26–29). Method **getOrderModel** (lines 32–91) constructs an **OrderModel** instance that contains **Order** details. Lines 42–44 populate the **OrderModel** with the values of the **Order** EJB's data members.

```
1 // Order.java
2 // Order is the remote interface for entity EJB Order.
3 package com.deitel.advjhttp1.bookstore.ejb;
4
5 // Java core packages
6 import java.rmi.RemoteException;
7
8 // Java extension packages
9 import javax.ejb.*;
10
11 // Deitel packages
12 import com.deitel.advjhttp1.bookstore.model.*;
13
14 public interface Order extends EJBObject {
15
16     // get Order details as OrderModel
17     public OrderModel getOrderModel() throws RemoteException;
18
19     // set shipped flag
20     public void setShipped( boolean flag )
21         throws RemoteException;
22
23     // get shipped flag
24     public boolean isShipped() throws RemoteException;
25 }
```

Fig. 19.14 **Order** remote interface for modifying details of **Order** EJB instances.

```
1 // OrderEJB.java
2 // Entity EJB Order represents an Order, including the
3 // orderID, Order date, total cost and whether the Order
4 // has shipped.
5 package com.deitel.advjhttp1.bookstore.ejb;
6
```

Fig. 19.15 **OrderEJB** implementation of **Order** remote interface (part 1 of 6).

```
7 // Java core packages
8 import java.util.*;
9 import java.text.DateFormat;
10 import java.rmi.RemoteException;
11
12 // Java extension packages
13 import javax.ejb.*;
14 import javax.naming.*;
15 import javax.rmi.PortableRemoteObject;
16
17 // Deitel packages
18 import com.deitel.advjhttp1.bookstore.model.*;
19
20 public class OrderEJB implements EntityBean {
21     private EntityContext entityContext;
22     private InitialContext initialContext;
23     private DateFormat dateFormat;
24
25     // container-managed fields
26     public Integer orderID;
27     public Integer customerID;
28     public String orderDate;
29     public boolean shipped;
30
31     // get Order details as OrderModel
32     public OrderModel getOrderModel() throws EJBException
33     {
34         // construct new OrderModel
35         OrderModel orderModel = new OrderModel();
36
37         // look up OrderProduct EJB to retrieve list
38         // of Products contained in the Order
39         try {
40
41             // populate OrderModel data members with data from Order
42             orderModel.setOrderID( orderID );
43             orderModel.setOrderDate( dateFormat.parse( orderDate ) );
44             orderModel.setShipped( shipped );
45
46             initialContext = new InitialContext();
47
48             Object object = initialContext.lookup(
49                 "java:comp/env/ejb/OrderProduct" );
50
51             OrderProductHome orderProductHome =
52                 ( OrderProductHome ) PortableRemoteObject.narrow(
53                     object, OrderProductHome.class );
54
55             // get OrderProduct records for Order
56             Collection orderProducts =
57                 orderProductHome.findByOrderID( orderID );
58
59             Iterator iterator = orderProducts.iterator();
```

Fig. 19.15 OrderEJB implementation of Order remote interface (part 2 of 6).

```
60      // OrderProductModels to place in OrderModel
61      Collection orderProductModels = new ArrayList();
62
63
64      // get OrderProductModel for each Product in Order
65      while ( iterator.hasNext() ) {
66          OrderProduct orderProduct = ( OrderProduct )
67              PortableRemoteObject.narrow( iterator.next(),
68                  OrderProduct.class );
69
70          // get OrderProductModel for OrderProduct record
71          OrderProductModel orderProductModel =
72              orderProduct.getOrderProductModel();
73
74          // add OrderProductModel to list of
75          // OrderProductModels in the Order
76          orderProductModels.add( orderProductModel );
77      }
78
79      // add Collection of OrderProductModels to OrderModel
80      orderModel.setOrderProductModels( orderProductModels );
81
82  } // end try
83
84  // handle exception working with OrderProduct EJB
85  catch ( Exception exception ) {
86      throw new EJBException( exception );
87  }
88
89  return orderModel;
90
91 } // end method getOrderModel
92
93 // set shipped flag
94 public void setShipped( boolean flag )
95 {
96     shipped = flag;
97 }
98
99 // get shipped flag
100 public boolean isShipped()
101 {
102     return shipped;
103 }
104
105 // create new Order EJB using given OrderModel and userID
106 public Integer ejbCreate( OrderModel order, String userID )
107     throws CreateException
108 {
109     // retrieve unique value for primary key of this
110     // Order using SequenceFactory EJB
111     try {
112         initialContext = new InitialContext();
```

Fig. 19.15 OrderEJB implementation of Order remote interface (part 3 of 6).

```
113     Object object = initialContext.lookup(
114         "java:comp/env/ejb/SequenceFactory" );
115
116     SequenceFactoryHome sequenceFactoryHome =
117         ( SequenceFactoryHome )
118             PortableRemoteObject.narrow(
119                 object, SequenceFactoryHome.class );
120
121     // find sequence for CustomerOrder table
122     SequenceFactory sequenceFactory =
123         sequenceFactoryHome.findByPrimaryKey(
124             "CustomerOrders" );
125
126     // get next unique orderID
127     orderID = sequenceFactory.getNextID();
128
129     // get date, cost, shipped flag and list of
130     // OrderProduct from provided OrderModel
131     orderDate = dateFormat.format( order.getOrderDate() );
132     shipped = order.getShipped();
133
134     // get OrderProductModels that comprise OrderModel
135     Collection orderProductModels =
136         order.getOrderProductModels();
137
138     // create OrderProduct EJBs for each Product in
139     // Order to keep track of quantity
140     object = initialContext.lookup(
141         "java:comp/env/ejb/OrderProduct" );
142
143     OrderProductHome orderProductHome =
144         ( OrderProductHome ) PortableRemoteObject.narrow(
145             object, OrderProductHome.class );
146
147     Iterator iterator = orderProductModels.iterator();
148
149     // create an OrderProduct EJB with Product's
150     // ISBN, quantity and orderID for this Order
151     while ( iterator.hasNext() ) {
152
153         OrderProductModel orderProductModel =
154             ( OrderProductModel ) iterator.next();
155
156         // set orderID for OrderProduct record
157         orderProductModel.setOrderID( orderID );
158
159         // create OrderProduct EJB instance
160         orderProductHome.create( orderProductModel );
161     }
162
163     // get customerID for customer placing Order
164     object = initialContext.lookup(
```

Fig. 19.15 OrderEJB implementation of Order remote interface (part 4 of 6).

```
166             "java:comp/env/ejb/Customer" );
167
168     CustomerHome customerHome =
169         ( CustomerHome ) PortableRemoteObject.narrow(
170             object, CustomerHome.class );
171
172     // use provided userID to find Customer
173     Customer customer =
174         customerHome.findByUserID( userID );
175
176     customerID = ( Integer ) customer.getPrimaryKey();
177
178 } // end try
179
180 // handle exception when looking up EJBs
181 catch ( Exception exception ) {
182     throw new CreateException( exception.getMessage() );
183 }
184
185 return null;
186
187 } // end method ejbCreate
188
189 // perform any necessary post-creation tasks
190 public void ejbPostCreate( OrderModel order, String id ) {}
191
192 // set EntityContext
193 public void setEntityContext( EntityContext context )
194 {
195     entityContext = context;
196     dateFormat = DateFormat.getDateInstance(
197         DateFormat.FULL, DateFormat.SHORT, Locale.US );
198 }
199
200 // unset EntityContext
201 public void unsetEntityContext()
202 {
203     entityContext = null;
204 }
205
206 // activate Order EJB instance
207 public void ejbActivate()
208 {
209     orderID = ( Integer ) entityContext.getPrimaryKey();
210 }
211
212 // passivate Order EJB instance
213 public void ejbPassivate()
214 {
215     orderID = null;
216 }
217
218 // remove Order EJB instanceCus
```

Fig. 19.15 OrderEJB implementation of Order remote interface (part 5 of 6).

```

219     public void ejbRemove() {}
220
221     // store Order EJB data in database
222     public void ejbStore() {}
223
224     // load Order EJB data from database
225     public void ejbLoad() {}
226 }

```

Fig. 19.15 *OrderEJB* implementation of *Order* remote interface (part 6 of 6).

In addition to the **orderDate**, **orderID** and **shipped** flag, an **Order** contains a list of **OrderProductModels**. The relationship between an **Order** and its associated **Products** and quantities is represented by a many-to-many relationship in the database (i.e., an **Order** can contain many **Products**, and a single **Product** can be found in many **Orders**). The **OrderProduct** EJB represents this relationship by mapping an **orderID** to the **ISBNs** of **Products** in the **Order**. For each **Order**, there are records in the **OrderProduct** table containing the **ISBNs** and quantities of each **Product** in the **Order**. For example, if a **Customer** orders one copy of *Java How to Program* and two copies of *Advanced Java 2 Platform How to Program*, there will be two records in the **OrderProduct** table. Each record will have the same **orderID**, but one will have the **ISBN** for *Java How to Program* and the **quantity** 1, and the other will have the **ISBN** for *Advanced Java 2 Platform How to Program* and the **quantity** 2.

Lines 56–57 invoke method **findByIdOrderID** to obtain the **OrderProduct** records for the **Order**. Method **findByIdOrderID** returns a **Collection** of **OrderProduct** remote references. Lines 65–77 traverse the **Collection** of **OrderProducts** using an **Iterator**, and lines 71–72 retrieve an **OrderProductModel** for each **OrderProduct** record. Line 76 adds each **OrderProductModel** to a **Collection**. Line 80 adds the **OrderProductModel Collection** to the **OrderModel**, and line 89 **returns** the newly created **OrderModel**.

Method **setShipped** (lines 94–97) accepts a **boolean** argument and updates the **Order** EJB's **shipped** flag. An order-tracking application could use method **setShipped** to update the status of the **Order** when the warehouse ships the **Order**. Method **isShipped** (lines 100–103) returns the **shipped** data member's current value, indicating whether the **Order** has been shipped from the warehouse.

Method **ejbCreate** (lines 106–187) creates an **Order** EJB using data from the given **OrderModel** and **userID**. Each **Order** has an associated **orderID**, which serves as the primary key in the **Order** EJB database table. **SequenceFactory** method **getNextID** generates a unique **orderID** for the **Order** (line 128).

Lines 132–133 populate the **Order** with data from the **OrderModel**. The **OrderModel** also provides the **Products** and quantities in the **Order** as an **Collection** of **OrderProductModels**. Lines 152–162 process the **Collection** of **OrderProductModels** and create **OrderProduct** records for each, using interface **OrderProductHome** method **create** (line 161).

Each **Order** also must have an associated **Customer** who placed the **Order**. This is a one-to-many relationship, because one **Customer** can place many orders, but an **Order** can be associated with only one **Customer**. Lines 173–174 retrieve the **Cus-**

**Customer** EJB for the given **userID**. **Customer** method **getPrimaryKey** retrieves the **Customer's customerID**. Line 176 sets the **customerID** for the **Order**.

### 19.5.3 OrderHome Interface

Interface **OrderHome** (Fig. 19.16) creates **Order** instances and finds existing **Orders**. Method **create** (lines 18–19) corresponds to method **ejbCreate** of Fig. 19.15 and creates new **Orders**, using an **OrderModel** and **userID**. Method **findByPrimaryKey** (lines 22–23) locates an existing **Order**, using its **orderID**. Method **findByCustomerID** (lines 26–27) retrieves a **Collection** of **Orders** for the given **Customer**.

### 19.5.4 OrderModel

Class **OrderModel** (Fig. 19.17) encapsulates the details of an **Order** EJB in a **Serializable** object suitable for delivery over RMI-IIOP. **OrderModel** has **private** data members (lines 19–22) with associated **set** and **get** methods (lines 31–102) for each **Order** EJB data member. **OrderModel** also maintains a **Collection** of **OrderProductModels**, to keep track of the **Products** in the **Order**. **OrderModel** implements interface **XMLGenerator** and method **getXML** to facilitate the generation of an XML representation of an **Order** (lines 105–166).

```
1 // OrderHome.java
2 // OrderHome is the home interface for entity EJB Order.
3 package com.deitel.advjhttp1.bookstore.ejb;
4
5 // Java core packages
6 import java.util.*;
7 import java.rmi.RemoteException;
8
9 // Java extension packages
10 import javax.ejb.*;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.bookstore.model.*;
14
15 public interface OrderHome extends EJBHome {
16
17     // create Order using given OrderModel and userID
18     public Order create( OrderModel orderModel, String userID )
19         throws RemoteException, CreateException;
20
21     // find Order using given orderID
22     public Order findByPrimaryKey( Integer orderID )
23         throws RemoteException, FinderException;
24
25     // find Orders for given customerID
26     public Collection findByCustomerID( Integer customerID )
27         throws RemoteException, FinderException;
28 }
```

Fig. 19.16 OrderHome interface for finding and creating Order EJB instances.

```
1 // OrderModel.java
2 // OrderModel represents an Order and contains the order ID,
3 // date, total cost and a boolean indicating whether or not the
4 // order has shipped.
5 package com.deitel.advjhttp1.bookstore.model;
6
7 // Java core packages
8 import java.io.*;
9 import java.util.*;
10 import java.text.*;
11
12 // third-party packages
13 import org.w3c.dom.*;
14
15 public class OrderModel implements Serializable,
16     XMLGenerator {
17
18     // OrderModel properties
19     private Integer orderID;
20     private Date orderDate;
21     private boolean shipped;
22     private Collection orderProductModels;
23
24     // construct empty OrderModel
25     public OrderModel()
26     {
27         orderProductModels = new ArrayList();
28     }
29
30     // set order ID
31     public void setOrderID( Integer id )
32     {
33         orderID = id;
34     }
35
36     // get order ID
37     public Integer getOrderID()
38     {
39         return orderID;
40     }
41
42     // set order date
43     public void setOrderDate( Date date )
44     {
45         orderDate = date;
46     }
47
48     // get order date
49     public Date getOrderDate()
50     {
51         return orderDate;
52     }
53
```

Fig. 19.17 **OrderModel** class for serializing **Order** data (part 1 of 4).

```
54     // get total cost
55     public double getTotalCost()
56     {
57         double total = 0.0;
58
59         Iterator iterator = orderProductModels.iterator();
60
61         // calculate Order's total cost
62         while ( iterator.hasNext() ) {
63
64             // get next OrderProduct in ShoppingCart
65             OrderProductModel orderProductModel =
66                 ( OrderProductModel ) iterator.next();
67
68             ProductModel productModel =
69                 orderProductModel.getProductModel();
70
71             // add OrderProduct extended price to total
72             total += ( productModel.getPrice() *
73                         orderProductModel.getQuantity() );
74         }
75
76         return total;
77     }
78
79     // set shipped flag
80     public void setShipped( boolean orderShipped )
81     {
82         shipped = orderShipped;
83     }
84
85     // get shipped flag
86     public boolean getShipped()
87     {
88         return shipped;
89     }
90
91     // set list of OrderProductModels
92     public void setOrderProductModels( Collection models )
93     {
94         orderProductModels = models;
95     }
96
97     // get OrderProductModels
98     public Collection getOrderProductModels()
99     {
100         return Collections.unmodifiableCollection(
101             orderProductModels );
102     }
103
104     // get XML representation of Order
105     public Element getXML( Document document )
106     {
```

Fig. 19.17 **OrderModel** class for serializing **Order** data (part 2 of 4).

```
107     // create order Element
108     Element order = document.createElement( "order" );
109
110     // create orderID Element
111     Element temp = document.createElement( "orderID" );
112     temp.appendChild( document.createTextNode(
113         String.valueOf( getOrderID() ) ) );
114     order.appendChild( temp );
115
116     // get DateFormat for writing Date to XML document
117     DateFormat formatter = DateFormat.getDateInstance(
118         DateFormat.DEFAULT, DateFormat.MEDIUM, Locale.US );
119
120     // create orderDate Element
121     temp = document.createElement( "orderDate" );
122     temp.appendChild( document.createTextNode(
123         formatter.format( getOrderDate() ) ) );
124     order.appendChild( temp );
125
126     NumberFormat costFormatter =
127         NumberFormat.getCurrencyInstance( Locale.US );
128
129     // create totalCost Element
130     temp = document.createElement( "totalCost" );
131     temp.appendChild( document.createTextNode(
132         costFormatter.format( getTotalCost() ) ) );
133     order.appendChild( temp );
134
135     // create shipped Element
136     temp = document.createElement( "shipped" );
137
138     if ( getShipped() )
139         temp.appendChild(
140             document.createTextNode( "yes" ) );
141     else
142         temp.appendChild(
143             document.createTextNode( "no" ) );
144
145     order.appendChild( temp );
146
147     // create orderProducts Element
148     Element orderProducts =
149         document.createElement( "orderProducts" );
150
151     Iterator iterator = getOrderProductModels().iterator();
152
153     // add orderProduct element for each OrderProduct
154     while ( iterator.hasNext() ) {
155         OrderProductModel orderProductModel =
156             ( OrderProductModel ) iterator.next();
157
158         orderProducts.appendChild(
159             orderProductModel.getXML( document ) );
```

Fig. 19.17 **OrderModel** class for serializing **Order** data (part 3 of 4).

```
160      }
161      order.appendChild( orderProducts );
162      return order;
163
164  } // end method getXML
165 }
```

Fig. 19.17 OrderModel class for serializing Order data (part 4 of 4).

Figure 19.18, Fig. 19.19 and Fig. 19.20 show the deployment settings for entity EJB Order. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods.

#### Order General Deployment Settings

Bean Type	Entity
Enterprise Bean Class	com.deitel.advjhttp1.bookstore.ejb.OrderEJB
Home Interface	com.deitel.advjhttp1.bookstore.ejb.OrderHome
Remote Interface	com.deitel.advjhttp1.bookstore.ejb.Order

Fig. 19.18 Order general deployment settings.

#### Order Entity and Deployment Settings

Persistence Management	Container-Managed Persistence
Primary Key Class	java.lang.Integer
Primary Key Field Name	orderID
Database JNDI Name	jdbc/Bookstore
Method findByCustomerID SQL Statement	SELECT orderID FROM CustomerOrders WHERE customerID = ?1

Fig. 19.19 Order entity and deployment settings (part 1 of 2).

### Order Entity and Deployment Settings

Method <b>ejb-Store SQL Statement</b>	<code>UPDATE CustomerOrders SET customerID = ?, orderDate = ?, shipped = ? WHERE orderID = ?</code>
Method <b>ejbCreate SQL Statement</b>	<code>INSERT INTO CustomerOrders ( customerID, orderDate, orderID, shipped ) VALUES ( ?, ?, ?, ? )</code>
Method <b>ejbRemove SQL Statement</b>	<code>DELETE FROM CustomerOrders WHERE orderID = ?</code>
Method <b>find-ByPrimaryKey SQL Statement</b>	<code>SELECT orderID FROM CustomerOrders WHERE orderID = ?</code>
Method <b>ejbLoad SQL Statement</b>	<code>SELECT customerID, orderDate, shipped FROM CustomerOrders WHERE orderID = ?</code>
Table Create SQL Statement	<code>CREATE TABLE CustomerOrders ( customerID INTEGER, orderDate VARCHAR(255), orderID INTEGER, shipped BOOLEAN NOT NULL, CONSTRAINT pk_CustomerOrders PRIMARY KEY ( orderID ) )</code>
Table Delete SQL Statement	<code>DROP TABLE CustomerOrders</code>

Fig. 19.19 **Order** entity and deployment settings (part 2 of 2).

### Order EJB References

Coded Name	<code>ejb/Product</code>
Type	<code>Entity</code>
Home	<code>com.deitel.advjhttp1.bookstore.ejb.ProductHome</code>
Remote	<code>com.deitel.advjhttp1.bookstore.ejb.Product</code>
JNDI Name	<code>Product</code>
Coded Name	<code>ejb/SequenceFactory</code>
Type	<code>Entity</code>
Home	<code>com.deitel.advjhttp1.bookstore.ejb.SequenceFactoryHome</code>
Remote	<code>com.deitel.advjhttp1.bookstore.ejb.SequenceFactory</code>
JNDI Name	<code>SequenceFactory</code>
Coded Name	<code>ejb/Customer</code>

Fig. 19.20 **Order** EJB references (part 1 of 2).

Order EJB References	
Type	Entity
Home	com.deitel.advjhttp1.bookstore.ejb.CustomerHome
Remote	com.deitel.advjhttp1.bookstore.ejb.Customer
JNDI Name	Customer
Coded Name	ejb/OrderProduct
Type	Entity
Home	com.deitel.advjhttp1.bookstore.ejb.OrderProductHome
Remote	com.deitel.advjhttp1.bookstore.ejb.OrderProduct
JNDI Name	OrderProduct

Fig. 19.20 Order EJB references (part 2 of 2).

## 19.6 OrderProduct Implementation

Entity EJB **OrderProduct** represents the many-to-many relationship between **Orders** and **Products**. Each **OrderProduct** EJB includes an **orderID**, **Product ISBN** and **quantity**, and represents one line item in an **Order**.

### 19.6.1 OrderProduct Remote Interface

The **OrderProduct** remote interface (Fig. 19.21) defines the business methods for the **OrderProduct** EJB. The **OrderProduct** EJB maps **Product ISBNs** to **orderIDs** and quantities. Method **getOrderProductModel** (lines 18–19) returns an **OrderProductModel** that contains the details of an **OrderProduct** record.

```
1 // OrderProduct.java
2 // OrderProduct is the remote interface for entity EJB
3 // OrderProduct.
4 package com.deitel.advjhttp1.bookstore.ejb;
5
6 // Java core packages
7 import java.rmi.RemoteException;
8
9 // Java extension packages
10 import javax.ejb.*;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.bookstore.model.*;
14
15 public interface OrderProduct extends EJBObject {
16
17     // get OrderProduct details as OrderProductModel
```

Fig. 19.21 OrderProduct remote interface for modifying details of OrderProduct EJB instances (part 1 of 2).

```
18     public OrderProductModel getOrderProductModel()
19         throws RemoteException;
20 }
```

Fig. 19.21 OrderProduct remote interface for modifying details of OrderProduct EJB instances (part 2 of 2).

### 19.6.2 OrderProductEJB Implementation

OrderProduct remote interface implementation OrderProductEJB (Fig. 19.22) declares container-managed fields ISBN, orderID and quantity (lines 22–24). Method getOrderProductModel (lines 27–69) returns the details of the OrderProduct record as an OrderProductModel. Method setOrderProductModel (lines 72–77) sets the details of the OrderProduct record, using data from the OrderProductModel argument.

```
1 // OrderProductEJB.java
2 // Entity EJB OrderProductEJB represents the mapping between
3 // a Product and an Order, including the quantity of the
4 // Product in the Order.
5 package com.deitel.advjhtp1.bookstore.ejb;
6
7 // Java core packages
8 import java.rmi.RemoteException;
9
10 // Java extension packages
11 import javax.ejb.*;
12 import javax.naming.*;
13 import javax.rmi.PortableRemoteObject;
14
15 // Deitel packages
16 import com.deitel.advjhtp1.bookstore.model.*;
17
18 public class OrderProductEJB implements EntityBean {
19     private EntityContext entityContext;
20
21     // container-managed fields
22     public String ISBN;
23     public Integer orderID;
24     public int quantity;
25
26     // get OrderProduct details as OrderProductModel
27     public OrderProductModel getOrderProductModel()
28         throws EJBException
29     {
30         OrderProductModel model = new OrderProductModel();
31
32         // get ProductModel for Product in this OrderProduct
33         try {
34             Context initialContext = new InitialContext();
```

Fig. 19.22 OrderProductEJB implementation of OrderProduct remote interface (part 1 of 3).

```
35      // look up Product EJB
36      Object object = initialContext.lookup(
37          "java:comp/env/ejb/Product" );
38
39      // get ProductHome interface
40      ProductHome productHome = ( ProductHome )
41          PortableRemoteObject.narrow( object,
42              ProductHome.class );
43
44      // find Product using its ISBN
45      Product product =
46          productHome.findByPrimaryKey( ISBN );
47
48      // get ProductModel
49      ProductModel productModel =
50          product.getProductModel();
51
52      // set ProductModel in OrderProductModel
53      model.setProductModel( productModel );
54
55  } // end try
56
57  // handle exception when looking up Product EJB
58  catch ( Exception exception ) {
59      throw new EJBException( exception );
60  }
61
62
63  // set orderID and quantity in OrderProductModel
64  model.setOrderID( orderID );
65  model.setQuantity( quantity );
66
67  return model;
68
69 } // end method getOrderProductModel
70
71 // set OrderProduct details using OrderProductModel
72 private void setOrderProductModel( OrderProductModel model )
73 {
74     ISBN = model.getProductModel().getISBN();
75     orderID = model.getOrderID();
76     quantity = model.getQuantity();
77 }
78
79 // create OrderProduct for given OrderProductModel
80 public OrderProductPK ejbCreate( OrderProductModel model )
81 {
82     setOrderProductModel( model );
83     return null;
84 }
85
86 // perform any necessary post-creation tasks
```

Fig. 19.22 **OrderProductEJB** implementation of **OrderProduct** remote interface (part 2 of 3).

```
87     public void ejbPostCreate( OrderProductModel model ) {}
88
89     // set EntityContext
90     public void setEntityContext( EntityContext context )
91     {
92         entityContext = context;
93     }
94
95     // unset EntityContext
96     public void unsetEntityContext()
97     {
98         entityContext = null;
99     }
100
101    // activate OrderProduct EJB instance
102    public void ejbActivate()
103    {
104        OrderProductPK primaryKey =
105            ( OrderProductPK ) entityContext.getPrimaryKey();
106
107        ISBN = primaryKey.getISBN();
108        orderID = primaryKey.getOrderID();
109    }
110
111    // passivate OrderProduct EJB instance
112    public void ejbPassivate()
113    {
114        ISBN = null;
115        orderID = null;
116    }
117
118    // remove OrderProduct EJB instance
119    public void ejbRemove() {}
120
121    // store OrderProduct EJB data in database
122    public void ejbStore() {}
123
124    // load OrderProduct EJB data from database
125    public void ejbLoad() {}
126 }
```

Fig. 19.22 **OrderProductEJB** implementation of **OrderProduct** remote interface (part 3 of 3).

The EJB container calls method **ejbCreate** (lines 80–84) to create new instances of the **OrderProduct** EJB. The **ISBN**, **orderID** and **quantity** for the **OrderProduct** record are provided in the **OrderProductModel** argument. Line 82 invokes method **setOrderProductModel** to complete the creation of the **OrderProduct** record.

### 19.6.3 OrderProductHome Interface

Interface **OrderProductHome** (Fig. 19.23) provides methods for creating new **OrderProduct** EJB instances and locating existing **OrderProduct** records. Method **create** (lines 19–20) corresponds to method **ejbCreate** of the **OrderProductEJB** implemen-

tation (Fig. 19.22). Method **findByIdOrderID** (lines 23–24) locates all **OrderProduct** records with the provided **orderID** and returns a **Collection** of **OrderProduct** remote references. Method **findByIdPrimaryKey** (lines 27–28) locates an **OrderProduct** record, using an instance of the **OrderProductPK** primary-key class.

#### 19.6.4 OrderProductPK Primary-Key Class

**OrderProductPK** (Fig. 19.24) is the primary-key class for the **OrderProduct** EJB. An **orderID** and **ISBN** are required to identify a particular **OrderProduct** EJB instance uniquely. An entity EJB that has a complex primary key (i.e., a primary key that consists of multiple fields) requires a custom primary-key class. A custom primary-key class must have a **public** data member for each field in the complex primary key. The primary-key class **OrderProductPK** has two **public** data members (lines 12–13)—**ISBN** and **orderID**, which correspond to **OrderProductEJB**'s two primary-key fields (Fig. 19.22). A custom primary-key class also must override methods **hashCode** and **equals** of class **Object**. The overridden implementations of methods **hashCode** (lines 38–41) and **equals** (lines 44–57) enable the EJB container and **OrderProduct** EJB clients to determine if two **OrderProduct** EJB instances are equal by comparing their primary-key class instances.

```
1 // OrderProductHome.java
2 // OrderProductHome is the home interface for entity EJB
3 // OrderProduct.
4 package com.deitel.advjhttp1.bookstore.ejb;
5
6 // Java core packages
7 import java.util.Collection;
8 import java.rmi.RemoteException;
9
10 // Java extension packages
11 import javax.ejb.*;
12
13 // Deitel packages
14 import com.deitel.advjhttp1.bookstore.model.*;
15
16 public interface OrderProductHome extends EJBHome {
17
18     // create OrderProduct using given OrderProductModel
19     public OrderProduct create( OrderProductModel model )
20         throws RemoteException, CreateException;
21
22     // find OrderProduct for given orderID
23     public Collection findByOrderID( Integer orderID )
24         throws RemoteException, FinderException;
25
26     // find OrderProduct for given primary key
27     public OrderProduct findByPrimaryKey( OrderProductPK pk )
28         throws RemoteException, FinderException;
29 }
```

Fig. 19.23 OrderProductHome interface for finding and creating OrderProduct EJB instances.

```
1 // OrderProductPK.java
2 // OrderProductPK is a primary-key class for entity EJB
3 // OrderProduct.
4 package com.deitel.advjhtp1.bookstore.ejb;
5
6 // Java core packages
7 import java.io.*;
8
9 public class OrderProductPK implements Serializable {
10
11     // primary-key fields
12     public String ISBN;
13     public Integer orderID;
14
15     // no-argument constructor
16     public OrderProductPK() {}
17
18     // construct OrderProductPK with ISBN and orderID
19     public OrderProductPK( String isbn, Integer id )
20     {
21         ISBN = isbn;
22         orderID = id;
23     }
24
25     // get ISBN
26     public String getISBN()
27     {
28         return ISBN;
29     }
30
31     // get orderID
32     public Integer getOrderID()
33     {
34         return orderID;
35     }
36
37     // calculate hashCode for this Object
38     public int hashCode()
39     {
40         return getISBN().hashCode() ^ getOrderID().intValue();
41     }
42
43     // custom implementation of Object equals method
44     public boolean equals( Object object )
45     {
46         // ensure object is instance of OrderProductPK
47         if ( object instanceof OrderProductPK ) {
48             OrderProductPK otherKey =
49                 ( OrderProductPK ) object;
50
51             // compare ISBNs and orderIDs
52             return ( getISBN().equals( otherKey.getISBN() )
```

Fig. 19.24 OrderProductPK primary-key class for OrderProduct EJB  
(part 1 of 2).

```
53             && getOrderID().equals( otherKey.getOrderID() ) );
54         }
55     }
56     return false;
57 }
58 }
```

Fig. 19.24 OrderProductPK primary-key class for OrderProduct EJB  
(part 2 of 2).

### 19.6.5 OrderProductModel

Model class **OrderProductModel** (Fig. 19.25) represents an **OrderProduct** record. Line 18 declares a **ProductModel** reference for the **Product** associated with this **OrderProduct** record. The **quantity** (line 19) is the quantity of the **Product** in the **Order**. The **Order** is identified by its **orderID** (line 20). Method **getXML** (lines 59–76) generates an XML **Element** that represents the **OrderProductModel**.

```
1 // OrderProductModel.java
2 // OrderProductModel represents a Product and its quantity in
3 // an Order or ShoppingCart.
4 package com.deitel.advjhtp1.bookstore.model;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.text.*;
10
11 // third-party packages
12 import org.w3c.dom.*;
13
14 public class OrderProductModel implements Serializable,
15     XMLGenerator {
16
17     // OrderProductModel properties
18     private ProductModel productModel;
19     private int quantity;
20     private Integer orderID;
21
22     // set ProductModel
23     public void setProductModel( ProductModel model )
24     {
25         productModel = model;
26     }
27
28     // get ProductModel
29     public ProductModel getProductModel()
30     {
31         return productModel;
32     }
```

Fig. 19.25 OrderProductModel class for serializing OrderProduct data  
(part 1 of 2).

```
33     // set quantity
34     public void setQuantity( int productQuantity )
35     {
36         quantity = productQuantity;
37     }
38
39     // get quantity
40     public int getQuantity()
41     {
42         return quantity;
43     }
44
45     // set orderID
46     public void setOrderID( Integer id )
47     {
48         orderID = id;
49     }
50
51     // get orderID
52     public Integer getOrderID()
53     {
54         return orderID;
55     }
56
57     // get XML representation of OrderProduct
58     public Element getXML( Document document )
59     {
60         // create orderProduct Element
61         Element orderProduct =
62             document.createElement( "orderProduct" );
63
64         // append ProductModel product Element
65         orderProduct.appendChild(
66             getProductModel().getXML( document ) );
67
68         // create quantity Element
69         Element temp = document.createElement( "quantity" );
70         temp.appendChild( document.createTextNode(
71             String.valueOf( getQuantity() ) ) );
72         orderProduct.appendChild( temp );
73
74         return orderProduct;
75     }
76 }
77 }
```

Fig. 19.25 **OrderProductModel** class for serializing **OrderProduct** data (part 2 of 2).

Figure 19.26, Fig. 19.27 and Fig. 19.28 show the deployment settings for entity EJB **OrderProduct**. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods. Note that because entity EJB **OrderProduct** uses a custom primary-key class, the **Primary Key Field Name** (Fig. 19.27) must be left blank.

**OrderProduct General Deployment Settings**

<b>Bean Type</b>	Entity
<b>Enterprise Bean Class</b>	<code>com.deitel.advjhttp1.bookstore.ejb.OrderProductEJB</code>
<b>Home Interface</b>	<code>com.deitel.advjhttp1.bookstore.ejb.OrderProductHome</code>
<b>Remote Interface</b>	<code>com.deitel.advjhttp1.bookstore.ejb.OrderProduct</code>

**Fig. 19.26 OrderProduct general deployment settings.****OrderProduct Entity and Deployment Settings**

<b>Persistence Management</b>	Container-Managed Persistence
<b>Primary Key Class</b>	<code>com.deitel.advjhttp1.bookstore.ejb.OrderProductPK</code>
<b>Primary Key Field Name</b>	N/A
<b>Database JNDI Name</b>	<code>jdbc/Bookstore</code>
<b>Method findByOrderID SQL Statement</b>	<code>SELECT ISBN, orderID FROM OrderProduct WHERE orderID = ?1</code>
<b>Method ejbStore SQL Statement</b>	<code>UPDATE OrderProduct SET quantity = ? WHERE ISBN = ? AND orderID = ?</code>
<b>Method ejbCreate SQL Statement</b>	<code>INSERT INTO OrderProduct ( ISBN, orderID, quantity ) VALUES ( ?, ?, ? )</code>
<b>Method ejbRemove SQL Statement</b>	<code>DELETE FROM OrderProduct WHERE ISBN = ? AND orderID = ?</code>
<b>Method find-ByPrimaryKey SQL Statement</b>	<code>SELECT ISBN, orderID FROM OrderProduct WHERE ISBN = ? AND orderID = ?</code>
<b>Method ejbLoad SQL Statement</b>	<code>SELECT quantity FROM OrderProduct WHERE ISBN = ? AND orderID = ?</code>

**Fig. 19.27 OrderProduct entity and deployment settings (part 1 of 2).**

**OrderProduct Entity and Deployment Settings**

<b>Table Create SQL Statement</b>	<code>CREATE TABLE OrderProduct ( ISBN VARCHAR( 255 ), orderID INTEGER, quantity INTEGER NOT NULL, CONSTRAINT pk_OrderProduct PRIMARY KEY ( ISBN, orderID ) )</code>
<b>Table Delete SQL Statement</b>	<code>DROP TABLE OrderProduct</code>

**Fig. 19.27 OrderProduct entity and deployment settings (part 2 of 2).****OrderProduct EJB References**

<b>Coded Name</b>	<code>ejb/Product</code>
<b>Type</b>	<code>Entity</code>
<b>Home</b>	<code>com.deitel.advjhttp1.bookstore.ejb.ProductHome</code>
<b>Remote</b>	<code>com.deitel.advjhttp1.bookstore.ejb.Product</code>
<b>JNDI Name</b>	<code>Product</code>

**Fig. 19.28 OrderProduct EJB references.**

In this chapter, we presented the business logic for managing the **Customer**'s **ShoppingCart** and the data model for **Products** and **Orders** in our on-line store. We also discussed how **Serializable** objects can be used to reduce network traffic when communicating with EJBs. In the next chapter, we present EJBs for managing **Customers** of the on-line store.

# 20

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# Enterprise Java Case Study: Business Logic Part 2

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## Objectives

- To understand the data model for **Customer** management in the Deitel Bookstore case study.
- To implement an EJB for storing billing and shipping information.
- To build an EJB for generating primary keys.
- To understand the benefits of declarative transaction semantics.
- To understand the steps necessary to deploy the Deitel Bookstore case study.

*The best investment is in the tools of one's own trade.*

Benjamin Franklin

*Creativity is not the finding of a thing, but the making something out of it after it is found.*

James Russell Lowell

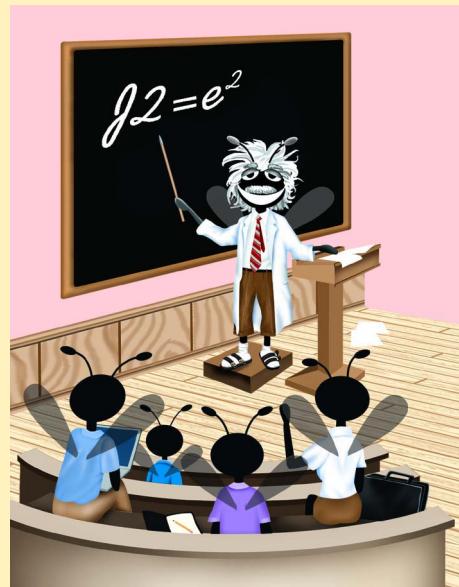
*Events that are predestined require but little management.*

*They manage themselves.*

Amelia Barr

*All meanings, we know, depend on the key of interpretation.*

George Eliot



## Outline

- 20.1 **Introduction**
- 20.2 **Customer Implementation**
  - 20.2.1 **Customer Remote Interface**
  - 20.2.2 **CustomerEJB Implementation**
  - 20.2.3 **CustomerHome Interface**
  - 20.2.4 **CustomerModel**
- 20.3 **Address Implementation**
  - 20.3.1 **Address Remote Interface**
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- 20.4 **SequenceFactory Implementation**
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  - 20.5.1 **Deploying Deitel Bookstore CMP Entity EJBs**
  - 20.5.2 **Deploying Deitel Bookstore Servlets**

## 20.1 Introduction

In this chapter, we present entity EJBs for managing customers. Maintaining information about the customers of an on-line store can make purchases more convenient, because billing and shipping information is stored on the server. The on-line store's marketing department also can use gathered data for distribution of marketing materials and analysis of demographic information.

We also present an entity EJB that generates unique IDs for the **Customer**, **Order** and **Address** EJBs. Instances of these EJBs are created when new **Customers** register and when **Customers** place new **Orders**. Relational databases require unique primary keys to maintain referential integrity and perform queries. We provide the **SequenceFactory** EJB to generate these unique IDs, because not all databases can generate these primary-key values automatically. Finally, we provide instructions for deploying the Deitel Bookstore case study on Sun Microsystems' J2EE reference implementation application server.

## 20.2 Customer Implementation

The **Customer** entity EJB represents a customer in the underlying database. The following subsections present the EJB implementation and its corresponding model class.

## 20.2.1 Customer Remote Interface

The **Customer** EJB remote interface (Fig. 20.1) defines the business logic methods in the EJB. Method **getCustomerModel** (lines 19–20) builds a **Serializable** object of class **CustomerModel**, which contains the details of the **Customer**. Method **getOrderHistory** (lines 23–24) returns a **Collection** of **OrderModels** that contains information about past **Orders** the **Customer** has placed. Method **getPasswordHint** (line 27) returns a **String** containing a hint to remind **Customers** of forgotten passwords.

## 20.2.2 CustomerEJB Implementation

The **CustomerEJB** implementation (Fig. 20.2) of remote interface **Customer** (Fig. 20.1) contains instance variables for each **Customer** property (lines 25–36). These instance variables are **public**, so the EJB container can synchronize their values with the associated database table.

```
1 // Customer.java
2 // Customer is the remote interface for entity EJB Customer.
3 package com.deitel.advjhttp1.bookstore.ejb;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7 import java.util.ArrayList;
8
9 // Java standard extensions
10 import javax.ejb.*;
11
12 // Deitel Bookstore libraries
13 import com.deitel.advjhttp1.bookstore.model.*;
14 import com.deitel.advjhttp1.bookstore.exceptions.*;
15
16 public interface Customer extends EJBObject {
17
18     // get Customer data as a CustomerModel
19     public CustomerModel getCustomerModel()
20         throws RemoteException;
21
22     // get Order history for CustomerModel
23     public Collection getOrderHistory()
24         throws RemoteException, NoOrderHistoryException;
25
26     // get password hint for CustomerModel
27     public String getPasswordHint() throws RemoteException;
28 }
```

Fig. 20.1 **Customer** remote interface for modifying **Customer** details, getting an **Order** history and password hint.

```
1 // CustomerEJB.java
2 // Entity EJB Customer represents a Customer, including
3 // the Customer's user name, password, billing
4 // address, shipping address and credit card information.
5 package com.deitel.advjhtp1.bookstore.ejb;
6
7 // Java core packages
8 import java.util.*;
9 import java.rmi.RemoteException;
10
11 // Java extension packages
12 import javax.ejb.*;
13 import javax.naming.*;
14 import javax.rmi.PortableRemoteObject;
15
16 // Deitel packages
17 import com.deitel.advjhtp1.bookstore.model.*;
18 import com.deitel.advjhtp1.bookstore.exceptions.*;
19
20 public class CustomerEJB implements EntityBean {
21     private EntityContext entityContext;
22     private InitialContext initialContext;
23
24     // container-managed fields
25     public Integer customerID;
26     public String userID;
27     public String password;
28     public String passwordHint;
29     public String firstName;
30     public String lastName;
31     public Integer billingAddressID;
32     public Integer shippingAddressID;
33
34     public String creditCardName;
35     public String creditCardNumber;
36     public String creditCardExpirationDate;
37
38     // get CustomerModel
39     public CustomerModel getCustomerModel() throws EJBException
40     {
41         // construct new CustomerModel
42         CustomerModel customer = new CustomerModel();
43
44         // populate CustomerModel with data for this Customer
45         customer.setCustomerID( customerID );
46         customer.setUserID( userID );
47         customer.setPassword( password );
48         customer.setPasswordHint( passwordHint );
49         customer.setFirstName( firstName );
50         customer.setLastName( lastName );
51
52         // use Address EJB to get Customer billing and shipping
```

Fig. 20.2 CustomerEJB implementation of Customer remote interface (part 1 of 6).

```
53     // Address instances
54     try {
55         initialContext = new InitialContext();
56
57         Object object = initialContext.lookup(
58             "java:comp/env/ejb/Address" );
59
60         AddressHome addressHome = ( AddressHome )
61             PortableRemoteObject.narrow( object,
62                 AddressHome.class );
63
64         // get remote reference to billing Address
65         Address billingAddress =
66             addressHome.findByPrimaryKey( billingAddressID );
67
68         // add billing AddressModel to CustomerModel
69         customer.setBillingAddress(
70             billingAddress.getAddressModel() );
71
72         // get remote reference to shipping Address
73         Address shippingAddress =
74             addressHome.findByPrimaryKey( shippingAddressID );
75
76         // add shipping AddressModel to CustomerModel
77         customer.setShippingAddress(
78             shippingAddress.getAddressModel() );
79
80     } // end try
81
82     // handle exception using Address EJB
83     catch ( Exception exception ) {
84         throw new EJBException( exception );
85     }
86
87     // set credit card information in CustomerModel
88     customer.setCreditCardName( creditCardName );
89     customer.setCreditCardNumber( creditCardNumber );
90     customer.setCreditCardExpirationDate(
91         creditCardExpirationDate );
92
93     return customer;
94
95 } // end method getCustomerModel
96
97 // get Order history for Customer
98 public Collection getOrderHistory()
99     throws NoOrderHistoryException, EJBException
100 {
101     Collection history = new ArrayList();
102
103     // use Order EJB to obtain list of Orders for Customer
104     try {
```

Fig. 20.2 **CustomerEJB** implementation of **Customer** remote interface (part 2 of 6).

```
105         initialContext = new InitialContext();
106
107         Object object = initialContext.lookup(
108             "java:comp/env/ejb/Order" );
109
110         OrderHome orderHome = ( OrderHome )
111             PortableRemoteObject.narrow( object,
112                 OrderHome.class );
113
114         // find Orders for this Customer
115         Collection orders =
116             orderHome.findByCustomerID( customerID );
117
118         Iterator iterator = orders.iterator();
119
120         // use list of Orders to build Order history
121         while ( iterator.hasNext() ) {
122             Order order = ( Order ) PortableRemoteObject.narrow(
123                 iterator.next(), Order.class );
124
125             // retrieve OrderModel for the Order
126             OrderModel orderModel = order.getOrderModel();
127
128             // add each OrderModel to Order history
129             history.add( orderModel );
130         }
131
132     } // end try
133
134     // handle exception when finding Order records
135     catch ( FinderException finderException ) {
136         throw new NoOrderHistoryException( "No order " +
137             "history found for the customer with userID " +
138             userID );
139     }
140
141     // handle exception when invoking Order EJB methods
142     catch ( Exception exception ) {
143         exception.printStackTrace();
144         throw new EJBException( exception );
145     }
146
147     return history;
148
149 } // end method getOrderHistory
150
151 // get password hint for Customer
152 public String getPasswordHint()
153 {
154     return passwordHint;
155 }
156
```

Fig. 20.2 **CustomerEJB** implementation of **Customer** remote interface (part 3 of 6).

```
157 // set Customer data using CustomerModel
158 private void setCustomerModel( CustomerModel customer )
159 {
160     // set Customer data members to CustomerModel values
161     userID = customer.getUserID();
162     password = customer.getPassword();
163     passwordHint = customer.getPasswordHint();
164     firstName = customer.getFirstName();
165     lastName = customer.getLastName();
166
167     billingAddressID =
168         customer.getBillingAddress().getAddressID();
169
170     shippingAddressID =
171         customer.getShippingAddress().getAddressID();
172
173     creditCardName = customer.getCreditCardName();
174     creditCardNumber = customer.getCreditCardNumber();
175
176     creditCardExpirationDate =
177         customer.getCreditCardExpirationDate();
178
179 } // end method setCustomerModel
180
181 // create Customer EJB using given CustomerModel
182 public Integer ejbCreate( CustomerModel customerModel )
183     throws CreateException
184 {
185     // retrieve unique value for primary key using
186     // SequenceFactory EJB
187     try {
188         initialContext = new InitialContext();
189
190         // look up SequenceFactory EJB
191         Object object = initialContext.lookup(
192             "java:comp/env/ejb/SequenceFactory" );
193
194         SequenceFactoryHome sequenceFactoryHome =
195             ( SequenceFactoryHome ) PortableRemoteObject.narrow(
196                 object, SequenceFactoryHome.class );
197
198         // find sequence for Customer EJB
199         SequenceFactory sequenceFactory =
200             sequenceFactoryHome.findByPrimaryKey( "Customer" );
201
202         // retrieve next available customerID
203         customerID = sequenceFactory.getNextID();
204
205         // create Address EJBs for billing and shipping
206         // Addresses
207         object = initialContext.lookup(
208             "java:comp/env/ejb/Address" );
```

Fig. 20.2 **CustomerEJB** implementation of **Customer** remote interface  
(part 4 of 6).

```
209     AddressHome addressHome = ( AddressHome )
210         PortableRemoteObject.narrow( object,
211             AddressHome.class );
212
213
214     // get Customer's billing address
215     AddressModel billingAddressModel =
216         customerModel.getBillingAddress();
217
218     // create Address EJB for billing Address
219     Address billingAddress =
220         addressHome.create( billingAddressModel );
221
222     // set addressID in billing AddressModel
223     billingAddressModel.setAddressID( ( Integer )
224         billingAddress.getPrimaryKey() );
225
226     // get Customer's shipping address
227     AddressModel shippingAddressModel =
228         customerModel.getShippingAddress();
229
230     // create Address EJB for shipping Address
231     Address shippingAddress =
232         addressHome.create( shippingAddressModel );
233
234     // set addressID in shipping AddressModel
235     shippingAddressModel.setAddressID( ( Integer )
236         shippingAddress.getPrimaryKey() );
237
238     // use CustomerModel to set data for new Customer
239     setCustomerModel( customerModel );
240
241 } // end try
242
243 // handle exception when looking up, finding and using EJBs
244 catch ( Exception exception ) {
245     throw new CreateException( exception.getMessage() );
246 }
247
248 // EJB container will return a remote reference
249 return null;
250
251 } // end method ejbCreate
252
253 // perform any necessary post-creation tasks
254 public void ejbPostCreate( CustomerModel customer ) {}
255
256 // set EntityContext
257 public void setEntityContext( EntityContext context )
258 {
259     entityContext = context;
260 }
```

Fig. 20.2 **CustomerEJB** implementation of **Customer** remote interface  
(part 5 of 6).

```
261      // unset EntityContext
262      public void unsetEntityContext()
263      {
264          entityContext = null;
265      }
266
267      // activate Customer EJB instance
268      public void ejbActivate()
269      {
270          customerID = ( Integer ) entityContext.getPrimaryKey();
271      }
272
273      // passivate Customer EJB instance
274      public void ejbPassivate()
275      {
276          customerID = null;
277      }
278
279      // remove Customer EJB instance
280      public void ejbRemove() {}
281
282      // store Customer EJB data in database
283      public void ejbStore() {}
284
285      // load Customer EJB data from database
286      public void ejbLoad() {}
287  }
```

Fig. 20.2 **CustomerEJB** implementation of **Customer** remote interface (part 6 of 6).

Method **getCustomerModel** (lines 39–95) constructs a **CustomerModel** whose data members contain values from the **CustomerEJB**.**Address** EJBs maintain address information for each **Customer**. The **Customer** EJB stores the **addressID** for each **Address** (billing and shipping). Method **getCustomerModel** uses interface **AddressHome** to obtain the **Customer**'s **Address** EJBs (lines 65–78). For each **Address** EJB, method **getCustomerModel** obtains an **AddressModel** and adds it to the **CustomerModel**.

Method **getOrderHistory** (lines 98–149) builds a **Collection** that contains an **OrderModel** for each **Order** the **Customer** has placed. Method **findByCustomerID** of interface **OrderHome** returns a **Collection** of **Orders** for a given **Customer** (line 116). Lines 115–130 obtain the **Collection** of **Orders** and build an **Collection** of **OrderModels** to represent the **Customer**'s **Order** history.

Method **setCustomerModel** (lines 158–179) is a helper method for method **ejbCreate** (lines 182–251). Method **setCustomerModel** modifies the details of the **CustomerEJB**, using data in the **CustomerModel** argument. Lines 161–177 retrieve the data members of the **CustomerModel** and set the values of the **CustomerEJB** data members.

The EJB container invokes method **ejbCreate** (lines 182–251) when creating a new instance of the **Customer** EJB. Method **ejbCreate** takes a **CustomerModel** argu-

ment, with which it invokes method `setCustomerModel` to initialize the `CustomerEJB` data members (line 239). Method `ejbCreate` uses `SequenceFactory` method `getNextID` to generate a unique `customerID` for the new `Customer` (line 203). Each `Customer` has a billing address and a shipping address, each of which is stored in an `Address` EJB. Lines 215–236 create these `Address` EJBs, using data from the `AddressModels` given in the `CustomerModel` argument.

### 20.2.3 CustomerHome Interface

Interface `CustomerHome` (Fig. 20.3) provides `create` methods for creating new `Customers` and `finder` methods for finding existing `Customers`. Method `create` (lines 17–18) corresponds to method `ejbCreate` in the `CustomerEJB` implementation (Fig. 20.2). Method `findByLogin` (lines 21–22) returns a `Customer` remote reference for the `Customer` with the given `userID` and `password`. This method authenticates `Customers` when they attempt to log into the store. Method `findByIDUserID` (lines 25–26) returns the `Customer` with the given `userID`. Method `findByPrimaryKey` (lines 29–30) returns the `Customer` with the given `customerID`. The EJB container provides implementations for these methods, using SQL queries the developer provides when deploying the application.

```
1 // CustomerHome.java
2 // CustomerHome is the home interface for entity EJB Customer.
3 package com.deitel.advjhtp1.bookstore.ejb;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7
8 // Java standard extensions
9 import javax.ejb.*;
10
11 // Deitel Bookstore libraries
12 import com.deitel.advjhtp1.bookstore.model.*;
13
14 public interface CustomerHome extends EJBHome {
15
16     // create Customer EJB using given CustomerModel
17     public Customer create( CustomerModel customerModel )
18         throws RemoteException, CreateException;
19
20     // find Customer with given userID and password
21     public Customer findByLogin( String userID, String pass )
22         throws RemoteException, FinderException;
23
24     // find Customer with given userID
25     public Customer findByUserID( String userID )
26         throws RemoteException, FinderException;
27
28     // find Customer with given customerID
```

Fig. 20.3 `CustomerHome` interface for creating and finding `Customer` EJB instances (part 1 of 2).

```
29     public Customer findByPrimaryKey( Integer customerID )
30         throws RemoteException, FinderException;
31 }
```

Fig. 20.3 **CustomerHome** interface for creating and finding **Customer** EJB instances (part 2 of 2).

#### 20.2.4 CustomerModel

**CustomerModel** (Fig. 20.4) is a model class for the **Customer** EJB. **CustomerModel** contains **private** data members (lines 17–29) for each **public** data member in the **CustomerEJB** implementation (Fig. 20.2). Class **CustomerModel** maintains references to **AddressModel** objects for the **Customer**'s billing and shipping addresses (lines 24–25). **CustomerModel** has *set* and *get* methods for each of its properties, implements interface **XMLGenerator** and provides method **getXML** (lines 168–233), for generating an XML **Element** that describes the **Customer**.

```
1 // CustomerModel.java
2 // CustomerModel represents a Deitel Bookstore Customer,
3 // including billing, shipping and credit card information.
4 package com.deitel.advjhtp1.bookstore.model;
5
6 // Java core libraries
7 import java.io.*;
8 import java.util.*;
9
10 // third-party libraries
11 import org.w3c.dom.*;
12
13 public class CustomerModel implements Serializable,
14     XMLGenerator {
15
16     // CustomerModel properties
17     private Integer customerID;
18     private String userID;
19     private String password;
20     private String passwordHint;
21     private String firstName;
22     private String lastName;
23
24     private AddressModel billingAddress;
25     private AddressModel shippingAddress;
26
27     private String creditCardName;
28     private String creditCardNumber;
29     private String creditCardExpirationDate;
30
31     // construct empty CustomerModel
32     public CustomerModel() {}
33
34     // set customer ID
```

Fig. 20.4 **CustomerModel** for serializing **Customer** data (part 1 of 5).

```
35     public void setCustomerID( Integer id )
36     {
37         customerID = id;
38     }
39
40     // get customer ID
41     public Integer getCustomerID()
42     {
43         return customerID;
44     }
45
46     // set user ID
47     public void setUserID( String id )
48     {
49         userID = id;
50     }
51
52     // get user ID
53     public String getUserID()
54     {
55         return userID;
56     }
57
58     // set password
59     public void setPassword( String customerPassword )
60     {
61         password = customerPassword;
62     }
63
64     // get password
65     public String getPassword()
66     {
67         return password;
68     }
69
70     // set password hint
71     public void setPasswordHint( String passwordHint )
72     {
73         passwordHint = passwordHint;
74     }
75
76     // get password hint
77     public String getPasswordHint()
78     {
79         return passwordHint;
80     }
81
82     // set first name
83     public void setFirstName( String name )
84     {
85         firstName = name;
86     }
87
```

Fig. 20.4 **CustomerModel** for serializing **Customer** data (part 2 of 5).

```
88     // get first name
89     public String getFirstName()
90     {
91         return firstName;
92     }
93
94     // set last name
95     public void setLastName( String name )
96     {
97         lastName = name;
98     }
99
100    // get last name
101    public String getLastName()
102    {
103        return lastName;
104    }
105
106    // set billing address
107    public void setBillingAddress( AddressModel address )
108    {
109        billingAddress = address;
110    }
111
112    // get billing address
113    public AddressModel getBillingAddress()
114    {
115        return billingAddress;
116    }
117
118    // set shipping address
119    public void setShippingAddress( AddressModel address )
120    {
121        shippingAddress = address;
122    }
123
124    // get shipping address
125    public AddressModel getShippingAddress()
126    {
127        return shippingAddress;
128    }
129
130    // set name of credit card
131    public void setCreditCardName( String name )
132    {
133        creditCardName = name;
134    }
135
136    // get name of credit card
137    public String getCreditCardName()
138    {
139        return creditCardName;
140    }
```

Fig. 20.4 **CustomerModel** for serializing **Customer** data (part 3 of 5).

```
141
142     // set credit card number
143     public void setCreditCardNumber( String number )
144     {
145         creditCardNumber = number;
146     }
147
148     // get credit card number
149     public String getCreditCardNumber()
150     {
151         return creditCardNumber;
152     }
153
154     // set expiration date of credit card
155     public void setCreditCardExpirationDate( String date )
156     {
157         creditCardExpirationDate = date;
158     }
159
160     // get expiration date of credit card
161     public String getCreditCardExpirationDate()
162     {
163         return creditCardExpirationDate;
164     }
165
166     // build an XML representation of this Customer including
167     // all public properties as nodes
168     public Element getXML( Document document )
169     {
170         // create customer Element
171         Element customer =
172             document.createElement( "customer" );
173
174         // create customerID Element
175         Element temp = document.createElement( "customerID" );
176         temp.appendChild( document.createTextNode(
177             String.valueOf( getCustomerID() ) ) );
178         customer.appendChild( temp );
179
180         // create userID Element
181         temp = document.createElement( "userID" );
182         temp.appendChild(
183             document.createTextNode( getUserId() ) );
184         customer.appendChild( temp );
185
186         // create firstName Element
187         temp = document.createElement( "firstName" );
188         temp.appendChild( document.createTextNode(
189             getFirstName() ) );
190         customer.appendChild( temp );
191
192         // create lastName Element
193         temp = document.createElement( "lastName" );
```

Fig. 20.4 **CustomerModel** for serializing **Customer** data (part 4 of 5).

```
194     temp.appendChild( document.createTextNode(
195         getLastName() ) );
196     customer.appendChild( temp );
197
198     // create billingAddress Element
199     temp = document.createElement( "billingAddress" );
200     temp.appendChild( billingAddress.getXML( document ) );
201
202     // create shippingAddress Element
203     temp = document.createElement( "shippingAddress" );
204     temp.appendChild( shippingAddress.getXML( document ) );
205
206     // create creditCardName Element
207     temp = document.createElement( "creditCardName" );
208     temp.appendChild( document.createTextNode(
209         getCreditCardName() ) );
210     customer.appendChild( temp );
211
212     // create creditCardNumber Element
213     temp = document.createElement( "creditCardNumber" );
214     temp.appendChild( document.createTextNode(
215         getCreditCardNumber() ) );
216     customer.appendChild( temp );
217
218     // create creditCardExpirationDate Element
219     temp = document.createElement(
220         "creditCardExpirationDate" );
221     temp.appendChild( document.createTextNode(
222         getCreditCardExpirationDate() ) );
223     customer.appendChild( temp );
224
225     // create passwordHint Element
226     temp = document.createElement( "passwordHint" );
227     temp.appendChild( document.createTextNode(
228         getPasswordHint() ) );
229     customer.appendChild( temp );
230
231     return customer;
232
233 } // end method getXML
234 }
```

Fig. 20.4 **CustomerModel** for serializing **Customer** data (part 5 of 5).

Figure 20.5, Fig. 20.6 and Fig. 20.7 list the deployment settings for entity EJB **Customer**. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods.

## 20.3 Address Implementation

The application maintains a billing address and a shipping address for each **Customer**. Each address contains similar information (e.g., street address, city, state and zip code), so we abstract these two address types into a single **Address** EJB. Each **Customer** EJB stores an ID for the billing address and an ID for the shipping address.

**Customer General Deployment Settings**

<b>Bean Type</b>	Entity
<b>Enterprise Bean Class</b>	com.deitel.advjhttp1.bookstore.ejb.CustomerEJB
<b>Home Interface</b>	com.deitel.advjhttp1.bookstore.ejb.CustomerHome
<b>Remote Interface</b>	com.deitel.advjhttp1.bookstore.ejb.Customer

**Fig. 20.5** *Customer* general deployment settings.**Customer Entity and Deployment Settings**

<b>Persistence Management</b>	Container-Managed Persistence
<b>Primary Key Class</b>	java.lang.Integer
<b>Primary Key Field Name</b>	customerID
<b>Database JNDI Name</b>	jdbc/Bookstore
<b>Method findBy- userID SQL Statement</b>	SELECT customerID FROM Customer WHERE userID = ?1
<b>Method findBy- Login SQL Statement</b>	SELECT customerID FROM Customer WHERE userID = ?1 AND password = ?2
<b>Method ejb- Store SQL Statement</b>	UPDATE Customer SET billingAddressID = ?, creditCardExpirationDate = ?, creditCardName = ?, creditCardNumber = ?, firstName = ?, lastName = ?, password = ?, passwordHint = ?, shippingAddressID = ?, userID = ? WHERE customerID = ?
<b>Method ejb- Create SQL Statement</b>	INSERT INTO Customer ( billingAddressID, creditCardExpirationDate, creditCardName, creditCardNumber, customerID, firstName, lastName, password, passwordHint, shippingAddressID, userID ) VALUES ( ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ? )

**Fig. 20.6** *Customer* entity and deployment settings (part 1 of 2).

**Customer Entity and Deployment Settings**

Method <b>ejb-Remove SQL Statement</b>	<code>DELETE FROM Customer WHERE customerID = ?</code>
Method <b>find-ByPrimaryKey SQL Statement</b>	<code>SELECT customerID FROM Customer WHERE customerID = ?</code>
Method <b>ejb-Load SQL Statement</b>	<code>SELECT billingAddressID, creditCardExpirationDate, creditCardName, creditCardNumber, firstName, lastName, password, passwordHint, shippingAddressID, userID FROM Customer WHERE customerID = ?</code>
<b>Table Create SQL Statement</b>	<code>CREATE TABLE Customer ( billingAddressID INTEGER, creditCardExpirationDate VARCHAR( 255 ), creditCardName VARCHAR( 255 ), creditCardNumber VARCHAR( 255 ), customerID INTEGER, firstName VARCHAR( 255 ), lastName VARCHAR( 255 ), password VARCHAR( 255 ), passwordHint VARCHAR( 255 ), shippingAddressID INTEGER, userID VARCHAR( 255 ), CONSTRAINT pk_Customer PRIMARY KEY ( customerID ) )</code>
<b>Table Delete SQL Statement</b>	<code>DROP TABLE Customer</code>

**Fig. 20.6** *Customer* entity and deployment settings (part 2 of 2).**Customer EJB References**

Coded Name	<code>ejb/Order</code>
Type	<code>Entity</code>
Home	<code>com.deitel.advjhttp1.bookstore.ejb.OrderHome</code>
Remote	<code>com.deitel.advjhttp1.bookstore.ejb.Order</code>
JNDI Name	<code>Order</code>
Coded Name	<code>ejb/SequenceFactory</code>
Type	<code>Entity</code>
Home	<code>com.deitel.advjhttp1.bookstore.ejb.SequenceFactoryHome</code>
Remote	<code>com.deitel.advjhttp1.bookstore.ejb.SequenceFactory</code>
JNDI Name	<code>SequenceFactory</code>
Coded Name	<code>ejb/Address</code>

**Fig. 20.7** *Customer* EJB References (part 1 of 2).

**Customer EJB References**

Type	Entity
Home	com.deitel.advjhttp1.bookstore.ejb.AddressHome
Remote	com.deitel.advjhttp1.bookstore.ejb.Address
JNDI Name	Address

Fig. 20.7 Customer EJB References (part 2 of 2).

**20.3.1 Address Remote Interface**

The **Address** remote interface (Fig. 20.8) has *set* and *get* methods for updating data in and retrieving data from the **Address** EJB. Method **getAddressModel** (lines 17–18) constructs an **AddressModel** that contains the details of a particular **Address** EJB.

**20.3.2 AddressEJB Implementation**

**AddressEJB** (Fig. 20.9) is the implementation of the **Address** remote interface. Class **AddressEJB** contains **public**, container-managed data members for the first and last names of the contact person at the **Address**, as well as the street address, city, state, zip code, country and phone number (lines 24–33).

```

1 // Address.java
2 // Address is the remote interface for entity EJB Address.
3 package com.deitel.advjhttp1.bookstore.ejb;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7
8 // Java standard extensions
9 import javax.ejb.*;
10
11 // Deitel Bookstore libraries
12 import com.deitel.advjhttp1.bookstore.model.*;
13
14 public interface Address extends EJBObject {
15
16     // get Address data as an AddressModel
17     public AddressModel getAddressModel()
18         throws RemoteException;
19 }
```

Fig. 20.8 Address remote interface for modifying **Address** details.

```

1 // AddressEJB.java
2 // Entity EJB Address represents an Address, including
3 // the street address, city, state and zip code.
```

Fig. 20.9 AddressEJB implementation of **Address** remote interface (part 1 of 4).

```
4 package com.deitel.advjhttp1.bookstore.ejb;
5
6 // Java core packages
7 import java.util.*;
8 import java.rmi.RemoteException;
9
10 // Java extension packages
11 import javax.ejb.*;
12 import javax.naming.*;
13 import javax.rmi.PortableRemoteObject;
14
15 // Deitel packages
16 import com.deitel.advjhttp1.bookstore.model.*;
17 import com.deitel.advjhttp1.bookstore.exceptions.*;
18
19 public class AddressEJB implements EntityBean {
20     private EntityContext entityContext;
21
22     // container-managed fields
23     public Integer addressID;
24     public String firstName;
25     public String lastName;
26     public String streetAddressLine1;
27     public String streetAddressLine2;
28     public String city;
29     public String state;
30     public String zipCode;
31     public String country;
32     public String phoneNumber;
33
34     // get AddressModel
35     public AddressModel getAddressModel()
36     {
37         // construct new AddressModel
38         AddressModel address = new AddressModel();
39
40         // populate AddressModel fields with Address EJB
41         // data members
42         address.setAddressID( addressID );
43         address.setFirstName( firstName );
44         address.setLastName( lastName );
45         address.setStreetAddressLine1( streetAddressLine1 );
46         address.setStreetAddressLine2( streetAddressLine2 );
47         address.setCity( city );
48         address.setState( state );
49         address.setZipCode( zipCode );
50         address.setCountry( country );
51         address.setPhoneNumber( phoneNumber );
52
53         return address;
54     }
55 } // end method getAddressModel
56
```

Fig. 20.9 AddressEJB implementation of **Address** remote interface (part 2 of 4).

```
57 // set Address data using AddressModel
58 private void setAddressModel( AddressModel address )
59 {
60     // update Address' data members using values provided
61     // in the AddressModel
62     firstName = address.getFirstName();
63     lastName = address.getLastName();
64     streetAddressLine1 = address.getStreetAddressLine1();
65     streetAddressLine2 = address.getStreetAddressLine2();
66     city = address.getCity();
67     state = address.getState();
68     zipCode = address.getZipCode();
69     country = address.getCountry();
70     phoneNumber = address.getPhoneNumber();
71
72 } // end method setAddressModel
73
74 // create Address EJB using given AddressModel
75 public Integer ejbCreate( AddressModel address )
76     throws CreateException
77 {
78     // retrieve unique value for primary key using
79     // SequenceFactory EJB
80     try {
81         Context initialContext = new InitialContext();
82
83         // look up SequenceFactory EJB
84         Object object = initialContext.lookup(
85             "java:comp/env/ejb/SequenceFactory" );
86
87         SequenceFactoryHome sequenceFactoryHome =
88             ( SequenceFactoryHome )
89             PortableRemoteObject.narrow(
90                 object, SequenceFactoryHome.class );
91
92         // find sequence for Address EJB
93         SequenceFactory sequenceFactory =
94             sequenceFactoryHome.findByPrimaryKey( "Address" );
95
96         // retrieve next available addressID
97         addressID = sequenceFactory.getNextID();
98
99         // set addressID for Address (primary key)
100        address.setAddressID( addressID );
101
102        // use AddressModel to set data for new Address
103        setAddressModel( address );
104
105    } // end try
106
107    // handle exception using SequenceFactory EJB
108    catch ( Exception exception ) {
109        throw new CreateException( exception.getMessage() );
110    }
111 }
```

Fig. 20.9 AddressEJB implementation of **Address** remote interface (part 3 of 4).

```
110      }
111
112      // EJB container will return a remote reference
113      return null;
114
115  } // end method ejbCreate
116
117  // perform any necessary post-creation tasks
118  public void ejbPostCreate( AddressModel address ) {}
119
120  // set EntityContext
121  public void setEntityContext( EntityContext context )
122  {
123      entityContext = context;
124  }
125
126  // unset EntityContext
127  public void unsetEntityContext()
128  {
129      entityContext = null;
130  }
131
132  // activate Address EJB instance
133  public void ejbActivate()
134  {
135      addressID = ( Integer ) entityContext.getPrimaryKey();
136  }
137
138  // passivate Address EJB instance
139  public void ejbPassivate()
140  {
141      addressID = null;
142  }
143
144  // remove Address EJB instance
145  public void ejbRemove() {}
146
147  // store Address EJB data in database
148  public void ejbStore() {}
149
150  // load Address EJB data from database
151  public void ejbLoad() {}
152 }
```

Fig. 20.9 **AddressEJB** implementation of **Address** remote interface (part 4 of 4).

Method **getAddressModel** (lines 35–55) constructs an **AddressModel**, sets its properties to the values of the **Address** EJB's **public** data members and returns the **AddressModel** to the caller. Method **setAddressModel** (lines 58–72) is a utility method that takes an **AddressModel** argument and updates the values in the **AddressEJB**'s data members.

The EJB container invokes method **ejbCreate** (lines 75–115) to create a new **AddressEJB**. Each **Address** must have a unique **addressID** for its primary key.

**SequenceFactory** method **getNextID** (line 97) generates this unique **addressID**. Line 100 sets the **addressID** value in the **AddressModel**. Line 103 passes the **AddressModel** to method **setAddressModel** to complete initialization of the **AddressEJB**.

### 20.3.3 AddressHome Interface

Interface **AddressHome** (Fig. 20.10) provides methods for creating and finding **Address** EJBs. Method **create** (lines 18–19) takes an **AddressModel** argument. The EJB container invokes method **ejbCreate** (Fig. 20.9) when a client invokes method **create**. Method **findByPrimaryKey** (lines 22–23) locates an existing **Address** EJB, using its **addressID** primary key, and returns a remote reference to the **Address**.

### 20.3.4 AddressModel

Class **AddressModel** (Fig. 20.11) is a model class that implements interface **XMLGenerator** and method **getXML** to generate an XML description of an **Address**. Class **AddressModel** contains properties (lines 17–149) for each **public** data member in the **AddressEJB** implementation (Fig. 20.9). Method **getXML** (lines 152–212) builds an XML **Element** that contains child **Elements** for each of the **AddressModel**'s properties.

```
1 // AddressHome.java
2 // AddressHome is the home interface for entity EJB Address.
3 package com.deitel.advjhttp1.bookstore.ejb;
4
5 // Java core libraries
6 import java.rmi.RemoteException;
7
8 // Java standard extensions
9 import javax.ejb.EJBHome;
10 import javax.ejb.*;
11
12 // Deitel Bookstore libraries
13 import com.deitel.advjhttp1.bookstore.model.*;
14
15 public interface AddressHome extends EJBHome {
16
17     // create Address EJB using given AddressModel
18     public Address create( AddressModel address )
19         throws RemoteException, CreateException;
20
21     // find Address with given addressID
22     public Address findByPrimaryKey( Integer addressID )
23         throws RemoteException, FinderException;
24 }
```

Fig. 20.10 **AddressHome** interface for creating and finding **Address** EJB instances.

```
1 // AddressModel.java
2 // AddressModel represents a Customer's address, including
3 // street, city, state and zip code.
4 package com.deitel.advjhttp1.bookstore.model;
5
6 // Java core libraries
7 import java.io.*;
8 import java.util.*;
9
10 // third-party libraries
11 import org.w3c.dom.*;
12
13 public class AddressModel implements Serializable,
14     XMLGenerator {
15
16     // AddressModel properties
17     private Integer addressID;
18     private String firstName;
19     private String lastName;
20     private String streetAddressLine1;
21     private String streetAddressLine2;
22     private String city;
23     private String state;
24     private String zipCode;
25     private String country;
26     private String phoneNumber;
27
28     // construct empty AddressModel
29     public AddressModel() {}
30
31     // set addressID
32     public void setAddressID( Integer id )
33     {
34         addressID = id;
35     }
36
37     // get addressID
38     public Integer getAddressID()
39     {
40         return addressID;
41     }
42
43     // set first name
44     public void setFirstName( String name )
45     {
46         firstName = name;
47     }
48
49     // get first name
50     public String getFirstName()
51     {
52         return firstName;
53     }
54
```

Fig. 20.11 **AddressModel** for serializing **Address** EJB data (part 1 of 4).

```
55     // set last name
56     public void setLastName( String name )
57     {
58         lastName = name;
59     }
60
61     // get last name
62     public String getLastName()
63     {
64         return lastName;
65     }
66
67     // set first line of street address
68     public void setStreetAddressLine1( String address )
69     {
70         streetAddressLine1 = address;
71     }
72
73     // get first line of street address
74     public String getStreetAddressLine1()
75     {
76         return streetAddressLine1;
77     }
78
79     // set second line of street address
80     public void setStreetAddressLine2( String address )
81     {
82         streetAddressLine2 = address;
83     }
84
85     // get second line of street address
86     public String getStreetAddressLine2()
87     {
88         return streetAddressLine2;
89     }
90
91     // set city
92     public void setCity( String addressCity )
93     {
94         city = addressCity;
95     }
96
97     // get city
98     public String getCity()
99     {
100        return city;
101    }
102
103    // set state
104    public void setState( String addressState )
105    {
106        state = addressState;
107    }
108
```

Fig. 20.11 **AddressModel** for serializing **Address** EJB data (part 2 of 4).

```
109     // get state
110    public String getState()
111    {
112        return state;
113    }
114
115    // set zip code
116    public void setZipCode( String zip )
117    {
118        zipCode = zip;
119    }
120
121    // get zip code
122    public String getZipCode()
123    {
124        return zipCode;
125    }
126
127    // set country
128    public void setCountry( String addressCountry )
129    {
130        country = addressCountry;
131    }
132
133    // get country
134    public String getCountry()
135    {
136        return country;
137    }
138
139    // set phone number
140    public void setPhoneNumber( String phone )
141    {
142        phoneNumber = phone;
143    }
144
145    // get phone number
146    public String getPhoneNumber()
147    {
148        return phoneNumber;
149    }
150
151    // build XML representation of Customer
152    public Element getXML( Document document )
153    {
154        // create address Element
155        Element address = document.createElement( "address" );
156
157        // create firstName Element
158        Element temp = document.createElement( "firstName" );
159        temp.appendChild(
160            document.createTextNode( getFirstName() ) );
161        address.appendChild( temp );
162
163        // create lastName Element
```

Fig. 20.11 **AddressModel** for serializing **Address** EJB data (part 3 of 4).

```
164     temp = document.createElement( "lastName" );
165     temp.appendChild(
166         document.createTextNode( getLastName() ) );
167     address.appendChild( temp );
168
169     // create streetAddressLine1 Element
170     temp = document.createElement( "streetAddressLine1" );
171     temp.appendChild(
172         document.createTextNode( getStreetAddressLine1() ) );
173     address.appendChild( temp );
174
175     // create streetAddressLine2 Element
176     temp = document.createElement( "streetAddressLine2" );
177     temp.appendChild(
178         document.createTextNode( getStreetAddressLine2() ) );
179     address.appendChild( temp );
180
181     // create city Element
182     temp = document.createElement( "city" );
183     temp.appendChild( document.createTextNode( city ) );
184     address.appendChild( temp );
185
186     // create state Element
187     temp = document.createElement( "state" );
188     temp.appendChild(
189         document.createTextNode( getState() ) );
190     address.appendChild( temp );
191
192     // create zipCode Element
193     temp = document.createElement( "zipCode" );
194     temp.appendChild(
195         document.createTextNode( getZipCode() ) );
196     address.appendChild( temp );
197
198     // create country Element
199     temp = document.createElement( "country" );
200     temp.appendChild(
201         document.createTextNode( getCountry() ) );
202     address.appendChild( temp );
203
204     // create phoneNumber Element
205     temp = document.createElement( "phoneNumber" );
206     temp.appendChild(
207         document.createTextNode( getPhoneNumber() ) );
208     address.appendChild( temp );
209
210     return address;
211
212 } // end method getXML
213 }
```

Fig. 20.11 **AddressModel** for serializing **Address** EJB data (part 4 of 4).

Figure 20.12, Fig. 20.13 and Fig. 20.14 show the deployment settings for entity EJB **Address**. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods.

**Address General Deployment Settings**

<b>Bean Type</b>	Entity
<b>Enterprise Bean Class</b>	com.deitel.advjhttp1.bookstore.ejb.AddressEJB
<b>Home Interface</b>	com.deitel.advjhttp1.bookstore.ejb.AddressHome
<b>Remote Interface</b>	com.deitel.advjhttp1.bookstore.ejb.Address

**Fig. 20.12 Address General deployment settings.****Address Entity and Deployment Settings**

<b>Persistence Management</b>	Container-Managed Persistence
<b>Primary Key Class</b>	java.lang.Integer
<b>Primary Key Field Name</b>	addressID
<b>Database JNDI Name</b>	jdbc/Bookstore
<b>Method ejb-Store SQL Statement</b>	UPDATE Address SET city = ?, country = ?, firstName = ?, lastName = ?, phoneNumber = ?, state = ?, streetAddressLine1 = ?, streetAddressLine2 = ?, zipCode = ? WHERE addressID = ?
<b>Method ejb-Create SQL Statement</b>	INSERT INTO Address ( addressID, city, country, firstName, lastName, phoneNumber, state, streetAddressLine1, streetAddressLine2, zipCode ) VALUES ( ?, ?, ?, ?, ?, ?, ?, ?, ?, ? )
<b>Method ejb-Remove SQL Statement</b>	DELETE FROM Address WHERE addressID = ?
<b>Method find-ByPrimaryKey SQL Statement</b>	SELECT addressID FROM Address WHERE addressID = ?
<b>Method ejb-Load SQL Statement</b>	SELECT city, country, firstName, lastName, phoneNumber, state, streetAddressLine1, streetAddressLine2, zipCode FROM Address WHERE addressID = ?

**Fig. 20.13 Address entity and deployment settings (part 1 of 2).**

**Address Entity and Deployment Settings**

<b>Table Create SQL Statement</b>	<code>CREATE TABLE Address ( addressID INTEGER, city VARCHAR( 255 ), country VARCHAR( 255 ), firstName VARCHAR( 255 ), lastName VARCHAR( 255 ), phoneNumber VARCHAR( 255 ), state VARCHAR( 255 ), streetAddressLine1 VARCHAR( 255 ), streetAddressLine2 VARCHAR( 255 ), zipCode VARCHAR( 255 ), CONSTRAINT pk_Address PRIMARY KEY ( addressID ) )</code>
<b>Table Delete SQL Statement</b>	<code>DROP TABLE Address</code>

Fig. 20.13 **Address** entity and deployment settings (part 2 of 2).**Address EJB References**

<b>Coded Name</b>	<code>ejb/SequenceFactory</code>
<b>Type</b>	<code>Entity</code>
<b>Home</b>	<code>com.deitel.advjhttp1.bookstore.ejb.SequenceFactory-Home</code>
<b>Remote</b>	<code>com.deitel.advjhttp1.bookstore.ejb.SequenceFactory</code>
<b>JNDI Name</b>	<code>SequenceFactory</code>

Fig. 20.14 **Address** EJB references.

## 20.4 SequenceFactory Implementation

One of the fundamental concepts in relational databases is that of a primary key, which uniquely identifies a row in a database table. The primary key is needed to define relationships between tables in the database. For example, in our case study, each **Order** relates to a **Customer** by storing the **Customer** table's primary key—**customerID**—as a field (called a *foreign key*) in the **Order** table. The **customerID** is guaranteed to be unique, so it can be used to determine which **Customer** placed an **Order**. The **Customer**, **Order** and **Address** EJBs all have **SequenceFactory** records from which these EJBs can obtain primary keys.

### 20.4.1 SequenceFactory Remote Interface

Interface **SequenceFactory** (Fig. 20.15) is the remote interface for the **SequenceFactory** EJB. Method **getNextID** (line 15) returns the next available primary key.

```
1 // SequenceFactory.java
2 // SequenceFactory is the remote interface for the entity EJB
3 // SequenceFactory.
4 package com.deitel.advjhtp1.bookstore.ejb;
5
6 // Java core packages
7 import java.rmi.RemoteException;
8
9 // Java extension packages
10 import javax.ejb.EJBObject;
11
12 public interface SequenceFactory extends EJBObject {
13
14     // get next available unique ID
15     public Integer getNextID() throws RemoteException;
16 }
```

Fig. 20.15 **SequenceFactory** remote interface for generating primary keys.

#### 20.4.2 SequenceFactoryEJB Implementation

Figure 20.16 shows the **SequenceFactoryEJB** implementation of the **SequenceFactory** remote interface. The EJB container manages the synchronization of the **public** data members (lines 19–22) with the database.

Method **getNextOrderID** (lines 25–31) calculates the next available unique **orderID** by incrementing the current value of the **orderID** (line 27). This new value is saved in the EJB (line 28) and returned to the caller (line 30). Method **getNextCustomerID**, (lines 34–40) increments the current value of the **customerID** field and returns the value to the caller (line 39). Method **getNextAddressID** (lines 43–49) increments the value of the **addressID** field and returns the value to the caller on line 48.

For the **SequenceFactory** EJB to calculate unique **orderIDs**, **customerIDs** and **addressIDs** properly, there must be only one **SequenceFactory** EJB instance. If there were more than one **SequenceFactory** EJB instance, duplicate **orderIDs**, **customerIDs** or **addressIDs** could be generated. **SequenceFactory** EJB clients should use only method **findSequenceFactory** of interface **SequenceFactoryHome** to obtain the correct **SequenceFactory** EJB instance. The deployer must specify an SQL query that will return the same **SequenceFactory** record each time a method **findSequenceFactory** is invoked.

```
1 // SequenceFactoryEJB.java
2 // Entity EJB SequenceFactory generates unique primary keys.
3 package com.deitel.advjhtp1.bookstore.ejb;
4
5 // Java core packages
6 import java.rmi.RemoteException;
7 import java.util.ArrayList;
8
9 // Java extension packages
```

Fig. 20.16 **SequenceFactoryEJB** implementation of **SequenceFactory** remote interface (part 1 of 3).

```
10 import javax.ejb.*;
11 import javax.naming.*;
12 import javax.rmi.PortableRemoteObject;
13
14 public class SequenceFactoryEJB implements EntityBean {
15     private EntityContext entityContext;
16
17     // container-managed fields
18     public String tableName;    // table name for ID sequence
19     public Integer nextID;      // next available unique ID
20
21     // get next available orderID
22     public Integer getNextID()
23     {
24         // store nextID for returning to caller
25         Integer ID = new Integer( nextID.intValue() );
26
27         // increment ID to produce next available unique ID
28         nextID = new Integer( ID.intValue() + 1 );
29
30         return ID;
31     }
32
33     // set entity context
34     public void setEntityContext( EntityContext context )
35     {
36         entityContext = context;
37     }
38
39     // unset entity context
40     public void unsetEntityContext()
41     {
42         entityContext = null;
43     }
44
45     // activate SequenceFactory EJB instance
46     public void ejbActivate()
47     {
48         tableName = ( String ) entityContext.getPrimaryKey();
49     }
50
51     // passivate SequenceFactory EJB instance
52     public void ejbPassivate()
53     {
54         tableName = null;
55     }
56
57     // remove SequenceFactory EJB instance
58     public void ejbRemove() {}
59
60     // store SequenceFactory EJB data in database
61     public void ejbStore() {}
```

Fig. 20.16 **SequenceFactoryEJB** implementation of **SequenceFactory** remote interface (part 2 of 3).

```
62
63     // load SequenceFactory EJB data from database
64     public void ejbLoad() {}
65 }
```

Fig. 20.16 **SequenceFactoryEJB** implementation of **SequenceFactory** remote interface (part 3 of 3).

### 20.4.3 **SequenceFactoryHome** Interface

Interface **SequenceFactoryHome** (Fig. 20.17) is the home interface for the **SequenceFactory** EJB. Method **findByPrimaryKey** (lines 15–16) returns a remote reference to the **SequenceFactory** EJB for the database table with the given name.

Figure 20.18 and Fig. 20.19 show the deployment settings for entity EJB **SequenceFactory**. In addition to the settings shown here, be sure to set the **Transaction Type** to **Required** for all business methods.

```
1 // SequenceFactoryHome.java
2 // SequenceFactoryHome is the home interface for entity EJB
3 // SequenceFactory.
4 package com.deitel.advjhttp1.bookstore.ejb;
5
6 // Java core packages
7 import java.rmi.RemoteException;
8
9 // Java extension packages
10 import javax.ejb.*;
11
12 public interface SequenceFactoryHome extends EJBHome {
13
14     // find SequenceFactory with given primary key
15     public SequenceFactory findByPrimaryKey( String tableName )
16         throws RemoteException, FinderException;
17 }
```

Fig. 20.17 **SequenceFactoryHome** interface for finding **SequenceFactory** EJB instances.

#### SequenceFactory General Deployment Settings

Bean Type	Entity
Enterprise Bean Class	com.deitel.advjhttp1.bookstore.ejb.SequenceFactoryEJB

Fig. 20.18 **SequenceFactory** general deployment settings (part 1 of 2).

**SequenceFactory General Deployment Settings**

Home Interface	com.deitel.advjhttp1.bookstore.ejb.SequenceFactoryHome
Remote Interface	com.deitel.advjhttp1.bookstore.ejb.SequenceFactory

Fig. 20.18 **SequenceFactory** general deployment settings (part 2 of 2).**SequenceFactory Entity and Deployment Settings**

Persistence Management	Container-Managed Persistence
Primary Key Class	java.lang.String
Primary Key Field Name	tableName
Database JNDI Name	jdbc/Bookstore
Method ejb-Store SQL Statement	UPDATE SequenceFactory SET nextID = ? WHERE tableName = ?
Method ejb-Create SQL Statement	INSERT INTO SequenceFactory ( nextID, tableName ) VALUES ( ?, ? )
Method ejb-Remove SQL Statement	DELETE FROM SequenceFactory WHERE tableName = ?
Method find-ByPrimaryKey SQL Statement	SELECT tableName FROM SequenceFactory WHERE tableName = ?
Method ejb-Load SQL Statement	SELECT nextID FROM SequenceFactory WHERE tablename = ?
Table Create SQL Statement	CREATE TABLE SequenceFactory ( nextID INTEGER, tableName VARCHAR( 255 ), CONSTRAINT pk_SequenceFactory PRIMARY KEY ( tableName ) )
Table Delete SQL Statement	DROP TABLE SequenceFactory

Fig. 20.19 **SequenceFactory** entity and deployment settings.

## 20.5 Deitel Bookstore Application Deployment with J2EE

Deploying the components of the Deitel Bookstore on the Java 2 Enterprise Edition (J2EE) Reference Implementation requires the use of the **Application Deployment Tool**. The following steps walk through the process of deploying the **Order** EJB. The deployment process for the other entity EJBs is similar. For general instructions on deploying stateful session EJBs, such as the **ShoppingCart** EJB, please refer to Chapter 14, Session EJBs and Distributed Transactions. For general instructions on deploying Java servlets, please refer to Chapter 11, Case Study: Servlet and JSP Bookstore.

### 20.5.1 Deploying Deitel Bookstore CMP Entity EJBs

To begin deploying the entity EJBs for the Deitel Bookstore, select the **New Enterprise Bean...** menu item in the **Application Deployment Tool**'s **File** menu (Fig. 20.20) to begin deploying the EJB. You then will be presented with a wizard-style interface for creating the EJB JAR file (Fig. 20.21). The **JAR Display Name** field contains the text that will appear for this EJB JAR in the **Application Deployment Tool**, but has no effect on the deployment of the application. Click the **Add...** button next to the **Contents** field to add the class files for the EJB to the JAR.

To add the EJB class files to the EJB JAR file, you must specify the **Root Directory** that contains the class' package structure (Fig. 20.22). For example, the **Order** EJB is in the package **com.deitel.advjhttp1.bookstore.ejb**. If the compiled class file is placed in the directory **D:\BookStore\com\deitel\advjhttp1\bookstore\ejb\**, select **D:\BookStore** as the **Root Directory**. Click the **Browse...** button to use a file selection dialog to select the **Root Directory**.

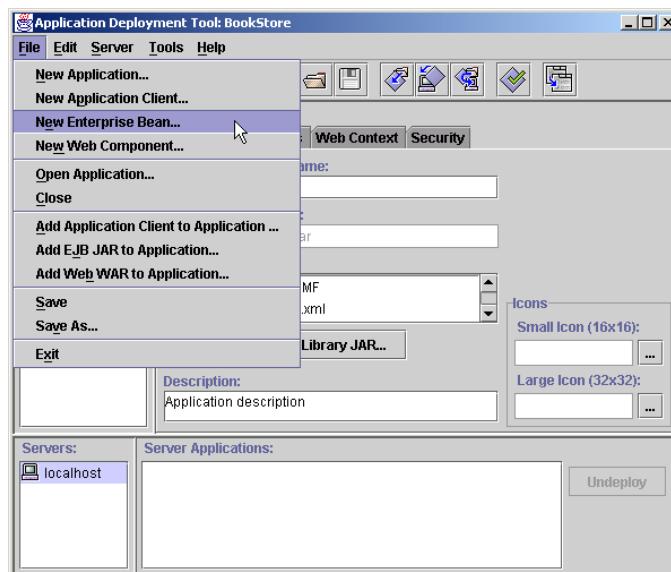
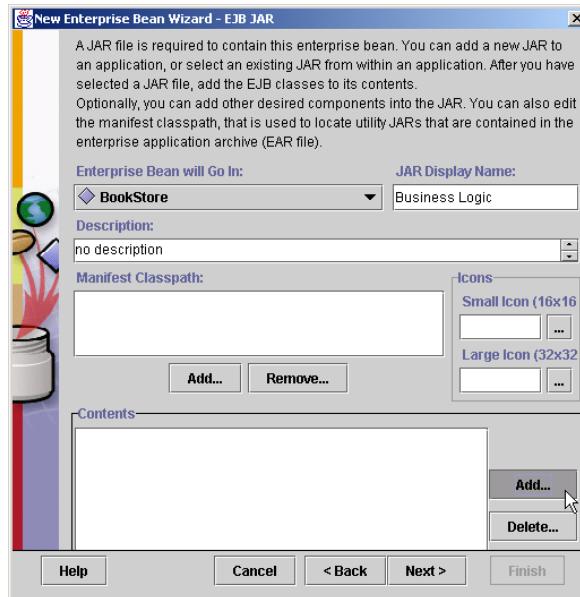
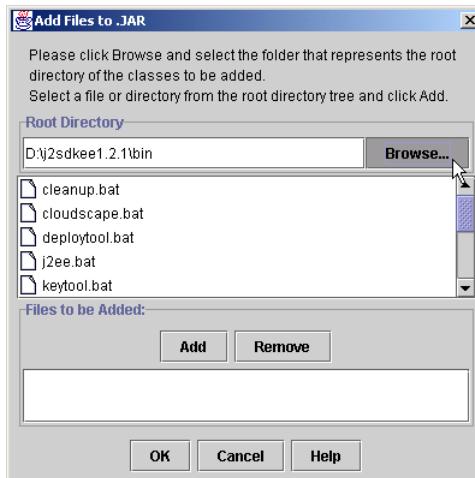


Fig. 20.20 Adding an EJB to an enterprise application.



**Fig. 20.21** Creating an EJB JAR file.



**Fig. 20.22** Specifying the **Root Directory** for EJB classes.

Once you have selected the proper **Root Directory**, select the class files for the EJB remote interface, home interface, implementation and other classes that the EJB requires (e.g., **OrderModel.class**, **XMLGenerator.class**, application-specific exception classes, etc.). By holding down the *CTRL* key, you may select multiple files at once. Click the **Add** button to add the selected class files to the EJB JAR and click **OK** (Fig. 20.23). Figure 20.24 shows the results of adding the class files for the **Order** EJB to the EJB JAR file.

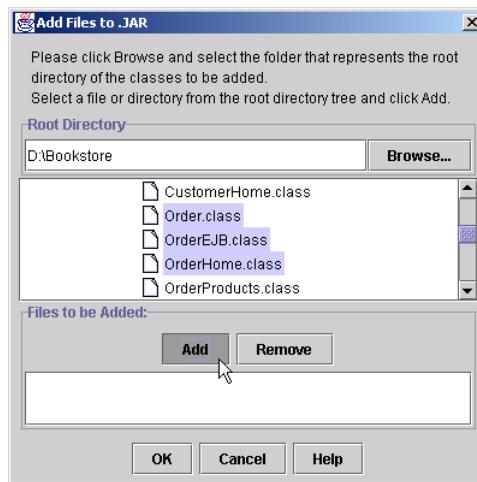


Fig. 20.23 Adding EJB classes to an EJB JAR file.

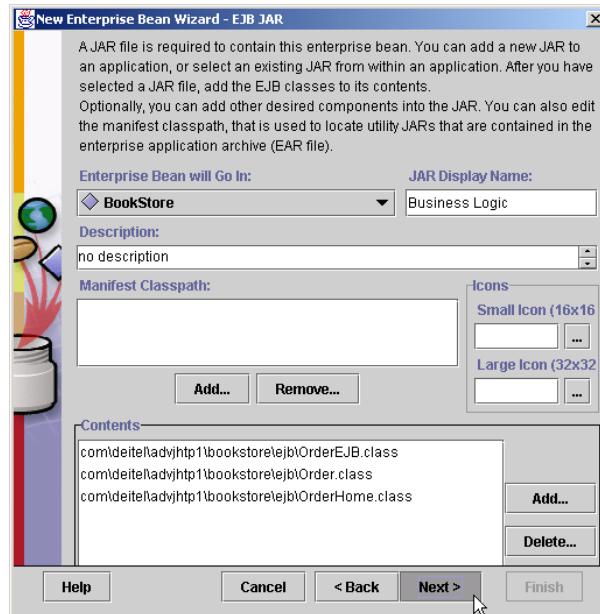


Fig. 20.24 Results of adding EJB classes to an EJB JAR file.

Once you have added the class files to the EJB JAR file, you must specify the class files that contain the remote interface, the home interface and the EJB implementation (Fig. 20.25). Select the appropriate class from the drop-down list as shown in Fig. 20.25. The **Order** EJB is an entity bean, so select the **Entity** radio button under the **Bean Type** heading (Fig. 20.26).

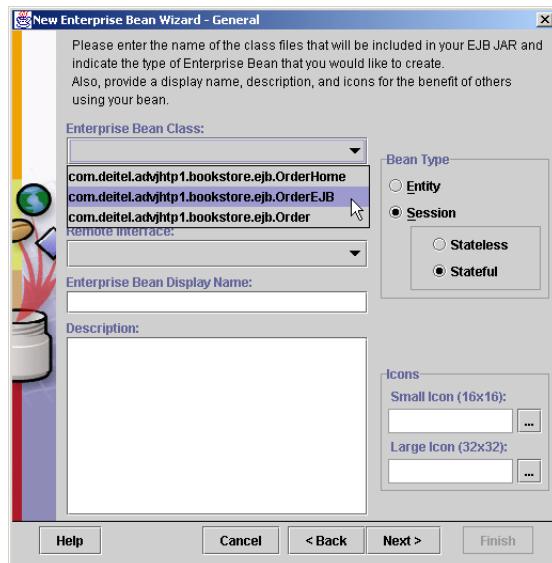


Fig. 20.25 Specifying classes for EJB, home interface and remote interface.

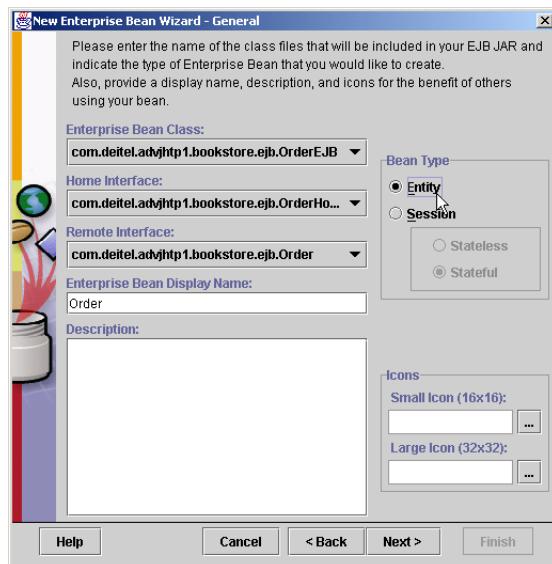


Fig. 20.26 Setting Bean Type to Entity.

The **Order** EJB uses container-managed persistence to synchronize its data with the corresponding database table. In the following step of the EJB wizard (Fig. 20.27), select the **Container-Managed Persistence** radio button and place checkmarks next to each of the container-managed fields. Specify the complete class name of the primary-key class (including its package name) in the **Primary Key Class** field. For the **Order** EJB, enter

**java.lang.Integer** as the primary-key class. If your EJB uses a user-defined primary-key class (e.g., the **OrderProduct** EJB), you must also specify the complete package name (e.g., **com.deitel.advjhttp1.bookstore.ejb.OrderProductPK**). Select the field that contains the primary key from the **Primary Key Field Name** drop-down list (e.g., **orderId**).

If your EJB references other EJBs in its implementation, these EJBs must be specified in the **Application Deployment Tool** (Fig. 20.28). Click the **Add** button to add a new EJB reference. The **Coded Name** column corresponds to the **String** used to locate the EJB in the JNDI directory. For example, to locate the **Product** EJB, we use the **String** **java:comp/env/ejb/Product**. The corresponding coded name is **ejb/Product**. Select the appropriate type for the EJB (i.e., **Session** or **Entity**) from the **Type** drop-down list. Provide the full class name (including the package name) for the home and remote interfaces in the **Home** and **Remote** columns. For example, in the **Home** column for the **Product** EJB, specify **com.deitel.advjhttp1.bookstore.ejb.ProductHome**. Enter the JNDI name for the referenced EJB in the **JNDI Name** field (e.g., **Product**).

J2EE application servers provide transaction management, the semantics of which can be specified when deploying an application. For each of the business methods, specify the appropriate **Transaction Type** (Fig. 20.29), as discussed in Chapter 15.

Figure 20.30 shows the XML descriptor that was generated by the previous steps. This XML descriptor can be used when deploying this application on any J2EE-compliant application server.

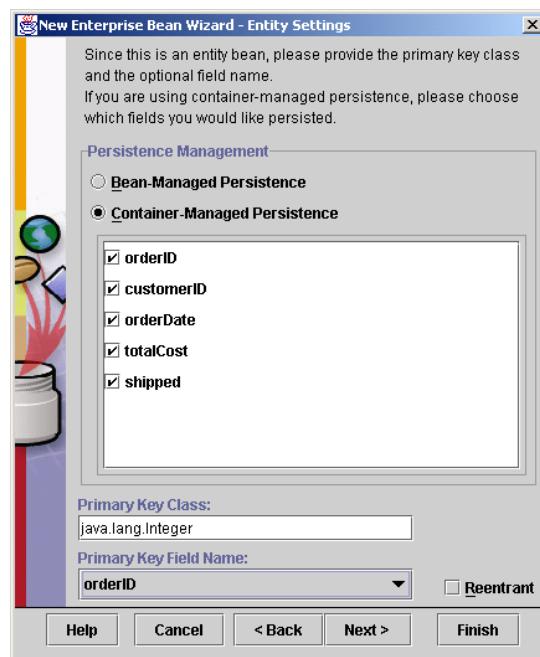


Fig. 20.27 Configuring container-managed fields and primary-key class.

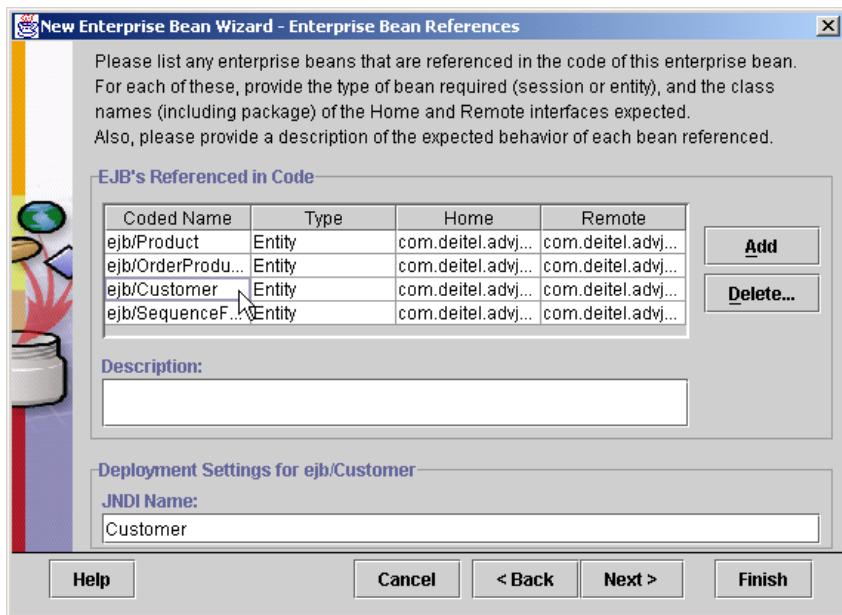


Fig. 20.28 Specifying other EJBs referenced by this EJB.

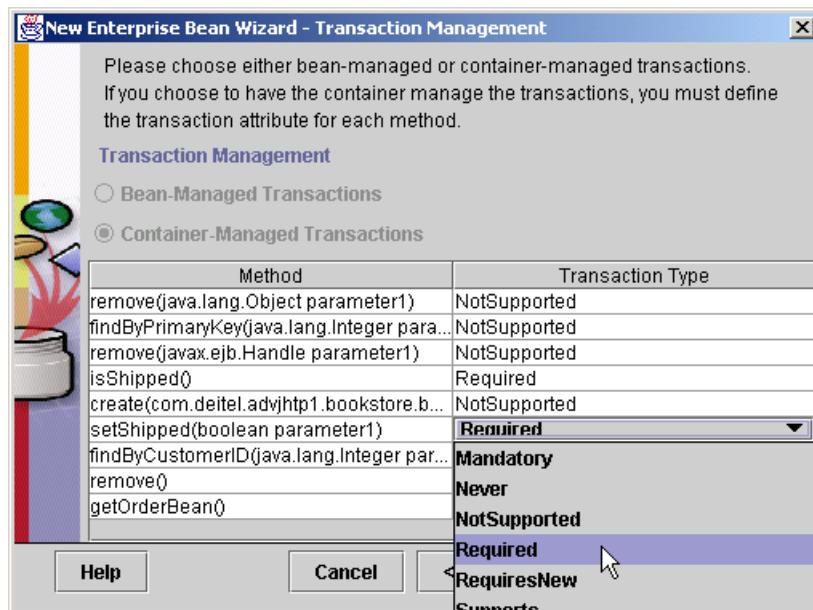
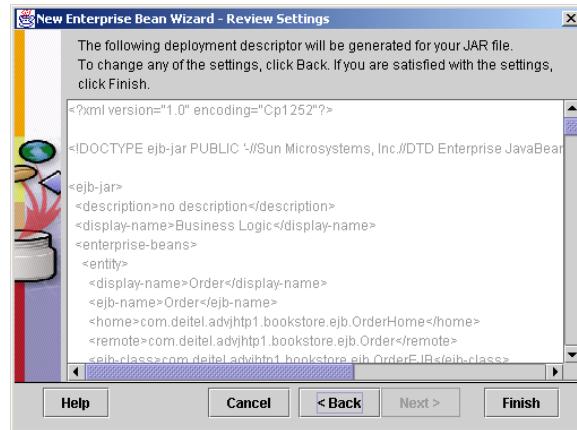


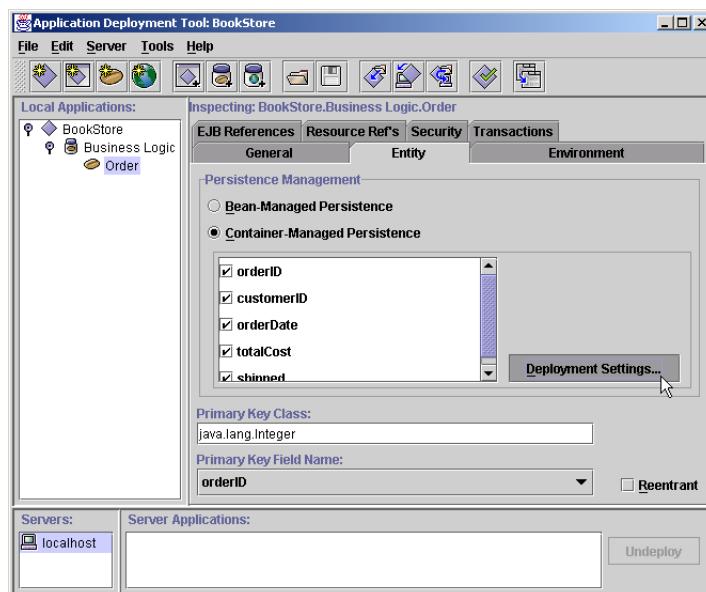
Fig. 20.29 Specifying Container-Managed Transactions for EJB business methods.



**Fig. 20.30** XML descriptor generated by Application Deployment Tool.

You must now configure the database to which the CMP entity bean will persist its data. Click the **Deployment Settings...** button in the **Entity** tab (Fig. 20.31).

Specify the JNDI name for the database in the **Database JNDI Name** field (Fig. 20.32). In the J2EE Reference Implementation, this value corresponds to the value specified in the **default.properties** configuration file (e.g., **jdbc/BookStore**). Once you have specified the JNDI name for the database, click the **Generate SQL Now** button to create the necessary SQL statements for the EJB *finder* and *create* methods.



**Fig. 20.31** Specifying EJB Deployment Settings.



Fig. 20.32 Configuring EJB **Database Settings**.

You will be prompted to provide SQL **WHERE** clauses for any custom *finder* methods specified in the EJB's home interface (Fig. 20.33). For each method listed under **EJB Method** (e.g., **findByPrimaryKey**, **ejbStore**, **Table Create**, etc.) enter the appropriate SQL query from the tables in Chapters 19–20. For example, Fig. 20.6 lists the appropriate SQL queries for the **Customer** EJB.

### 20.5.2 Deploying Deitel Bookstore Servlets

The servlets in the Deitel Bookstore take advantage of context and initialization parameters—which the deployer supplies when deploying the application—to facilitate the installation of new client types. Figure 20.35 lists each servlet, the value for that servlet's **XSL\_FILE** initialization parameter and that servlet's alias.

In addition, you must set the Web Context for the servlet's WAR file to the value **bookstore** (Fig. 20.36).

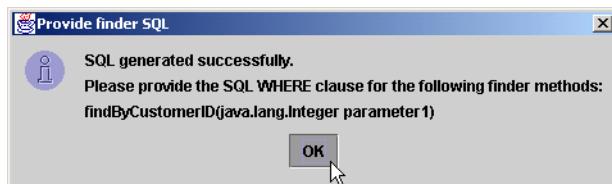


Fig. 20.33 Dialog indicating methods that require **WHERE** clauses for SQL queries.

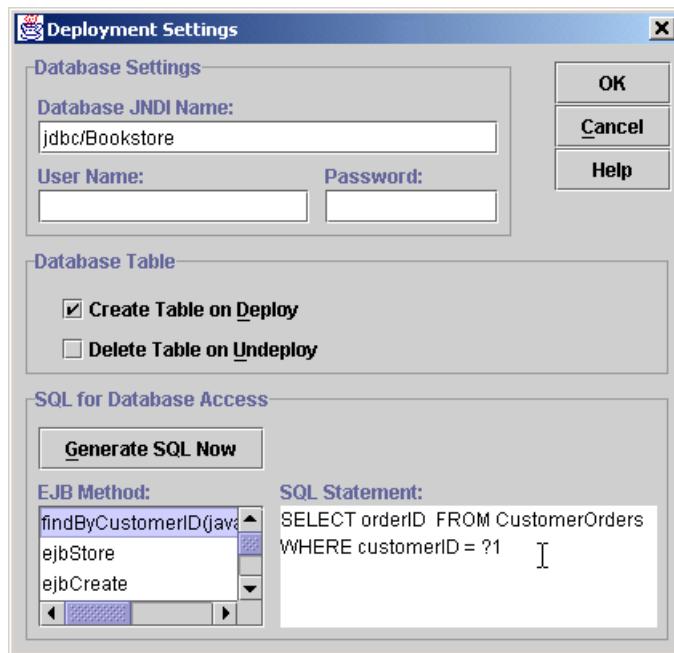
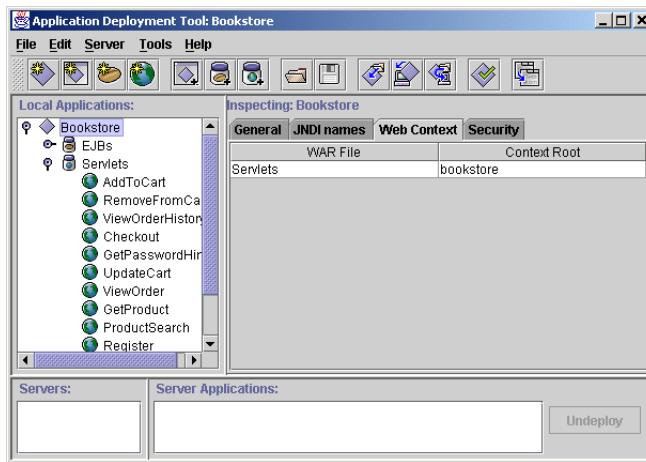


Fig. 20.34 Specifying SQL query for method `findByCustomerID`.

Servlet	XSL_FILE Initialization Parameter Value	Servlet Alias
AddToCartServlet	error.xsl	AddToCart
RemoveFromCartServlet	error.xsl	RemoveFromCart
UpdateCartServlet	error.xsl	UpdateCart
ViewCartServlet	viewCart.xsl	ViewCart
CheckoutServlet	error.xsl	Checkout
ViewOrderServlet	viewOrder.xsl	ViewOrder
ViewOrderHistoryServlet	viewOrderHistory.xsl	ViewOrderHistory
GetAllProductsServlet	products.xsl	GetAllProducts
GetProductServlet	productDetails.xsl	GetProduct
ProductSearchServlet	products.xsl	ProductSearch
RegisterServlet	error.xsl	Register
LoginServlet	login.xsl	Login
GetPasswordHintServlet	passwordHint.xsl	GetPasswordHint

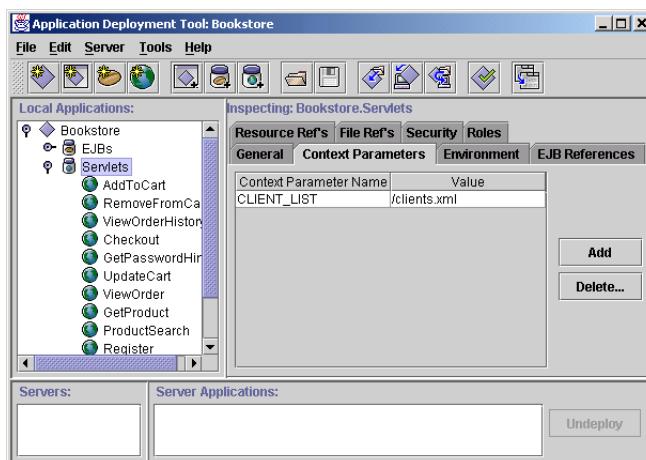
Fig. 20.35 Deployment settings for Deitel Bookstore servlets.



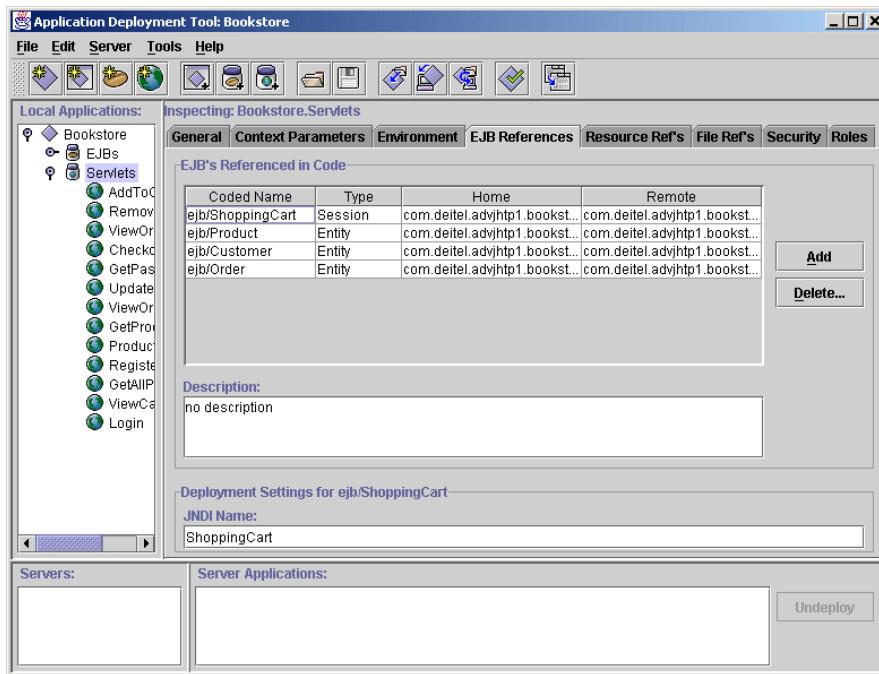
**Fig. 20.36** Setting the **Context Root** for the Deitel Bookstore servlets.

Recall that the servlets in the Deitel Bookstore read client configuration information from the **CLIENT\_LIST** servlet context parameter. Specify the value for this context parameter as shown in Fig. 20.37.

The servlets in the Deitel Bookstore utilize EJB business logic to maintain the customers shopping cart, create customer registrations, etc. To enable the servlets to access the EJBs, we must specify EJB references in the deployment tool. Figure 20.38 shows the necessary EJB references. Be sure to specify the JNDI name for each EJB (e.g., **ShoppingCart**) and full class names for the home and remote interfaces.



**Fig. 20.37** Setting the **CLIENT\_LIST** Context Parameter for the Deitel Bookstore servlets.



**Fig. 20.38** Servlet EJB References.

The final step before deploying the Deitel Bookstore case study is to add the XSL transformation documents and other supporting files to the servlet WAR file. Figure 20.39 lists these supporting files, their relative paths in the servlet WAR file and a description of each.

File Name(s)	Relative Path	Description
<b>clients.xml</b>	/	Configuration file for enabling client support.
<b>index.html</b>	/	Welcome page for XHTML clients.
<b>login.html</b>	/	Login form for XHTML clients.
<b>registration.html</b>	/	Registration form for XHTML clients.
<b>index.wml</b>	/	Welcome page for WML clients.
<b>login.wml</b>	/	Login form for WML clients
<b>default.css</b>	/styles/	Cascading Style Sheet for XHTML clients.
<b>*.jpg</b>	/images/	Book cover images for bookstore products.
<b>*.xsl</b>	/XSLT/XHTML/	XSL transformations for XHTML clients.
<b>navigation.xml</b>	/XSLT/XHTML/	Navigation header for XHTML clients.

**Fig. 20.39** Supporting files for inclusion in servlet WAR file (part 1 of 2).

File Name(s)	Relative Path	Description
*.xsl	/XSLT/WML/	XSL transformations for WML clients.
*.xsl	/XSLT/cHTML/	XSL transformations for cHTML clients.

Fig. 20.39 Supporting files for inclusion in servlet WAR file (part 2 of 2).

After completing the EJB and servlet configuration in the **Application Deployment Tool**, select **Deploy Application** from the **Tools** menu to deploy the application to the J2EE reference implementation application server. You can access the newly deployed application by opening the URL **http://localhost:8000/bookstore/index.html** in a Web browser or i-mode simulator, or the URL **http://localhost:8000/bookstore/index.wml** for a WML simulator.

This concludes our discussion of the Deitel Bookstore case study. This case study integrated several enterprise Java technologies into a substantial online application. In Chapter 21, Application Servers, we introduce three of the most popular J2EE-compliant commercial application servers—BEA’s WebLogic, IBM’s WebSphere and the iPlanet Application Server. We then discuss the steps necessary to deploy the Deitel Bookstore case study on BEA’s WebLogic and IBM’s WebSphere.

# 21

## Application Servers

### Objectives

- To introduce several popular commercial application servers.
- To introduce open-source alternatives to commercial application servers.
- To understand the requirements for J2EE-compliant application servers.
- To understand the differences among commercial application server implementations.
- To deploy the Deitel Bookstore Enterprise Java case study on two leading commercial application servers.

*Can anything be so elegant as to have few wants, and to serve them one's self?*

Ralph Waldo Emerson

*"Contrariwise," continued Tweedledee, "if it was so, it might be; and if it were so, it would be; but as it isn't, it ain't. That's logic."*

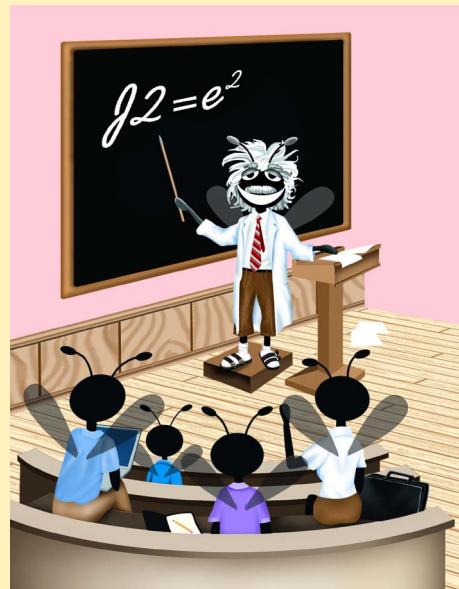
Lewis Carroll

*Eloquence is logic on fire.*

Lyman Beecher

*...a pool that nobody's fathomed the depth of, and paths threaded with flowers planted by the mind.*

Katherine Mansfield



## Outline

- 21.1 Introduction**
- 21.2 J2EE Specification and Benefits**
- 21.3 Commercial Application Servers**
  - 21.3.1 BEA WebLogic 6.0**
  - 21.3.2 iPlanet Application Server 6.0**
  - 21.3.3 IBM WebSphere Advanced Application Server 4.0**
  - 21.3.4 JBoss 2.2.2 Application Server**
- 21.4 Deploying the Deitel Bookstore on BEA WebLogic**
- 21.5 Deploying the Deitel Bookstore on IBM WebSphere**
- 21.6 Internet and World Wide Web Resources**

*Summary • Terminology • Works Cited*

## 21.1 Introduction

The Java 2 Enterprise Edition is a specification for enterprise runtime environments. Although Sun provides a reference implementation of this specification, real-world systems must use an application server from a commercial vendor. In this chapter, we introduce the three most popular J2EE-compliant, commercial application servers—BEA WebLogic, IBM WebSphere and iPlanet Application Server. We also introduce the JBoss open-source application server. We deploy the Deitel Bookstore application from Chapters 17–20 to demonstrate the portability of applications written for the J2EE specification. After reading this chapter you will understand the role of an Application Server in an enterprise application, and be able to deploy your own applications on commercial application servers.

## 21.2 J2EE Specification and Benefits

For many years, there did not exist a standard for application servers. Each application server vendor provided its own set of APIs and varying functionality. If a company wished to move its enterprise applications to a new application-server platform, that company's developers would need to rewrite large amounts of code, resulting in a complex and expensive migration process. Sun Microsystems, along with a large community of application-server vendors, developed the Java 2 Enterprise Edition specification through the Java Community Process (Appendix F, Java Community Process). J2EE defines an application server platform and supporting APIs for building enterprise applications that are portable across application servers, and, because they use Java, across platforms. J2EE extends Java's “*Write Once, Run Anywhere™*” principle to enterprise applications. J2EE facilitates portability among application servers by enabling deployers to specify server-dependant features, such as distributed transactions and database queries at deployment time. At the time of this writing, the J2EE specification was evolving through the Java Community Process. The current release is 1.2.1, and version 1.3 is in beta.

The J2EE specification can be broken down into several pieces, including API support, security, transaction management and deployment processes. An application server vendor is required to provide runtime support for the APIs of the J2EE platform. Figure 21.1 lists the specific API requirements for version 1.2 of the J2EE specification.<sup>3</sup>

## 21.3 Commercial Application Servers

To be J2EE certified, an application server must implement the minimum functionality that the J2EE specification defines. Application server vendors can provide functionality that goes beyond the J2EE specification to differentiate their products. For example, application servers can provide advanced deployment tools, enhanced security strength, higher performance, error recovery, etc. This section describes four popular application servers—BEA WebLogic, iPlanet Application Server, IBM WebSphere and JBoss.

### 21.3.1 BEA WebLogic 6.0

BEA Systems is currently the number one application-server provider in the world. WebLogic's popularity is largely based upon its first-to-market advantage and its reputation with current enterprises. BEA provides a general-purpose application server, balancing speed with stability and solid support for various features beyond the J2EE specification.

Required APIs	Web Containers	EJBs
Java Data Base Connectivity(JDBC) 2.0 Extension	required	required
Remote Method Invocation-Internet Inter-ORB Protocol(RMI-IIOP) 1.0	required	required
Enterprise Java Beans(EJB) 1.1	required	required
Servlets 2.2	required	N/A
Java Server Pages(JSP) 1.1	required	N/A
Java Messaging System(JMS) 1.0	required	required
Java Naming and Directory Interface(JNDI) 1.2	required	required
Java Transaction API (JTA) 1.0	required	required
JavaMail 1.1	required	required
Java Activation Framework(JAF) 1.0	required	required

Fig. 21.1 Application server required APIs.

WebLogic provides *data pools*, which eliminate the need to create new database connections for each client. Establishing database connections has considerable overhead—up to several seconds per connection for some database servers. By maintaining a pool of open connections and assigning these to clients as needed, WebLogic increases application performance. WebLogic also provides a mechanism for “*hot*” deployment. The application server continually checks a specified directory for new applications; if the application server finds a new application in that directory, WebLogic automatically deploys the application without restarting the server. WebLogic also will undeploy an application if the administrator removes that application from the deployment directory. Hot deployment increases server up time and makes deployment simpler. However, BEA does not recommend enabling hot deployment in production environments. Rather, hot deployment can be useful for developers when testing applications.

WebLogic uses *clustering* to increase availability through *failover* support for EJBs and Web components. Servers within a cluster enable redundancy—if a server conducting a transaction fails, another server can take over transparently without interrupting the transaction. This redundancy also facilitates *load balancing*. In a load-balanced environment, the application server distributes requests among several servers based on their load (i.e., how many requests each server already is handling). Load balancing helps prevent individual servers from failing under high numbers of requests.

For single-server environments, WebLogic provides *multi-pooling*—a service that distributes transactions among data sources. Whereas a connection pool is limited to a single data source; multi-pooling allows an application to access several pools, thus distributing requests among multiple data sources. Multi-pooling divides labor among data sources to provide a degree of load balancing within a single application server.

WebLogic is completely J2EE 1.2 compliant and already supports many requirements of the J2EE 1.3 beta specification. WebLogic includes a Web server, but no longer includes a graphical deployment tool, so deployers must code deployment descriptors manually. WebLogic also works with several popular Java Development environments, including JBuilder and Visual Café.

WebLogic also provides advanced security. User access and control are managed within WebLogic through *Access control lists* (ACLs)—ACLs provide an efficient method for managing users and permissions, WebLogic also includes SSL support and digital certificates.<sup>1</sup>

### 21.3.2 iPlanet Application Server 6.0

iPlanet E-Commerce Solutions is an alliance between Netscape Communications and Sun Microsystems. iPlanet has created a fully J2EE-certified application server as a replacement for Netscape’s application server. iPlanet’s primary goals are speed, stability and full J2EE compliance. iPlanet integrates C++ with Java to produce a fast, scalable application server. iPlanet provides failover support, connection pooling and several unique features.

The *Web connector* controls load balancing in iPlanet application server. The Web connector manages communication between the application server and the Web server. The Web connector distributes requests among server instances based on server response time. For more control, the application server may handle its own load balancing. Requests are distributed according to a specific algorithm defined by the deployer in the configuration tool. iPlanet includes support for “*sticky*” *load balancing*—if a component is flagged as

“sticky,” then the normal load-balancing algorithm will be bypassed and the component will always be executed on the “sticky” machine. “Sticky” load balancing helps in situations where the overhead of creating connections between servers for a given EJB is greater than the time saved by load balancing.

iPlanet uses the *Lightweight Directory Access Protocol (LDAP)* to manage security. Users may be assigned group and individual permissions to access parts of applications. Configuring LDAP permissions adds additional complexity to the server configuration process, but enables tight control over user permissions. iPlanet Application Server is integrated with, and includes, the iPlanet Directory Server and the iPlanet Web Server.

At the time of this writing, iPlanet was about to release a new version of iPlanet Application Server. To download the latest version, please visit [www.iplanet.com/ias\\_deitel](http://www.iplanet.com/ias_deitel). When this new version of iPlanet is available, we will provide a complete description of the iPlanet deployment process for the Deitel Bookstore application on our Web site, [www.deitel.com](http://www.deitel.com).

### 21.3.3 IBM WebSphere Advanced Application Server 4.0

IBM WebSphere is a popular application server that is approaching BEA’s WebLogic in market share. Version 4.0 is a substantial improvement over previous versions, including simpler configuration options, faster response time and enhanced security. Version 4.0 provides a simple user interface for administration and deployment, and a focus on speed and scalability. WebSphere includes IBM’s version of the Apache Web server, failover support, data pooling, and user-level security controls.

### 21.3.4 JBoss 2.2.2 Application Server

JBoss, combined with the Apache Software Foundation’s Tomcat servlet container, currently is the only J2EE 1.2-compliant, open-source application server. JBoss is distributed under the Lesser General Public License (LGPL). The source code for JBoss is freely available, and can be used to serve commercial applications. JBoss aims to maintain compliance with future J2EE specifications. Currently, JBoss includes most features of commercial application servers. JBoss was one of the first application servers to support hot deployment, and it runs with a small memory footprint, which leaves more resources for applications.<sup>2</sup>

JBoss lacks clustering support, which may not be a concern for many small to mid-sized businesses, but prevents JBoss from competing in the commercial market. JBoss also does not provide graphical tools for deployment or configuration. Fortunately, the JBoss community consists of a large and generally helpful user base that will help with most configuration issues quickly.

## 21.4 Deploying the Deitel Bookstore on BEA WebLogic

Configuring an application server can be a complex task. In this section, we guide you through the steps required to install and configure BEA WebLogic for the Deitel Bookstore case study. Please refer to [e-docs.bea.com/wls/docs60/install/install-prg.html](http://e-docs.bea.com/wls/docs60/install/install-prg.html) for installation instructions. For these configuration instructions we assume **c:\bea** as the home directory, **Deitel** as the WebLogic administration domain name, and **bookstore** as the server name. We also assume Cloudscape is installed in

**c:\cloudscape\_3.6** and our database is **c:\cloudscape\_3.6\database\Bookstore**. Depending on your security requirements you may wish to create a file named **password.ini** with the password you entered during installation. Placing **password.ini** in **c:\bea\wlserver6.0\config\deitel\** will prevent WebLogic from asking for your password each time you start the application server.

First, we configure WebLogic to enable Cloudscape database support. Open the file **c:\bea\wlserver6.0\config\CaseStudyDS\startWebLogic.cmd** with a text editor, such as Notepad. Near the bottom of the file replace the line

```
set CLASSPATH=.;.\lib\weblogic_sp.jar;.\lib\weblogic.jar
```

with

```
set CLASSPATH=.;.\lib\weblogic_sp.jar;.\lib\weblogic.jar;
c:\cloudscape_3.6\lib\cloudscape.jar
```

which includes the Cloudscape packages in the **CLASSPATH**. The following line contains the parameters to start the server:

```
%JAVA_HOME%\bin\java -hotspot -ms64m -mx64m -classpath
%CLASSPATH% -Dweblogic.Domain=deitel
-Dweblogic.Name=bookstore -Dbea.home=C:\bea
-Djava.security.policy==C:\bea\wlserver6.0\lib\weblogic.pol-
icy -Dweblogic.management.password=%WLS_PW% weblogic.Server
```

To simplify detection of our database, we specify property **cloudscape.system.home** with value **c:/cloudscape\_3.6/databases/** on the command line.

Next, run **startWeblogic.cmd** either by double clicking it, or typing its name at the console. If a console window loads, and, after a minute, presents text similar to:

```
<WebLogic Server started>
<Notice> <WebLogicServer> <SSLListenThread listening on port
7002>
<Notice> <WebLogicServer> <ListenThread listening on port
7001>
```

the application server is ready for configuration.

Use your Web browser to access **localhost:7001/console**. A window should prompt for your network password. Enter **system** under **User Name** and the password you specified during WebLogic installation. Your Web browser should display the page shown in Fig. 21.2. This is the administration console for managing most aspects of the application server.

We now configure the JDBC data pool and data source. In the main pane of the administration console, select **Connection Pools** under the **JDBC** heading. The top of the right pane should contain the link **Create new JDBC Connection Pool**. Configure the options as shown in Fig. 21.3. Specify **BookstorePool** for the pool **Name**, the **URL** **jdbc:cloudscape:Bookstore** and the **Driver Classname** **COM.cloudscape.core.JDBCDriver**. Finally, set the **password** and **server** properties to **none**. After entering these values, select **Apply**. You need not restart the server until we have made a few more changes.

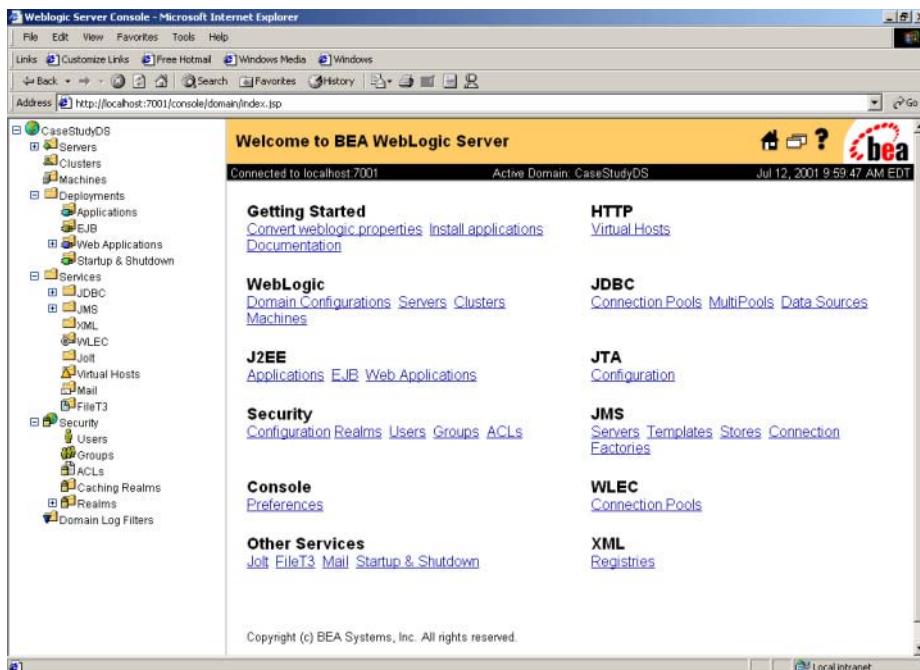


Fig. 21.2 WebLogic administration console. (Courtesy BEA Systems.)



Fig. 21.3 JDBC Connection pool properties. (Courtesy of BEA Systems, Inc.)

Next, select the **Targets** tab—select **Bookstore** from available servers, click the arrow pointing right to add this connection pool to the bookstore server then click **Apply**. In the right pane select **CaseStudyDS > Services > JDBC > Data Sources** then,

**Create new JDBC data source.** Specify the name of the data source (e.g., **BookstoreDataSource**), enter **jdbc/Bookstore** as the JNDI name, **BookstorePool** as the pool name and select **Create**. Finally, assign **Bookstore** under the **Targets** tab and click **Apply**. Shut down the server, close the WebLogic command window and restart the server with **startWebLogic.cmd**.

We now create the deployment descriptors for our bookstore application. Extract the contents of **bookstore.ear** into a new directory. You may use any zip or jar utility to extract the files. To extract the files via the **jar** utility included with the JDK, enter the command

```
jar xvf bookstore.ear
```

Next, extract the contents of **ejb-jar-ic.jar** into a temporary directory named **ejb-jar**. Create a text file named **weblogic-ejb-jar.xml** and save it in the **ejb-jar\META-INF** directory. This file is the WebLogic-specific deployment descriptor. If you are not familiar with XML please refer to Appendix A, Creating Markup with XML.

The Deployment descriptor **webLogic-ejb-jar.xml** (Fig. 21.4) defines name caching, persistence, transaction options, and other options for the EJBs in the Deitel Bookstore. Lines 6–8 specify the DTD for the descriptor. We specify the WebLogic 5.1.0 doc-type because our application uses EJB 1.1. Element **weblogic-ejb-jar** (line 11–356) contains deployment information for all EJBs in the EJB JAR. Element **weblogic-enterprise-bean** (line 13–71) contains deployment information for the **Customer** EJB. Element **ejb-name** (line 14) specifies the name of this bean. Element **ejb-name** must match the name found in **ejb-jar.xml** for WebLogic to correctly identify the current bean. Lines 17–21 contain the descriptions of caching properties. Element **max-beans-in-cache** (Line 18) defines the maximum number of active instances the container should allow. When this limit is reached, the EJB container will passivate idle EJB instances. Element **cache-strategy** (line 19) sets how EJBs should cache data. Valid values include **Read-Write** or **Read-Only**. **Read-Write**, the default value, allows clients to write information to the bean in a standard transaction, and the container invokes **ejbStore** at the completion of the transaction. **Read-Only** does not allow the **ejb-Store** method to be called, but it does allow the bean to be updated by an underlying data source periodically, for example this may be useful as a stock ticker bean. Line 19 defines this bean as a standard transaction bean. Element **read-timeout-seconds** is not used for **Read-Write** beans, if this were a **Read-Only** bean, the value specifies the number of seconds between database update intervals. When set to **0**, the Read-Only bean updates only when it is first created.

```
1 <?xml version = "1.0" encoding = "UTF-8"?>
2
3 <!-- weblogic-ejb-jar.xml deployment descriptor for bookstore -->
4 <!-- describes weblogic specific properties of each bean -->
5
6 <!DOCTYPE weblogic-ejb-jar PUBLIC
7   '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB//EN'
8   'http://www.bea.com/servers/wls510/dtd/weblogic-ejb-jar.dtd'>
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 1 of 8).

```
9
10 <!-- Customer EJB weblogic descriptor -->
11 <weblogic-ejb-jar>
12
13     <weblogic-enterprise-bean>
14         <ejb-name>Customer</ejb-name>
15
16         <!-- determines caching properties -->
17         <caching-descriptor>
18             <max-beans-in-cache>100</max-beans-in-cache>
19             <cache-strategy>Read-Write</cache-strategy>
20             <read-timeout-seconds>0</read-timeout-seconds>
21         </caching-descriptor>
22
23         <!-- maps cmp types for bean -->
24         <persistence-descriptor>
25
26             <persistence-type>
27                 <type-identifier>
28                     WebLogic_CMP_RDBMS
29                 </type-identifier>
30                 <type-version>5.1.0</type-version>
31                 <type-storage>
32                     META-INF/weblogic-cmp-rdbms-jar-Customer.xml
33                 </type-storage>
34             </persistence-type>
35
36             <persistence-use>
37                 <type-identifier>
38                     WebLogic_CMP_RDBMS
39                 </type-identifier>
40                 <type-version>5.1.0</type-version>
41             </persistence-use>
42         </persistence-descriptor>
43
44         <!-- transaction paramaters -->
45         <transaction-descriptor>
46             <trans-timeout-seconds>200</trans-timeout-seconds>
47         </transaction-descriptor>
48
49         <!-- maps references to ejb names -->
50         <reference-descriptor>
51             <ejb-reference-description>
52                 <ejb-ref-name>ejb/Order</ejb-ref-name>
53                 <jndi-name>ejb/Order</jndi-name>
54             </ejb-reference-description>
55
56             <ejb-reference-description>
57                 <ejb-ref-name>ejb/SequenceFactory</ejb-ref-name>
58                 <jndi-name>ejb/SequenceFactory</jndi-name>
59             </ejb-reference-description>
60
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 2 of 8).

```
61      <ejb-reference-description>
62          <ejb-ref-name>ejb/Address</ejb-ref-name>
63          <jndi-name>ejb/Address</jndi-name>
64      </ejb-reference-description>
65
66  </reference-descriptor>
67
68  <!-- assigns JNDI name to EJB -->
69  <jndi-name>ejb/Customer</jndi-name>
70
71  </weblogic-enterprise-bean> <!-- end customer descriptor -->
72
73  <!-- Sequence factory EJB weblogic descriptor -->
74  <weblogic-enterprise-bean>
75
76      <ejb-name>SequenceFactory</ejb-name>
77
78      <!-- manages beans caching behavior -->
79      <caching-descriptor>
80          <max-beans-in-cache>100</max-beans-in-cache>
81          <idle-timeout-seconds>20</idle-timeout-seconds>
82          <cache-strategy>Read-Write</cache-strategy>
83          <read-timeout-seconds>0</read-timeout-seconds>
84      </caching-descriptor>
85
86      <!-- map bean to CMP descriptor -->
87      <persistence-descriptor>
88          <persistence-type>
89              <type-identifier>
90                  WebLogic_CMP_RDBMS
91              </type-identifier>
92              <type-version>5.1.0</type-version>
93              <type-storage>
94                  META-INF/weblogic-cmp-rdbms-jar-Sequence.xml
95              </type-storage>
96          </persistence-type>
97
98          <persistence-use>
99              <type-identifier>
100                 WebLogic_CMP_RDBMS
101             </type-identifier>
102             <type-version>5.1.0</type-version>
103         </persistence-use>
104     </persistence-descriptor>
105
106     <!-- transaction management properties -->
107     <transaction-descriptor>
108         <trans-timeout-seconds>200</trans-timeout-seconds>
109     </transaction-descriptor>
110
111     <!-- assigns JNDI name to bean -->
112     <jndi-name>ejb/SequenceFactory</jndi-name>
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 3 of 8).

```
113      </weblogic-enterprise-bean>
114      <!-- end SequenceFactory descriptor -->
115
116      <!-- Order EJB weblogic descriptor -->
117      <weblogic-enterprise-bean>
118          <ejb-name>Order</ejb-name>
119
120              <!-- defines caching properties, set to defaults -->
121              <caching-descriptor>
122                  <max-beans-in-cache>100</max-beans-in-cache>
123                  <idle-timeout-seconds>20</idle-timeout-seconds>
124                  <cache-strategy>Read-Write</cache-strategy>
125                  <read-timeout-seconds>0</read-timeout-seconds>
126              </caching-descriptor>
127
128              <!-- maps bean to specific CMP descriptor -->
129              <persistence-descriptor>
130                  <persistence-type>
131                      <type-identifier>
132                          WebLogic_CMP_RDBMS
133                      </type-identifier>
134                      <type-version>5.1.0</type-version>
135                      <type-storage>
136                          META-INF/weblogic-cmp-rdbms-jar-order.xml
137                      </type-storage>
138                  </persistence-type>
139
140                  <persistence-use>
141                      <type-identifier>
142                          WebLogic_CMP_RDBMS
143                      </type-identifier>
144                      <type-version>5.1.0</type-version>
145                  </persistence-use>
146              </persistence-descriptor>
147
148              <!-- defines transaction attributes -->
149              <transaction-descriptor>
150                  <trans-timeout-seconds>200</trans-timeout-seconds>
151              </transaction-descriptor>
152
153
154              <!-- maps bean references to JNDI names -->
155              <reference-descriptor>
156                  <ejb-reference-description>
157                      <ejb-ref-name>ejb/SequenceFactory</ejb-ref-name>
158                      <jndi-name>ejb/SequenceFactory</jndi-name>
159                  </ejb-reference-description>
160
161
162                  <ejb-reference-description>
163                      <ejb-ref-name>ejb/OrderProduct</ejb-ref-name>
164                      <jndi-name>ejb/OrderProduct</jndi-name>
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 4 of 8).

```
165      </ejb-reference-description>
166
167      <ejb-reference-description>
168          <ejb-ref-name>ejb/Customer</ejb-ref-name>
169          <jndi-name>ejb/Customer</jndi-name>
170      </ejb-reference-description>
171
172      </reference-descriptor>
173      <jndi-name>ejb/Order</jndi-name>
174
175  </weblogic-enterprise-bean> <!-- end Order descriptor -->
176
177  <!-- Address EJB weblogic deployment descriptor -->
178  <weblogic-enterprise-bean>
179      <ejb-name>Address</ejb-name>
180
181      <!-- defines caching properties for bean -->
182      <caching-descriptor>
183          <max-beans-in-cache>100</max-beans-in-cache>
184          <idle-timeout-seconds>20</idle-timeout-seconds>
185          <cache-strategy>Read-Write</cache-strategy>
186          <read-timeout-seconds>0</read-timeout-seconds>
187      </caching-descriptor>
188
189      <!-- maps EJB to specific cmp descriptor -->
190      <persistence-descriptor>
191          <persistence-type>
192              <type-identifier>
193                  WebLogic_CMP_RDBMS
194              </type-identifier>
195              <type-version>5.1.0</type-version>
196              <type-storage>
197                  META-INF/weblogic-cmp-rdbms-jar-address.xml
198              </type-storage>
199          </persistence-type>
200
201          <persistence-use>
202              <type-identifier>
203                  WebLogic_CMP_RDBMS
204              </type-identifier>
205              <type-version>5.1.0</type-version>
206          </persistence-use>
207      </persistence-descriptor>
208
209      <!-- defines transaction properties -->
210      <transaction-descriptor>
211          <trans-timeout-seconds>200</trans-timeout-seconds>
212      </transaction-descriptor>
213
214      <!-- maps referenced to JNDI names of beans -->
215      <reference-descriptor>
216          <ejb-reference-description>
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 5 of 8).

```
217      <ejb-ref-name>ejb/SequenceFactory</ejb-ref-name>
218      <jndi-name>ejb/SequenceFactory</jndi-name>
219      </ejb-reference-description>
220    </reference-descriptor>
221
222    <!-- assigns JNDI name to this bean -->
223    <jndi-name>ejb/Address</jndi-name>
224
225  </weblogic-enterprise-bean> <!-- end Address descriptor -->
226
227  <!-- OrderProduct EJB weblogic deployment descriptor -->
228  <weblogic-enterprise-bean>
229    <ejb-name>OrderProduct</ejb-name>
230
231    <!-- sets default caching properties -->
232    <caching-descriptor>
233      <max-beans-in-cache>100</max-beans-in-cache>
234      <idle-timeout-seconds>20</idle-timeout-seconds>
235      <cache-strategy>Read-Write</cache-strategy>
236      <read-timeout-seconds>0</read-timeout-seconds>
237    </caching-descriptor>
238
239    <!-- maps this bean to specific cmp descriptor -->
240    <persistence-descriptor>
241      <persistence-type>
242        <type-identifier>
243          WebLogic_CMP_RDBMS
244        </type-identifier>
245        <type-version>5.1.0</type-version>
246        <type-storage>
247          META-INF/weblogic-cmp-rdbms-jar-orderProduct.xml
248        </type-storage>
249      </persistence-type>
250
251      <persistence-use>
252        <type-identifier>
253          WebLogic_CMP_RDBMS
254        </type-identifier>
255        <type-version>5.1.0</type-version>
256      </persistence-use>
257    </persistence-descriptor>
258
259    <!-- maps references to JNDI names of beans -->
260    <reference-descriptor>
261      <ejb-reference-description>
262        <ejb-ref-name>ejb/Product</ejb-ref-name>
263        <jndi-name>ejb/Product</jndi-name>
264      </ejb-reference-description>
265    </reference-descriptor>
266
267    <!-- assigns JNDI name of this bean -->
268    <jndi-name>ejb/OrderProduct</jndi-name>
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 6 of 8).

```
269      </weblogic-enterprise-bean>
270      <!-- end OrderProduct Descriptor -->
271
272      <!-- Product EJB weblogic deployment descriptor -->
273      <weblogic-enterprise-bean>
274          <ejb-name>Product</ejb-name>
275
276          <!-- defines caching properties for EJB -->
277          <caching-descriptor>
278              <idle-timeout-seconds>20</idle-timeout-seconds>
279              <cache-strategy>Read-Write</cache-strategy>
280              <read-timeout-seconds>0</read-timeout-seconds>
281          </caching-descriptor>
282
283          <!-- maps this bean to its CMP descriptor -->
284          <persistence-descriptor>
285              <persistence-type>
286                  <type-identifier>
287                      WebLogic_CMP_RDBMS
288                  </type-identifier>
289                  <type-version>5.1.0</type-version>
290                  <type-storage>
291                      META-INF/weblogic-cmp-rdbms-jar-product.xml
292                  </type-storage>
293              </persistence-type>
294
295              <persistence-use>
296                  <type-identifier>
297                      WebLogic_CMP_RDBMS
298                  </type-identifier>
299                  <type-version>5.1.0</type-version>
300              </persistence-use>
301          </persistence-descriptor>
302
303          <!-- defines transaction properties -->
304          <transaction-descriptor>
305              <trans-timeout-seconds>200</trans-timeout-seconds>
306          </transaction-descriptor>
307
308          <!-- assigns JNDI name -->
309          <jndi-name>ejb/Product</jndi-name>
310
311      </weblogic-enterprise-bean> <!-- end Product descriptor -->
312
313      <!-- ShoppingCart EJB weblogic deployment descriptor -->
314      <weblogic-enterprise-bean>
315          <ejb-name>ShoppingCart</ejb-name>
316
317          <!-- defines chaching properties, set to defaults -->
318          <caching-descriptor>
319              <max-beans-in-cache>100</max-beans-in-cache>
```

Fig. 21.4 **Weblogic-ejb-jar.xml** defines WebLogic deployment properties for Bookstore case study (part 7 of 8).

```
321      <idle-timeout-seconds>20</idle-timeout-seconds>
322      <cache-strategy>Read-Write</cache-strategy>
323      <read-timeout-seconds>0</read-timeout-seconds>
324    </caching-descriptor>
325
326    <!-- assigns a store directory for bean -->
327    <persistence-descriptor>
328      <stateful-session-persistent-store-dir>
329        /config/deitel/
330      </stateful-session-persistent-store-dir>
331    </persistence-descriptor>
332
333    <!-- defines transaction attributes -->
334    <transaction-descriptor>
335      <trans-timeout-seconds>200</trans-timeout-seconds>
336    </transaction-descriptor>
337
338    <!-- maps EJB references to JNDI names -->
339    <reference-descriptor>
340
341      <ejb-reference-description>
342        <ejb-ref-name>ejb/Product</ejb-ref-name>
343        <jndi-name>ejb/Product</jndi-name>
344      </ejb-reference-description>
345
346      <ejb-reference-description>
347        <ejb-ref-name>ejb/Order</ejb-ref-name>
348        <jndi-name>ejb/Order</jndi-name>
349      </ejb-reference-description>
350
351    </reference-descriptor>
352    <jndi-name>ejb/ShoppingCart</jndi-name>
353
354  </weblogic-enterprise-bean> <!-- end ShoppingCart descriptor -->
355
356 </weblogic-ejb-jar> <!-- end weblogic descriptor -->
```

Fig. 21.4 `Weblogic-ejb-jar.xml` defines WebLogic deployment properties for Bookstore case study (part 8 of 8).

Element **persistence-descriptor** (Lines 24–42) defines the EJBs persistence properties. The **Customer** bean uses container-managed persistence (CMP). WebLogic requires each CMP bean to have its own separate XML descriptor, thus the persistence block in this code simply identifies the name and type of persistence-management descriptor. Element **persistence-type** (lines 26–34) contains the elements **type-identifier** (line 27–29), which must be **WebLogic\_CMP\_RDBMS**. Element **type-version** is 5.1.0 for EJB 1.1 and 6.0 for EJB 1.2. The version number must correspond to the **weblogic-ejb-jar** DTD. Element **type-storage** (lines 31–33) specifies the location of the CMP descriptor, a file we will create next. You may define multiple **persistence-types**, in the next block, **persistence-use** you choose which **persistence-type** to use. Lines 36–41 tell WebLogic to use the persistence given in the previous element. Currently, element **transaction-descriptor** contains only a

single option—**trans-timeout-seconds** (Line 46). If a transaction lasts longer than the specified length, it will be rolled back. Element **reference-descriptor** (lines 50–66) maps each reference to the correct JNDI name. Each block contains **ejb-ref-name** and **jndi-name** elements for resolving references to other EJBs.

The descriptors for each of the other entity EJBs follow the same format as the descriptor for **Customer**. The only differences are the reference to the RDBMS persistence descriptor file and each bean's EJB references.

Stateful session EJB **ShoppingCart** (lines 315–354) requires slightly different deployment information. Stateful session beans do not require a RDBMS persistence descriptor file. Instead they simply require a location in which to store persistent sessions and a directory location in which to store passivated sessions. Element **stateful-session-persistent-store-dir** within element **persistence-descriptor** defines where the container should store passivated sessions.<sup>4</sup>

Figure 21.5 lists some optional elements in **weblogic-ejb-jar.xml**. For a full listing, please consult [edocs.bea.com](http://edocs.bea.com). If an element is not defined, WebLogic uses its default value.

The RDBMS descriptor specifies the interactions of an entity EJB with the database. The descriptor specifies a connection pool and table name, maps EJB fields to database fields, and defines custom finders for home interface methods.

Parent Element	Element	Description
<b>caching-descriptor</b>	<b>max-beans-in-free-pool</b>	Valid for stateless session EJBs, defines the maximum number of free beans to keep in the pool. The default is no limit.
<b>caching-descriptor</b>	<b>initial-beans-in-free-pool</b>	Valid for stateless session EJBs, defines the number of initial bean instances. The default is 0.
<b>persistence-descriptor</b>	<b>is-modified-method-name</b>	Method name to be called when EJB is stored, method must return a boolean value. If method returns <b>true</b> EJB is saved.

Fig. 21.5 Optional tags for **weblogic-ejb-jar.xml** not used in text (part 1 of 3).

Parent Element	Element	Description
<code>persistence-descriptor</code>	<code>delay-updates-until-end-of-tx</code>	When set to <b>false</b> , the beans database table is updated after every method. If <b>true</b> database is updated at the end of the transaction. The default is <b>true</b> .
<code>persistence-descriptor</code>	<code>finders-call-ejbload</code>	Valid for entity beans, the value <b>true</b> specifies that bean is loaded after it is first referenced with a <i>finder</i> method. Value <b>false</b> specifies that the bean is loaded when first invoked. The default is <b>false</b> .
<code>persistence-descriptor</code>	<code>db-is-shared</code>	Valid for entity beans, For value <b>false</b> bean assumes it has exclusive access to database and does not reload data. For value <b>true</b> data is reloaded before each transaction. The default is <b>true</b> .
<code>reference-descriptor</code>	<code>resource-descriptor</code>	Contains description of resource factories referenced in <b>ejb-jar.xml</b>
<code>resource-descriptor</code>	<code>res-ref-name</code>	Resource reference name found in <b>ejb-jar.xml</b>
<code>resource-descriptor</code>	<code>jndi-name</code>	Assigns a JNDI name for resource factory

Fig. 21.5 Optional tags for **weblogic-ejb-jar.xml** not used in text (part 2 of 3).

Parent Element	Element	Description
<b>security-role-assignment</b>	<b>role-name</b>	Security role name defined in ejb-jar.xml
<b>security-role-assignment</b>	<b>principal-name</b>	Maps the role name to a principal defined in WebLogic. Consult <a href="http://edocs.bea.com">edocs.bea.com</a> for valid principal names.
<b>weblogic-enterprise-bean</b>	<b>enable-call-by-reference</b>	When EJBs are on the same server arguments are passed by reference, setting this value to <b>false</b> will cause variables to be passed by value.

Fig. 21.5 Optional tags for **weblogic-ejb-jar.xml** not used in text (part 3 of 3).

Descriptor **weblogic-cmp-rdbms-jar-address.xml** (Fig. 21.6) follows the WebLogic version 5.1 DTD. Element **weblogic-rdbms-bean** (line 11) is the base element for the descriptor, there may be only one **webLogic-rdbms-bean** element per file. Element **pool-name** on line 14 must contain the name for a data pool already defined in WebLogic. The value of **table-name** must correspond to the table within the data-source that this bean uses. In our case study, EJB **Address** writes to table **Address** (line 17). Element **attribute-map** contains the mappings between EJB fields and database fields defined in **ejb-jar.xml**. In our example the database field names are the same as the EJB field names, but this is not required. Defining mappings within a deployment descriptor allows deployers to customize EJBs to particular databases without changing any EJB code. Element **object-link** (line 21–24) contains the mappings between the EJB fields and database fields for **zipCode**. The bean field and database field names are specified within **bean-field** and **dbms-column**, respectively.

```

1 <?xml version = "1.0" encoding = "UTF-8" ?>
2
3 <!-- weblogic-cmp-rdbms-jar-address.xml rdbms deployment      -->
4 <!-- descriptor for EJB Address. Defines database properties -->
5

```

Fig. 21.6 **Weblogic-cmp-rdbms-jar-address.xml** defines WebLogic CMP database properties for EJB **Address** (part 1 of 3).

```
6  <!DOCTYPE weblogic-rdbms-bean PUBLIC
7      '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB RDBMS Persistence/
/EN'
8      'http://www.bea.com/servers/wls510/dtd/weblogic-rdbms-persistence.dtd'>
9
10     <!-- main block for rdbms descriptor -->
11     <weblogic-rdbms-bean>
12
13         <!-- Sets data pool to BookstorePool -->
14         <pool-name>BookstorePool</pool-name>
15
16         <!-- Sets database table to ADDRESS -->
17         <table-name>Address</table-name>
18
19         <!-- maps EJB fields to database fields -->
20         <attribute-map>
21             <object-link>
22                 <bean-field>zipCode</bean-field>
23                 <dbms-column>zipCode</dbms-column>
24             </object-link>
25
26             <object-link>
27                 <bean-field>state</bean-field>
28                 <dbms-column>state</dbms-column>
29             </object-link>
30
31             <object-link>
32                 <bean-field>addressID</bean-field>
33                 <dbms-column>addressID</dbms-column>
34             </object-link>
35
36             <object-link>
37                 <bean-field>streetAddressLine2</bean-field>
38                 <dbms-column>streetAddressLine2</dbms-column>
39             </object-link>
40
41             <object-link>
42                 <bean-field>country</bean-field>
43                 <dbms-column>country</dbms-column>
44             </object-link>
45
46             <object-link>
47                 <bean-field>streetAddressLine1</bean-field>
48                 <dbms-column>streetAddressLine1</dbms-column>
49             </object-link>
50
51             <object-link>
52                 <bean-field>city</bean-field>
53                 <dbms-column>city</dbms-column>
54             </object-link>
55
```

Fig. 21.6 `Weblogic-cmp-rdbms-jar-address.xml` defines WebLogic CMP database properties for EJB `Address` (part 2 of 3).

---

```

56      <object-link>
57          <bean-field>firstName</bean-field>
58          <dbms-column>firstName</dbms-column>
59      </object-link>
60
61      <object-link>
62          <bean-field>lastName</bean-field>
63          <dbms-column>lastName</dbms-column>
64      </object-link>
65
66      <object-link>
67          <bean-field>phoneNumber</bean-field>
68          <dbms-column>phoneNumber</dbms-column>
69      </object-link>
70  </attribute-map>
71
72  <options>
73      <use-quoted-names>false</use-quoted-names>
74  </options>
75
76 </weblogic-rdbms-bean> <!-- end Address RDBMS descriptor -->

```

---

Fig. 21.6 **Weblogic-cmp-rdbms-jar-address.xml** defines WebLogic CMP database properties for EJB **Address** (part 3 of 3).

WebLogic XML descriptor **weblogic-cmp-rdbms-jar-Customer.xml** (Fig. 21.7) is the database deployment descriptor for the **Customer** EJB. The database descriptors closely mirror each other in terms of structure. For each EJB you must provide field mappings, the database table name and custom queries for finder methods.

---

```

1  <?xml version = "1.0" encoding = "UTF-8"?>
2
3  <!-- weblogic-cmp-rdbms-jar-Customer.xml ejb descriptor for -->
4  <!-- CustomerEJB defines rdbms properties for WebLogic -->
5
6  <!DOCTYPE weblogic-rdbms-bean PUBLIC
7      '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB RDBMS Persistence/
/EN'
8      'http://www.bea.com/servers/wls510/dtd/weblogic-rdbms-persis-
tence.dtd'>
9
10 <!-- element containing rdbms properties for Customer EJB -->
11 <weblogic-rdbms-bean>
12
13     <!-- assigns this bean to pool named BookstorePool -->
14     <pool-name>BookstorePool</pool-name>
15
16     <!-- assigns this bean to table named CUSTOMER -->
17     <table-name>Customer</table-name>
18

```

---

Fig. 21.7 **WebLogic-cmp-rdbms-jar-Customer.xml** defines WebLogic CMP database properties for EJB **CustomerEJB** (part 1 of 4).

```
19      <!-- element containing field mappings -->
20      <attribute-map>
21
22          <!-- field mapping for customerID -->
23          <object-link>
24              <bean-field>customerID</bean-field>
25              <dbms-column>customerID</dbms-column>
26          </object-link>
27
28          <!-- field mapping for creditCardExpirationDate -->
29          <object-link>
30              <bean-field>creditCardExpirationDate</bean-field>
31              <dbms-column>creditCardExpirationDate</dbms-column>
32          </object-link>
33
34          <!-- field mapping for shippingAddressID -->
35          <object-link>
36              <bean-field>shippingAddressID</bean-field>
37              <dbms-column>shippingAddressID</dbms-column>
38          </object-link>
39
40          <!-- field mapping for billingAddressID -->
41          <object-link>
42              <bean-field>billingAddressID</bean-field>
43              <dbms-column>billingAddressID</dbms-column>
44          </object-link>
45
46          <!-- field mapping for passwordHint -->
47          <object-link>
48              <bean-field>passwordHint</bean-field>
49              <dbms-column>passwordHint</dbms-column>
50          </object-link>
51
52          <!-- field mapping for creditCardName -->
53          <object-link>
54              <bean-field>creditCardName</bean-field>
55              <dbms-column>creditCardName</dbms-column>
56          </object-link>
57
58          <!-- field mapping for firstName -->
59          <object-link>
60              <bean-field>firstName</bean-field>
61              <dbms-column>firstName</dbms-column>
62          </object-link>
63
64          <!-- field mapping for password -->
65          <object-link>
66              <bean-field>password</bean-field>
67              <dbms-column>password</dbms-column>
68          </object-link>
69
```

Fig. 21.7 **WebLogic-cmp-rdbms-jar-Customer.xml** defines WebLogic CMP database properties for EJB **CustomerEJB** (part 2 of 4).

```
70      <!-- field mapping for lastName -->
71      <object-link>
72          <bean-field>lastName</bean-field>
73          <dbms-column>lastName</dbms-column>
74      </object-link>
75
76      <!-- field mapping for userID -->
77      <object-link>
78          <bean-field>userID</bean-field>
79          <dbms-column>userID</dbms-column>
80      </object-link>
81
82      <!-- field mapping for creditCardNumber -->
83      <object-link>
84          <bean-field>creditCardNumber</bean-field>
85          <dbms-column>creditCardNumber</dbms-column>
86      </object-link>
87
88  </attribute-map>
89
90  <!-- list of custom finders -->
91  <finder-list>
92
93      <!-- finder for findByUserID -->
94      <finder>
95          <method-name>findByUserID</method-name>
96          <method-params>
97              <method-param>java.lang.String</method-param>
98          </method-params>
99
100         <!-- get fields where userID matches argument string -->
101         <finder-query>
102             <![CDATA[(& like userID $0 )]]>
103         </finder-query>
104     </finder>
105
106     <!-- finder for findByLogin -->
107     <finder>
108         <method-name>findByLogin</method-name>
109         <method-params>
110             <method-param>java.lang.String</method-param>
111             <method-param>java.lang.String</method-param>
112         </method-params>
113
114         <!-- fields where userID and password match arguments -->
115         <finder-query>
116             <![CDATA[(& ( like userID $0 )( like password $1 ))]]>
117         </finder-query>
118     </finder>
119
120 </finder-list>
121
```

Fig. 21.7 **WebLogic-cmp-rdbms-jar-Customer.xml** defines WebLogic CMP database properties for EJB **CustomerEJB** (part 3 of 4).

```

122    <!-- additional options -->
123    <options>
124      <use-quoted-names>false</use-quoted-names>
125    </options>
126
127  </weblogic-rdbms-bean>
128 <!-- end rdbms descriptor for CustomerEJB -->

```

**Fig. 21.7 WebLogic-cmp-rdbms-jar-Customer.xml** defines WebLogic CMP database properties for EJB **CustomerEJB** (part 4 of 4).

Element **finder-list** (lines 91–120) contains *finder* methods for the customer EJB. WebLogic requires a **finder** element for each customer *finder* method in the home interface. You must define the *finder* name, parameters, and the query to use. The value of element **method-name** (line 95) is a string that matches a *finder* method defined in the home interface. Element **method-params** (lines 96–98) contains element **method-param** (line 97), which specifies the fully qualified type of any passed parameters (e.g. **java.lang.String**). The **finder-query** is a query written in WebLogic Query Language (WQL). Be sure to place WQL expressions in **CDATA** sections to escape special characters.

Figure 21.8 lists operators and syntax examples in WQL. The operands of the expressions may be arguments, literals, **bean-fields** within this descriptor, or other expressions. The syntax **\$n** signifies that the operator is an argument and *n* corresponds to the order of the passed arguments, beginning at 0. Literals must always be enclosed in single quotes. Lines 107–118 define **findByLogin**, which takes two arguments and returns only the fields that match both.<sup>5</sup>

Operator	Function	Syntax example
=	equal to	( = ID \$0 )
<	less than	( < price \$0 )
>	greater than	( > quantity \$0 )
<=	less than or equal	( <= operand1 operand2 )
>=	greater than or equal	( >= operand1 operand2 )
!	not	( ! (= quantity '0') )
&	and	( & (< price \$0) ( > quantity \$1) )
	or	(   ( > quantity '0') ( > onOrder \$0 )
like	string equal to, % indicates wildcard	( like '%Java%' )
isNull	check for null reference	( isNull bookID )
isNotNull	check if not null	( isNotNull bookID )

**Fig. 21.8 Some WebLogic Query Language operations and examples (part 1 of 2).**

Operator	Function	Syntax example
<b>orderBy</b>	order by a column name, desc indicates descending	( like '%Java%' orderBy 'Price' )

Fig. 21.8 Some WebLogic Query Language operations and examples (part 2 of 2).

Figure 21.9 through Fig. 21.12 contain the remaining CMP descriptors, which each follow the same basic structure.

```

1  <?xml version = "1.0" encoding = "UTF-8"?>
2
3  <!-- weblogic-cmp-rdbms-jar-order.xml ejb descriptor for -->
4  <!-- OrderEJB defines rdbms properties for WebLogic -->
5
6  <!DOCTYPE weblogic-rdbms-bean PUBLIC
7      '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB RDBMS Persistence/
EN'
8      'http://www.bea.com/servers/wls510/dtd/weblogic-rdbms-persistence.dtd'>
9
10
11 <!-- element containing rdbms properties for OrderEJB -->
12 <weblogic-rdbms-bean>
13
14     <!-- assigns this bean to pool named BookstorePool -->
15     <pool-name>BookstorePool</pool-name>
16
17
18     <!-- assigns this bean to table named CUSTOMERORDERS -->
19     <table-name>CustomerOrders</table-name>
20
21     <!-- element containing field mappings -->
22     <attribute-map>
23
24
25         <!-- field mapping for orderDate -->
26         <object-link>
27             <bean-field>orderDate</bean-field>
28             <dbms-column>orderDate</dbms-column>
29         </object-link>
30
31
32         <!-- field mapping for shipped -->
33         <object-link>
34             <bean-field>shipped</bean-field>
35             <dbms-column>shipped</dbms-column>
36         </object-link>
```

Fig. 21.9 **Weblogic-cmp-rdbms-jar-order.xml** defines WebLogic CMP database properties for EJB **OrderEJB** (part 1 of 2).

```
37
38
39      <!-- field mapping for customerID -->
40      <object-link>
41          <bean-field>customerID</bean-field>
42          <dbms-column>customerID</dbms-column>
43      </object-link>
44
45      <!-- field mapping for orderID -->
46      <object-link>
47          <bean-field>orderID</bean-field>
48          <dbms-column>orderID</dbms-column>
49      </object-link>
50
51  </attribute-map>
52
53  <finder-list>
54
55      <!-- finder for findByCustomerID -->
56      <finder>
57          <method-name>findByCustomerID</method-name>
58          <method-params>
59              <method-param>java.lang.Integer</method-param>
60          </method-params>
61
62          <!-- return enumeration where customerID = argument -->
63          <finder-query>
64              <![CDATA[ ( = customerID $0 ) ]]>
65          </finder-query>
66      </finder>
67
68  </finder-list>
69
70  <!-- additional options -->
71  <options>
72      <use-quoted-names>false</use-quoted-names>
73  </options>
74
75 </weblogic-rdbms-bean>
76 <!-- end rdbms descriptor for OrderEJB -->
```

Fig. 21.9 **Weblogic-cmp-rdbms-jar-order.xml** defines WebLogic CMP database properties for EJB **OrderEJB** (part 2 of 2).

```
1  <?xml version = "1.0" encoding = "UTF-8"?>
2
3  <!-- weblogic-cmp-rdbms-jar-orderProduct.xml ejb descriptor for -->
4  <!-- OrderProductEJB defines rdbms properties for WebLogic -->
5
```

Fig. 21.10 **Weblogic-cmp-rdbms-jar-orderProduct.xml** defines WebLogic CMP database properties for the **OrderProduct** EJB (part 1 of 3).

```
6  <!DOCTYPE weblogic-rdbms-bean PUBLIC
7      '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB RDBMS Persistence/
/EN'
8      'http://www.bea.com/servers/wls510/dtd/weblogic-rdbms-persistence.dtd'>
9
10     <!-- element containing rdbms properties for OrderProductsEJB -->
11     <weblogic-rdbms-bean>
12
13         <!-- assigns this bean to pool named BookstorePool -->
14         <pool-name>BookstorePool</pool-name>
15
16         <!-- assigns this bean to table named ORDERPRODUCT -->
17         <table-name>OrderProduct</table-name>
18
19         <!-- element containing field mappings -->
20         <attribute-map>
21
22             <!-- field mapping for quantity -->
23             <object-link>
24                 <bean-field>quantity</bean-field>
25                 <dbms-column>quantity</dbms-column>
26             </object-link>
27
28             <!-- field mapping for ISBN -->
29             <object-link>
30                 <bean-field>ISBN</bean-field>
31                 <dbms-column>ISBN</dbms-column>
32             </object-link>
33
34             <!-- field mapping for orderID -->
35             <object-link>
36                 <bean-field>orderID</bean-field>
37                 <dbms-column>orderID</dbms-column>
38             </object-link>
39
40         </attribute-map>
41
42         <finder-list>
43
44             <!-- finder for findByOrderID -->
45             <finder>
46                 <method-name>findByOrderID</method-name>
47                 <method-params>
48                     <method-param>java.lang.Integer</method-param>
49                 </method-params>
50
51                 <!-- select fields where orderID matches argument -->
52                 <finder-query>
53                     <![CDATA[( like orderID $0 )]]>
```

Fig. 21.10 **Weblogic-cmp-rdbms-jar-orderProduct.xml** defines WebLogic CMP database properties for the **OrderProduct** EJB (part 2 of 3).

```
55      </finder-query>
56    </finder>
57
58  </finder-list>
59
60  <!-- additional options -->
61  <options>
62    <use-quoted-names>false</use-quoted-names>
63  </options>
64
65 </weblogic-rdbms-bean> <!-- end OrderProduct Descriptor -->
```

Fig. 21.10 **Weblogic-cmp-rdbms-jar-orderProduct.xml** defines WebLogic CMP database properties for the **OrderProduct** EJB (part 3 of 3).

```
1  <?xml version = "1.0" encoding = "UTF-8"?>
2
3  <!-- weblogic-cmp-rdbms-jar-product.xml ejb descriptor for -->
4  <!-- ProductEJB defines rdbms properties for WebLogic -->
5
6  <!DOCTYPE weblogic-rdbms-bean PUBLIC
7    '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB RDBMS Persistence/
/EN'
8    'http://www.bea.com/servers/wls510/dtd/weblogic-rdbms-persistence.dtd'>
9
10 <!-- element containing rdbms properties for ProductEJB -->
11 <weblogic-rdbms-bean>
12
13  <!-- assigns this bean to pool named BookstorePool -->
14  <pool-name>BookstorePool</pool-name>
15
16  <!-- assigns this bean to table named PRODUCT -->
17  <table-name>Product</table-name>
18
19  <!-- element containing field mappings -->
20  <attribute-map>
21
22    <!-- field mapping for pages -->
23    <object-link>
24      <bean-field>pages</bean-field>
25      <dbms-column>pages</dbms-column>
26    </object-link>
27
28    <!-- field mapping for author -->
29    <object-link>
30      <bean-field>author</bean-field>
31      <dbms-column>author</dbms-column>
32    </object-link>
```

Fig. 21.11 **weblogic-cmp-rdbms-jar-product.xml** defines WebLogic CMP database properties for the **Product** EJB (part 1 of 3).

```
33      <!-- field mapping for publisher -->
34      <object-link>
35          <bean-field>publisher</bean-field>
36          <dbms-column>publisher</dbms-column>
37      </object-link>
38
39      <!-- field mapping for price -->
40      <object-link>
41          <bean-field>price</bean-field>
42          <dbms-column>price</dbms-column>
43      </object-link>
44
45      <!-- field mapping for image -->
46      <object-link>
47          <bean-field>image</bean-field>
48          <dbms-column>image</dbms-column>
49      </object-link>
50
51      <!-- field mapping for ISBN -->
52      <object-link>
53          <bean-field>ISBN</bean-field>
54          <dbms-column>ISBN</dbms-column>
55      </object-link>
56
57      <!-- field mapping for title -->
58      <object-link>
59          <bean-field>title</bean-field>
60          <dbms-column>title</dbms-column>
61      </object-link>
62
63  </attribute-map>
64
65  <finder-list>
66
67      <!-- finder for findAllProducts -->
68      <finder>
69          <method-name>findAllProducts</method-name>
70
71          <!-- select fields where ISBN is not null -->
72          <finder-query>
73              <![CDATA[ ( isNotNull ISBN ) ]]>
74          </finder-query>
75      </finder>
76
77      <!-- finder for findByTitle -->
78      <finder>
79          <method-name>findByTitle</method-name>
80          <method-params>
81              <method-param>java.lang.String</method-param>
82          </method-params>
83
84
```

Fig. 21.11 `weblogic-cmp-rdbms-jar-product.xml` defines WebLogic CMP database properties for the `Product` EJB (part 2 of 3).

```
85      <!-- select fields that title matches argument -->
86      <finder-query>
87          <![CDATA[ ( like title $0 )]]>
88      </finder-query>
89  </finder>
90
91  </finder-list>
92
93
94  <!-- additional options -->
95  <options>
96      <use-quoted-names>false</use-quoted-names>
97  </options>
98
99  </weblogic-rdbms-bean> <!-- end ProductEJB Descriptor -->
```

Fig. 21.11 `weblogic-cmp-rdbms-jar-product.xml` defines WebLogic CMP database properties for the `Product` EJB (part 3 of 3).

```
1  <?xml version = "1.0" encoding = "UTF-8"?>
2
3  <!-- weblogic-cmp-rdbms-jar-sequence.xml ejb descriptor for -->
4  <!-- SequenceFactory defines rdbms properties for WebLogic -->
5
6  <!DOCTYPE weblogic-rdbms-bean PUBLIC
7      '-//BEA Systems, Inc.//DTD WebLogic 5.1.0 EJB RDBMS Persistence/
EN'
8      'http://www.bea.com/servers/wls510/dtd/weblogic-rdbms-persistence.dtd'>
9
10 <!-- element containing rdbms properties for SequenceFactoryEJB -->
11 <weblogic-rdbms-bean>
12
13     <!-- assigns this bean to pool named BookstorePool -->
14     <pool-name>BookstorePool</pool-name>
15
16     <!-- assigns this bean to table SEQUENCEFACTORY -->
17     <table-name>SequenceFactory</table-name>
18
19     <!-- element containing field mappings -->
20     <attribute-map>
21
22         <!-- field mapping for addressID -->
23         <object-link>
24             <bean-field>tableName</bean-field>
25             <dbms-column>tableName</dbms-column>
26         </object-link>
27
```

Fig. 21.12 `Weblogic-cmp-rdbms-jar-sequence.xml` defines WebLogic CMP database properties for the `SequenceFactory` EJB (part 1 of 2).

---

```

28      <!-- field mapping for primaryKey -->
29      <object-link>
30          <bean-field>nextID</bean-field>
31          <dbms-column>nextID</dbms-column>
32      </object-link>
33
34  </attribute-map>
35
36  <options>
37      <use-quoted-names>false</use-quoted-names>
38  </options>
39
40 </weblogic-rdbms-bean>

```

---

**Fig. 21.12 Weblogic-cmp-rdbms-jar-sequence.xml** defines WebLogic CMP database properties for the **SequenceFactory** EJB (part 2 of 2).

Finally, the EJB references in the servlets must be mapped to the JNDI names for each EJB. The deployment descriptor **weblogic.xml** in Web application directory **WEB-INF** defines these mappings. Figure 21.13 contains the mappings for the Bookstore servlets. Optional element **description** provides a simple description for the web application. Element **reference-descriptor** is the only required element for our application. This element maps references defined in **web.xml** to the JNDI names of the referenced EJBs. We have named the references the same as the JNDI names, but that is not required. Each reference description is contained within element **ejb-reference-description**. A mapping requires the **ejb-ref-name** and **jndi-name** contained within **ejb-reference-description**. Lines 22–29 map the **ShoppingCart** EJB reference to its JNDI name.

---

```

1 <?xml version = "1.0" encoding = "UTF-8"?>
2
3 <!-- weblogic.xml Deployment descriptor for servlets -->
4 <!-- maps ejb references to JNDI names -->
5
6 <!DOCTYPE weblogic-web-app PUBLIC
7     "-//BEA Systems, Inc.//DTD Web Application 6.0//EN"
8     "http://www.bea.com/servers/wls600/dtd/weblogic-web-jar.dtd">
9
10 <!-- main block for descriptor -->
11 <weblogic-web-app>
12
13     <!-- optional, provides description for war file. -->
14     <description>
15         Bookstore servlets
16     </description>
17
18     <!-- block contains ejb reference maps -->
19     <reference-descriptor>
20

```

---

**Fig. 21.13 Weblogic.xml** Web application deployment descriptor (part 1 of 2).

```
21      <!-- individual reference map -->
22      <ejb-reference-description>
23
24          <!-- reference name defined in web.xml -->
25          <ejb-ref-name>ejb/ShoppingCart</ejb-ref-name>
26
27          <!-- JNDI name specified within weblogic-ejb-jar.xml -->
28          <jndi-name>ejb/ShoppingCart</jndi-name>
29      </ejb-reference-description>
30
31      <!-- individual reference map -->
32      <ejb-reference-description>
33          <ejb-ref-name>ejb/Product</ejb-ref-name>
34          <jndi-name>ejb/Product</jndi-name>
35      </ejb-reference-description>
36
37      <!-- individual reference map -->
38      <ejb-reference-description>
39          <ejb-ref-name>ejb/Customer</ejb-ref-name>
40          <jndi-name>ejb/Customer</jndi-name>
41      </ejb-reference-description>
42
43      <!-- individual reference map -->
44      <ejb-reference-description>
45          <ejb-ref-name>ejb/Order</ejb-ref-name>
46          <jndi-name>ejb/Order</jndi-name>
47      </ejb-reference-description>
48
49      </reference-descriptor>
50
51  </weblogic-web-app>
52 <!-- end servlet descriptor -->
```

Fig. 21.13 **Weblogic.xml** Web application deployment descriptor (part 2 of 2).

This completes the deployment descriptors for our case study application; you are almost ready to deploy. Our application uses Xalan version 2.1, so prepend **xalan.jar** and **xerces.jar** to the **CLASSPATH** in **startWeblogic.cmd**. Your final **classpath** entry should be:

```
set CLASSPATH=.;c:\xalan-j_2_1_0\xerces.jar;c:\xalan-
j_2_1_0\xalan.jar;.\lib\weblogic_sp.jar;.\lib\weblogic.jar;c:
\cloudscape_3.6\lib\cloudscape.jar
```

Be sure to replace **c:\xalan-j\_2\_1\_0** with the correct path to the Xalan JAR files. Execute **startWeblogic.cmd** and open your Web browser to **localhost:7001/bookstore** to access the bookstore.

## 21.5 Deploying the Deitel Bookstore on IBM WebSphere

This section presents the configuration and deployment of the Deitel Bookstore application on IBM WebSphere 4.0. Consult the WebSphere documentation for specific information

on installing the application server on your system. We assume that Cloudscape is installed in **C:\cloudscape\_3.6**, the WebSphere application server is installed in **c:\WebSphere\AppServer** and the IBM HTTP Server (included with installation) is installed in **c:\IBM HTTP Server**. You also must copy **xalan.jar** and **xerces.jar** to **c:\WebSphere\AppServer\lib\ext**, which ensures that our application has access to the correct XML parser and XSL transformer.

Next, run the **StartServerBasic** script from the **WebSphere\AppServer\bin** directory to launch the application server. When the server completes loading, open the URL **localhost:9090/admin** in a Web browser. You may specify any user name in the login page—the name is used to track changes, not for security. To configure the JDBC driver and data source, select **Resources > JDBC Drivers** then click the **New** button from the right pane. Enter **c:\cloudscape\_3.6\lib\cloudscape.jar** for the **Server Class Path**, **Bookstore** for the **Name** and **COM.cloudscape.core.LocalConnectionPoolDataSource** for the **Implementation Class Name**. After entering these values, click **OK** and save the configuration. Expand the recently created driver (**Bookstore**) and select **Data Sources**. Click the **New** button, and fill in the fields as follows. The **Name** is **Bookstore**, the **JNDI Name** is **jdbc/Bookstore**, the **Database Name** should be the full path to the database (e.g., **c:\cloudscape\_3.6\databases\bookstore\**). Click **OK** and save the configuration.

Next, we must generate the deployment descriptors for WebSphere. WebSphere includes a graphical tool for creating deployment descriptors. Open the **Application Assembly Tool** by executing the assembly script in the **WebSphere/AppServer/bin** directory. When the tool loads, select the **Existing** tab from the welcome window. Then, enter the full path to **bookstore.ear**, or select browse to locate the file. Click **Open** to open the file and begin deployment configuration.

In the left pane, expand **Bookstore > EJB modules > EJBs > Session Beans > Shopping Cart**. Select EJB **ShoppingCart** and choose the **Bindings** tab from the main pane (the bottom right pane). Enter **ShoppingCart** as the **JNDI Name**. Select **EJB References** from the upper right pane. Be sure **ejb/Order** is selected and use the **Link** drop-down box to select the appropriate reference. You also must select the **Bindings** tab from the main pane and enter **Order** for the reference's **JNDI Name**. Complete the same steps to map the reference **ejb/Product** to the **Product** EJB.

Select **Bookstore > EJB Modules > EJBs > Entity Beans > Address**. Select the **Bindings** tab from the main pane and enter the **JNDI Name Address**, and set the datasource **JNDI Name jdbc/Bookstore**. Select **EJB References** from the upper pane and map **ejb/SequenceFactory** to **SequenceFactory** with **JNDI Name SequenceFactory**. Configure the EJB references for the other EJBs using the same process.

After defining the JNDI names and EJB references for the **Customer** EJB select **Method Extensions**. You must define custom *finder* queries for methods **findById** and **findByLogin**. To define a custom query, select each method, check the **Finder Descriptor** box and specify the appropriate **WHERE** clause (Fig. 21.14). The **WHERE** clause option will fill in the **SELECT** and **FROM** SQL statements for you—all you must define is the **WHERE** clause. WebSphere determines the table name from the EJB name, thus to specify a different table you must rename the EJB. When deploying the Deitel

Bean	method	Where clause
Customer	findByLogin	userID = ? AND password = ?
Customer	findByID	userID = ?
Order	findByCustomerID	customerID = ?
OrderProduct	findByOrderID	orderID = ?
Product	findAllProducts	1 = 1
Product	findByTitle	title like ?

Fig. 21.14 WHERE clauses for bookstore finder methods.

Bookstore be sure to select the **Order** EJB and change the EJB name to **Customer-Orders**, which is the table for storing order information.

To configure the servlets in WebSphere you must select **Bookstore > Web Modules > Servlets > EJB references** and map each reference as you did for each EJB. After you map the references you can generate the code for deployment. Select the **File** menu and **Generate code for deployment**. Specify the **Deployed module location** text field to the path in which to save the deployed EAR. Enter the path to **xalan.jar** and **xerces.jar** in the **Dependent Classpath** field. The **Database type** is **Generic/SQL-92**, **Database Name** is **jdbc/Bookstore** and **Schema** is **APP**. Fill in these values then select the **Generate Now** button.

You may now deploy the application in the administration tool Web page (**localhost:9090/admin**). In the left pane, select **Nodes > Computer Name > Enterprise Applications**. Click the **Install** button then use the **Browse** button to locate the deployed EAR file (e.g., **Deployed\_Bookstore.ear**) and click **Next**. The following page shows the JNDI name mapping—be sure to double check each value then select **Next**. The following page shows each EJB reference. The following page verifies the database mappings. Each field must contain the value **jdbc/Bookstore**. The **Database type** must be **Generic/SQL-92** and the **Schema** name is **APP**. The next page defines the servlet mapping to **default\_host**. In the following page, uncheck the option to redeploy the application. Click **Next**, confirm the values and click **Finish** to deploy. After the application is deployed, click the link at the top of the page to regenerate the Web server plug-in configuration. Save the configuration and restart the server by running the **stopServer** script followed by the **startServerBasic** script. Finally, open the URL **localhost/bookstore** to browse the Deitel Bookstore.

## 21.6 Internet and World Wide Web Resources

[serverwatch.internet.com/appservers.html](http://serverwatch.internet.com/appservers.html)

Application server news site, also includes reviews and comparisons of popular application servers.

[www.appserver-zone.com](http://www.appserver-zone.com)

The Application Server Zone Web site provides technical articles, product comparisons and other information related to application servers.

[java.sun.com/j2ee](http://java.sun.com/j2ee)

Sun's J2EE site, includes the J2EE specification, J2EE news and SDK download and support.

## SUMMARY

- The Java 2 Enterprise Edition is a specification for enterprise runtime environments. Although Sun provides a reference implementation of this specification, real-world systems must use an application server from a commercial vendor.
- Sun Microsystems, along with a large community of application-server vendors, developed the Java 2 Enterprise Edition specification through the Java Community Process. J2EE defines an application server platform and supporting APIs for building enterprise applications that are portable across application servers, and, because they use Java, across platforms.
- The J2EE specification can be broken down into several pieces, including API support, security, transaction management and deployment processes. An application server vendor is required to provide runtime support for the APIs of the J2EE platform.
- To be J2EE certified, an application server must implement the minimum functionality that the J2EE specification defines. Application server vendors also can provide functionality that goes beyond the J2EE specification to differentiate their products.
- BEA provides a general-purpose application server, balancing speed with stability and solid support for various features beyond the J2EE specification, including data pools, “hot” deployment clustering, *failover* support for EJBs and Web components and *load balancing*.
- For single-server environments, WebLogic provides multi-pooling—a service that distributes transactions among data sources. Whereas a connection pool is limited to a single data source; multi-pooling allows an application to access several pools, thus distributing requests among multiple data sources.
- iPlanet E-Commerce Solutions is an alliance between Netscape Communications and Sun Microsystems. iPlanet’s primary goals are speed, stability and full J2EE compliance. iPlanet provides failover support, connection pooling and several unique features.
- The Web connector controls load balancing in iPlanet application server. The Web connector manages communication between the application server and the Web server. The Web connector distributes requests among server instances based on server response time.
- iPlanet includes support for “sticky” load balancing—if a component is flagged as “sticky,” then the normal load-balancing algorithm will be bypassed and the component will always be executed on the “sticky” machine.
- iPlanet uses the Lightweight Directory Access Protocol (LDAP) to manage security. Users may be assigned group and individual permissions to access parts of applications. Configuring LDAP permissions enables tight control over user permissions.
- IBM WebSphere is a popular application server that is approaching BEA’s WebLogic in market share. Version 4.0 provides a simple user interface for administration and deployment, and a focus on speed and scalability. WebSphere includes IBM’s version of the Apache Web server, failover support, data pooling, and user-level security controls.
- JBoss, combined with the Apache Software Foundation’s Tomcat servlet container, currently is the only J2EE 1.2-compliant, open-source application server. JBoss aims to maintain compliance with future J2EE specifications. Currently, JBoss includes most features of commercial application servers.

## TERMINOLOGY

Access Control List (ACL)  
application server  
**attribute-map**

BEA Weblogic  
**bean-field** element  
**cache-strategy** element

data pool  
data source  
**dbms-column** element  
deployment descriptor  
**description** element  
**ejb-name** element  
**ejb-reference-description** element  
**ejb-ref-name** element  
**ejbStore** method  
failover  
**finder** element  
**finder-list** element  
**finder-query** element  
hot deployment  
IBM WebSphere  
iPlanet Application Server  
J2EE specification  
JBoss  
**jndi-name** element  
life cycle  
load balancing  
**max-beans-in-cache** element  
**method-name** element  
**method-param** element  
**method-params** element  
multi pool

**object-link** element  
**persistence-descriptor** element  
**persistence-type** element  
**persistence-use** element  
**pool-name** element  
**read-timeout-seconds** element  
**reference-descriptor** element  
**reference-descriptor** element  
**stateful-session-persistent-store-dir** element  
sticky load balancing  
**table-name** element  
three-tier  
transaction management  
**transaction-descriptor** element  
**trans-timeout-seconds** element  
**type-identifier** element  
**type-storage** element  
**type-version** element  
Web connector  
WebLogic Query Language (WQL)  
**WebLogic\_CMP\_RDBMS** element  
**weblogic-ejb-jar** element  
**weblogic-enterprise-bean** element  
**weblogic-rdbms-bean** element  
**weblogic-web-app** element

## WORKS CITED

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5. "**weblogic-cmp-rdbms-jar.xml** Properties," 2000 <[www.weblogic.com/docs51/classdocs/API\\_ejb/EJB\\_reference.html#1026608](http://www.weblogic.com/docs51/classdocs/API_ejb/EJB_reference.html#1026608)>.

# 22

## Jini

### Objectives

- To understand the Jini Technology Architecture.
- To be able to identify the major components of a Jini solution.
- To be able to implement Jini services and register those services with Jini lookup services.
- To be able to write a Jini client.
- To be able to use Jini helper classes to simplify service implementations.

*The real voyage of discovery consists not in seeking new landscapes, but in having new eyes.*

Marcel Proust

*For, when with beauty we can virtue join,  
We paint the semblance of a form divine.*

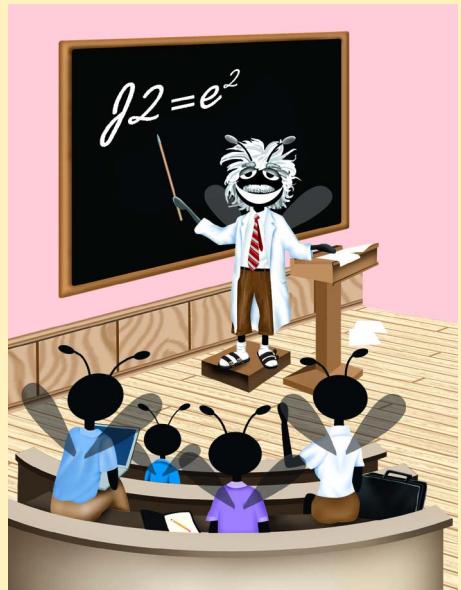
Matthew Prior

*...To tell your name the livelong day  
To an admiring bog.*

Emily Dickinson

*...And summer's lease hath all too short a date.*

William Shakespeare



## Outline

- 22.1 Introduction**
- 22.2 Installing Jini**
- 22.3 Configuring the Jini Runtime Environment**
- 22.4 Starting the Required Services**
- 22.5 Running the Jini `LookupBrowser`**
- 22.6 Discovery**
  - 22.6.1 Unicast Discovery**
  - 22.6.2 Multicast Discovery**
- 22.7 Jini Service and Client Implementations**
  - 22.7.1 Service Interfaces and Supporting Classes**
  - 22.7.2 Service Proxy and Service Implementations**
  - 22.7.3 Registering the Service with Lookup Services**
  - 22.7.4 Jini Service Client**
- 22.8 Introduction to High-Level Helper Utilities**
  - 22.8.1 Discovery Utilities**
  - 22.8.2 Entry Utilities**
  - 22.8.3 Lease Utilities**
  - 22.8.4 `JoinManager` Utility**
  - 22.8.5 Service Discovery Utilities**
- 22.9 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Bibliography*

## 22.1 Introduction

Many network devices provide *services* to network clients. For example, a network printer provides printing services to many clients by allowing them to share the printer. Similarly, a Web server provides a service by allowing many clients to access documents over a network. We can extend this idea of providing services beyond computer-based networks and into home-based networks. For example, when you arrive home, your car could use a wireless network to notify your home's lighting service to turn on the lights over the walkway, so you can walk into your home safely. Each service mentioned here has a well-defined interface. The network-printing service provides an interface that enables applications to print documents. A Web server provides an HTTP interface that enables Web browsers to download documents. Your home's lighting service provides an interface that enables other devices on the network to turn the lights on and off.

To use a service, a client must be able to discover that a service exists and must know the interface for interacting with the service. For example, your car must be able to discover that your home provides a lighting service and must know the service's interface to interact with the lighting service. However, the car need not know the implementation of the underlying lighting service.

Jini extends RMI (Chapter 13) to provide services, such as those mentioned above, to a network. Jini services are plug-and-play—clients can discover services on the network dynamically, transparently download classes required to use those services, then begin interacting with those services. Jini, like RMI, requires clients to know the interface of a service to use that service. However, RMI’s dynamic class-downloading capability enables Jini clients to use services without installing special driver software for those services in advance. For Jini clients to discover and use Jini services, standardized interfaces for common services must be developed. Many such interfaces are under development now. For example, printer manufacturers are working on a standard interface for Jini-based printing services.

In this chapter, we introduce Jini technology to build plug-and-play, network-based services. We begin with Jini lookup services, which enable clients to discover other services on the network. We build a simple Jini service that provides information about fictitious professional seminars offered by Deitel & Associates, Inc. and we build a simple Jini client to use that service. The chapter ends with introductions to various Jini utility classes that facilitate discovering lookup services, registering Jini services and building Jini clients. After completing this chapter, you will be able to build simple Jini services and clients that interact with those services. [Note: The commands to execute the examples in this chapter often are quite long. For this reason, we provide batch files containing the commands. These batch files can be found with the examples on the CD that accompanies this book. You can modify these batch files as specified in the text, then use them to execute the programs.]

A new technology that is generating excitement in the computing industry is peer-to-peer computing, which enables communication between computers without connecting through a centralized server. In Chapter 28, we use the Jini technology presented in this chapter as one means of implementing a peer-to-peer instant-messaging application.

## 22.2 Installing Jini

The basic software requirements for Jini include the Java 2 Standard Edition (J2SE) and the *Jini Technology Starter Kit*. If you are going to write commercial Jini services and want to test their compatibility with the Jini platform, you also need to download the *Jini Technology Core Platform Compatibility Kit* (Jini TCK).

The Jini Starter Kit has three components—the *Jini Technology Core Platform (JCP)*, the *Jini Technology Extended Platform (JXP)* and the *Jini Software Kit (JSK)*. The JCP contains the fundamental Jini interfaces and classes. The JXP provides helper utilities for implementing Jini services and clients. The JSK contains an implementation of the services specified in the JCP and the JXP. The JSK also includes a *JavaSpaces* technology implementation. We discuss JavaSpaces in Chapter 23.

Jini can be downloaded from Sun’s Web site at:

[www.sun.com/community/source/jini/download.html](http://www.sun.com/community/source/jini/download.html)

Downloading Jini requires a free registration. After completing the registration, download and extract **JINI-1.1-G-CS.zip**, which contains the Jini Technology Starter Kit. At the time of this writing, the latest version of Jini is 1.1.

## 22.3 Configuring the Jini Runtime Environment

To compile and execute Jini services and clients the JAR files **jini-core.jar**, **jini-ext.jar** and **sun-util.jar** must be included in the **CLASSPATH** environment vari-

able. These three JAR files are in the **lib** directory of the Jini Starter Kit—they correspond to the Jini Technology Core Platform, the Jini Technology Extended Platform and the Jini Software Kit, respectively. To set the **CLASSPATH** environment variable on Windows platforms, enter

```
set CLASSPATH=C:\jini1_1\lib\jini-core.jar;C:\jini1_1\lib\
jini-ext.jar;C:\jini1_1\lib\sun-util.jar;%CLASSPATH%.
```

in a command window. To set the **CLASSPATH** environment variable on most UNIX systems, enter

```
set CLASSPATH=/jini1_1/lib/jini-core.jar:/jini1_1/lib/
jini-ext.jar:/jini1_1/lib/sun-util.jar:$CLASSPATH:.

export CLASSPATH
```

in a command window. Note that you will need to do this in every command window from which you intend to use Jini unless you set the **CLASSPATH** permanently on your system. See your operating system's documentation for information on setting environment variables. These are the only Jini JAR files that should be in the **CLASSPATH**. Be sure not to include other JAR files from the Jini distribution. If you extracted the Jini files to a different directory, be sure to specify the appropriate directory name.

## 22.4 Starting the Required Services

Jini depends heavily on a number of network services at run time. Jini uses Java and RMI to provide facilities for downloading resources from the network and for moving Java objects from one JVM to another on demand. To achieve these capabilities, Jini provides various support services. The Jini distribution comes with three services that must be running correctly before executing Jini applications. The following required services must be started:

1. A Web server to enable Jini clients to download class files through RMI, so the clients can access Jini services dynamically.
2. The RMI activation daemon (**rmid**) to enable the RMI infrastructure that allows Jini clients to communicate with Jini services. The RMI activation daemon enables **Activatable** services to function properly.
3. A lookup service to maintain information about available Jini services, and to enable clients to discover and use those services.



### Testing and Debugging Tip 22.1

The Web server and **rmid** must be executing (they can be started in any order) before starting the lookup service.

The Jini Technology Core Platform implementation includes the **StartService** GUI tool for launching required services. Before running the **StartService** tool, be sure to set the **CLASSPATH** environment variable properly as specified in Section 22.3. To start the GUI on Windows, enter the following at a command prompt:

```
java -classpath %CLASSPATH%;C:\jini1_1\lib\jini-examples.jar
com.sun.jini.example.launcher.StartService
```

Figure 22.1 shows the **StartService** user interface. Jini provides a basic *property file* for configuring the **StartService** tool. For Windows, the property file is **jini1\_1\example\launcher\jini11\_win32.properties**. To load this property file, go to the **File** menu, select **Open Property File** and select the property file from the appropriate directory.

### Configure the Web Server

To configure the Web server, select the **WebServer** panel. Figure 22.2 shows the values for configuring the Web server. If you install the Jini Starter Kit in a directory other than **C:\jini1\_1**, be sure to enter the appropriate directory name. Note the **Port** number in Fig. 22.2, which is required in each of the later examples.

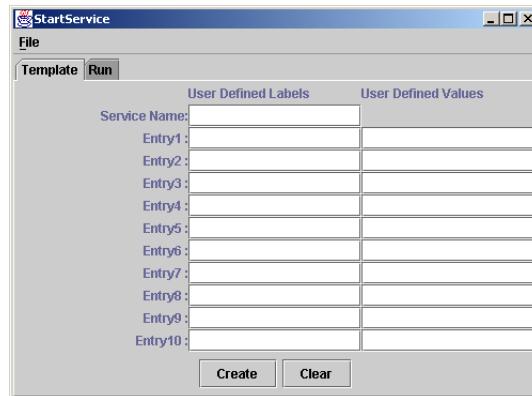


Fig. 22.1 StartService window.

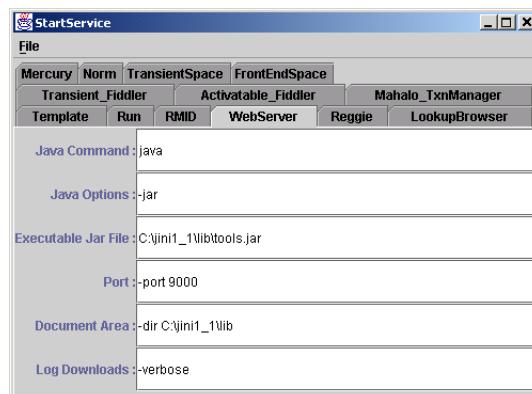


Fig. 22.2 WebServer configuration tab.

### Configure the RMI Activation Daemon

To configure the RMI activation daemon (`rmid`), select the **RMID** panel. Figure 22.3 shows the default values used to configure the RMI activation daemon. If you want to use your own policy, or you want to add other options (i.e., port number or log directory), you can put all of them in the **Options** parameter. Use a single space to separate the options. Figure 22.4 shows a sample that specifies the directory in which `rmid` will write its log files.

### Configure the Lookup Service

To configure the lookup service, select the **Reggie** panel. Figure 22.5 shows the configuration values. Replace *hostname* in the **Codebase** field with the name or IP address of your computer. Replace the port number (8081) with the port number you specified in the Web server's configuration (e.g., **9000**). Also, be sure to specify for **Log Directory** a directory that actually exists on your computer, or create a new directory, to avoid exceptions when running the lookup service. The **Groups** value in this example (**public**) specifies that the lookup service supports any clients on the network. You can define other values that can be used to restrict the set of clients supported by the lookup service.

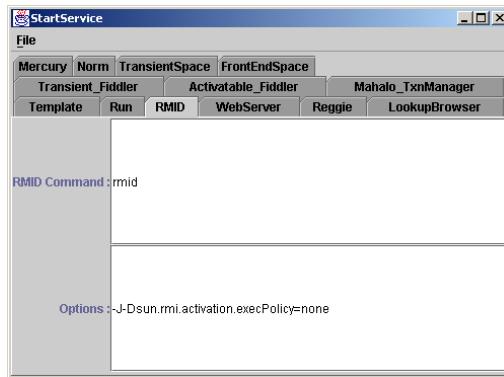


Fig. 22.3 RMID configuration tab.



Fig. 22.4 Specifying the RMID log directory.

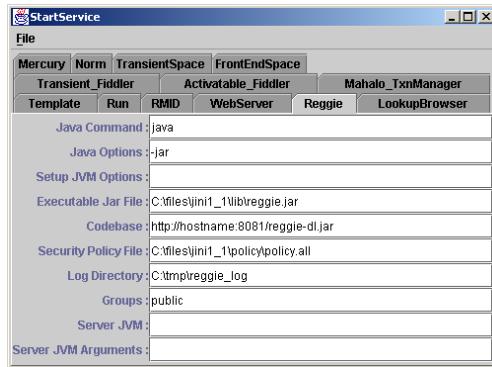


Fig. 22.5 Reggie lookup service configuration tab.



### Common Programming Error 22.1

Specifying the local computer's name or using a **file:** URL for the **Codebase** is an error. Use an **http:** URL with a fully qualified name or IP address.



### Common Programming Error 22.2

Starting the lookup service without creating a log directory causes exceptions at run-time. Create the log directory before starting the lookup service.



### Common Programming Error 22.3

Create different log directories if you run multiple lookup service instances. Failure to do so can cause an exception that says the directory exists when trying to start a lookup service.

### Starting Required Services

To run the required services, select the **Run** panel in the **StartService** window (Fig. 22.6). Click the **Start RMID** button to start the RMI activation daemon. Click the **Start WebServer** button to start the Web server. Click the **Start Reggie** button to start the lookup service. Remember to start the RMI activation daemon and the Web server before starting the lookup service.

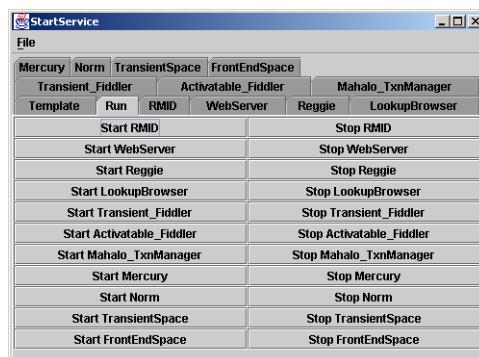


Fig. 22.6 Run panel for starting and stopping Jini basic services.

## 22.5 Running the Jini LookupBrowser

After starting these services, use the Jini **LookupBrowser** to test your configuration. The following command starts the browser on Windows:

```
java -cp c:\jini1_1\lib\jini-examples.jar  
      -Djava.security.policy=c:\jini1_1\example\browser\policy  
      -Djava.rmi.server.codebase=http://hostname:port/  
jini-examples-dl.jar  
      com.sun.jini.example.browser.Browser
```

where *hostname* is the hostname running the Web server and *port* is the port number for the Web server (e.g., **9000**).

You also can start the browser via the **StartService** GUI. Select the **LookupBrowser panel**. Replace *hostname* with the name or IP address of the computer on which the Web server is running. Change the port number if you specified a different one when you started the Web server. Then go to the **Run** panel and click the **Start LookupBrowser** button. Figure 22.7 shows the **LookupBrowser** panel in the **StartService** window.

Figure 22.8 shows the result of running the **LookupBrowser** sample. This output indicates that there is one lookup service registered with **rmid**. Actually, this uses a discovery protocol to find the lookup service. If you set up two lookup services, you would see “**2 registrars, not selected**.” The number of registrars found is equal to the number of lookup services. If you see “**no registrar to select**,” the part of the prior configuration was performed incorrectly. In this case, check whether the lookup service started, then check that you specified the correct **Codebase** in the **Reggie** panel.

If you click the **Registrar menu**, you should see the *hostname* (or IP address) and port number on which the lookup service registered. In Fig. 22.9, the *hostname* is **DRAGONFLY**. The default port number was used, so no port number appears in this screen capture.

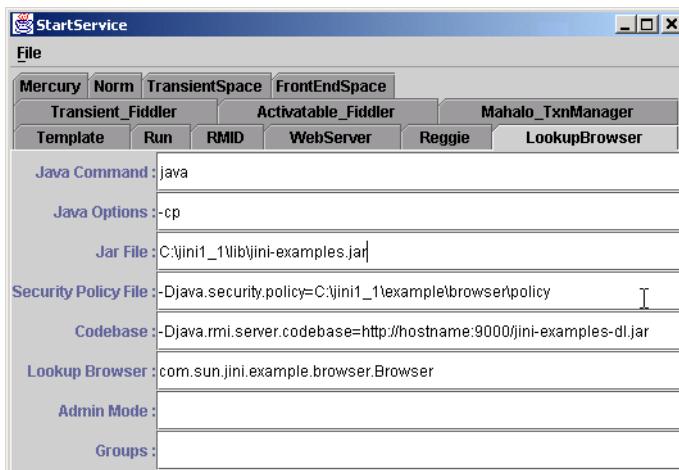


Fig. 22.7 **LookupBrowser** configuration tab.

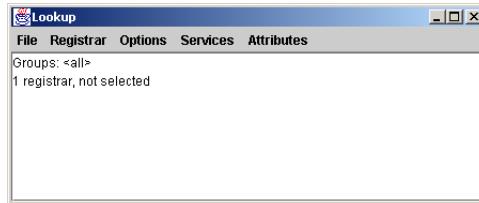


Fig. 22.8 **LookupBrowser** application window.

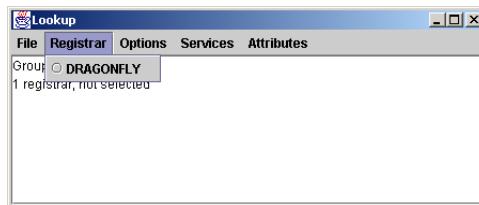


Fig. 22.9 **Registrar** menu for viewing computers that provide lookup services.

## 22.6 Discovery

The Jini lookup service is the heart of a Jini community. The process of finding the lookup services and obtaining references to them is called *discovery*. A service registers itself with one or more lookup services to make itself available to clients. To do so, the services must first discover the lookup services. Clients search the lookup services to locate the services they require. To do so, the clients must first discover the lookup services. Hence discovery is a common task for both services and clients.

Discovery distinguishes Jini technology from RMI. In RMI, you must know in advance where to register an object. In Jini, you do not need to know where—just how. The discovery process determines where, but hides the details from the developer. Discovery can be accomplished using either *unicast discovery* or *multicast discovery*.

### 22.6.1 Unicast Discovery

*Unicast discovery*, or *locator discovery*, enables a Jini service or client to discover lookup services on a specific host. The Jini service or client sends a discovery request to the computer, which responds with a remote reference to the lookup service running on that computer on the given port.

The application of Fig. 22.10 demonstrates unicast discovery. Class **UnicastDiscovery** uses class **net.jini.core.discovery.LookupLocator** to perform unicast discovery. Lines 17–18 import class **LookupLocator**, for discovering lookup services, and interface **ServiceRegistrar** (package **net.jini.core.lookup**), which represents a lookup service. The **UnicastDiscovery** constructor (lines 29–52) creates **JButton discoverButton** and **JTextArea outputArea**. When the user clicks **discoverButton**, line 43 invokes method **discoverLookupServices**, which displays information about discovered lookup services in **outputArea**.

```
1 // UnicastDiscovery.java
2 // UnicastDiscovery is an application that demonstrates Jini
3 // lookup service discovery for a known host (unicast).
4 package com.deitel.advjhttp1.jini.discovery;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.net.*;
9 import java.io.*;
10 import java.awt.*;
11 import java.awt.event.*;
12
13 // Java extension packages
14 import javax.swing.*;
15
16 // Jini core packages
17 import net.jini.core.discovery.LookupLocator;
18 import net.jini.core.lookup.ServiceRegistrar;
19
20 public class UnicastDiscovery extends JFrame {
21
22     private JTextArea outputArea = new JTextArea( 10, 20 );
23     private JButton discoverButton;
24
25     // hostname for discovering lookup services
26     private String hostname;
27
28     // UnicastDiscovery constructor
29     public UnicastDiscovery( String host )
30     {
31         super( "UnicastDiscovery Output" );
32
33         hostname = host; // set target hostname for discovery
34
35         // create JButton to discover lookup services
36         discoverButton = new JButton( "Discover Lookup Services" );
37         discoverButton.addActionListener(
38             new ActionListener() {
39
40                 // discover lookup services on given host
41                 public void actionPerformed( ActionEvent event )
42                 {
43                     discoverLookupServices();
44                 }
45             }
46         );
47
48         Container contentPane = getContentPane();
49         contentPane.add( outputArea, BorderLayout.CENTER );
50         contentPane.add( discoverButton, BorderLayout.NORTH );
51
52     } // end UnicastDiscovery constructor
```

Fig. 22.10 **UnicastDiscovery** performs unicast discovery to locate Jini lookup services (part 1 of 3).

```
53 // discover lookup services on given host and get details
54 // about each lookup service from ServiceRegistrar
55 public void discoverLookupServices()
56 {
57     // construct Jini URL
58     String lookupURL = "jini://" + hostname + "/";
59
60     // connect to the lookup service at lookupURL
61     try {
62         LookupLocator locator = new LookupLocator( lookupURL );
63         outputArea.append( "Connecting to " + lookupURL + "\n" );
64
65         // perform unicast discovery to get ServiceRegistrar
66         ServiceRegistrar registrar =
67             locator.getRegistrar();
68
69         // print lookup service information and
70         outputArea.append( "Got ServiceRegistrar\n" +
71             " Lookup Service Host: " + locator.getHost() + "\n" +
72             " Lookup Service Port: " + locator.getPort() + "\n" );
73
74         // get groups that lookup service supports
75         String[] groups = registrar.getGroups();
76         outputArea.append( "Lookup service supports " +
77             + groups.length + " group(s):\n" );
78
79         // get group names; if empty, write public
80         for ( int i = 0; i < groups.length ; i++ ) {
81
82             if ( groups[ i ].equals( "" ) )
83                 outputArea.append( " public\n" );
84
85             else
86                 outputArea.append( " " + groups[ i ] + "\n" );
87         }
88     }
89
90
91     // handle exception if URL is invalid
92     catch ( MalformedURLException exception ) {
93         exception.printStackTrace();
94         outputArea.append( exception.getMessage() );
95     }
96
97     // handle exception communicating with ServiceRegistrar
98     catch ( RemoteException exception ) {
99         exception.printStackTrace();
100        outputArea.append( exception.getMessage() );
101    }
102}
```

Fig. 22.10 **UnicastDiscovery** performs unicast discovery to locate Jini lookup services (part 2 of 3).

```
103     // handle ClassNotFoundException obtaining ServiceRegistrar
104     catch ( ClassNotFoundException exception ) {
105         exception.printStackTrace();
106         outputArea.append( exception.getMessage() );
107     }
108
109     // handle IOException obtaining ServiceRegistrar
110     catch ( IOException exception ) {
111         exception.printStackTrace();
112         outputArea.append( exception.getMessage() );
113     }
114
115 } // end method discoverLookupServices
116
117 // launch UnicastDiscovery application
118 public static void main( String args[] )
119 {
120     // set SecurityManager
121     if ( System.getSecurityManager() == null )
122         System.setSecurityManager(
123             new RMISecurityManager() );
124
125     // check command-line arguments for hostname
126     if ( args.length != 1 ) {
127         System.err.println(
128             "Usage: java UnicastDiscovery hostname" );
129     }
130
131     // create UnicastDiscovery for given hostname
132     else {
133         UnicastDiscovery discovery =
134             new UnicastDiscovery( args[ 0 ] );
135
136         discovery.setDefaultCloseOperation( EXIT_ON_CLOSE );
137         discovery.pack();
138         discovery.setVisible( true );
139     }
140 }
141 }
```

Fig. 22.10 **UnicastDiscovery** performs unicast discovery to locate Jini lookup services (part 3 of 3).

Method **discoverLookupServices** (lines 56–115) locates services on a particular computer. Line 59 creates a **String** that represents the URL for the computer running the lookup services. This URL must specify the **jini** protocol, a hostname and, optionally, the port on which to connect (e.g., **jini://mycomputer.mydomain.com:1234**). If the URL does not specify a port, the default port **4160** is used. Class **UnicastDiscovery** reads the hostname from a command-line argument and stores it in instance variable **hostname**. Line 63 creates a new **Locator** for discovering lookup services. This **Locator** constructor takes as an argument the Jini URL for the

computer running the lookup service. A **MalformedURLException** occurs if the URL specified does not follow the appropriate format.

Line 68 invokes method **getRegistrar** of class **LookupLocator** to perform unicast discovery. Method **getRegistrar** returns a **ServiceRegistrar**, which represents a lookup service. An overloaded version of method **getRegistrar** takes as an integer argument the maximum number of milliseconds to wait for the unicast discovery to locate a **ServiceRegistrar** before issuing a timeout.

Lines 71–88 display information about the discovered lookup service in **outputArea**. Lines 72–73 invoke methods **getHost** and **getPort** of class **LookupLocator** to retrieve the hostname and port number where the lookup service was discovered. Line 76 invokes method **getGroups** of interface **ServiceRegistrar** to retrieve an array of supported group names. An empty string indicates the **public** group.

Method **main** (lines 118–140) launches the **UnicastDiscovery** application. Lines 121–122 install an **RMI Security Manager** to enable network class loading—downloading executable code over the network. When class **UnicastDiscovery** discovers a new lookup service, the classes that implement that lookup service are loaded over the network. This class loading is a security risk, because the code will execute locally. A malicious programmer could access, modify or destroy sensitive data on the local machine. Installing a **SecurityManager** restricts downloaded code from performing tasks that are not granted explicitly in the current security policy. For more information on setting security policies, please see Chapter 7, Security. For the examples in this chapter, we use the policy file of Fig. 22.11, which grants **AllPermission** to the code in each example. This is a security risk and should not be used with production applications.

Lines 126–128 of Fig. 22.10 check the command-line arguments for a hostname and print out usage instructions if no hostname is provided. Lines 133–138 create a new **UnicastDiscovery** instance and display the user interface.

Before executing class **UnicastDiscovery**, start **rmid**, the Web server and the Reggie lookup service (if necessary, review Section 22.4). To execute the **UnicastDiscovery** application, enter

```
java -Djava.security.policy=polcy  
com.deitel.advjhttp1.jini.discovery.UnicastDiscovery host
```

where *polcy* is a security file that specifies the security policy and *host* is the hostname or IP address of the computer running the lookup service. Be sure that you execute this command from the directory that contains the **com.deitel.advjhttp1** package structure, and be sure that the **CLASSPATH** environment variable includes the current directory. Figure 22.12 shows the running application.

---

```
1 // policy.all  
2 // grant AllPermission to all code (DANGEROUS!)  
3 grant {  
4     permission java.security.AllPermission "", "";  
5 };
```

Fig. 22.11 Policy file that grants **AllPermission** to all code.



Fig. 22.12 **UnicastDiscovery** application output.

## 22.6.2 Multicast Discovery

*Multicast discovery*, or *group discovery*, enables a Jini service or client to discover lookup services when the particular host running the lookup service is not known. Recall that when using unicast discovery, the Jini service or client must request lookup services from a particular host. A multicast discovery request uses network multicast to discover nearby lookup services. Lookup services, in turn, periodically issue multicast announcements to notify interested Jini services and clients that the lookup services are available.

The application of Fig. 22.13 demonstrates multicast discovery. Class **MulticastDiscovery** uses class **net.jini.discovery.LookupDiscovery** to perform discovery. Class **MulticastDiscovery** implements the interface **DiscoveryListener** (line 22) to enable the class **MulticastDiscovery** to receive **DiscoveryEvents**—notifications of discovered lookup services. Line 36 creates a **LookupDiscovery**. The **LookupDiscovery** constructor takes as an argument an array of **Strings** in which each element is the name of a group. The **LookupDiscovery** object will discover all nearby lookup services that support the groups specified in this **String** array. Line 37 creates a new **String** array with an empty string as its only element. This indicates that the **LookupDiscovery** instance should discover lookup services that support the “**public**” group. Line 43 invokes method **addDiscoveryListener** of class **LookupDiscovery** to register the **MulticastDiscovery** object as the listener for **DiscoveryEvents**.

Class **LookupDiscovery** invokes method **discovered** (lines 56–114) when **LookupDiscovery** locates new lookup services. Line 59 invokes method **getRegistrars** of class **DiscoveryEvent** to obtain an array of discovered **ServiceRegistrars**. Lines 74–80 create a new **TextAppender** that contains information about a **discoveredServiceRegistrar**. Class **TextAppender** (lines 130–148) appends text to the **outputArea**. Lines 75–80 obtain information about the **ServiceRegistrar** and build an output string. Line 83 invokes method **invokeLater** of class **SwingUtilities** with the **TextAppender** as an argument to append the text to **outputArea**. Lines 91–97 obtain group information from the **ServiceRegistrar** and lines 100–101 append the group information to **outputArea**.

Class **LookupDiscovery** invokes method **discarded** (lines 118–126) when a lookup service should be discarded because it is no longer available or because it no longer matches the set of groups in which the Jini service or client is interested. Lines 120–121 invoke method **getRegistrars** of class **DiscoveryEvent** to obtain an array of discarded **ServiceRegistrars**. Lines 123–125 add the number of discarded **ServiceRegistrars** to the display.

```
1 // MulticastDiscovery.java
2 // MulticastDiscovery is an application that demonstrates Jini
3 // lookup service discovery using multicast.
4 package com.deitel.advjhttp1.jini.discovery;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.io.*;
9 import java.awt.*;
10 import java.awt.event.*;
11
12 // Java extension packages
13 import javax.swing.*;
14
15 // Jini core packages
16 import net.jini.core.lookup.ServiceRegistrar;
17
18 // Jini extension packages
19 import net.jini.discovery.*;
20
21 public class MulticastDiscovery extends JFrame
22     implements DiscoveryListener {
23
24     // number of lookup services discovered through multicast
25     private int servicesFound = 0;
26
27     private JTextArea outputArea = new JTextArea( 10, 20 );
28
29     // MulticastDiscovery constructor
30     public MulticastDiscovery () {
31     {
32         super( "MulticastDiscovery" );
33
34         // discover lookup services in public group using multicast
35         try {
36             LookupDiscovery lookupDiscovery = new LookupDiscovery(
37                 new String[] { "" } );
38
39             outputArea.append( "Finding lookup services for " +
40                 "public group ...\\n" );
41
42             // listen for DiscoveryEvents
43             lookupDiscovery.addDiscoveryListener ( this );
44         }
45
46         // handle exception discovering lookup services
47         catch ( IOException exception ) {
48             exception.printStackTrace();
49         }
50     }
```

Fig. 22.13 **MulticastDiscovery** performs multicast discovery to locate Jini lookup services (part 1 of 4).

```
51     getContentPane().add( new JScrollPane( outputArea ),  
52         BorderLayout.CENTER );  
53 }  
54  
55 // receive notification of found lookup services  
56 public void discovered ( DiscoveryEvent event )  
57 {  
58     // get the ServiceRegistrars for found lookup services  
59     ServiceRegistrar[] registrars = event.getRegistrars();  
60     int order = 0;  
61  
62     // get the information for each lookup service found  
63     for ( int i = 0; i < registrars.length ; i++ ) {  
64         ServiceRegistrar registrar = registrars[ i ];  
65  
66         if ( registrar != null ) {  
67  
68             // append information about discovered services  
69             // to outputArea  
70             try {  
71                 order = servicesFound + i + 1;  
72  
73                 // get the hostname and port number  
74                 Runnable appender = new TextAppender(  
75                     "Lookup Service " + order + ":\n" +  
76                     " Host: " +  
77                     registrar.getLocator().getHost() + "\n" +  
78                     "\n Port: " +  
79                     registrar.getLocator().getPort() + "\n" +  
80                     " Group support: " );  
81  
82                 // append to outputArea on event-dispatch thread  
83                 SwingUtilities.invokeLater( appender );  
84  
85                 // get the group(s) the lookup service served  
86                 String[] groups = registrar.getGroups();  
87  
88                 StringBuffer names = new StringBuffer();  
89  
90                 // get the group names, if empty write public  
91                 for ( int j = 0; j < groups.length ; j++ ) {  
92  
93                     if ( groups[ j ].equals( "" ) )  
94                         names.append( "public\t" );  
95                     else  
96                         names.append( groups[ j ] + "\t" );  
97                 }  
98  
99                 // append group names to outputArea  
100                SwingUtilities.invokeLater(  
101                    new TextAppender( names + "\n" ) );  
102            }
```

Fig. 22.13 **MulticastDiscovery** performs multicast discovery to locate Jini lookup services (part 2 of 4).

```
103          // handle exception communicating with ServiceRegistrar
104      catch ( RemoteException exception ) {
105          exception.printStackTrace();
106      }
107  }
108 }
109 }
110
111     // update number of services found
112     servicesFound = order;
113
114 } // end method discovered
115
116 // receive notification of discarded lookup services that
117 // are no longer valid
118 public void discarded( DiscoveryEvent event )
119 {
120     ServiceRegistrar[] discardedRegistrars =
121         event.getRegistrars();
122
123     SwingUtilities.invokeLater(
124         new TextAppender( "Number of discarded registrars: " +
125             discardedRegistrars.length + "\n" ) );
126 }
127
128 // TextAppender is a Runnable class for appending
129 // text to outputArea on the event-dispatching thread.
130 private class TextAppender implements Runnable {
131
132     private String textToAppend; // text to append to outputArea
133
134     // TextAppender constructor
135     public TextAppender( String text )
136     {
137         textToAppend = text;
138     }
139
140     // append text to outputArea and scroll to bottom
141     public void run()
142     {
143         outputArea.append( textToAppend );
144         outputArea.setCaretPosition(
145             outputArea.getText().length() );
146     }
147
148 } // end inner class TextAppender
149
150 // launch MulticastDiscovery application
151 public static void main( String args[] )
152 {
```

Fig. 22.13 **MulticastDiscovery** performs multicast discovery to locate Jini lookup services (part 3 of 4).

```
153     // set SecurityManager
154     if ( System.getSecurityManager() == null )
155         System.setSecurityManager(
156             new RMISecurityManager() );
157
158     MulticastDiscovery discovery = new MulticastDiscovery();
159     discovery.setDefaultCloseOperation( EXIT_ON_CLOSE );
160     discovery.pack();
161     discovery.setVisible( true );
162 }
163 }
```

Fig. 22.13 **MulticastDiscovery** performs multicast discovery to locate Jini lookup services (part 4 of 4).

Before running this example, start several instances of the Reggie lookup service. If there is only one lookup service running, the result is the same as the **UnicastDiscovery** example (Fig. 22.10). To start multiple instances of the Reggie lookup service, specify a different log directory in the **Reggie** panel, then click **Start Reggie** from the **Run** panel. Try adding new group names to some of the lookup services (e.g., “**test**” or “**MyGroup**”). To execute **MulticastDiscovery**, enter the following at a command prompt:

```
java -Djava.security.policy=polcy
      com.deitel.advjhtp1.jini.discovery.MulticastDiscovery
```

where *polcy* is an appropriate security policy. Figure 22.14 shows the output window with several lookup services running.



Fig. 22.14 **MulticastDiscovery** application output.

## 22.7 Jini Service and Client Implementations

In this section, we develop a Jini service that provides information about fictitious seminars offered at Deitel & Associates, Inc. Then, we create a client for that service. A Jini service consists of several components, each of which contributes to the flexibility and portability of the Jini architecture. A *service proxy* is an intermediary between a Jini service and its clients. The seminar service proxy implements the service's **public** interface, which declares the methods that the service provides. The service proxy communicates with the actual service implementation through the service's *back-end interface*, which defines methods in the service implementation. A separate application discovers lookup services and registers the Jini service, making the service available to Jini clients.



### Software Engineering Observation 22.1

*Providing a back-end interface for the service implementation is not required. However, using a back-end interface makes the Jini service more flexible, since the back-end implementation can be changed without requiring changes in the service proxy.*



### Software Engineering Observation 22.2

*An alternative to providing a back-end interface and implementation is to implement the service's functionality in the service proxy itself.*

A Jini client uses the lookup service discovery techniques presented earlier in this chapter to discover lookup services. The Jini client then uses the discovered lookup services to locate the desired Jini service. When the lookup service locates the service requested by the Jini client, the lookup service serializes the service proxy and delivers the proxy to the Jini client. The client can then invoke methods defined in the service's **public** interface directly on the service proxy, which implements that interface. The service proxy communicates with the service implementation through the back-end interface.

Our Jini service provides information about fictitious seminars offered at Deitel & Associates, Inc. Information about these seminars is stored in instances of class **Seminar** (Fig. 22.15). Interface **SeminarInterface** (Fig. 22.16) is the public interface for the Jini service. Class **SeminarProxy** (Fig. 22.18) implements interface **SeminarInterface** and communicates with the service implementation through **BackendInterface** (Fig. 22.17). Class **SeminarInfo** (Fig. 22.19) is the service implementation, which implements interface **BackendInterface**. Class **SeminarInfoService** (Fig. 22.21) discovers lookup services and registers the **SeminarInfo** Jini service. Class **UnicastSeminarInfoClient** (Fig. 22.22) is a Jini client that uses unicast discovery to discover lookup services and locate the **SeminarInfo** Jini service. This client allows a user to select a day of the week and view the seminars offered on that day.

### 22.7.1 Service Interfaces and Supporting Classes

Class **Seminar** (Fig. 22.15) represents a fictitious seminar, including the seminar's title and location. It implements **Serializable**, so that objects of this class can be sent from the Jini service to its clients across the network.

Line 13 explicitly specifies the **serialVersionUID** for class **Seminar**. Developers can define this **static** member in **Serializable** classes to ensure compatibility between versions of such classes. If an object of one version of a class is serialized, the object can be deserialized into an object of a newer version of the class as long as both ver-

sions use the same `serialVersionUID` (and are implemented in a compatible manner). Changing the `serialVersionUID` for a new version of the class indicates that the new version is not compatible with older versions. In this case, deserialization would not work correctly.

Interface `SeminarInterface` (Fig. 22.16) defines a single method `getSeminar`, which takes as a `String` argument a day of the week. Method `getSeminar` returns a `Seminar` object containing information about the `Seminar` offered on the given day. The service proxy must implement this interface, because Jini clients use this interface to interact with the service.

```
1 // Seminar.java
2 // Seminar represents a seminar, or lecture, including the
3 // Seminar title and location.
4 package com.deitel.advjhtp1.jini.seminar;
5
6 // Java core package
7 import java.io.Serializable;
8
9 public class Seminar implements Serializable
10 {
11     private String title;
12     private String location;
13     private static final long serialVersionUID = 20010724L;
14
15     // Seminar constructor
16     public Seminar( String seminarTitle, String seminarLocation )
17     {
18         title = seminarTitle;
19         location = seminarLocation;
20     }
21
22     // get String representation of Seminar object
23     public String toString()
24     {
25         return "Seminar title: " + getTitle() +
26             "; location: " + getLocation();
27     }
28
29     // get Seminar title
30     public String getTitle()
31     {
32         return title;
33     }
34
35     // get Seminar location
36     public String getLocation()
37     {
38         return location;
39     }
40 }
```

Fig. 22.15 `Seminar` maintains the location and title of a seminar.

```
1 // SeminarInterface.java
2 // SeminarInterface defines methods available from the SeminarInfo
3 // Jini service.
4 package com.deitel.advjhttp1.jini.seminar.service;
5
6 // Java core packages
7 import java.rmi.Remote;
8
9 // Deitel packages
10 import com.deitel.advjhttp1.jini.seminar.Seminar;
11
12 public interface SeminarInterface {
13
14     // get Seminar for given date
15     public Seminar getSeminar( String date );
16 }
```

Fig. 22.16 **SeminarInterface** defines the methods available from the **SeminarInfo** Jini service.

Interface **BackendInterface** (Fig. 22.17) defines methods that the service proxy uses to communicate with the service implementation. The proxy invokes method **getSeminar** to retrieve **Seminar** information for the requested day. In this Jini service, the seminar proxy communicates with the service implementation using RMI, although Jini implementations may use any protocol to communicate with back-end implementations.

#### Software Engineering Observation 22.3



Jini does not require that service proxies communicate with back-end implementations using RMI. Service proxies may use RMI, TCP/IP, CORBA or any suitable protocol to connect to back-end implementations.

```
1 // BackendInterface.java
2 // BackendInterface defines the interface through which the
3 // service proxy communicates with the back-end service.
4 package com.deitel.advjhttp1.jini.seminar.service;
5
6 // Java core packages
7 import java.rmi.*;
8
9 // Deitel packages
10 import com.deitel.advjhttp1.jini.seminar.Seminar;
11
12 public interface BackendInterface extends Remote {
13
14     // get Seminar for given day of the week
15     public Seminar getSeminar( String day ) throws RemoteException;
16 }
```

Fig. 22.17 **BackEndInterface** defines methods available to the **SeminarInfo** service proxy.



### Software Engineering Observation 22.4

Service proxies can use non-Java protocols (e.g., TCP/IP or CORBA) to communicate with back-end implementations, enabling programmers to provide Jini services that are implemented in languages other than Java.

#### 22.7.2 Service Proxy and Service Implementations

Class **SeminarProxy** (Fig. 22.18) is a service proxy for the **SeminarInfo** Jini service. Line 12 specifies that class **SeminarProxy** implements **SeminarInterface**, which is the **public** interface for the **SeminarInfo** Jini service. The service proxy must implement this interface to enable Jini clients to communicate with the **SeminarInfo** service. The service proxy also must implement interface **Serializable** (line 13), so that instances can be delivered to the remote client over RMI. The **SeminarProxy** constructor (lines 18–21) initializes the proxy with a remote reference to the back-end implementation. Method **getSeminar** (lines 24–38) invokes the back-end implementation's **getSeminar** method to retrieve the seminar information (line 28).

```
1 // SeminarProxy.java
2 // SeminarProxy is a proxy for the SeminarInfo Jini service.
3 package com.deitel.advjhtp1.jini.seminar.service;
4
5 // Java core packages
6 import java.io.Serializable;
7 import java.rmi.*;
8
9 // Deitel packages
10 import com.deitel.advjhtp1.jini.seminar.Seminar;
11
12 public class SeminarProxy implements SeminarInterface,
13     Serializable {
14
15     private BackendInterface backInterface;
16
17     // SeminarProxy constructor
18     public SeminarProxy( BackendInterface inputInterface )
19     {
20         backInterface = inputInterface;
21     }
22
23     // get Seminar for given date through BackendInterface
24     public Seminar getSeminar( String date )
25     {
26         // get Seminar from service through BackendInterface
27         try {
28             return backInterface.getSeminar( date );
29         }
30     }
```

Fig. 22.18 **SeminarProxy** is a service proxy that clients use to communicate with the **SeminarInfo** service (part 1 of 2).

```
31     // handle exception communicating with back-end service
32     catch ( RemoteException remoteException ) {
33         remoteException.printStackTrace();
34     }
35
36     return null;
37 }
38 } // end method getSeminar
39 }
```

Fig. 22.18 **SeminarProxy** is a service proxy that clients use to communicate with the **SeminarInfo** service (part 2 of 2).

Class **SeminarInfo** (Fig. 22.19) is an RMI object that implements the Jini service's back-end interface. The service proxy communicates with this back-end implementation through interface **BackendInterface** using RMI. Method **getSeminar** (lines 29–91) reads seminar information from file **SeminarInfo.txt** and returns a new **Seminar** object containing **Seminar** information for the given day of the week.

File **SeminarInfo.txt** (Fig. 22.20) contains **Seminar** information that the **SeminarInfo** service provides to its clients. A semicolon separates the **Seminar** title from the **Seminar** location.

```
1 // SeminarInfo.java
2 // SeminarInfo is a Jini service that provides information
3 // about Seminars offered throughout the week.
4 package com.deitel.advjhttp1.jini.seminar.service;
5
6 // Java core packages
7 import java.io.*;
8 import java.rmi.server.UnicastRemoteObject;
9 import java.rmi.RemoteException;
10 import java.util.StringTokenizer;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.jini.seminar.Seminar;
14
15 public class SeminarInfo extends UnicastRemoteObject
16     implements BackendInterface {
17
18     // Strings that represent days of the week
19     private static final String MONDAY = "MONDAY";
20     private static final String TUESDAY = "TUESDAY";
21     private static final String WEDNESDAY = "WEDNESDAY";
22     private static final String THURSDAY = "THURSDAY";
23     private static final String FRIDAY = "FRIDAY";
24
25     // SeminarInfo no-argument constructor
26     public SeminarInfo() throws RemoteException {}
27 }
```

Fig. 22.19 **SeminarInfo** implements the **SeminarInfo** Jini service (part 1 of 3).

```
28 // get Seminar information for given day
29 public Seminar getSeminar( String date )
30     throws RemoteException
31 {
32     String[] titles = new String[] { "", "", "", "", "" };
33     String[] locations = new String[] { "", "", "", "", "" };
34
35     // read seminar information from text file
36     try {
37         String fileName = SeminarInfo.class.getResource(
38             "SeminarInfo.txt" ).toString();
39         fileName = fileName.substring( 6 );
40
41         FileInputStream inputStream =
42             new FileInputStream( fileName );
43
44         BufferedReader reader = new BufferedReader(
45             new InputStreamReader( inputStream ) );
46
47         String line = reader.readLine();
48
49         // read seminar info from the file
50         for ( int lineNo = 0; ( line != null )
51             && ( lineNo < 5 ); lineNo++ ) {
52             StringTokenizer tokenizer =
53                 new StringTokenizer( line, ";" );
54
55             titles[ lineNo ] = tokenizer.nextToken();
56             locations[ lineNo ] = tokenizer.nextToken();
57             line = reader.readLine();
58         }
59     }
60
61     // handle exception loading Seminar file
62     catch ( FileNotFoundException fileException ) {
63         fileException.printStackTrace();
64     }
65
66     // handle exception reading from Seminar file
67     catch ( IOException ioException ) {
68         ioException.printStackTrace();
69     }
70
71     // match given day of the week to available seminars
72     if ( date.equalsIgnoreCase( MONDAY ) ) {
73         return new Seminar( titles[ 0 ], locations[ 0 ] );
74     }
75     else if ( date.equalsIgnoreCase( TUESDAY ) ) {
76         return new Seminar( titles[ 1 ], locations[ 1 ] );
77     }
78     else if ( date.equalsIgnoreCase( WEDNESDAY ) ) {
79         return new Seminar( titles[ 2 ], locations[ 2 ] );
80     }
```

Fig. 22.19 `SeminarInfo` implements the `SeminarInfo` Jini service (part 2 of 3).

```

81     else if ( date.equalsIgnoreCase( THURSDAY ) ) {
82         return new Seminar( titles[ 3 ], locations[ 3 ] );
83     }
84     else if ( date.equalsIgnoreCase( FRIDAY ) ) {
85         return new Seminar( titles[ 4 ], locations[ 4 ] );
86     }
87     else {
88         return new Seminar( "Empty", "Not available" );
89     }
90 }
91 } // end method getSeminar
92 }
```

Fig. 22.19 **SeminarInfo** implements the **SeminarInfo** Jini service (part 3 of 3).

```

1 Advanced Swing GUI Components; Deitel Seminar Room
2 Model-View-Controller Architecture; Deitel Seminar Room
3 Java 2 Enterprise Edition; Deitel Seminar Room
4 Introduction to Jini; Deitel Seminar Room
5 Java 2 Micro Edition; Deitel Seminar Room
```

Fig. 22.20 Content of **SeminarInfo.txt**.

### 22.7.3 Registering the Service with Lookup Services

Class **SeminarInfoService** (Fig. 22.21) discovers lookup services using multicast discovery and registers the **SeminarInfo** service with discovered lookup services. Lines 29–30 create a **LookupDiscovery** object to perform multicast discovery for the “**public**” group. Line 33 registers the **SeminarInfoService** object as a **DiscoveryListener** to receive lookup service discovery notifications. Line 42 creates an array of **Entry** objects. An **Entry** (in package **net.jini.core.entry**) describes a service, which enables Jini clients to search for services of a particular description. Line 43 creates a new **NameEntry** (in package **net.jini.lookup.entry**) and adds it to array **entries** to provide the name of the Jini service. Lines 46–47 create a new **ServiceItem** (in package **net.jini.core.lookup**) for the **SeminarInfo** Jini service. The lookup service requires a **ServiceItem** to register a Jini service. The first argument to the **ServiceItem** constructor is the Jini service’s ID. The **null** argument on line 53 causes the lookup service to assign a new, unique ID to the service. To keep the services persistent, the service provider should use the previously assigned service ID when re-registering services. The second argument is an instance of the service proxy for the Jini service. The third argument is the array of **Entry** objects that describe the service.

```

1 // SeminarInfoService.java
2 // SeminarInfoService discovers lookup services and registers
3 // the SeminarInfo service with those lookup services.
4 package com.deitel.advjhtp1.jini.seminar.service;
5
```

Fig. 22.21 **SeminarInfoService** registers the **SeminarInfo** service with lookup services (part 1 of 4).

```
6 // Java core packages
7 import java.rmi.RMISecurityManager;
8 import java.rmi.RemoteException;
9 import java.io.IOException;
10
11 // Jini core packages
12 import net.jini.core.lookup.*;
13 import net.jini.core.entry.Entry;
14
15 // Jini extension packages
16 import net.jini.discovery.*;
17 import net.jini.lookup.entry.Name;
18
19 public class SeminarInfoService implements DiscoveryListener {
20
21     private ServiceItem serviceItem;
22     private final int LEASETIME = 10 * 60 * 1000;
23
24     // SeminarInfoService constructor
25     public SeminarInfoService()
26     {
27         // search for lookup services with public group
28         try {
29             LookupDiscovery discover =
30                 new LookupDiscovery( new String[] { "" } );
31
32             // add listener for DiscoveryEvents
33             discover.addDiscoveryListener( this );
34         }
35
36         // handle exception creating LookupDiscovery
37         catch ( IOException exception ) {
38             exception.printStackTrace();
39         }
40
41         // create an Entry for this service
42         Entry[] entries = new Entry[ 1 ];
43         entries[ 0 ] = new Name( "Seminar" );
44
45         // set the service's proxy and Entry name
46         serviceItem = new ServiceItem(
47             null, createProxy(), entries );
48
49     } // end SeminarInfoService constructor
50
51     // receive lookup service discovery notifications
52     public void discovered( DiscoveryEvent event )
53     {
54         ServiceRegistrar[] registrars = event.getRegistrars();
```

Fig. 22.21 **SeminarInfoService** registers the **SeminarInfo** service with lookup services (part 2 of 4).

```
56     // register service with each lookup service
57     for ( int i = 0; i < registrars.length; i++ ) {
58         ServiceRegistrar registrar = registrars[ i ];
59
60         // register service with discovered lookup service
61         try {
62             ServiceRegistration registration =
63                 registrar.register( serviceItem, LEASETIME );
64         }
65
66         // catch the remote exception
67         catch ( RemoteException exception) {
68             exception.printStackTrace();
69         }
70
71     } // end for
72
73 } // end method discovered
74
75 // ignore discarded lookup services
76 public void discarded( DiscoveryEvent event ) {}
77
78 // create the seminar service proxy
79 private SeminarInterface createProxy()
80 {
81     // get BackendInterface for service and create SeminarProxy
82     try {
83         return new SeminarProxy( new SeminarInfo() );
84     }
85
86     // handle exception creating SeminarProxy
87     catch ( RemoteException exception ) {
88         exception.printStackTrace();
89     }
90
91     return null;
92
93 } // end method discovered
94
95 // method main keeps the application alive
96 public static void main( String args[] )
97 {
98     // set SecurityManager
99     if ( System.getSecurityManager() == null )
100         System.setSecurityManager( new RMISecurityManager() );
101
102     new SeminarInfoService();
103
104     Object keepAlive = new Object();
105 }
```

Fig. 22.21 **SeminarInfoService** registers the **SeminarInfo** service with lookup services (part 3 of 4).

```
106     synchronized ( keepAlive ) {  
107         // keep application alive  
108         try {  
109             keepAlive.wait();  
110         }  
111         // handle exception if wait interrupted  
112         catch ( InterruptedException exception ) {  
113             exception.printStackTrace();  
114         }  
115     }  
116 } // end method main  
120 }
```

Fig. 22.21 **SeminarInfoService** registers the **SeminarInfo** service with lookup services (part 4 of 4).

Method **discovered** (lines 52–73) receives notifications of discovered lookup services. For each discovered lookup service, line 62 invokes method **register** of interface **ServiceRegistrar** to register the Jini service's **serviceItem** with the lookup service. Method **register** takes as arguments a **serviceItem**, which contains the service proxy and a *lease time*. The lease time specifies the length of time for which the service should be available from the lookup service. For this example, the lease time is 10 minutes. The **LEASETIME** specified in method **register** is the service requested lease time. In fact, Sun's implementation limits it to 5 minutes. This means the desired lease time is not necessarily granted. After 10 minutes or even less, the Jini service's lease expires and the service is no longer available through the lookup service. It is the service provider's responsibility to store the **ServiceRegistration** (line 62) returned by method **register** and use it to periodically renew the lease. We discuss leasing and how to manage leases in Section 22.8.3.

Method **createProxy** (lines 79–93) creates a new **SeminarProxy** service proxy for our Jini service. Line 83 creates a new instance of the **SeminarInfo** back-end implementation. Line 84 returns a new **SeminarProxy** service proxy for the **SeminarInfo** service back-end implementation.

Method **main** (lines 95–118) launches the **SeminarInfoService** application. Line 99 sets a **SecurityManager** and line 101 creates a new instance of class **SeminarInfoService**, which discovers lookup services and registers the **SeminarInfo** service. Lines 103–115 create an **Object** named **keepAlive**. The **synchronized** block (lines 105–116) prevents the **main** thread from terminating, which would cause the **SeminarInfoService** application to terminate, thus shutting down the **SeminarInfo** service. Clients then would be unable to access **Seminar** information.

## 22.7.4 Jini Service Client

Class **UnicastSeminarInfoClient** (Fig. 22.22) is a Jini client that uses the **SeminarInfo** service to retrieve information about **Seminars** available on a given day. Class **UnicastSeminarInfoClient** performs unicast discovery to discover lookup

services. The **UnicastSeminarInfoClient** constructor (lines 44–82) initializes the application GUI.

Line 51 creates a **JButton** that the user can click to begin the discovery process and retrieve **Seminar** information. Line 61 invokes method **discoverLookupServices** to discover lookup services using unicast discovery. Lines 63–64 obtain a remote reference to the **SeminarInfo** service's service proxy by invoking method **lookupSeminarService**. Lines 66–69 prompt the user for the day of the week for which the user would like **Seminar** information. Line 71 invokes method **showSeminars** to display the **Seminar** information for the selected day.

```
1 // UnicastSeminarInfoClient.java
2 // UnicastSeminarInfoClient uses unicast discovery to locate
3 // lookup services for the SeminarInfo service.
4 package com.deitel.advjhttp1.jini.seminar.client;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.io.*;
10 import java.rmi.*;
11 import java.net.*;
12 import java.util.*;
13
14 // Java extension packages
15 import javax.swing.*;
16
17 // Jini core packages
18 import net.jini.core.discovery.LookupLocator;
19 import net.jini.core.lookup.*;
20 import net.jini.core.entry.Entry;
21
22 // Jini extension packages
23 import net.jini.lookup.entry.Name;
24
25 // Deitel packages
26 import com.deitel.advjhttp1.jini.seminar.Seminar;
27 import com.deitel.advjhttp1.jini.seminar.service.SeminarInterface;
28
29 public class UnicastSeminarInfoClient extends JFrame {
30
31     // Strings representing the days of the week on which
32     // Seminars are offered
33     private static final String[] days = { "Monday", "Tuesday",
34                                         "Wednesday", "Thursday", "Friday" };
35
36     // hostname and ServiceRegistrar for lookup services
37     private String hostname;
38     private ServiceRegistrar registrar;
39 }
```

Fig. 22.22 **UnicastSeminarInfoClient** is a client for the SeminarInfo service (part 1 of 4).

```
40     // JButton for finding Seminars
41     private JButton findSeminarButton;
42
43     // UnicastSeminarInfoClient constructor
44     public UnicastSeminarInfoClient( String host )
45     {
46         super( "UnicastSeminarInfoClient" );
47
48         hostname = host; // set target hostname for discovery
49
50         // create JButton for finding Seminars
51         findSeminarButton = new JButton( "Find Seminar" );
52         findSeminarButton.addActionListener(
53
54             new ActionListener() {
55
56                 // discover lookup services, look up SeminarInfo
57                 // service, prompt user for desired day of the
58                 // week and display available Seminars
59                 public void actionPerformed( ActionEvent event )
60             {
61                 discoverLookupServices();
62
63                 SeminarInterface seminarService =
64                     lookupSeminarService();
65
66                 String day = ( String ) JOptionPane.showInputDialog(
67                     UnicastSeminarInfoClient.this, "Select Day",
68                     "Day Selection", JOptionPane.QUESTION_MESSAGE,
69                     null, days, days[ 0 ] );
70
71                 showSeminars( seminarService, day );
72             }
73         }
74     );
75     // end call to addActionListener
76
77     JPanel buttonPanel = new JPanel();
78     buttonPanel.add( findSeminarButton );
79
80     getContentPane().add( buttonPanel, BorderLayout.CENTER );
81
82 } // end UnicastSeminarInfoClient constructor
83
84 // discover lookup services using unicast discovery
85 private void discoverLookupServices()
86 {
87     String lookupURL = "jini://" + hostname + "/";
88
89     // Get the lookup service locator at jini://hostname
90     // use default port
91     try {
```

Fig. 22.22 **UnicastSeminarInfoClient** is a client for the SeminarInfo service (part 2 of 4).

```
92         LookupLocator locator = new LookupLocator( lookupURL );
93
94         // return registrar
95         registrar = locator.getRegistrar();
96     }
97
98     // handle exceptions discovering lookup services
99     catch ( Exception exception ) {
100         exception.printStackTrace();
101     }
102
103 } // end method discoverLookupServices
104
105 // lookup SeminarInfo service in given ServiceRegistrar
106 private SeminarInterface lookupSeminarService()
107 {
108     // specify the service requirement
109     Class[] types = new Class[] { SeminarInterface.class };
110     Entry[] attribute = new Entry[] { new Name( "Seminar" ) };
111     ServiceTemplate template =
112         new ServiceTemplate( null, types, attribute );
113
114     // find the service
115     try {
116         SeminarInterface seminarInterface =
117             ( SeminarInterface ) registrar.lookup( template );
118         return seminarInterface;
119     }
120
121     // handle exception looking up SeminarInfo service
122     catch ( RemoteException exception ) {
123         exception.printStackTrace();
124     }
125
126     return null;
127 }
128 } // end method lookupSeminarService
129
130 // show Seminar in given SeminarInfo service for given
131 // day of the week
132 private void showSeminars( SeminarInterface seminarService,
133     String day )
134 {
135     StringBuffer buffer = new StringBuffer();
136
137     // get Seminar from SeminarInfo service
138     if ( seminarService != null ) {
139         Seminar seminar = seminarService.getSeminar( day );
140
141         // get subject and location from Seminar object
142         buffer.append( "Seminar information: \n" );
143         buffer.append( day + ": \n" );
```

Fig. 22.22 **UnicastSeminarInfoClient** is a client for the SeminarInfo service (part 3 of 4).

```
144         buffer.append( seminar.getTitle() + "\n" ); // title
145         buffer.append( seminar.getLocation() ); // location
146     }
147     else // SeminarInfo service does not available
148         buffer.append(
149             "SeminarInfo service does not available. \n" );
150
151     // display Seminar information
152     JOptionPane.showMessageDialog( this, buffer );
153
154 } // end method showSeminars
155
156 // launch UnicastSeminarInfoClient application
157 public static void main ( String args[] )
158 {
159     // check command-line arguments for hostname
160     if ( args.length != 1 ) {
161         System.err.println(
162             "Usage: java UnicastSeminarInfoClient hostname" );
163     }
164
165     // create UnicastSeminarInfoClient for given hostname
166     else {
167         System.setSecurityManager( new RMISecurityManager() );
168
169         UnicastSeminarInfoClient client =
170             new UnicastSeminarInfoClient( args[ 0 ] );
171
172         client.setDefaultCloseOperation( EXIT_ON_CLOSE );
173         client.pack();
174         client.setSize( 250, 65 );
175         client.setVisible( true );
176     }
177
178 } // end method main
179 }
```

Fig. 22.22 **UnicastSeminarInfoClient** is a client for the SeminarInfo service (part 4 of 4).

Method **discoverLookupServices** (lines 85–103) performs unicast discovery to discover lookup services on a particular host, specified at the command line. Line 92 creates a **Locator**, and line 95 invokes method **getRegistrar** of class **Locator** to obtain a **ServiceRegistrar** reference to the lookup service, which is stored in instance variable **registrar**.

Method **lookupSeminarService** uses the **ServiceRegistrar** discovered in method **discoverLookupServices** to obtain a **SeminarProxy** for the **Seminar-Info** service. Line 109 creates an array of **Class** objects and initializes the first element to **SeminarInterface**'s **Class** object. The **ServiceRegistrar** uses this array of **Class** objects to locate the appropriate service proxies for the Jini client. Line 110 creates an array of **Entry** objects. Recall that when we registered the **SeminarInfo** service, we provided an array of **Entry** objects to describe that service. Line 110 populates the

**entries** array with a single **Name Entry**. The **ServiceRegistrar** uses this array of **Entry** objects to locate the desired service. Lines 111–112 create a **ServiceTemplate** (package `net.jini.core.lookup`) that contains the **Class** and **Entry** arrays from lines 109–110. The **ServiceRegistrar** uses this **ServiceTemplate** to locate a service that matches the given set of **Class** and **Entry** objects. The first argument to the **ServiceTemplate** constructor is the service ID for the Jini service. We pass a **null** argument to indicate that we do not know the service ID for the desired service.

Lines 116–117 invoke method **lookup** of interface **ServiceRegistrar** to perform the lookup and retrieve a **SeminarProxy** service proxy. Line 117 passes the **ServiceTemplate** to method **lookup**. The **ServiceRegistrar** matches the information in the **ServiceTemplate** to the **ServiceItems** registered in the lookup service. For a **ServiceItem** to match a **ServiceTemplate** when a **ServiceTemplate** contains a non-null service ID, the service ID must match that in the **ServiceTemplate**. Also, the service must be an instance of every class in the **Class** array in the **ServiceTemplate**. Finally, the service attributes must match one or more of the attributes in the **Entry** array in the **ServiceTemplate**. Line 118 returns a reference to the **SeminarProxy** returned by method **lookup**.

Method **showSeminars** (lines 132–154) takes as arguments a **SeminarInterface** and a **String** containing the day of the week for which the user would like **Seminar** information. Line 139 invokes method **getSeminar** of interface **SeminarInterface** and passes as an argument the day. Recall that **SeminarInterface** is the **public** interface for the **SeminarInfo** Jini service and defines all methods available for that service. Line 152 displays the **Seminar** information in a **JOptionPane** message dialog.

Method **main** (lines 157–178) launches the **UnicastSeminarInfoClient** application. Lines 160–163 ensure that the user enters the hostname on which to perform lookup service discovery. Lines 167–175 set a **SecurityManager** and start **UnicastSeminarInfoClient**.

### *Running the Service and Client*

Clients and services typically run on different computers. To mimic this configuration on a single computer, we must separate the class files for the Jini client, the class files for the Jini service and the downloadable Jini service class files. In this example, we package the service's class files in a JAR file named **SeminarService.jar**. Figure 22.23 shows the contents of **SeminarService.jar**.

Class File	Directory in SeminarService.jar
<b>Seminar.class</b>	com\deitel\advjhttp1\jini\seminar\
<b>SeminarInterface.class</b>	com\deitel\advjhttp1\jini\seminar\service\
<b>SeminarProxy.class</b>	com\deitel\advjhttp1\jini\seminar\service\

Fig. 22.23 **SeminarService.jar** contents (part 1 of 2).

Class File	Directory in SeminarService.jar
BackendInterface.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarInfo.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarInfo_Stub.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarInfoService.class	com\deitel\advjhttp1\jini\seminar\service\

Fig. 22.23 SeminarService.jar contents (part 2 of 2).

Recall that class **SeminarInfo** is an RMI remote object from which the **SeminarProxy** retrieves **Seminar** information. This requires that we use the RMI stub compiler (**rmic**) to compile a stub file for class **SeminarInfo** and place this stub file (**SeminarInfo\_Stub.class**) in **SeminarService.jar**.

We place our Jini client's class files in JAR file **SeminarClient.jar**. To access the **SeminarInfo** Jini Service, the client needs the class file for the service's **public** interface, as well as any supporting classes that used by methods in the **public** interface. **SeminarClient.jar** contains **Seminar.class** and **SeminarInterface.class**, which contains the service's **public** interface. Figure 22.24 shows the contents of **SeminarClient.jar**.

When the client requests the **SeminarInfo** service from a lookup service, the client uses network class loading to load the service proxy class into memory and execute methods on the Jini service. Therefore, we must package the necessary class files for the Jini client to download. The client requires the service proxy's class file and class files for objects that the service proxy references. Recall that the client interacts with the service proxy through interface **SeminarInterface**. The client does not know about the service proxy **SeminarProxy** or its supporting classes. Therefore, the client must download the **SeminarProxy** class file and its supporting class files at run time using network class loading. The download classes include **BackendInterface.class** and **SeminarInfo\_Stub.class**, which the service proxy uses to communicate with the **SeminarInfo** remote object. We package these files in **SeminarServiceDownload.jar** (Fig. 22.25) and publish this JAR file on a Web server for the client to download.

After creating these JAR files, start **rmid**, a Web server and the Reggie lookup service (if necessary, review Section 22.4 for detailed instructions). Configure and start an additional Web server to enable clients to download the service proxy and supporting files. Place **SeminarServiceDownload.jar** in the **Document Area** directory specified in this additional Web server's configuration (e.g., **C:\Jini\seminar\service**). Figure 22.26 shows a sample Web server configuration that uses port 9090. We specify this port number in the **java.rmi.server.codebase** command-line property when we launch the **SeminarInfo** service.

Class File	Directory in SeminarClient.jar
Seminar.class	com\deitel\advjhttp1\jini\seminar\
SeminarInterface.class	com\deitel\advjhttp1\jini\seminar\service\
UnicastSeminarInfoClient.class	com\deitel\advjhttp1\jini\seminar\client\
UnicastSeminarInfoClient\$1.class	com\deitel\advjhttp1\jini\seminar\client\
UnicastSeminarInfoClient\$2.class	com\deitel\advjhttp1\jini\seminar\client\

Fig. 22.24 SeminarClient.jar contents.

Class File	Directory in SeminarServiceDownload.jar
SeminarProxy.class	com\deitel\advjhttp1\jini\seminar\service\
BackendInterface.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarInfo_Stub.class	com\deitel\advjhttp1\jini\seminar\service\

Fig. 22.25 SeminarServiceDownload.jar contents.

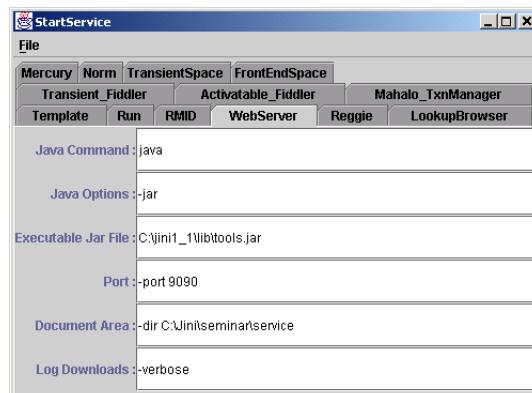


Fig. 22.26 Web server configuration for SeminarInfo service.

Start the **SeminarInfo** service by launching **SeminarInfoService**. Be sure that **jini-core.jar**, **jini-ext.jar** and **sun-util.jar** are in your **CLASSPATH**, and enter the following command at the command prompt:

```
java -classpath %CLASSPATH%;SeminarService.jar  
-Djava.security.policy=policy  
-Djava.rmi.server.codebase=http://hostname:9090/  
SeminarServiceDownload.jar  
com.deitel.advjhtp1.jini.seminar.service.SeminarInfoService
```

where *policy* is an appropriate security policy and *hostname* is the hostname on which the Web server for downloading the Jini service proxy is running. Be sure to specify the proper port number for the Web server that serves **SeminarServiceDownload.jar** (e.g., **9090**).

Start the **SeminarInfo** Jini client by launching **UnicastSeminarInfoService**. Ensure that **jini-core.jar**, **jini-ext.jar** and **sun-util.jar** are in your **CLASSPATH**, and that none of the **SeminarInfo** service class files are in your **CLASSPATH**. Type the following from a command prompt:

```
java -classpath %CLASSPATH%;SeminarClient.jar  
-Djava.security.policy=policy  
com.deitel.advjhtp1.jini.seminar.client.  
UnicastSeminarInfoClient hostname
```

where *policy* is an appropriate security policy and *hostname* is the hostname of the computer providing lookup services. Figure 22.27 shows the **UnicastSeminarInfoClient** application output.



### Common Programming Error 22.4

Placing the JAR file or classes for the **SeminarInfo** service in the Jini client's **CLASSPATH** prevents the client from downloading the class files at runtime using network class loading.

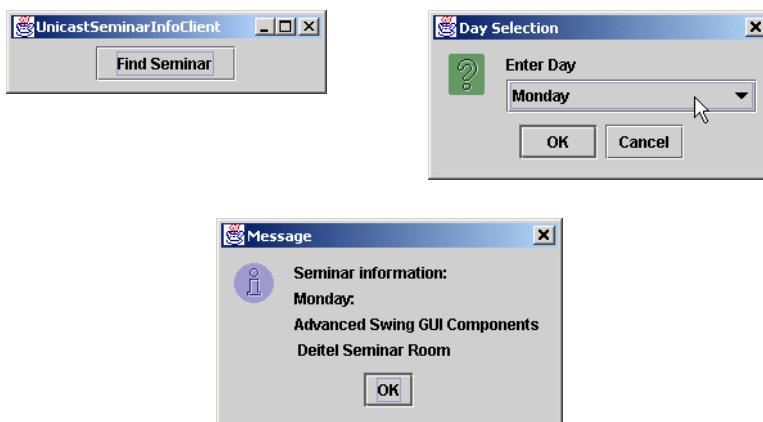


Fig. 22.27 **UnicastSeminarInfoClient** application output.

## 22.8 Introduction to High-Level Helper Utilities

One can build a complete Jini-aware service using previously introduced technology. However, Jini helper utilities simplify the process of developing the Jini applications. These helper utilities provide high-level management capabilities. As we proceed, you will see how these utilities make developing and using Jini services easier.

### 22.8.1 Discovery Utilities

As you now know, before a client or a server can interact with a lookup service, it must first discover the lookup service. Figure 22.13 introduced a low-level discovery utility, **LookupDiscovery**. This section discusses two high-level discovery utilities—class **net.jini.discovery.LookupLocatorDiscovery** and class **net.jini.discovery.LookupDiscoveryManager**.

#### *LookupLocatorDiscovery Utility*

In the **UnicastDiscovery** example (Fig. 22.10), we used class **LookupLocator** to discover lookup services on a known host. Using that technique to discover lookup services located on several known hosts would require several **LookupLocators**—one for each host that provides lookup services. Class **LookupLocatorDiscovery** enables a Jini service or client to discover lookup services on multiple known hosts more easily. Class **LookupLocatorDiscovery** uses **DiscoveryEvents** to notify the Jini service or client of discovered lookup services. This is similar to the task class **LookupDiscovery** performs for multicast discovery.

Class **UnicastDiscoveryUtility** (Fig. 22.28) uses class **LookupLocatorDiscovery** to perform unicast lookup-service discovery on multiple known hosts. Class **UnicastDiscoveryUtility** implements interface **DiscoveryListener** to receive **DiscoveryEvents** from the **LookupLocatorDiscovery** object.

The **UnicastDiscoveryUtility** constructor (lines 31–62) takes a **String** array as an argument containing a list of **jini:** URLs on which to perform unicast discovery. Lines 42–43 create an array of **LookupLocators** and lines 49–50 create a **LookupLocator** object for each URL in array **urls**. Line 53 registers the **UnicastDiscoveryUtility** object as a **DiscoveryListener** for the **LookupLocatorDiscovery** object.

```
1 // UnicastDiscoveryUtility.java
2 // Demonstrating how to locate multiple lookup services
3 // using LookupLocatorDiscovery utility
4 package com.deitel.advjhtp1.jini.utilities.discovery;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.io.*;
9 import java.awt.*;
10 import java.awt.event.*;
11 import java.net.*;
```

Fig. 22.28 **UnicastDiscoveryUtility** uses class **LookupLocatorDiscovery** to facilitate lookup service discovery (part 1 of 4).

```
12 // Java swing package
13 import javax.swing.*;
14
15 // Jini core packages
16 import net.jini.core.lookup.ServiceRegistrar;
17 import net.jini.core.discovery.LookupLocator;
18
19 // Jini extension packages
20 import net.jini.discovery.LookupLocatorDiscovery;
21 import net.jini.discovery.DiscoveryListener;
22 import net.jini.discovery.DiscoveryEvent;
23
24 public class UnicastDiscoveryUtility extends JFrame
25     implements DiscoveryListener {
26
27     private JTextArea outputArea = new JTextArea( 10, 20 );
28
29     // UnicastDiscoveryUtility constructor
30     public UnicastDiscoveryUtility( String urls[] )
31     {
32         super( "UnicastDiscoveryUtility" );
33
34         getContentPane().add( new JScrollPane( outputArea ),
35             BorderLayout.CENTER );
36
37         // discover lookup services using LookupLocatorDiscovery
38         try {
39
40             // create LookupLocator for each URL
41             LookupLocator locators[] =
42                 new LookupLocator[ urls.length ];
43
44             for ( int i = 0; i < locators.length ; i++ )
45                 locators[ i ] = new LookupLocator( urls[ i ] );
46
47             // create LookupLocatorDiscovery object
48             LookupLocatorDiscovery locatorDiscovery =
49                 new LookupLocatorDiscovery( locators );
50
51             // register DiscoveryListener
52             locatorDiscovery.addDiscoveryListener( this );
53
54         } // end try
55
56         // handle invalid Jini URL
57         catch ( MalformedURLException exception ) {
58             exception.printStackTrace();
59         }
60     }
61
62 } // end UnicastDiscoveryUtility constructor
63
```

Fig. 22.28 **UnicastDiscoveryUtility** uses class **LookupLocatorDiscovery** to facilitate lookup service discovery (part 2 of 4).

```
64      // receive notification of found lookup services
65      public void discovered( DiscoveryEvent event )
66      {
67          // get the proxy registrars for those services
68          ServiceRegistrar[] registrars = event.getRegistrars();
69
70          // display information for each lookup service found
71          for ( int i = 0; i < registrars.length ; i++ )
72              displayServiceDetails( registrars[ i ] );
73
74      } // end method discovered
75
76      // display details of given ServiceRegistrar
77      private void displayServiceDetails( ServiceRegistrar registrar )
78      {
79          try {
80              final StringBuffer buffer = new StringBuffer();
81
82              // get the hostname and port number
83              buffer.append( "Lookup Service: " );
84              buffer.append( "\n    Host: " +
85                          registrar.getLocator().getHost() );
86              buffer.append( "\n    Port: " +
87                          registrar.getLocator().getPort() );
88              buffer.append( "\n    Group support: " );
89
90              // get lookup service groups
91              String[] groups = registrar.getGroups();
92
93              // get group names; if empty write public
94              for ( int i = 0; i < groups.length ; i++ ) {
95
96                  if ( groups[ i ].equals( "" ) )
97                      buffer.append( "public," );
98
99                  else
100                     buffer.append( groups[ i ] + "," );
101
102
103                 buffer.append( "\n\n" );
104
105                 // append information to outputArea
106                 SwingUtilities.invokeLater(
107
108                     // create Runnable for appending text
109                     new Runnable() {
110
111                         // append text and update caret position
112                         public void run()
113                         {
114                             outputArea.append( buffer.toString() );
```

Fig. 22.28 **UnicastDiscoveryUtility** uses class **LookupLocatorDiscovery** to facilitate lookup service discovery (part 3 of 4).

```
115             outputArea.setCaretPosition(
116                     outputArea.getText().length() );
117         }
118     }
119 }
120 ); // end call to invokeLater
121 }
122 } // end try
123
124 // handle exception communicating with lookup service
125 catch ( RemoteException exception ) {
126     exception.printStackTrace();
127 }
128
129 } // end method displayServiceDetails
130
131 // ignore discarded lookup services
132 public void discarded( DiscoveryEvent event ) {}
133
134 // launch UnicastDiscoveryUtility application
135 public static void main( String args[] )
136 {
137     // set SecurityManager
138     if ( System.getSecurityManager() == null )
139         System.setSecurityManager( new RMISecurityManager() );
140
141     // check command-line arguments for hostnames
142     if ( args.length < 1 ) {
143         System.err.println(
144             "Usage: java UnicastDiscoveryUtility " +
145             "jini://hostname:port [ jini://hostname:port ] ..." );
146     }
147
148     // launch UnicastDiscoveryUtility for set of hostnames
149     else {
150         UnicastDiscoveryUtility unicastUtility =
151             new UnicastDiscoveryUtility( args );
152
153         unicastUtility.setDefaultCloseOperation( EXIT_ON_CLOSE );
154         unicastUtility.setSize( 300, 300 );
155         unicastUtility.setVisible( true );
156     }
157
158 } // end method main
159 }
```

Fig. 22.28 **UnicastDiscoveryUtility** uses class **LookupLocatorDiscovery** to facilitate lookup service discovery (part 4 of 4).

Class **LookupLocatorDiscovery** invokes method **discovered** (lines 65–74) when it discovers new lookup services. Line 68 retrieves an array of **ServiceRegisters** from the **DiscoveryEvent** object and line 72 invokes method **displayServiceDetails** to show information about each discovered lookup service. Method **displayServiceDetails** (lines 77–129) places host, port and group information

about a **ServiceRegistrar** in a **StringBuffer** (lines 83–103) and appends the text in that **StringBuffer** to **outputArea** (lines 106–120).

To demonstrate the **UnicastDiscoverUtility** application on a single computer, start multiple instances of the Jini lookup service. Remember that you must specify a different log directory for each Reggie instance. After starting several Reggie instances, run the **MulticastDiscovery** application of Fig. 22.13 to obtain the various port numbers on which **Reggies** are running. Recall that **UnicastDiscoverUtility** uses unicast discovery, therefore you must specify the hostnames and port numbers for the computers running the lookup services. Using the **MulticastDiscovery** application is an easy way to determine these hostnames and port numbers for testing class **UnicastDiscoverUtility**. Figure 22.29 shows sample output from application **MulticastDiscovery** with four lookup services running on the local machine. Note that each lookup service uses a different port number. We use these port numbers when specifying **jini:** URLs for application **UnicastDiscoveryUtility**.

After running the **MulticastDiscovery** application to find the available lookup services, enter the following to launch **UnicastDiscoveryUtility**:

```
java -Djava.security.policy=policy
      com.deitel.advjhttp1.jini.utilities.discovery.
      UnicastDiscoveryUtility
      jini://hostname:3249 jini://hostname:3257 jini://hostname:3240
      jini://hostname:4160
```

where *policy* is an appropriate security policy and *hostname* is the hostname running the lookup services. Remember to replace the port numbers in the preceding command with the port numbers that application **MulticastDiscovery** found on your computer. Figure 22.30 shows the **UnicastDiscoveryUtility** application output.



Fig. 22.29 Using **MulticastDiscovery** to obtain sample data for testing **UnicastDiscoveryUtility**.

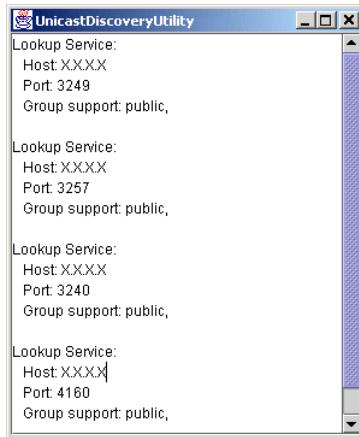


Fig. 22.30 **UnicastDiscoveryUtility** application output.

#### ***LookupDiscoveryManager Utility***

Class **LookupDiscoveryManager** provides flexible lookup service discovery by enabling Jini applications and clients to perform both unicast and multicast lookup service discovery using a single class. Class **LookupDiscoveryManager** combines the functionality provided in classes **LookupLocatorDiscovery** (for unicast discovery) and **LookupDiscovery** (for multicast discovery).

Class **GeneralDiscoveryUtility** (Fig. 22.31) performs unicast and multicast discovery using class **LookupDiscoveryManager**. Lines 38–51 create and lay out two **JTextAreas**—one for displaying unicast discovery notifications and one for displaying multicast discovery notifications. Lines 55–60 create an array of **LookupLocators** and populate the array with **jini:** URLs from the command-line arguments. Lines 63–64 create a new **LookupDiscoveryManager**. The **LookupDiscoveryManager** constructor takes as its first argument an array of group names for performing multicast discovery. The constant **DiscoveryGroupManagement.ALL\_GROUPS** specifies that the **LookupDiscoveryManager** should discover all lookup services. This constant is equivalent to passing **null** as the first argument. If the first argument is an empty **String** array, no multicast discovery is performed. The second argument to the **LookupDiscoveryManager** constructor is an array of **LookupLocators** for performing unicast discovery. If the **LookupLocator** array is **null** or empty, no unicast discovery is performed. The final argument is the **DiscoveryListener** to which discovery notifications should be sent.

Method **discovered** (lines 80–101) receives discovery notifications from the **LookupDiscoveryManager**. Line 83 retrieves an array of discovered **ServiceRegistrars** from the **DiscoveryEvent** object. Line 89 invokes method **getFrom** of class **LookupDiscoveryManager** to determine which form of discovery—unicast or multicast—discovered the given **ServiceRegistrar**. Constant **LookupDiscoveryManager.FROM\_GROUP** (line 90) identifies **ServiceRegistrars** discovered through multicast, or group, discovery. If the **ServiceRegistrar** was discovered through multicast discovery, lines 92–93 invoke method **displayServiceDetails** to

display information about the **ServiceRegistrar** in **multicastArea**. If the **ServiceRegistrar** was not discovered through multicast discovery, line 98 invokes method **displayServiceDetails** to display the **ServiceRegistrar** information in **unicastArea**.

```
1 // GeneralDiscoveryUtility.java
2 // GeneralDiscoveryUtility demonstrates using class
3 // LookupDiscoveryManager for performing multicast
4 // and unicast discovery.
5 package com.deitel.advjhtp1.jini.utilities.discovery;
6
7 // Java core packages
8 import java.rmi.*;
9 import java.io.*;
10 import java.awt.*;
11 import java.awt.event.*;
12 import java.net.*;
13
14 // Java standard extensions
15 import javax.swing.*;
16 import javax.swing.border.*;
17
18 // Jini core packages
19 import net.jini.core.lookup.ServiceRegistrar;
20 import net.jini.core.discovery.LookupLocator;
21
22 // Jini extension packages
23 import net.jini.discovery.*;
24
25 public class GeneralDiscoveryUtility extends JFrame
26     implements DiscoveryListener {
27
28     private LookupDiscoveryManager lookupManager;
29     private JTextArea multicastArea = new JTextArea( 15, 20 );
30     private JTextArea unicastArea = new JTextArea( 15, 20 );
31
32     // GeneralDiscoveryUtility constructor
33     public GeneralDiscoveryUtility( String urls[] )
34     {
35         super( "GeneralDiscoveryUtility" );
36
37         // lay out JTextAreas
38         JPanel multicastPanel = new JPanel();
39         multicastPanel.setBorder(
40             new TitledBorder( "Multicast (Group) Notifications" ) );
41         multicastPanel.add( new JScrollPane( multicastArea ) );
42
43         JPanel unicastPanel = new JPanel();
44         unicastPanel.setBorder(
45             new TitledBorder( "Unicast (Locator) Notifications" ) );
```

Fig. 22.31 **GeneralDiscoveryUtility** uses class **LookupDiscoveryManager** to perform both unicast and multicast lookup service discovery (part 1 of 4).

```
46     unicastPanel.add( new JScrollPane( unicastArea ) );
47
48     Container contentPane = getContentPane();
49     contentPane.setLayout( new FlowLayout() );
50     contentPane.add( unicastPanel );
51     contentPane.add( multicastPanel );
52
53     // get LookupLocators and LookupDiscoveryManager
54     try {
55         LookupLocator locators[] =
56             new LookupLocator[ urls.length ];
57
58         // get array of LookupLocators
59         for ( int i = 0; i < urls.length ; i++ )
60             locators[ i ] = new LookupLocator( urls[ i ] );
61
62         // instantiate a LookupDiscoveryManager object
63         lookupManager = new LookupDiscoveryManager(
64             DiscoveryGroupManagement.ALL_GROUPS, locators, this );
65     }
66
67     // handle invalid Jini URL
68     catch ( MalformedURLException exception ) {
69         exception.printStackTrace();
70     }
71
72     // handle exception creating LookupDiscoveryManager
73     catch ( IOException exception ) {
74         exception.printStackTrace();
75     }
76
77 } // end GeneralDiscoveryUtility constructor
78
79 // receive notifications of discovered lookup services.
80 public void discovered( DiscoveryEvent event )
81 {
82     // get the proxy registrars for those services
83     ServiceRegistrar[] registrars = event.getRegistrars();
84
85     // display information for each lookup service found
86     for ( int i = 0; i < registrars.length ; i++ ) {
87
88         // display multicast results in multicastArea
89         if ( lookupManager.getFrom( registrars[ i ] ) ==
90             LookupDiscoveryManager.FROM_GROUP ) {
91
92             displayServiceDetails( registrars[ i ],
93                                 multicastArea );
94         }
95     }
96 }
```

Fig. 22.31 **GeneralDiscoveryUtility** uses class **LookupDiscoveryManager** to perform both unicast and multicast lookup service discovery (part 2 of 4).

```
96         // display unicast results in unicastArea
97     else
98         displayServiceDetails( registrars[ i ], unicastArea );
99     }
100 }
101 } // end method discovered
102
103 // display details of given ServiceRegistrar
104 private void displayServiceDetails(
105     ServiceRegistrar registrar, final JTextArea outputArea )
106 {
107     try {
108         final StringBuffer buffer = new StringBuffer();
109
110         // get hostname and port number
111         buffer.append( "Lookup Service: " );
112         buffer.append( "\n    Host: " +
113             registrar.getLocator().getHost() );
114         buffer.append( "\n    Port: " +
115             registrar.getLocator().getPort() );
116         buffer.append( "\n    Group support: " );
117
118         // get lookup service groups
119         String[] groups = registrar.getGroups();
120
121         // get group names; if empty write public
122         for ( int i = 0; i < groups.length ; i++ ) {
123
124             if ( groups[ i ].equals( "" ) )
125                 buffer.append( "public," );
126
127             else
128                 buffer.append( groups[ i ] + "," );
129         }
130
131         buffer.append( "\n\n" );
132
133         // append information to outputArea
134         SwingUtilities.invokeLater(
135
136             // create Runnable for appending text
137             new Runnable() {
138
139                 // append text and update caret position
140                 public void run()
141                 {
142                     outputArea.append( buffer.toString() );
143                     outputArea.setCaretPosition(
144                         outputArea.getText().length() );
145                 }
146             }
147         );
148     }
149 }
```

Fig. 22.31 **GeneralDiscoveryUtility** uses class **LookupDiscoveryManager** to perform both unicast and multicast lookup service discovery (part 3 of 4).

```
147             ); // end call to invokeLater
148
149     } // end try
150
151     // handle exception communicating with lookup service
152     catch ( RemoteException exception ) {
153         exception.printStackTrace();
154     }
155
156
157 } // end method displayServiceDetails
158
159 // receive discarded lookup service notifications
160 public void discarded( DiscoveryEvent event ) {}
161
162 // launch GeneralDiscoveryUtility application
163 public static void main( String[] args )
164 {
165     // set SecurityManager
166     if ( System.getSecurityManager() == null )
167         System.setSecurityManager( new RMISecurityManager() );
168
169     // launch GeneralDiscoveryUtility for set of hostnames
170     GeneralDiscoveryUtility utility =
171         new GeneralDiscoveryUtility( args );
172     utility.setDefaultCloseOperation( EXIT_ON_CLOSE );
173     utility.pack();
174     utility.setVisible( true );
175
176 } // end method main
177 }
```

Fig. 22.31 **GeneralDiscoveryUtility** uses class **LookupDiscoveryManager** to perform both unicast and multicast lookup service discovery (part 4 of 4).

Method **displayServiceDetails** (lines 104–159) takes as arguments a **ServiceRegistrar** and a **JTextArea** in which to display that **ServiceRegistrar**'s information. Lines 111–131 append the **ServiceRegistrar**'s information to a **StringBuffer**. Lines 134–148 invoke **static** method **invokeLater** of class **SwingUtilities** to append the **ServiceRegistrar** information to the appropriate **JTextArea**.

Method **main** (lines 163–176) installs an **RMISecurityManager** (line 167) and creates a new **GeneralDiscoveryUtility** instance, passing the array of command-line arguments to the constructor (lines 170–171). If the user does not supply any **jini:** URLs as command-line arguments, **GeneralDiscoveryUtility** will not perform unicast discovery. To execute **GeneralDiscoveryUtility**, enter the following at a command prompt:

```
java -Djava.security.policy=polcy
      com.deitel.advjhttp1.jini.utilities.discovery.
      GeneralDiscoveryUtility jini://hostname:4160
```

where *policy* is an appropriate security policy, *hostname* is the hostname for a known computer running a lookup service and **4160** is the default lookup service port number. Figure 22.32 shows the output from **GeneralDiscoveryUtility** with several lookup services running on the local machine.

## 22.8.2 Entry Utilities

**Entry** attributes specify characteristics of Jini services. We used the **Name Entry** in Fig. 22.21 to provide a name for the **SeminarInfo** Jini service. **Entry** attributes help clients identify Jini services. By attaching attributes to services, service providers can publish services with detailed information, such as the service location and the functionality of the service. Jini provides seven common attributes (Fig. 22.33).

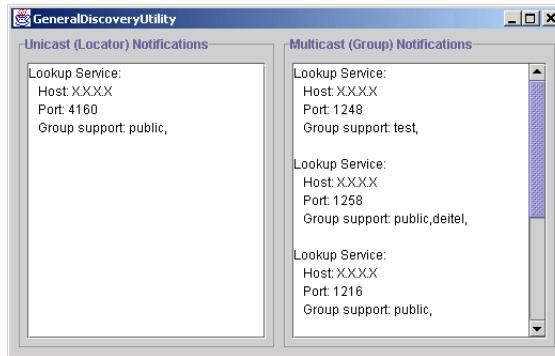


Fig. 22.32 **GeneralDiscoveryUtility** application output.

Attribute	Description
<b>Address</b>	Specifies the physical location of a service. (e.g., the city and street address of an Automated Teller Machine).
<b>Comment</b>	Provides general descriptive comments about a service.
<b>Location</b>	Provides more detailed location information, such as floor, suite and room number.
<b>Name</b>	Provides the service's name, suitable for use by people to identify a service (e.g., "BankABC ATM").
<b>ServiceInfo</b>	Provides basic information about a service. For example, the manufacturer and model number of a printer.
<b>ServiceType</b>	Provides a human-understandable description of the service type (e.g., "Print Queue").
<b>Status</b>	Describes the current status of the service in varying levels of severity.

Fig. 22.33 Standard Jini **Entry** attributes.

Developers also can create custom attributes for Jini services. Class **SeminarProvider** (Fig. 22.34) is an **Entry** attribute that gives the name of the company that provides **Seminars** for a given **SeminarInfo** service. Class **SeminarProvider** extends class **AbstractEntry** and implements interface **ServiceControlled**. **AbstractEntry** is a basic implementation of interface **Entry**. By implementing interface **ServiceControlled**, class **SeminarProvider** indicates that the service itself controls the **SeminarProvider** attribute.

An **Entry** class must supply a no-argument constructor (line 12). Also, instance variables must be **public** references to **Serializable** objects, so clients can perform searches using these instance variables. Line 12 declares **public String** reference **providerName**, which contains the name of the organization providing the **Seminars**.

To use the **SeminarProvider** attribute for our **SeminarInfo** Jini service, we need to modify class **SeminarInfoService**, which registers the **SeminarInfo** service with **ServiceRegistrars**. Replace line 43 of Fig. 22.21 with the line

```
entries[ 0 ] = new
    com.deitel.advjhttp1.jini.utilities.entry.SeminarProvider(
        "Deitel" );
```

We also must modify **UnicastSeminarInfoClient** to search for the **SeminarInfoServices** using the new **SeminarProvider** attribute. Replace line 110 of Fig. 22.22 with the line

```
Entry[] attribute = new Entry[] { new
    com.deitel.advjhttp1.jini.utilities.entry.SeminarProvider(
        "Deitel" ) };
```

```
1 // SeminarProvider.java
2 // SeminarProvider is an Entry object for the SeminarInfo service.
3 package com.deitel.advjhttp1.jini.utilities.entry;
4
5 // Jini extension package
6 import net.jini.entry.*;
7 import net.jini.lookup.entry.*;
8
9 public class SeminarProvider extends AbstractEntry
10    implements ServiceControlled
11 {
12     public String providerName = "";
13
14     // no-argument constructor
15     public SeminarProvider() {}
16
17     // SeminarProvider constructor for specifying providerName
18     public SeminarProvider( String provider )
19     {
20         providerName = provider;
21     }
22 }
```

Fig. 22.34 **SeminarProvider** subclass of **Entry** for describing the **Seminar** provider as a Jini attribute.

Compile and run the Jini service and **UnicastSeminarInfoClient** to locate the **SeminarInfo** service using the new **SeminarProvider** attribute. Be sure to include **SeminarProvider.class** in the service and client JAR files.

### 22.8.3 Lease Utilities

Jini uses *leasing* to ensure integrity in distributed systems built with Jini. Recall that Jini services register with lookup services to make the Jini service's functionality available to other members in the Jini community. If all goes well, other members of the Jini community use the service and the service stays up and running perpetually. However, in reality, services fail for many reasons. Network outages can make a service unreachable. A physical device associated with a service (e.g., a printer) might need repairs. The service itself could encounter an unrecoverable exception. In these and many other situations, a service could become unavailable and that service might not be able to unregister itself from lookup services to prevent other clients from attempting to use that service.

One goal of Jini technology is to make Jini communities “self-healing” and able to recover from common problems, such as network outages, hardware failures and software failures. Therefore, when a Jini service registers with a lookup service, the registration is not permanent. The registration is leased for a specific amount of time, after which the lookup service revokes the registration. This prevents problematic services from disrupting the entire Jini community. If a Jini service fails, the Jini service's lease eventually expires, and lookup services will no longer provide the failed Jini service to clients.

The leasing strategy that Jini employs is strict—if a Jini service does not renew its lease, the lookup service terminates the registration when the lease expires and the service becomes unavailable to clients. Therefore, developers must ensure that their Jini services manage registration leases to ensure that services do not lose their registrations prematurely.

Our **SeminarInfo** Jini service does not perform any lease maintenance. After the **SeminarInfo** service's first lease expires (i.e., 10 minutes), the **SeminarInfo** service is no longer available to clients. The service itself continues executing, but the lookup services with which the service registered will have terminated the registrations.

Class **LeaseRenewalManager** is a Jini utility class that enables services to manage their leases to ensure that the service's leases do not expire prematurely. Class **SeminarInfoLeaseService** (Fig. 22.35) uses class **LeaseRenewalManager** to manage leases for the **SeminarInfo** service. Class **SeminarInfoLeaseService** is similar to class **SeminarInfoService** (Fig. 22.21), so we concentrate only on lease management in this example.

```
1 // SeminarInfoLeaseService.java
2 // SeminarInfoLeaseService discovers lookup services, registers
3 // the SeminarInfo service, and creates a LeaseRenewalManager
4 // to maintain the SeminarInfo service lease.
5 package com.deitel.advjhtp1.jini.utilities.leasing;
6
7 // Java core packages
8 import java.rmi.RMISecurityManager;
```

Fig. 22.35 **SeminarInfoLeaseService** uses class **LeaseRenewalManager** to manage **SeminarInfo** service leasing (part 1 of 4).

```
9 import java.rmi.RemoteException;
10 import java.io.IOException;
11
12 // Jini core packages
13 import net.jini.core.lookup.*;
14 import net.jini.core.entry.Entry;
15 import net.jini.core.lease.Lease;
16
17 // Jini extension packages
18 import net.jini.discovery.*;
19 import net.jini.lookup.entry.Name;
20 import net.jini.lease.LeaseRenewalManager;
21
22 // Deitel packages
23 import com.deitel.advjhttp1.jini.seminar.service.*;
24 import com.deitel.advjhttp1.jini.utilities.entry.SeminarProvider;
25
26 public class SeminarInfoLeaseService implements DiscoveryListener {
27
28     private LookupDiscovery discover;
29     private ServiceItem item;
30     private static final int LEASETIME = 10 * 60 * 1000;
31
32     // SeminarInfoLeaseService constructor
33     public SeminarInfoLeaseService()
34     {
35         // search for lookup services with public group
36         try {
37             discover = new LookupDiscovery( new String[] { "" } );
38
39             // register DiscoveryListener
40             discover.addDiscoveryListener( this );
41         }
42
43         // handle exception creating LookupDiscovery
44         catch ( IOException exception ) {
45             exception.printStackTrace();
46         }
47
48         // create and set Entry name for service
49         Entry[] entries = new Entry[ 1 ];
50         entries[ 0 ] = new SeminarProvider( "Deitel" );
51
52         // specify the service's proxy and entry
53         item = new ServiceItem( null, createProxy(), entries );
54
55     } // end SeminarInfoLeaseService constructor
56
57     // receive notifications of discovered lookup services
58     public void discovered ( DiscoveryEvent event )
59     {
60         ServiceRegistrar[] registrars = event.getRegistrars();
```

Fig. 22.35 SeminarInfoLeaseService uses class LeaseRenewalManager to manage SeminarInfo service leasing (part 2 of 4).

```
61      // register the service with the lookup service
62      for ( int i = 0; i < registrars.length; i++ ) {
63
64          ServiceRegistrar registrar = registrars[ i ];
65
66          // register the service with the lookup service
67          try {
68              ServiceRegistration registration =
69                  registrar.register( item, LEASETIME );
70
71              // create LeaseRenewalmanager
72              LeaseRenewalManager leaseManager =
73                  new LeaseRenewalManager();
74
75              // renew SeminarInfo lease indefinitely
76              leaseManager.renewUntil( registration.getLease(),
77                  Lease.FOREVER, null );
78
79          } // end try
80
81
82          // handle exception registering ServiceItem
83          catch ( RemoteException exception ) {
84              exception.printStackTrace();
85          }
86
87      } // end for
88
89  } // end method discovered
90
91  // ignore discarded lookup services
92  public void discarded( DiscoveryEvent event ) {}
93
94  // create seminar service proxy
95  private SeminarInterface createProxy()
96  {
97      // get BackendInterface reference to SeminarInfo
98      try {
99          BackendInterface backInterface = new SeminarInfo();
100
101         return new SeminarProxy( backInterface );
102     }
103
104     // handle exception creating SeminarProxy
105     catch ( RemoteException exception ) {
106         exception.printStackTrace();
107     }
108
109     return null;
110
111 } // end method createProxy
112
```

Fig. 22.35 **SeminarInfoLeaseService** uses class **LeaseRenewalManager** to manage **SeminarInfo** service leasing (part 3 of 4).

```
113 // launch SeminarInfoLeaseService
114 public static void main( String args[] )
115 {
116     // set SecurityManager
117     if ( System.getSecurityManager() == null ) {
118         System.setSecurityManager( new RMISecurityManager() );
119     }
120
121     SeminarInfoLeaseService service =
122         new SeminarInfoLeaseService();
123
124     Object keepAlive = new Object();
125
126     // wait on keepAlive Object to keep service running
127     synchronized ( keepAlive ) {
128
129         // keep application alive
130         try {
131             keepAlive.wait();
132         }
133
134         // handle exception if wait interrupted
135         catch ( InterruptedException exception ) {
136             exception.printStackTrace();
137         }
138
139     } // end synchronized block
140
141 } // end method main
142 }
```

Fig. 22.35 **SeminarInfoLeaseService** uses class **LeaseRenewalManager** to manage **SeminarInfo** service leasing (part 4 of 4).

In method **discovered**, lines 69–70 register the **SeminarInfo** service's **ServiceItem** with the discovered **ServiceRegistrar**. Lines 73–74 create a new **LeaseRenewalManager**, which class **SeminarInfoLeaseService** uses to manage the **SeminarInfo** service's lease. Lines 77–78 invoke method **renewUntil** of class **LeaseRenewalManager**. Method **renewUntil** takes as its first argument the **Lease** object to be renewed. In this example, we obtain the **Lease** object by invoking method **getLease** of class **ServiceRegistration**. The second argument specifies the desired expiration time (in milliseconds) for renewed **Leases**. Line 78 specifies the constant **Lease.FOREVER** to request a **Lease** that never expires. This does not guarantee that the lookup service will provide an everlasting **Lease**—the lookup service is free to grant a lease that is shorter than the requested length. The third argument to method **renewUntil** is the **LeaseListener**, to notify of problems encountered when renewing the **Lease**. We pass **null** as the third argument to disregard such notifications.

To run the **SeminarInfo** Jini service with lease management, create a new JAR file named **SeminarServiceWithLeasing.jar**. Figure 22.36 shows the contents of **SeminarServiceWithLeasing.jar**. Note that this JAR file replaces **SeminarInfoService.class** with **SeminarInfoLeaseService.class**. Note also that

this JAR file includes **SeminarProvider.class**, which is our custom **Entry** object for the **SeminarInfo** service.

After packaging the classes in **SeminarServiceWithLeasing.jar**, run the new version of the service by typing the following command at a command prompt:

```
java -classpath %CLASSPATH%;SeminarServiceWithLeasing.jar  
-Djava.security.policy=policy  
-Djava.rmi.server.codebase=http://hostname:9090/  
SeminarServiceDownload.jar  
com.deitel.advjhttp1.jini.utilities.leasing.  
SeminarInfoLeaseService
```

where *policy* is an appropriate security policy and *hostname* is the hostname where the Web server for downloading the **SeminarInfo** service proxy is running. The **LeaseRenewalManager** will renew the **SeminarInfo** service's lease to maintain the service's lookup service registrations.

#### 22.8.4 JoinManager Utility

As we have seen, making a Jini service available in a Jini community requires several steps. The service must discover lookup services, register with discovered lookup services and maintain registration leases. Class **JoinManager** is a utility class that facilitates the process of deploying a Jini service by performing lookup discovery, service registration and lease management in a single class.

Class File	Directory in SeminarServiceWithLeasing.jar
Seminar.class	com\deitel\advjhttp1\jini\seminar\
SeminarInterface.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarProxy.class	com\deitel\advjhttp1\jini\seminar\service\
BackendInterface.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarInfo.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarInfo_Stub.class	com\deitel\advjhttp1\jini\seminar\service\
SeminarProvider.class	com\deitel\advjhttp1\jini\utilities\entry\
SeminarInfoLeaseService.class	com\deitel\advjhttp1\jini\utilities\leasing\

Fig. 22.36 **SeminarServiceWithLeasing.jar** contents.

Class **SeminarInfoJoinService** (Fig. 22.37) uses class **JoinManager** to deploy the **SeminarInfo** service. Lines 38–40 create a **LookupDiscoveryManger** that the **JoinManager** will use to discover lookup services. We pass as the first argument to the **LookupDiscoveryManager** constructor a **String** array with a single element, which is an empty **String**. This argument specifies that the **LookupDiscoveryManager** should perform multicast discovery for lookup services that support the “**public**” group. For the second and third arguments, line 40 passes the value **null**. These arguments disable unicast discovery and specify a **null DiscoveryListener**, respectively. The **JoinManager** handles the discovery process, so class **SeminarInfoJoinService** need not handle **DiscoveryEvents**.

Lines 43–44 create a new **Entry** array with a single **SeminarProvider** element that specifies the provider of **Seminars** for the **SeminarInfo** service. Lines 47–49 create a new instance of class **JoinManager** to discover lookup services, register the service and maintain the service’s registration leases. Line 47 invokes method **createProxy** to create a **SeminarProxy** for the **SeminarInfo** service. The second argument to the **JoinManager** constructor is the array of **Entry** attributes that describe the service. The third argument is a reference to a **ServiceIDLListener**. When the **JoinManager** registers the Jini service with a lookup service, the **JoinManager** notifies the **ServiceIDLListener** of the service ID that the lookup service assigns to the Jini service. The fourth argument is a **DiscoveryManagement** object for discovering lookup services. For this example, we pass the **LookupDiscoveryManager** created on lines 38–40. The final argument to the **JoinManager** constructor is a **LeaseRenewalManager** for maintaining the service’s registration leases.

```
1 // SeminarInfoJoinService.java
2 // SeminarInfoJoinService uses a JoinManager to find lookup
3 // services, register the Seminar service with the lookup
4 // services and manage lease renewal.
5 package com.deitel.advjhttp1.jini.utilities.join;
6
7 // Java core packages
8 import java.rmi.RMISecurityManager;
9 import java.rmi.RemoteException;
10 import java.io.IOException;
11
12 // Jini core packages
13 import net.jini.core.lookup.ServiceID;
14 import net.jini.core.entry.Entry;
15
16 // Jini extension packages
17 import net.jini.lookup.entry.Name;
18 import net.jini.lease.LeaseRenewalManager;
19 import net.jini.lookup.JoinManager;
20 import net.jini.discovery.LookupDiscoveryManager;
21 import net.jini.lookup.ServiceIDLListener;
22
```

Fig. 22.37 **SeminarInfoJoinService** uses class **JoinManager** to facilitate registering the **SeminarInfo** service and manage its leasing (part 1 of 3).

```
23 // Deitel packages
24 import com.deitel.advjhttp1.jini.seminar.service.*;
25 import com.deitel.advjhttp1.jini.utilities.entry.*;
26
27 public class SeminarInfoJoinService implements ServiceIDListener {
28
29     // SeminarInfoJoinService constructor
30     public SeminarInfoJoinService()
31     {
32         // use JoinManager to register SeminarInfo service
33         // and manage lease
34         try {
35
36             // create LookupDiscoveryManager for discovering
37             // lookup services
38             LookupDiscoveryManager lookupManager =
39                 new LookupDiscoveryManager( new String[] { "" },
40                     null, null );
41
42             // create and set Entry name for service
43             Entry[] entries = new Entry[ 1 ];
44             entries[ 0 ] = new SeminarProvider( "Deitel" );
45
46             // create JoinManager
47             JoinManager manager = new JoinManager( createProxy(),
48                 entries, this, lookupManager,
49                 new LeaseRenewalManager() );
50         }
51
52         // handle exception creating JoinManager
53         catch ( IOException exception ) {
54             exception.printStackTrace();
55         }
56
57     } // end SeminarInfoJoinService constructor
58
59     // create seminar service proxy
60     private SeminarInterface createProxy()
61     {
62         // get SeminarProxy for SeminarInfo service
63         try {
64             return new SeminarProxy( new SeminarInfo() );
65         }
66
67         // handle exception creating SeminarProxy
68         catch ( RemoteException exception ) {
69             exception.printStackTrace();
70         }
71
72         return null;
73     } // end method createProxy
```

Fig. 22.37 **SeminarInfoJoinService** uses class **JoinManager** to facilitate registering the **SeminarInfo** service and manage its leasing (part 2 of 3).

```
75      // receive notification of ServiceID assignment
76      public void serviceIDNotify( ServiceID serviceID )
77      {
78          System.err.println( "Service ID: " + serviceID );
79      }
80
81
82      // launch SeminarInfoJoinService
83      public static void main( String args[] )
84      {
85          // set SecurityManager
86          if ( System.getSecurityManager() == null ) {
87              System.setSecurityManager( new RMISecurityManager() );
88          }
89
90          // create SeminarInfoJoinService
91          new SeminarInfoJoinService();
92      }
93 }
```

```
Service ID: 0084d3a0-4bbe-4b76-aa0b-f73294738fec
```

Fig. 22.37 `SeminarInfoJoinService` uses class `JoinManager` to facilitate registering the `SeminarInfo` service and manage its leasing (part 3 of 3).

Method `serviceIDNotify` (lines 77–80) is required by interface `ServiceIDListener`. The `JoinManager` invokes method `serviceIDNotify` to notify a `ServiceIDListener` that a lookup service has assigned a service ID to the Jini service. Line 79 simply prints out the service ID.

Method `main` (lines 83–92) sets the `RMISecurityManager` and launches the `SeminarInfoJoinService` application. Note that method `main` does not use a `keepAlive Object` to keep the application running, as was required in previous examples. The `JoinManager` keeps the application alive.

To run the `SeminarInfo` service using the `JoinManager`, create the JAR file `SeminarServiceJoinManager.jar` with the contents listed in Figure 22.38.

Class File	Directory in SeminarServiceJoinManager.jar
------------	--

<code>Seminar.class</code>	<code>com\deitel\advjhttp1\jini\seminar\</code>
<code>SeminarInterface.class</code>	<code>com\deitel\advjhttp1\jini\seminar\service\</code>
<code>SeminarProxy.class</code>	<code>com\deitel\advjhttp1\jini\seminar\service\</code>

Fig. 22.38 `SeminarServiceJoinManager.jar` contents (part 1 of 2).

Class File	Directory in SeminarServiceJoinManager.jar
------------	--

```
BackendInterface.class  
    com\deitel\advjhttp1\jini\seminar\service\  
SeminarInfo.class  
    com\deitel\advjhttp1\jini\seminar\service\  
SeminarInfo_Stub.class  
    com\deitel\advjhttp1\jini\seminar\service\  
SeminarProvider.class  
    com\deitel\advjhttp1\jini\utilities\entry\  
SeminarInfoJoinService.class  
    com\deitel\advjhttp1\jini\utilities\join\
```

Fig. 22.38 SeminarServiceJoinManager.jar contents (part 2 of 2).

After packaging the classes in **SeminarServiceJoinManager.jar**, run the new version of the service by typing the following at a command prompt:

```
java -classpath %CLASSPATH%;SeminarServiceJoinManager.jar  
    -Djava.security.policy=policy  
    -Djava.rmi.server.codebase=http://hostname:9090/  
SeminarServiceDownload.jar  
    com.deitel.advjhttp1.jini.utilities.join.  
SeminarInfoJoinService
```

where *policy* is an appropriate security policy and *hostname* is the hostname where the Web server for downloading the **SeminarInfo** service proxy is running. Figure 22.37 shows a sample service ID output from application **SeminarInfoJoinService**.

## 22.8.5 Service Discovery Utilities

Complex Jini clients often have specific requirements for the Jini services they employ. To satisfy these requirements, the Jini client often must work with sets of Jini services. The client searches through these services to locate the particular service that can satisfy the client's needs. For example, a Jini client that provides users with information about printers available in a given office needs a set of services for the available printers. This printer-monitoring program would need to be aware of the status of each printer to know when a new printer has been added. The service also should be able to search among the printers for particular features (color support, print quality, capacity, speed etc.).

Class **net.jini.lookup.ServiceDiscoveryManager** provides Jini clients with a richer set of service and lookup-service management features than interface **ServiceRegistrar** provides. Class **ServiceDiscoveryManager** facilitates discovering available services and enables clients to perform finer-grained searches than are possible with the **ServiceRegistrar** interface. Jini clients also can use class **ServiceDiscoveryManager** to enhance application performance by maintaining a local cache of services. There are three primary ways in which Jini clients use class **ServiceDiscoveryManager**—creating a local cache of services, receiving event notifications

when services become available or unavailable and performing detailed searches not possible with simple **ServiceTemplates**.

Class **ServiceDiscoveryManager** can enhance Jini-client performance by creating a local cache of discovered services. This local cache—implemented as a **net.jini.lookup.LookupCache**—enables the client to perform additional service lookups without incurring the network overhead of a remote call to a lookup service. When the client needs a particular service that is in the **LookupCache**, the client simply invokes method **lookup** of interface **LookupCache** to retrieve the service from the local cache.

Jini clients also can use a **LookupCache** retrieved from a **ServiceDiscoveryManager** to receive notifications related to a set of services. By implementing interface **ServiceDiscoveryListener** and registering with a **LookupCache**, a Jini client can receive events indicating when a particular service has been discovered, when a service's attributes have changed and when the service is removed from the **LookupCache**. This event notification is particularly useful for Jini clients that monitor available resources, such as our printer-monitoring example.

Class **ServiceDiscoveryManager** also provides an enhanced interface that enables Jini clients to search for services using more specific search criteria. Jini clients can use class **ServiceDiscoverManager** with implementations of interface **ServiceItemFilter** to locate services whose attribute values fall within a particular range. For example, a Jini client could use a **ServiceItemFilter** to locate all automated teller machines in the area whose service charge is less than two dollars. Such a specific query is not possible using the standard **ServiceTemplate** matching available through interface **ServiceRegistrar**.

For more information on class **ServiceDiscoveryManager**, please see the Jini API documentation included with the Jini Technology Core Platform.

## 22.9 Internet and World Wide Web Resources

[www.jini.org](http://www.jini.org)

Home of the Jini community.

[www.sun.com/jini/specs/jini1.1html/coreTOC.html](http://www.sun.com/jini/specs/jini1.1html/coreTOC.html)

The site for *Jini Technology Core Platform Specification*.

[www.sun.com/jini/specs/jini1.1html/collectionTOC.html](http://www.sun.com/jini/specs/jini1.1html/collectionTOC.html)

This site contains a collection of *Jini Technology Helper Utilities and Services Specifications*.

[www.sun.com/jini/specs/jini1.1html/jsTOC.html](http://www.sun.com/jini/specs/jini1.1html/jsTOC.html)

This site provides *JavaSpaces Service Specification*.

[developer.java.sun.com/developer/products/jini/installation.index.html](http://developer.java.sun.com/developer/products/jini/installation.index.html)

This site provides installation instructions for Jini technology.

### SUMMARY

- Many network devices provide services to network clients.
- Each service has a well-defined interface.
- To use a service, a client must be able to discover that a service exists and must know the interface for interacting with the service.
- Jini extends RMI to provide services to a network.

- Jini services are plug-and-play—clients can discover services on the network dynamically, transparently download classes required to use those services, then begin interacting with those services.
- RMI's dynamic class-downloading capability enables Jini clients to use services without installing special driver software for those services in advance.
- For Jini clients to discover and use Jini services, standardized interfaces for common services must be developed.
- The basic software requirements for Jini include the Java 2 Standard Edition (J2SE) and the Jini Technology Starter Kit. If you are going to write commercial Jini services and want to test their compatibility with the Jini platform, you also need to download the Jini Technology Core Platform Compatibility Kit (Jini TCK).
- The Jini Starter Kit has three components—the Jini Technology Core Platform (JCP), the Jini Technology Extended Platform (JXP) and the Jini Software Kit (JSK). The JCP contains the fundamental Jini interfaces and classes. The JXP provides helper utilities for implementing Jini services and clients. The JSK contains an implementation of the services specified in the JCP and the JXP.
- To compile and execute Jini services and clients the JAR files **jini-core.jar**, **jini-ext.jar** and **sun-util.jar** must be included in the **CLASSPATH** environment variable. These three JAR files are in the **lib** directory of the Jini Starter Kit—they correspond to the Jini Technology Core Platform, the Jini Technology Extended Platform and the Jini Software Kit, respectively.
- The Jini distribution comes with three services that must be running correctly before executing Jini applications—a Web server to enable Jini clients to download class files through RMI, so the clients can access Jini services dynamically; the RMI activation daemon (**rmid**) to enable the RMI infrastructure that allows Jini clients to communicate with Jini services; and a lookup service to maintain information about available Jini services, and to enable clients to discover and use those services. The Web server and **rmid** must be executing (they can be started in any order) before starting the lookup service.
- The Jini Technology Core Platform implementation includes the **StartService** GUI tool for launching required services.
- The Jini lookup service is the heart of a Jini community. The process of finding the lookup services and obtaining references to them is called discovery.
- Discovery distinguishes Jini technology from RMI. In RMI, you must know in advance where to register an object. In Jini, you do not need to know where—just how. The discovery process determines where, but hides the details from the developer.
- Discovery can be accomplished using either unicast discovery or multicast discovery.
- Unicast discovery, or locator discovery, enables a Jini service or client to discover lookup services on a specific host.
- Method **getRegistrar** of class **LookupLocator** performs unicast discovery. The method returns a **ServiceRegistrar**, which represents a lookup service. An overloaded version of method **getRegistrar** takes as an integer argument the maximum number of milliseconds to wait for the unicast discovery to locate a **ServiceRegistrar** before issuing a timeout.
- Methods **getHost** and **getPort** of class **LookupLocator** retrieve the hostname and port number where a lookup service was discovered.
- Multicast discovery, or group discovery, enables a Jini service or client to discover lookup services when the particular host running the lookup service is not known. A multicast discovery request uses network multicast to discover nearby lookup services. Lookup services periodically issue multicast announcements to notify interested Jini services and clients that the lookup services are available.
- Class **net.jini.discovery.LookupDiscovery** performs multicast discovery.
- Implementing interface **DiscoveryListener** enables an object of a class to receive **DiscoveryEvents**—notifications of discovered lookup services.

- Class **LookupDiscovery** invokes method **discovered** when **LookupDiscovery** locates new lookup services.
- Method **getRegistrars** of **DiscoveryEvent** obtains an array of **ServiceRegistrars**.
- Class **LookupDiscovery** invokes method **discarded** when a lookup service should be discarded because it is no longer available or because it no longer matches the set of groups in which the Jini service or client is interested.
- A Jini service consists of several components, each of which contributes to the flexibility and portability of the Jini architecture. A service proxy is an intermediary between a Jini service and its clients. The service proxy communicates with the actual service implementation through the service's back-end interface, which defines methods in the service implementation. A separate application discovers lookup services and registers the Jini service, making the service available to Jini clients.
- A Jini client uses the lookup service discovery techniques to discover lookup services. The Jini client then uses the discovered lookup services to locate the desired Jini service. When the lookup service locates the service requested by the Jini client, the lookup service serializes the service proxy and delivers the proxy to the Jini client. The client can then invoke methods defined in the service's **public** interface directly on the service proxy, which implements that interface. The service proxy communicates with the service implementation through the back-end interface.
- An **Entry** (package **net.jini.core.entry**) describes a service, which enables Jini clients to search for services of a particular description.
- The lookup service requires a **ServiceItem** (package **net.jini.core.lookup**) to register a Jini service.
- Jini helper utilities simplify the process of developing the Jini applications. These helper utilities provide high-level management capabilities.
- Class **LookupLocatorDiscovery** enables a Jini service or client to discover lookup services on multiple known hosts. Class **LookupLocatorDiscovery** uses **DiscoveryEvents** to notify the Jini service or client of discovered lookup services.
- Class **LookupDiscoveryManager** provides flexible lookup service discovery by enabling Jini applications and clients to perform both unicast and multicast lookup service discovery using a single class.
- **Entry** attributes specify characteristics of Jini services. By attaching attributes to services, service providers can publish services with detailed information, such as the service location and the functionality of the service. Developers also can create custom attributes for Jini services. Class **AbstractEntry** provides a basic implementation of interface **Entry**.
- An **Entry** class must supply a no-argument constructor. Also, instance variables must be **public** references to **Serializable** objects.
- One goal of Jini technology is to make Jini communities “self-healing” and able to recover from common problems, such as network outages, hardware failures and software failures. Therefore, when a Jini service registers with a lookup service, the registration is not permanent. The registration is leased for a specific amount of time, after which the lookup service revokes the registration. This prevents problematic services from disrupting the entire Jini community.
- The leasing strategy that Jini employs is strict—if a Jini service does not renew its lease, the lookup service terminates the registration when the lease expires, making the service unavailable to clients.
- Class **LeaseRenewalManager** is a Jini utility class that enables services to manage their leases to ensure that the service's leases do not expire prematurely.
- Class **JoinManager** is a utility class that facilitates the process of deploying a Jini service by performing lookup discovery, service registration and lease management in a single class.
- Complex Jini clients often have specific requirements for the Jini services they employ. To satisfy these requirements, the Jini client often must work with sets of Jini services. The client searches

through these services to locate the particular service that can satisfy the client's needs. Class **ServiceDiscoveryManager** facilitates discovering available services and enables clients to perform finer-grained searches than are possible with the **ServiceRegistrar** interface.

- There are three primary ways in which Jini clients use class **ServiceDiscoveryManager**—creating a local cache of services, receiving event notifications when services become available or unavailable and performing detailed searches not possible with simple **ServiceTemplates**.
- Class **ServiceDiscoveryManager** can enhance Jini-client performance by creating a local cache of discovered services. This local cache—is implemented as a **LookupCache**.

## TERMINOLOGY

<b>serviceAdded</b> method of	<b>LeaseRenewalManager</b> class
<b>ServiceDiscoveryListener</b>	locator discovery
<b>AbstractEntry</b> class	<b>lookup</b> method of
<b>createLookupCache</b> method of	<b>ServiceDiscoveryManager</b>
<b>ServiceDiscoveryManager</b>	<b>lookup</b> method of
discovery	<b>ServiceDiscoveryManager</b>
<b>DiscoveryEvent</b> class	<b>lookup</b> method of <b>LookupCache</b>
<b>DiscoveryListener</b> interface	lookup service
<b>DiscoveryManagement</b> class	<b>LookupCache</b> interface
<b>Entry</b> interface	<b>LookupDiscovery</b> class
<b>getFrom</b> method of	<b>LookupDiscoveryManager</b> class
<b>LookupDiscoveryManager</b>	<b>LookupLocator</b> class
<b>getGroups</b> method of <b>LookupDiscovery</b>	<b>LookupLocatorDiscovery</b> class
<b>getHost</b> method of class <b>LookupLocator</b>	multicast discovery
<b>getPort</b> method of class <b>LookupLocator</b>	<b>Name</b> class
<b>getRegistrar</b> method of class	plug and play
<b>LookupLocator</b>	Reggie lookup service
<b>getRegistrars</b> method of class	<b>renewFor</b> method of
<b>LookupDiscovery</b>	<b>LeaseRenewalManager</b>
group discovery	<b>renewUntil</b> method of
Jini	<b>LeaseRenewalManager</b>
Jini client	<b>ServiceDiscoveryListener</b> interface
Jini Software Kit	<b>ServiceDiscoveryManager</b> class
Jini Technology Core Platform Compatibility Kit	<b>ServiceID</b> class
Jini Technology Starter Kit	<b>serviceIDNotify</b> method of
Jini transaction manager service	<b>ServiceIDLListener</b>
<b>jini:</b> URL	<b>ServiceItem</b> class
<b>join</b> protocol	<b>ServiceItemFilter</b> interface
<b>JoinManager</b> class	<b>ServiceRegistrar</b> interface
<b>Lease</b> class	<b>serviceRemoved</b> method in
lease renewal service	<b>ServiceDiscoveryListener</b>
<b>Lease.FOREVER</b> constant	<b>ServiceTemplate</b> class
<b>LeaseListener</b> interface	unicast discovery

## SELF-REVIEW EXERCISES

22.1 Fill in the blanks in each of the following statements:

- Name three required services for running Jini services and clients: \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- Two ways to discover lookup services are \_\_\_\_\_ and \_\_\_\_\_.

- c) To generate the stub file for a remote object, use \_\_\_\_\_.
  - d) A service proxy that is exported to the remote client must implement interface \_\_\_\_\_.
  - e) Service providers use \_\_\_\_\_ to describe a service. Jini clients use \_\_\_\_\_ to find a matching service.
- 22.2** State whether each of the following is *true* or *false*. If *false*, explain why.
- a) Unicast discovery is also known as locator discovery.
  - b) The **JoinManager** can discover lookup services, register a service and renew a service's lease.
  - c) Class **LookupDiscoveryManager** can perform only unicast discovery.
  - d) Jini requires only the RMI activation daemon (**rmid**) and a Web server.
  - e) Jini clients must have all the **.class** files for a Jini service in the local **CLASSPATH**.

## ANSWERS TO SELF-REVIEW EXERCISES

**22.1** a) the HTTP Web server, the **rmi** activation daemon, the lookup service. b) unicast discovery, multicast discovery. c) **rmic**. d) **Serializable**. e) **ServiceItem**, **ServiceTemplate**.

**22.2** a) True. b) True. c) False. Class **LookupDiscoveryManager** performs both unicast and multicast discovery. d) False. Jini also requires lookup services to enable clients to locate Jini services. e) False. Jini clients require that only the public interface and supporting classes be in the local **CLASSPATH**. Having the Jini service's **.class** files in the client's **CLASSPATH** prevents network class loading.

## EXERCISES

**22.3** Modify class **MulticastDiscovery** (Fig. 22.13) to perform multicast discovery for lookup services that support any group, not just the public group. Can you use **null** for a wildcard match?

**22.4** Create an application to find all services that are registered with local lookup services.

**22.5** Write a currency exchange service using Jini technology. This currency exchange service simply does one function: It exchanges the currency of one country to the currency of another country. The exchange rate can be dynamically loaded from an on-line resource or can be just statically loaded from a file. Create the public interface, service proxy, back-end interface and service implementation.

**22.6** Register the currency exchange service with the lookup services on the local machine using **JoinManager**.

**22.7** Create a Jini client that allows a user to use the exchange service. Search the currency exchange service with the lookup service on the local machine, and use the found service to exchange one currency into another currency.

**22.8** Modify Exercise 22.6 to add a set of **Entry** attributes to the service. The attributes should include the name of the exchange service, the address of the exchange service and any other attributes you want to add to the service. Use part or all of the attributes set to find a matching service.

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Oaks, S., and Wong, H., *Jini in a Nutshell*, Sebastopol, CA: O'Reilly & Associates, Inc. 2000

# 23

## JavaSpaces

### Objectives

- To be able to use the JavaSpaces service for building distributed applications.
- To understand the operations available in a JavaSpaces service.
- To be able to match entries in a JavaSpaces service against templates.
- To understand the use of transactions in JavaSpaces services.
- To be able to use notifications to build event-driven JavaSpaces applications.

*The world is a book, and those who do not travel read only a page.*

Saint Augustine

*Write what you like; there is no other rule.*

O. Henry

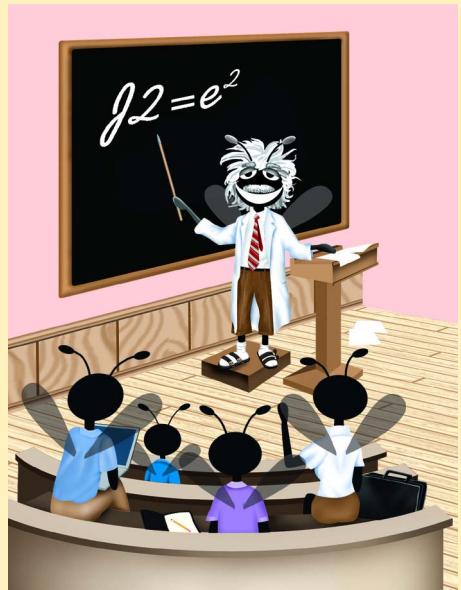
*Take nothing on its looks: take everything on evidence.*

*There's no better rule.*

Charles Dickens

*Believe nothing, no matter where you read it, or who said it, no matter if I have said it, unless it agrees with your own reason and your own common sense.*

Buddha



## Outline

- 23.1 Introduction
- 23.2 JavaSpaces Service Properties
- 23.3 JavaSpaces Service
- 23.5 JavaSpace Interface
- 23.6 Defining an Entry
- 23.4 Discovering the JavaSpaces Service
- 23.7 Write Operation
- 23.8 Read and Take Operations
  - 23.8.1 Read Operation
  - 23.8.2 Take Operation
- 23.9 Notify Operation
- 23.10 Method `snapshot`
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*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Works Cited • Bibliography*

### 23.1 Introduction

Objects that take part in distributed systems must be able to communicate with one another and share information. Thus far we have introduced several mechanisms by which Java objects in distributed systems can communicate. Java servlets (Chapter 9) enable Java objects (and non-Java objects) to communicate using the HTTP protocol. RMI (Chapter 13) enables Java objects running in separate virtual machines to invoke methods on one another as if those objects were in the same virtual machine. The Java Message Service (Chapter 16) enables Java objects (and non-Java objects) to communicate by publishing and consuming simple messages.

The *JavaSpaces service* is a Jini service that implements a simple, high-level architecture for building distributed systems. The JavaSpaces service enables Java objects to communicate, share objects and coordinate tasks using an area of shared memory.<sup>1</sup> A JavaSpaces service provides three fundamental operations—*write*, *take* and *read*. The write operation places an object—called an *entry*—into the JavaSpaces service. The take opera-

tion specifies a *template* and removes from the JavaSpaces service an entry that matches the given template. The read operation is similar to the take operation, but does not remove the matching entry from the JavaSpaces service. In addition to the three basic operations, JavaSpaces services support transactions through the Jini transaction manager, and a notification mechanism that notifies an object when an entry that matches a given template is written to the JavaSpaces service.

In the first half of this chapter, we present fundamental JavaSpaces technology concepts and use simple examples to demonstrate operations, transactions and notifications. The case study at the end of this chapter uses JavaSpaces services to build a distributed image-processing application. This image-processing application uses JavaSpaces services to distribute the work of applying filters to images across many programs (normally on separate computers).

## 23.2 JavaSpaces Service Properties

JavaSpaces technology eases the design and development of distributed systems. A JavaSpaces service has five major properties:<sup>2</sup>

1. A JavaSpaces service is a Jini service.
1. Multiple processes can access a JavaSpaces service concurrently.
2. An entry stored in a JavaSpaces service will remain in the JavaSpaces service until its lease expires or until a program takes the entry from the JavaSpaces service.
3. A JavaSpaces service locates objects by comparing those objects to a template. The template specifies the search criteria against which the JavaSpaces service compares each entry. When one or more entries match the template, the JavaSpaces service returns a single matching entry.
4. JavaSpaces services use the Jini transaction manager to ensure operations execute atomically.
5. Objects in a JavaSpaces service are shared. Programs can read and take entries from the JavaSpaces service, modify the **public** fields in those entries and write them back to the JavaSpaces service for other programs to use.

## 23.3 JavaSpaces Service

The JavaSpaces service provides distributed, shared storage for Java objects. Any Java-compatible client can put shared objects into the storage. However, several restrictions apply to these Java objects. First, any object stored in the JavaSpaces service must implement interface **Entry** (package **net.jini.core.entry**). JavaSpaces service **Entries** adhere to the Jini **Entry** contract defined in the Jini Core Specification (see Chapter 22, Jini). An **Entry** can have multiple constructors and as many methods as required. Other requirements include a **public** no-argument constructor, **public** fields and no-primitive type fields. The JavaSpaces service proxy uses the no-argument constructor to instantiate the matching **Entry** during the deserialization process. All fields that will be used as the template matching fields in an **Entry** must be **public** (for more information on template matching fields, see Section 23.8). As defined by the Jini Core Specification, an **Entry** cannot have primitive-type fields. The object field requirement simplifies the model for template matching because primitive types cannot have **null** values, which are used as wildcards in templates.

JavaSpaces technology, like Jini, requires several underlying services. The JavaSpaces service depends on the Jini lookup service (for more information on Jini services, see Chapter 22, Jini). When transactions are required, the Jini transaction service (Section 23.11.2) must be started. JavaSpaces services also depend on a Web server and **rmid** (for more information on starting these services, see Chapter 22, Jini). Section 23.6 explains the relationships between JavaSpaces services and these Jini services. Section 23.11 demonstrates using the Transaction service with the JavaSpaces service. To use the JavaSpaces service, we need to start **outrigger**, which is Sun's implementation of the JavaSpaces service. Two versions of the JavaSpaces service are available. One is the *transient JavaSpaces service* (nonactivatable). The other is the *persistent JavaSpaces service* (activatable). The transient JavaSpaces service does not require the RMI activation daemon (**rmid**), because the transient JavaSpaces service is not activatable. Once the transient JavaSpaces service terminates, all state information is lost and **rmid** is unable to restart the service. The persistent JavaSpaces service is activatable, and therefore requires the RMI activation daemon. If the persistent JavaSpaces service terminates, all of its state information is stored in a log file and **rmid** can restart the service at a later time.

To start the transient JavaSpaces service enter the following a command prompt

```
java -Djava.security.policy=polcy  
-Djava.rmi.server.codebase=  
http://hostname:port/outrigger-d1.jar  
-jar c:\files\jini1_1\lib\transient-outrigger.jar public
```

where *policy* is the path to an appropriate policy file, *hostname* is the name of the machine on which the Web server is running and *port* specifies the port number on which the Web server will accept connections. The argument **public** specifies to which group this service belongs.

The following command starts the persistent JavaSpaces service:

```
java -jar c:\files\jini1_1\lib\outrigger.jar  
http://hostname:port/outrigger-d1.jar  
policy log_path public
```

where *hostname* is the name of the machine on which the Web server is running, *port* specifies the port number from which the Web server will accept connections, *policy* is the full path of the policy file and *log\_path* is the location where the **outrigger** log will be created.

An additional parameter is useful in systems where two or more JavaSpaces services operate. The parameter is

```
-Dcom.sun.jini.outrigger.spaceName=name
```

where *name* defines the **String** with which the JavaSpaces service will register itself in the Jini lookup service. The default name for the JavaSpaces service is "**JavaSpace**". When searching for a specific JavaSpaces service in the Jini lookup service, you must use a **Name Entry** (package **net.jini.lookup.entry**) and initialize it to the **String** specified in the previous parameter. While this is a necessary parameter for systems with two or more JavaSpaces services, the examples in this chapter assume that only one JavaSpaces service exists in the system. The examples introduce a simple by which clients can locate the JavaSpaces service from the Jini lookup service.

You can start either a transient or persistent JavaSpaces service from the **StartService** GUI tool included in the Jini distributions. Start the GUI as in Chapter 21, then choose the **TransientSpace** tab (for a transient JavaSpaces service) or the **FrontEndSpace** (for a persistent JavaSpaces service). Go to the **Run** tab and click the **Start TransientSpace** button to run the transient service or click the **Start FrontEndSpace** button to run the persistent service.

## 23.4 Discovering the JavaSpaces Service

Upon initialization, each JavaSpaces service registers itself with local Jini lookup services. We assume that you already know how to start a Web server and RMI activation daemon from Chapter 22. The following is an example of a command that starts the persistent JavaSpaces service. Replace *hostname* with the name or IP address of your computer and *port* with the port number on which the Web server is listening.

```
java -jar C:\files\jini1_1\lib\outrigger.jar
      http://hostname:port/outrigger-d1.jar
      C:\files\jini1_1\policy\policy.all
      C:\tmp\outrigger_log public
```

Class **JavaSpaceFinder** (Fig. 23.1) shows how to obtain access to a JavaSpaces service. (We use this class in the example of Fig. 23.3.) The application performs unicast discovery to find the Jini lookup service on the hostname that the user specifies. Lines 35–36 get the **LookupLocator** at a user-specified Jini URL and obtain its **ServiceRegistrar**. Lines 55–68 look for all JavaSpaces services registered in the lookup service. Lines 55–57 specify a **ServiceTemplate** object (package **net.jini.core.lookup**). Lines 61–62 use the **ServiceTemplate** to search for all matching services in the lookup service and obtain a **JavaSpace**. Method **getJavaSpace** (lines 77–80) returns the discovered **JavaSpace**. For more information on how to use the Jini lookup service, please refer to Chapter 22, Jini.

```
1 // JavaSpaceFinder.java
2 // This application unicast discovers the JavaSpaces service.
3 package com.deitel.advjhtp1.javaspaces.common;
4
5 // Jini core packages
6 import net.jini.core.discovery.LookupLocator;
7 import net.jini.core.lookup.*;
8 import net.jini.core.entry.Entry;
9
10 // Jini extension package
11 import net.jini.space.JavaSpace;
12
13 // Java core packages
14 import java.io.*;
15 import java.rmi.*;
16 import java.net.*;
```

Fig. 23.1 Discovering a JavaSpaces service (part 1 of 3).

```
18 // Java extension package
19 import javax.swing.*;
20
21 public class JavaSpaceFinder {
22
23     private JavaSpace space;
24
25     public JavaSpaceFinder( String jiniURL )
26     {
27         LookupLocator locator = null;
28         ServiceRegistrar registrar = null;
29
30         System.setSecurityManager( new RMISecurityManager() );
31
32         // get lookup service locator at "jini://hostname"
33         // use default port and registrar of the locator
34         try {
35             locator = new LookupLocator( jiniURL );
36             registrar = locator.getRegistrar();
37         }
38
39         // handle exception invalid jini URL
40         catch ( MalformedURLException malformedURLException ) {
41             malformedURLException.printStackTrace();
42         }
43
44         // handle exception I/O
45         catch ( java.io.IOException ioException ) {
46             ioException.printStackTrace();
47         }
48
49         // handle exception finding class
50         catch ( ClassNotFoundException classNotFoundException ) {
51             classNotFoundException.printStackTrace();
52         }
53
54         // specify the service requirement
55         Class[] types = new Class[] { JavaSpace.class };
56         ServiceTemplate template =
57             new ServiceTemplate( null, types, null );
58
59         // find service
60         try {
61             space =
62                 ( JavaSpace ) registrar.lookup( template );
63         }
64
65         // handle exception getting JavaSpaces service
66         catch ( RemoteException remoteException ) {
67             remoteException.printStackTrace();
68         }
69 }
```

Fig. 23.1 Discovering a JavaSpaces service (part 2 of 3).

```
70      // if does not find any matching service
71      if ( space == null ) {
72          System.out.println( "No matching service" );
73      }
74
75  } // end JavaSpaceFinder constructor
76
77  public JavaSpace getJavaSpace()
78  {
79      return space;
80  }
81 }
```

Fig. 23.1 Discovering a JavaSpaces service (part 3 of 3).

## 23.5 JavaSpace Interface

Clients access objects in a JavaSpaces service through interface **JavaSpace** (package `net.jini.space`). Interface **JavaSpace** provides several methods—**notify**, **read**, **readIfExists**, **take**, **takeIfExists**, **write** and **snapshot**. The purpose of each method is as follows:<sup>3</sup>

1. **write**—This method implements the **write** operation. The **write** operation inserts an **Entry** into a JavaSpaces service. If an identical **Entry** already exists in the JavaSpaces service, this operation does not overwrite the existing **Entry**. Instead, the **write** operation places a copy of the **Entry** into the JavaSpaces service. JavaSpaces services may contain multiple copies of the same **Entry**. Section 23.7 demonstrates how to use the **write** operation.
2. **read**, **readIfExists**—These two methods implement the **read** operation, which attempts to read an **Entry** that matches an **Entry** template from a JavaSpaces service. If no matching **Entry** exists in the JavaSpaces service, this operation returns **null**. If multiple matching **Entry** exist in the JavaSpaces service, the **read** operation arbitrarily picks one among the matching **Entries**. Method **read** blocks until a matching **Entry** is found in the JavaSpaces service or until a time-out occurs. Method **readIfExists** checks to see if a matching **Entry** exists within the JavaSpaces service. If an **Entry** does not exist in the JavaSpaces service, method **readIfExists** should return **null** immediately. Method **readIfExists** does not block unless the matching **Entry** is a participant in an uncommitted transaction. For information on transactions, see Section 23.11. Section 23.8.1 demonstrates the **read** and **readIfExists** operations.
3. **take**, **takeIfExists**—These two methods implement the **take** operation, which attempts to remove an **Entry** that matches an **Entry** template from a JavaSpaces service. This operation works like the **read** operation, except that the **take** operation removes the matching **Entry** from the JavaSpaces service. Method **take** blocks until a matching **Entry** is found in the JavaSpaces service or until a time-out occurs. Method **takeIfExists** checks to see if a matching **Entry** exists within the JavaSpaces service. If an **Entry** does not exist in the JavaSpaces service, method **takeIfExists** should return **null** immediately.

Method **takeIfExists** does not block unless the matching **Entry** is part of an uncommitted transaction. Section 23.8.2 demonstrates the **take** and **takeIfExists** operations.

4. **notify**—This method implements the **notify** operation, which requests that the JavaSpaces service sends a notification to a listener object when a client writes a matching **Entry** into the JavaSpaces service. With this method, an application does not need to check repeatedly for an **Entry** in a JavaSpaces service. Section 23.9 demonstrates the **notify** operation.
5. **snapshot**—This method increases performance when a program must serialize one **Entry** repeatedly. Each time a program transfers an **Entry** into a JavaSpaces service (e.g., by writing that **Entry** or by using that **Entry** as a template), that **Entry** must be serialized. If a program transfers the same **Entry** to a JavaSpaces service many times, the serialization process can be time consuming. Invoking method **snapshot** serializes the **Entry** once and reuses this serialized **Entry** for future transfers. Section 23.10 demonstrates how to use method **snapshot**.

## 23.6 Defining an Entry

The following sections and subsections create an application for managing registrations for fictitious seminars offered at Deitel & Associates, Inc. For each seminar, an administration tool writes an **AttendeeCounter** (Fig. 23.2) into the JavaSpaces service. Each **AttendeeCounter** keeps track of the number of attendees registered for a particular seminar. We implement the complete application one step at a time to demonstrate the mechanics of each of each JavaSpaces service operation.

**AttendeeCounter** (Fig. 23.2) is an **Entry** that represents a count of the number of people attending a seminar. Recall that **Entries** require non-primitive type, **public** fields (lines 9–10) and an empty constructor (line 13). The **AttendeeCounter** constructor on lines 16–19 takes as a **String** argument the day of the week for which this **AttendeeCounter** tracks attendee registrations.



### Common Programming Error 23.1

Including primitive fields in an **Entry** does not cause an error during compilation. However, an **IllegalArgumentException** does occur during serialization.

```
1 // Fig. 23.2: AttendeeCounter.java
2 // This class defines the AttendeeCounter Entry.
3 package com.deitel.advjhtp1.javaspaces.common;
4
5 import net.jini.core.entry.Entry;
6
7 public class AttendeeCounter implements Entry {
8
9     public String day;
10    public Integer counter;
11}
```

Fig. 23.2 **AttendeeCounter** is an **Entry** for keeping track of registrations for a seminar on a particular day (part 1 of 2).

```

12  // empty constructor
13  public AttendeeCounter() {}
14
15  // constructor has a single String input
16  public AttendeeCounter( String seminarDay )
17  {
18      day = seminarDay;
19  }
20 }
```

**Fig. 23.2** `AttendeeCounter` is an **Entry** for keeping track of registrations for a seminar on a particular day (part 2 of 2).



### Software Engineering Observation 23.1

*Use wrapper classes rather than primitive types in **Entry** fields.*

## 23.7 Write Operation

The write operation places an **Entry** in a JavaSpaces service. Method `write` takes three arguments—an **Entry**, a **Transaction** object and a **long** value that requests an amount of time for which the JavaSpaces service should keep the **Entry**. The **long** value represents the lease length for the **Entry**. Normally, the JavaSpaces service grants each written **Entry** a lease time of 5 minutes. The JavaSpaces service will not keep the **Entry** beyond the lease time granted. A developer can extend the life of an **Entry** by renewing its lease before it expires. Method `write` returns a `net.jini.lease.Lease` object that contains the time that the JavaSpaces service granted to the **Entry**. Method `write` throws two exceptions. Method `write` throws a `RemoteException` (package `java.rmi`) when a network failure occurs or a variety of other errors occur on the server. When a `write` operation takes place under an invalid transaction, method `write` throws a `TransactionException` (package `net.jini.core.transaction`). For information on transactions, see Section 23.11.

The `WriteOperation` application (Fig. 23.3) uses class `AttendeeCounter` (Fig. 23.2) and class `JavaSpaceFinder` (Fig. 23.1) to demonstrate writing an **Entry** into a JavaSpaces service. In this example, a seminar administrator would use the `WriteOperation` application to place `AttendeeCounter` **Entry**s for each available seminar in the JavaSpaces service. The constructor (lines 30–36) takes a **JavaSpace** as an argument. Method `writeEntry` (lines 39–62) writes an **Entry** into the JavaSpaces service. Lines 44–45 initialize an **Entry** by setting the number of people who register for the seminar to zero. Line 46 writes the **Entry** into the JavaSpaces service. The first argument (`counter`) specifies the **Entry** to write into the JavaSpaces service. The second argument (`null`) indicates that the `write` operation does not use a **Transaction**. When the write operation completes, the written **Entry** is ready for a `read` or `take` operation. If a **Transaction** object is specified, the `write` operation uses that **Transaction** to ensure that a series of operations completes successfully. This means that until the transaction completes successfully, other clients cannot `read` or `take` the **Entry** from the JavaSpaces service. The third argument (`Lease.FOREVER`) specifies how long the JavaSpaces service should keep the **Entry**. Although we request that the JavaSpaces service keep our **Entry** forever, Sun's implementation limits the lease to 5 minutes. Pro-

grams can use the Jini lease-renewal mechanism to maintain **Leases** for **Entries**. After the lease expires, the JavaSpaces service removes and destroys the object.

Method **showOutput** (lines 65–75) displays the results. In method **main**, lines 81–85 check the user-specified hostname. Lines 88–90 ask user to choose a particular day to write. Figure 23.4 shows the results of running the **WriteOperation** application.

```
1 // WriteOperation.java
2 // This application initializes an new Entry,
3 // and puts this Entry to the JavaSpace.
4 package com.deitel.advjhtp1.javaspaces.write;
5
6 // Jini core packages
7 import net.jini.core.lease.Lease;
8 import net.jini.core.transaction.TransactionException;
9
10 // Jini extension package
11 import net.jini.space.JavaSpace;
12
13 // Java core package
14 import java.rmi.RemoteException;
15
16 // Java extension package
17 import javax.swing.*;
18
19 // Deitel package
20 import com.deitel.advjhtp1.javaspaces.common.*;
21
22 public class WriteOperation {
23
24     private JavaSpace space;
25     private static final String[] days = { "Monday", "Tuesday",
26             "Wednesday", "Thursday", "Friday" };
27     private String output = "\n";
28
29     // WriteOperation constructor
30     public WriteOperation( String hostname )
31     {
32         // get JavaSpace
33         String jiniURL = "jini://" + hostname;
34         JavaSpaceFinder findtool = new JavaSpaceFinder( jiniURL );
35         space = findtool.getJavaSpace();
36     }
37
38     // deposit new Entry to JavaSpace
39     public void writeEntry( String day )
40     {
41         // initialize AttendeeCounter Entry and deposit
42         // Entry in JavaSpace
43         try {
44             AttendeeCounter counter = new AttendeeCounter( day );
45             space.write( counter, null, Lease.FOREVER );
46         }
```

Fig. 23.3 Writing an Entry into a JavaSpaces service (part 1 of 2).

```
47         output += "Initialize the Entry: \n";
48         output += "    Day: " + day + "\n";
49         output += "    Count: 0\n";
50     }
51
52     // handle exception network failure
53     catch ( RemoteException exception ) {
54         exception.printStackTrace();
55     }
56
57     // handle exception invalid transaction
58     catch ( TransactionException exception ) {
59         exception.printStackTrace();
60     }
61 }
62
63 // show output
64 public void showOutput()
65 {
66     JTextArea outputArea = new JTextArea();
67     outputArea.setText( output );
68     JOptionPane.showMessageDialog( null, outputArea,
69         "WriteOperation Output",
70         JOptionPane.INFORMATION_MESSAGE );
71
72     // terminate program
73     System.exit( 0 );
74 }
75
76 // method main
77 public static void main( String args[] )
78 {
79     // get hostname
80     if ( args.length != 1 ) {
81         System.out.println(
82             "Usage: WriteOperation hostname" );
83         System.exit( 1 );
84     }
85
86     // get user input day
87     String day = ( String ) JOptionPane.showInputDialog(
88         null, "Select Day", "Day Selection",
89         JOptionPane.QUESTION_MESSAGE, null, days, days[ 0 ] );
90
91     // write Entry
92     WriteOperation write = new WriteOperation( args[ 0 ] );
93     write.writeEntry( day );
94
95     write.showOutput();
96
97 } // end method main
98 }
```

Fig. 23.3 Writing an Entry into a JavaSpaces service (part 2 of 2).

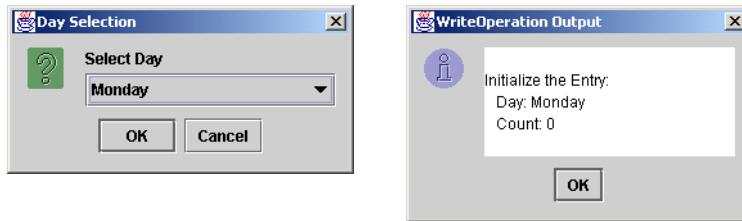


Fig. 23.4 Results of running the `WriteOperation` application.

This application takes a command-line argument that specifies the hostname of a computer that has the JavaSpaces service running. The following steps compile and execute the `WriteOperation` application. Ensure that your `CLASSPATH` includes `jini-core.jar`, `jini-ext.jar` and `sun-util.jar`. Compile the java files in the `com\deitel\advjhpt1\javaspaces\common` directory. Run `WriteOperation` by specifying the hostname of the Jini lookup service. Do not forget to specify to the JVM the policy file with the proper permissions.

## 23.8 Read and Take Operations

The `read` and the `take` operations retrieve `Entry`s from a JavaSpaces service. A client can read or take an `Entry` from the JavaSpaces service by supplying a template `Entry` against which to compare the `public` fields of `Entry`s in the JavaSpaces service. The template indicates which fields to use for comparison purposes.

The retrieval process uses a *template-matching mechanism* to match `Entry`s according to the values of their `public` fields. Each `Entry` in the JavaSpaces service requires its `public` fields to be object references, so each field is either `null` or a reference to an object. Fields in the template with non-`null` values must match with their `Entry` counterparts in the JavaSpaces service exactly. Fields in the template that are set to `null` act as wildcards. If a set of `Entry`s of the same type exist within a JavaSpaces service, only those fields which equal those of the template are used to match an `Entry` or a set of `Entry`s contained in the JavaSpaces service. Fields in the template set to `null` can have their matching counterparts in the JavaSpaces service have any value in the corresponding field(s).

### 23.8.1 Read Operation

The `read` operation obtains `Entry`s without removing them from the JavaSpaces service. Methods `read` and `readIfExists` perform the read operation. Each method takes three arguments—an `Entry` that specifies the template to match, a `Transaction` object and a `long` value. The `long` value has different meanings in methods `read` and `readIfExists`. Method `read` specifies a period of time for which the read operation should block before simply returning `null`. Method `readIfExists` is a non-blocking version of method `read`. If there are no matching `Entry`s, `readIfExists` returns `null` immediately. Method `readIfExists` blocks only if the developer specifies a period of time for which the `readIfExists` waits if, at first, the matching `Entry` is a part of an incomplete transaction. If the matching `Entry` is not involved in any transaction, then the `read` operation returns the matching `Entry` immediately. Both the `read` and `readIfExists` methods re-

turn only one **Entry**. If multiple **Entries** match the template, the **read** operation picks one arbitrarily. These methods throw four exception types—**RemoteException**, **TransactionException**, **UnusableEntryException** and **InterruptedException**. The first two are the same as in method **write**. If the matching **Entry** cannot be deserialized, these methods throw an **UnusableEntryException** (package `net.jini.core.entry`).

The **ReadOperation** application (Fig. 23.5) uses class **AttendeeCounter** (Fig. 23.2) and class **JavaSpaceFinder** (Fig. 23.1) to demonstrate reading an **Entry** from a JavaSpaces service. A seminar administrator or prospective attendee could use this application to determine the current enrollment for a particular seminar. Line 47 specifies the matching template against which to compare **Entries**. Users must specify the day for which they would like to see attendee registrations.

```
1 // ReadOperation.java
2 // This application reads an Entry from the JavaSpace and
3 // displays the Entry information.
4 package com.deitel.advjhtp1.javaspaces.read;
5
6 // Jini core packages
7 import net.jini.core.transaction.TransactionException;
8 import net.jini.core.entry.UnusableEntryException;
9
10 // Jini extension package
11 import net.jini.space.JavaSpace;
12
13 // Java core packages
14 import java.rmi.RemoteException;
15 import java.lang.InterruptedException;
16
17 // Java extension package
18 import javax.swing.*;
19
20 // Deitel package
21 import com.deitel.advjhtp1.javaspaces.common.*;
22
23 public class ReadOperation {
24
25     private JavaSpace space;
26     private static final String[] days = { "Monday", "Tuesday",
27         "Wednesday", "Thursday", "Friday" };
28     private String output = "\n";
29
30     // constructor gets JavaSpace
31     public ReadOperation( String hostname )
32     {
33         // get JavaSpace
34         String jiniURL = "jini://" + hostname;
35         JavaSpaceFinder findtool = new JavaSpaceFinder( jiniURL );
36         space = findtool.getJavaSpace();
37     }
38 }
```

Fig. 23.5 Reading an Entry from JavaSpaces service (part 1 of 3).

```
39 // read Entry from JavaSpace
40 public void readEntry( String day )
41 {
42     // specify matching template, read template
43     // from JavaSpace and output Entry information
44     try {
45
46         // read Entry from JavaSpace
47         AttendeeCounter counter = new AttendeeCounter( day );
48         AttendeeCounter resultCounter = ( AttendeeCounter )
49             space.read( counter, null, JavaSpace.NO_WAIT );
50
51         if (resultCounter == null) {
52             output += "Sorry, cannot find an Entry for "
53                 + day + "!\n";
54         }
55         else {
56
57             // get Entry information
58             output += "Count Information:\n";
59             output += "    Day: " + resultCounter.day;
60             output += "\n";
61             output += "    Count: "
62                 + resultCounter.counter.intValue() + "\n";
63         }
64     }
65
66     // handle exception network failure
67     catch ( RemoteException exception ) {
68         exception.printStackTrace();
69     }
70
71     // handle exception invalid transaction
72     catch ( TransactionException exception ) {
73         exception.printStackTrace();
74     }
75
76     // handle exception unusable Entry
77     catch ( UnusableEntryException exception ) {
78         exception.printStackTrace();
79     }
80
81     // handle exception interrupting
82     catch ( InterruptedException exception ) {
83         exception.printStackTrace();
84     }
85
86 } // end method readEntry
87
88 // show output
89 public void showOutput()
90 {
91     JTextArea outputArea = new JTextArea();
```

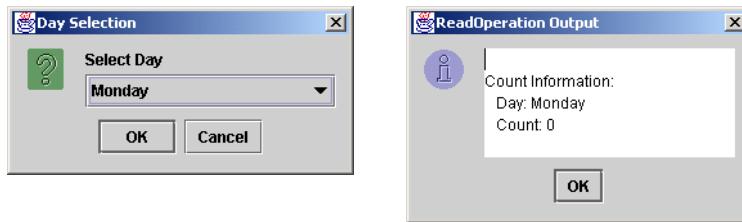
Fig. 23.5 Reading an Entry from JavaSpaces service (part 2 of 3).

```
92     outputArea.setText( output );
93     JOptionPane.showMessageDialog( null, outputArea,
94         "ReadOperation Output",
95         JOptionPane.INFORMATION_MESSAGE );
96
97     // terminate program
98     System.exit( 0 );
99 }
100
101 // method main
102 public static void main( String args[] )
103 {
104     // get hostname
105     if ( args.length != 1 ) {
106         System.out.println(
107             "Usage: ReadOperation hostname" );
108         System.exit( 1 );
109     }
110
111     // get user input day
112     String day = ( String ) JOptionPane.showInputDialog(
113         null, "Select Day", "Day Selection",
114         JOptionPane.QUESTION_MESSAGE, null, days, days[ 0 ] );
115
116     // read an Entry
117     ReadOperation read = new ReadOperation( args[ 0 ] );
118     read.readEntry( day );
119
120     read.showOutput();
121
122 } // end method main
123 }
```

Fig. 23.5 Reading an Entry from JavaSpaces service (part 3 of 3).

The first argument to method **read** (lines 48–49) specifies an **Entry** that the template-matching mechanism will use. The second argument (**null**) indicates that this **read** operation does not use a **Transaction**. The third argument (**JavaSpace.NO\_WAIT**) specifies the period for which the read operations wait for the read operation to find a matching **Entry** before simply returning **null**. Our example sets the method **read** to **JavaSpace.NO\_WAIT**, which equals zero. If the template-matching mechanism does not locate a matching **Entry**, the **read** operation returns **null** immediately. Figure 23.6 shows the results of running the **ReadOperation** application.

This application takes a command-line argument that specifies the hostname of a machine that has the JavaSpaces service service running. The following steps compile and execute the **ReadOperation** application. Ensure that your **CLASSPATH** includes **jini-core.jar**, **jini-ext.jar** and **sun-util.jar**. Compile the java files in the **com\deitel\advjhttp1\javaspaces\read** directory. Run **ReadOperation** by specifying the hostname of the Jini lookup service. Do not forget to specify to the JVM the policy file with the proper permissions.



**Fig. 23.6** Results of running the **ReadOperation** application.



### Software Engineering Observation 23.2

The **read** operation returns only a single matching **Entry**. If multiple matching **Entries** exist, the **read** operation may return different matching objects each time.

#### 23.8.2 Take Operation

The **take** operation obtains an **Entry** and removes it from the JavaSpaces service. Methods **take** and **takeIfExists** perform the take operation. Methods **take** and **takeIfExists** are similar to methods **read** and **readIfExists**. The only difference is that the matching **Entry** returned by a **take** or **takeIfExists** operation is removed from the JavaSpaces service.

The **TakeOperation** application (Fig. 23.7) uses class **AttendeeCounter** (Fig. 23.2) and class **JavaSpaceFinder** (Fig. 23.1) to demonstrate taking an **Entry** from a JavaSpaces service. This application is similar to the **ReadOperation** application. The only difference is that this application calls method **take** (lines 46–47) of interface **JavaSpace** to remove the **AttendeeCounter** from the JavaSpaces service. A seminar administrator could use this application to remove from the JavaSpaces service an **AttendeeCounter** for a seminar that has already been given or for a seminar that was cancelled. Figure 23.8 shows the results of running the **TakeOperation** application.

This application takes a command-line argument that specifies the hostname of a machine that has the JavaSpaces service running. The following steps compile and execute the **TakeOperation** application. Ensure that your **CLASSPATH** includes **jini-core.jar**, **jini-ext.jar** and **sun-util.jar**. Compile the java files in the **com\deitel\advjhttp1\javaspaces\take** directory. Run **TakeOperation** by specifying the hostname of the Jini lookup service. Do not forget to specify to the JVM the policy file with the proper permissions.

```

1 // TakeOperation.java
2 // This application removes an Entry from the JavaSpace.
3 package com.deitel.advjhttp1.javaspaces.take;
4
5 // Jini core packages
6 import net.jini.core.transaction.TransactionException;
7 import net.jini.core.entry.UnusableEntryException;
8

```

**Fig. 23.7** Taking an Entry from a JavaSpaces service (part 1 of 4).

```
9 // Jini extension package
10 import net.jini.space.JavaSpace;
11
12 // Java core packages
13 import java.rmi.RemoteException;
14
15 // Java extension package
16 import javax.swing.*;
17
18 // Deitel package
19 import com.deitel.advjhttp1.javaspaces.common.*;
20
21 public class TakeOperation {
22
23     private JavaSpace space = null;
24     private static final String[] days = { "Monday", "Tuesday",
25         "Wednesday", "Thursday", "Friday" };
26     private String output = "\n";
27
28     // constructor gets JavaSpace
29     public TakeOperation( String hostname )
30     {
31         // get JavaSpace
32         String jiniURL = "jini://" + hostname;
33         JavaSpaceFinder findtool = new JavaSpaceFinder( jiniURL );
34         space = findtool.getJavaSpace();
35     }
36
37     // remove Entry from JavaSpace
38     public void TakeAnEntry( String day )
39     {
40         AttendeeCounter resultCounter = null;
41
42         // specify matching template, remove template
43         // from JavaSpace
44         try {
45             AttendeeCounter count = new AttendeeCounter( day );
46             resultCounter = ( AttendeeCounter ) space.take( count,
47                 null, JavaSpace.NO_WAIT );
48
49             if ( resultCounter == null ) {
50                 output += "No Entry for " + day
51                     + " is available from the JavaSpace.\n";
52             }
53             else {
54                 output += "Entry is taken away from ";
55                 output += "the JavaSpace successfully.\n";
56             }
57         }
58     }
}
```

Fig. 23.7 Taking an Entry from a JavaSpaces service (part 2 of 4).

```
59      // handle exception network failure
60      catch ( RemoteException exception ) {
61          exception.printStackTrace();
62      }
63
64      // handle exception invalid transaction
65      catch ( TransactionException exception ) {
66          exception.printStackTrace();
67      }
68
69      // handle exception unusable entry
70      catch ( UnusableEntryException exception ) {
71          exception.printStackTrace();
72      }
73
74      // handle exception interrupt
75      catch ( InterruptedException exception ) {
76          exception.printStackTrace();
77      }
78
79 } // end method TakeAnEntry
80
81 // show output
82 public void showOutput()
83 {
84     JTextArea outputArea = new JTextArea();
85     outputArea.setText( output );
86     JOptionPane.showMessageDialog( null, outputArea,
87         "TakeOperation Output",
88         JOptionPane.INFORMATION_MESSAGE );
89
90     // terminate program
91     System.exit( 0 );
92 }
93
94 public static void main( String args[] )
95 {
96     // get hostname
97     if ( args.length != 1 ) {
98         System.out.println(
99             "Usage: WriteOperation hostname" );
100        System.exit( 1 );
101    }
102
103    // get user input day
104    String day = ( String ) JOptionPane.showInputDialog(
105        null, "Select Day", "Day Selection",
106        JOptionPane.QUESTION_MESSAGE, null, days, days[ 0 ] );
107
108    // take Entry
109    TakeOperation take = new TakeOperation( args[ 0 ] );
110    take.TakeAnEntry( day );
```

Fig. 23.7 Taking an Entry from a JavaSpaces service (part 3 of 4).

```

112     take.showOutput();
113
114 } // end method main
115 }
```

Fig. 23.7 Taking an Entry from a JavaSpaces service (part 4 of 4).



Fig. 23.8 Results of running the **TakeOperation** application.



### Software Engineering Observation 23.3

The **take** operation returns only a single matching **Entry**. If multiple matching **Entries** exist, the **take** operation can remove only one **Entry** from the JavaSpaces service each time. To take all the matching **Entries** away from the JavaSpaces service, execute the **TakeOperation** application repeatedly until the **TakeOperation** application returns a message that says “No Entry is available from the JavaSpaces service”.

## 23.9 Notify Operation

The **notify** operation asks the JavaSpaces service to send a notification to a listener when a client writes a matching **Entry** into the JavaSpaces service. Method **notify** takes five parameters—an **Entry** that specifies the matching template, a **Transaction** object, a listener that implements interface **RemoteEventListener** (package **net.jini.core.event**), a **long** value that specifies the lease time for the registration of the listener and a **MarshalledObject** (package **java.rmi**) that the JavaSpaces service will pass to the remote listener as part of a notification. This method may throw exceptions of type **RemoteException** and **TransactionException**. A **RemoteException** occurs due to a network failure. A **TransactionException** occurs when a notify operation takes place as part of an invalid transaction.

Class **EntryListener** (Fig. 23.9) defines a listener that the JavaSpaces service will notify when an **Entry** matching the given template is written to the JavaSpaces service. The **EntryListener** listens on the JavaSpaces service for a matching **Entry** written into the JavaSpaces service. This listener must implement interface **RemoteEventListener** (line 14). A person interested in attending a seminar on a particular day could use this application to be notified when an **AttendeeCounter** is added for a seminar on a particular day. The constructor takes one argument—a **RemoteEventListener** and exports the listener to the JavaSpaces service so that when a client writes a matching **Entry** into the JavaSpaces service, the JavaSpaces service will call **notify**. Method **notify** (lines 35–40) forwards the notification to the **NotifyOperation** application (Fig. 23.10).

```
1 // EntryListener.java
2 // This class defines the listener for the NotifyOperation
3 // application.
4 package com.deitel.advjhttp1.javaspaces.notify;
5
6 // Jini core packages
7 import net.jini.core.event.*;
8
9 // Java core packages
10 import java.rmi.RemoteException;
11 import java.rmi.server.UnicastRemoteObject;
12 import java.io.Serializable;
13
14 public class EntryListener implements RemoteEventListener {
15
16     private RemoteEventListener eventListener;
17
18     // EntryListener constructor
19     public EntryListener( RemoteEventListener listener ) {
20
21         eventListener = listener;
22
23         // export stub object
24         try {
25             UnicastRemoteObject.exportObject( this );
26         }
27
28         // handle exception exporting stub
29         catch ( RemoteException remoteException ) {
30             remoteException.printStackTrace();
31         }
32     }
33
34     // receive notifications
35     public void notify( RemoteEvent remoteEvent )
36         throws UnknownEventException, RemoteException
37     {
38         // forward notifications to NotifyOperation application
39         eventListener.notify( remoteEvent );
40     }
41 }
```

Fig. 23.9 **EntryListener** for **NotifyOperation** application.

The **NotifyOperation** application (Fig. 23.10) demonstrates how to write a program that receives a notification when a matching **Entry** is written into a JavaSpaces service. Lines 30–36 define the constructor, which gets a JavaSpaces service. In method **notifyEntry** (lines 39–61), line 42 gets an **EntryListener** that listens on the JavaSpaces service for matching **Entries**. This **EntryListener** will be passed to method **notify** of interface **JavaSpace**. Line 48 creates the matching template. Lines 50–51 define the object to send to the listener when a notification occurs. Lines 52–53 call the **notify** method of the **JavaSpace** interface. The first argument (**counter**) specifies an **Entry** that is used as a matching template. The second argument (**null**) indicates that

the **notify** operation does not occur within a transaction. The third argument (**listener**) is an instance of the **EntryListener** class. The fourth argument (**600000**) specifies the number of milliseconds requested for the lease. After the expiration of the listener's granted lease, the listener will cease to be active. The last argument (**handback**—a reference to a **MarshalledObject**) is an object that the JavaSpaces service provides to the remote listener as part of the notification.

```
1 // NotifyOperation.java
2 // This application receives a notification when a matching entry
3 // is written to the JavaSpace.
4 package com.deitel.advjhttp1.javaspaces.notify;
5
6 // Jini core packages
7 import net.jini.core.transaction.TransactionException;
8 import net.jini.core.lease.Lease;
9 import net.jini.core.event.*;
10
11 // Jini extension package
12 import net.jini.space.JavaSpace;
13
14 // Java core packages
15 import java.rmi.*;
16
17 // Java standard extensions
18 import javax.swing.*;
19
20 // Deitel packages
21 import com.deitel.advjhttp1.javaspaces.common.*;
22
23 public class NotifyOperation implements RemoteEventListener
24 {
25     private JavaSpace space;
26     private static final String[] days = { "Monday", "Tuesday",
27         "Wednesday", "Thursday", "Friday" };
28
29     // constructor gets JavaSpace
30     public NotifyOperation( String hostname )
31     {
32         // get JavaSpace
33         String jiniURL = "jini://" + hostname;
34         JavaSpaceFinder findtool = new JavaSpaceFinder( jiniURL );
35         space = findtool.getJavaSpace();
36     }
37
38     // call notify method of JavaSpace
39     public void notifyEntry( String day )
40     {
41         // get Entry listener
42         EntryListener listener = new EntryListener( this );
43 }
```

Fig. 23.10 Receiving notifications when matching **Entries** are written into **JavaSpace** (part 1 of 3).

```
44      // specify matching template, asks JavaSpace to
45      // send notification when matching entry is written
46      // to JavaSpace
47      try {
48          AttendeeCounter counter = new AttendeeCounter( day );
49
50          MarshalledObject handback = new MarshalledObject(
51              "JavaSpace Notification" );
52          space.notify(
53              counter, null, listener, 10 * 60 * 1000, handback );
54      }
55
56      // handle exception notifying space
57      catch ( Exception exception ) {
58          exception.printStackTrace();
59      }
60
61 } // end method notifyEntry
62
63 // show output
64 public void showOutput( String output )
65 {
66     JTextArea outputArea = new JTextArea();
67     outputArea.setText( output );
68     JOptionPane.showMessageDialog( null, outputArea,
69         "NotifyOperation Output",
70         JOptionPane.INFORMATION_MESSAGE );
71 }
72
73 // receive notifications
74 public void notify( RemoteEvent remoteEvent )
75 {
76     String output = "\n";
77
78     // prepare output
79     try {
80         output += "id: " + remoteEvent.getID() + "\n";
81         output += "sequence number: "
82             + remoteEvent.getSequenceNumber() + "\n";
83         String handback = ( String )
84             remoteEvent.getRegistrationObject().get();
85         output += "handback: " + handback + "\n";
86
87         // display output
88         showOutput( output );
89     }
90
91     // handle exception getting handback
92     catch ( Exception exception ) {
93         exception.printStackTrace();
94     }
95 }
```

Fig. 23.10 Receiving notifications when matching **Entries** are written into **JavaSpace** (part 2 of 3).

```

96
97     // method main
98     public static void main( String args[] )
99     {
100         // get hostname
101         if ( args.length != 1 ) {
102             System.out.println(
103                 "Usage: NotifyOperation hostname" );
104             System.exit( 1 );
105         }
106
107         // get user input day
108         String day = ( String ) JOptionPane.showInputDialog(
109             null, "Select Day", "Day Selection",
110             JOptionPane.QUESTION_MESSAGE, null, days, days[ 0 ] );
111
112         // notify Entry
113         NotifyOperation notifyOperation =
114             new NotifyOperation( args[ 0 ] );
115
116         notifyOperation.notifyEntry( day );
117
118     } // end method main
119 }
```

Fig. 23.10 Receiving notifications when matching **Entries** are written into **JavaSpace** (part 3 of 3).

The following steps execute the **NotifyOperation** application. Ensure that your **CLASSPATH** includes **jini-core.jar**, **jini-ext.jar** and **sun-util.jar**. Compile the source files in the **com\deitel\advjhttp1\javaspaces\notify** directory. Start a Web server. Generate a stub for class **EntryListener** (Fig. 23.9). Create a **JAR** file for **EntryListener\_Stub.class** and place it in the Web server's document directory. Run **NotifyOperation** by specifying the hostname of the Jini lookup service. Do not forget to specify to the JVM the codebase and the policy file with the proper permissions.

Figure 23.11 shows sample outputs of this application. To test this application, execute several **WriteOperation** applications.

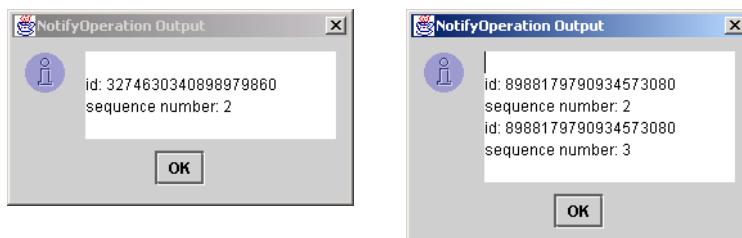


Fig. 23.11 NotifyOperation Output samples.



### Software Engineering Observation 23.4

JavaSpaces service notifications are not guaranteed to be delivered, as network problems may interfere with notification delivery.

## 23.10 Method **snapshot**

Method **snapshot** optimizes interactions with a JavaSpaces service by reducing the overhead of continually serializing **Entry**s. Every time we pass a matching template to methods in the **JavaSpace** interface, the template must be serialized before it is moved to the JavaSpaces service. When the same template is passed to a JavaSpaces service repeatedly, it is preferable to avoid multiple serializations of the same **Entry**. Fortunately, method **snapshot** provides such a mechanism. Method **snapshot** takes a matching template and returns a specialized representation of the **Entry** (a *snapshot Entry*). This snapshot **Entry** can be used only in the JavaSpaces service that generated it. For example, to remove all the seminar **Entry**s for Monday from the JavaSpaces service, we call the **snapshot** method to create a snapshot **Entry**, then pass this snapshot **Entry** to the **take** method repeatedly.

The **SnapshotUsage** application (Fig. 23.12) removes **Entry**s from the JavaSpaces service and uses method **snapshot** to avoid repeated serialization of the matching template. Line 49 defines the original matching template. We do not pass this original template to method **take**. Instead, we pass the snapshot to the **take** method. Line 50 calls method **snapshot** to get the snapshot **Entry** of the original template.

```
1 // SnapshotUsage.java
2 // This application removes entries from the JavaSpace using
3 // method snapshot.
4 package com.deitel.advjhttp1.javaspace.snapshot;
5
6 // Jini core packages
7 import net.jini.core.transaction.TransactionException;
8 import net.jini.core.entry.UnusableEntryException;
9 import net.jini.core.entry.Entry;
10
11 // Jini extension package
12 import net.jini.space.JavaSpace;
13
14 // Java core packages
15 import java.rmi.RemoteException;
16
17 // Java extension package
18 import javax.swing.*;
19
20 // Deitel packages
21 import com.deitel.advjhttp1.javaspace.common.*;
22
23 public class SnapshotUsage {
24     private JavaSpace space;
```

Fig. 23.12 Removing entries from JavaSpaces service using method **snapshot** (part 1 of 3).

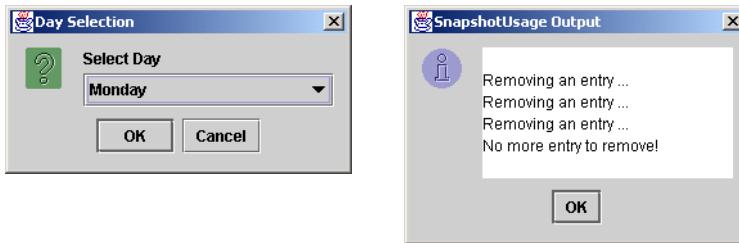
```
26     private static final String[] days = { "Monday", "Tuesday",
27             "Wednesday", "Thursday", "Friday" };
28     private String output = "\n";
29
30     // constructor gets JavaSpace
31     public SnapshotUsage( String hostname )
32     {
33         // get JavaSpace
34         String jiniURL = "jini://" + hostname;
35         JavaSpaceFinder findtool = new JavaSpaceFinder( jiniURL );
36         space = findtool.getJavaSpace();
37     }
38
39     // create snapshot Entry, pass this object as
40     // Entry parameter to take method
41     public void snapshotEntry( String day )
42     {
43         // specify matching template, snapshot template
44         // and remove matching entries from JavaSpace using
45         // snapshot entry
46         try {
47             AttendeeCounter counter = new AttendeeCounter( day );
48             Entry snapshotentry = space.snapshot( counter );
49             AttendeeCounter resultCounter = ( AttendeeCounter )
50                 space.take( snapshotentry, null, JavaSpace.NO_WAIT );
51
52             // keep removing entries until no more entry exists
53             // in space
54             while ( resultCounter != null ) {
55                 output += "Removing an entry ... \n";
56                 resultCounter = ( AttendeeCounter ) space.take(
57                     snapshotentry, null, JavaSpace.NO_WAIT );
58             }
59
60             output += "No more entry to remove!\n";
61         }
62
63         // handle exception network failure
64         catch ( RemoteException remoteException ) {
65             remoteException.printStackTrace();
66         }
67
68         // handle exception invalid transaction
69         catch ( TransactionException transactionException ) {
70             transactionException.printStackTrace();
71         }
72
73         // handle exception unusable entry
74         catch ( UnusableEntryException unusableEntryException ) {
75             unusableEntryException.printStackTrace();
76         }
77     }
```

Fig. 23.12 Removing entries from JavaSpaces service using method **snapshot** (part 2 of 3).

```
78     // handle exception interrupt
79     catch ( InterruptedException interruptedException ) {
80         interruptedException.printStackTrace();
81     }
82
83 } // end method snapshotEntry
84
85 // show output
86 public void showOutput()
87 {
88     JTextArea outputArea = new JTextArea();
89     outputArea.setText( output );
90     JOptionPane.showMessageDialog( null, outputArea,
91         "SnapshotUsage Output",
92         JOptionPane.INFORMATION_MESSAGE );
93
94     // terminate program
95     System.exit( 0 );
96 }
97
98 // method main
99 public static void main( String args[] )
100 {
101     // get hostname
102     if ( args.length != 1 ) {
103         System.out.println(
104             "Usage: SnapshotUsage hostname" );
105         System.exit( 1 );
106     }
107
108     // get user input day
109     String day = ( String ) JOptionPane.showInputDialog(
110         null, "Select Day", "Day Selection",
111         JOptionPane.QUESTION_MESSAGE, null, days, days[ 0 ] );
112
113     // snapshot Entry
114     SnapshotUsage snapshot = new SnapshotUsage( args[ 0 ] );
115     snapshot.snapshotEntry( day );
116
117     snapshot.showOutput();
118
119 } // end method main
120 }
```

Fig. 23.12 Removing entries from JavaSpaces service using method **snapshot** (part 3 of 3).

The only argument of method **snapshot** (line 48) specifies the template to serialize. Method **snapshot** returns a snapshot **Entry** that represents the matching template. Lines 49–51 call method **take** to remove the **Entries** that match the template from the JavaSpaces service. Lines 54–58 remove all matching **Entries** in the JavaSpaces service. Figure 23.13 shows the output of running the **SnapshotUsage** application. This output indicates that there are three matching **Entries** in the JavaSpaces service. The take operation removes all three matching **Entries** from the JavaSpaces service.



**Fig. 23.13 SnapshotUsage Output window.**

The following steps compile and execute the **SnapshotUsage** application. Make sure your **CLASSPATH** includes **jini-core.jar**, **jini-ext.jar** and **sun-util.jar**. Compile the java files in the **com\deitel\advjhttp1\javaspaces\snapshot** directory. Run **SnapshotUsage** by specifying the hostname of the Jini lookup service. Do not forget to specify to the JVM the policy file with the proper permissions.



#### Software Engineering Observation 23.5

*Using the snapshot **Entry** is equivalent to using the original **Entry**, as long as all operations take place on the same JavaSpaces service that generated the snapshot.*

### 23.11 Updating Entries with Jini Transaction Service

We cannot modify an **Entry** in a JavaSpaces service directly. Instead, we must take the **Entry** away from the JavaSpaces service, change the values of the **Entry** fields, then place the **Entry** back into the JavaSpaces service. To ensure that the JavaSpaces service does not lose the **Entry** when a process takes that **Entry** away, we can perform the take, update and write processes in a transaction. If all these processes succeed, the transaction completes. Otherwise, the transaction fails and the JavaSpaces service returns the **Entry** to its state prior to the transaction.

Assume a distributed system in which dedicated nodes take **Entries** from a JavaSpaces service, process each **Entry**, and **write** them back to the JavaSpaces service when finished. What happens if a problem occurs and one of the dedicated nodes never returns a processed **Entry**? The information that node processed could be permanently lost. Furthermore, because the processing node removed the **Entry** from the JavaSpaces service, the unprocessed **Entry** is also lost. The use of a transaction manager protects a JavaSpaces service from these situations. When a transaction fails, the transaction manager restores the **Entry** to its previous state—as if the client never took the **Entry**.

Our next example demonstrates how to update an **Entry** in a JavaSpaces service. The application takes an **AttendeeCounter Entry** from the JavaSpaces service, updates the count variable and reinserts the **Entry** back into the JavaSpaces service. A seminar administrator could use this application to register a new attendee for a seminar and update the appropriate **AttendeeCounter**. We have to ensure that if a client takes an **Entry** from the JavaSpaces service, it will write the **Entry** back into the JavaSpaces service later. In this example, we use the Jini transaction manager to guarantee that only one client at a time can update a seminar **Entry**. Otherwise, one client potentially could overwrite a previously written **Entry**, thus corrupting the proper count of the number of people who will attend a seminar.

### 23.11.1 Defining the User Interface

This section defines the user interface for the application. To update an **Entry**, the program must know which **AttendeeCounter** to update and the number to add to the counter. Class **UpdateInputWindow** (Fig. 23.14) prompts the user for the day of the week to update and the number of people who will attend the seminar on that day.

```
1 // UpdateInputWindow.java
2 // This application is an user interface used
3 // to get the input data.
4 package com.deitel.advjhtp1.javaspace.update;
5
6 // Java extension package
7 import javax.swing.*;
8
9 // Java core packages
10 import java.awt.*;
11 import java.awt.event.*;
12
13 public class UpdateInputWindow extends JFrame {
14
15     private String[] dates = { "Monday", "Tuesday",
16         "Wednesday", "Thursday", "Friday" };
17     private JButton okButton;
18     private JComboBox dateComboBox;
19     private JLabel firstLabel;
20     private JTextField numberText;
21     private String date = "Monday";
22     private int count = 0;
23     private String hostname;
24
25     public UpdateInputWindow( String name )
26     {
27         super( "UpdateInputWindow" );
28         Container container = getContentPane();
29
30         hostname = name;
31
32         // define center panel
33         JPanel centerPanel = new JPanel();
34         centerPanel.setLayout( new GridLayout( 2, 2, 0, 5 ) );
35
36         // add label
37         firstLabel = new JLabel( "Please choose a date:",
38             SwingConstants.CENTER );
39         centerPanel.add( firstLabel );
40
41         // add combo box
42         dateComboBox = new JComboBox( dates );
43         dateComboBox.setSelectedIndex( 0 );
44         centerPanel.add( dateComboBox );
45 }
```

Fig. 23.14 **UpdateInputWindow** user interface (part 1 of 3).

```
46     // install listener to combo box
47     dateComboBox.addItemListener(
48
49         new ItemListener() {
50
51             public void itemStateChanged( ItemEvent itemEvent ) {
52                 {
53                     date = ( String )dateComboBox.getSelectedItem();
54                 }
55             }
56         );
57
58     // add label
59     JLabel numberLabel = new JLabel(
60         "Please specify a number:", SwingConstants.CENTER );
61     centerPanel.add( numberLabel );
62
63     // add text field
64     numberText = new JTextField( 10 );
65     centerPanel.add( numberText );
66
67     // install listener to text field
68     numberText.addActionListener(
69
70         new ActionListener() {
71
72             public void actionPerformed( ActionEvent event ) {
73                 {
74                     count = Integer.parseInt(
75                         event.getActionCommand() );
76                 }
77             }
78         );
79
80     // define button panel
81     JPanel buttonPanel = new JPanel();
82     buttonPanel.setLayout( new GridLayout( 1, 1, 0, 5 ) );
83
84     // add OK button
85     okButton = new JButton( "OK" );
86     buttonPanel.add( okButton );
87
88     // add listener to OK button
89     okButton.addActionListener(
90
91         new ActionListener() {
92
93             public void actionPerformed( ActionEvent event ) {
94                 {
95                     // get user input
96                     count = Integer.parseInt( numberText.getText() );
97                 }
98             }
99         );
100 }
```

Fig. 23.14 UpdateInputWindow user interface (part 2 of 3).

```
98             if ( count == 0 ) {
99                 System.out.println(
100                     "Please Specify a Number" );
101             }
102
103             else {
104                 UpdateOperation update = new UpdateOperation();
105                 String jiniURL = "jini://" + hostname;
106                 update.getServices( jiniURL );
107                 update.updateEntry( date, count );
108
109                 setVisible( false );
110                 update.showOutput();
111             }
112         }
113     }
114 }
115
116 // put everything together
117 container.add( centerPanel, BorderLayout.CENTER );
118 container.add( buttonPanel, BorderLayout.SOUTH );
119
120 // set window size and display it
121 setSize( 320, 130 );
122 setVisible( true );
123
124 } // end updateInputWindow constructor
125 }
```

Fig. 23.14 `UpdateInputWindow` user interface (part 3 of 3).

### 23.11.2 Discovering the `TransactionManager` Service

Creating a transaction, requires a transaction manager. In our example, we use Jini's `TransactionManager` service to obtain a transaction manager. We assume that you already know how to start the Web server and the RMI activation daemon from Chapter 22.

```
java -jar
    -Dcom.sun.jini.mahalo.managerName=TransactionManager
    c:\files\jini1_1\lib\mahalo.jar
    http://hostname:port/mahalo-dl.jar
    c:\files\jini1_1\policy\policy.all
    c:\mahalo\txn_log public
```

Class `TransactionManagerFinder` (Fig. 23.15) demonstrates the `TransactionManager` service. This application performs unicast discovery to find the Jini lookup service, through which we can get a reference to the `TransactionManager`. The application looks for a `ServiceTemplate` object with which lines 46–47 search the lookup service. Method `getTransactionManager` (lines 72–75) returns a `TransactionManager`.

```
1 // TransactionManagerFinder.java
2 // This application unicast discovers the
3 // TransactionManager service.
4 package com.deitel.advjhttp1.javaspace.common;
5
6 // Jini core packages
7 import net.jini.core.discovery.LookupLocator;
8 import net.jini.core.lookup.*;
9 import net.jini.core.entry.Entry;
10 import net.jini.core.transaction.server.TransactionManager;
11
12 // Java core packages
13 import java.io.*;
14 import java.rmi.RMISecurityManager;
15 import java.net.*;
16
17 // Java extension package
18 import javax.swing.*;
19
20 public class TransactionManagerFinder {
21
22     private TransactionManager transactionManager = null;
23
24     public TransactionManagerFinder( String jiniURL )
25     {
26         LookupLocator locator = null;
27         ServiceRegistrar registrar = null;
28
29         System.setSecurityManager( new RMISecurityManager() );
30
31         // get lookup service locator at "jini://hostname"
32         // use default port
33         try {
34             locator = new LookupLocator( jiniURL );
35
36             // get registrar for the locator
37             registrar = locator.getRegistrar();
38
39             // specify service requirement
40             Class[] types = new Class[] {
41                 TransactionManager.class };
42             ServiceTemplate template =
43                 new ServiceTemplate( null, types, null );
44
45             // find service
46             transactionManager =
47                 (TransactionManager) registrar.lookup( template );
48         }
49
50         // handle exception invalid jini URL
51         catch ( MalformedURLException malformedURLException ) {
52             malformedURLException.printStackTrace();
53         }
```

Fig. 23.15 Finding Jini **TransactionManager** (part 1 of 2).

```
54      // handle exception I/O
55      catch ( IOException ioException ) {
56          ioException.printStackTrace();
57      }
58
59      // handle exception finding class
60      catch ( ClassNotFoundException classNotFoundException ) {
61          classNotFoundException.printStackTrace();
62      }
63
64      // does not find any matching service
65      if ( transactionManager == null ) {
66          System.out.println( "No matching service" );
67      }
68
69  } // end TransactionManagerFinder constructor
70
71  public TransactionManager getTransactionManager()
72  {
73      return transactionManager;
74  }
75
76 }
```

Fig. 23.15 Finding Jini **TransactionManager** (part 2 of 2).

### 23.11.3 Updating an Entry

We now have the user interface (class **UpdateInputWindow**), the transaction manager (class **TransactionManagerFinder**) and the JavaSpaces service (class **JavaSpaceFinder**) ready for use. The next step is to put everything together to build an application for updating **AttendeeCounters**.

The **UpdateOperation** application (Fig. 23.16) demonstrates updating an **Entry** within a transaction. The **main** method constructs an **UpdateInputWindow** to allow the user to select a day and enter a count for the **AttendeeCounter** to update. Method **getServices** (lines 40–50) obtains a reference to the JavaSpaces service.

Method **updateEntry** (lines 53–136) updates an **AttendeeCounter** in the context of a transaction. Lines 67–68 create a transaction by passing the transaction manager and the lease duration to **TransactionFactory** method **create**, which returns a **Transaction.Created** object. Lines 69–70 specify the lease time for the transaction. Line 85 creates an **AttendeeCounter** template that will match all **AttendeeCounters** in the JavaSpaces service. Lines 86–87 take an **Entry** from the JavaSpaces service using **transactionCreated.transaction**. If **UpdateOperation** retrieves an **AttendeeCounter** successfully, then it modifies the **AttendeeCounter** with the day and count information (lines 98–102) and writes it back to the JavaSpaces service. If **UpdateOperation** finds no **AttendeeCounter**, then it does nothing. Lines 115–116 commit the transaction, thus finalizing the transaction and ending the transaction's lease. If an exception occurs at any time, lines 126–127 abort the transaction and end the transaction's lease.

```
1 // UpdateOperation.java
2 // This application removes an Entry from the JavaSpace,
3 // changes the variable's value in the returned Entry and
4 // deposits the updated Entry into the JavaSpace. All these
5 // operations are occurred within a transaction.
6 package com.deitel.advjhttp1.javaspace.update;
7
8 // Jini core package
9 import net.jini.core.lease.Lease;
10 import net.jini.core.transaction.*;
11 import net.jini.core.entry.UnusableEntryException;
12 import net.jini.core.transaction.server.TransactionManager;
13
14 // Jini extension package
15 import net.jini.space.JavaSpace;
16 import net.jini.lease.*;
17
18 // Java core packages
19 import java.rmi.RemoteException;
20
21 // Java extension packages
22 import javax.swing.*;
23
24 // Deitel packages
25 import com.deitel.advjhttp1.javaspace.common.*;
26
27 public class UpdateOperation {
28
29     private JavaSpace space;
30     private TransactionManager transactionManager;
31     private static String hostname = "";
32     private static String day = "";
33     private static int inputCount = 0;
34     private static String output = "\n";
35
36     // default constructor
37     public UpdateOperation() {}
38
39     // constructor gets JavaSpace and TransactionManager
40     public void getServices( String jiniURL )
41     {
42         // get JavaSpace and TransactionManager
43         JavaSpaceFinder findtool =
44             new JavaSpaceFinder( jiniURL );
45         space = findtool.getJavaSpace();
46         TransactionManagerFinder findTransaction =
47             new TransactionManagerFinder( jiniURL );
48         transactionManager =
49             findTransaction.getTransactionManager();
50     }
51 }
```

Fig. 23.16 Updating an entry using Jini **TransactionManager** (part 1 of 4).

```
52     // update Entry
53     public void updateEntry( String inputDay, int countNumber )
54     {
55         day = inputDay;
56         inputCount = countNumber;
57
58         AttendeeCounter resultCounter = null;
59         Transaction.Created transactionCreated = null;
60         LeaseRenewalManager manager = new LeaseRenewalManager();
61
62         int oldCount = 0;
63         int newCount = 0;
64
65         // create transaction and renew transaction's lease
66         try {
67             transactionCreated = TransactionFactory.create(
68                 transactionManager, Lease.FOREVER );
69             manager.renewUntil(
70                 transactionCreated.lease, Lease.FOREVER, null );
71         }
72
73         // handle exception creating transaction and renewing lease
74         catch ( Exception exception ) {
75             exception.printStackTrace();
76         }
77
78         // specify matching template, remove template
79         // from JavaSpace in transaction, change
80         // variable's value and write updated template back
81         // to JavaSpace within a transaction
82         try {
83
84             // take Entry away from JavaSpace
85             AttendeeCounter count = new AttendeeCounter( day );
86             resultCounter = ( AttendeeCounter ) space.take( count,
87                 transactionCreated.transaction, JavaSpace.NO_WAIT );
88
89             // if no matching entry
90             if ( resultCounter == null ) {
91
92                 // set output message
93                 output += " No matching Entry is available!\n";
94             }
95             else { // if find a matching entry
96
97                 // update value
98                 oldCount = resultCounter.counter.intValue();
99                 newCount = oldCount + inputCount;
100
101                // put updated Entry back to JavaSpace
102                resultCounter.counter = new Integer( newCount );
103                space.write( resultCounter,
104                    transactionCreated.transaction, Lease.FOREVER );
```

Fig. 23.16 Updating an entry using Jini **TransactionManager** (part 2 of 4).

```
105         // output result if transaction completes
106         output += "Count Information:\n";
107         output += "    Day: ";
108         output += resultCounter.day + "\n";
109         output += "    Old Count: " + oldCount + "\n";
110         output += "    New Count: " + newCount + "\n";
111     }
112 }
113
114     // commit transaction and release lease
115     transactionCreated.transaction.commit();
116     manager.remove( transactionCreated.lease );
117
118 } // end try
119
120     // handle exception updating Entry
121     catch ( Exception exception ) {
122         exception.printStackTrace();
123
124         // revert change and release lease
125         try {
126             transactionCreated.transaction.abort();
127             manager.remove( transactionCreated.lease );
128         }
129
130         // handle exception reverting change
131         catch ( Exception abortException ) {
132             abortException.printStackTrace();
133         }
134     }
135
136 } // end method updateEntry
137
138     // show output
139     public void showOutput()
140     {
141         JTextArea outputArea = new JTextArea();
142         outputArea.setText( output );
143         JOptionPane.showMessageDialog( null, outputArea,
144             "UpdateOperation Output",
145             JOptionPane.INFORMATION_MESSAGE );
146
147         // terminate program
148         System.exit( 0 );
149     }
150
151     public static void main( String args[])
152     {
153         // get hostname
154         if ( args.length != 1 ) {
155             System.out.println(
156                 "Usage: UpdateOperation hostname" );
```

Fig. 23.16 Updating an entry using Jini **TransactionManager** (part 3 of 4).

```
157         System.exit( 1 );
158     }
159     else
160         hostname = args[ 0 ];
161
162     // get user input day
163     UpdateInputWindow input = new UpdateInputWindow( hostname );
164
165 } // end method main
166 }
```

Fig. 23.16 Updating an entry using Jini **TransactionManager** (part 4 of 4).

Figure 23.17 and Fig. 23.18 show the results of running the update **Entry** application. The **WriteOperation Output** window in Fig. 23.17 is the result of running the **WriteOperation** application. We initialize the **Entry** for Wednesday. The **UpdateInputWindow** in Fig. 23.17 is the interface for the user to provide the update information, such as the number of attendees for a seminar on a given day. In that window, we want to send 15 people to attend Wednesday's seminar. The **UpdateOperation Output** window in Fig. 23.18 shows the result of running the **UpdateOperation** application. The **ReadOperation Output** window in Fig. 23.18 shows the result of reading Wednesday's **Entry** via the **ReadOperation** application.

To execute this application a Web server, the RMI activation daemon, the Jini lookup service, the JavaSpaces service and the **TransactionManager** service should be running. The following steps compile and execute the **UpdateOperation** application. Ensure that your **CLASSPATH** includes **jini-core.jar**, **jini-ext.jar** and **sun-util.jar**. Compile the java files in the **com\deitel\advjhttp1\javaspaces\common** and **com\deitel\advjhttp1\javaspaces\update** directories. Run application **UpdateOperation** by specifying the hostname of the Jini lookup service. Do not forget to specify a policy file with the proper permissions.

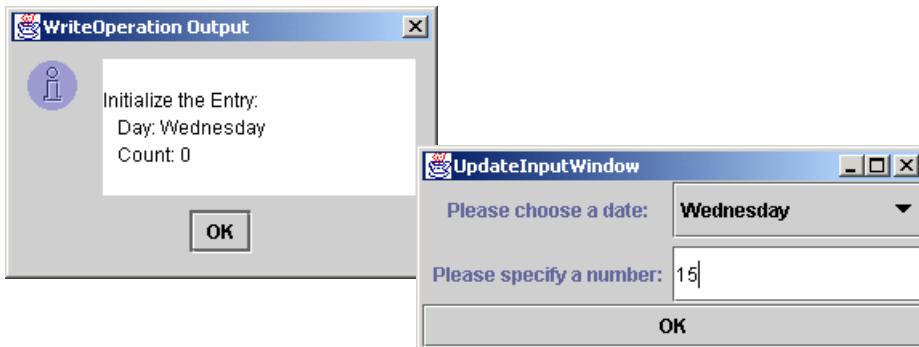


Fig. 23.17 WriteOperation Output and UpdateInputWindow user interface.

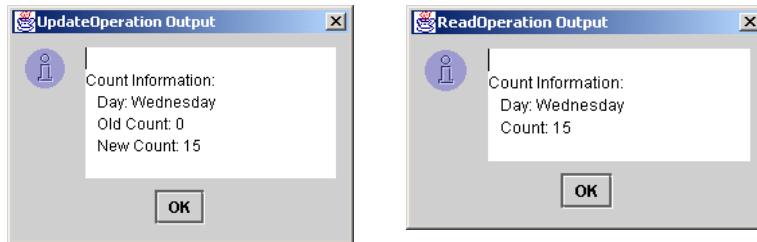
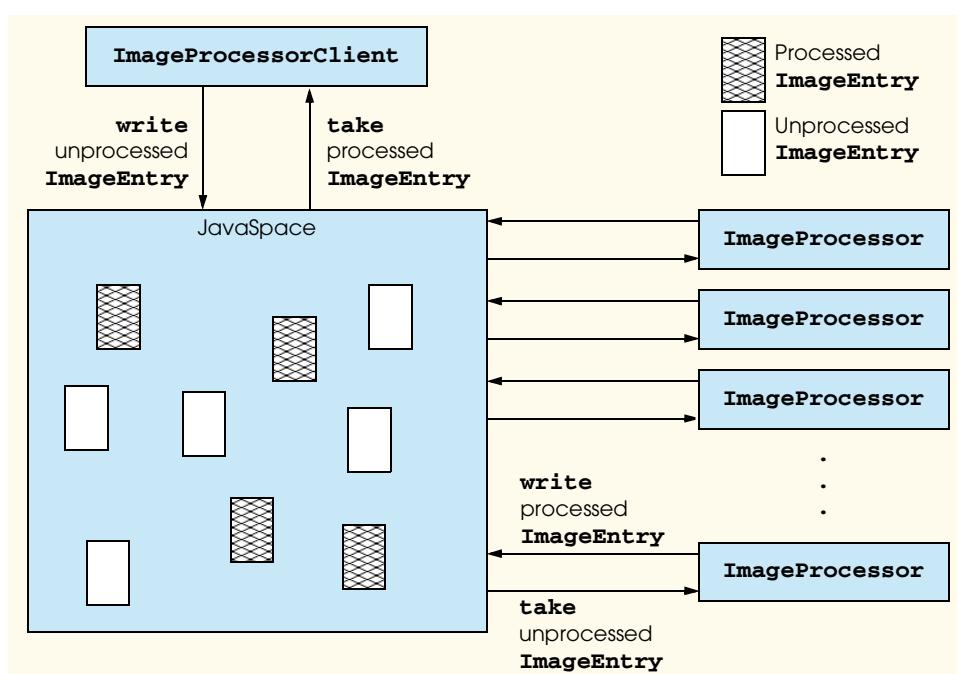


Fig. 23.18 UpdateOperation Output and ReadOperation Output.

## 23.12 Case Study: Distributed Image Processing

Image processing can be a time-consuming task, especially for large images. In this case study, we use JavaSpaces services to build a distributed image-processing system for applying filters to images (e.g., blur, sharpen, etc.). We define class **ImageProcessorClient** to partition a large image into smaller pieces and write these pieces into a JavaSpaces service. Multiple **ImageProcessors** run in parallel to process the smaller images by applying appropriate filters, then write the processed images back into the JavaSpaces service. The **ImageProcessorClient** then takes the processed subimages from the JavaSpaces service and builds the complete, processed image. Figure 23.19 shows the basic structure of the **ImageProcessor** application.

Fig. 23.19 Structure of the **ImageProcessor** distributed application.

### 23.12.1 Defining an Image Processor

In this case study, the distributed infrastructure consists of a set of dedicated image-processor nodes that retrieve **Entries** from a JavaSpaces service. Each of these nodes processes an **Entry** and writes it back to the JavaSpaces service. The image processors have four filters—blur, color, invert and sharpen. A blur filter blurs an image. A color filter alters the RGB color bands of an image. An invert filter inverts an image’s RGB color values. A sharpen filter sharpens the edges of an image. Each image-processor node in this distributed system polls the JavaSpaces service constantly looking for **Entries** to process.

Applications can use the distributed system to process images. The application in our case study is **ImageProcessorClient** (Fig. 23.23). **ImageProcessorClient** will prompt the user for a file name and the number of pieces in which to divide the original image. **ImageProcessorClient** then writes the pieces to the JavaSpaces service. **ImageProcessorClient** will then poll the JavaSpaces service until it retrieves all of the processed pieces. Finally, the application will assemble the image and display the results to the user.

Class **ImageEntry** (Fig. 23.20) defines the **Entries** that the application can store in the JavaSpaces service. Lines 16–20 define the **public** fields of the **Entry**. Line 23 defines the required empty constructor. Lines 26–34 define a constructor that initializes all fields in **ImageEntry**. Lines 37–41 define a constructor that initializes the **name** and **processed** fields. Lines 44–47 define a constructor that initializes the **name** field.

Class **ImageProcessor** (Fig. 23.21) represents each node of the image-processing distributed system that is capable of processing images. Each **ImageProcessor** node polls the JavaSpaces service for **ImageEntries**. When a client writes an unprocessed **ImageEntry** into the JavaSpaces service, the first **ImageProcessor** node to retrieve that **Entry** will process it. Each **ImageProcessor** node creates a transaction for each **Entry** it retrieves and doesn’t commit the transaction until it successfully writes the processed **ImageEntry** back to the JavaSpaces service, so if an **ImageProcessor** were to fail, the **ImageEntry** would not be lost.

```
1 // Fig. 23.20 ImageEntry.java
2 // This class defines the Entry for the image.
3 package com.deitel.advjhtp1.javaspace.ImageProcessor;
4
5 // Java core packages
6 import java.util.*;
7
8 // Java standard extension
9 import javax.swing.ImageIcon;
10
11 // Jini core packages
12 import net.jini.core.entry.Entry;
13
14 public class ImageEntry implements Entry {
15
16     public String name;
17     public String filter;
```

Fig. 23.20 **ImageEntry** defines the **Entries** to store in the JavaSpaces service (part 1 of 2).

```

18     public Integer number;
19     public Boolean processed;
20     public ImageIcon imageIcon;
21
22     // empty constructor
23     public ImageEntry() {}
24
25     // ImageEntry constructor
26     public ImageEntry( String imageName, String imageFilter,
27         int order, boolean done, ImageIcon icon )
28     {
29         name = imageName;
30         filter = imageFilter;
31         number = new Integer( order );
32         processed = new Boolean( done );
33         imageIcon = icon;
34     }
35
36     // ImageEntry constructor
37     public ImageEntry( String imageName, boolean done )
38     {
39         name = imageName;
40         processed = new Boolean( done );
41     }
42
43     // ImageEntry constructor
44     public ImageEntry( String imageName )
45     {
46         name = imageName;
47     }
48 }
```

Fig. 23.20 **ImageEntry** defines the **Entries** to store in the JavaSpaces service (part 2 of 2).

```

1 // Fig. 23.21 ImageProcessor.java
2 // Takes entries from the JavaSpace, applies a filter to
3 // the image piece, and writes processed entry back to JavaSpace.
4 package com.deitel.advjhtp1.javaspaces.ImageProcessor;
5
6 // Java standard extensions
7 import javax.swing.*;
8
9 // Jini core packages
10 import net.jini.core.lease.Lease;
11 import net.jini.core.transaction.*;
12 import net.jini.core.transaction.server.TransactionManager;
13 import net.jini.core.entry.*;
14 import net.jini.core.transaction.*;
15 import net.jini.lease.*;
16
```

Fig. 23.21 Image processing node that uses the JavaSpaces service (part 1 of 4).

```
17 // Jini extension package
18 import net.jini.space.JavaSpace;
19
20 // Deitel packages
21 import com.deitel.advjhtp1.javaspaces.common.*;
22
23 public class ImageProcessor {
24
25     private JavaSpace space;
26     private TransactionManager manager;
27
28     // ImageProcessor constructor
29     public ImageProcessor ( String hostname )
30     {
31         // get the JavaSpace
32         String jiniURL = "jini://" + hostname;
33         JavaSpaceFinder finder =
34             new JavaSpaceFinder( jiniURL );
35         space = finder.getJavaSpace();
36
37         // get the TransactionManager
38         TransactionManagerFinder findTransaction =
39             new TransactionManagerFinder( jiniURL );
40         manager =
41             findTransaction.getTransactionManager();
42     }
43
44     // wait for unprocessed image
45     public void waitForImage()
46     {
47         LeaseRenewalManager leaseManager =
48             new LeaseRenewalManager();
49
50         while ( true ) {
51
52             // get unprocessed image and process it
53             try {
54                 Transaction.Created transactionCreated =
55                     TransactionFactory.create(
56                         manager, Lease.FOREVER );
57
58                 // renew transaction's lease
59                 leaseManager.renewUntil(
60                     transactionCreated.lease, Lease.FOREVER, null );
61
62                 ImageEntry template = new ImageEntry( null, false );
63                 ImageEntry entry = ( ImageEntry ) space.take(
64                     template, transactionCreated.transaction,
65                     Lease.FOREVER );
66             }
```

Fig. 23.21 Image processing node that uses the JavaSpaces service (part 2 of 4).

```
67         if ( entry != null ) {
68
69             // get image icon
70             ImageIcon imageIcon = entry.imageIcon;
71
72             Filters filters = new Filters( imageIcon );
73
74             if ( entry.filter.equals( "BLUR" ) )
75                 filters.blurImage();
76
77             else if ( entry.filter.equals( "COLOR" ) )
78                 filters.colorFilter();
79
80             else if ( entry.filter.equals( "INVERT" ) )
81                 filters.invertImage();
82
83             else if ( entry.filter.equals( "SHARP" ) )
84                 filters.sharpenImage();
85
86             // update the fields of result entry
87             entry.imageIcon = filters.getImageIcon();
88             entry.processed = new Boolean( true );
89
90             // put the updated Entry back to JavaSpace
91             Lease writeLease = space.write( entry,
92                 transactionCreated.transaction,
93                 Lease.FOREVER );
94             leaseManager.renewUntil(
95                 writeLease, Lease.FOREVER, null );
96
97         } // end if
98
99         // commit the transaction and release the lease
100        transactionCreated.transaction.commit();
101        leaseManager.remove( transactionCreated.lease );
102
103    } // end try
104
105    // handle exception
106    catch ( Exception exception ) {
107        exception.printStackTrace();
108    }
109
110 } // end while
111
112 } // end method wait for images
113
114 public static void main( String[] args )
115 {
116     // get the hostname
117     if ( args.length != 1 ) {
118         System.out.println(
119             "Usage: ImageProcessor hostname" );
```

Fig. 23.21 Image processing node that uses the JavaSpaces service (part 3 of 4).

```
120         System.exit( 1 );
121     }
122
123     ImageProcessor processor =
124         new ImageProcessor( args[ 0 ] );
125
126     // wait for image
127     processor.waitForImage();
128
129 } // end method main
130 }
```

Fig. 23.21 Image processing node that uses the JavaSpaces service (part 4 of 4).

Constructor **ImageProcessor** (lines 29–42) gets a JavaSpaces service and a **TransactionManager** service from the user-specified hostname. Classes **JavaSpaceFinder** and **TransactionManagerFinder** are defined in Fig. 23.1 and Fig. 23.15 respectively. Method **waitForImage** (lines 45–112) waits for an unprocessed image. Lines 50–110 cycle indefinitely to process **Entries** from the JavaSpaces service. Line 62 defines the **Entry** template that **ImageProcessor** will use to retrieve unprocessed **ImageEntry** from the JavaSpaces service. Lines 63–65 retrieve an object from the JavaSpaces service. If the **Entry** retrieved from the JavaSpaces service is not **null**, lines 70–84 apply a filter to the image. Lines 87–88 set fields in the **ImageEntry** with values that will identify the **ImageEntry** as a processed **Entry**. Lines 91–91–93 write the processed **ImageEntry** back to the JavaSpaces service. Line 100 commits the transaction. Line 101 expires the lease on the transaction.

Method **main** (lines 114–129) gets the user-specified hostname and calls **ImageProcessor** constructor. Method **waitForImage** starts polling the JavaSpaces service for an unprocessed image.

Class **Filters** (Fig. 23.22) filters an image. It provides four types of filters—blur, sharpen, invert and color. These four filters can be found in the Chapter 4 package **com.deitel.advjhttp.java2d**. The **Filters** constructor (lines 26–40) takes an **ImageIcon** and converts the **ImageIcon** to the **BufferedImage**. Method **blurImage** (lines 43–46) applies a blur filter to the **BufferedImage**. Method **sharpenImage** (lines 49–53) applies a sharpen filter to the **BufferedImage**. Method **invertImage** (lines 56–60) applies an invert filter to the **BufferedImage**. Method **colorFilter** (lines 63–67) applies a color filter to a **BufferedImage**. Method **getImageIcon** (lines 70–73) returns the filtered image as an **ImageIcon**.

```
1 // Fig. 23.22: Filters.java
2 // Applies blurring, sharpening, converting, modifying on images.
3 package com.deitel.advjhttp1.javaspaces.ImageProcessor;
4
5 // Java core packages
6 import java.awt.*;
7 import java.awt.image.*;
```

Fig. 23.22 Class **Filters** applies a Java 2D filter to an image (part 1 of 3).

```
9 // Java standard extensions
10 import javax.swing.*;
11
12 // Deitel packages
13 import com.deitel.advjhtp1.java2d.*;
14
15 public class Filters {
16
17     Java2DImageFilter blurFilter;
18     Java2DImageFilter sharpenFilter;
19     Java2DImageFilter invertFilter;
20     Java2DImageFilter colorFilter;
21
22     BufferedImage bufferedImage;
23
24     // constructor method initializes ImageFilters and pulls
25     // BufferedImage out of ImageIcon
26     public Filters( ImageIcon icon )
27     {
28         blurFilter = new BlurFilter();
29         sharpenFilter = new SharpenFilter();
30         invertFilter = new InvertFilter();
31         colorFilter = new ColorFilter();
32
33         Image image = icon.getImage();
34         bufferedImage = new BufferedImage(
35             image.getWidth( null ), image.getHeight( null ),
36             BufferedImage.TYPE_INT_RGB );
37
38         Graphics2D gg = bufferedImage.createGraphics();
39         gg.drawImage( image, null, null );
40     }
41
42     // apply BlurFilter to bufferedImage
43     public void blurImage()
44     {
45         bufferedImage = blurFilter.processImage( bufferedImage );
46     }
47
48     // apply SharpenFilter to bufferedImage
49     public void sharpenImage()
50     {
51         bufferedImage = sharpenFilter.processImage(
52             bufferedImage );
53     }
54
55     // apply InvertFilter to bufferedImage
56     public void invertImage()
57     {
58         bufferedImage = invertFilter.processImage(
59             bufferedImage );
60     }
61 }
```

Fig. 23.22 Class **Filters** applies a Java 2D filter to an image (part 2 of 3).

```
62     // apply ColorFilter to bufferedImage
63     public void colorFilter()
64     {
65         bufferedImage = colorFilter.processImage(
66             bufferedImage );
67     }
68
69     // constructs and returns an ImageIcon from bufferedImage
70     public ImageIcon getIcon()
71     {
72         return ( new ImageIcon( bufferedImage ) );
73     }
74 }
```

Fig. 23.22 Class **Filters** applies a Java 2D filter to an image (part 3 of 3).

### 23.12.2 Partitioning an Image into Smaller Pieces

To parallelize the task of filtering a large image, we can partition the image into smaller pieces and let multiple **ImageProcessors** concurrently filter the smaller images. Then, we can combine the processed pieces to create the complete, processed image. Class **ImageProcessorClient** (Fig. 23.23) prompts the user for an image file to process and partitions the large image. **ImageProcessorClient** wraps the image pieces in **ImageEntries**s and write them into the JavaSpaces service. Once **ImageProcessorClient** writes all image pieces into the JavaSpaces service, it reads back all processed **ImageEntry**s.

The **ImageProcessorClient** constructor (lines 42–192) defines the user interface to get the user input data. Lines 66–81 display a **JChooserPanel** when a user presses the **Choose file to process** button to prompt the user for an image file. Lines 90–111 define a **JLabel** and a **JTextfield** which obtains the user-specified number of subimages. Lines 114–135 create a label and a drop-down box that allows the user to specify the filter to apply on the image. Lines 142–186 add an **OK** button to the window. Lines 152–186 define the action when the user clicks the **OK** button. The application first checks whether the user specified the image name and partition number. If so, the application passes the user specified data to the **ImageSeparator** (Fig. 23.24) constructor and calls methods **partitionImage** and **storeImage** of class **ImageSeparator** to partition the image and store the sub images in a JavaSpaces service, respectively. Method **collect** obtains a reference to the JavaSpaces service (lines 198–201). Lines 211–212 verify that the user input number divides evenly between columns and rows. If the user-input number does not divide evenly, then the image will be broken into 4 pieces. Line 215 creates a template that will match all processed image pieces. Line 218 creates a snapshot of the template. Lines 221–225 retrieve all processed **ImageEntries** from the JavaSpaces service. Lines 251–265 reassemble the image and display the resulting image in a separate window. Lines 267–274 display an error message if the file was not found. Method **main** (lines 278–294) gets the user-specified hostname from the command line and displays the GUI.

Class **ImageSeparator** (Fig. 23.24) partitions an image into smaller pieces and places the subimages into a JavaSpaces service. The constructor (lines 33–39) gets the image name, number of subimages and this filter to be apply to the image. Method **partitionImage** (lines 42–50) gets the **ImageIcon** from the image file (lines 44–45) and calls method **parseImage** of class **ImageParser** (Fig. 23.25) to partition the image

into smaller pieces. Method **displayImage** (lines 53–60) creates a **ImageDisplayer** (Fig. 23.26) to display the original image. Method **storeImage** (lines 63–101) writes the subimages into a JavaSpaces service. Lines 77–88 write each image into the JavaSpaces service and renew the image's lease to **Lease.FOREVER**.

```
1 // Fig. 23.23 ImageProcessingClient.java
2 // The application asks for user-specified image file, image
3 // filter type and image partition number, filters the image
4 // and displays the processed image.
5 package com.deitel.advjhtp1.javaspace.ImageProcessor;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.util.*;
11 import java.io.*;
12
13 // Java extension packages
14 import javax.swing.*;
15
16 // Jini core packages
17 import net.jini.core.lease.Lease;
18 import net.jini.core.entry.*;
19 import net.jini.core.transaction.*;
20 import net.jini.core.transaction.server.TransactionManager;
21
22 // Jini extension packages
23 import net.jini.space.JavaSpace;
24
25 // Deitel packages
26 import com.deitel.advjhtp1.javaspace.common.*;
27
28 public class ImageProcessingClient extends JFrame {
29
30     private String[] operations = { "BLUR", "COLOR",
31         "INVERT", "SHARP" };
32     private JButton okButton;
33     private JComboBox operationComboBox;
34     private JTextField imageName;
35     private JTextField numberText;
36
37     private static String hostname = "";
38     private String imageName;
39     private String operation = "BLUR";
40     private int partitionNumber = 0;
41
42     public ImageProcessingClient( String host )
43     {
44         super ( "ImageProcessInput" );
45
46         hostname = host;
47         Container container = getContentPane();
```

Fig. 23.23 Image-processing distributed system client (part 1 of 6).

```
48      // define the center panel
49      JPanel centerPanel = new JPanel();
50      centerPanel.setLayout( new GridLayout( 3, 2, 0, 5 ) );
51
52      // add image label
53      JLabel imageLabel = new JLabel( "Image File:",
54          SwingConstants.CENTER );
55      centerPanel.add( imageLabel );
56
57      JButton openFile = new JButton(
58          "Choose file to process" );
59      openFile.addActionListener(
60
61          new ActionListener() {
62
63              public void actionPerformed( ActionEvent event )
64              {
65                  JFileChooser fileChooser = new JFileChooser();
66
67                  fileChooser.setFileSelectionMode(
68                      JFileChooser.FILES_ONLY );
69                  int result = fileChooser.showOpenDialog( null );
70                  File file;
71
72
73                  // user clicked Cancel button on dialog
74                  if ( result == JFileChooser.CANCEL_OPTION )
75                      file = null;
76                  else {
77                      file = fileChooser.getSelectedFile();
78                      imageName = file.getPath();
79                  }
80
81              } // end method actionPerformed
82
83          } // end ActionListener constructor
84
85      ); // end addActionListener
86
87      centerPanel.add( openFile );
88
89      // add number label
90      JLabel numberLabel = new JLabel( "Partition Number:",
91          SwingConstants.CENTER );
92      centerPanel.add( numberLabel );
93
94      // add number text field
95      numberText = new JTextField( 10 );
96      centerPanel.add( numberText );
97
98      // install a listener to the number text field
99      numberText.addActionListener(
100
```

Fig. 23.23 Image-processing distributed system client (part 2 of 6).

```
101     new ActionListener() {
102
103         // get the text when the user feeds a return
104         // character in the text field
105         public void actionPerformed( ActionEvent event )
106         {
107             partitionNumber = Integer.parseInt(
108                 event.getActionCommand() );
109         }
110     );
111 );
112
113 // add operation label
114 JLabel operationLabel = new JLabel( "Operation Type:",
115     SwingConstants.CENTER );
116 centerPanel.add( operationLabel );
117
118 // add a combo box
119 operationComboBox = new JComboBox( operations );
120 operationComboBox.setSelectedIndex( 0 );
121 centerPanel.add( operationComboBox );
122
123 // install a listener to the combo box
124 operationComboBox.addItemListener(
125
126     new ItemListener() {
127
128         // an operation other than BLUR is selected
129         public void itemStateChanged( ItemEvent itemEvent )
130         {
131             operation =
132                 ( String ) operationComboBox.getSelectedItem();
133         }
134     );
135 );
136
137 // define the button panel
138 JPanel buttonPanel = new JPanel();
139 buttonPanel.setLayout( new GridLayout( 1, 1, 0, 5 ) );
140
141 // add the OK button
142 okButton = new JButton( "OK" );
143 buttonPanel.add( okButton );
144
145 // add a listener to the OK button
146 okButton.addActionListener(
147
148     new ActionListener() {
```

Fig. 23.23 Image-processing distributed system client (part 3 of 6).

```
150          // partition image file into number of pieces user
151          // specified
152      public void actionPerformed( ActionEvent event )
153      {
154          // get user inputs
155          partitionNumber = Integer.parseInt(
156              numberText.getText() );
157
158          // check whether the user
159          // fills in both text fields
160          if ( ( partitionNumber == 0 )
161              || ( imageName == null ) ) {
162              JOptionPane.showMessageDialog( null,
163                  "Either image name or partition number "
164                  + "is not specified!", "Error",
165                  JOptionPane.ERROR_MESSAGE );
166          }
167
168          else {
169              setVisible( false );
170
171              // partition the image into smaller pieces
172              // and store the sub images into a JavaSpace
173              ImageSeparator imageSeparator =
174                  new ImageSeparator(
175                      imageName, operation, partitionNumber );
176              imageSeparator.partitionImage();
177              imageSeparator.storeImage( hostname );
178              imageSeparator.displayImage();
179              collect();
180          }
181
182      } // end method actionPerformed
183
184  } // end ActionListener constructor
185
186  ); // end addActionListener
187
188  // put everything together
189  container.add( centerPanel, BorderLayout.CENTER );
190  container.add( buttonPanel, BorderLayout.SOUTH );
191
192 } // end ImageProcessingClient constructor
193
194 // collect processed images
195 public void collect()
196 {
197     // get the JavaSpace
198     String jiniURL = "jini://" + hostname;
199     JavaSpaceFinder findtool =
200         new JavaSpaceFinder( jiniURL );
201     JavaSpace space = findtool.getJavaSpace();
202 }
```

Fig. 23.23 Image-processing distributed system client (part 4 of 6).

```
203     Vector unOrderedImages = new Vector();
204     Vector orderedImages = null;
205
206     // removes all images in the JavaSpace
207     // that have the specified name
208     try {
209         double squareRoot = Math.sqrt( partitionNumber );
210
211         if ( Math.floor( squareRoot ) != ( squareRoot ) )
212             partitionNumber = 4;
213
214         // specify the matching template
215         ImageEntry template = new ImageEntry( imageName, true );
216
217         // snapshot the template
218         Entry snapshotEntry = space.snapshot( template );
219
220         // collect images
221         for ( int i = 0; i < partitionNumber ; i++ ) {
222             ImageEntry remove = ( ImageEntry ) space.take(
223                 snapshotEntry, null, Lease.FOREVER );
224             unOrderedImages.add( remove );
225         }
226
227         int imageCount = unOrderedImages.size();
228         orderedImages =
229             new Vector( imageCount );
230
231         // initialize the Vector
232         for ( int i = 0; i < imageCount; i++ )
233             orderedImages.add( null );
234
235         // order the sub images
236         for ( int i = 0; i < imageCount; i++ ) {
237             ImageEntry image =
238                 ( ImageEntry ) unOrderedImages.elementAt( i );
239             orderedImages.setElementAt(
240                 image.imageIcon, image.number.intValue() );
241         }
242
243     } // end try
244
245     // handle exception collecting images
246     catch ( Exception exception ) {
247         exception.printStackTrace();
248     }
249
250     // put images together and display the result image
251     if ( orderedImages.size() > 0) {
252         ImageParser imageParser = new ImageParser();
253
254         ImageIcon icon = imageParser.putTogether(
255             orderedImages );
```

Fig. 23.23 Image-processing distributed system client (part 5 of 6).

```
256     ImageDisplayer imageDisplayer =
257         new ImageDisplayer( icon );
258
259         imageDisplayer.setSize( icon.getIconWidth() + 50,
260             icon.getIconHeight() + 50 );
261         imageDisplayer.setVisible( true );
262         imageDisplayer.setDefaultCloseOperation(
263             JFrame.EXIT_ON_CLOSE );
264     }
265 }
266
267 else {
268     JOptionPane.showMessageDialog( null,
269         "Invalid image name", "Error",
270         JOptionPane.ERROR_MESSAGE);
271
272     // terminate program
273     System.exit( 0 );
274 }
275
276 } // end method collect
277
278 public static void main( String[] args )
279 {
280     // get the hostname
281     if ( args.length != 1 ) {
282         System.out.println(
283             "Usage: ImageProcessingClient hostname" );
284         System.exit( 1 );
285     }
286
287     ImageProcessingClient processor =
288         new ImageProcessingClient( args[ 0 ] );
289
290     // set the window size and display it
291     processor.setSize( 350, 150 );
292     processor.setVisible( true );
293
294 } // end method main
295 }
```

Fig. 23.23 Image-processing distributed system client (part 6 of 6).

```
1 // Fig. 23.24 ImageSeparator.java
2 // This class partitions the image into smaller pieces evenly
3 // and stores the smaller images into a JavaSpace.
4 package com.deitel.advjhtp1.javaspaces.ImageProcessor;
5
6 // Java core packages
7 import java.util.*;
8 import java.rmi.*;
```

Fig. 23.24 Partitioning an image into smaller pieces and storing subimages in a JavaSpaces service (part 1 of 3).

```
9
10 // Java standard extensions
11 import javax.swing.*;
12
13 // Jini core packages
14 import net.jini.core.lease.Lease;
15 import net.jini.core.transaction.TransactionException;
16
17 // Jini extension packages
18 import net.jini.space.JavaSpace;
19 import net.jini.lease.*;
20
21 // Deitel packages
22 import com.deitel.advjhttp1.javaspace.common.*;
23
24 public class ImageSeparator {
25
26     private String imageName;
27     private String filterType;
28     private int partitionNumber;
29     private Vector imagePieces;
30     private ImageIcon icon;
31
32     // ImageSeparator constructor
33     public ImageSeparator(
34         String name, String type, int number )
35     {
36         imageName = name;
37         filterType = type;
38         partitionNumber = number;
39     }
40
41     // partition the image into smaller pieces evenly
42     public void partitionImage()
43     {
44         ImageParser imageParser = new ImageParser();
45         icon = new ImageIcon( imageName );
46
47         // partition the image
48         imagePieces = imageParser.parseImage(
49             icon, partitionNumber );
50     }
51
52     // display the image
53     public void displayImage( )
54     {
55         ImageDisplayer imageDisplayer =
56             new ImageDisplayer( icon );
57         imageDisplayer.setSize( icon.getIconWidth() + 50,
58             icon.getIconHeight() + 50 );
59         imageDisplayer.setVisible( true );
60     }
}
```

Fig. 23.24 Partitioning an image into smaller pieces and storing subimages in a JavaSpaces service (part 2 of 3).

```
61      // write image pieces into a JavaSpace
62      public void storeImage( String hostname )
63      {
64          // get the JavaSpace
65          String jiniURL = "jini://" + hostname;
66          JavaSpaceFinder findtool =
67              new JavaSpaceFinder( jiniURL );
68          JavaSpace space = findtool.getJavaSpace();
69
70          LeaseRenewalManager leaseManager =
71              new LeaseRenewalManager();
72
73          // write sub images to JavaSpace
74          try {
75
76              for ( int i = 0; i < imagePieces.size(); i++ ) {
77                  ImageIcon subImage =
78                      ( ImageIcon ) imagePieces.elementAt( i );
79
80                  ImageEntry imageEntry = new ImageEntry(
81                      imageName, filterType, i, false, subImage );
82
83                  Lease writeLease = space.write(
84                      imageEntry, null, Lease.FOREVER );
85                  leaseManager.renewUntil(
86                      writeLease, Lease.FOREVER, null );
87
88              }
89          }
90
91          // if a network failure occurs
92          catch ( RemoteException remoteException ) {
93              remoteException.printStackTrace();
94          }
95
96          // if write operates under an invalid transaction
97          catch ( TransactionException transactionException ) {
98              transactionException.printStackTrace();
99          }
100     } // end method storeImage
101 }
```

Fig. 23.24 Partitioning an image into smaller pieces and storing subimages in a JavaSpaces service (part 3 of 3).

Class **ImageParser** (Fig. 23.25) partitions an image into smaller pieces and puts subimages together to reform a large image. Method **parseImage** (lines 25–66) partitions an image into smaller pieces. If the number of subimages specified by the user does not divide evenly between the number of rows and columns, then the default number 4 is used (lines 29–35). Lines 42–62 partition the image. The resulting subimages are stored in a **Vector**. Method **putTogether** (lines 71–106) puts subimages back together. Lines 93–102 get the subimages from the input **Vector** and piece them together into a **BufferedImage** to form a complete image. Line 104 returns the image as an **ImageIcon**.

Class **ImageDisplayer** (Fig. 23.26) is a **JFrame** subclass for displaying an image. The constructor (lines 15–30) gets an **ImageIcon** and displays it in a **JLabel**.

```
1 // Fig. 23.25: ImageParser.java
2 // This class partitions an image into smaller pieces.
3 package com.deitel.advjhtp1.javaspace.ImageProcessor;
4
5 // Java core packages
6 import java.awt.image.*;
7 import java.net.URL;
8 import java.awt.*;
9 import java.lang.*;
10 import java.util.Vector;
11 import java.awt.geom.*;
12
13 // Java standard extensions
14 import javax.swing.*;
15
16 public class ImageParser {
17
18     ImageIcon image;
19
20     public ImageParser() {}
21
22     // pass parseImage an ImageIcon on the number of piece
23     // you want it split into the number of piece must be a
24     // perfect square - this can be extended later
25     public Vector parseImage(
26         ImageIcon imageIcon, int numberPieces )
27     {
28         Vector vector = new Vector();
29         double squareRoot = Math.sqrt( numberPieces );
30
31         if ( Math.floor( squareRoot ) != ( squareRoot ) ) {
32             System.out.println( "This is not a square number,"
33                 + " setting to default..." );
34             numberPieces = 4;
35         }
36
37         // get number of rows and columns
38         int numberOfRows = ( int ) Math.sqrt( numberPieces );
39         int numberColumns = ( int ) Math.sqrt( numberPieces );
40
41         // retrieve Image from BufferedImage
42         Image image = imageIcon.getImage();
43         BufferedImage bufferedImage = new BufferedImage(
44             image.getWidth( null ), image.getHeight( null ),
45             BufferedImage.TYPE_INT_RGB );
46
47         Graphics2D g2D = bufferedImage.createGraphics();
48         g2D.drawImage( image, null, null );
49 }
```

Fig. 23.25 Partitioning and reforming an image (part 1 of 3).

```
50     // get size of each piece
51     int width = bufferedImage.getWidth() / numberColumns;
52     int height = bufferedImage.getHeight() / numberOfRows;
53
54     // make each of images
55     for ( int x = 0; x < numberOfRows; x++ ) {
56
57         for ( int y = 0; y < numberColumns; y++ ) {
58             vector.add( new ImageIcon(
59                 bufferedImage.getSubimage(
60                     x * width, y * height, width, height ) ) );
61         }
62     }
63
64     return vector;
65
66 } // end method parseImage
67
68 // takes a vector of image icons (must be a square number)
69 // of elements and returns an image icon with the images
70 // put back together again
71 public ImageIcon putTogether( Vector vector )
72 {
73     double size = vector.size();
74     int numberRowColumn = ( int ) Math.sqrt( size );
75
76     // step 1, get first Image
77     Image tempImage =
78         ( ( ImageIcon ) vector.get( 0 ) ).getImage();
79
80     // get total size of one piece
81     int width = tempImage.getWidth( null );
82     int height = tempImage.getHeight( null );
83
84     // create buffered image
85     BufferedImage totalPicture = new BufferedImage(
86         width * numberRowColumn, height * numberRowColumn,
87         BufferedImage.TYPE_INT_RGB );
88
89     // create Graphics for BufferedImage
90     Graphics2D graphics = totalPicture.createGraphics();
91
92     // draw images from the vector into buffered image
93     for ( int x = 0; x < numberRowColumn; x++ ) {
94
95         for ( int y = 0; y < numberRowColumn; y++ ) {
96             Image image = ( ( ImageIcon ) vector.get(
97                 y + numberRowColumn * x ) ).getImage();
98             graphics.drawImage( image,
99                 AffineTransform.getTranslateInstance(
100                     x * width, y * height ), null );
101         }
102     }
```

Fig. 23.25 Partitioning and reforming an image (part 2 of 3).

```
103     return new ImageIcon( totalPicture );
104 }
105 } // end method putTogether
106 }
```

Fig. 23.25 Partitioning and reforming an image (part 3 of 3).

```
1 // Fig. 23.26: ImageDisplayer.java
2 // This application is an user interface used
3 // to display an image.
4 package com.deitel.advjhtp1.javaspace.ImageProcessor;
5
6 // Java extension packages
7 import javax.swing.*;
8
9 // Java core packages
10 import java.awt.*;
11 import java.awt.event.*;
12
13 public class ImageDisplayer extends JFrame {
14
15     public ImageDisplayer( ImageIcon icon )
16     {
17         super( "ImageDisplay" );
18         Container container = getContentPane();
19
20         // define the center panel
21         JPanel centerPanel = new JPanel();
22
23         // add display label
24         JLabel imageLabel = new JLabel(
25             icon, SwingConstants.LEFT );
26         centerPanel.add( imageLabel );
27
28         container.add( centerPanel, BorderLayout.CENTER );
29
30     } // end ImageDisplayer constructor
31 }
```

Fig. 23.26 Displaying an image.

### 23.12.3 Compiling and Running the Example

Before compiling the sample code, ensure that **jini-core.jar**, **jini-ext.jar** and **sun-util.jar** are included in the **CLASSPATH**. To execute the example, start:

1. a Web server,
2. the RMI activation daemon,
3. the Jini lookup service,
4. the JavaSpaces service, and
5. the Jini **Transaction** service.

On a second computer, perform the following tasks:

1. compile all java files in directory `com\deitel\advjhttp1\javaspace\ImageProcessor`, and
2. start the **ImageProcessorClient** application by specifying the hostname of the computer running the Jini lookup service (you also must specify an appropriate policy file).

On at least one other machine, start an **ImageProcessor** node and specify the hostname of the computer running the Jini lookup service (you also must specify an appropriate policy file).

One important thing to note in this example is that doubling the number of **ImageProcessor** nodes that retrieve **Entries** from the JavaSpaces service doubles the processing power of the application. If you do not have multiple computers, you can run the entire application on a single computer. Although this defeats the purpose of a distributed system, running the application on a single computer can be useful for testing and debugging the application. Figure 23.27 displays the GUI for the **ImageProcessorClient** application.

Fig. 23.28 displays the image on the left-hand side before application **ImageProcessorClient** distributes the image to the **ImageProcessor** nodes. The **ImageProcessor** nodes apply the blur filter to the image. The image on the right-hand side shows the resulting image after **ImageProcessorClient** assembles the processed pieces.

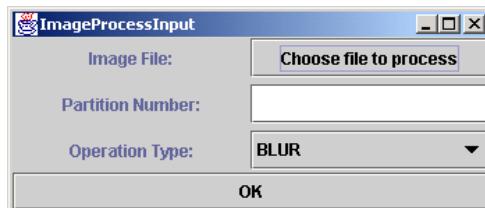


Fig. 23.27 GUI from **ImageProcessorMain** and **ImageCollector** applications.



Fig. 23.28 Images before and after blurring.

### 23.13 Internet and World Wide Web Resources

[www.sun.com/jini/specs/js1\\_1.pdf](http://www.sun.com/jini/specs/js1_1.pdf)

This site provides the Jini JavaSpaces service Specification.

[www.javaworld.com/jw-11-1999/jw-11-jiniology.html](http://www.javaworld.com/jw-11-1999/jw-11-jiniology.html)

[www.javaworld.com/jw-01-2000/jw-01-jiniology.html](http://www.javaworld.com/jw-01-2000/jw-01-jiniology.html)

[www.javaworld.com/jw-03-2000/jw-03-jiniology.html](http://www.javaworld.com/jw-03-2000/jw-03-jiniology.html)

[www.javaworld.com/jw-04-2000/jw-0421-jiniology.html](http://www.javaworld.com/jw-04-2000/jw-0421-jiniology.html)

[www.javaworld.com/jw-06-2000/jw-0623-jiniology.html](http://www.javaworld.com/jw-06-2000/jw-0623-jiniology.html)

These JavaWorld online magazine URLs represent a series of articles that introduce JavaSpaces technology, including the available operations, transactions and leasing.

[www.byte.com/documents/s=146/BYT19990921S0001/index.htm](http://www.byte.com/documents/s=146/BYT19990921S0001/index.htm)

This article provides an overview of JavaSpaces technology and introduces its basic concepts.

#### SUMMARY

- A JavaSpaces service is a Jini service that implements a simple, high-level architecture for building distributed systems. The JavaSpaces service enables Java objects to communicate, share objects and coordinate tasks using an area of shared memory.
- A JavaSpaces service provides three fundamental operations—write, take and read. The write operation places an object—called an entry—into the JavaSpaces service.
- The take operation specifies a template and removes from the JavaSpaces service an entry that matches the given template. The read operation is similar to the take operation, but does not remove the matching entry from the JavaSpaces service.
- In addition to the three basic operations, JavaSpaces services support transactions through the Jini transaction manager, and a notification mechanism that notifies an object when an entry that matches a given template is written to the JavaSpaces service.
- An entry stored in a JavaSpaces service will remain in the JavaSpaces service until its lease expires or until a program takes the entry from the JavaSpaces service.
- A JavaSpaces service locates objects by comparing those objects to a template. The template specifies the search criteria against which the JavaSpaces service compares each entry. When one or more entries match the template, the JavaSpaces service returns a single matching entry.
- JavaSpaces services can use the Jini transaction manager to ensure operations execute atomically.
- Objects in a JavaSpaces service are shared. Programs can read and take entries from the JavaSpaces service, modify the **public** fields in those entries and write them back to the JavaSpaces service for other programs to use.
- Any object stored in the JavaSpaces service must implement interface **Entry** (package **net.jini.core.entry**). JavaSpaces services **Entries** adhere to the Jini **Entry** contract defined in the Jini Core Specification.
- An **Entry** can have multiple constructors and as many methods as required. Other requirements include a **public** no-argument constructor, **public** fields and no-primitive type fields. The JavaSpaces service proxy uses the no-argument constructor to instantiate the matching **Entry** during the deserialization process.
- All fields that will be used as the template matching fields in an **Entry** must be **public** (for more information on template matching fields, see Section 23.8). As defined by the Jini Core Specification, an **Entry** cannot have primitive-type fields.
- JavaSpaces technology, like Jini, requires several underlying services. The JavaSpaces service depends on the Jini lookup service. When transactions are required, the Jini transaction service must be started. JavaSpaces services also depend on a Web server and **rmid**.

- Two versions of JavaSpaces services are available. One is the transient JavaSpaces service (non-activatable). The other is the persistent JavaSpaces service (activatable).
- The transient JavaSpaces service does not require the RMI activation daemon (**rmid**), because the transient JavaSpaces service is not activatable. Once the transient JavaSpaces service terminates, all state information is lost and **rmid** is unable to restart the service.
- The persistent JavaSpaces service is activatable, and therefore requires the RMI activation daemon. If the persistent JavaSpaces service terminates, all of its state information is stored in a log file and **rmid** can restart the service at a later time.
- Upon initialization, each JavaSpaces service registers itself with local Jini lookup services.
- Clients access objects in a JavaSpaces service through interface **JavaSpace** (package **net.jini.space**). Interface **JavaSpace** provides several methods—**notify**, **read**, **readIfExists**, **take**, **takeIfExists**, **write** and **snapshot**.
- The **write** operation inserts an **Entry** into a JavaSpaces service. If an identical **Entry** already exists in the JavaSpaces service, this operation does not overwrite the existing **Entry**. Instead, the **write** operation places a copy of the **Entry** into the JavaSpaces service.
- The **read** operation attempts to read an **Entry** that matches an **Entry** template from a JavaSpaces service. If no matching **Entry** exists in the JavaSpaces service, this operation returns **null**. If multiple matching **Entry** exist in the JavaSpaces service, the **read** operation arbitrarily picks one among the matching **Entries**. Method **read** blocks until a matching **Entry** is found in the JavaSpaces service or until a time-out occurs.
- Method **readIfExists** checks to see if a matching **Entry** exists within the JavaSpaces service. If an **Entry** does not exist in the JavaSpaces service, method **readIfExists** should return **null** immediately. Method **readIfExists** does not block unless the matching **Entry** is a participant in an uncommitted transaction.
- The **take** operation attempts to remove an **Entry** that matches an **Entry** template from a JavaSpaces service. This operation works like the **read** operation, except that the **take** operation removes the matching **Entry** from the JavaSpaces service.
- Method **take** blocks until a matching **Entry** is found in the JavaSpaces service or until a time-out occurs.
- Method **takeIfExists** checks to see if a matching **Entry** exists within the JavaSpaces service. If an **Entry** does not exist in the JavaSpaces service, method **takeIfExists** should return **null** immediately. Method **takeIfExists** does not block unless the matching **Entry** is part of an uncommitted transaction.
- The **notify** operation requests that the JavaSpaces service sends a notification to a listener object when a client writes a matching **Entry** into the JavaSpaces service. With this method, an application does not need to check repeatedly for an **Entry** in a JavaSpaces service.
- Method **snapshot** increases performance when a program must serialize one **Entry** repeatedly. Each time a program transfers an **Entry** into a JavaSpaces service (e.g., by writing that **Entry** or by using that **Entry** as a template), that **Entry** must be serialized. Invoking method **snapshot** serializes the **Entry** once and reuses this serialized **Entry** for future transfers.
- Method **write** takes three arguments—an **Entry**, a **Transaction** object and a **long** value that requests an amount of time for which the JavaSpaces service should keep the **Entry**. The **long** value represents the lease length for the **Entry**.
- The **read** and the **take** operations retrieve **Entries** from a JavaSpaces service. A client can read or take an **Entry** from the JavaSpaces service by supplying a template **Entry** against which to compare the public fields of **Entries** in the JavaSpaces service. The template indicates which fields should be used for comparison purposes.

- The retrieval process is based on the template-matching mechanism, which matches **Entries** according to the values of their **public** fields. Fields in the template with non-**null** values must match with their **Entry** counterparts in the JavaSpaces service exactly. Fields in the template that are set to **null** act as wildcards.
- If a set of **Entries** of the same type exist within a JavaSpaces service, only those fields which equal those of the template are used to match an **Entry** or a set of **Entries** contained in the JavaSpaces service. Fields in the template set to **null** can have their matching counterparts in the JavaSpaces service have any value in the corresponding field(s).
- The **read** operation obtains **Entries** without removing them from the JavaSpaces service. Methods **read** and **readIfExists** perform the read operation. Each method takes three arguments—an **Entry** that specifies the template to match, a **Transaction** object and a **long** value.
- Method **read** specifies a period of time for which the read operation should block before simply returning **null**. Method **readIfExists** is a non-blocking version of method **read**. If there are no matching **Entries**, **readIfExists** returns **null** immediately.
- Method **readIfExists** blocks only if the developer specifies a period of time for which the **readIfExists** waits if, at first, the matching **Entry** is a part of an incomplete transaction. If the matching **Entry** is not involved in any transaction, then the **read** operation returns the matching **Entry** immediately.
- Both the **read** and **readIfExists** methods return only one **Entry**. If multiple **Entries** match the template, the **read** operation picks one arbitrarily.
- The **take** operation obtains an **Entry** and removes it from the JavaSpaces service. Methods **take** and **takeIfExists** perform the take operation. Methods **take** and **takeIfExists** are similar to methods **read** and **readIfExists**. The only difference is that the matching **Entry** returned by a **take** or **takeIfExists** operation is removed from the JavaSpaces service.
- The **notify** operation asks the JavaSpaces service to send a notification to a listener when a client writes a matching **Entry** into the JavaSpaces service. Method **notify** takes five parameters—an **Entry** that specifies the matching template, a **Transaction** object, a listener that implements interface **RemoteEventListener** (package **net.jini.core.event**), a **long** value that specifies the lease time for the registration of the listener and a **MarshalledObject** (package **java.rmi**) that the JavaSpaces service will pass to the remote listener as part of a notification.
- Method **snapshot** takes a matching template and returns a specialized representation of the **Entry** (a snapshot **Entry**). This snapshot **Entry** can be used only in the JavaSpaces service that generated it.

## TERMINOLOGY

**abort** method of class **Transaction**  
**commit** method of class **Transaction**  
**Entry** class (**net.jini.core.entry**)  
**JavaSpace** interface (**net.jini.space**)  
JavaSpaces service  
**notify** method of **JavaSpace**  
**outtrigger JavaSpace** implementation  
persistent JavaSpaces service  
**read** method of interface **JavaSpace**  
**readIfExists** method of interface  
  **JavaSpace**  
**RemoteEventListener** interface  
  (**net.jini.core.event**)

**snapshot** method of **JavaSpace**  
**take** method of **JavaSpace**  
**takeIfExists** method of **JavaSpace**  
template matching mechanism  
transaction  
**Transaction.Created** class  
**Transaction.Created.transaction**  
  interface  
**TransactionException** class  
**TransactionManager** service  
transient JavaSpaces service  
**UnusableEntryException** class  
**write** method of **JavaSpace**

## SELF-REVIEW EXERCISES

**23.1** Fill in the blanks in each of the following statements:

- a) The JavaSpaces technology is an \_\_\_\_\_ queue.
- b) Objects placed in the JavaSpaces service must implement the \_\_\_\_\_ interface.
- c) Two methods of the **JavaSpace** interface that read an **Entry** from the JavaSpaces service are \_\_\_\_\_ and \_\_\_\_\_.
- d) Creating a transaction, requires a \_\_\_\_\_.
- e) Method \_\_\_\_\_ can be used to avoid unnecessary serializations of an **Entry**.

**23.2** State whether each of the following is *true* or *false*. If *false*, explain why.

- a) **Entries** may have **private** fields that are used for template matching.
- b) Method **take** can remove all matching **Entries** from the JavaSpaces service.
- c) To modify an **Entry** in a JavaSpaces service, we need to take the **Entry** away from the JavaSpaces service, change the values of the **Entry** and put the **Entry** back to the JavaSpaces service.
- d) Objects stored in a JavaSpaces service cannot have primitive type fields.
- e) When writing an **Entry** to a JavaSpaces service, if the **Entry** already exists, the new **Entry** overwrites the old **Entry**.

## ANSWERS TO SELF-REVIEW EXERCISES

**23.1** a) object-based message-oriented. b) **Entry**. c) **read**, **readIfExists**. d) transaction manager. e) **snapshot**.

**23.2** a) False. The fields in an **Entry** used for template matching must be **public** because the JavaSpaces service needs to access these fields. b) False. If multiple **Entries** match the template, method **take** removes only one. c) True. d) True. e) False. JavaSpaces services can have multiple copies of the same **Entry**. No matter whether an **Entry** exist, the write operation puts the **Entry** into the JavaSpaces service, unless an exception occurs during the write process.

## EXERCISES

**23.3** Describe the difference between method **take** and method **takeIfExists** in the **JavaSpace** interface.

**23.4** Start a JavaSpaces service with a name other than the default name and find this JavaSpaces service with Jini lookup service using a **Name Entry**.

**23.5** In the **WriteOperation** application (Fig. 23.3), the **Entries** written into the JavaSpaces service are kept in the JavaSpaces service for at most 5 minutes. Using **LeaseRenewalManager**, rewrite the application so that the written **Entries** are kept in the JavaSpaces service forever.

**23.6** Write a program that uses method **take** to remove all **Entries** that match a specific template. Compare the speed of running this application with the speed of running the **SnapshotEntry** application.

**23.7** Write a program that uses method **notify** to track all **Entries** written into a JavaSpaces service. Can you tell whether there are any **Entries** that the listener does not track?

**23.8** In our examples, we use class **JavaSpaceFinder** to find a JavaSpaces service and class **TransactionManagerFinder** to find a transaction manager. These two classes are similar. Write a program called **ServiceFinder** that takes the **Class** object (i.e., **JavaSpace.class**) as input and returns the service object (i.e., **JavaSpace** object). Does **ServiceFinder** return the same **JavaSpace** object if you have multiple JavaSpaces services running? If not, how can you fix it so that **ServiceFinder** always returns the JavaSpaces service you wanted. [Hint: set the name

for each JavaSpaces service instance using the **com.sun.jini.outrigger.spaceName** property when running the JavaSpaces service from the commandline. This property will register the corresponding **JavaSpace** stub in the Jini lookup service with the **Name Entry** set to the value specified.

**23.9** Write a program that reads all matching **Entries** from a JavaSpaces service without removing them from the JavaSpaces service.

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3. <[www.javaworld.com/javaworld/jw-11-1999/jw-11-jiniology\\_p.html](http://www.javaworld.com/javaworld/jw-11-1999/jw-11-jiniology_p.html)>.

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# 24

## Java Management Extensions (JMX)

### Objectives

- To understand the JMX technology architecture.
- To understand the design pattern of the standard MBeans.
- To make a resource manageable by defining a management interface for the resource and exposing this interface through MBeans.
- To understand the JMX agent architecture.
- To be able to design and develop management agents to expose MBeans.
- To be able to develop management applications to interact with management agents.

*Imagination is a powerful agent for creating, as it were, a second nature out of the material supplied to it by actual nature.*

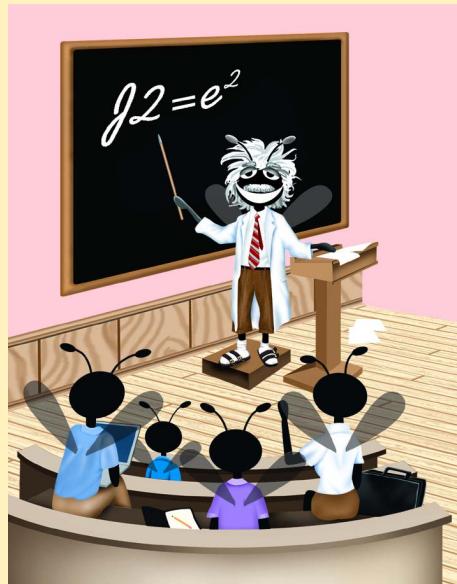
Immanuel Kant

*There's nothing remarkable about it. All one has to do is hit the right keys at the right time and the instrument plays itself.*

Johann Sebastian Bach

*Facts are stupid until brought into connection with some general law.*

Louis Agassiz



## Outline

### 24.1 Introduction

### 24.2 Installation

### 24.3 Case Study

#### 24.3.1 Instrument Resources

#### 24.3.2 Implementation of the JMX Management Agent

#### 24.3.3 Broadcasting and Receiving Notifications

#### 24.3.4 Management Application

#### 24.3.5 Compiling and Running the Example

### 24.4 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Bibliography*

## 24.1 Introduction

Networks play an important role in today's business. Businesses increasingly need networks that provide services which are customized to customer demands, consistently available and easily updated. As more organizations add networks and expand existing networks to increase productivity, network management becomes more difficult. Furthermore, every day more devices are network capable. The proper functionality of printers, network routers and other devices—many of which play an integral role in the productivity of a firm—has increased in importance. As more devices are networked and as networks grow larger, more problems can occur. Existing tools for managing networked devices often use proprietary protocols and management tools. The diversity of such protocols and tools make managing a diverse network difficult.

Another problem that plagues network management is that many existing network management schemes are inflexible and non-automated. This usually means that large amounts of time and resources are spent trying to fix and operate large networks. New technologies are required that will help shift the burden of routine network management issues to the network management software itself and leave special network maintenance issues to the network manager.

Most current network-management solutions distribute management responsibilities among several autonomous programs called *agents*. Typical agents pass information from the network resources to the management application and control the network resources based on commands from the management application. Only the management application makes decisions in the agent-based paradigm. These types of agents—called *static agents*—cannot respond on their own to problems that occur within the network. An *SNMP (Simple Network Management Protocol)* agent is a good example. An SNMP agent is a static agent designed to handle communication between a manageable network device and a management application. For these agent types, all managed resources must be pre-defined during development. This makes extending management applications to manage new resources difficult. Agents, such as the SNMP agents, lack management intelligence, because they do not have the capacity to respond to problems as they occur.

Recent technological advances have provided network management developers with the tools necessary to develop smart agents that are capable of assuming various responsibilities in a network management solution. These technological developments allow agents to incorporate themselves into frameworks in which numerous agents interact with each other and provide a dynamic and extensible network management solution.

The *Java Management Extensions (JMX)*, developed by Sun and network-management industry leaders, define a component framework that enables developers to build automated, intelligent and dynamic network-management solutions. JMX defines a three-level management architecture—*instrumentation level*, *agent level* and *manager level* (Fig. 24.1).<sup>1</sup> The instrumentation level makes any Java-based object manageable. The agent level provides management services that expose the managed resources for management. The manager level allows management application access to managed resources and operates these resources via the JMX agents. In addition, JMX provides support for existing management protocols (such as SNMP) so JMX can integrate itself with existing management solutions.

With these design specifications, JMX provides:

1. platform independence, through of the Java programming language.
2. protocol independence, through support for multiple protocols.
3. reusable code, because managed resources follow **JavaBeans** component guidelines.
4. intelligent agents, because JMX allows agents to respond to resources directly, without having to wait for decisions from a resource manager.
5. scalability, because the agents are deployed in any device that runs a JVM.

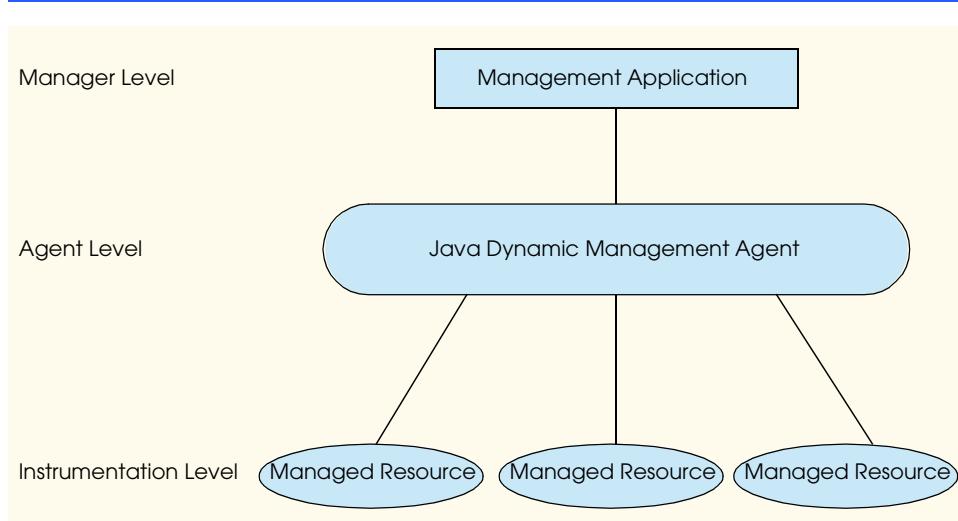


Fig. 24.1 JMX's three-level management architecture.

1. Sun Microsystems, Inc. “JMX Instrumentation and Agent Specification v1.0,” July 2000 <[jcp.org/aboutJava/communityprocess/final/jsr003/index.html](http://jcp.org/aboutJava/communityprocess/final/jsr003/index.html)>

## 24.2 Installation

Many implementations of the JMX standard exist. One such implementation is Sun's *Java Dynamic Management Kit (JDMK)*. JMX provides a standard API for building network management applications, but there are numerous vendors that provide additional features not specified in the JMX standard. Each vendor implementation offers advantages when solving different management problems.

To build dynamic network management solutions using JDMK, you must first download the Java Dynamic Management Kit. The Java Dynamic Management Kit 4.2 evaluation software is available at:

[www.sun.com/software/java-dynamic/try.html](http://www.sun.com/software/java-dynamic/try.html)

The Java Dynamic Management Kit is compatible with Solaris SPARC, Linux, Windows 2000 and Windows NT platforms. To download JDMK for Windows 2000 and Linux, select the link for "Other Platforms." Download the appropriate file for your platform.

The download for Windows 2000 is a zip file. Unzipping the file creates the **SUN-Wjdmk** directory, which contains directories and files needed for developing management solution with JDMK. The files **jdmkrt.jar** and **jdmktk.jar** (located in the **SUN-Wjdmk\jdmk4.2\1.2\lib** directory) must be added to the **CLASSPATH** to compile and execute the examples.

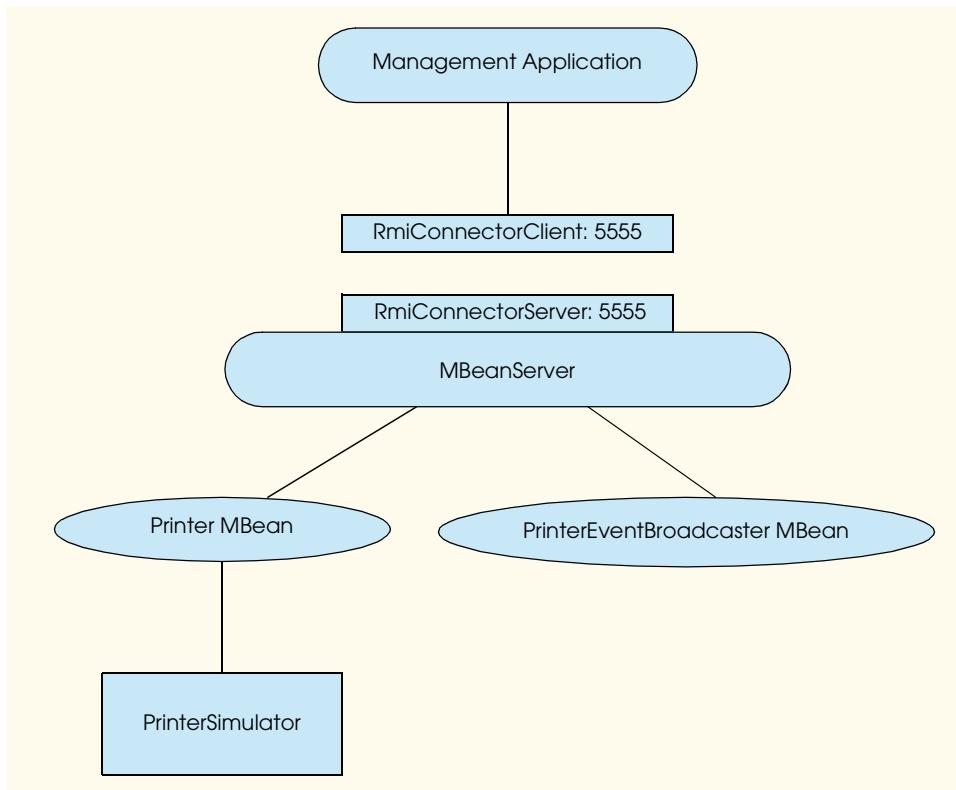
## 24.3 Case Study

In the following sections, we develop a management solution using the Java Dynamic Management Kit. A complete management solution includes managed resources, the management agent and the management application. In this case study, the managed resource is a printer. Not everyone has access to a printer with management capabilities, so we developed a printer simulator. The printer is manageable by instrumenting it as an **MBean**—a manageable JavaBean component. The management application manages the printer through the **MBeanServer**—a registry for **MBeans**. The RMI connector service, provided by the JDMK, makes remote management possible. Figure 24.2 shows the architecture of the management solution.

Section 24.3.1 describes how to make a Java object manageable by exposing the managed resource. Section 24.3.2 demonstrates how to create a JMX management agent with an **MBeanServer** and the RMI connector service provided by JDMK. Section 24.3.3 describes how the management agent receives notifications sent by the managed resource. Section 24.3.4 develops a management application to interact with the management agent. Section 24.3.5 explains how to compile and run the example.

### 24.3.1 Instrument Resources

*Instrumentation* makes resources manageable. Resources can be devices, applications, or any Java-based objects that need to be managed through a management application. Instrumenting a resource exposes the resource's *management interface* so that managers can communicate with the resource. The management interface contains properties that describe the resource and operations for managing the resource.



**Fig. 24.2** Architecture of case study management application.

To instrument a resource, the simplest and fastest way is to write a *standard MBean*. MBeans, also called *Managed Beans*, are Java objects that instrument the resources to be managed.<sup>2</sup> A standard MBean has two parts—an MBean interface and a Java class that implements the MBean interface (called an *MBean class*). A standard MBean must follow *design patterns* defined by the Java Management Extensions to standardize the instrumentation of managed resources. The design patterns for the MBean interface are as follows:

1. The MBean interface name must be composed of the MBean implementation's Java class name followed by the suffix *MBean*.
  2. The MBean interface specifies all *get* and *set* methods that expose the properties of the management interface.
  3. Each property can have at most one *set* method and one *get* method in the management interface.
  4. The MBean interface declares all operations available through the management interface. An operation is a **public** method whose name does not begin with **get**, **is** or **set**. Only **public** methods are exposed.
- 
2. Another type of MBean is a dynamic MBean that only exposes its methods at runtime. Dynamic MBeans allow developers to change MBean behaviors at runtime.

5. Return values and parameters for the *set* and *get* methods must be serializable objects.

The design patterns for the MBean class are as follows:

1. The MBean class must implement its corresponding MBean interface.
2. The MBean class must be **public** and concrete (non-abstract) so that it can be instantiated.
3. The MBean class must have at least one **public** constructor.

Interface **PrinterMBean** (Fig. 24.3) is the MBean interface for our simulated printer. The MBean interface declares printer features that will be manageable. This example exposes only a small number of the printer's manageable resources. The number of manageable resources exposed through the MBean interface relies heavily on the particular management solution being developed. The **PrinterMBean** interface defines three *get* methods whose names begin with **is** (lines 11–17) for **Boolean** properties, four *get* methods whose names begin with **get** (lines 20–29) and one *set* method whose name begins with **set** (line 32). In addition, three operations are defined—replenish the paper tray (line 35), cancel pending print jobs (line 38) and start the printing process (line 41).

```
1 // Fig. 24.3: PrinterMBean.java
2 // This interface specifies the methods that will be implemented
3 // by Printer, which will function as an MBean.
4
5 // deitel package
6 package com.deitel.advjhttp1.jmx.PrinterManagement;
7
8 public interface PrinterMBean {
9
10    // is it printing?
11    public Boolean isPrinting();
12
13    // is it online?
14    public Boolean isOnline();
15
16    // is paper jammed?
17    public Boolean isPaperJam();
18
19    // returns paper amount in tray
20    public Integer getPaperTray();
21
22    // returns ink level in toner cartridge
23    public Integer getToner();
24
25    // returns ID of print job that is currently printing
26    public String getCurrentPrintJob();
27
28    // returns array of all queued up print jobs
29    public String [] getPendingPrintJobs();
30}
```

Fig. 24.3 Defining the **PrinterMBean** interface that exposes the printer's management capabilities (part 1 of 2).

```
31 // sets availability status of printer
32 public void setOnline( Boolean online );
33
34 // fills up paper tray again with paper
35 public void replenishPaperTray();
36
37 // cancel pending print jobs
38 public void cancelPendingPrintJobs();
39
40 // start printing process
41 public void startPrinting();
42 }
```

Fig. 24.3 Defining the **PrinterMBean** interface that exposes the printer's management capabilities (part 2 of 2).

Interface **PrinterEventListener** (Fig. 24.4) defines the methods a printer-event listener must implement. The interface defines three events—out of paper, low toner and paper jam.

Class **Printer** (Fig. 24.5) is the implementation of interface **PrinterMBean**. It shows how to implement and instrument this particular MBean.

```
1 // Fig. 24.4: PrinterEventListener.java
2 // The listener interface for printer events.
3
4 // deitel package
5 package com.deitel.advjhttp1.jmx.Printer;
6
7 public interface PrinterEventListener {
8
9     public void outOfPaper();
10
11    public void lowToner();
12
13    public void paperJam();
14 }
```

Fig. 24.4 Defining an event listener for the printer to handle out-of-paper, low-toner, and paper-jam events.

```
1 // Fig. 24.5: Printer.java
2 // This class provides implementation for interface PrinterMBean
3 // and registers a managing MBean for the Printer device,
4 // which is simulated by PrinterSimulator.java.
5
6 // deitel package
7 package com.deitel.advjhttp1.jmx.PrinterManagement;
8
9 // Java core package
10 import java.lang.Thread;
```

Fig. 24.5 **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 1 of 7).

```
11 import java.util.ArrayList;
12
13 // JMX core packages
14 import javax.management.*;
15
16 // Deitel packages
17 import com.deitel.advjhttp1.jmx.Printer.*;
18
19 public class Printer implements PrinterMBean,
20     PrinterEventListener {
21
22     private PrinterSimulator printerSimulator;
23     private static final int PAPER_STACK_SIZE = 50;
24     private ObjectInstance eventBroadcasterInstance;
25     private ObjectName eventBroadcasterName;
26     private ObjectName printerName;
27     private MBeanServer mBeanServer;
28
29     public Printer()
30     {
31         // connect to the printer device
32         printerSimulator = new PrinterSimulator( this );
33         Thread myThread = new Thread( printerSimulator );
34         myThread.start();
35
36         // find all MBean servers in current JVM
37         ArrayList arrayList =
38             MBeanServerFactory.findMBeanServer( null );
39
40         // retrieve the MBeanServer reference
41         if ( arrayList.size() == 0 )
42             System.out.println( "Cannot find a MBeanServer!" );
43
44     else {
45
46         // get the MBeanServer that has the
47         // PrinterEventBroadcaster MBean registered with it
48         for ( int i = 0; i < arrayList.size(); i++ ) {
49             MBeanServer foundMBeanServer =
50                 ( MBeanServer ) arrayList.get( i );
51
52             // obtain the object name for the
53             // PrinterEventBroadcaster MBean
54             try {
55                 String name = foundMBeanServer.getDefaultDomain()
56                     + ":type=" + "PrinterEventBroadcaster";
57                 eventBroadcasterName = new ObjectName( name );
58             }
59         }
```

Fig. 24.5 **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 2 of 7).

```
60          // handle exception when creating ObjectName
61      catch ( MalformedObjectNameException exception ) {
62          exception.printStackTrace();
63      }
64
65          // check whether the PrinterEventBroadcaster MBean is
66          // registered with this MBeanServer
67      if ( foundMBeanServer.isRegistered(
68          eventBroadcasterName ) ) {
69          mBeanServer = foundMBeanServer;
70          break;
71      }
72
73  } // end for loop
74
75 } // end if-else to get the MBeanServer reference
76
77 } // end PrinterSimulator constructor
78
79 // will stop the printer thread from executing
80 // once execution should stop.
81 public void stop()
82 {
83     printerSimulator.stop();
84 }
85
86 // Is it printing?
87 public Boolean isPrinting()
88 {
89     return new Boolean( printerSimulator.isPrinting() );
90 }
91
92 // is online?
93 public Boolean isOnline()
94 {
95     return printerSimulator.isOnline();
96 }
97
98 // is paper jammed?
99 public Boolean isPaperJam()
100 {
101     return printerSimulator.isPaperJam();
102 }
103
104 // is paper tray empty?
105 public Integer getPaperTray()
106 {
107     return printerSimulator.getPaperTray();
108 }
109
```

Fig. 24.5 **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 3 of 7).

```
110 // is toner low?
111 public Integer getToner()
112 {
113     return printerSimulator.getToner();
114 }
115
116 // returns ID of print job that is currently printing
117 public String getCurrentPrintJob()
118 {
119     return printerSimulator.getCurrentPrintJob();
120 }
121
122 // returns array of all queued up print jobs
123 public String[] getPendingPrintJobs()
124 {
125     return printerSimulator.getPendingPrintJobs();
126 }
127
128 // sets status availability of printer
129 public void setOnline( Boolean online )
130 {
131     if ( online.booleanValue() == true )
132         printerSimulator.setOnline();
133     else
134         printerSimulator.setOffline();
135 }
136
137 // fills up the paper tray again with paper.
138 public void replenishPaperTray()
139 {
140     printerSimulator.replenishPaperTray (
141         Printer.PAPER_STACK_SIZE );
142 }
143
144 // cancel pending print jobs
145 public void cancelPendingPrintJobs()
146 {
147     printerSimulator.cancelPendingPrintJobs();
148 }
149
150 // start the printing process
151 public void startPrinting()
152 {
153     printerSimulator.startPrintingProcess();
154 }
155
156 // send out of paper event to JMX layer
157 protected void fireOutOfPaperEvent()
158 {
159     // construct parameters and signatures
160     Object[] parameter = new Object[ 1 ];
```

Fig. 24.5 **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 4 of 7).

```
161     parameter[ 0 ] = new Notification(
162         "PrinterEvent.OUT_OF_PAPER", this, 0L );
163     String[] signature = new String[ 1 ];
164     signature[ 0 ] = "javax.management.Notification";
165
166     // invoke notification
167     try {
168         mBeanServer.invoke( eventBroadcasterName,
169             "sendNotification", parameter, signature );
170     }
171
172     // handle exception when invoking method
173     catch ( ReflectionException exception ) {
174         exception.printStackTrace();
175     }
176
177     // handle exception when communicating with MBean
178     catch ( MBeanException exception ) {
179         exception.printStackTrace();
180     }
181
182     // handle exception if MBean not found
183     catch ( InstanceNotFoundException exception ) {
184         exception.printStackTrace();
185     }
186
187 } // end method outOfPaperEvent
188
189 // send low toner event to JMX layer
190 protected void fireLowTonerEvent()
191 {
192     // construct parameters and signatures
193     Object[] parameter = new Object[ 1 ];
194     parameter[ 0 ] = new Notification(
195         "PrinterEvent.LOW_TONER", this, 0L );
196     String[] signature = new String[ 1 ];
197     signature[ 0 ] = "javax.management.Notification";
198
199     // invoke notification
200     try {
201         mBeanServer.invoke( eventBroadcasterName,
202             "sendNotification", parameter, signature );
203     }
204
205     // handle exception when invoking method
206     catch ( ReflectionException exception ) {
207         exception.printStackTrace();
208     }
209 }
```

Fig. 24.5 **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 5 of 7).

```
210     // handle exception communicating with MBean
211     catch ( MBeanException exception ) {
212         exception.printStackTrace();
213     }
214
215     // handle exception if MBean not found
216     catch ( InstanceNotFoundException exception ) {
217         exception.printStackTrace();
218     }
219
220 } // end method lowTonerEvent
221
222 // send paper jam event to JMX layer
223 protected void firePaperJamEvent()
224 {
225     // construct parameters and signatures
226     Object[] parameter = new Object[ 1 ];
227     parameter[ 0 ] = new Notification(
228         "PrinterEvent.PAPER_JAM", this, 0L );
229     String[] signature = new String[ 1 ];
230     signature[ 0 ] = "javax.management.Notification";
231
232     // invoke notification
233     try {
234         mBeanServer.invoke( eventBroadcasterName,
235             "sendNotification", parameter, signature );
236     }
237
238     // handle exception when invoking method
239     catch ( ReflectionException exception ) {
240         exception.printStackTrace();
241     }
242
243     // handle exception communicating with MBean
244     catch ( MBeanException exception ) {
245         exception.printStackTrace();
246     }
247
248     // handle exception if MBean not found
249     catch ( InstanceNotFoundException exception ) {
250         exception.printStackTrace();
251     }
252
253 } // end method paperJamEvent
254
255 // interface implementation
256 public void outOfPaper()
257 {
258     // delegate call
259     fireOutOfPaperEvent();
260 }
261
```

Fig. 24.5 **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 6 of 7).

```

262     // interface implementation
263     public void lowToner()
264     {
265         // delegate call
266         fireLowTonerEvent();
267     }
268
269     // interface implementation
270     public void paperJam()
271     {
272         // delegate call
273         firePaperJamEvent();
274     }
275 }
```

**Fig. 24.5** **Printer** MBean implementation class that represents the management contact point for all applications wishing to manage the printer (part 7 of 7).

In the **Printer** constructor, a **Printer** first connects to a printer device (lines 32–34). Typically, when managing networked resources, a connection must be established to the networked device. Because the managed resource in our example exists in the same machine as a printer simulator, we do not include the code that would establish a network connection with the printer resource. Lines 36–38 find all MBean servers in the current JVM. Method **findMBeanServer** of class **MBeanServerFactory** (package **javax.management**) provides a way to find references to MBean servers that have been instantiated in the current JVM. Method **findMBeanServer** takes one argument—a **String** that specifies the agent of the MBean server. If **null** is passed to method **findMBeanServer**, it returns all MBean servers in the JVM.

Lines 48–73 retrieve the **MBeanServer** reference that has the **PrinterEventBroadcaster** (discussed in Fig. 24.10) MBean registered with it. An **ObjectName** uniquely identifies an MBean in the MBean server. Lines 55–57 define the **ObjectName** for the **PrinterEventBroadcaster** MBean. The **ObjectName** constructor takes one argument—an arbitrary **String** that uniquely identifies the MBean within the **MbeanServer** instance. The input string must follow the format *domainName*: followed by a list of one or more *property=value* pairs separated by commas.<sup>3</sup>

The *domainName* is any **String** that describes a location to which one or more MBeans may belong. This helps organize MBeans into different categories. For example, a *domainName* may be anything, such as "**MyBuilding**", "**Boston**", "**College-Printers**", etc... These categories can be defined such that all managed devices of a specific type on the same network are included in the same *domainName* or such that all networked devices in a particular area are grouped together. MBeans with different *domainNames* may register with the same MBean server. JMX provides an MBean pattern matching mechanism that allows users to single out MBeans that match specific *domainNames* or other search criteria. The pattern matching mechanism requires that \* represents zero or more characters, ? represents one or more characters and any other characters appearing in the string are matched literally.

3. The **String** may contain any characters except \* ? , : =

When categorizing MBeans is not of great importance, a default *domainName* can be used. This *domainName* can be obtained from method **getDefaulDomain** of interface **MBeanServer**. Lines 67–68 check whether the **PrinterEventBroadcaster** MBean is registered with the retrieved **MBeanServer**. If so, the loop terminates.

Lines 86–102 implement the “**is**” getter methods defined in the **PrinterMBean** interface. Lines 104–126 implement the “**get**” getter methods defined in the MBean interface. Lines 128–135 implement the setter method defined in the MBean interface. Lines 137–154 implement the operations defined in the MBean interface. Each of the operations interacts with the printer simulator in Fig. 24.6.

Lines 156–253 handle delegated calls from the method implementations of interface **PrinterEventListener** (lines 255–274). Three events could happen to the printer—the out-of-paper event, the low-toner event and the paper-jam event. Lines 168–169 propagate the out-of-paper event to the management agent, lines 201–202 propagate the low-toner event to the management agent and lines 234–235 propagate the paper-jam event to the management agent. In each case, the notification of the event occurs by invoking the method **sendNotification** of **PrinterEventBroadcaster** MBean. The **MBeanServer**’s method **invoke** performs this invocation. Method **invoke** takes four arguments—an **ObjectName** that specifies the MBean on which the method is invoked (**PrinterEventBroadcaster** MBean), a **String** that specifies the method to be invoked (“**sendNotification**”), an array of **Objects** that indicates the parameters to be set when the method is invoked and an array of **Strings** that indicates the signature of the operation. Method **invoke** throws three exceptions—**ReflectionException**, **MbeanException** and **InstanceNotFoundException**.

Class **PrinterSimulator** (Fig. 24.6) mimics the printer device to which **Printer** (Fig. 24.5) connects.

```
1 // Fig. 24.6: PrinterSimulator.java
2 // This class simulates a printer device on a network.
3
4 // deitel package
5 package com.deitel.advjhtp1.jmx.Printer;
6
7 // java core package
8 import java.util.Stack;
9
10 public class PrinterSimulator implements Runnable {
11
12     private Stack printerStack = new Stack();
13     private boolean isOnline = true;
14     private boolean isPrinting = false;
15     private boolean isPaperJam = false;
16
17     // 50 sheets of paper in tray
18     private Integer paperInTray = new Integer( 50 );
19
20     // 100% full of ink
21     private Integer tonerCartridge = new Integer( 100 );
22 }
```

Fig. 24.6 Printer simulation class capable of triggering three events (part 1 of 6).

```
23     private String currentPrintJob;
24     private boolean isAlive = true;
25     private PrinterEventListener eventListener;
26
27     // default public constructor
28     public PrinterSimulator(
29         PrinterEventListener listener )
30     {
31         eventListener = listener;
32     }
33
34     // stops execution of thread
35     public void stop()
36     {
37         isAlive = false;
38     }
39
40     // main life-cycle of the printer.
41     // prints one job from print job stack
42     // 1) if offline, it pauses and waits.
43     // 2) if online, handles one print job
44     public void run()
45     {
46         // main loop within thread
47         while ( isAlive ) {
48
49             // pause if offline
50             if ( !isOnline ) {
51                 synchronized ( this ) {
52
53                     // waits for printer become online
54                     try {
55                         wait();
56                     }
57
58                     // if interrupt occurs
59                     catch ( InterruptedException exception ) {
60                         exception.printStackTrace();
61                         System.exit( -1 );
62                     }
63
64                 } // end synchronized
65
66             } // end if
67
68             // prints one job from print job stack
69             startPrintingProcess();
70
71         } // end while
72     }
73 }
```

Fig. 24.6 Printer simulation class capable of triggering three events (part 2 of 6).

```
74     public void startPrintingProcess()
75     {
76         // warm up the printer, print top print job from print
77         // stack and adjust paper values and toner values
78         try {
79             // warm up printer for incoming batch of print jobs
80             Thread.sleep( 1000 * 5 );
81
82             if ( ( paperInTray.intValue() > 0 ) &&
83                 ( tonerCartridge.intValue() > 10 ) &&
84                 ( !isPaperJam ) ) {
85
86                 // start the printing process
87                 currentPrintJob = getNextPrintJob();
88                 isPrinting = true;
89
90                 // 12 seconds to print a normal document
91                 Thread.sleep( 1000 * 12 );
92
93                 // each print job uses 10 pages
94                 updatePaperInTray( paperInTray.intValue() - 10 );
95                 updateToner();
96                 updatePaperJam();
97                 isPrinting = false;
98
99                 // make sure no references are left dangling
100                currentPrintJob = null;
101            }
102        }
103
104        // if interrupt occurs
105        catch ( InterruptedException exception ) {
106            exception.printStackTrace();
107            System.exit( -1 );
108        }
109    } // end method startPrintingProcess
110
111    // returns current printed job
112    public String getCurrentPrintJob()
113    {
114        return currentPrintJob;
115    }
116
117
118    // is printer online?
119    public Boolean isOnline()
120    {
121        return new Boolean ( isOnline );
122    }
123
```

Fig. 24.6 Printer simulation class capable of triggering three events (part 3 of 6).

```
124 // update amount of paper in paper tray
125 public synchronized void updatePaperInTray( int newValue )
126 {
127     paperInTray = new Integer ( newValue );
128
129     // fire event if paper tray low
130     if ( paperInTray.intValue() <= 0 ) {
131         eventListener.outOfPaper();
132     }
133 }
134
135 // is paper jammed?
136 public Boolean isPaperJam()
137 {
138     return new Boolean( isPaperJam );
139 }
140
141 // cancel pending print jobs
142 public void cancelPendingPrintJobs()
143 {
144     synchronized ( printerStack ) {
145         printerStack.clear();
146     }
147 }
148
149 // update amount of toner available in toner cartridge
150 public synchronized void updateToner()
151 {
152     // after every print job, toner levels drop 1%
153     tonerCartridge = new Integer (
154         tonerCartridge.intValue() - 1 );
155
156     // fire event if toner is low
157     if ( tonerCartridge.intValue() <= 10 ) {
158         eventListener.lowToner();
159     }
160 }
161
162 public synchronized void updatePaperJam()
163 {
164     if ( Math.random() > 0.9 ) {
165         isPaperJam = true;
166         eventListener.paperJam();
167     }
168 }
169
170 // returns number of pages in paper tray
171 public synchronized Integer getPaperTray()
172 {
173     return paperInTray;
174 }
175
```

Fig. 24.6 Printer simulation class capable of triggering three events (part 4 of 6).

```
176     // returns amount of toner in toner cartridge
177     public synchronized Integer getToner()
178     {
179         return tonerCartridge;
180     }
181
182     // generates a random number of print jobs with varying IDs
183     public void populatePrintStack()
184     {
185         int numOfJobs = ( int ) ( Math.random ( ) * 10 ) + 1;
186
187         // generate print jobs
188         synchronized ( printerStack ) {
189             for ( int i = 0 ; i < numOfJobs ; i++ ) {
190                 printerStack.add ( "PRINT_JOB_ID #" + i );
191             }
192         }
193     }
194
195     // returns next print job in stack, populating the stack
196     // if it is empty
197     public String getNextPrintJob()
198     {
199         if ( printerStack.isEmpty() ) {
200             populatePrintStack ( );
201
202             // simulates absence of print jobs
203             try {
204                 Thread.sleep (
205                     ( int ) ( Math.random() * 1000 * 10 ) );
206             }
207
208             // if interrupt occurs
209             catch ( InterruptedException exception ) {
210                 exception.printStackTrace ( );
211                 System.exit ( -1 ) ;
212             }
213         }
214
215         // Remove topmost queued resource.
216         String printJob;
217
218         synchronized ( printerStack ) {
219             printJob = ( String ) printerStack.pop();
220         }
221
222         return printJob;
223     }
224 } // end method getNextPrintJob
225
```

Fig. 24.6 Printer simulation class capable of triggering three events (part 5 of 6).

```
226     // returns all jobs yet to be printed
227     public String[] getPendingPrintJobs()
228     {
229         String[] pendingPrintJobs;
230
231         // create array of pending print jobs
232         synchronized ( printerStack ) {
233             Object[] temp = printerStack.toArray() ;
234             pendingPrintJobs = new String[ temp.length ] ;
235
236             for ( int i = 0 ; i < pendingPrintJobs.length ; i++ ) {
237                 pendingPrintJobs [ i ] = ( String )temp[ i ];
238             }
239         }
240
241         return pendingPrintJobs;
242     }
243
244     // sets printer status to online
245     public void setOnline()
246     {
247
248         isOnline = true;
249
250         // notify all waiting states
251         synchronized ( this ) {
252             notifyAll() ;
253         }
254     }
255
256     // sets printer status to offline
257     public void setOffline()
258     {
259         isOnline = false;
260     }
261
262     // replenishes amount of paper in paper tray to specified
263     // value
264     public void replenishPaperTray ( int paperStack )
265     {
266         updatePaperInTray( paperStack ) ;
267     }
268
269     // is printer printing?
270     public boolean isPrinting()
271     {
272         return isPrinting;
273     }
274 }
```

Fig. 24.6 Printer simulation class capable of triggering three events (part 6 of 6).

The **PrinterSimulator** constructor (lines 28–32) takes as an argument the **PrinterEventListener** to which **PrinterSimulator** should send events. In this example, **PrinterEventListener** will be the gateway through which **Printer-**

**Simulator** communicates events to the **Printer** MBean. As mentioned before, real scenarios would make use of other communication protocols, such as SNMP or HTTP, to facilitate communications between the managed resource on the network and the corresponding MBean. Method **stop** (lines 35–38) sets the printer off-line.

Method **run** (lines 44–72) defines the life-cycle of **PrinterSimulator**, which will be associated with a **Thread** object in the simulation. If the printer is online, **run** calls method **startPrintingProcess** (lines 74–110) to mimic the printer functionality.

Method **startPrintingProcess** takes five seconds to warm up the printer. If the paper tray is not empty, toner is not low and no paper is jammed, the printer starts printing the next print job. Line 91 assumes each print job takes twelve seconds. Lines 94–96 call methods to reset the properties of the printer.

Method **getCurrentPrintJob** (lines 113–116) returns the current print job. Method **isOnline** (lines 119–122) returns **true** if the printer is online. Method **updatePaperTray** (lines 125–133) updates the amount of paper in the paper tray. If no paper is available in the paper tray, it fires an out-of-paper event. Method **isPaperJam** (lines 136–139) returns **true** if the paper is jammed. Method **cancelPendingPrintJobs** (lines 142–147) removes pending print jobs.

Method **updateToner** (lines 150–160) updates the amount of toner available in the toner cartridge. If the toner is low, it fires a low-toner event. Method **updatePaperJam** (lines 162–168) fires a paper-jam event if the paper is jammed.

Method **getPaperTray** (lines 171–174) returns the number of pages in the paper tray. Method **getToner** (lines 177–180) returns the toner level of the printer. Method **populatePrintStack** (lines 183–193) generates print jobs. Method **getNextPrintJob** (lines 197–224) returns the next print job and generates new print jobs if the print job stack is empty. Method **getPendingPrintJobs** (lines 227–243) returns a list of print jobs to be printed. Method **setOnline** (lines 246–254) sets the printer status to online. Method **setOffline** (lines 257–260) sets the printer status to offline. Method **replenishPaperTray** (lines 264–267) fills the paper tray with the specified amount of paper. Method **isPrinting** (lines 270–273) returns **true** if the printer is printing.

### 24.3.2 Implementation of the JMX Management Agent

The JMX management agent acts as a bridge between the MBeans and the management application. A JMX agent typically contains an MBean server, a set of MBeans that represent the managed resources and at least one *protocol adaptor* or *connector*—MBeans that allow remote management applications to access the **MBeanServer**. An **MBeanServer** instance behaves as a registry for all MBeans. The MBeans representing the manageable resources are controlled by the management application through the MBean server. Figure 24.7 shows the JMX Agent Architecture.

MBeans represent the managed resources or management services; they are registered with the MBean server. The protocol adaptor or connector provides a gateway that allows remote applications to interact with the MBean server's registered MBeans. Because connectors are MBeans and all MBeans can interact with each other through the MBean server, the JMX Agent Architecture allows either local or remote management applications access to MBean properties and **public** operations. Local management applications can manipulate MBeans directly through the MBean server; remote management applications can manipulate MBeans indirectly through connector or adapter MBeans.

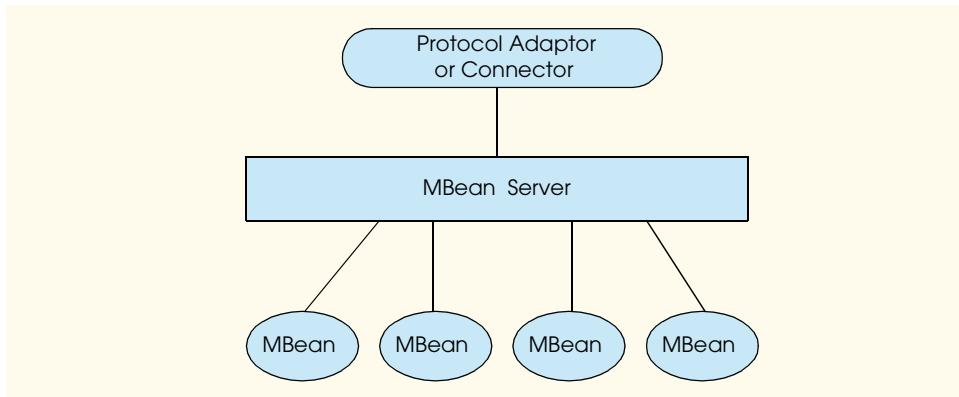


Fig. 24.7 JMX Agent Architecture.

Application **PrinterManagementAgent** (Fig. 24.8) is a JMX management agent. **PrinterManagementAgent** creates an **MBeanServer** and starts an RMI connector MBean service to act as a connector, starts a **PrinterEventBroadcaster** MBean that broadcasts notifications sent by the printer and starts a **Printer** MBean that is the communication bridge between the **PrinterSimulator** and the MBean server. Method **createMBeanServer** of class **MBeanServerFactory** creates a new MBean server. Lines 21–22 create an MBean server with a default domain name provided by the **MBeanServerFactory**. Lines 29–30 create an **RMICConnectorServer** by calling method **createMBean** of interface **MBeanServer**. Method **createMBean** of interface **MBeanServer** takes two arguments—a **String** that specifies the class name to be instantiated and an **ObjectName** object that specifies the name of the MBean. Method **createMBean** returns an **ObjectInstance** that represents the MBean. The string that specifies the class name cannot be **null**. If **ObjectName** is **null**, the **RMICConnectorServer** MBean—the MBean responsible for handling remote RMI connections—can provide the object name automatically. Lines 33–40 instantiate and register a **PrinterEventBroadcaster** MBean in the MBean server. Lines 43–50 instantiate and register the **Printer** MBean in the MBean server. Lines 55–77 catch the exceptions that may occur when creating the MBean and defining the object names of the MBeans. Lines 88–90 invoke method **setPort** of the **RMICConnectorServer** MBean to set the RMI connector's port number to **5555**. Lines 91–93 invoke method **start** of the **RMICConnectorServer** MBean to start the connector. Lines 97–109 catch the exceptions that may occur when invoking the methods of the MBean.

```
1 // Fig. 24.8: PrinterManagementAgent.java
2 // This application creates an MBeanServer and starts an RMI
3 // connector MBean service.
4
5 // deitel package
6 package com.deitel.advjhttp1.jmx.PrinterManagement;
7
```

Fig. 24.8 Creating and starting a management agent (part 1 of 3).

```
8 // JMX core packages
9 import javax.management.*;
10
11 public class PrinterManagementAgent {
12
13     public static void main( String[] args )
14     {
15         ObjectInstance rmiConnectorServer = null;
16         ObjectInstance printer = null;
17         ObjectInstance broadcaster = null;
18         ObjectName objectName = null;
19
20         // create an MBeanServer
21         MBeanServer server =
22             MBeanServerFactory.createMBeanServer();
23
24         // create an RMI connector service, a printer simulator
25         // MBean and a broadcaster MBean
26         try {
27
28             // create an RMI connector server
29             rmiConnectorServer = server.createMBean(
30                 "com.sun.jdmk.comm.RmiConnectorServer", null );
31
32             // create a broadcaster MBean
33             String name = server.getDefaultDomain()
34                 + ":type=" + "PrinterEventBroadcaster";
35             String className = "com.deitel.advjhtp1.jmx."
36                 + "PrinterManagement.PrinterEventBroadcaster";
37
38             objectName = new ObjectName( name );
39             printer = server.createMBean(
40                 className, objectName );
41
42             // create a printer simulator MBean
43             name = server.getDefaultDomain()
44                 + ":type=" + "Printer";
45             className = "com.deitel.advjhtp1.jmx."
46                 + "PrinterManagement.Printer";
47
48             objectName = new ObjectName( name );
49             broadcaster = server.createMBean(
50                 className, objectName );
51
52         } // end try
53
54         // handle class not JMX-compliant MBean exception
55         catch ( NotCompliantMBeanException exception ) {
56             exception.printStackTrace();
57         }
58
59         // handle MBean constructor exception
60         catch ( MBeanException exception ) {
```

Fig. 24.8 Creating and starting a management agent (part 2 of 3).

```
61         exception.printStackTrace();
62     }
63
64     // handle MBean already exists exception
65     catch ( InstanceAlreadyExistsException exception ) {
66         exception.printStackTrace();
67     }
68
69     // handle MBean constructor exception
70     catch ( ReflectionException exception ) {
71         exception.printStackTrace();
72     }
73
74     // handle invalid object name exception
75     catch ( MalformedObjectNameException exception) {
76         exception.printStackTrace();
77     }
78
79     // set port number
80     Object[] parameter = new Object[ 1 ];
81     parameter[ 0 ] = new Integer( 5555 );
82     String[] signature = new String[ 1 ];
83     signature[ 0 ] = "int";
84
85     // invoke method setPort on RmiConnectorServer MBean
86     // start the RMI connector service
87     try {
88         server.invoke(
89             rmiConnectorServer.getObjectName(), "setPort",
90             parameter, signature );
91         server.invoke(
92             rmiConnectorServer.getObjectName(), "start",
93             new Object[ 0 ], new String[ 0 ] );
94     }
95
96     // handle exception when executing method
97     catch ( ReflectionException exception ) {
98         exception.printStackTrace();
99     }
100
101    // handle exception communicating with MBean
102    catch ( MBeanException exception ) {
103        exception.printStackTrace();
104    }
105
106    // handle exception if MBean not found
107    catch ( InstanceNotFoundException exception ) {
108        exception.printStackTrace();
109    }
110
111 } // end method main
112 }
```

Fig. 24.8 Creating and starting a management agent (part 3 of 3).

### 24.3.3 Broadcasting and Receiving Notifications

This section explains how the managed resources or devices broadcast notifications via a *notification broadcaster* MBean and how the remote management application receives notifications sent by a notification broadcaster MBean. A notification broadcaster is an MBean that defines one or more event types. It has the ability to broadcast events to all registered listeners as the events are received from the managed resources. The notification broadcaster MBean must implement the **NotificationBroadcaster** interface to declare itself as a source of notifications. To receive notifications, the management application needs to contact the notification broadcasters of the manageable resource MBeans. In our case, the manageable resource is the **Printer** MBean, and the notification broadcaster is the **PrinterEventBroadcaster** MBean that is registered with the MBean server instantiated in the **PrinterManagementAgent** class (Fig. 24.8).

Interface **PrinterEventBroadcasterMBean** (Fig. 24.9) is an interface for the notification broadcaster MBean of the printer. This interface defines a single operation—**sendNotification**. The broadcaster is also an MBean, so we need this interface to successfully register it as a standard MBean in the **MBeanServer** instance.

Class **PrinterEventBroadcaster** (Fig. 24.10) is a standard MBean that implements the **PrinterEventBroadcasterMBean** interface. **PrinterEventBroadcaster** sends notifications of printer events to registered listeners. It extends the functionality of the **javax.management.NotificationBroadcasterSupport** class (line 15), which provides services such as listener registration. Lines 18–23 define three notification types. **PrinterEventBroadcaster** overrides method **getNotificationInfo** to return an array of **MBeanNotificationInfo** objects (package **javax.management**) containing the notification class name and the notification types sent. Lines 33–39 specify an array of **Strings** containing the notification types. Line 42 specifies the class name of the notifications. Lines 45–46 create a **String** that describes the notifications that **PrinterEventBroadcaster** MBean can broadcast. The **MBeanNotificationInfo** constructor (lines 49–50) takes three arguments—an array of **Strings** that specifies the notification types, a **String** that indicates the class name of the notifications and a **String** containing the notifications' description. Line 52 returns the **MBeanNotificationInfo** array.

```
1 // Fig. 24.9: PrinterEventBroadcasterMBean.java
2 // This class defines the MBean interface.
3
4 // deitel package
5 package com.deitel.advjhtp1.jmx.PrinterManagement;
6
7 // JMX core packages
8 import javax.management.Notification;
9
10 public interface PrinterEventBroadcasterMBean {
11
12     public void sendNotification( Notification notification );
13 }
```

Fig. 24.9 Notification broadcaster MBean interface.

Class **PrinterEventHandler** (Fig. 24.11) receives event notifications from the broadcaster MBean. Lines 24–53 define an anonymous inner class implementing the notification listener interface (**javax.management.NotificationListener**). The implementation of method **handleNotification** (lines 26–51) handles incoming events. Lines 33–37 handle the out-of-paper event. Lines 39–43 handle the low-toner event. Lines 45–49 handle the paper-jam event. Line 64 of the **PrinterEventHandler** constructor (lines 56–86) sets the notification forwarding mode to **ClientNotificationHandler.PUSH\_MODE** (package **com.sun.jdmk.comm**). In push mode, as soon as the RMI connector server receives a notification, it forwards the notification to the RMI connector client. Lines 68–73 add a notification listener to the broadcaster MBean. Lines 68–70 specify the object name of the broadcaster MBean. Method **addNotificationListener** (lines 72–73) takes four arguments—an **ObjectName** that specifies the name of the broadcaster MBean on which the notification listener will be registered, a **NotificationListener** that handles the notifications sent by the broadcaster MBean, a class that implements interface **NotificationFilter** to filter the notification and an **Object** that contains the context to be sent to the listener. In our example, the **NotificationListener** (specified in lines 24–53) is registered with the **PrinterEventBroadcaster** MBean that is connected to the MBean server. Lines 76–84 catch the exceptions that may occur when adding the listener. Method **handleOutOfPaperEvent** (lines 89–92) delegates the out-of-paper event. Method **handleLowTonerEvent** (lines 95–98) delegates the low-toner event. Method **handlePaperJamEvent** (lines 101–104) delegates the paper-jam event.

```
1 // Fig. 24.10: PrinterEventBroadcaster.java
2 // This class defines an MBean that
3 // provides events information.
4
5 // deitel package
6 package com.deitel.advjhttp1.jmx.PrinterManagement;
7
8 // JMX core packages
9 import javax.management.MBeanNotificationInfo;
10 import javax.management.NotificationBroadcasterSupport;
11
12 // extends NotificationBroadcasterSupport to adopt its
13 // functionality.
14 public class PrinterEventBroadcaster
15     extends NotificationBroadcasterSupport
16     implements PrinterEventBroadcasterMBean {
17
18     private static final String OUT_OF_PAPER =
19         "PrinterEvent.OUT_OF_PAPER";
20     private static final String LOW_TONER =
21         "PrinterEvent.LOW_TONER";
22     private static final String PAPER_JAM =
23         "PrinterEvent.PAPER_JAM";
24 }
```

Fig. 24.10 Notification broadcaster MBean implementation that broadcasts events generated by the printer (part 1 of 2).

```

25     // provide information about deliverable events
26     public MBeanNotificationInfo[] getNotificationInfo()
27     {
28         // array containing descriptor objects
29         MBeanNotificationInfo[] descriptorArray =
30             new MBeanNotificationInfo[ 1 ];
31
32         // different event types
33         String[] notificationTypes = new String[ 3 ];
34         notificationTypes[ 0 ] =
35             PrinterEventBroadcaster.OUT_OF_PAPER;
36         notificationTypes[ 1 ] =
37             PrinterEventBroadcaster.LOW_TONER;
38         notificationTypes[ 2 ] =
39             PrinterEventBroadcaster.PAPER_JAM;
40
41         // notification class type
42         String classType = "javax.management.Notification";
43
44         // description of MBeanNotificationInfo
45         String description =
46             "Notification types for PrinterEventBroadcaster";
47
48         // populate descriptor array
49         descriptorArray[ 0 ] = new MBeanNotificationInfo(
50             notificationTypes, classType, description );
51
52         return descriptorArray;
53
54     } // end method getNotificationInfo
55 }

```

**Fig. 24.10** Notification broadcaster MBean implementation that broadcasts events generated by the printer (part 2 of 2).

```

1 // Fig. 24.11: PrinterEventHandler.java
2 // The class adds a listener to the broadcaster MBean and
3 // defines the event handlers when event occurs.
4
5 // deitel package
6 package com.deitel.advjhttp1.jmx.Client;
7
8 // JMX core packages
9 import javax.management.*;
10
11 // JDMK core packages
12 import com.sun.jdmk.comm.RmiConnectorClient;
13 import com.sun.jdmk.comm.ClientNotificationHandler;
14
15 // Deitel packages
16 import com.deitel.advjhttp1.jmx.Printer.*;

```

**Fig. 24.11** Receiving event notifications from the MBean server and handling the printer-specific events (part 1 of 3).

```
17 public class PrinterEventHandler {
18
19     private RmiConnectorClient rmiClient;
20     private PrinterEventListener eventTarget;
21
22
23     // notification listener anonymous inner class
24     private NotificationListener notificationListener =
25         new NotificationListener() {
26         public void handleNotification(
27             Notification notification, Object handback )
28         {
29             // retrieve notification type
30             String notificationType = notification.getType();
31
32             // handle different notifications
33             if ( notificationType.equals(
34                 "PrinterEvent.OUT_OF_PAPER" ) ) {
35                 handleOutOfPaperEvent();
36                 return;
37             }
38
39             if ( notificationType.equals(
40                 "PrinterEvent.LOW_TONER" ) ) {
41                 handleLowTonerEvent();
42                 return;
43             }
44
45             if ( notificationType.equals(
46                 "PrinterEvent.PAPER_JAM" ) ) {
47                 handlePaperJamEvent();
48                 return;
49             }
50
51         } // end method handleNotification
52
53     }; // end anonymous inner class
54
55     // default constructor
56     public PrinterEventHandler(
57         RmiConnectorClient inputRmiClient,
58         PrinterEventListener inputEventTarget )
59     {
60         rmiClient = inputRmiClient;
61         eventTarget = inputEventTarget;
62
63         // set notification push mode
64         rmiClient.setMode( ClientNotificationHandler.PUSH_MODE );
65     }
```

Fig. 24.11 Receiving event notifications from the MBean server and handling the printer-specific events (part 2 of 3).

```
66      // register listener
67      try {
68          ObjectName objectName = new ObjectName(
69              rmiClient.getDefaultDomain()
70              + ":type=" + "PrinterEventBroadcaster" );
71
72          rmiClient.addNotificationListener( objectName,
73              notificationListener, null, null );
74      }
75
76      // if MBean does not exist in the MBean server
77      catch ( InstanceNotFoundException exception) {
78          exception.printStackTrace();
79      }
80
81      // if the format of the object name is wrong
82      catch ( MalformedObjectNameException exception ) {
83          exception.printStackTrace();
84      }
85
86  } // end PrinterEventHandler constructor
87
88  // delegate out of paper event
89  private void handleOutOfPaperEvent()
90  {
91      eventTarget.outOfPaper();
92  }
93
94  // delegate low toner event
95  private void handleLowTonerEvent()
96  {
97      eventTarget.lowToner();
98  }
99
100 // delegate paper jam event
101 private void handlePaperJamEvent()
102 {
103     eventTarget.paperJam();
104 }
```

Fig. 24.11 Receiving event notifications from the MBean server and handling the printer-specific events (part 3 of 3).

#### 24.3.4 Management Application

The management application in our example provides a simple graphical user interface for managing the printer. Class **ClientPrinterManagement** (Fig. 24.12) establishes a connection to the MBean server via the **RmiConnectorClient** (package **com.sun.jdmk.comm**). The management of the printer relies on the MBean server. The **ClientPrinterManagement** constructor (lines 24–39) creates a **RmiConnectorClient** corresponding to the **RmiConnectorServer** that is attached to the **MBeanServer** created by **PrinterManagementAgent** (Fig. 24.8). Line 27 creates the

**RmiConnectorClient**. Lines 30–31 obtain the address for the connector client. Line 34 specifies the port number for the connector client. The port number of the connector client should agree with that of the connector server. Line 37 establishes a connection with the remote **MBeanServer**. Method **getClient** (lines 42–45) returns **RmiConnectorClient** reference. In the **main** method, lines 57–58 start the GUI for the management application. Lines 61–63 display the output window (shown in Fig. 24.14–Fig. 24.18).

```
1 // Fig. 24.12: ClientPrinterManagement.java
2 // This application establishes a connection to the MBeanServer
3 // and creates an MBean for PrinterSimulator.
4
5 // deitel package
6 package com.deitel.advjhttp1.jmx.Client;
7
8 // Java core packages
9 import java.awt.*;
10 import java.awt.event.*;
11
12 // JMX core packages
13 import javax.management.*;
14
15 // JDMX core packages
16 import com.sun.jdmk.comm.RmiConnectorClient;
17 import com.sun.jdmk.comm.RmiConnectorAddress;
18
19 public class ClientPrinterManagement {
20
21     private RmiConnectorClient rmiClient;
22
23     // instantiate client connection
24     public ClientPrinterManagement()
25     {
26         // create connector client instance
27         rmiClient = new RmiConnectorClient();
28
29         // create address instance
30         RmiConnectorAddress rmiAddress =
31             new RmiConnectorAddress();
32
33         // specify port
34         rmiAddress.setPort( 5555 );
35
36         // establish connection
37         rmiClient.connect( rmiAddress );
38
39     } // end ClientPrinterManagement constructor
40
```

Fig. 24.12 Connecting to the **MBeanServer** remotely and creating a PrinterSimulator MBean (part 1 of 2).

---

```

41     // return RmiConnectorClient reference
42     public RmiConnectorClient getClient()
43     {
44         return rmiClient;
45     }
46
47     public static void main( String[] args )
48     {
49         // instantiate client connection
50         ClientPrinterManagement clientManager =
51             new ClientPrinterManagement();
52
53         // get RMICollectorClient handle
54         RmiConnectorClient client = clientManager.getClient();
55
56         // start GUI
57         PrinterManagementGUI printerManagementGUI =
58             new PrinterManagementGUI( client );
59
60         // display the output
61         printerManagementGUI.setSize(
62             new Dimension( 500, 500 ) );
63         printerManagementGUI.setVisible( true );
64
65     } // end method main
66 }
```

---

**Fig. 24.12** Connecting to the **MBeanServer** remotely and creating a **PrinterSimulator** MBean (part 2 of 2).

Class **PrinterManagementGUI** (Fig. 24.13) defines the GUI for the management application. The GUI contains a panel for displaying the printer status and buttons for updating the status, adding paper and cancelling pending print jobs.

---

```

1 // Fig. 24.13: PrinterManagementGUI.java
2 // This class defines the GUI for the
3 // printer management application.
4
5 // deitel package
6 package com.deitel.advjhttp1.jmx.Client;
7
8 // Java AWT core package
9 import java.awt.*;
10 import java.awt.event.*;
11
12 // Java standard extensions
13 import javax.swing.*;
14
15 // JMX core packages
16 import javax.management.*;
```

---

**Fig. 24.13** GUI for the management application (part 1 of 9).

```
18 // JDMX core packages
19 import com.sun.jdmk.comm.RmiConnectorClient;
20 import com.sun.jdmk.comm.RmiConnectorAddress;
21
22 // Deitel packages
23 import com.deitel.advjhttp1.jmx.Printer.*;
24
25 public class PrinterManagementGUI extends JFrame
26 implements PrinterEventListener {
27
28     // TextAppender appends text to a JTextArea. This Runnable
29     // object should be executed only using SwingUtilities
30     // methods invokeLater or invokeAndWait as it modifies
31     // a live Swing component.
32     private class TextAppender implements Runnable {
33
34         private String text;
35         private JTextArea textArea;
36
37         // TextAppender constructor
38         public TextAppender( JTextArea area, String newText )
39         {
40             text = newText;
41             textArea = area;
42         }
43
44         // display new text in JTextArea
45         public void run()
46         {
47             // append new message
48             textArea.append( text );
49
50             // move caret to end of messageArea to ensure new
51             // message is visible on screen
52             textArea.setCaretPosition(
53                 textArea.getText().length() );
54         }
55
56     } // end TextAppender inner class
57
58     private ObjectName objectName;
59     private RmiConnectorClient client;
60     private JTextArea printerStatusTextArea = new JTextArea();
61     private JTextArea printerEventTextArea = new JTextArea();
62
63     public PrinterManagementGUI( RmiConnectorClient rmiClient )
64     {
65         super( "JMX Printer Management Example" );
66
67         Container container = getContentPane();
68
69         // status panel
70         JPanel printerStatusPanel = new JPanel();
```

Fig. 24.13 GUI for the management application (part 2 of 9).

```
71     printerStatusPanel.setPreferredSize(
72         new Dimension( 512, 200 ) );
73     JScrollPane statusScrollPane = new JScrollPane();
74     statusScrollPane.setAutoscrolls( true );
75     statusScrollPane.setPreferredSize(
76         new Dimension( 400, 150 ) );
77     statusScrollPane.setViewportView().add(
78         printerStatusTextArea, null );
79     printerStatusPanel.add( statusScrollPane, null );
80
81     // buttons panel
82     JPanel buttonPanel = new JPanel();
83     buttonPanel.setPreferredSize(
84         new Dimension( 512, 200 ) );
85
86     // define action for Check Status button
87     JButton checkStatusButton =
88         new JButton( "Check Status" );
89     checkStatusButton.addActionListener(
90
91         new ActionListener() {
92
93             public void actionPerformed( ActionEvent event ) {
94                 checkStatusButtonAction( event );
95             }
96         }
97     );
98
99     // define action for Add Paper button
100    JButton addPaperButton = new JButton( "Add Paper" );
101    addPaperButton.addActionListener(
102        new ActionListener() {
103
104            public void actionPerformed(ActionEvent event) {
105                addPaperButtonAction( event );
106            }
107        }
108    );
109
110    // define action for Cancel Pending Print Jobs button
111    JButton cancelPendingPrintJobsButton = new JButton(
112        "Cancel Pending Print Jobs" );
113    cancelPendingPrintJobsButton.addActionListener(
114        new ActionListener() {
115
116            public void actionPerformed( ActionEvent event ) {
117                cancelPendingPrintJobsButtonAction( event );
118            }
119        }
120    );
121
122    // add three buttons to the panel
123    buttonPanel.add( checkStatusButton, null );
```

Fig. 24.13 GUI for the management application (part 3 of 9).

```
124     buttonPanel.add( addPaperButton, null );
125     buttonPanel.add( cancelPendingPrintJobsButton, null );
126
127     // events panel
128     JPanel printerEventPanel = new JPanel();
129     printerEventPanel.setPreferredSize(
130         new Dimension( 512, 200 ) );
131     JScrollPane eventsScrollPane = new JScrollPane();
132     eventsScrollPane.setAutoscrolls( true );
133     eventsScrollPane.setPreferredSize(
134         new Dimension( 400, 150 ) );
135     eventsScrollPane.setViewportView().add(
136         printerEventTextArea, null );
137     printerEventPanel.add( eventsScrollPane, null );
138
139     // initialize the text
140     printerStatusTextArea.setText( "Printer Status: ---\n" );
141     printerEventTextArea.setText( "Events: --- \n" );
142
143     // put all the panels together
144     container.add( printerStatusPanel, BorderLayout.NORTH );
145     container.add( printerEventPanel, BorderLayout.SOUTH );
146     container.add( buttonPanel, BorderLayout.CENTER );
147
148     // set RmiConnectorClient reference
149     client = rmiClient;
150
151     // invoke method startPrinting of the
152     // PrinterSimulator MBean
153     try {
154         String name = client.getDefaultDomain()
155             + ":type=" + "Printer";
156         objectName = new ObjectName( name );
157         client.invoke( objectName, "startPrinting",
158             new Object[ 0 ], new String[ 0 ] );
159     }
160
161     // invalid object name
162     catch ( MalformedObjectNameException exception ) {
163         exception.printStackTrace();
164     }
165
166     // if cannot invoke the method
167     catch ( ReflectionException exception ) {
168         exception.printStackTrace();
169     }
170
171     // if invoked method throws exception
172     catch ( MBeanException exception ) {
173         exception.printStackTrace();
174     }
175
```

Fig. 24.13 GUI for the management application (part 4 of 9).

```
176     // if MBean is not registered with MBean server
177     catch ( InstanceNotFoundException exception ) {
178         exception.printStackTrace();
179     }
180
181     // instantiate PrinterEventNotifier
182     PrinterEventHandler printerEventHandler =
183         new PrinterEventHandler( client, this );
184
185     // unregister MBean when close the window
186     addWindowListener(
187         new WindowAdapter() {
188             public void windowClosing( WindowEvent event )
189             {
190                 // unregister MBean
191                 try {
192
193                     // unregister the PrinterSimulator MBean
194                     client.unregisterMBean( objectName );
195
196                     // unregister the PrinterEventBroadcaster
197                     // MBean
198                     String name = client.getDefaultDomain()
199                         + ":type=" + "PrinterEventBroadcaster";
200                     objectName = new ObjectName( name );
201                     client.unregisterMBean( objectName );
202                 }
203
204                 // if invalid object name
205                 catch ( MalformedObjectNameException exception) {
206                     exception.printStackTrace();
207                 }
208
209                 // if exception is caught from method preDeregister
210                 catch ( MBeanRegistrationException exception ) {
211                     exception.printStackTrace();
212                 }
213
214                 // if MBean is not registered with MBean server
215                 catch ( InstanceNotFoundException exception ) {
216                     exception.printStackTrace();
217                 }
218
219                 // terminate the program
220                 System.exit( 0 );
221
222             } // end method windowClosing
223
224         } // end WindowAdapter constructor
225
226     ); // end addWindowListener
227
228 } // end PrinterManagementGUI constructor
```

Fig. 24.13 GUI for the management application (part 5 of 9).

```
229
230     // out of paper events
231     public void outOfPaper()
232     {
233         SwingUtilities.invokeLater(
234             new TextAppender( printerEventTextArea,
235                             "\nEVENT: Out of Paper!\n" ) );
236     }
237
238     // toner low events
239     public void lowToner()
240     {
241         SwingUtilities.invokeLater(
242             new TextAppender( printerEventTextArea,
243                             "\nEVENT: Toner Low!\n" ) );
244     }
245
246     // paper jam events
247     public void paperJam()
248     {
249         SwingUtilities.invokeLater(
250             new TextAppender( printerEventTextArea,
251                             "\nEVENT: Paper Jam!\n" ) );
252     }
253
254     // add paper to the paper tray
255     public void addPaperButtonAction( ActionEvent event )
256     {
257         try {
258             client.invoke( objectName, "replenishPaperTray",
259                           new Object[ 0 ], new String[ 0 ] );
260         }
261
262         // if cannot invoke the method
263         catch ( ReflectionException exception )
264         {
265             exception.printStackTrace();
266         }
267
268         // if invoked method throws exception
269         catch ( MBeanException exception ) {
270             exception.printStackTrace();
271         }
272
273         // if MBean is not registered with MBean server
274         catch ( InstanceNotFoundException exception ) {
275             exception.printStackTrace();
276         }
277
278     } // end method addPaperButtonAction
279 }
```

Fig. 24.13 GUI for the management application (part 6 of 9).

```
280 // cancel pending print jobs
281 public void cancelPendingPrintJobsButtonAction(
282     ActionEvent event )
283 {
284     try {
285         client.invoke( objectName, "cancelPendingPrintJobs",
286             new Object[ 0 ], new String[ 0 ] );
287     }
288
289     // if cannot invoke the method
290     catch ( ReflectionException exception)
291     {
292         exception.printStackTrace();
293     }
294
295     // if invoked method throws exception
296     catch ( MBeanException exception ) {
297         exception.printStackTrace();
298     }
299
300     // if MBean is not registered with MBean server
301     catch ( InstanceNotFoundException exception ) {
302         exception.printStackTrace();
303     }
304
305 } // end method cancelPendingPrintJobsButtonAction
306
307 public void checkStatusButtonAction( ActionEvent event )
308 {
309     Object onlineResponse = null;
310     Object paperJamResponse = null;
311     Object printingResponse = null;
312     Object paperTrayResponse = null;
313     Object pendingPrintJobsResponse = null;
314
315     // manage printer remotely
316     try {
317
318         // check if the printer is on line
319         onlineResponse = client.invoke( objectName,
320             "isOnline", new Object[ 0 ], new String[ 0 ] );
321
322         // check if the printer is paper jammed
323         paperJamResponse = client.invoke( objectName,
324             "isPaperJam", new Object[ 0 ], new String[ 0 ] );
325
326         // check if the printing is pringint
327         printingResponse = client.invoke( objectName,
328             "isPrinting", new Object[ 0 ], new String[ 0 ] );
329
330         // get the paper tray
331         paperTrayResponse = client.invoke( objectName,
332             "getPaperTray", new Object[ 0 ], new String[ 0 ] );
```

Fig. 24.13 GUI for the management application (part 7 of 9).

```
333         // get pending print jobs
334         pendingPrintJobsResponse = client.invoke( objectName,
335             "getPendingPrintJobs" , new Object[ 0 ],
336             new String[ 0 ] );
337     }
338 }
339
340     // if cannot invoke the method
341     catch ( ReflectionException exception ) {
342         exception.printStackTrace();
343     }
344
345     // if invoked method throws exception
346     catch ( MBeanException exception ) {
347         exception.printStackTrace();
348     }
349
350     // if MBean is not registered with MBean server
351     catch ( InstanceNotFoundException exception ) {
352         exception.printStackTrace();
353     }
354
355     // status for the online condition
356     boolean isOnline =
357         ( ( Boolean ) onlineResponse ).booleanValue();
358
359     // display status
360     if ( isOnline ) {
361         SwingUtilities.invokeLater( new TextAppender(
362             printerStatusTextArea,
363             "\nPrinter is ONLINE.\n" ) );
364     }
365     else {
366         SwingUtilities.invokeLater( new TextAppender(
367             printerStatusTextArea,
368             "\nPrinter is OFFLINE.\n" ) );
369     }
370
371     // status for the paper jam condition
372     boolean isPaperJam =
373         ( ( Boolean ) paperJamResponse ).booleanValue();
374
375     // display status
376     if ( isPaperJam ) {
377         SwingUtilities.invokeLater( new TextAppender(
378             printerStatusTextArea,
379             "Paper jammed.\n" ) );
380     }
381     else {
382         SwingUtilities.invokeLater( new TextAppender(
383             printerStatusTextArea,
384             "No Paper Jam.\n" ) );
385     }
```

Fig. 24.13 GUI for the management application (part 8 of 9).

```

386     // status for the printing condition
387     boolean isPrinting =
388         ( ( Boolean )printingResponse ).booleanValue();
389
390     // display status
391     if ( isPrinting ) {
392         SwingUtilities.invokeLater( new TextAppender(
393             printerStatusTextArea,
394             "Printer is currently printing.\n" ) );
395     }
396     else {
397         SwingUtilities.invokeLater( new TextAppender(
398             printerStatusTextArea,
399             "Printer is not printing.\n" ) );
400     }
401
402
403     // status for paper tray condition
404     int paperRemaining =
405         ( ( Integer )paperTrayResponse ).intValue();
406
407     // display status
408     SwingUtilities.invokeLater( new TextAppender(
409         printerStatusTextArea,
410         "Printer paper tray has " + paperRemaining +
411         " pages remaining.\n" ) );
412
413     // status for pending print jobs
414     Object[] pendingPrintJobs =
415         ( Object[] ) pendingPrintJobsResponse;
416     int pendingPrintJobsNumber = pendingPrintJobs.length;
417
418     // display status
419     SwingUtilities.invokeLater( new TextAppender(
420         printerStatusTextArea,
421         "Number of pending print jobs: " +
422         pendingPrintJobsNumber + "\n" ) );
423
424
425 } // end method checkStatusButtonAction
426 }
```

Fig. 24.13 GUI for the management application (part 9 of 9).

Lines 32–56 define a **private** inner class, **TextAppender** to append text to the Swing container in a thread-safe manner. Lines 154–158 call method **startPrinting** of the **Printer** MBean to ask the printer to start the printing process. The management application needs to handle events received from the broadcaster MBean. Lines 182–183 call the **PrinterEventHandler** (Fig. 24.11) constructor to add a notification listener to the broadcaster MBean. The constructor takes two arguments. The first argument, **Rmi**-

**ConnectorClient**, provides a reference to the connector client through which the registration process can occur. The second argument, **PrinterEventListener**, is a reference to class **PrinterManagementGUI** that will handle all transmitted events.

Lines 186–226 install a window listener that unregisters the **Printer** MBean and the **PrinterEventBroadcaster** MBean when the user closes the output window. Line 194 unregisters the **PrinterSimulator** MBean. Lines 198–201 unregister the **PrinterEventBroadcaster** MBean. Method **unregisterMBean** (lines 194 and 201) takes one argument—an **ObjectName** that specifies the name of the MBean to be removed from the remote **MBeanServer**. Method **unregisterMBean** deletes an MBean reference from the remote **MBeanServer**.

Method **outOfPaper** (lines 231–236) displays the out-of-paper event in the event panel. Method **lowToner** (lines 239–244) displays the low-toner event in the event panel. Method **paperJam** (lines 247–252) displays the paper-jam event in the event panel. Method **addPaperButtonAction** (lines 255–278) executes when the user clicks the **Add Paper** button. Lines 258–259 invoke the **Printer** MBean's **replenishPaperTray** operation, which fills the paper tray with 50 pages. Method **cancelPendingPrintJobsButtonAction** (lines 281–305) executes when the user clicks the **Cancel Pending Print Jobs** button. Lines 285–288 invoke the **Printer** MBean's **cancelPendingPrintJobs** operation. Method **checkStatusButtonAction** (lines 307–425) performs when the user clicks on the **Check Status** button. Lines 318–337 invoke the **Printer** MBean's **isOnline**, **isPaperJam**, **isPrinting**, **getPaperTray**, and **getPendingPrintJobs** *get* methods. Lines 355–422 prepare the outputs.

### 24.3.5 Compiling and Running the Example

Before compiling the Java code, the JAR files **jdmkrt.jar** and **jdmktk.jar** should be included in the **CLASSPATH**. Compile the files in package **com.deitel.advjhttp1.jmx.Printer** first, then compile the files in package **com.deitel.advjhttp1.jmx.PrinterManagement**. Finally compile the files in package **com.deitel.advjhttp1.jmx.Client**.

To run the example, first start the **PrinterManagementAgent**. Class **PrinterManagementAgent** creates an **MBeanServer** and initializes the RMI connector service. Start the **ClientPrinterManagement** application. Class **ClientPrinterManagement** starts the printer simulator and invokes the GUI to manage the printer. Figure 24.14 shows the initial output window.

Figure 24.15 shows the printer status by after an out-of-paper event has occurred and the user pressed the **Check Status** button.

Figure 24.16 shows the printer status by after clicking the **Add Paper** button and the **Check Status** button.

Figure 24.17 shows the printer status after a paper-jam event has occurred and the user clicked the **Check Status** button.

Figure 24.18 shows the printer status after clicking the **Cancel Pending Print Jobs** button and **Check Status** button.

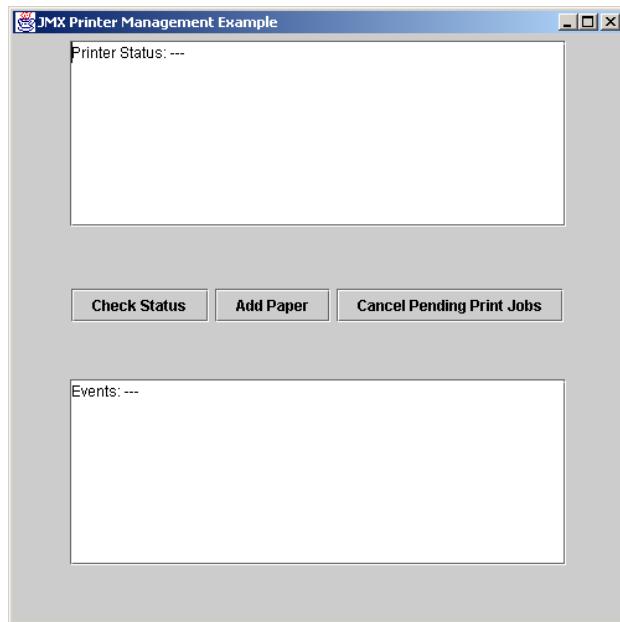


Fig. 24.14 Initial output window.

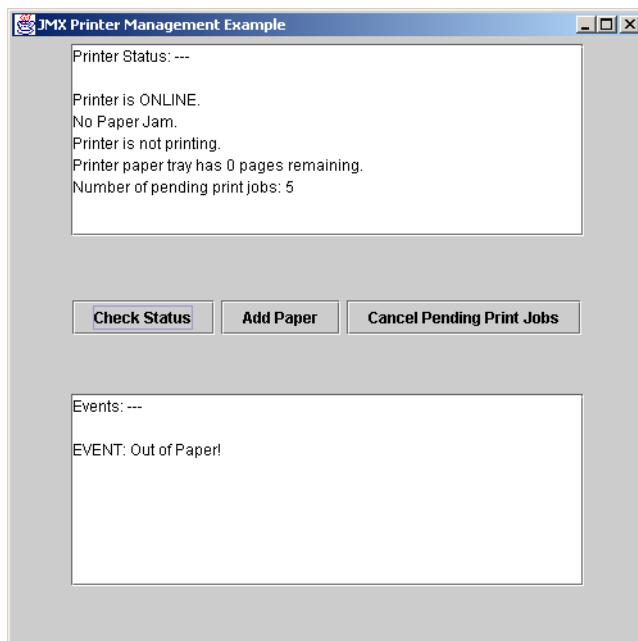


Fig. 24.15 Printer status after an out-of-paper event occurred.

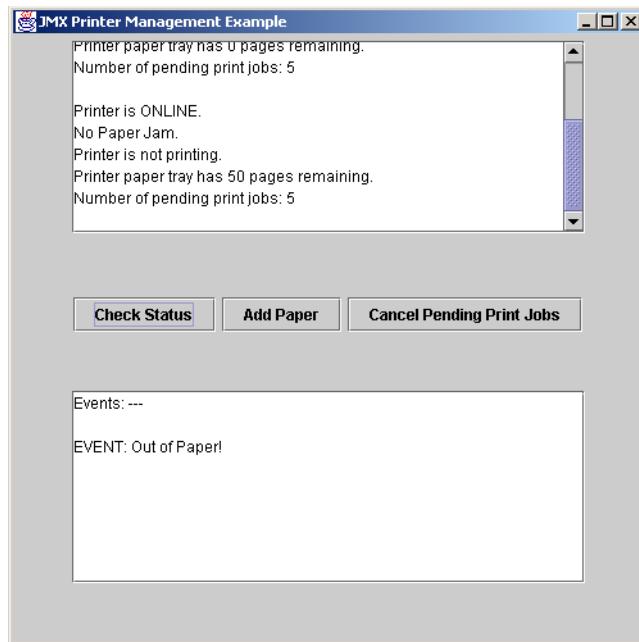


Fig. 24.16 Printer status after an add-paper action is taken.

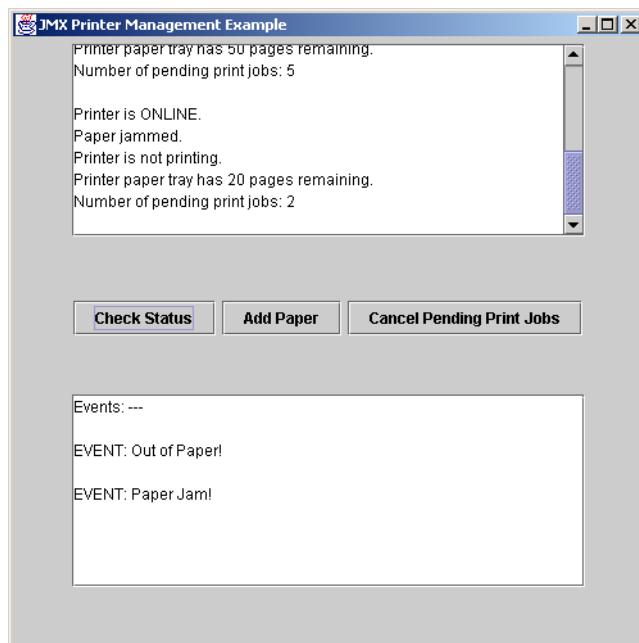


Fig. 24.17 Printer status after a paper-jam event occurred.

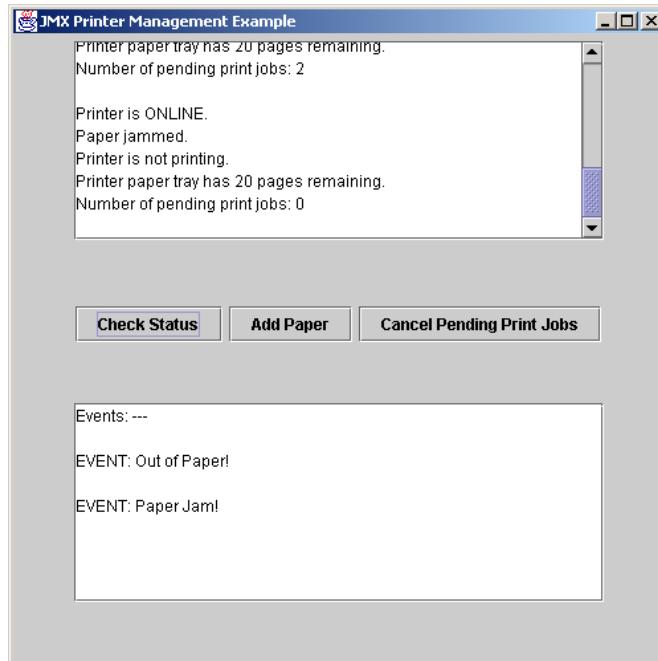


Fig. 24.18 Printer status after a cancel pending print jobs action is taken.

## 24.4 Internet and World Wide Web Resources

[www.sun.com/software/java-dynamic/service\\_driven.html](http://www.sun.com/software/java-dynamic/service_driven.html)

This page introduces the new generation network—service driven network.

[www.sun.com/software/java-dynamic/wp\\_jdkmk40.html](http://www.sun.com/software/java-dynamic/wp_jdkmk40.html)

This page is the white paper for the Java Dynamic Management Kit.

[www.sun.com/software/java-dynamic/wp\\_jini\\_jdmk.html](http://www.sun.com/software/java-dynamic/wp_jini_jdmk.html)

This page demonstrates how the Jini and the Java Dynamic Management Kit work together to provide spontaneous management.

[www.sun.com/software/java-dynamic/qa.html](http://www.sun.com/software/java-dynamic/qa.html)

This site contains the FAQs about the Java Dynamic Management Kit.

[jw.itworld.com/javaworld/jw-11-1999/jw-11-management\\_p.html](http://jw.itworld.com/javaworld/jw-11-1999/jw-11-management_p.html)

This site contains the article *Java enters the management arena with JMX and Java DMK* written by Max Goff.

[java.sun.com/products/JavaManagement/wp](http://java.sun.com/products/JavaManagement/wp)

This page contains the Java Management Extensions White Paper.

### SUMMARY

- Today's network management is performed through management applications via agents.
- Many existing agents are limited because they lack event handling capabilities that adapt to changing network conditions.

- The management capabilities of a static agent must be predefined during development.
- The Java Dynamic Management Kit (JDMK) provides developers of Java-based applications with means to build automated and intelligent dynamic network management solutions.
- JMX defines a three-level management architecture—instrumentation level, agent level and manager level. The instrumentation level makes any Java-based object manageable by exposing its management interface. The agent level provides management services to expose the managed resources for management. The management level allows a management application to access and operate the managed resources via the JMX agents.
- JMX implementations provide interfaces to existing management protocols so that developers can integrate new management applications with existing management solutions.
- JMX uses JavaBeans to build reusable management solutions.
- Java Dynamic Management Kit (JDMK) is one of many implementations of the JMX specification.
- To run an management application written with JDMK, the JAR files **jdmkrt.jar** and **jdmktk.jar** must be added to the **CLASSPATH**.
- A complete management solution includes the managed resources, the management agent and the management application.
- The task of instrumentation is to make resources manageable. Resources can be devices, applications and any Java-based objects that need to be managed through a management application.
- An MBean is used to instrument a resource (i.e., make it manageable).
- A standard MBean has two parts—the MBean interface and the Java class that implements the MBean interface (i.e., the MBean class).
- A standard MBean must follow design patterns defined by the Java Management Extensions specification to standardize the instrumentation of managed resources.
- The MBean interface must have MBean implementation's Java class name followed by the MBean suffix.
- An operation is a **public** method whose name does not begin with **get**, **is** or **set**. Only **public** methods are exposed.
- Method **findMBeanServer** of class **MBeanServerFactory** provides a way to obtain references to MBean servers that have been instantiated in the JVM.
- Method **invoke** of interface **MBeanServer** invokes a specified method on the indicated MBean.
- Method **createMBean** of interface **MBeanServer** instantiates an MBean object and gives it a unique identifying name.
- The JMX management agent acts as a communication bridge between the MBeans and the management application.
- A JMX agent typically contains an MBean server, a set of MBeans that represent either the managed sources or the management resources, and at least one protocol adaptor or connector to allow remote management application access to the agent.
- The MBeans represent the managed resources or management services; they are registered with the MBean server.
- The local management application manipulates the MBean directly through the MBean server. The remote management application manipulates the MBean indirectly through the MBean server via either a protocol adaptor or a connector.
- Method **createMBeanServer** of class **MBeanServerFactory** creates an MBean server.
- A notification broadcaster MBean is an MBean that contains the source of notifications.

- The notification broadcaster MBean has the ability to broadcast the notifications received from the managed resources or devices to the MBean server.
- Event broadcaster classes can extend class **NotificationBroadcasterSupport** (package **javax.management**) to inherit services such as listener registration.
- In push mode, as soon as the RMI connector server receives a notification, it forwards the notification to the RMI connector client.
- Method **unregisterMBean** removes an MBean reference from the remote MBean server.

## TERMINOLOGY

<b>addNotificationListener</b> of	JDMK
<b>RmiConnectorClient</b>	JMX
agent	JMX management agent
agent level	Managed Beans
<b>ClientNotificationHandler</b> interface	management level
connector	MBean
design patterns	<b>MBeanException</b>
<b>findMBeanServer</b> method of	<b>MBeanNotificationInfo</b>
<b>MBeanServerFactory</b>	<b>MBeanServer</b> interface
<b>getDefaultValue</b> method of	<b>MBeanServerFactory</b> class
<b>MBeanServer</b>	notification broadcaster
<b>handleNotification</b> method of	protocol adaptor
<b>NotificationListener</b>	protocol independent
instrumentation level	<b>ReflectionException</b>
intelligent agent	<b>RmiConnectorClient</b> class
Java Dynamic Management Kit (JDMK)	scalability
Java Management Extensions (JMX)	SNMP
<b>JavaBeans</b>	standard MBean

## SELF-REVIEW EXERCISES

**24.1** Fill in the blanks in each of the following:

- JMX defines a three-level management architecture: \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- A(n) \_\_\_\_\_ instruments a resource for management.
- Method \_\_\_\_\_ of class **MBeanServerFactory** obtains references to MBean servers instantiated in the JVM.
- To instantiate and register an MBean in the MBean server, call method \_\_\_\_\_ of interface **MBeanServer**.
- A JMX agent contains at least one \_\_\_\_\_ or \_\_\_\_\_ to allow remote management applications to access the agent.
- The notification broadcaster MBean can implement interface \_\_\_\_\_ to declare itself as a source of notifications.

**24.2** State whether each of the following is *true* or *false*. If *false*, explain why.

- A property in a standard MBean can have multiple *set* methods.
- When implementing an MBean, if no **public** constructor is defined, the Java compiler will display an error message.
- Each MBean object registered in the MBean server must have a unique object name.
- By extending class **NotificationBroadcasterSupport**, a notification broadcaster MBean inherits the services of this class and does not need to implement interface **NotificationBroadcaster**.

- e) The MBean interface must have the MBean implementation's Java class name followed by the MBean suffix.

## ANSWERS TO SELF-REVIEW EXERCISES

**24.1** a) instrumentation level, agent level, manager level. b) standard MBean.  
c) **findMBeanServer**. d) **createMBean**. e) protocol adaptor, connector.  
f) **NotificationBroadcaster**.

**24.2** a) False. Only one setter method and one getter method are allowed for a single property in the management interface. b) False. The Java compiler provides a **public**, no-argument constructor to the MBean class by default. c) True. d) True. e) True.

## EXERCISES

**24.3** What is the purpose of connector and adaptor MBeans in JMX? How are connector and adaptor MBeans similar to other MBeans? How are they different? Compare and contrast connector MBeans to our **Printer** MBean.

**24.4** Add an HTML protocol adaptor to the **MBeanServer** created in **PrinterManagement-Agent.java**. Run the **ClientPrinterManagement** application as before. Use URL **http://localhost:8082** to view the MBeans that are registered with the MBean server. How many MBeans can you see? Explain why they are there. Can you distinguish the MBeans that are directly registered with the MBean server from those that are not? Use the JMX API documentation for assistance.

**24.5** Try to change properties and perform operations in the **Printer** MBean (Fig. 24.5) from the URL given in the previous exercise. Do results correspond with those of the GUI that is invoked by the **ClientPrinterManagement** application?

**24.6** Expand the capabilities of class **PrinterSimulator** (Fig. 24.6) to include a method called **removePaperJam** that will fix any paper jam event that occurs. Modify the GUI in Fig. 24.13 to include a button labeled **Remove Paper Jam**. Modify all necessary files in the printer simulator example such that when a paper jam event occurs, the user may fix the paper jam by pressing the new button.

**24.7** Modify all necessary files in the printer simulator example to allow a manager to shut down and start up a printer remotely through the **PrinterManagementGUI**.

**24.8** Modify the **PrinterSimulator** MBean and GUI such that the client application can perform a **refillToner** operation when the toner is lower than 10%.

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# 25

## Jiro

### Objectives

- To understand the Jiro technology architecture.
- To be able to locate static services.
- To understand how the controller service, event service, log service, scheduling service and transaction service work.
- To be able to deploy dynamic services.
- To be able to instantiate dynamic services.

*All love that has not friendship for its base,*

*Is like a mansion built upon the sand*

Ella Wheeler Wilcox

*You know my method. It is founded upon the observance of trifles.*

Arthur Conan Doyle

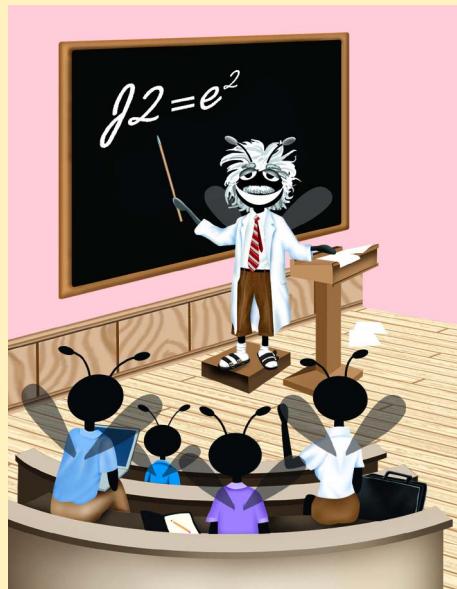
*Oh let us love our occupations,*

*Bless the squire and his relations,*

*Live upon our daily rations,*

*And always know our proper stations.*

Charles Dickens



## Outline

- 25.1 Introduction**
- 25.2 Installation**
- 25.3 Starting Jiro**
- 25.4 Dynamic vs. Static Services**
- 25.5 Dynamic Services**
  - 25.5.1 Dynamic-Service Implementation**
- 25.6 Static Services**
  - 25.6.1 Locating Static Services with Class `ServiceFinder`**
  - 25.6.2 Event Service**
  - 25.6.3 Log Service**
  - 25.6.4 Scheduling Service**
- 25.7 Dynamic Service Deployment**
  - 25.7.1 Dynamic-Service Usage**
- 25.8 Management Policies**
  - 25.8.1 Policy-Management Deployment**
- 25.9 Closing Notes on the Printer Management Solution**
- 25.10 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises• Bibliography*

## 25.1 Introduction

The management of distributed resources, networks and storage devices is becoming increasingly sophisticated in response to the complexity of distributed resources, heterogeneous networks and heterogeneous storage devices. A network may include computers and devices from many different manufacturers. Computers connected to a network may have different architectures, platforms and even data formats. All of these increase the complexity and costs of managing networks.

To reduce complexity and cost, a management solution should be:

1. automated, so that the management can be monitored and controlled to minimize human response when problems occur;
2. centralized, so that distributed resources can be managed from a single location;
3. standardized, so that management software can communicate with other related management software;
4. open and interoperable, so that management software can interact with various different types of manageable resources across a network;
5. platform independent, so that cross-platform information can be managed;
6. fast to develop and easy to deploy,

## 7. highly available.

Sun's Java-based *Jiro™* Technology provides infrastructure to develop management solutions that can manage distributed resources over heterogeneous networks. Jiro is an implementation of the *Federated Management Architecture (FMA)* specification (developed under the Java Community Process) that defines an architecture for communication between heterogeneous managed resources (such as devices, systems and applications). Jiro technology uses a three-tier architecture for management solutions (Fig. 25.1). The top tier is the *client tier*. The client, in the top tier, locates and communicates with the management services. The *middle tier* is the Jiro technology that provides both static and dynamic management services. The *bottom tier* consists of the heterogeneous managed resources.

Besides Jiro, several other industry standards exist. Among these standards, the best known are *SNMP* and *CIM*. The *Simple Network Management Protocol (SNMP)* provides a standardized network-management protocol for managing devices connected to a TCP/IP network. The *Common Information Model (CIM)* defines a standard model for describing management information in networks. Jiro supports both standards.

Jiro does not manage resources directly. Instead, it provides both a management infrastructure and management services, which are necessary to develop a management application. The management infrastructure uses the RMI activation system, Jini and a *class server*. The RMI activation system activates or restarts services as they are needed. Jini provides a dynamic lookup service that enable management domains to find services and each other without prior knowledge of the lookup service's location. The class server provides the classes downloaded dynamically by clients.

## 25.2 Installation

To develop a management application with Jiro, first ensure that you have the Java 2 SDK version 1.3.x installed. Then, download and install the *Jiro Runtime Environment* and the *Jiro Technology Software Development Kit (Jiro SDK)*. The Jiro Runtime Environment and the Jiro SDK (for Windows NT/2000 and Solaris) can be downloaded from:

[www.jiro.com/downloads](http://www.jiro.com/downloads)

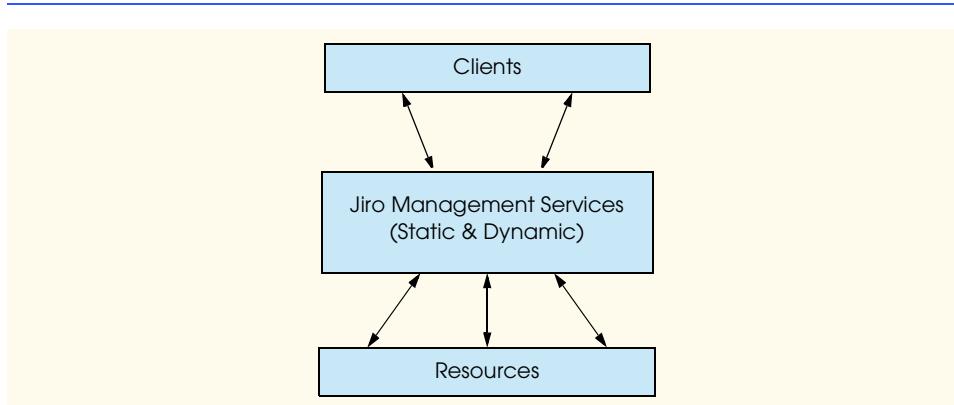


Fig. 25.1 Jiro technology three-tier management architecture.

We discuss the Windows NT/2000 version here. The steps for the Solaris version are similar. Although downloading Jiro is free, you are required to register and accept the licence agreement first. At the time of this publication, the current version of the Jiro Runtime is v1.5 and the current version of the Jiro SDK is v1.5.

When installing the Jiro Runtime Environment, you will be asked to provide the location of Java v1.3.x. You also will be asked to provide the Jiro management domain's name. A Jiro management domain contains the managed resources and the management services to manage those resources. The name of the Jiro management domain should be a **String** that uniquely identifies on the local network each shared management server (responsible for providing many of the essential services in a Jiro network). The domain name can be of any string format, as long as the string does not contain space characters. A typical representation of the domain name has the format **jiro:domainName**. To ensure the uniqueness of the *domainName*, replace our domain name with the hostname of the machine on which you install Jiro.

When installing the Jiro SDK, you will be asked to enter the location of Java v1.3.x and the Jiro management domain name. Use the same *domainName* as in the Jiro Runtime Environment installation.

After installing the Jiro Runtime Environment and the Jiro SDK, update the execution **PATH** environment variable so that it includes the path to the Jiro executables. The Jiro executables normally are located in **JiroSDK\bin**.



#### Software Engineering Observation 25.1

The Jiro management domain name should be unique within the IP multicast radius.<sup>1</sup> Use the localhost name as the management domain name, to ensure uniqueness.

### 25.3 Starting Jiro

Before starting Jiro, the Jiro management domain name must be specified. If you did not specify the domain name at installation time, you should specify the domain name in the **JiroSDK\etc\server.config** file. The Jiro distribution provides a graphical user interface for configuring, starting and stopping the Jiro framework. You can execute this GUI using the file **igniter.bat** in the **bin** directory of the Jiro installation. Figure 25.2 shows the initial screen of the GUI.



Fig. 25.2 Jiro GUI: **Igniter** initial screen.

1. The IP multicast radius defines the "range" of the Jini multicast discovery protocols.

The five red lights indicate that Jiro is not yet running. You can start Jiro with a *cleaning process* by checking the **Clean before start** checkbox, or you can start without a cleaning process by unchecking the **Clean before start** checkbox. The cleaning process removes previously deployed dynamic services and resets state information from previous Jiro executions. Clicking the **Start** button starts Jiro with the default configuration, unless the Jiro configuration files have been modified previously. Once Jiro starts, the class server, the **rmid**, the transaction service, the shared Jiro station, the controller service, the log service, the event service and the scheduling service also start. We discuss these services in Section 25.6. The transaction service, the shared Jiro station, the controller service, the log service, the event service and the scheduling service register with the Jini lookup service, which also starts when the user clicks the **Start** button. If startup completes successfully, the five lights turn green. To view the output of the start process, go to the **Options** menu and check the **Display Console** checkbox. Figure 25.3 shows the **Igniter** GUI with **Display Console** checked after the startup process completes. Select the **Errors** panel to view the error messages during the startup process.

To configure the settings of Jiro, stop Jiro by clicking the **Stop** button if Jiro is running, then go to the **File** menu and select **Edit Configuration**. For information about configuration parameters, please refer to the *Jiro Technology Installation and Configuration Guide* that comes with the Jiro SDK installation. This document is located in the Jiro installation's docs directory and is available in PDF (**install\_config.pdf**) and postscript (**install\_config.ps**) formats.

### Software Engineering Observation 25.2



You cannot edit the Jiro configuration while Jiro is running.

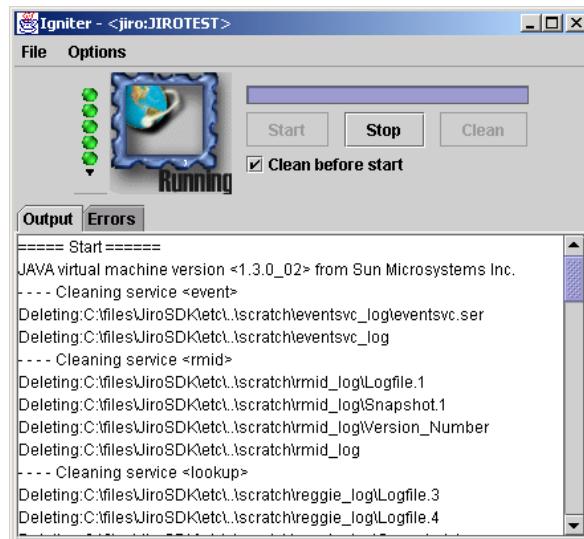


Fig. 25.3 GUI with **Display Console** checked after the start process is completed.

## 25.4 Dynamic vs. Static Services

At the heart of all Jiro management solutions lies the *management software*. Management software, in the Jiro sense, consists of one or more *services* that provide customized management functionality to a network. These services—*dynamic services*—represent software that manages one or more resources.

Developers often find, when developing management solutions for any network, that it is necessary for their dynamic services to perform a fixed set of routine procedures. To aid dynamic-service developers and reduce development time, Jiro provides a set of standard services required by many management solutions. During initialization, Jiro starts a series of *static services*—also known as *base services*, because they commonly are used in distributed management solutions—and registers them with the Jini lookup service. The difference between dynamic services and static services is that dynamic services define the management solution that is deployed in a network and static services are tools that are globally available to all dynamic services to simplify development. The static services include:

1. the *Jiro event service* transmits events via the network to registered listeners;
2. the *Jiro scheduling service* fires events at scheduled times;
3. the *Jiro log service* enables logging of selected actions that occur in a Jiro network and any error messages that occur;
4. the *Jiro transaction service* is responsible for ensuring synchronized access to methods; and
5. the *Jiro controller service* creates controllers to enforce synchronized access to dynamic services.

Each Jiro domain has one instance of each standard service for use by remote clients or dynamic services. [Note: The transaction service and the controller service topics are beyond the scope of this chapter. For further information, please visit [www.jiro.com](http://www.jiro.com).]

## 25.5 Dynamic Services

Jiro provides each management domain with a *station* that hosts dynamic services and enables remote clients to invoke methods on the hosted dynamic services. Jiro provides the station at startup.

In Jiro, a dynamic service that provides access to a managed resource or a set of related dynamic services is called a *Management Facade*. A Jiro component's Management Facade enables other Jiro components to manage those devices to which the Management Facade provides access. The Facade provides access to manage these devices by serving as a unique entry point for all Jiro components to interact with that Facade's dynamic services. The Management Facade shields clients from that Facade's complex underlying structure and behavior.

The Management Facade is an example of the *Facade design pattern*. This design pattern reduces system complexity, because a client interacts with only one object—called the *facade object*. In the field of software development, the Facade design pattern shields applications developers from subsystem complexities. Developers need to be familiar with only the operations of the facade object, rather than with the more detailed operations of the entire subsystem.

When driving a car, you know that pressing the gas pedal accelerates your car, but you are unaware of exactly how the gas pedal causes your car to accelerate. The facade object provides a simple interface for the behaviors of a *subsystem*—an aggregate of objects that collectively comprise a major system responsibility. The gas pedal, for example, is the facade object for the car’s acceleration subsystem, the steering wheel is the facade object for the car’s steering subsystem and the brake is the facade object for the car’s deceleration subsystem. A *client object* uses the facade object to interact with the objects behind the facade. The client remains unaware of how the objects behind the facade fulfill responsibilities, so the subsystem complexity is hidden from the client. When you press the gas pedal you act as a client object. In Jiro, the Management Facade is the facade object, and Jiro components that use the Management Facade to manage underlying resources are the client objects.

To make a dynamic service available in a management domain, dynamic-service providers must follow two steps—implement the dynamic service (a step performed by a developer) and deploy the dynamic service to a station in a management domain (a step usually performed by a system administrator). In the rest of this section, we demonstrate how to develop, deploy and access a dynamic service that manages a network printer. As in Chapter 24, this chapter uses a printer simulator to represent the resource that our dynamic service manages.

The printer interface has a limited number of operations. Our dynamic service exposes this interface. We will create a management console that enables a system administrator to manage the printer remotely. The resulting management solution provides a simple example of a typical Jiro management solution.

### 25.5.1 Dynamic-Service Implementation

To implement a dynamic service, a developer must first define a **public** interface for the service. The **public** interface exposes to clients and to other dynamic services the operations one can perform on a resource<sup>2</sup> that will be managed.

**PrinterManagement** (Fig. 25.4) exposes the management operations we can perform on the printer. From this interface, a developer will be able to provide access to the printer’s state at any given moment, through such methods as **isPrinting**, **isOnline**, **isPaperJam** and **getPendingPrintJobs**. Developers will also have the ability to operate the printer, through such operations as **addPaper**, **addToner** and **cancelPendingPrintJobs**. In our implementation, the **PrinterManagement** dynamic service will schedule the printer to shut down every weekend. Operation **terminateScheduledTasks** permits clients to cancel all tasks scheduled for the printer by the **PrinterManagement** dynamic service.

```
1 // Fig. 25.4: PrinterManagement.java
2 // This class defines the interface for the dynamic service.
3 package com.deitel.advjhtp1.jiro.DynamicService.service;
4
```

Fig. 25.4 **PrinterManagement** interface definition (part 1 of 2).

2. Resources in the Jiro sense are not limited to physical devices on a network. They also include other dynamic services that can be accessed through the Jiro station or through other means.

```
5 // Java core package
6 import java.rmi.*;
7 import java.util.*;
8
9 // Jini core package
10 import net.jini.core.event.*;
11
12 public interface PrinterManagement
13     extends RemoteEventListener {
14
15     public void addPaper( int amount )
16         throws RemoteException;
17
18     public boolean isPrinting() throws RemoteException;
19
20     public boolean isPaperJam() throws RemoteException;
21
22     public int getPaperInTray() throws RemoteException;
23
24     public boolean isOnline() throws RemoteException;
25
26     public void cancelPendingPrintJobs() throws RemoteException;
27
28     public void terminateScheduledTasks() throws RemoteException;
29
30     public void addToner() throws RemoteException;
31
32     public String[] getPendingPrintJobs() throws RemoteException;
33 }
```

Fig. 25.4 **PrinterManagement** interface definition (part 2 of 2).

Class **PrinterManagementImpl** (Fig. 25.5) is the dynamic service implementation that we developed for the network printer simulator (class **Printer** in Fig. 25.8). Note that **PrinterManagementImpl** uses static services that we explain in subsequent sections (see Section 25.6 for more details).

```
1 // PrinterManagementImpl.java
2 // This class schedules turn-on and turn-off printer
3 // periodically and issues a log message to LogService
4 // when error events happen.
5 package com.deitel.advjhtp1.jiro.DynamicService.service;
6
7 // Java core packages
8 import java.io.Serializable;
9 import java.rmi.*;
10 import java.util.*;
11
12 // Java standard extensions
13 import javax.swing.*;
```

Fig. 25.5 **PrinterManagementImpl** implementation of interface **PrinterManagement** (part 1 of 8).

```
14 // Jini core packages
15 import net.jini.core.event.*;
16 import net.jini.core.entry.*;
17 import net.jini.core.lease.*;
18
19 // Jini extension packages
20 import net.jini.lease.LeaseRenewalManager;
21 import net.jini.lookup.entry.*;
22
23 // Jiro packages
24 import javax.fma.services.ServiceFinder;
25 import javax.fma.services.event.EventService;
26 import javax.fma.services.log.LogMessage;
27 import javax.fma.services.log.LogService;
28 import javax.fma.services.scheduling.SchedulingService;
29 import javax.fma.services.scheduling.SchedulingService.*;
30 import javax.fma.util.*;
31
32 // Deitel packages
33 import com.deitel.advjhttp1.jiro.DynamicService.printer.*;
34
35
36 public class PrinterManagementImpl
37     implements PrinterManagement {
38
39     private Printer printer;
40     private LogService logService = null;
41     private Lease observerLease;
42     private LeaseRenewalManager leaseRenewalManager;
43     private Ticket turnOffPrinter;
44     private Ticket turnOnPrinter;
45
46     // default constructor
47     public PrinterManagementImpl()
48     {
49         System.out.println( "Dynamic service started.\n" );
50
51         // start a printer
52         printer = new Printer() ;
53         Thread printerThread = new Thread( printer ) ;
54         printerThread.start();
55
56         // subscribe to printer events
57         try {
58
59             // get the event service
60             EventService eventService =
61                 ServiceFinder.getEventService();
62
63             // get the log service
64             logService = ServiceFinder.getLogService();
65 }
```

Fig. 25.5 `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 2 of 8).

```
66         // get a listener
67         PrinterEventListener listener =
68             new PrinterEventListener( this );
69
70         // subscribe as an observing listener to event with
71         // topic ".Printer.Error"
72         observerLease = eventService.subscribeObserver(
73             ".Printer.Error", listener, null, 10 * 60 * 1000 );
74
75         // renew observer listener's lease
76         leaseRenewalManager = new LeaseRenewalManager();
77         leaseRenewalManager.renewUntil(
78             observerLease, Lease.FOREVER, null );
79
80         // get the scheduling service
81         SchedulingService schedulingService =
82             ServiceFinder.getSchedulerService();
83
84         // define the schedule for turn-off printer task
85         // printer is turned off at 8:00PM every friday
86         GregorianCalendar calendar = new GregorianCalendar();
87         calendar.set( 2001, 7, 27 );
88         Date startDate = calendar.getTime();
89         calendar.set( 2003, 7, 27 );
90         Date endDate = calendar.getTime();
91         int[] monthsOff = { Calendar.JANUARY,
92             Calendar.FEBRUARY, Calendar.MARCH, Calendar.APRIL,
93             Calendar.MAY, Calendar.JUNE, Calendar.JULY,
94             Calendar.AUGUST, Calendar.SEPTEMBER,
95             Calendar.OCTOBER, Calendar.NOVEMBER,
96             Calendar.DECEMBER };
97         int[] daysOfWeekOff = { Calendar.FRIDAY };
98         int[] hoursOff = { 20 };
99         int[] minutesOff = { 0 };
100
101        // create the schedule for turn-off printer task
102        Schedule turnOffSchedule =
103            schedulingService.newRepeatedDateSchedule(
104                startDate, endDate, monthsOff, null,
105                daysOfWeekOff, hoursOff, minutesOff,
106                calendar.getTimeZone() );
107
108        // create the message description
109        LocalizableMessage turnOffMessage =
110            new LocalizableMessage( PrinterManagementImpl.class,
111                "TurnOffPrinter", null, null );
112
113        // define the handback object of the
114        // turn-off printer task
115        MarshalledObject handbackOff = new MarshalledObject(
116            new String( "turn-off" ) );
117
```

Fig. 25.5 `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 3 of 8).

```
118     // schedule task and get the Ticket for
119     // the scheduled task
120     turnOffPrinter = schedulingService.scheduleTask(
121         listener, turnOffMessage, turnOffSchedule,
122         SchedulingService.NONE, handbackOff );
123
124     // define the schedule for turn-on printer task
125     // printer is turned on at 7:00AM every Monday
126     calendar = new GregorianCalendar();
127     calendar.set( 2001, 7, 27 );
128     startDate = calendar.getTime();
129     calendar.set( 2003, 7, 27 );
130     endDate = calendar.getTime();
131     int[] monthsOn = { Calendar.JANUARY,
132         Calendar.FEBRUARY, Calendar.MARCH, Calendar.APRIL,
133         Calendar.MAY, Calendar.JUNE, Calendar.JULY,
134         Calendar.AUGUST, Calendar.SEPTEMBER,
135         Calendar.OCTOBER, Calendar.NOVEMBER,
136         Calendar.DECEMBER };
137     int[] daysOfWeekOn = { Calendar.MONDAY } ;
138     int[] hoursOn = { 7 };
139     int[] minutesOn = { 0 };
140
141     // create the schedule for turn-on printer task
142     Schedule turnOnSchedule =
143         schedulingService.newRepeatedDateSchedule(
144             startDate, endDate, monthsOn, null,
145             daysOfWeekOn, hoursOn, minutesOn,
146             calendar.getTimeZone() );
147
148     // create the message description
149     LocalizableMessage turnOnMessage =
150         new LocalizableMessage( PrinterManagementImpl.class,
151             "TurnOnPrinter", null, null );
152
153     // define the handback object of the
154     // turn-on printer task
155     MarshalledObject handbackOn = new MarshalledObject(
156         new String( "turn-on" ) );
157
158     // schedule task and get the Ticket for
159     // the scheduled task
160     turnOnPrinter = schedulingService.scheduleTask(
161         listener, turnOnMessage, turnOnSchedule,
162         SchedulingService.NONE, handbackOn );
163
164 } // end try
165
166 // handle exception scheduling task
167 catch ( Exception exception ) {
168     System.out.println( "PrinterManagementImpl: " +
169         "Exception occurred when scheduling tasks." );
```

Fig. 25.5 `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 4 of 8).

```
170     System.out.println( "Please read debug file ...\\n" );
171     Debug.debugException( "scheduling task", exception );
172 }
173
174 } // end PrinterManagementImpl constructor
175
176 // cancel scheduled tasks
177 public void terminateScheduledTasks()
178 {
179     // cancel turn-on and turn-off printer tasks
180     try {
181         turnOffPrinter.cancel();
182         turnOnPrinter.cancel();
183     }
184
185     // handle exception canceling scheduled task
186     catch ( Exception exception ) {
187         System.out.println( "PrinterManagementImpl: " +
188             "Exception occurred when canceling tasks." );
189         System.out.println( "Please read debug file ...\\n" );
190         Debug.debugException(
191             "cancel scheduled task", exception );
192     }
193
194 } // end cancel scheduled task
195
196 // add paper to printer
197 public void addPaper( int amount )
198 {
199     System.out.println(
200         "PrinterManagementImpl: Adding paper ...\\n" );
201     printer.replenishPaperTray( amount );
202 }
203
204 // is printer printing?
205 public boolean isPrinting()
206 {
207     return printer.isPrinting();
208 }
209
210 // is printer jammed?
211 public boolean isPaperJam()
212 {
213     return printer.isPaperJam();
214 }
215
216 // get printer's pages count
217 public int getPaperInTray()
218 {
219     return printer.getPaperInTray();
220 }
221
```

Fig. 25.5 `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 5 of 8).

```
222     // get pending jobs
223     public String[] getPendingPrintJobs()
224     {
225         return printer.getPendingPrintJobs();
226     }
227
228     // is printer online?
229     public boolean isOnline()
230     {
231         return printer.isOnline();
232     }
233
234     // cancel pending printing jobs
235     public void cancelPendingPrintJobs()
236     {
237         System.out.println( "PrinterManagementImpl: "
238             + "Canceling pending print jobs ... \n" );
239         printer.cancelPendingPrintJobs();
240     }
241
242     // receive notifications
243     public void notify( RemoteEvent remoteEvent )
244         throws UnknownEventException, RemoteException
245     {
246         String subString =
247             "com.deitel.advjhttp1.jiro.DynamicService.printer";
248         String source = ( String ) remoteEvent.getSource();
249         source = source.substring( 0, subString.length() );
250
251         // printer event
252         if ( source.equals( subString ) )
253             eventHandler( remoteEvent );
254
255         else // scheduled task
256             performTask( remoteEvent );
257     }
258
259     // add toner to printer
260     public void addToner()
261     {
262         System.out.println(
263             "PrinterManagementImpl: Adding toner ...\\n" );
264         printer.addToner();
265     }
266
267     // perform task when scheduled time arrives
268     private void performTask( RemoteEvent remoteEvent )
269     {
270         // perform task
271         try {
272
```

Fig. 25.5 `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 6 of 8).

```
273     // get task type
274     String type =
275         ( String ) remoteEvent.getRegistrationObject().get();
276
277     // turn-off printer
278     if ( type.equals( "turn-off" ) )
279         printer.setOffline();
280
281     // turn-on printer
282     else if ( type.equals( "turn-on" ) )
283         printer.setOnline();
284 }
285
286     // handle exception performing scheduled task
287     catch ( Exception exception ) {
288         System.out.println( "PrinterManagementImpl: " +
289             "Exception occurred when performing tasks." );
290         System.out.println( "Please read debug file ...\\n" );
291         Debug.debugException(
292             "perform scheduled task", exception );
293     }
294
295 } // end method performTask
296
297 // handle event
298 private synchronized void eventHandler (
299     RemoteEvent remoteEvent )
300 {
301     String source = ( String ) remoteEvent.getSource();
302
303     // generate the log message
304     Serializable params[] = new Serializable[ 2 ];
305     params[ 0 ] = source;
306     params[ 1 ] = new Date();
307
308     // define localizable message
309     LocalizableMessage localizableMessage =
310         new LocalizableMessage( PrinterManagementImpl.class,
311             "Event", params, Locale.US );
312
313     // define log message
314     LogMessage logMessage = new LogMessage(
315         localizableMessage, LogMessage.TRACE + ".printer."
316         + source, null );
317
318     // post the log message
319     try {
320         logService.log( logMessage );
321     }
322 }
```

Fig. 25.5 `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 7 of 8).

---

```

323     // handle exception posting log message
324     catch ( Exception exception ) {
325         System.out.println( "PrinterManagementImpl: " +
326             "Exception occurred when posting log message." );
327         System.out.println( "Please read debug file ...\\n" );
328         Debug.debugException( "log service", exception );
329     }
330 }
331 } // end eventHandler
332
333 // entry object
334 private Entry[] getLookupEntries()
335 {
336     return ( new Entry[] {
337         new ServiceInfo( "PrinterManagementImpl",
338             "Deitel Association, Inc.",
339             "Deitel Association, Inc",
340             "1.0", "Model 0", "0.0.0.1" )
341     });
342 };
343 }
344 }
```

---

**Fig. 25.5** `PrinterManagementImpl` implementation of interface `PrinterManagement` (part 8 of 8).

Access to dynamic services occurs through proxy objects that a client instantiates. The `jirocw` tool generates a dynamic service's proxy class at deployment time. We discuss the deployment of this management application in Section 25.7. We generate `PrinterManagementImplProxy`—the proxy class for dynamic service implementation `PrinterManagementImpl`—using the `jirocw` tool. The only means by which a dynamic service can be instantiated is through instantiating its proxy object. When a client instantiates `PrinterManagementImplProxy`, the proxy remotely calls the no-argument constructor of the `PrinterManagementImpl` dynamic service.

If the dynamic service implements method `getLookupEntries` (lines 334–343), the Jiro station submits a `PrinterManagementImplProxy` reference to the domain's Jini lookup service with the `Entry` attributes returned by `getLookupEntries` at instantiation time. Dynamic services and clients wanting to interact with the `PrinterManagement` dynamic service after a different client instantiates the proxy, must do so through the `PrinterManagementImplProxy` reference stored in the Jini lookup service.

Lines 52–54 start the thread that will simulate the printer we are managing. Class `Printer`'s `run` method controls the thread. Lines 60–82 obtain references to several static services used by the `PrinterManagement` dynamic service. We mention each static service here and discuss each in detail in Section 25.6. The standard static services are obtained through helper class `ServiceFinder` (discussed in Section 25.6.1). Lines 60–61 obtain a reference to the *event service* (see Section 25.6.2). Line 64 obtains a reference to the *log service* (Section 25.6.3). Lines 67–68 create a new `PrinterEventListener` to listen for events originating from the `Printer`. Lines 72–73 subscribe `PrinterEventListener` in the event service. Lines 80–81 renew the lease granted to the listener. Lines 81–82 obtain a reference to the *scheduling service* (Section 25.6.4). Lines

86–122 and 126–162 schedule two events—*turn printer off* and *turn printer on*—to occur every weekend.

Method **terminateScheduledTasks** (lines 177–194) will terminate all scheduled tasks. Method **addPaper** will add paper to the printer by delegating its call to **Printer**. Methods **isOnline**, **isPrinting**, **isPaperJam**, **getPaperTray**, **getPendingPrintJobs**, **addToner** and **cancelPendingPrintJobs** follow the pattern of **addPaper**, delegating calls to their respective methods in **Printer**.

Method **notify** (lines 243–257) receives delegated notifications from a **PrinterEventListener** and determines whether the event notification is an event triggered by **Printer** or by the scheduling service. Method **notify** calls to method **performTask** (lines 268–295) if the event received was triggered by the scheduling service. Lines 252–256 determine the type of event and perform the corresponding action. Method **notify** makes a call to method **eventHandler** (lines 298–331) if the event received was triggered by the **Printer**. Method **eventHandler** logs a message pertaining to the event received (lines 304–320).

Lines 334–343 implement method **getLookupEntries**—the only way to declare a class as a dynamic service. A class that presents a declaration of method **getLookupEntries** is called a *point object*. Dynamic services may involve more than one class to provide the underlying definition of a dynamic service. The Jiro specification states that only one object, the *entry point* for a dynamic service instance, may exist. Instantiating the entry-point object is the only allowed way to instantiate a dynamic service and the classes on which it depends. Method **getLookupEntries** returns a set of entries. These entries are used by the station to register the dynamic service's proxy in the Jini lookup service of the domain.

Figure 25.6 (**PrinterEventListener.java**) is the event listener instantiated in **PrinterManagementImpl** lines 67–68. **PrinterEventListener** implements interface **RemoteEventListener**—Jiro requires this for all event subscribers. Figure 25.6 shows our **RemoteEventListener** implementation. The event service calls method **notify** (lines 36–41) when an event occurs

```
1 // PrinterEventListener.java
2 // This class defines the listener that listens for events
3 // issued by a printer.
4 package com.deitel.advjhtp1.jiro.DynamicService.service;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.rmi.server.UnicastRemoteObject;
9
10 // Jini core packages
11 import net.jini.core.event.*;
12
13 public class PrinterEventListener
14     implements RemoteEventListener {
15
16     private RemoteEventListener eventListener;
```

Fig. 25.6 **PrinterEventListener** used by all classes subscribed for events from **Printer** (part 1 of 2).

```
17 // PrinterEventListener constructor
18 public PrinterEventListener( RemoteEventListener listener )
19 {
20     eventListener = listener;
21
22     // export the stub object
23     try {
24         UnicastRemoteObject.exportObject( this );
25     }
26
27     // handle exception exporting stub
28     catch ( RemoteException remoteException ) {
29         remoteException.printStackTrace();
30     }
31
32 }
33 // end PrinterEventListener constructor
34
35 // receive the notification
36 public void notify( RemoteEvent remoteEvent )
37     throws UnknownEventException, RemoteException
38 {
39     // forward notification
40     eventListener.notify( remoteEvent );
41 }
42 }
```

Fig. 25.6 **PrinterEventListener** used by all classes subscribed for events from **Printer** (part 2 of 2).

## 25.6 Static Services

**Printer** (Fig. 25.8) and **PrinterManagementImpl** (Fig. 25.5) use Jiro's static services. **Printer** publishes events to the event service (line 320 of Fig. 25.8). Class **PrinterManagementImpl** uses the event service to listen for events, the log service to record messages pertaining to events received and the scheduling service to schedule the printer to go offline for servicing every week from 8PM on Friday to 7AM on Monday. The following subsections explain how to obtain and use Jiro's static services. The case study does not use all the static services provided by Jiro, so the following sections discuss the remaining services.

### 25.6.1 Locating Static Services with Class **ServiceFinder**

Before using the static services, we need to get the service proxies of these static services. Class **ServiceFinder** (package `javax.fma.service`) provides methods for locating the static services. The class contains ten methods—two for each static service. To get the proxy for a static service, an application or dynamic service either calls method **ServiceFinder.getServiceName** with no arguments, which locates the service for the local management domain<sup>3</sup>, or calls method **ServiceFinder.getServiceName** with an argument that specifies the management domain, which locates the service for that specific management domain. For example, method **getLogService** with no arguments returns

the log service for the local management domain. Similarly, static services can also be found through the Jini lookup service. **ServiceFinder** is a convenience class that encapsulates the calls to the Jini lookup service.

## 25.6.2 Event Service

*Event* objects encapsulate an action that happened in a network (locally or remotely). They allow actions that occur in one part of the network to be handled in another part. *Publish-subscribe* event systems, such as Jiro's, are one type of event-driven network. Such networks generally are composed of three types of elements—the *event publisher* that propagates events throughout the network, the *event subscriber* that listens on one end of the network for events that are published and the events. The *event service* is a bridge between the event publisher and the event subscriber. In the context of Jiro, an event publisher posts an event or series of events to the event service. An event subscriber receives the event(s) from the event service. The event subscriber can subscribe to types of events—also known as *topics* of events—that have not yet been published.

An event subscriber can subscribe to the event service as an *observer listener* or a *responsible listener*. An observer listener can receive an event, but cannot handle or consume an event. A responsible listener has special priority to respond and consume specific events. Responsible listeners must decide whether or not to consume an event. If a responsible listener decides not to consume an event, its **notify** method must throw an **EventNotHandledException**. This causes the event service to propagate the event to the next responsible listener in the chain.

Jiro's event service uses the *Chain-of-Responsibility design pattern* to ensure that a responsible listener handles an event. Often, a system needs to determine at run time the object that will handle a particular message. For example, consider the design of a three-line office phone system. When a person calls the office, the first line handles the call—if the first line is busy, the second line handles the call, and if the second line is busy, the third line handles the call. If all lines in the system are busy, an automated speaker instructs that person to wait for the next available line—when a line becomes available, that line handles the call. When an event occurs that applies to both responsible listeners and observer listeners, all observer listeners and the first responsible listener in the chain will get the event.

The Chain-of-Responsibility design pattern enables a system to determine at run time the object that will handle a message. This pattern allows an object to send a message to several objects in a *chain* of objects. Each object in the chain either may handle the message or pass the message to the next object in the chain. For instance, the first line in the phone system is the first object in the chain of responsibility, the second line is the second object, the third line is the third object, and the automated speaker is the fourth object. Note that this mechanism is not the final object in the chain—the next available line handles the message, and that line is the final object in the chain. The chain is created dynamically in response to the presence or absence of specific message handlers. In Jiro, the event publisher sends an event to a responsible listener—if the listener cannot handle the event, the Event Service sends the event to another responsible listener. The Event Service propagates this event to other listeners, until a listener handles the event.

- 
3. Clients can find the local management domain information through the **javax.fma.domain** system property.

Class **PrinterManagementImpl** (Fig. 25.5) is an example of a class that subscribes a listener to the event service. Class **PrinterManagementImpl** registers its **PrinterEventListener** as an observer listener upon initialization. Lines 72–73 subscribe to events with “**.Printer.Error**” as their *topic*. Method **subscribe-Observer** takes four arguments—a **String** that specifies the topic of the event, a listener that implements the **RemoteEventListener** so that notifications can be sent when the event service receives events for that topic, a **MarshalledObject** that is passed to the listener with each event (may be **null**) and a **long** value that specifies the length of the lease for the listener’s subscription. In the Jiro architecture, topics classify events and enable the event service to deliver events to the proper subscriber(s). A topic is a dot-delimited **String** that defines a tree-like structure. This structure helps identify event types and related subtypes.

All event types start at the root—“**.**”. A simple dot represents the root of the tree-like structure. All elements belong to the root; therefore, all event topics match the “**.**” string. “**.A**” represents all events of topic “**.A**”. To define a subtype for this topic, append a period and the subtype name. Examples of two possible subtype topics for event topic “**.A**” could be “**.A.aa**” and “**.A.bb**”. If an event subscriber registers with the event service as an observer for all events of topic “**.A**”, the event subscriber will receive events of topic “**.A**” as well as events of topic “**.A.aa**” and “**.A.bb**”. If a listener subscribes to event topics of type “**.A.bb**”, only events of type “**.A.bb**” and its subtypes will be received.

Any event object posted to the event service must extend **Event** (package **javax.fma.services.event**). Class **PrinterErrorEvent** (Fig. 25.7) extends class **Event**. **Event** classes must implement method **clone**, so that the event service can copy event-objects and pass them to all the subscribed listeners (lines 18–21).

```

1 // PrinterErrorEvent.java
2 // This class defines the events issued by a printer.
3 package com.deitel.advjhttp1.jiro.DynamicService.printer;
4
5 // Jiro package
6 import javax.fma.services.event.Event;
7
8 public class PrinterErrorEvent
9     extends Event implements Cloneable {
10
11     // PrinterErrorEvent constructor
12     public PrinterErrorEvent( Object source, String topic )
13     {
14         super ( source, topic );
15     }
16
17     // clone event
18     public Object clone()
19     {
20         return new PrinterErrorEvent( source, getTopic() );
21     }
22 }
```

Fig. 25.7 Custom error class thrown by Printer.

Class **Printer** (Fig. 25.8) is a slightly different implementation from class **PrinterSimulator** implementation presented in Chapter 24. (See Chapter 24 for implementation details on class **Printer**). Class **Printer** is an example of a class that publishes events to the event service. Method **fireEvent** (lines 308–328) publishes all events originating from the printer. Lines 314–317 create a **PrinterErrorEvent** (Fig. 25.7) object and initialize it to the proper value. The first argument in the **PrinterErrorEvent** is the source. We have chosen our source to be a **String** that describes where the event originated, plus additional information pertaining to the type of event that occurred. The second argument contains the event topic. The topic's root is **".Printer.Error"**; the child of the event can be either **OutofPaper**, **LowToner** or **PaperJam**. A source of an event can be any object except **null**. To post an event, call method **post** (line 320). Method **post** takes one argument—the event to post for delivery to the listeners.

```
1 // Printer.java
2 // This class simulates a printer device on a network.
3 // deitel package
4 package com.deitel.advjhttp1.jiro.DynamicService.printer;
5
6 // java core package
7 import java.util.Stack;
8 import java.rmi.*;
9 import java.io.*;
10
11 // Jiro packages
12 import javax.fma.services.ServiceFinder;
13 import javax.fma.services.event.EventService;
14 import javax.fma.util.*;
15
16 public class Printer implements Runnable {
17
18     private Stack printerStack = new Stack();
19     private boolean isPrinting = false;
20     private boolean isPaperJam = false;
21     private boolean isOnline = true;
22
23     // 50 sheets of paper in tray
24     private int paperInTray = 50;
25
26     // 100% full of ink
27     private int tonerCartridge = 100;
28
29     private String currentPrintJob;
30     private boolean isAlive = true;
31
32     private EventService eventService;
33
34     // printer constructor
35     public Printer()
36     {
```

Fig. 25.8 Printer simulator implementation (part 1 of 7).

```
37     // get EventService at gaven management domain
38     try {
39         eventService = ServiceFinder.getEventService();
40     }
41
42     // handle exception getting EventService
43     catch ( Exception exception ) {
44         Debug.debugException(
45             "getting EventService", exception );
46     }
47 }
48
49 // stops execution of thread
50 public void stop()
51 {
52     isAlive = false;
53 }
54
55 // main life-cycle of the printer.
56 // prints one job from print job stack
57 // 1) if offline, it pauses and waits.
58 // 2) if online, handles one print job
59 public void run()
60 {
61     // main loop within thread
62     while ( isAlive ) {
63
64         // printer will be offline
65         if ( !isOnline ) {
66
67             synchronized ( this ) {
68
69                 // waits for printer become online
70                 try {
71                     wait();
72                 }
73
74                 // handle exception waiting
75                 catch ( InterruptedException exception ) {
76                     Debug.debugException(
77                         "printer wait", exception );
78                 }
79
80             } // end synchronized
81
82         } // end if
83
84         // prints one job from print job stack
85         startPrintingProcess();
86
87     } // end while
88 }
89 }
```

Fig. 25.8 Printer simulator implementation (part 2 of 7).

```
90     // start printing process
91     private synchronized void startPrintingProcess()
92     {
93         // warm up the printer, print top print job from print
94         // stack and adjust paper values and toner values
95         try {
96
97             // warm up printer for incoming batch of print jobs
98             Thread.sleep( 1000 * 2 );
99
100            if ( isOnline && ( paperInTray > 0 ) &&
101                ( tonerCartridge > 10 ) && ( !isPaperJam ) ) {
102
103                // start the printing process
104                currentPrintJob = getNextPrintJob();
105                isPrinting = true;
106
107                // 12 seconds to print a normal document
108                Thread.sleep( 1000 * 12 );
109
110                // each print job uses 10 pages
111                updatePaperInTray( paperInTray - 10 );
112                updateToner();
113                updatePaperJam();
114                isPrinting = false;
115
116                // make sure no references are left dangling
117                currentPrintJob = null;
118
119            } // end if
120        }
121
122        // handle exception starting printing process
123        catch( InterruptedException exception ) {
124            Debug.debugException(
125                "starting printing process", exception );
126        }
127
128    } // end method startPrintingProcess
129
130    // returns current printed job
131    private String getCurrentPrintJob()
132    {
133        return currentPrintJob;
134    }
135
136    // update amount of paper in paper tray
137    private synchronized void updatePaperInTray( int newValue )
138    {
139        paperInTray = newValue;
```

Fig. 25.8 Printer simulator implementation (part 3 of 7).

```
141     // fire event if paper tray low
142     if ( paperInTray <= 0 ) {
143         System.out.println( "Printer: out of paper. " );
144         fireEvent( "OutofPaper" );
145     }
146 }
147
148 // is paper jammed?
149 public boolean isPaperJam()
150 {
151     return isPaperJam;
152 }
153
154 // is printer printing?
155 public boolean isPrinting()
156 {
157     return isPrinting;
158 }
159
160 // is printer online?
161 public boolean isOnline()
162 {
163     return isOnline;
164 }
165
166 // return number of pages in paper tray
167 public synchronized int getPaperInTray()
168 {
169     return paperInTray;
170 }
171
172 // update amount of toner available in toner cartridge
173 public synchronized void updateToner()
174 {
175     // after every print job, toner levels drop 1%
176     tonerCartridge = tonerCartridge - 1;
177
178     // fire event if toner is low
179     if ( tonerCartridge <= 10 ) {
180         System.out.println( "Printer: low toner. " );
181         fireEvent( "LowToner" );
182     }
183 }
184
185 // update paper jam
186 public synchronized void updatePaperJam()
187 {
188     if ( Math.random() > 0.9 ) {
189         isPaperJam = true;
190         System.out.println( "Printer: paper jam. " );
191         fireEvent( "PaperJam" );
192     }
193 }
```

Fig. 25.8 Printer simulator implementation (part 4 of 7).

```
194
195 // return amount of toner in toner cartridge
196 public synchronized int getToner()
197 {
198     return tonerCartridge;
199 }
200
201 // replenishes amount of paper in paper tray to specified
202 // value
203 public void replenishPaperTray ( int paperStack )
204 {
205     System.out.println( "Printer: adding " + paperStack
206                         + " pages to printer . . . \n" );
207     updatePaperInTray ( paperInTray + paperStack ) ;
208 }
209
210 // generates a random number of print jobs with varying IDs
211 private synchronized void populatePrintStack()
212 {
213     int numOfJobs = ( int ) ( Math.random ( ) * 10 ) + 1;
214
215     // generate print jobs
216     for ( int i = 0; i < numOfJobs ; i++ ) {
217
218         synchronized ( printerStack ) {
219             printerStack.add ( "PRINT_JOB_ID #" + i );
220         }
221     }
222 }
223
224 // add toner
225 public synchronized void addToner()
226 {
227     System.out.println( "Printer: adding toner . . . \n" );
228     tonerCartridge = 100;
229 }
230
231 // cancel pending print jobs
232 public synchronized void cancelPendingPrintJobs()
233 {
234     synchronized ( printerStack ) {
235         printerStack.clear();
236     }
237 }
238
239 // return next print job in stack, populating the stack
240 // if it is empty
241 private synchronized String getNextPrintJob()
242 {
243     if ( printerStack.isEmpty() ) {
244         populatePrintStack ( );
245 }
```

Fig. 25.8 Printer simulator implementation (part 5 of 7).

```
246         // simulates absence of print jobs
247         try {
248             Thread.sleep (
249                 ( int ) ( Math.random() * 1000 * 10 ) );
250         }
251
252         // handle exception thread sleep
253         catch ( InterruptedException exception ) {
254             Debug.debugException(
255                 "getting next print job", exception );
256         }
257     }
258
259     // Remove topmost queued resource.
260     String nextJob;
261
262     synchronized ( printerStack ) {
263         nextJob = ( String ) printerStack.pop();
264     }
265
266     return nextJob;
267
268 } // end method getNextPrintJob
269
270 // return all jobs yet to be printed
271 public synchronized String[] getPendingPrintJobs()
272 {
273     String[] pendingJobs;
274
275     // create array of pending print jobs
276     synchronized ( printerStack ) {
277         Object[] temp = printerStack.toArray() ;
278         pendingJobs = new String[ temp.length ] ;
279
280         for ( int i = 0; i < pendingJobs.length ; i++ ) {
281             pendingJobs [ i ] = ( String ) temp[ i ];
282         }
283     }
284
285     return pendingJobs;
286 }
287
288 // set printer status to online
289 public void setOnline()
290 {
291     System.out.println( "Printer: setting online ... \n" );
292     isOnline = true;
293
294     // notify all waiting states
295     synchronized ( this ) {
296         notifyAll() ;
297     }
298 }
```

Fig. 25.8 Printer simulator implementation (part 6 of 7).

```
299      // set printer status to offline
300  public void setOffline()
301  {
302      System.out.println( "Printer: setting offline ... \n" );
303      isOnline = false;
304  }
305
306
307      // fire event
308  private void fireEvent( String error )
309  {
310      // post event to EventService
311      try {
312
313          // define event
314          PrinterErrorEvent event = new PrinterErrorEvent(
315              "com.deitel.advjhttp1.jiro.DynamicService.printer."
316              + "ErrorMessage=" + error,
317              ".Printer.Error." + error );
318
319          // post event
320          eventService.post( event );
321      }
322
323      // handle exception posting event
324      catch ( Exception exception ) {
325          Debug.debugException( "posting event", exception );
326      }
327
328  } // end method fireEvent
329 }
```

Fig. 25.8 Printer simulator implementation (part 7 of 7).

### 25.6.3 Log Service

The *log service* can be used to log information when an important event such as application invocation or an error occurs. The log service provides methods **log** and **search** to access to the log repository. Each message written to the log repository must be in the form of a **javax.fma.service.log.LogMessage** object. The log service is internationalized. This means that applications can adapt logged messages for viewing in different languages and different regions. The client or the service can either post a log message to the log service or retrieve log messages from the log service, obeying search criteria.

Class **PrinterManagementImpl** (Fig. 25.5) uses the log service to log every event it receives from the printer. This class uses **ServiceFinder** to get the service proxy for the log service. Line 64 of **PrinterManagementImpl** gets the log service by calling method **ServiceFinder.getLogService** with no arguments.

A log message contains a localizable message (a message in a format that any application can convert to a readable format for a given locale), a category to specify the type of log message and a **Throwable**—posted if the message is created when an error condition arises. The category of a log message must be a dot-delimited **String** that begins with

one of the following standard categories: `LogMessage.AUDIT`, `LogMessage.DEBUG`, `LogMessage.WARNING`, `LogMessage.INFO`, `LogMessage.ERROR`, `LogMessage TRACE`. Lines 309–311 of `PrinterManagementImpl` create a localizable message. The `LocalizableMessage` (package `javax.fma.util`) constructor takes four arguments—a `Class` representing the localization resource file, a `String` that specifies the message key, an array of `Serializable` objects and a `Locale` that is used to create the fall-back text for this message. Both the `Class` and the `String` arguments passed to the `LocalizableMessage` cannot be `null`, otherwise an `IllegalArgumentException` will be thrown. Both the `Serializable` array and the `Locale` may be `null`. Both serve special purposes that are out of the scope of this example—the `Serializable` array serves as a way of storing object types within the message,<sup>4</sup> `Locale` helps specify what language format the message is originally stored in. If a client cannot convert the `LocalizableMessage` to its current locale, then the log service generates a fall-back message, using the `Locale`. If a client passes `null` as the `Locale` argument, the default locale is used. In this example, the class specifies the `PrinterManagementImpl.class` as the root of the resource file and "TurnOnPrinter" as the message key. A `properties` file that will be associated to `LocalizableMessage` must be created and be placed in a specified directory. Instructions on how to create the `properties` file will be provided shortly. The `properties` file contain a "key=value" pair with "TurnOnPrinter" as the message key.

The log message is created in lines 314–316 of `PrinterManagementImpl`. The `LogMessage` (package `javax.fma.service.log`) constructor takes three arguments—a `LocalizableMessage` that contains the message, a `String` that indicates the category of the message and a `Throwable` that contains the stored exceptions. Both the `LocalizableMessage` argument and the category `String` arguments cannot be `null`. The `Throwable` argument can be `null`. The class specifies the category of the log message as `TRACE.printer.source`, where `source` is the event source. Line 320 of `PrinterManagementImpl` posts the log message to the log service by calling method `log` of interface `LogService`.

Before executing an application that uses the log service, you must provide a resource file. The resource file for `PrinterManagementImpl` must have the name `PrinterManagementImpl.properties`. This file should be stored in the `resources` directory where `PrinterManagementImpl.class` is located. In our example, `PrinterManagementImpl.class` is located at

```
C:\com\deitel\advjhttp1\jiro\DynamicService\service
```

so the `PrinterManagementImpl.properties` resource file should be located at

```
C:\com\deitel\advjhttp1\jiro\DynamicService\service\resources
```

The resource file contains `messageKey=messageText` pairs. Both the message key and the message text must be strings. Figure 25.9 shows the resource file used in `PrinterManagement` application.

4. Contents of the serializable array will replace the numbers enclosed within braces (e.g., `{0}`, `{1}`, `{2}`) in a log message template obtained from the `properties` file.

```
1 Event = {0} event occurred on {1}.
2 TurnOffPrinter = Turn off the printer.
3 TurnOnPrinter = Turn on the printer.
```

Fig. 25.9 `PrinterManagementImpl.properties` file.

The Jiro SDK has a `viewlog` tool to view log messages. To start the `viewlog` tool, open a command prompt and type

```
viewlog -domain jiro:JIROTEST
```

This command starts the `viewlog` tool, which displays log messages for domain `jiro:JIROTEST`. Figure 25.32 shows the `viewlog` tool GUI. For information about how to use this tool, refer to the *Jiro Technology SDK programmer's Reference* in the Jiro SDK installation directory's `docs` subdirectory. The Jiro Technology SDK Programmer's Reference is available in PDF (`install_config.pdf`) and postscript (`install_config.ps`) formats.



### Common Programming Error 25.1

Class `LocalizableMessage` throws a `javax.fma.util.LocalizableMessage.LocalizationError` if the resource file does not exist, the location of the resource file is not correct or the resource file does not contain the message key.



### Software Engineering Observation 25.3

Starting Jiro with the `Clean before start` checkbox checked clears the log messages.

## 25.6.4 Scheduling Service

The *scheduling service* schedules tasks that to be performed at future times. The scheduling service provides methods to schedule tasks at specific times, repeatedly for a specific duration or repeatedly according to calendar dates.

Class `PrinterManagementImpl` (Fig. 25.5) uses the scheduling service to schedule the shutdown of the printer during the week, from Friday at 8PM to Monday at 7AM. Lines 81–82 obtain the scheduling service. All schedules are created by using a factory method that the scheduling service provides.

Lines 86–162 create a schedule for two tasks that will be performed based on a calendar date. `PrinterManagement` performs two tasks: shut down printer on Friday at 8PM and turn on printer on Monday at 7AM. The tasks are performed by two separate scheduled events. In both cases, method `newRepeatedDateSchedule` schedules the events. Method `newRepeatedDateSchedule` takes eight arguments—a `Date` that specifies the date and time on which the task will first be performed; a `Date` that specifies the date and time after which no task will be performed; an `int` array that specifies the months (0–11) during which the task will be performed; an `int` array that specifies the days in a month on which the task will be performed; an `int` array that specifies the days in a week on which the task will be performed; an `int` array that specifies the hours (0–23) at which the task will be performed; an `int` array that specifies the minutes (0–59) at which the task will be performed; and a `TimeZone` that specifies the time zone in which the task will be performed. If any of the arguments are `null`, an `IllegalArgumentException` occurs.

Method `newRepeatedDateSchedule` returns a `Schedule` object. Lines 102–106 and 160–162 of `PrinterManagementImpl` create the message descriptions for each schedule created. These descriptions are passed to method `scheduleTask` to schedule the task. Method `scheduleTask` takes five arguments—a task that implements `RemoteEventListener`, a `LocalizableMessage` that describes the task, a `Schedule` on which the task runs, an `int` that states the late-performance policy and a `MarshalledObject` that the scheduling service passes to the task listener when the scheduled event is fired. In our case, the `MarshalledObject` will be a `String` object that describes what task the dynamic service should perform. The task, the description of the task and the schedule of the task cannot be `null`, otherwise an `IllegalArgumentException` occurs. The late-performance policy specifies those tasks that must be performed upon restarting if a scheduling service misses scheduled tasks, such as during system shut down or for any reason that renders the service inoperable. There are three choices for the late performance policy—`SchedulingService.NONE` indicates no late performances, `SchedulingService.ONE` indicates one late performance and `SchedulingService.ALL` indicates the maximum integer value of `Integer` worth of late performances. If the policy is set to `NONE`, then late performances are not allowed. If the policy is set to `ONE`, then only one late performance is allowed. If the policy is set to `ALL`, then all late performances are allowed. Method `scheduleTask` returns a `Ticket` object that can be used later to cancel the task.

A listener that implements the `RemoteEventListener` interface is required to schedule tasks. At the scheduled times, the scheduling service calls method `notify` of classes implementing interface `RemoteEventListener`. The implementation of method `notify` performs or delegates the tasks received. Class `PrinterEventListener` (Fig. 25.6) is the `RemoteEventListener` in this example.

## 25.7 Dynamic Service Deployment

Various command-line tools provided by Jiro facilitate the complicated task of dynamic service deployment.

The first step in deploying our dynamic service is to generate a proxy for our dynamic services. Generating a proxy creates the entry-point object that is remotely accessible to clients. The proxy also is responsible for instantiating the dynamic service each time the proxy constructor is called. Jiro provides two tools to generate the proxy for a dynamic service—`jiroc` and `jirocw` (available in the `bin` directory of the Jiro SDK installation). The `jiroc` tool is a GUI tool to generate the proxy, while the `jirocw` tool is a command-line tool to generate the proxy. These tools are available in the `bin` directory of the Jiro SDK installation. To generate the proxy with `jirocw`, first compile the interface and implementation of the service (`PrinterManagement.java` and `PrinterManagementImpl.java`). These examples are compiled under Windows 2000. For instructions on how to compile under different operating systems, please refer to Java documentation. We assume that the JiroSDK was installed at the location `c:\jirosdk`.

You will need to set a `JIRO_CLASSPATH` environment variable. This variable contains the path to all necessary `JAR` files located in the `JiroSDK\lib` directory—`jini-core.jar`, `jini-ext.jar`, `jiro.jar`, and `jiro-tools.jar`. For the Windows 2000 environment, the following command line sets the `JIRO_CLASSPATH`:

```
set JIRO_CLASSPATH=
  c:\jirosdk\lib\jini-core.jar;
  c:\jirosdk\lib\jini-ext.jar;
  c:\jirosdk\lib\jiro.jar;
  c:\jirosdk\lib\jiro-tools.jar
```

[Note: You can also set this environment variable permanently, so you do not need to type the preceding command in each new command window.] The following command lines compile the necessary files for our case study:

```
javac -classpath .;%JIRO_CLASSPATH% com\deitel\
      advjhttp1\jiro\DynamicService\common\*.java

javac -classpath .;%JIRO_CLASSPATH% com\deitel\
      advjhttp1\jiro\DynamicService\printer\*.java

javac -classpath .;%JIRO_CLASSPATH% com\deitel\
      advjhttp1\jiro\DynamicService\service\*.java
```

**PrinterManagement.class** should now exist. Next, use command **jirocw** to generate the dynamic-service entry-point-object proxy file<sup>5</sup>:

```
jirocw com.deitel.advjhttp1.jiro.DynamicService.service.
      PrinterManagementImpl
```

The resulting file (**PrinterManagementProxy.java**) is located in the **com\deitel\advjhttp1\jiro\DynamicService\service** directory. Next, compile the newly generated proxy file with the command:

```
javac -classpath .;%JIRO_CLASSPATH% com\deitel\
      advjhttp1\jiro\DynamicService\service\
      PrinterManagementImplProxy.java
```

**PrinterManagement** subscribes **PrinterEventListener** as an observer listener, therefore it must implement **RemoteEventListener** which uses RMI to deliver events. Generate the proxy stub for **RemoteEventListener** with the following command line:

```
rmic -classpath .;%JIRO_CLASSPATH% com.deitel.
      advjhttp1.jiro.DynamicService.service.PrinterEventListener
```

The next step involves creating a deployment **JAR** file that will contain all of our dynamic service's class files, plus all related properties files. The following command line generates a **JAR** file called **PrinterManagementService.jar**:

```
jar -cvf PrinterManagementService.jar
  com\deitel\advjhttp1\jiro\DynamicService\common\*.class
  com\deitel\advjhttp1\jiro\DynamicService\printer\*.class
  com\deitel\advjhttp1\jiro\DynamicService\service\*.class
  com\deitel\advjhttp1\jiro\DynamicService\service\resources\
  *.properties
```

5. The root directory (in this case `c:\`) must be in CLASSPATH, because **jirocw** does not include a classpath parameter option.

We must create an *interface JAR* file. The interface JAR file contains all the interfaces that a dynamic service implements plus the classes these interfaces depend on:

```
jar -cvf PrinterManagementService-ifc.jar
    com\deitel\advjhtp1\jiro\DynamicService\service\
        PrinterManagement.class
    com\deitel\advjhtp1\jiro\DynamicService\service\
        PrinterManagementImplProxy.class
```

We also must create a *download JAR* file. The download **JAR** file contains all the classes that the clients of the dynamic service might need to load dynamically:

```
jar -cvf PrinterManagementService-dl.jar
    com\deitel\advjhtp1\jiro\DynamicService\service\
        PrinterManagement.class
    com\deitel\advjhtp1\jiro\DynamicService\service\
        PrinterManagementImplProxy.class
```

Finally, we must create an *implementation JAR* file. The implementation **JAR** file contains all the classes required to run the dynamic service.

```
jar -cvf PrinterManagementService-impl.jar
    com\deitel\advjhtp1\jiro\DynamicService\common\*.class
    com\deitel\advjhtp1\jiro\DynamicService\printer\*.class
    com\deitel\advjhtp1\jiro\DynamicService\service\*.class
    com\deitel\advjhtp1\jiro\DynamicService\service\resources\
        *.properties
```

At this point, all the files required by the **jarpackw** tool have been created. The **jarpackw** tool creates the **JAR** files we need to deploy dynamic services. To use the **jarpackw** tool, type

```
jarpackw -pool %JIRO_CLASSPATH%
    c:\PrinterManagementService.jar
    -ifc PrinterManagementService-ifc.jar
    -impl PrinterManagementService-impl.jar
    -dl PrinterManagementService-dl.jar
```

The **-pool** option specifies the path to the source and the JAR files needed to execute the dynamic service. The **-ifc** option specifies the interface JAR file. The **-impl** option specifies the implementation JAR file. The **-dl** option specifies the download JAR file.

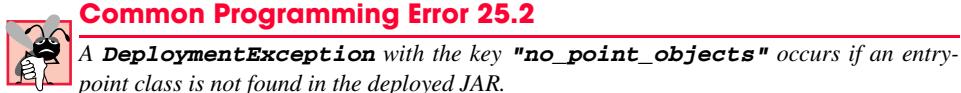
Finally, **jardeploy** tool deploys our dynamic service in the specified domain:

```
jardeploy -station SharedJiroStation -domain domainName
    -impl PrinterManagementService-impl.jar
    -dl PrinterManagementService-dl.jar -verbose -inventory
```

where *domainName* is the domain name in which to deploy our dynamic service. The command-line option **station** specifies the deployment station name. In this case, **SharedJiroStation** is the default name given to the Jiro station during installation. The **domain** option specifies the management domain on which the station is running. The **impl** option specifies the implementation JAR file. The **dl** option specifies the download **JAR** file. The **verbose** option activates the verbose mode to display status information

on the deployment of the dynamic service. The **inventory** option prints out the inventory of the station that contains deployed dynamic services.

If deployment is successful, the **jardeploy** tool displays the deployment results in the **Output** panel of the **Igniter** GUI. Figure 25.10 shows the deployment results.



### 25.7.1 Dynamic-Service Usage

Deployment does not instantiate our dynamic service. We must do this by constructing an instance of the proxy we generated using the **jirockw** tool. **PrinterManagementStarter** (Fig. 25.11) is a class that remotely instantiates the **PrinterManagementImpl** dynamic service.

A **StationAddress** identifies the station to which we will connect. The **StationAddress** constructor requires eight arguments—a **String** that specifies the management domain on which the station runs, a **String** that specifies the role of the station, and six other fields inherited from the **ServiceInfo** entry.<sup>6</sup> Line 35 calls **PrinterManagementImplProxy** constructor. Upon initialization, the Jiro station will register the proxy stub of **PrinterManagementImpl** in the Jini lookup service. From this point forward, all clients use this stub located in the lookup service to access the **PrinterManagementImpl** instance. Compile class **PrinterManagementStarter** and execute it to instantiate the **PrinterManagement** dynamic service.

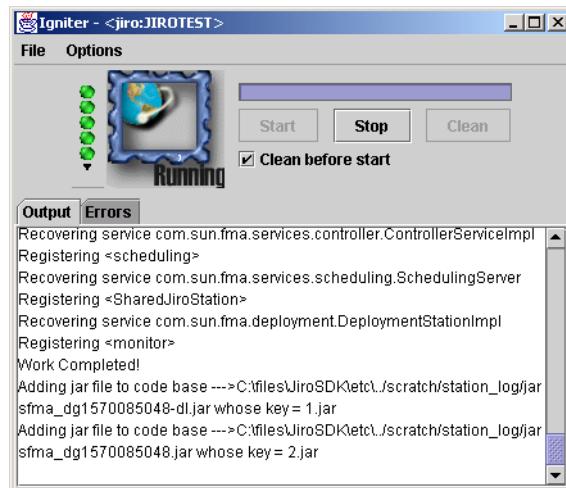


Fig. 25.10 Deployment results.

6. **StationAddress**'s fields are used to match Station Proxies registered in the Jini lookup service. All non **null** fields are matched exactly. Fields that are **null** act as wild cards, thus matching any values. Precisely specifying as many fields as possible is the key to accurate results.

```
1 // Fig. 25.11 : PrinterManagementStarter.java
2 // This application demonstrates how to obtain the proxies of
3 // a dynamic service.
4 package com.deitel.advjhttp1.jiro.DynamicService.client;
5
6 // Java core package
7 import java.rmi.*;
8
9 // Jiro packages
10 import javax.fma.common.*;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.jiro.DynamicService.service.*;
14
15 public class PrinterManagementStarter {
16
17     // PrinterManagementStarter constructor
18     public PrinterManagementStarter( String domain ) {
19
20         PrinterManagement managementProxy;
21
22         // set security manager
23         if ( System.getSecurityManager() == null )
24             System.setSecurityManager( new RMISecurityManager() );
25
26         // obtain station address
27         StationAddress stationAddress =
28             new StationAddress( domain,
29                 null, null, null, null, null, null, null );
30
31         // get the proxies of dynamic services
32         // and start the services
33         try {
34             managementProxy =
35                 new PrinterManagementImplProxy( stationAddress );
36         }
37
38         // handle exception getting proxies and starting policies
39         catch ( RemoteException exception ) {
40             exception.printStackTrace();
41         }
42
43     } // end PrinterManagementStarter constructor
44
45     // method main
46     public static void main( String args[] )
47     {
48         String domain = "";
49     }
```

Fig. 25.11 **PrinterManagementStarter** dynamic service instantiator program (part 1 of 2).

```
50     // get the domain name
51     if ( args.length != 1 ) {
52         System.out.println(
53             "Usage: PrinterManagementStarter Domain" );
54         System.exit( 1 );
55     }
56     else
57         domain = args[ 0 ];
58
59     PrinterManagementStarter printerManagementStarter =
60         new PrinterManagementStarter( domain );
61
62 } // end main method
63 }
```

Fig. 25.11 **PrinterManagementStarter** dynamic service instantiator program (part 2 of 2).

After instantiating the **PrinterManagement** dynamic service, a reference to the dynamic service can be obtained through the Jini lookup service. We provide class **DynamicServiceFinder** (Fig. 25.12) as a helper class that encapsulates the Jini lookup service discovery process and the retrieval of services. For details on the Jini lookup service, Chapter 22.

```
1 // DynamicServiceFinder.java
2 // This class discovers lookup services and
3 // gets dynamic service proxy.
4 package com.deitel.advjhtp1.jiro.DynamicService.common;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.io.*;
9
10 // Jini core packages
11 import net.jini.core.entry.Entry;
12 import net.jini.core.lookup.*;
13
14 // Jini extension packages
15 import net.jini.discovery.*;
16 import net.jini.lookup.entry.ServiceInfo;
17
18 // Jiro packages
19 import javax.fma.util.*;
20
21 public class DynamicServiceFinder
22     implements DiscoveryListener {
23
24     private int servicesFound = 0;
25     private ServiceRegistrar[] registrars;
26     private Entry[] entries;
27 }
```

Fig. 25.12 Finds dynamic service proxies within a lookup service (part 1 of 3).

```
28 // DynamicServiceFinder constructor
29 public DynamicServiceFinder (
30     String domain, Entry[] serviceEntries )
31 {
32     System.setSecurityManager( new RMISecurityManager() );
33
34     entries = serviceEntries;
35     LookupDiscovery lookupDiscovery = null;
36
37     // discover lookup services
38     try {
39         lookupDiscovery = new LookupDiscovery(
40             new String[] { domain } );
41     }
42
43     // catch the IOException
44     catch ( IOException exception ) {
45         Debug.debugException(
46             "discover lookup service", exception );
47     }
48
49     // install a listener
50     lookupDiscovery.addDiscoveryListener ( this );
51
52     // wait until woken up by notification
53     try {
54
55         synchronized ( this ) {
56             wait();
57         }
58     }
59
60     // handle exception waiting for notification
61     catch ( Exception exception ) {
62         Debug.debugException(
63             "wait for lookup service", exception );
64     }
65
66 } // end DynamicServiceFinder constructor
67
68 // discover new lookup services
69 public void discovered( DiscoveryEvent event )
70 {
71     // get the proxy registrars for those services
72     registrars = event.getRegistrars();
73
74     // wake up all waiting threads
75     synchronized ( this ) {
76         notifyAll();
77     }
78 }
79 }
```

Fig. 25.12 Finds dynamic service proxies within a lookup service (part 2 of 3).

```
80    // discover invalid lookup services
81    public void discarded( DiscoveryEvent event) {}
82
83    // get dynamic service proxy
84    public Object getService()
85    {
86        // search lookup service to get dynamic service proxy
87        try {
88            ServiceTemplate template = new ServiceTemplate(
89                null, null, entries );
90            Object service = registrars[ 0 ].lookup( template );
91
92            return service;
93        }
94
95        // handle exception getting dynamic service proxy
96        catch ( Exception exception ) {
97            Debug.debugException( "getting proxy", exception );
98        }
99
100       return null;
101   }
102 } // end method getService
103 }
```

Fig. 25.12 Finds dynamic service proxies within a lookup service (part 3 of 3).

The **DynamicServiceFinder** constructor (lines 29–66) uses multicast request protocol to discover all Jini lookup services in the network. The constructor blocks until the first Jini lookup service is discovered. The constructor achieves the blocking behavior by calling method **wait** (line 56). Method **discovered** (lines 69–78) is called when a lookup service is discovered. This calls method **notifyAll** (line 76) to allow the constructor to continue execution. Method **getService** (lines 84–102) returns all matching entries from the first lookup service found.<sup>7</sup>

Class **PrinterClientGUI** (Fig. 25.13) demonstrates remote method calls to the dynamic service. Our constructor (lines 48–160) takes one argument that specifies the management domain. Lines 271–274 register **RemoteEventListenerImpl** as an observer listener with the event service. Lines 275–276 create a lease renewal manager that renews the lease granted to the listener. **RemoteEventListenerImpl** receives all notifications of topic `".Printer.Error"`. Note that **RemoteEventListenerImpl** is a convenience class provided by Jiro. It is a simple remote event listener implementation available to both clients and Jiro stations. This eliminates the need for dynamic class loading. Lines 66–75 define the upper panel (the printer status panel) of the GUI. Lines 78–110 define the middle panel (the button panel) of the GUI, which contains two buttons—**Check Status** and **Cancel Pending Print Jobs**. Lines 113–122 define the lower panel (the event panel) of the GUI, which displays the printer events. Lines 135–158 define a window listener for the output window. When the window is closed, the observer listener is released and the scheduled task is cancelled.

7. Please note that in our example, line 90 makes the assumption that only one Jini lookup service exists in the network. In some cases, multiple Jini lookup services may exist.

Method **checkStatusButtonAction** (lines 163–226) displays the printer's status to the status panel when **Check Status** button is clicked. Lines 175–188 call the proxy's methods to get the current status of the printer. Lines 197–224 process the information obtained and display it in the status panel.

Method **cancelJobsButtonAction** (lines 229–241) executes when the user clicks the **Cancel Pending Print Jobs** button. Line 233 invokes the proxy's **cancelPendingPrintJobs** method to cancel pending print jobs.

Method **getPrinterManagementProxy** (lines 244–260) obtains a proxy reference to the **PrinterManagement** dynamic service. This reference enables us to invoke methods on the **PrinterManagement** dynamic service.

```
1 // Fig. 25.13: PrinterClientGUI.java
2 // This application demonstrates how to obtain the proxy of
3 // a dynamic service and management policies, and call methods
4 // of the dynamic service.
5 package com.deitel.advjhttp1.jiro.DynamicService.client;
6
7 // Java core packages
8 import java.rmi.*;
9 import java.io.*;
10 import java.awt.*;
11 import java.awt.event.*;
12 import java.util.*;
13 import java.net.*;
14
15 // Java standard extensions
16 import javax.swing.*;
17
18 // Jini core package
19 import net.jini.core.lease.Lease;
20 import net.jini.core.event.*;
21 import net.jini.core.entry.Entry;
22
23 // Jini extension package
24 import net.jini.lease.LeaseRenewalManager;
25 import net.jini.lookup.entry.*;
26
27 // Jiro packages
28 import javax.fma.common.*;
29 import javax.fma.services.*;
30 import javax.fma.services.event.EventService;
31 import com.sun.jiro.util.*;
32
33 // Deitel packages
34 import com.deitel.advjhttp1.jiro.DynamicService.common.*;
35 import com.deitel.advjhttp1.jiro.DynamicService.service.*;
36
37 public class PrinterClientGUI extends JFrame
38     implements RemoteEventListener {
39
40     private PrinterManagement printerManagementProxy;
```

Fig. 25.13 Management console user interface (part 1 of 7).

```
41     private JTextArea printerStatusTextArea =
42         new JTextArea();
43     private JTextArea printerEventTextArea =
44         new JTextArea();
45     private Lease observerLease;
46     private LeaseRenewalManager leaseRenewalManager;
47
48     public PrinterClientGUI( String domain )
49     {
50         super( "JIRO Printer Management Example" );
51
52         // set security manager
53         if ( System.getSecurityManager() == null )
54             System.setSecurityManager( new RMISecurityManager() );
55
56         // obtain reference to proxy
57         printerManagementProxy =
58             getPrinterManagementProxy( domain );
59
60         // subscribe to event service as an observer listener
61         subscriberObserver( domain );
62
63         Container container = getContentPane();
64
65         // status panel
66         JPanel printerStatusPanel = new JPanel();
67         printerStatusPanel.setPreferredSize(
68             new Dimension( 512, 200 ) );
69         JScrollPane statusScrollPane = new JScrollPane();
70         statusScrollPane.setAutoscrolls( true );
71         statusScrollPane.setPreferredSize(
72             new Dimension( 400, 150 ) );
73         statusScrollPane.setViewport().add(
74             printerStatusTextArea, null );
75         printerStatusPanel.add( statusScrollPane, null );
76
77         // buttons panel
78         JPanel buttonPanel = new JPanel();
79         buttonPanel.setPreferredSize(
80             new Dimension( 512, 200 ) );
81
82         // define action for Check Status button
83         JButton checkStatusButton =
84             new JButton( "Check Status" );
85         checkStatusButton.addActionListener(
86
87             new ActionListener() {
88
89                 public void actionPerformed( ActionEvent event ) {
90                     checkStatusButtonAction( event );
91                 }
92             }
93         );
```

Fig. 25.13 Management console user interface (part 2 of 7).

```
94
95     // define action for Remove Jammed Paper button
96     JButton cancelJobsButton = new JButton(
97         "Cancel Pending Print Jobs" );
98     cancelJobsButton.addActionListener(
99
100        new ActionListener() {
101
102            public void actionPerformed( ActionEvent event ) {
103                cancelJobsButtonAction( event );
104            }
105        }
106    );
107
108    // add three buttons to the panel
109    buttonPanel.add( checkStatusButton, null );
110    buttonPanel.add( cancelJobsButton, null );
111
112    // events panel
113    JPanel printerEventPanel = new JPanel();
114    printerEventPanel.setPreferredSize(
115        new Dimension( 512, 200 ) );
116    JScrollPane eventsScrollPane = new JScrollPane();
117    eventsScrollPane.setAutoscrolls( true );
118    eventsScrollPane.setPreferredSize(
119        new Dimension( 400, 150 ) );
120    eventsScrollPane.setViewportView( printerEventTextArea, null );
121    printerEventPanel.add( eventsScrollPane, null );
122
123    // initialize the text
124    printerStatusTextArea.setText( "Printer Status: ---\n" );
125    printerEventTextArea.setText( "Events: --- \n" );
126
127    // put all the panels together
128    container.add( printerStatusPanel, BorderLayout.NORTH );
129    container.add( printerEventPanel, BorderLayout.SOUTH );
130    container.add( buttonPanel, BorderLayout.CENTER );
131
132    // release observer listener and cancel scheduled task
133    // when window closing
134    addWindowListener(
135
136        new WindowAdapter() {
137
138            public void windowClosing( WindowEvent event ) {
139
140                {
141                    // release listener and cancel scheduled task
142                    try {
143                        leaseRenewalManager.remove( observerLease );
144                    }
145                }
146            }
147        }
148    );
149
```

**Fig. 25.13** Management console user interface (part 3 of 7).

```
146         // handle exception releasing observer listener
147         catch ( Exception exception ) {
148             exception.printStackTrace();
149         }
150
151         // terminate the program
152         System.exit( 0 );
153
154     } // end method windowClosing
155
156 } // end WindowAdapter constructor
157
158 ); // end addWindowListener
159
160 } // end PrinterManagementGUI constructor
161
162 // check print status
163 public void checkStatusButtonAction( ActionEvent event )
164 {
165     boolean isOnline = false;
166     boolean isPaperJam = false;
167     boolean isPrinting = false;
168     int paperRemaining = 0;
169     String[] pendingJobs = null;
170
171     // manage printer remotely
172     try {
173
174         // check if the printer is on line
175         isOnline = printerManagementProxy.isOnline();
176
177         // check if the printer is paper jammed
178         isPaperJam = printerManagementProxy.isPaperJam();
179
180         // check if the printing is pringint
181         isPrinting = printerManagementProxy.isPrinting();
182
183         // get the paper tray
184         paperRemaining = printerManagementProxy.getPaperInTray();
185
186         // get pending jobs
187         pendingJobs =
188             printerManagementProxy.getPendingPrintJobs();
189     }
190
191     // handle exception calling dynamic service methods
192     catch ( Exception exception ) {
193         exception.printStackTrace();
194     }
195 }
```

Fig. 25.13 Management console user interface (part 4 of 7).

```
196     // status for the online condition
197     if ( isOnline )
198         printerStatusTextArea.append(
199             "\nPrinter is ONLINE.\n" );
200     else
201         printerStatusTextArea.append(
202             "\nPrinter is OFFLINE.\n" );
203
204     // status for the paper jam condition
205     if ( isPaperJam )
206         printerStatusTextArea.append( "Paper jammed.\n" );
207     else
208         printerStatusTextArea.append( "No Paper Jam.\n" );
209
210     // status for the printing condition
211     if ( isPrinting )
212         printerStatusTextArea.append(
213             "Printer is currently printing.\n" );
214     else
215         printerStatusTextArea.append(
216             "Printer is not printing.\n" );
217
218     // status for paper tray condition
219     printerStatusTextArea.append( "Printer paper tray has "
220         + paperRemaining + " pages remaining.\n" );
221
222     // number of pending jobs
223     printerStatusTextArea.append( "Number of pending jobs: "
224         + pendingJobs.length + "\n" );
225
226 } // end method checkStatusButtonAction
227
228 // cancel print jobs
229 public void cancelJobsButtonAction( ActionEvent event )
230 {
231     // cancel pending print jobs
232     try {
233         printerManagementProxy.cancelPendingPrintJobs();
234     }
235
236     // handle exception canceling pending print jobs
237     catch ( Exception exception ) {
238         exception.printStackTrace();
239     }
240
241 } // end method cancelJobsButtonAction
242
243 // get dynamic service proxy
244 public PrinterManagement getPrinterManagementProxy(
245     String domain )
246 {
```

Fig. 25.13 Management console user interface (part 5 of 7).

```
247     Entry[] entries = new Entry[] {
248         new ServiceInfo( "PrinterManagementImpl",
249             "Deitel Association, Inc.",
250             "Deitel Association, Inc",
251             "1.0", "Model 0", "0.0.0.1" )
252     };
253
254     DynamicServiceFinder finder = new DynamicServiceFinder(
255         domain, entries );
256
257     // return dynamic service proxy
258     return ( PrinterManagement ) finder.getService();
259
260 } // end method getPrinterManagementProxy
261
262 // listener for events
263 public void subscriberObserver( String domain )
264 {
265     // subscribe to printer events
266     try {
267         EventService eventService =
268             ServiceFinder.getEventService( domain );
269
270         // subscribe as an observing listener to certain event
271         RemoteEventListener listener =
272             new RemoteEventListenerImpl( this );
273         observerLease = eventService.subscribeObserver(
274             ".Printer.Error", listener, null, 10 * 60 * 1000 );
275         leaseRenewalManager = new LeaseRenewalManager(
276             observerLease, Lease.FOREVER, null );
277     }
278
279     // handle exception subscribing to events
280     catch ( Exception exception ) {
281         exception.printStackTrace();
282     }
283 }
284
285 // receive notification
286 public void notify( RemoteEvent event )
287 {
288     String output = "\nEVENT: " + ( String ) event.getSource()
289     + "\n";
290     SwingUtilities.invokeLater(
291         new TextAppender( printerEventTextArea, output ) );
292 }
293
294 // method main
295 public static void main( String args[] )
296 {
297     String domain = "";
298 }
```

Fig. 25.13 Management console user interface (part 6 of 7).

```
299      // get the domain
300      if ( args.length != 1 ) {
301          System.out.println(
302              "Usage: PrinterClientGUI Domain" );
303          System.exit( 1 );
304      }
305      else
306          domain = args[ 0 ];
307
308      PrinterClientGUI client = new PrinterClientGUI( domain );
309      client.setSize( 500, 500 );
310      client.setVisible( true );
311
312 } // end main method
313
314 // TextAppender appends text to a JTextArea. This Runnable
315 // object should be executed only using SwingUtilities
316 // methods invokeLater or invokeAndWait as it modifies
317 // a live Swing component.
318 private class TextAppender implements Runnable {
319
320     private String text;
321     private JTextArea textArea;
322
323     // TextAppender constructor
324     public TextAppender( JTextArea area, String newText )
325     {
326         text = newText;
327         textArea = area;
328     }
329
330     // display new text in JTextArea
331     public void run()
332     {
333         // append new message
334         textArea.append( text );
335
336         // move caret to end of messageArea to ensure new
337         // message is visible on screen
338         textArea.setCaretPosition(
339             textArea.getText().length() );
340     }
341
342 } // end TextAppender inner class
343 }
```

Fig. 25.13 Management console user interface (part 7 of 7).

We would like **PrinterClientGUI** to receive notifications when printer events occur. Lines 263–283 subscribe to printer events as an observer listener. The event services invokes method **notify** (lines 286–292) when a printer event occurs. Lines 290–291 display the printer event in the lower panel of the GUI. Lines 318–342 define a **private** inner class, **TextAppender** to append text to the Swing container in a thread-safe manner.

Compile **PrinterClientGUI.java** and all other files in its package directory with the command:

```
javac -classpath c:\;c:\jirosdk\lib\jiro.jar  
      com\deitel\advjhttp1\jiro\DynamicService\client\*.java
```

Run **PrinterManagementStarter** to instantiate the **PrinterManagement** dynamic service:

```
java -cp c:\;c:\jirosdk\lib\jiro.jar  
      -Djava.security.policy=policy.all  
      com.deitel.advjhttp1.jiro.DynamicService.client.  
          PrinterManagementStarter  
      domainName
```

where *domainName* is the domain where we deployed the **PrinterManagement** dynamic service.

Now execute the management console (**PrinterClientGUI**):

```
java -cp c:\;c:\jirosdk\lib\jiro.jar  
      -Djava.security.policy=policy.all  
      com.deitel.advjhttp1.jiro.DynamicService.client.  
          PrinterClientGUI  
      domainName
```

Figure 25.14 shows the resulting output when the user clicks the **Check Status** button.

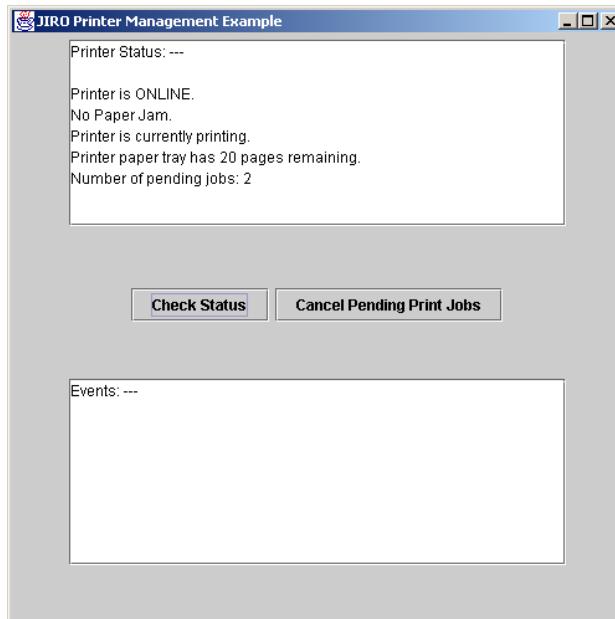


Fig. 25.14 Checking printer status.

Figure 25.15 shows the output on the **Igniter** tool display window after an out-of-paper event occurs.

Figure 25.16 shows the corresponding output on the **PrinterClientGUI** window after it receives notification of an out-of-paper event.

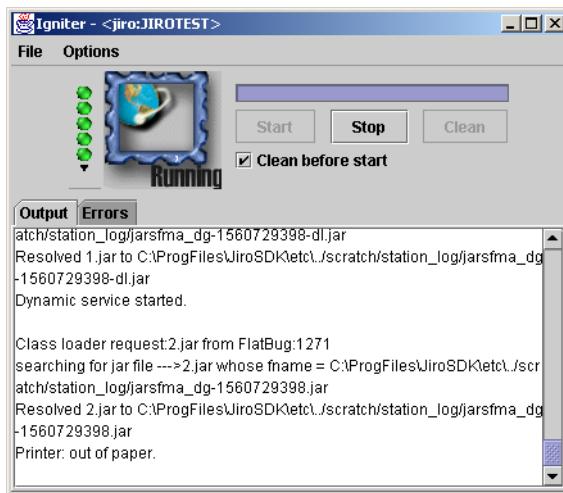


Fig. 25.15 **Igniter** showing printer out-of-paper event.

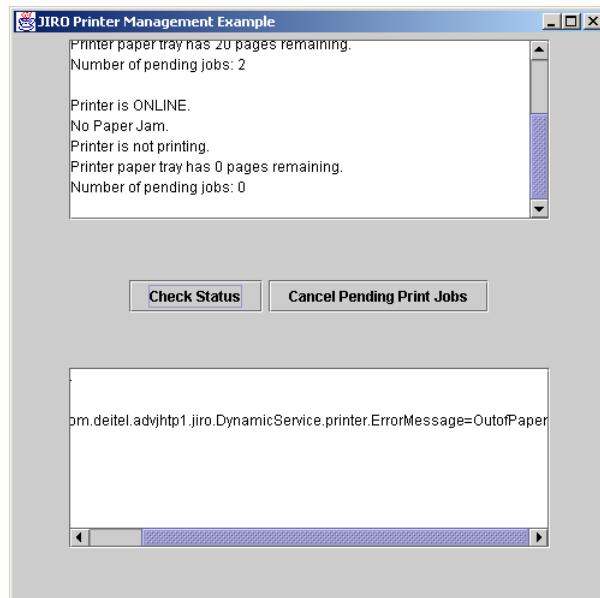


Fig. 25.16 **PrinterClientGUI** showing printer out-of-paper event.

We designed this case study to report exceptions using method `debugException` from class `Debug`. Jiro includes the tools `viewdbg` and `viewdbgw` that provide access to the debug files. Whenever an exception occurs, the `Igniter` error panel displays the location and filename that contains the debug information. The full path name for debug files usually follows the following format:

`FMA_number\xnumber.debug`

where *number* represents a number that identifies the debug message.

To view a debug error message, type

`viewdbg path\filename.debug`

or

`viewdbgw path\filename.debug`

where *path* and *filename* are the path and name of the file which contains the debug information.

## 25.8 Management Policies

The dynamic service we have developed is capable of many tasks. Unfortunately, one task it cannot perform is handling events autonomously. *Management policies* define how events that occur in a network should be handled. Management policies in Jiro are defined as dynamic services. Developers can customize such dynamic services to respond to events without system-administrator intervention. By defining management policies, network administrators are free to deal exclusively with important events that cannot be automated.

In our example, we would like to use the following management policy

*Printers should always have paper and toner.*

Each management policy should have a single well-defined task. The preceding management policy has two tasks—the printer must always have paper *and* must always have toner. In this case, we should break up the preceding management policy for our printer example into two smaller management policies:

*Printers should always have paper.*

and

*Printers should always have toner.*

The proper definition of a policy gives network administrators fine-grained control over how to manage a network. Furthermore, distributing the management policy to a set of dynamic services allows network administrators to replace and extend individual policies.

Our printer-management example will use two policies to enhance our network-management solution. Class `OutofPaperPolicyImpl` defines the policy, “Printers should always have paper.” `OutofPaperPolicy` (Fig. 25.17) exposes the interface for our out of paper policy dynamic service.

Class `OutofPaperPolicyImpl` (Fig. 25.18) implements `OutofPaperPolicy`. Lines 65–68 register class `PrinterEventListener` with the event service as a respon-

sible listener. Method **subscribeResponsibleBefore** takes six arguments—the event topic to which this event listener will respond, the responsible listener in front of which to place our responsible listener (**null** will cause the listener to be placed at the front of the responsible listener list), the subscriber that is the listener we are attempting to register, the object that the event service passes to the listener with each event (may be **null**) and the lease length (which represents the length for which this listener is requesting to be active). The method returns a **Lease** object representing the amount of time the event service granted to the listener. To keep our listener active for a longer period than the event service grants, we must renew the lease using a **LeaseRenewalManager**. Lines 71–72 renew our listener's lease with **Lease.FOREVER**. Constructor **LeaseRenewalManager** takes three arguments—a reference to the lease that will be renewed, the desired expiration for the lease and the lease listener that will receive notifications if exceptions occur during lease renewal (may be **null**).

Method **stopPolicy** exposes the stop operation on the out-of-paper policy. Clients may call method **stopPolicy** to halt the **OutofPaperPolicy** dynamic service execution. Line 96 cancels the lease on the **LeaseRenewalManager** object by passing as an argument the lease object to expire. Method **notify** receives events from the **PrinterEventListener**. Line 121 obtains the source object, which contains information pertaining to the entity that triggered the event. Line 134 verifies that the source object is an instance of **String**. If it is not, we know that the event was not fired by our printer. In this case, line 136 throws a **NotHandledException** that causes the event service to continue propagating the event to its internal list of listeners. If the source object is a **String**, we verify that the **String** is of the format that our printer implementation fires (lines 143–144). Line 153 calls method **addPaper** in the entry-point object of the **PrinterManagement** dynamic service. Lines 156–172 log a message describing the action taken when handling the out-of-paper event. Lines 200–216 define method **getPrinterManagementProxy**, which uses our **DynamicServiceFinder** helper class to find a previously initialized proxy stub for the **PrinterManagement** dynamic service. Lines 219–228 define method **getLookupEntries**, which is required for all entry-point objects of a dynamic service.

```
1 // OutofPaperPolicy.java
2 // This class defines the interface for the dynamic service.
3 package com.deitel.advjhtp1.jiro.DynamicService.policy;
4
5 // Java core package
6 import java.rmi.*;
7 import java.util.*;
8
9 // Jini core package
10 import net.jini.core.event.*;
11
12 public interface OutofPaperPolicy extends RemoteEventListener {
13
14     public void stopPolicy( ) throws RemoteException;
15 }
```

Fig. 25.17 **OutofPaperPolicy** interface.

```
1 // OutofPaperPolicyImpl.java
2 // Handles events generated by printer by registering
3 // as a responsible listener
4 package com.deitel.advjhttp1.jiro.DynamicService.policy;
5
6 // Java core packages
7 import java.io.Serializable;
8 import java.rmi.*;
9 import java.util.*;
10
11 // Java standard extensions
12 import javax.swing.*;
13
14 // Jini core packages
15 import net.jini.core.event.*;
16 import net.jini.core.entry.*;
17 import net.jini.core.lease.*;
18
19 // Jini extension packages
20 import net.jini.lease.LeaseRenewalManager;
21 import net.jini.lookup.entry.*;
22
23 // Jiro packages
24 import javax.fma.services.ServiceFinder;
25 import javax.fma.services.event.*;
26 import javax.fma.services.log.*;
27 import javax.fma.util.*;
28 import javax.fma.common.*;
29 import javax.fma.server.*;
30
31 // Deitel packages
32 import com.deitel.advjhttp1.jiro.DynamicService.service.*;
33 import com.deitel.advjhttp1.jiro.DynamicService.common.*;
34
35 public class OutofPaperPolicyImpl
36     implements OutofPaperPolicy {
37
38     private Lease listenerLease;
39     private LeaseRenewalManager leaseRenewalManager;
40
41     private LogService logService;
42     private PrinterEventListerner listener;
43     private PrinterManagement printerManagementProxy;
44
45     // OutofPaperPolicyImpl constructor
46     public OutofPaperPolicyImpl()
47     {
48         // subscribe as an responsible listener to certain event
49         listener = new PrinterEventListerner( this );
50     }
```

Fig. 25.18 OutofPaperPolicy implementation (part 1 of 5).

```
51     // start the OutofPaper management policy
52     try {
53
54         // obtain reference to dynamic service entry point
55         printerManagementProxy = getPrinterManagementProxy();
56
57         // obtain reference to log service
58         logService = ServiceFinder.getLogService();
59
60         // obtain reference to log service
61         EventService eventService =
62             ServiceFinder.getEventService();
63
64         // subscribe as responsible listener
65         listenerLease =
66             eventService.subscribeResponsibleBefore(
67                 ".Printer.Error.OutofPaper", null, listener,
68                 "OutofPaperEventListener", null, Lease.FOREVER );
69
70         // renew lease indefinitely
71         leaseRenewalManager = new LeaseRenewalManager(
72             listenerLease, Lease.FOREVER, null );
73
74     } // end try
75
76     // handle exception starting policy
77     catch ( Exception exception ) {
78         System.out.println( "OutofPaperPolicyImpl: " +
79             "Exception occurred when starting policy." );
80         System.out.println( "Please read debug file ... \n" );
81         Debug.debugException(
82             "starting LowTonerPolicy", exception );
83     }
84
85     System.out.println( "OutofPaperPolicyImpl: started." );
86
87 } // end OutofPaperPolicyImpl constructor
88
89 // stop OutofPaperPolicyImpl
90 public void stopPolicy()
91 {
92     // stopping OutofPaper management policy
93     try {
94
95         // expire lease
96         leaseRenewalManager.cancel( listenerLease );
97         System.out.println( "OutofPaperPolicyImpl: stopping." );
98     }
99
100    // handle exception canceling lease
101    catch ( Exception exception ) {
102        System.out.println( "OutofPaperPolicyImpl: " +
103            "Exception occurred when canceling lease." );
```

Fig. 25.18 OutofPaperPolicy implementation (part 2 of 5).

```
104     System.out.println( "Please read debug file ... \n" );
105     Debug.debugException(
106         "stopping OutofPaper policy", exception );
107     }
108   }
109
110  // receive notification calls
111 public void notify( RemoteEvent remoteEvent )
112   throws UnknownEventException, RemoteException,
113   EventNotHandledException
114 {
115   Object sourceObject = null;
116
117   // event source
118   try {
119
120     // get event source
121     sourceObject = remoteEvent.getSource();
122   }
123
124   // handle exception getting event source
125   catch ( Exception exception ) {
126     System.out.println( "OutofPaperPolicyImpl: " +
127       "Exception occurred when getting event source." );
128     System.out.println( "Please read debug file ... \n" );
129     Debug.debugException(
130       "getting event source", exception );
131   }
132
133   // definitely not from our printer
134   if ( !( sourceObject instanceof String ) ) {
135
136     throw new EventNotHandledException();
137   }
138
139   // obtain String value
140   String source = ( String ) sourceObject;
141
142   // verify origin of event
143   if ( source.equals( "com.deitel.advjhtp1.jiro."
144     + "DynamicService.printer.ErrorMessage=OutofPaper" ) ) {
145
146     System.out.println( "OutofPaperPolicy: "
147       + "handling OutofPaperEvent..." );
148
149   // take action
150   try {
151
152     // replenish paper tray
153     printerManagementProxy.addPaper( 50 );
154
155     // generate the log message parameters
156     Serializable params[] = new Serializable[ 2 ];
```

Fig. 25.18 OutofPaperPolicy implementation (part 3 of 5).

```
157         params[ 0 ] = source;
158         params[ 1 ] = new Date();
159
160         // generate localizable message
161         LocalizableMessage localizableMessage =
162             new LocalizableMessage(
163                 OutofPaperPolicyImpl.class,
164                 "Action", params, Locale.US );
165
166         // generate log message
167         LogMessage logMessage = new LogMessage(
168             localizableMessage, LogMessage.TRACE
169             + ".OutofPaperEvent." + source, null );
170
171         // log action message
172         logService.log( logMessage );
173
174     } // end try
175
176     // handle exception posting log message
177     catch ( Exception exception ) {
178         System.out.println( "OutofPaperPolicyImpl: " +
179             "Exception occurred when posting log message." );
180         System.out.println( "Please read debug file ...\\n" );
181         Debug.debugException( "log service", exception );
182     }
183
184 } // end if
185
186 // not event from our printer
187 else {
188
189     System.out.println( "OutofPaperPolicy: " +
190         " NOT handling OutofPaperEvent..." );
191
192     // responsible listener requirement
193     // when not handling event.
194     throw new EventNotHandledException();
195 }
196
197 } // end method notify
198
199 // get dynamic services proxies
200 public PrinterManagement getPrinterManagementProxy()
201 {
202     Entry[] entries = new Entry[] {
203         new ServiceInfo( "PrinterManagementImpl",
204             "Deitel Association, Inc.",
205             "Deitel Association, Inc",
206             "1.0", "Model 0", "0.0.0.1" )
207     };
208 }
```

Fig. 25.18 OutofPaperPolicy implementation (part 4 of 5).

```

209     String domain = System.getProperty( "javax.fma.domain" );
210     DynamicServiceFinder finder =
211         new DynamicServiceFinder( domain, entries );
212
213     // return proxy
214     return ( PrinterManagement ) finder.getService();
215
216 } // end method getPrinterManagementProxy
217
218 // defines class as dynamic service during deployment
219 private Entry[] getLookupEntries()
220 {
221     return ( new Entry[] {
222         new ServiceInfo( "OutofPaperPolicyImpl",
223             "Deitel Association, Inc.",
224             "Deitel Association, Inc",
225             "1.0", "Model 0", "0.0.0.1" )
226     });
227 }
228 }
229 }
```

Fig. 25.18 OutofPaperPolicy implementation (part 5 of 5).

**OutofPaperPolicyImpl** requires a **properties** file to log messages through the log service. See Section 25.6.3 for information on how to create the properties file. Fig. 25.19 shows the contents of that file.

**LowTonerPolicy** (Fig. 25.20) defines the interface for our second management policy, “Printers should always have toner.” The implementation details are similar to those of management policy **OutofPaperPolicyImpl** (Fig. 25.18). The differences between the two management policy implementations occur in the information that is logged by the log service and the actions taken when handling events. Fig. 25.20 shows the interface for the **LowTonerPolicy** dynamic service. Figure 25.21 shows the implementation for **LowTonerPolicyImpl**.

```
1 Action = Added paper to {0} on {1}.
```

Fig. 25.19 OutofPaperPolicyImpl.properties property file for OutofPaperPolicyImpl.

```

1 // Fig. 25.20 : LowTonerPolicy.java
2 // This class defines the interface for the dynamic service.
3 package com.deitel.advjhtp1.jiro.DynamicService.policy;
4
5 // Java core package
6 import java.rmi.*;
7 import java.util.*;
```

Fig. 25.20 Low toner policy interface (part 1 of 2).

```
9 // Jini core package
10 import net.jini.core.event.*;
11
12 public interface LowTonerPolicy extends RemoteEventListener {
13
14     public void stopPolicy() throws RemoteException;
15 }
```

Fig. 25.20 Low toner policy interface (part 2 of 2).

**LowTonerPolicyImpl** also requires a **properties** file to log messages through the log service. See Section 25.6.3 for information on how to create the properties file. Figure 25.22 shows the contents of that file.

```
1 // LowTonerPolicyImpl.java
2 // Handles events generated by printer by registering
3 // as a responsible listener
4 package com.deitel.advjhttp1.jiro.DynamicService.policy;
5
6 // Java core packages
7 import java.io.Serializable;
8 import java.rmi.*;
9 import java.util.*;
10
11 // Java standard extensions
12 import javax.swing.*;
13
14 // Jini core packages
15 import net.jini.core.event.*;
16 import net.jini.core.entry.*;
17 import net.jini.core.lease.*;
18
19 // Jini extension packages
20 import net.jini.lease.LeaseRenewalManager;
21 import net.jini.lookup.entry.*;
22
23 // Jiro packages
24 import javax.fma.services.*;
25 import javax.fma.services.event.*;
26 import javax.fma.services.log.*;
27 import javax.fma.util.*;
28 import javax.fma.common.*;
29 import javax.fma.server.*;
30
31 // Deitel packages
32 import com.deitel.advjhttp1.jiro.DynamicService.service.*;
33 import com.deitel.advjhttp1.jiro.DynamicService.common.*;
34
35 public class LowTonerPolicyImpl
36     implements LowTonerPolicy {
37
38     private Lease listenerLease;
```

Fig. 25.21 Low toner policy implementation (part 1 of 5).

```
39     private LeaseRenewalManager leaseRenewalManager;
40
41     private LogService logService;
42     private PrinterEventListener listener;
43     private PrinterManagement printerManagementProxy;
44
45     // LowTonerPolicyImpl constructor
46     public LowTonerPolicyImpl()
47     {
48         // subscribe as an responsible listener to certain event
49         listener = new PrinterEventListener( this );
50
51         // start the LowToner management policy
52         try {
53
54             // obtain reference to dynamic service entry point
55             printerManagementProxy = getPrinterManagementProxy();
56
57             // obtain reference to log service
58             logService = ServiceFinder.getLogService();
59
60             // obtain reference to log service
61             EventService eventService =
62                 ServiceFinder.getEventService();
63
64             // subscribe as responsible listener
65             listenerLease =
66                 eventService.subscribeResponsibleBefore(
67                     ".Printer.Error.LowToner", null, listener,
68                     "LowTonerEventListener", null, Lease.FOREVER );
69
70             // renew lease indefinitely
71             leaseRenewalManager = new LeaseRenewalManager(
72                 listenerLease, Lease.FOREVER, null );
73         }
74
75         // handle exception starting policy
76         catch ( Exception exception ) {
77             System.out.println( "LowTonerPolicyImpl: " +
78                 "Exception occurred when starting policy." );
79             System.out.println( "Please read debug file ... \n" );
80             Debug.debugException(
81                 "starting LowTonerPolicyImpl", exception );
82         }
83
84         System.out.println( "LowTonerPolicyImpl: started." );
85
86     } // end LowTonerPolicyImpl constructor
87
88     // stop OutofPaperPolicy
89     public void stopPolicy()
90     {
```

Fig. 25.21 Low toner policy implementation (part 2 of 5).

```
91     // stop the LowToner management policy
92     try {
93
94         // expire lease
95         leaseRenewalManager.cancel( listenerLease );
96         System.out.println( "LowTonerPolicyImpl: stopping." );
97     }
98
99     // handle exception canceling lease
100    catch ( Exception exception ) {
101        System.out.println( "LowTonerPolicyImpl: " +
102            "Exception occurred when canceling lease." );
103        System.out.println( "Please read debug file ... \n" );
104        Debug.debugException(
105            "stopping LowTonerPolicyImpl", exception );
106    }
107 }
108
109 // receive notification calls
110 public void notify( RemoteEvent remoteEvent )
111     throws UnknownEventException, RemoteException,
112     EventNotHandledException
113 {
114     // event source
115     Object sourceObject = null;
116
117     // get event source
118     try {
119         sourceObject = remoteEvent.getSource();
120     }
121
122     // handle exception getting event source
123     catch ( Exception exception ) {
124         System.out.println( "LowTonerPolicyImpl: " +
125             "Exception occurred when getting event source." );
126         System.out.println( "Please read debug file ... \n" );
127         Debug.debugException(
128             "getting event source", exception );
129     }
130
131     // definitely not from our printer
132     if ( !( sourceObject instanceof String ) ) {
133
134         throw new EventNotHandledException();
135     }
136
137     // obtain String value
138     String source = ( String ) sourceObject;
139
140     // verify origin of event
141     if ( source.equals( "com.deitel.advjhttp1.jiro."
142         + "DynamicService.printer.ErrorMessage=LowToner" ) ) {
143 }
```

Fig. 25.21 Low toner policy implementation (part 3 of 5).

```
144     System.out.println(
145         "LowTonerPolicyImpl: handling LowTonerEvent..." );
146
147     // take action
148     try {
149
150         // replenish toner cartridge
151         printerManagementProxy.addToner();
152
153         // generate the log message parameters
154         Serializable params[] = new Serializable[ 2 ];
155         params[ 0 ] = source;
156         params[ 1 ] = new Date();
157
158         // generate localizable message
159         LocalizableMessage localizableMessage =
160             new LocalizableMessage(
161                 LowTonerPolicyImpl.class, "Action",
162                 params, Locale.US );
163
164         // generate log message
165         LogMessage logMessage = new LogMessage(
166             localizableMessage, LogMessage.TRACE
167             + ".LowTonerEvent." + source, null );
168
169         // log action message
170         logService.log( logMessage );
171
172     } // end try
173
174     // handle exception posting log message
175     catch ( Exception exception ) {
176         System.out.println( "LowTonerPolicyImpl:" +
177             "Exception occurred when taking action." );
178         System.out.println( "Please read debug file...\\n" );
179         Debug.debugException( "take action", exception );
180     }
181
182 } // end if
183
184 // not event from our printer
185 else {
186     System.out.println( "LowTonerPolicyImpl: "
187         + "NOT handling OutofPaperEvent..." );
188
189     // responsible listener requirement
190     // when not handling event.
191     throw new EventNotHandledException();
192 }
193
194 } // end method notify
195
```

Fig. 25.21 Low toner policy implementation (part 4 of 5).

```

196 // get dynamic services proxies
197 public PrinterManagement getPrinterManagementProxy()
198 {
199     Entry[] entries = new Entry[] {
200         new ServiceInfo( "PrinterManagementImpl",
201             "Deitel Association, Inc.",
202             "Deitel Association, Inc",
203             "1.0", "Model 0", "0.0.0.1" )
204     };
205
206     String domain = System.getProperty( "javax.fma.domain" );
207     DynamicServiceFinder finder =
208         new DynamicServiceFinder( domain, entries );
209
210     // return proxy
211     return ( PrinterManagement ) finder.getService();
212 }
213 // end method getPrinterManagementProxy
214
215 // defines class as dynamic service during deployment
216 private Entry[] getLookupEntries()
217 {
218     return ( new Entry[] {
219         new ServiceInfo( "LowTonerPolicyImpl",
220             "Deitel Association, Inc.",
221             "Deitel Association, Inc",
222             "1.0", "Model 0", "0.0.0.1" )
223     });
224 }
225 }
226 }
```

Fig. 25.21 Low toner policy implementation (part 5 of 5).

1 Action = Added toner to {0} on {1}.

Fig. 25.22 Property file for **LowTonerPolicyImpl**.

### 25.8.1 Policy-Management Deployment

Before we activate our management policies, we must deploy them. For this example, we will restart Jiro with the **Clean before Start** option checked. This ensures that the previous **PrinterManagement** dynamic service is not operating when we redeploy the **PrinterManagement** dynamic service with our new management policies. We must follow the same steps shown in Section 25.7 for both management policies. Due to the dependencies between **PrinterManagement** dynamic service and the management policies, we will deploy them together.

To deploy the new management solution, review Section 25.7 and perform the following steps:

1. Compile all **.java** files in the following directories:

```
com\deitel\advjhttp1\jiro\dynamicService\common\  
com\deitel\advjhttp1\jiro\dynamicService\printer\  
com\deitel\advjhttp1\jiro\dynamicService\service\  
com\deitel\advjhttp1\jiro\dynamicService\policy\
```

2. Generate the proxy **.java** file using the **jirocw** tool for the following classes:

```
com.deitel.advjhttp1.jiro.DynamicService.service.  
    PrinterManagementImpl  
com.deitel.advjhttp1.jiro.DynamicService.policy.  
    OutofPaperPolicyImpl  
com.deitel.advjhttp1.jiro.DynamicService.policy.  
    LowTonerPolicyImpl
```

3. Compile the newly generated proxy files:

```
com\deitel\advjhttp1\jiro\DynamicService\service\  
    PrinterManagementImplProxy.java  
com\deitel\advjhttp1\jiro\DynamicService\policy\  
    OutofPaperPolicyImplProxy.java  
com\deitel\advjhttp1\jiro\DynamicService\policy\  
    LowTonerPolicyImplProxy.java
```

4. Use **rmic** to generate the proxy stub for the :

```
com.deitel.advjhttp1.jiro.DynamicService.service.  
    PrinterEventListener
```

5. Create **PrinterManagementService.jar** with the files listed in Fig. 25.23.

Directory	Files
	<pre>com\deitel\advjhttp1\jiro\DynamicService\common\     DynamicServiceFinder.class com\deitel\advjhttp1\jiro\DynamicService\printer\     Printer.class     PrinterErrorEvent.class com\deitel\advjhttp1\jiro\DynamicService\service\     PrinterEventListener.class     PrinterEventListener_Stub.class     PrinterManagement.class     PrinterManagementImpl.class     PrinterManagementImplProxy.class com\deitel\advjhttp1\jiro\DynamicService\service\resources\     PrinterManagementImpl.properties</pre>

Fig. 25.23 Contents of **PrinterManagementService.jar** (part 1 of 2).

Directory	Files
com\deitel\advjhttp1\jiro\DynamicService\policy\	LowTonerPolicy.class LowTonerPolicyImpl.class LowTonerPolicyImplProxy.class OutOfPaperPolicy.class OutOfPaperPolicyImpl.class OutOfPaperPolicyImplProxy.class
com\deitel\advjhttp1\jiro\DynamicService\policy\resources\	LowTonerPolicyImpl.properties OutOfPaperPolicyImpl.properties

Fig. 25.23 Contents of **PrinterManagementService.jar** (part 2 of 2).

6. Create **PrinterManagementService-ifc.jar** with the files listed in Fig. 25.24.
7. Create **PrinterManagementService-d1.jar** with the files listed in Fig. 25.25.
8. Create **PrinterManagementService-impl.jar** with the files listed in Fig. 25.26.
9. Use the **jarpackw** tool with the command-line arguments in Fig. 25.27.

Directory	Class Files
com\deitel\advjhttp1\jiro\DynamicService\service\	PrinterManagement.class PrinterManagementImplProxy.class

Fig. 25.24 Contents of **PrinterManagementService-ifc.jar**

Directory	Class Files
com\deitel\advjhttp1\jiro\DynamicService\service\	PrinterManagement.class PrinterManagementImplProxy.class

Fig. 25.25 Contents of **PrinterManagementService-ifc.jar**.

Directory	Files
com\deitel\advjhttp1\jiro\DynamicService\common\	DynamicServiceFinder.class
com\deitel\advjhttp1\jiro\DynamicService\printer\	Printer.class
	PrinterErrorEvent.class
com\deitel\advjhttp1\jiro\DynamicService\service\	PrinterEventListener.class
	PrinterEventListener_Stub.class
	PrinterManagement.class
	PrinterManagementImpl.class
	PrinterManagementImplProxy.class
com\deitel\advjhttp1\jiro\DynamicService\service\resources\	PrinterManagementImpl.properties
com\deitel\advjhttp1\jiro\DynamicService\policy\	LowTonerPolicy.class
	LowTonerPolicyImpl.class
	LowTonerPolicyImplProxy.class
	OutofPaperPolicy.class
	OutofPaperPolicyImpl.class
	OutofPaperPolicyImplProxy.class
com\deitel\advjhttp1\jiro\DynamicService\policy\resources\	LowTonerPolicyImpl.properties
	OutofPaperPolicyImpl.properties

Fig. 25.26 Contents of **PrinterManagementService-impl.jar**.

Flag	Value
-pool	%JIRO_CLASSPATH%
	c:\PrinterManagementService.jar
-ifc	PrinterManagementService-ifc.jar
-impl	PrinterManagementService-impl.jar

Fig. 25.27 Command line arguments for **jarpackw** (part 1 of 2).

Flag	Value
-dl	<b>PrinterManagementService-dl.jar</b>

Fig. 25.27 Command line arguments for **jarpackw** (part 2 of 2).

10. Deploy the dynamic services in the Jiro station using the **jardeploy** tool with the command-line arguments in Fig. 25.28.

We have now deployed our two management policies with the **PrinterManagement** dynamic service. Now we must start our **PrinterManagement** dynamic service. Run **PrinterManagementStarter** (Fig. 25.11) to instantiate the **PrinterManagement** dynamic service remotely. Next, we will start the deployed management policies. Class **PoliciesStarter** (Fig. 25.29) instantiates **OutofPaperPolicyImpl** and **LowTonerPolicyImpl** remotely.

Lines 28–30 define the **StationAddress** where our management policies should be instantiated. Lines 34–37 instantiate both management policies—**OutofPaperPolicy** and **LowTonerPolicy**.

Flag	Value
-station	<b>SharedJiroStation</b>
-domain	<i>domainName</i>
-impl	<b>PrinterManagementService-Impl.jar</b>
-dl	<b>PrinterManagementService-dl.jar</b>
-verbose	
-inventory	

Fig. 25.28 Command line arguments for **jardeploy**.

```

1 // Fig. 25.29 : PoliciesStarter.java
2 // This application demonstrates how to obtain the proxies of
3 // management policies.
4 package com.deitel.advjhttp1.jiro.DynamicService.client;
5
6 // Java core package
7 import java.rmi.*;
```

Fig. 25.29 Management policies instantiating utility (part 1 of 3).

```
8
9 // Jiro packages
10 import javax.fma.common.*;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.jiro.DynamicService.policy.*;
14
15 public class PoliciesStarter {
16
17     // PoliciesStarter constructor
18     public PoliciesStarter( String domain ) {
19
20         OutofPaperPolicy paperPolicyProxy;
21         LowTonerPolicy tonerPolicyProxy;
22
23         // set security manager
24         if ( System.getSecurityManager() == null )
25             System.setSecurityManager( new RMISecurityManager() );
26
27         // obtain station address
28         StationAddress stationAddress =
29             new StationAddress( domain,
30                 null, null, null, null, null, null, null );
31
32         // get the proxies of management policies
33         try {
34             paperPolicyProxy =
35                 new OutofPaperPolicyImplProxy( stationAddress );
36             tonerPolicyProxy =
37                 new LowTonerPolicyImplProxy( stationAddress );
38         }
39
40         // handle exception getting proxies and starting policies
41         catch ( RemoteException exception ) {
42             exception.printStackTrace();
43         }
44
45     } // end PoliciesStarter constructor
46
47     // method main
48     public static void main( String args[] )
49     {
50         String domain = "";
51
52         // get the domain name
53         if ( args.length != 1 ) {
54             System.out.println(
55                 "Usage: PoliciesStarter Domain" );
56             System.exit( 1 );
57         }
58         else
59             domain = args[ 0 ];
60     }
```

Fig. 25.29 Management policies instantiating utility (part 2 of 3).

```

61     PoliciesStarter policiesStarter =
62         new PoliciesStarter( domain );
63
64     } // end main method
65 }

```

Fig. 25.29 Management policies instantiating utility (part 3 of 3).

To instantiate our **PrinterManagement**, **OutofPaperPolicy** and **LowTonerPolicy** dynamic services, we must:

1. Compile **PrinterClientGUI**, **PrinterManagementStarter** and **PoliciesStarter** in the following directory:  
`com\deitel\advjhttp1\jiro\DynamicService\client\`
2. Run class `com.deitel.advjhttp1.jiro.DynamicService.client.PrinterManagementStarter` using a **policy.all** policy file. You must include the *domainName* as an argument to **PrinterManagementStarter**.
3. Run class `com.deitel.advjhttp1.jiro.DynamicService.client.PoliciesStarter` using a **policy.all** policy file. You must include the *domainName* as an argument to **PoliciesStarter**.
4. Run class `com.deitel.advjhttp1.jiro.DynamicService.client.PrinterClientGUI` using a **policy.all** policy file. You must include the *domainName* as an argument to **PrinterClientGUI**.

Figure 25.30 shows the output on the **Igniter** display window when an out-of-paper event occurs.

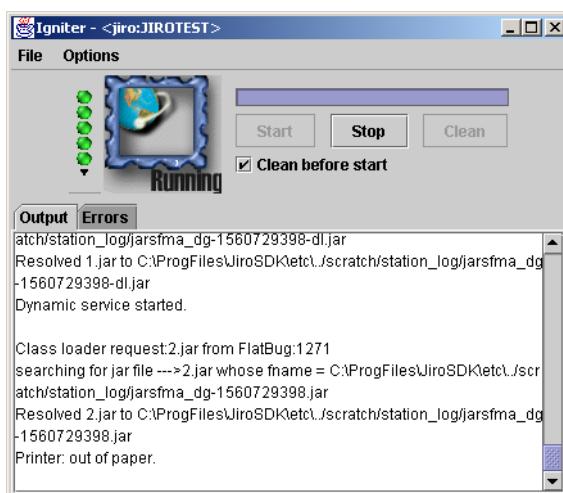


Fig. 25.30 **Igniter** displaying out-of-paper event.

Figure 25.31 shows the resulting action by the **OutofPaperPolicy** dynamic service when it receives an out-of-paper event notification.

Figure 25.32 shows the information displayed by the **viewlog** tool after running the management policies.

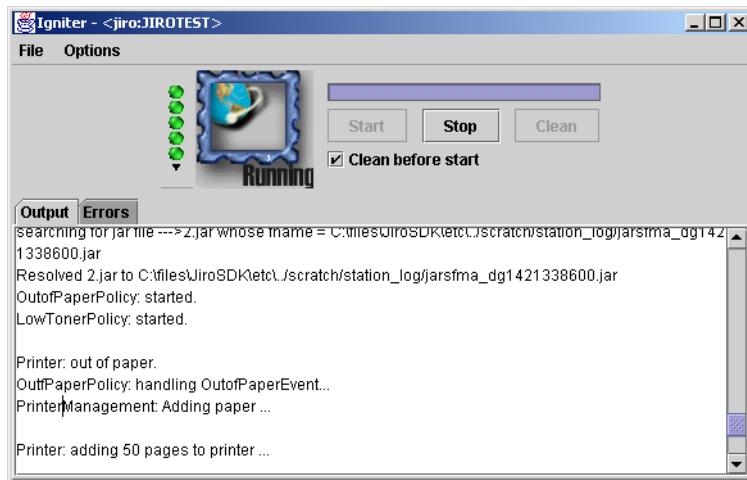


Fig. 25.31 **OutofPaperPolicy** handling out-of-paper event.

The screenshot shows the Log Viewer application window titled "Log Viewer - <jiro:JIROTEST>". The window displays a table of log messages:

Log Messages: 1-5 of 5		
Time Stamp	Category	Log Message
07/30/2001 01:12PM	trace.printer.com.deitel.advjhtp1.jiro.DynamicService....	com.deitel.advjhtp1.jiro.DynamicService.printer....
07/30/2001 01:12PM	trace.OutofPaperEvent.com.deitel.advjhtp1.jiro.Dyna...	com.deitel.advjhtp1.jiro.DynamicService.printer....
07/30/2001 01:14PM	trace.printer.com.deitel.advjhtp1.jiro.DynamicService....	com.deitel.advjhtp1.jiro.DynamicService.printer....
07/30/2001 01:14PM	trace.OutofPaperEvent.com.deitel.advjhtp1.jiro.Dyna...	com.deitel.advjhtp1.jiro.DynamicService.printer....
07/30/2001 01:15PM	trace.printer.com.deitel.advjhtp1.jiro.DynamicService....	com.deitel.advjhtp1.jiro.DynamicService.printer....

Below the table are search controls:

- Begin Date
- End Date
- Category
- Message
- 

Fig. 25.32 Log contents after events handled by management policies.

Figure 25.33 shows the result of double-clicking a message log entry in the **viewlog** tool GUI.

## 25.9 Closing Notes on the Printer Management Solution

The system developed in this chapter has a complex workflow that can be difficult to follow. Obtaining a solid grasp on the workflow of this system is necessary to understand the elegance of a Jiro solution for network management.

Our system contains several important components. The **PrinterManagement** component represents our entry point object. **PrinterManagementImpl** implements the core functionality of **PrinterManagement**. **PrinterManagementImpl** can delegate calls to a **Printer** and return events from a **Printer**. **PrinterManagementImpl** is responsible for logging all events it receives from the printer.

Our managed entity is the **Printer** simulator, which exposes an interface that **PrinterManagement** represents. **Printer** simulates three events and posts them to the event service with a corresponding topic—".**Printer.Error.OutOfPaper**" or "**Printer.Error.LowToner**" or "**Printer.Error.PaperJam**". The event service sends a posted event to all observer listeners (**PrinterClientGUI** and **PrinterManagementImpl**) and the first responsible listener in the event service's list of responsible listeners (**OutOfPaperPolicyImpl**'s listener or **LowTonerPolicyImpl**'s listener, depending on the event topic).

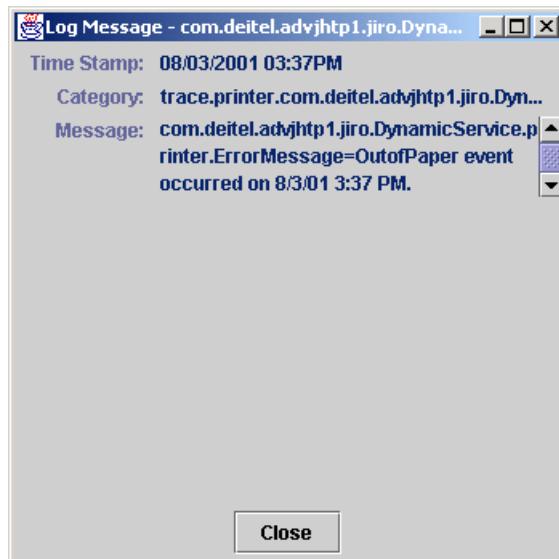


Fig. 25.33 Detailed log information for a specified entry.

Classes **OutofPaperPolicyImpl** and **LowTonerPolicyImpl** are the management policy implementations that we deployed to help automate trivial and not-so-trivial tasks. **OutofPaperPolicyImpl** registers an instance of **PrinterEventListener** (a listener we developed for all printer-related events) as a responsible listener to handle all events with topic **".Printer.Error.OutofPaper"**. The event service sends all **OutofPaperEvents** from the printer to this instance of **PrinterEventListener**, which delegates the event to **OutofPaperPolicyImpl**. Class **OutofPaperPolicyImpl** handles an **OutOfPaperEvent** by invoking method **addPaper** on **PrinterManagementImpl**, then logs a message through the log service reporting which action it took. **LowTonerPolicy** handles all **LowTonerEvents**. **LowTonerPolicyImpl**'s response to events is similar to that of **OutofPaperPolicyImpl**.

We also created a management console. All events are sent to the management console **PrinterClientGUI**, because it registered for events of topic **".Printer.Error"**. **PrinterClientGUI** displays all information about each event it receives. It also enables users to view the printer status at any time and allows users to cancel pending print jobs, which may be useful when paper-jam events occur. To cancel print jobs, **PrinterClientGUI** remotely invokes method **cancelPendingPrintJobs** of class **PrinterManagementImpl** through the shared station.

The resulting system is an automated, self-contained management system that can log events and respond to those event in an appropriate manner. Figure 25.34 illustrates the general structure of the application.

The power of the Jiro management solution in this case study is its ability to delegate responsibilities elegantly and efficiently. Jiro is not limited to bridging the gap between the system administrator's console and the device; it extends to providing highly extensible, dynamic management facilities to any network.

## 25.10 Internet and World Wide Web Resources

**[jiro.com/documentcenter/](http://jiro.com/documentcenter/)**

This site contains the Jiro-related documents from the Jiro-technology home page.

**[www.jiro.com/overview/](http://www.jiro.com/overview/)**

This site provides an overview of Jiro technology.

**[sunjweb-001.jiro.com/faqs/](http://sunjweb-001.jiro.com/faqs/)**

This site contains frequently asked questions about Jiro technology.

**[www.jiro.com/education/recipes/](http://www.jiro.com/education/recipes/)**

This site contains links to technical analysis of the event service.

**[www.jiro.com/education/recipes/service/](http://www.jiro.com/education/recipes/service/)**

This site describes how to declare a class as a dynamic service.

**[www.sce.carleton.ca/netmanage/NMfor90s/SimpleNM.html](http://www.sce.carleton.ca/netmanage/NMfor90s/SimpleNM.html)**

This article discusses network management for the 1990s.

**[sunjweb-001.jiro.com/cgi-bin/Ultimate.cgi?action=intro](http://sunjweb-001.jiro.com/cgi-bin/Ultimate.cgi?action=intro)**

This site contains a Jiro discussion forum.

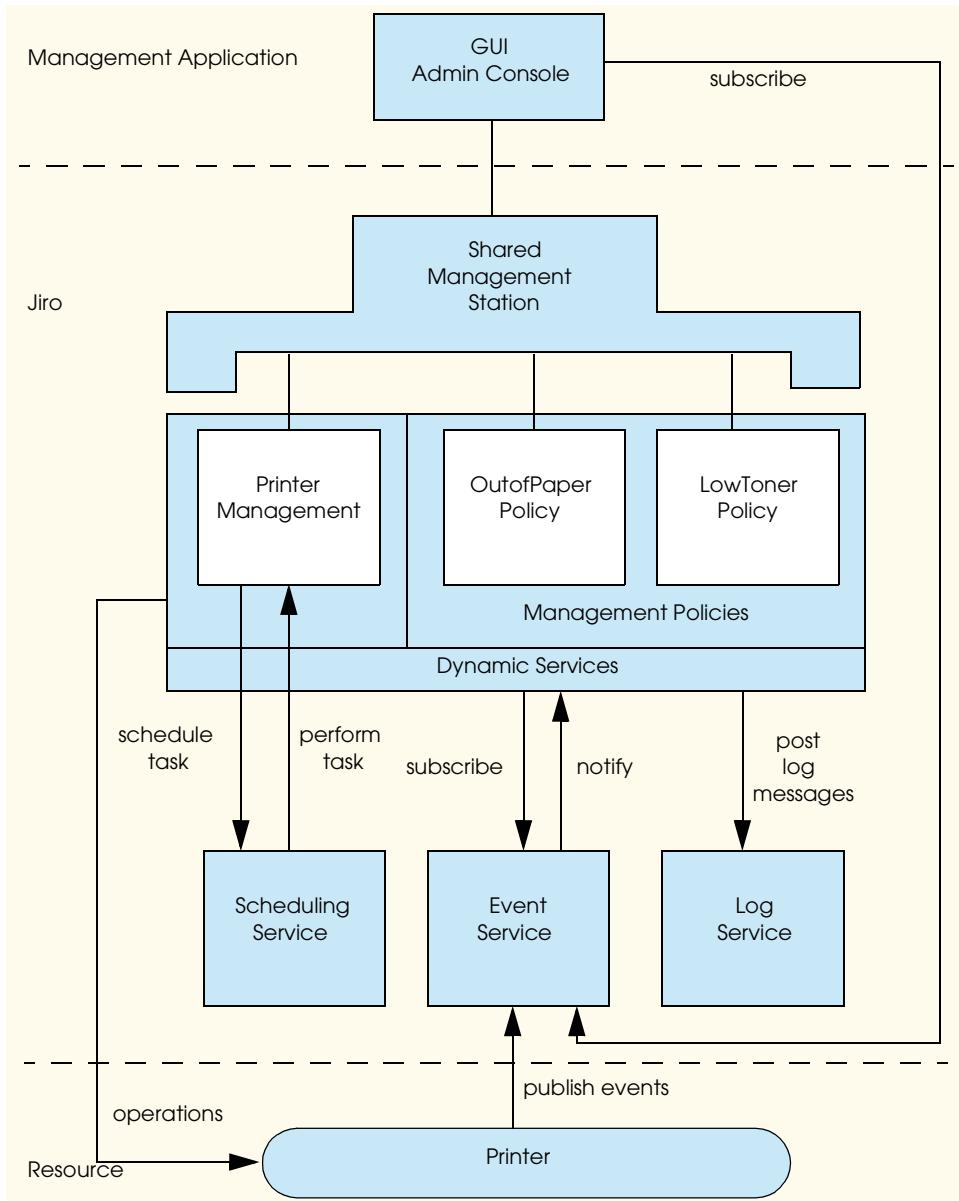


Fig. 25.34 Printer management solution work flow diagram.

## SUMMARY

- Jiro provides infrastructure to develop management solutions for distributed resources on a heterogeneous network.
- Jiro technology can simplify and automate management of distributed resources.

- Automated management can monitor and control management to minimize human response when reaction is needed.
- Jiro facilitates the development of management solutions that are easy to deploy and expand.
- Jiro uses a three-tier architecture for management solutions.
- Jiro supports other industry standards, such as SNMP and CIM.
- A Jiro management domain contains the managed network resources and the management services that manage the resources.
- Before starting Jiro, a Jiro management domain name must be specified.
- Starting Jiro also starts the class server, **rmid**, transaction service, shared Jiro station, controller service, log service, event service and scheduling service.
- Jiro provides a lookup service for each management domain, so that the static management services and the dynamic management services can be registered with the lookup service.
- Base services or static services include the controller service, the event service, the log service, the scheduling service and the transaction service. Base services are available to the entire management domain.
- Class **javax.fma.services.ServiceFinder** provides a convenient way to locate static services.
- An event publisher posts events to the event service. An event subscriber receives events from the event service.
- A client or service can either post a log message to the log service or retrieve log messages from the log service, obeying search criteria.
- If an application uses the log service, then a resource file that describes the log-message key and value (message template) is required.
- The scheduling service provides methods to schedule a task to perform on a specific date, schedule tasks to perform on event intervals or schedule tasks to perform repeatedly, based on a calendar.
- Method **newRepeatedDateSchedule** creates a schedule for tasks that will be performed repeatedly, based on a calendar date.
- There are three choices for the later-performance policy—**SchedulingService.NONE**, **SchedulingService.ONE** and **SchedulingService.ALL**.
- Static services are always present in a management domain, but dynamic services are not.
- Jiro provides a management station to support dynamic services distributed throughout the management domain and communicate with managed resources.
- A dynamic service that provides access to a managed resource is called Management Facade.
- To make a dynamic service available in a management domain, the dynamic service provider is required to implement the dynamic service and deploy the dynamic service to a station within a management domain.
- Implementing method **getLookupEntries** declares a class as a dynamic service.
- A class that defines method **getLookupEntries** is called a point object. Such a class is the entry point for the dynamic service.
- Jiro provides tools **jiroc** and **jirocwl** to generate the proxy of a service.
- Before a dynamic service can be instantiated, it must be deployed to a station. Jiro provides the tool **jardeploy** to deploy a dynamic service.

- Jiro provides the GUI tool **jarpack** and the command-line tool **jarpackw** to create the JAR files used by the **jardeploy** tool.
- To use the **jarpackw** tool, three seed JAR files are required—an interface JAR file, an implementation JAR file and a download JAR file.
- The interface JAR file contains all the interfaces that a dynamic service implements, as well as all classes the interfaces depend on.
- The implementation JAR file contains all the classes that required to run the dynamic service.
- The download JAR file contains all the classes that should be available to clients of the dynamic service for downloading purposes.

## TERMINOLOGY

automated management	<b>jirocw</b> tool
base services	<b>LocalizableMessage</b>
<b>cancel</b> method of <b>Ticket</b>	<b>log</b> method of class <b>LogSearchCriteria</b>
centralized management	<b>LogMessage.AUDIT</b>
<b>ClientController</b> class	<b>LogMessage.DEBUG</b>
Common Information Model	<b>LogMessage.ERROR</b>
<b>Context</b> class	<b>LogMessage.INFO</b>
<b>Controller</b> class	<b>LogMessage TRACE</b>
distributed resources	<b>LogMessage.WARNING</b>
download JAR	management facade
Federated Management Architecture	<b>newClientController</b> method of <b>ControllerService</b>
<b>getControllerService</b> method of <b>ServiceFinder</b>	<b>newDateSchedule</b> method of <b>SchedulingService</b>
<b>getEventService</b> method of <b>ServiceFinder</b>	<b>newDurationSchedule</b> method of <b>SchedulingService</b>
<b>getLogService</b> method of <b>ServiceFinder</b>	<b>newRepeatedSchedule</b> method of <b>SchedulingService</b>
<b>getLookupEntries</b> method	point object
<b>getSchedulingService</b> method of <b>ServiceFinder</b>	<b>post</b> method of <b>EventService</b>
<b>getTransactionService</b> method of <b>ServiceFinder</b>	<b>search</b> of class <b>LogSearchCriteria</b>
heterogeneous network	<b>ServiceFinder</b> class
<b>igniter</b>	Simple Network Management Protocol (SNMP)
<b>IllegalArgumentException</b>	static management services
implementation JAR	station
interface JAR	<b>StationAddress</b> class
interoperable	<b>subscribeObserver</b> method of <b>EventService</b>
<b>jardeploy</b> tool	three-tier architecture
<b>jarpack</b> tool	<b>Throwable</b>
<b>jarpackw</b> tool	<b>TransactionManager</b>
Jiro Technology Software Development Kit	<b>viewlog</b> tool
<b>jiroc</b> tool	

## SELF-REVIEW EXERCISES

25.1 Fill in the blanks in each of the following statements:

- a) Jiro is an implementation of the \_\_\_\_\_.
- b) Five static services provided by Jiro are \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.

- c) Class \_\_\_\_\_ provides a convenient way to locate the static services.
  - d) A \_\_\_\_\_ file must be defined before posting a log message to the **LogService**.
  - e) A dynamic service must have method \_\_\_\_\_ declared in its class.
  - f) To use the **jarpackw** tool, three seed JAR files are required: \_\_\_\_\_, and \_\_\_\_\_.
  - g) Jiro provides a tool \_\_\_\_\_ to deploy dynamic services.
- 25.2** State whether each of the following is *true* or *false*. If *false*, explain why.
- a) Jiro allows cross-platform information management.
  - b) Management applications wishing to listen to events from the event service must register a **RemoteEventListenerImpl** and be running a Web server.
  - c) Devices using the Simple Network Management Protocol can be managed by Jiro.
  - d) Jiro can manage devices on its own.
  - e) The Jiro Event Service sends matching events to all responsible listeners registered for those events.

## ANSWERS TO SELF-REVIEW EXERCISES

**25.1** a) Federated Management Architecture. b) controller service, event service, log service, scheduling service, transaction service. c) **ServiceFinder**. d) resource. e) **getLookupEntries**. f) Interface JAR file, implementation JAR file, download JAR file. g) **jardeploy**.

**25.2** a) True. b) False. If a management application registers a **RemoteEventListenerImpl** with the event service, the need for a Web server is avoided because both the management application and the Jiro station share **RemoteEventListenerImpls**. If a management application registers its custom **RemoteEventListener** implementation, then the management application system must run a Web server that will allow the event service to dynamically load the custom **RemoteEventListener** implementation. c) True. d) False. Developers need to write applications using Jiro to manage devices and services. e) False. The event service sends matching events to the first responsible listener in the responsible listener chain. If that responsible listener throws an **EventNotHandledException**, then the event service will send the event to the next responsible listener in the chain. The event will propagate down the chain of responsible listeners until a responsible listener does not throw an **EventNotHandledException**.

## EXERCISES

- 25.3** Describe the similarities and differences between static services and dynamic services.
- 25.4** Describe the difference between responsible listeners and observer listeners. Why is it important to have two different types of listeners?
- 25.5** Compare and contrast the **PrinterManagement** dynamic service and the management policies **OutofPaperPolicy** and **LowTonerPolicy**. How are these dynamic services similar? How are they different?
- 25.6** Modify our **Printer** simulator to include a method **handlePaperJam**, which will fix any paper jams in our printer. Modify the **PrinterManagement** dynamic service to expose this new operation on the printer. Finally, modify **PrinterClientGUI** to include a button which, when pressed, will call to the new operation through the dynamic service.
- 25.7** Create and deploy the following management policy:

**"Printer will never be inoperational because of a paper jam."**

**25.8** Lines 52–54 of **PrinterManagementImpl.java** (Fig. 25.5) create a **Printer**-simulator thread. In a real-world scenario, a dynamic service would establish a remote connection to this

printer. This connection could be performed via any popular management protocol (SNMP, WEBM, RMI, etc.). For this exercise:

- a) Define interface **RemotePrinter** which exposes the management operations of class **Printer** (Fig. 25.8). **RemotePrinter** must extend interface **Remote**. Create a stand-alone application, **RemotePrinterImpl**, that starts a **Printer** thread. Class **RemotePrinterImpl** must implement **RemotePrinter** interface. **RemotePrinterImpl** must post an RMI stub reference of itself in the Jini lookup service of the Jiro domain. Class **RemotePrinterImpl** must delegate any remote method calls to its **Printer** instance.
- b) Modify **PrinterManagementImpl** (Fig. 25.5) to retrieve a **RemotePrinter** stub from the Jini lookup service of the local Jiro domain. **PrinterManagement** dynamic service must delegate all printer management operations to stub **RemotePrinter**.

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# Common Object Request Broker Architecture (CORBA): Part 1

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## Objectives

- To introduce CORBA (Common Object Request Broker Architecture).
- To introduce the Interface Definition Language (IDL).
- To use CORBA to develop push-model and pull-model applications.
- To understand distributed exceptions.
- To implement the Deitel Messenger application using CORBA.
- To compare CORBA to other technologies for building distributed systems.

*In the master there is a servant, in the servant a master.*

Marcus Tullius Cicero

*Excellence is to do a common thing in an uncommon way.*

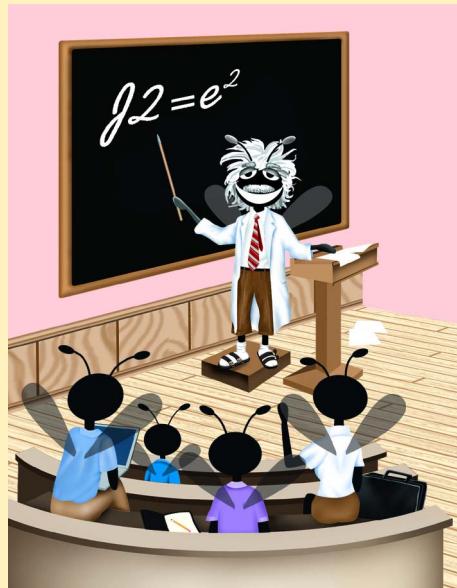
Booker T. Washington

*The virtue in most request is conformity.*

Ralph Waldo Emerson

*It is often wonderful how putting down on paper a clear statement of a case helps one to see, not perhaps the way out, but the way in.*

A.C. Benson



## Outline

- 26.1 Introduction**
- 26.2 Step-by-Step**
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  - 26.3.1 SystemClock.idl**
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  - 26.3.3 SystemClockClient.java**
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- 26.9 Comments and Comparisons**
- 26.10 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Works Cited • Bibliography*

## 26.1 Introduction\*

To appreciate what Java has brought to the software-development industry in the past few years, one must first appreciate the happenings just beneath the radar screens of most developers prior to Java's introduction—the gradual acceptance that legacy systems were not going away and that there existed a need to take advantage of these systems. In addition, the explosive growth of the Web has made it critical to develop systems that can be distributed (networked) “out of the box” rather than building the same communications infrastructure repeatedly. Java offered several features that made these systems possible but did not offer higher-level classes, tools or abstractions for building large-grained distributed systems in generic and predictable fashions. Java lacked the ability to make invocations on

\*. This chapter was co-authored by Carlos Valcarcel of EinTech, Inc.

local objects that, in reality, were invocations on remote objects. This capability would have allowed Java to make standard method calls on objects that appeared local, but were in a different process space. The supporting infrastructure was not available to Java, so vendors in the distributed-object arena began porting their infrastructure products to support Java. The infrastructure that was the best fit with Java turned out to be CORBA.

CORBA stands for the *Common Object Request Broker Architecture*. More accurately, CORBA stands for “glue.” It allows programs written in various languages, with varying implementations running in disparate locations, to communicate with each other as easily as if they were in the same process address space. Conceptually, in the same way objects cooperate to accomplish specific tasks, CORBA describes architecture made of cooperating services.



### Software Engineering Observation 26.1

*CORBA does not enforce good systems-integration practice; it merely enables the integration of disparate systems.*

CORBA relies on object technology to accomplish this. Encapsulation, inheritance, polymorphism and dynamic binding hide implementation details, making CORBA’s work appear transparent. Transparency is a crucial goal of CORBA. This transparency enables developers and system integrators to define standard services that legacy systems provide and make these services available to other systems that want to use them. Within this transparent infrastructure, a myriad of services are available to other users that need the services. Three areas leveraged by clients using CORBA are invocation transparency, implementation transparency and location transparency.

*Invocation transparency* defines the viewpoint of a client sending a message to a server. The language used to implement a client specifies how a called object receives a message—how arguments are passed on the stack, how the proper method is called, and how return values are delivered. Once a server (an object that is responsible for delivering a collection of related services) is defined within a CORBA framework, a client can make method calls to this CORBA-enabled object similarly as a call to any other object implemented within the target language. This kind of behavior is more naturally understood by developers using an object-oriented language (e.g., Java, C++, and Smalltalk), but is equally valid for developers using a non-OO language (e.g., C, COBOL, or Lisp). CORBA supports a number of object-oriented and non-object-oriented languages (10 altogether)—C, C++, Java, COBOL, Ada, Lisp, Smalltalk, PL/1, Python and IDLscript.

*Implementation transparency* is a encapsulation applied to distributed systems. A client knows three things about a method invocation—the method name, the method parameters (if any) and the method return type. The client is not concerned with how the underlying code processes parameters and ensures returning valid values—even with performance considerations, the client can notify the server as to any performance constraints prior to making any method invocations. A client invokes a method in the target (client’s) language, and the code invoked to satisfy the method call is executed in any language supported by an OMG mapping.

*Location transparency* allows a client to invoke CORBA-enabled code that might execute elsewhere on the network. This builds on implementation transparency—the clients appear to make local calls, but in reality, they call code that executes in different languages outside of the process space where the client is located (e.g., a Java servlet running in New

York communicates with a COBOL legacy database running in Japan). All of this is possible because of various object-technology concepts (encapsulation, inheritance, and polymorphism) used in implementation-independent ways.

The *Object Management Group (OMG)* is the consortium responsible for CORBA. Founded in April 1989, the OMG's goals are far reaching and have the backing of approximately 800 members. Their main goal is to create a “component-based software marketplace by hastening the introduction of standardized object software.”<sup>1</sup> A major step toward the creation of this object marketplace was the defining of the OMG’s Object Management Architecture (OMA).

The *Object Management Architecture (OMA)* distinguishes CORBA from other distributed system technologies. Objects in an object-oriented system cooperate to achieve solutions to domain problems. The OMA (as a reference architecture) defines a system consisting of cooperating services solving a domain problem. The granularity of the solution is larger, but the concept of objects (or components) working together toward a common goal remains the same.

So, how do the goals of systems integration, transparency, and ease of use come together, using a reference architecture in a fashion that allows multilanguage, multiplatform, and multilocation issues to be handled in a consistent and straightforward fashion? The answer is in these three acronyms—IDL, ORB and IIOP.

For objects to appear to speak the same language, they must use a common mapping to their particular language. For code in languages such as COBOL, Java, C, and Python to communicate to one another, an intermediate language must bind them. This intermediate language should be simple to use, easy to learn and have minimal overhead.

*OMG IDL™*, the *OMG Interface Definition Language* (commonly referred to as IDL), allows developers to describe the interface (or API) of the data type they wish to use remotely in a language-independent fashion. IDL is a pure description language—no implementation details are included in IDL files (unless someone deliberately inserts comments describing implementation assumptions). Using a C++-like syntax, developers describe only two things—the interface to an object and any data structures a method call to the object may take or return as values. An IDL compiler takes an IDL file (conventionally ending with `.idl`) and generates the code needed for a client to call a CORBA-compliant object and for the CORBA-compliant object to receive and return values. When we speak of a CORBA-compliant “object” we make no assumptions about whether it is an object in the way Java describes a object or procedural COBOL code that implements the operations (methods) defined in an IDL file in a non-object oriented fashion. The code that implements the operations (i.e., handles client requests to a CORBA object) constitutes a *servant*. In a non-object-oriented language there is an individual servant for each operation. In an object-oriented language, one servant (object) may implement all of the operations. The client does not know about the implementation issues involved, so a servant can exist for the duration of a method call, for until the server within which the servant is running is shut down or for some duration in between (this, however, is controlled by an object adapter which mediates all access to servants. We discuss this in more detail in Section 26.4).

An IDL compiler creates a number of language-dependent files for each IDL file compiled. A project would need as many IDL compilers as there are target languages in the system to be developed. To develop a Java front-end to a legacy COBOL system, two IDL

compilers are needed—one to generate the client-side Java code, and one to generate the server-side COBOL code. For example, a Java front end would need the following generated client-side Java files to interact with a back-end system named **StockTicker**:

```
StockTicker.java
StockTickerOperations.java
StockTickerHolder.java
StockTickerHelper.java
_StockTickerStub.java
```

**StockTicker.java** contains the base definition of the remote server. The **StockTickerOperations** source file contains method definitions of the operations that the CORBA object supports. The **\_StockTickerStub** class is responsible for client-side communication, while the **StockTickerHelper** file defines a convenience class usable by the client for CORBA-related tasks.

These files hide the invocation mechanism from a caller. **StockTicker.java** and **StockTickerOperations.java** define interfaces for use by implementation classes; **\_StockTickerStub.java** defines actual CORBA invocation code to make the remote method call to a server. Files **StockTickerHelper.java** and **StockTickerHolder.java** are additional support files that we discuss later.

The vendor who supplies the server component ships an IDL file that describes the API to their server object. Using the vendor-supplied IDL file and an IDL compiler, a developer would generate the needed client-side files to talk directly to this server-side object.

If a GUI written in C for the **StockTicker** system were to attempt to send messages to server-side objects written in Java (CORBA-enabled Java objects) the following Java files would have been generated by an IDL compiler to allow the Java server object to receive messages from any callers:

```
StockTicker.java
StockTickerOperations.java
_StockTickerImplBase.java
```

The files **StockTicker.java** and **StockTickerOperations.java** are the same as above (interfaces for use by implementation classes), and **\_StockTickerImplBase.java** represents the CORBA code used by the server to accept method calls and deliver values across the network.

In addition to declaring Java interfaces for developer use, both client-side and server-side files defined above implement base classes as *proxies*—stand-ins for other objects. Proxies allow a client to believe it is sending a message to one object when the client is really sending the message to another object. CORBA defines two related proxies—a *stub* and a *skeleton*. A stub is the client-side proxy and a skeleton is the server-side proxy. Both proxies hide the use of the ORB from the client and the server.

The *Object Request Broker* is the “ORB part” of CORBA. Interoperability is the ORB’s central purpose. All CORBA-enabled objects must use an ORB to make or receive method requests, but those same objects rarely see the ORB. In the examples that follow, note the similarity of the code for connecting various pieces. This code similarity is the OMG at work. The base connectivity CORBA API is the same regardless of the CORBA implementation.



### Portability Tip 26.1

*Unless you use vendor-specific value-added features under CORBA 3.0, the replacement of an existing ORB installation with an ORB vendor's new product should not require the modification of existing CORBA code.*

When a client invokes an operation on a distributed object, the client's ORB uses an object reference to complete the invocation request. For example, if the client was written in Java, it behaves as if the reference is to a local version of the object being invoked. The object reference used by the client (supporting the public API of the object defined in the IDL file) contain an *opaque network reference* (opaque because neither the client nor server infer implementation details with the information contained in the reference). A client invokes operations on a distributed object through an object reference, whereas an *Interoperable Object Reference (IOR)* refers specifically to an object reference whose structure is well-understood by ORBs using the OMG-supported protocols (such as IIOP, discussed momentarily). The object reference comes from an *object adapter* pointing to the remote object. The object reference contains three important pieces of information—the distributed object's location (an address, but not a memory address), a reference to the adapter that created the object reference and an *object ID* for the servant. All CORBA-compliant ORBs understand what object references are (and, for true interoperability, they must understand IORs) and how to use them to connect clients to servants. The final piece needed for interoperability is the creation and parsing of the IOR into the “on-the-wire” protocol to send a request across the network.<sup>2</sup> However, knowledge of IORs is not enough to allow one vendor's ORB to communicate predictably with another vendor's ORB. To enable robust, predictable communication, the OMG specified the *Internet Inter-ORB Protocol* or *IIOP*.

All vendors must support *IIOP* (*Internet Inter-ORB Protocol*) for their ORBs to be CORBA-compliant. Vendors can support their own protocol as well, but, at a minimum, they must also support IIOP. IIOP is the protocol for how ORBs communicate with each other. The average developer does not need to know anything about IIOP; a CORBA site administrator maintains the appropriate ORB protocol at any particular location. ORBs that expect to communicate with each other must speak the same protocol. If the ORBs support different protocols, custom bridges must be developed to map the protocols to enable communications between nonstandard-protocol ORBs. As the standard ORB protocol, IIOP should be the default protocol for any ORB installation, although IIOP is not the only choice.

IIOP is the implementation of another OMG standard—the *General Inter-ORB Protocol*, or *GIOP*. GIOP defines the messages needed by ORBs to communicate with each other and the support for the underlying transport mechanism of the platform on which the ORB runs. TCP/IP is the preferred transport—there is also specification support for Novell IPX and OSI. Vendors are free to support other transport mechanisms. Java, with its built-in network support, and CORBA, with its “under-the-covers” transport to connect distributed objects transparently, are complementary technologies.

Every programming language that the OMG supports must have an IDL-to-target-language mapping. Shortly after Java's introduction, a number of ORB vendors made their own mappings to satisfy the demand for distributed Java applications. The OMG adopted a Java mapping as a CORBA standard in July 1998. When the OMG ratified the official IDL-to-Java mapping, vendors upgraded their products to conform. Conformity to the IDL mappings is an important step to maintaining integrity in the CORBA world. The IDL-to-Java mapping defines how the standard IDL keywords and data types translate into Java

constructs. Java 2 was the first official Sun release to support the OMG mappings directly. We discuss IDL-to-Java mappings shortly.

## 26.2 Step-by-Step

The steps necessary to implement a distributed system using Java and CORBA are:

1. Perform analysis and design by modeling the problem domain, modeling the system domain and defining subsystems using the system domain.
2. Define the IDL by specifying the API of the subsystems to be distributed and specifying any data structures that cross system boundaries.
3. Implement the servant, using files generated by the IDL compiler.
4. Implement a client, using the stub files generated by the IDL compiler.
5. Decide on a method to distribute the servant's object reference (traditionally done using a Naming Service, but this is not required).
6. Start the servant implementation.
7. Run the client.



### Software Engineering Observation 26.2

*Implementing a distributed system is a nontrivial task. Developers must follow standard software development practices when using CORBA as an enabling infrastructure to bind various legacy systems together.*



### Good Programming Practice 26.1

*Several processes and methodologies for modeling problem domains exist. Make sure the model you choose maps to the problem being solved (otherwise, you might find yourself redoing your project).*

The OMG's OMA remains the preferred reference architecture for directing architectural concerns. OMA defines architecture in the context of a collection of cooperating services. Consider the subsystems you declare as sharing responsibilities. There are more opportunities for process reuse if your system defines fundamental services that are usable by other development groups.

Once subsystems have been defined, you want to decide which subsystems to configure as distributed services. If all of the subsystem designs assume distributed/sharable functionality, the migration of subsystems to CORBA becomes much easier. In any case, the public API of the service becomes the interface accessible by clients. In typical OO fashion, the interface revealed in the IDL can be a subset of the available functionality offered by a server. It is not until the implementation of the server (we use Java as the target language) that the developer worries about how much additional functionality (administration, security, etc.) the server is given.

If there are data structures that a server must return to a client (or vice versa), the identification and definition of these data structures must be in the IDL file. This is a bit of a throwback to the way languages such as C define data structures, but the CORBA model makes allows non-object-oriented languages to describe non-object-oriented constructs in a "pseudo-object" fashion. Two CORBA constructs support this mechanism—the **struct**

and the **valuetype**. A client and a server pass IDL **structs** back and forth as raw data for allowing local handling of information. A standard optimization is sending this data directly to the client so the server can handle more demanding requests. The **valuetype** construct is the IDL description of an entity consisting of both data and behavior. A **struct** consists of pure data (and a **struct** compiled into Java defines the instance attributes as **public**), whereas a **valuetype** encapsulates the data and adds any logic for making the object as simple or complex as needed. Section 26.8.5 explains a CORBA **valuetype** in more detail.



### Performance Tip 26.1

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*Make all methods transactional. Remember, every method call is a call across the network. The granularity of services should be such that a useful level of functionality is achievable in as few methods as possible (preferably one method call). If you need to get a **Customer**'s street address, city, state and zip code, create an **Address** class that encapsulates this information. The caller can make one call to the **Address**, rather than make five individual method calls.*

After declaring the server API in an IDL file, the only thing missing is the actual implementation of the server. The IDL compiler parses the completed IDL file and generates a collection of support files needed by the server to handle incoming requests. Once the support files are created, the developer can now write implementation code; until this time, the only thing the developer has done is declare the interface, attributes and data needed by the server to handle requests. As a first cut, a developer could implement a “dummy” server that simply returns test data so another developer could write a system client (or possibly a test client) to exercise the server. A more typical example is to write a server that wraps around a legacy back end but hides that fact from any clients.

Assume that the declared server API is in an IDL file and an IDL compiler has compiled the file. Now the client uses the generated client-side files needed to speak with the server. The client needs only the IDL-generated files to take advantage of the underlying mechanism that allows communication across the network transparently. The client could instantiate a local version of the server (instead of using a CORBA object reference, they could simply perform a **new ServerImpl()**) and send messages directly, but the server would no longer be a distributed object—the server would be running in the client’s process space having lost the low-coupling advantage we originally had by using the glue code located in the generated files.

## 26.3 First Example: SystemClock

This example provides a basic service (time) and allows a client to query for the current time. The requirements are:

- Retrieve the current system time.
- Display the current system time in a GUI window.

The **SystemClock** server interface declares a single method **currentTimeMillis** (which mimics the call in class **java.lang.System**). The method returns the system time as a **long**. A **Date** object would have been more appropriate for Java. If this were an example of the *CORBA Time Service*, a *Universal Time Object* would have been even more appropriate. However, a **long** helps keep this pure-Java example simple (a non-trivial time service factors issues such as network latency).

### 26.3.1 SystemClock.idl

Figure 26.1 declares the IDL for the **SystemClock** server. Lines 1 and 2 are single-line comments; they follow standard C++ syntax with the double slash (//) denoting a single-line comment. Line 4 is the first real line of “code” (CORBA does not dictate implementation, so the IDL is not technically code). The **module** keyword maps a given name directly to a Java package. Nested **module** names concatenated together create a complete package name. The **module** name in Fig. 26.1 is **clock**.

The curly braces at lines 4 and 10 denote scope boundaries of the block. Note that, in IDL, a semicolon always identifies the end of a block (including the **module** declaration). Java, C and C++ are block-scoped languages and use a similar syntax but do not consider the block itself as a line that requires a semicolon to be complete. A missing semicolon is a syntax error in IDL.

Lines 7-9 declare the interface the **SystemClock** server. Is the server type actually **SystemClock**? From the client’s perspective, the answer is yes—the data type of the server is **SystemClock**. From the server’s perspective, the answer is no—that is not the direct type. The server is a derived class (concrete implementation) of **interface SystemClock**. The indirection to the client is deliberate, allowing an arbitrary server implementation.

The curly braces at lines 7 and 9 mark the boundary of the **interface** declaration. Again, notice the semicolon at the end of line 9 used to identify the end of the block.

Line 8 is a method/function/message declaration. Everything declared in IDL is **public**, so there are no special keywords in IDL **interfaces** to denote **public**, **private** or **protected** declarations (although metatypes **component** and **valuetype** have keywords **private** and **public**). The method **currentTimeMillis**, by definition, is **public** and returns an IDL **long long**, which maps to a Java **long** (a single IDL **long** maps to a Java **int**).

The Java IDL compiler, **idlj**, compiles **systemclock.idl** with the command line

```
idlj -td c:\src -pkgPrefix clock com.deitel.advjhttp1.idl
      -fall systemclock.idl
```

We discuss the Java tool **idlj** and its command line options shortly. The Java IDL compiler generates the following server-side files after compiling **systemclock.idl**:

```
SystemClock.java
SystemClockOperations.java
_SystemClockImplBase.java
```

```
1 // Fig. 26.1: systemclock.idl
2 // IDL definition of SystemClock.
3
4 module clock {
5
6     // The definition of the CORBA-enabled service
7     interface SystemClock {
8         long long currentTimeMillis();
9     };
10};
```

Fig. 26.1 IDL definition for server **SystemClock**.

`SystemClock.java` and `SystemClockOperations.java` are **interfaces**. `SystemClock.java` (Fig. 26.2) shows **interface SystemClock**.

Lines 11 and 12 declare **interface SystemClock** and the three **interfaces** from which **SystemClock** inherits. Two of the three are CORBA-defined types from which all CORBA-enabled objects must inherit `org.omg.CORBA.Object` and `org.omg.CORBA.portable.IDLEntity`. The third—**interface SystemClockOperations** (Fig. 26.3)—is generated from the IDL and declares the public operations of the server. `SystemClock` inherits from `SystemClockOperations`, but is otherwise empty. `SystemClock` defines a base class that inherits from `SystemClockOperations` and the CORBA **interfaces** mentioned previously—part of the structure needed by derived classes to appear as proper CORBA objects. `SystemClockOperations`, inheriting from nothing, declares the single method `currentTimeMillis` originally defined in the IDL. `_SystemClockImplBase` inherits from `SystemClock`, another CORBA interface (`InvokeHandler`), and a base CORBA implementation class named `org.omg.CORBA.portable.ObjectImpl` (`Impl` is an abbreviation for “implementation”). The server requires these three object types to inherit the structure and behavior needed to be a valid CORBA-enabled distributed object. The interface `InvokeHandler` declares method `invoke`, which `_SystemClockImplBase` implements. The ORB uses method `invoke` to call the various `SystemClock` methods in a generic fashion. The `_SystemClockImplBase` method `invoke` is generated by the IDL compiler based on the IDL interface declared in the IDL file `systemclock.idl`.

### 26.3.2 `SystemClockImpl.java`

`SystemClockImpl` (Fig. 26.4) is the `SystemClock` interface implementation. Conventionally, the concrete class that implements a CORBA distributed object’s public interface is named `<IDL interface name>Impl`. This class does not have to declare a `main` method, but it can.

Lines 7–9 are standard `import` statements. We use classes outside the `java.lang` namespace, so we include them in the Java file. A discussion of the classes declared in these `imports` follows shortly.

```

1 package com.deitel.advjhtp1.idl.clock;
2
3
4 /**
5  * com/deitel/jhtp4/idl/clock/SystemClock.java
6  * Generated by the IDL-to-Java compiler (portable), version "3.0"
7  * from systemclock.idl
8  * Wednesday, February 28, 2001 8:24:01 PM PST
9 */
10
11 public interface SystemClock extends SystemClockOperations,
12     org.omg.CORBA.Object, org.omg.CORBA.portable.IDLEntity
13 {
14 } // interface SystemClock

```

Fig. 26.2 A Java interface generated by `idlj`.

```

1 package com.deitel.advjhtp1.idl.clock;
2
3
4 /**
5 * com/deitel/advjhtp1/idl/clock/SystemClockOperations.java
6 * Generated by the IDL-to-Java compiler (portable), version "3.0"
7 * from systemclock.idl
8 * Sunday, July 1, 2001 10:36:53 PM PDT
9 */
10
11
12 // The definition of the CORBA-enabled service
13 public interface SystemClockOperations
14 {
15     long currentTimeMillis ();
16 } // interface SystemClockOperations

```

Fig. 26.3 **SystemClockOperations** interface generated by **idlj**.

Method **main** (lines 62–74) starts the **SystemClock** server. Line 65 instantiates the **SystemClockImpl** object. The **SystemClockImpl** constructor (lines 20–23) is for the startup initialization. We instantiate **SystemClockImpl** like any other Java object and, in this example, we do not appear to use the object for anything (in fact, the object is waiting for an incoming client request). Line 68 creates an object we can lock against and call its thread's **wait** method (line 72). The use of keyword **synchronized** (line 71) means no other object can access **object** while the **synchronized** block is active. Line 72 stores the object in the thread queue until someone calls **object.notify**. Object **timeServer** could call **notify** within its own scope, but that would potentially cause the server to terminate when it completes handling an incoming call.

```

1 // Fig. 26.4: SystemClockImpl.java
2 // SystemClock service implementation.
3
4 package com.deitel.advjhtp1.idl.clock;
5
6 // OMG CORBA packages
7 import org.omg.CORBA.ORB;
8 import org.omg.CosNaming.*;
9 import org.omg.CosNaming.NamingContextPackage.*;
10
11 public class SystemClockImpl extends _SystemClockImplBase {
12
13     // return computer's current time in milliseconds
14     public long currentTimeMillis()
15     {
16         return System.currentTimeMillis();
17     }
18

```

Fig. 26.4 Implementation of the **SystemClock** server (part 1 of 3).

```

19     // initialize SystemClockImpl object by calling method register
20     public SystemClockImpl( String params[] ) throws Exception
21     {
22         register( "TimeServer", params );
23     }
24
25     // register SystemClockImpl object with Naming Service
26     private void register( String corbaName, String params[] )
27         throws org.omg.CORBA.ORBPackage.InvalidName,
28             org.omg.CosNaming.NamingContextPackage.InvalidName,
29                 CannotProceed, NotFound
30     {
31         // Check name of service. If name is null or blank
32         // do not attempt to bind to Naming Service.
33         if ( ( corbaName == null ) ||
34             ( corbaName.trim().length() == 0 ) )
35             throw new IllegalArgumentException(
36                 "Registration name cannot be null or blank." );
37
38         // create and initialize ORB
39         ORB orb = ORB.init( params, null );
40
41         // register this object with ORB
42         orb.connect( this );
43
44         // find Naming Service
45         org.omg.CORBA.Object corbaObject =
46             orb.resolve_initial_references( "NameService" );
47         NamingContext naming =
48             NamingContextHelper.narrow( corbaObject );
49
50         // create NameComponent array with path information to
51         // find this object
52         NameComponent namingComponent =
53             new NameComponent( corbaName, "" );
54         NameComponent path[] = { namingComponent };
55
56         // bind SystemClockImpl object with ORB
57         naming.rebind( path, this );
58         System.out.println( "Rebind complete" );
59     }
60
61     // main method to execute server
62     public static void main( String[] args ) throws Exception
63     {
64         // Create the SystemClock CORBA object.
65         SystemClock timeServer = new SystemClockImpl( args );
66
67         // Wait for requests from the outside.
68         java.lang.Object object = new java.lang.Object();
69

```

Fig. 26.4 Implementation of the **SystemClock** server (part 2 of 3).

```

70      // keep server alive
71      synchronized( object ) {
72          object.wait();
73      }
74  }
75 } // end class SystemClockImpl

```

Fig. 26.4 Implementation of the **SystemClock** server (part 3 of 3).

The **SystemClockImpl** constructor can throw exceptions of type **Exception**. For this example, we allow the constructor to throw **Exception** out of expedience and not out of correctness. The incoming argument **params** is an array of **Strings** that may contain properties needed to run the server. The **register** method takes array **params** and the **String** “**TimeServer**” to initialize the **SystemClock** service.

Lines 26–59 declare method **register**. Aside from the **SystemClock** service receiving a name (contained in variable **corbaName**) and any useful configuration parameters (**params**), this method can throw one of four exceptions:

- **InvalidName** thrown by the ORB
- **InvalidName** thrown by the Naming Service
- **CannotProceed**
- **NotFound**

The ORB or the Naming Service may throw one of these exceptions based on server interactions. In this case, the ORB is part of the process space of the **SystemClock** server. The server instantiates the objects needed to accomplish its tasks and does not know what kind of ORB it uses. As the CORBA standard does not specify the ORB’s implementation the ORB can be either a local object taking care of network connectivity or a proxy to a *daemon* process (a background process running in its own address space) taking care of network connectivity. The Naming Service is a separate process the server registers with to allow clients to find them.

Lines 35–36 throw a Java **IllegalArgumentException** if the incoming argument **corbaName** is **null** or blank (checked at line 33–34). The server cannot register itself for use by others without a name—this error is severe enough that we would not want to continue without one.

Line 39 is a **static** method call to the ORB class requesting the creation of a new ORB object based on the incoming arguments. A valid incoming argument is a command-line option telling the ORB what communications port to use (for example, **ORBInitialPort**). There is also a no-argument version of **init** that returns a default ORB instead of instantiating a newly configured ORB based on incoming properties. The **init** method can have its arguments as **null**.

Line 42 passes the implementation object to the ORB. All access to the server is now the responsibility of the ORB. The ORB (depending on its implementation) is responsible for load balancing, security, custom filters, etc. In addition, the ORB is responsible for the underlying protocol’s basic operation—the particulars of every generated **ImplBase** class will vary based on its IDL definition (the methods being invoked and the object types

involved can be different per server type), but ultimately the functionality is the same. The ORB calls method `_invoke` (found in the `_SystemClockImplBase` class); `_invoke` takes care of *marshaling* incoming arguments (converting values into a format suitable for network transport) and *unmarshaling* any return values (converting values back into a usable form). Once the ORB has the implementation object, the object cannot be accessed except through the ORB.

A server can make itself available to clients in a number of ways. Lines 45–48 show the easiest way to register a distributed object for client access. The `SystemClock` server (implemented in `SystemClockImpl`) registers itself with some directory service clients can reference when they look for services. A directory service serves the same purpose a file system does—it maintains a listing of resources and their locations in an accessible form. A standard CORBA directory service is the *Naming Service*, which lists resources for future use by clients. The act of registration with Naming does not mean a server is performing any tasks; the server is merely making itself available for client use. The service should be prepared to handle incoming requests for functionality needed by a calling client at any moment. The startup sequence for a server, or *bootstrapping*, can be problematic—how does the server find the Naming Service the first time the server starts up? Is there a Naming Service finder?

The ORB solves the problem for us—method `resolve_initial_references` knows a select list of services reachable directly from the ORB. The string “`NameService`” is a standard name defined in the CORBA specification (along with a list of other names<sup>3</sup>). The ORB effectively has a mini-naming service with which it can perform the lookup of base services.

Lines 45–46 retrieve the object reference to the Naming Service. However, for `resolve_initial_reference` to work with any of a number of different services, the method returns the object reference as an object of type `org.omg.CORBA.Object`. Lines 47–48 use `static` method `narrow` of class `NamingContextHelper` to convert the returned object reference into an object of the proper type (in this case, `NamingContext`). The `narrow` method is the CORBA mechanism to cast one reference type into another safely. The `narrow` method checks if the interface into which we are trying to cast the target object is supported by the target object. Standard casting does not work with CORBA object references, because the object reference is a proxy to remote information. All `Helper` classes have a `static narrow` method that allows us to cast from a parent class to a derived class.

Lines 52–54 create a `NameComponent` object and place it in an array. For a name to be properly registered (or *bound*) the resource must set up a *naming context*. The server is registered in the main (or root) naming context, so the only thing needed by the Naming Service is the server’s name, which the server sends at line 57 (the name was passed in as an argument to `register`) using `rebind`. Method `rebind` enters the `NameComponent` if it is not in the Naming Service or re-enters the `NameComponent` if it is in the Naming Service. However, using `rebind` in this way allows only one instance of the `SystemClock` to be accessed at a time (the `NamingContext` has been hard-coded to the incoming `corbaName` and every running instance will use the same name). The last `SystemClock` registered is the server to which clients bind.

In summary, the IDL describes the server, the compiler generates the needed Java support files and `SystemClockImpl` implements the server.

### 26.3.3 SystemClockClient.java

**SystemClockClient** (Fig. 26.5) represents the client that connects to **SystemClock**. **SystemClockClient**'s primary functionality is in method **run** (lines 58–80). This object connects to the **SystemClock** service, requests the current time and displays a **String** in a **JOptionPane**. Every time the user clicks the **OK** button, the client requests the latest time from the server and displays the new time. When the user clicks **Cancel**, the client application exits.

Method **connectToTimeServer** (lines 29–48) throws the same exceptions (**InvalidName**, **NotFound** and **CannotProceed**) as method **register** of class **SystemClockImpl**. The client and the server throw the same exceptions, because the logic the client uses to read from the Naming Service is similar to the logic used by the server to write to the Naming Service.

Line 35 calls **static** method **init** of class **ORB** to create an ORB. The **String** array **params** allows the dynamic configuration of the ORB at runtime (which was passed from method **main**, which received the **String** array from the command line). When the client obtains the ORG, lines 37–38 call method **resolve\_initial\_references** of this ORB to get the object reference to the Naming Service. Lines 39–40 cast the object reference from a CORBA **Object** to a **NamingContext** object using method **NamingContextHelper.narrow**.

```

1 // Fig. 26.5: SystemClockClient.java
2 // Client application for the SystemClock example.
3
4 package com.deitel.advjhtp1.idl.clock;
5
6 // Java core packages
7 import java.text.DateFormat;
8 import java.util.*;
9
10 // Java extension packages
11 import javax.swing.JOptionPane;
12
13 // OMG CORBA packages
14 import org.omg.CORBA.ORB;
15 import org.omg.CosNaming.*;
16 import org.omg.CosNaming.NamingContextPackage.*;
17
18 public class SystemClockClient implements Runnable {
19     private SystemClock timeServer;
20
21     // initialize client
22     public SystemTimeClient( String params[] ) throws Exception
23     {
24         connectToTimeServer( params );
25         startTimer();
26     }
27 }
```

Fig. 26.5 Client that connects to **SystemClock** (part 1 of 3).

```
28 // use NameService to connect to time server
29 private void connectToTimeServer( String params[] )
30     throws org.omg.CORBA.ORBPackage.InvalidName,
31             org.omg.CosNaming.NamingContextPackage.InvalidName,
32             NotFound, CannotProceed
33 {
34     // connect to SystemClock server
35     ORB orb = ORB.init( params, null );
36
37     org.omg.CORBA.Object corbaObject =
38         orb.resolve_initial_references( "NameService" );
39     NamingContext naming =
40         NamingContextHelper.narrow( corbaObject );
41
42     // resolve object reference in naming
43     NameComponent nameComponent =
44         new NameComponent( "TimeServer", "" );
45     NameComponent path[] = { nameComponent };
46     corbaObject = naming.resolve( path );
47     timeServer = SystemClockHelper.narrow( corbaObject );
48 }
49
50 // start timer thread
51 private void startTimer()
52 {
53     Thread thread = new Thread( this );
54     thread.start();
55 }
56
57 // talk to server on regular basis and display results
58 public void run()
59 {
60     long time = 0;
61     Date date = null;
62     DateFormat format =
63         DateFormat.getTimeInstance( DateFormat.LONG );
64     String timeString = null;
65     int response = 0;
66
67     while( true ) {
68         time = timeServer.currentTimeMillis();
69         date = new Date( time );
70         timeString = format.format( date );
71
72         response = JOptionPane.showConfirmDialog( null, timeString,
73             "SystemClock Example", JOptionPane.OK_CANCEL_OPTION );
74
75         if ( response == JOptionPane.CANCEL_OPTION )
76             break; // Get us out of here
77     }
78
79     System.exit( 0 );
80 }
```

Fig. 26.5 Client that connects to **SystemClock** (part 2 of 3).

```

81
82     // main method to execute client application
83     public static void main( String args[] ) throws Exception
84     {
85         // create client
86         try {
87             new SystemClockClient( args );
88         }
89
90         // process exceptions that occur while client executes
91         catch ( Exception exception ) {
92             System.out.println(
93                 "Exception thrown by SystemClockClient:" );
94             exception.printStackTrace();
95         }
96     }
97 } // end of class SystemClockClient

```

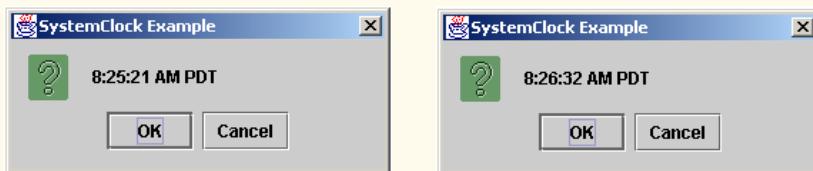


Fig. 26.5 Client that connects to **SystemClock** (part 3 of 3).

The client must ask the Naming Service for an object reference to the service the client seeks—the **SystemClock** service, named “**TimeServer**” (declared in the **SystemClockImpl** class).



### Good Programming Practice 26.2

*Store service names in a **.properties** file, rather than hard-code them in a class. Hard-coding implies additional maintenance of the class files when the values change. A **.properties** file allows for configuring an already deployed system, thereby making the fix an administrative issue, not a development issue.*

Lines 43–44 creates a **NameComponent** object. In **SystemClockImpl** (Fig. 26.4) we used the **NameComponent** object to register with the **NamingContext** the path to (and IOR of) where the **SystemClock** is located. In this case, **SystemClockClient** uses the **NameComponent** object to ask the **NamingContext** for the location of a service with a particular name. Lines 45–46 store the **NameComponent** object in an array, then pass the array to the **NamingContext** through its method **resolve**. This method returns an object of type CORBA **Object**, so we use **static** method **SystemClockHelper.narrow** to downcast the object reference to the desired derived class. At this point, the client has an active distributed object, and the client calls the distributed object when the user clicks the **OK** button.

### 26.3.4 Running the Example

Before running the preceding example, make sure that JDK 1.3 is installed on a workstation and the **PATH** environment variable is updated to include the **bin** directory of the JDK 1.3 installation.

The steps to execute the **SystemClock** example are as follows:

1. Compile the IDL file using **idlj**.
2. Implement and compile the server class.
3. Implement and compile the client class.
4. Run a Naming Service.
5. Run the server.
6. Run the client.

To compile the IDL file on the command line, use the **idlj** compiler supplied with the JDK. A partial list of **idlj**'s command-line options are:

- **-f<client | server | all>**
- **-pkgPrefix <module name or IDL type> <prefix to be appended>**
- **-td <output directory>**

The **-f** option to the **idlj** compiler controls the code generation of the stubs and skeletons. Option **-fclient** generates only client-side files, **-fserver** generates only server-side files and **-fall** generates both. The **-pkgPrefix** option generates package names. This option is used with a module name. A module named **modName** compiled with **-pkgPrefix modName prefix** would generate Java files with a package name of **prefix.modName**. The **-td** option directs **idlj** to write the generated files in the specified directory.

For example, if you had your source code in **C:\src**, the command line would look like this (based on the IDL defined in Fig. 26.1):

```
idlj -pkgPrefix clock com.deitel.advjhttp1.idl -td c:\src
      -fall SystemClock.idl
```

This generates both the server-side and client-side CORBA-Java files. After implementing the client and server, compile the client and server code. The code supplied in Fig. 26.4 and Fig. 26.5 (**SystemClockImpl.java** and **SystemClockClient.java**) is sufficient for this example.

Java 2 includes **tnameserv**, which is the basic implementation of the *CORBA Object Service (COS) Naming Service*. The **tnameserv** tool is not intended as a production-ready Naming Service; rather, it serves as a testing tool to ensure that clients and servers communicate properly. The Naming Service must execute before the server (**SystemClockImpl**) can run. Run **tnameserv** as a background process (in Windows, run **tnameserv** in a separate command window; under UNIX, just append an ampersand to the end of the line starting **tnameserv**):

```
tnameserv -ORBInitialPort 1050
```

All the processes started for this example use port 1050 to communicate. The default port for the name server shipped with Java 2 is port 900—however, sometimes that port is available only to administrators.

Start **SystemClockImpl** as a separate process:

```
java com.deitel.advjhttp1.idl.clock.SystemClockImpl
-ORBInitialPort 1050
```

Start **SystemClockClient** in the same way:

```
java com.deitel.advjhttp1.idl.clock.SystemClockClient
-ORBInitialPort 1050
```

When the client displays its GUI, clicking the **OK** button notifies the client to read the time from the server and to display a **String** with the formatted time. The first Java/CORBA example is complete.

## 26.4 Technical/Architectural Overview

The underlying concepts in CORBA discussed so far should be familiar to those developers who are familiar with design patterns. Stubs and skeletons are *proxies* (objects that control access to other objects). Services that return objects are *factories* (objects that create objects, but defer object implementation to derived classes). Factories and proxies can be found everywhere in the CORBA landscape. Those classes and objects that use design patterns hide a multitude of implementation details from developers.



### Good Programming Practice 26.3

*Design patterns standardize design terms and solutions. Learning design patterns helps developers reuse designs, components, services and frameworks.*

The ORB is the central mechanism of CORBA. All CORBA-enabled objects must have an ORB standing between them and whatever is calling them (Fig. 26.6). One ORB must exist for every object in a CORBA-enabled distributed system.

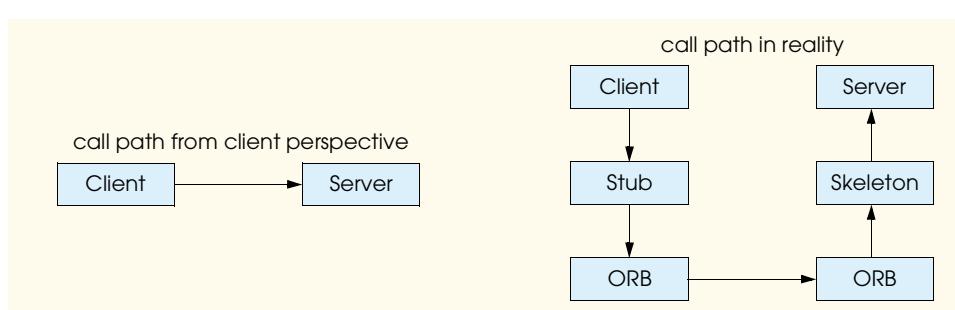


Fig. 26.6 Call path from a client to a distributed object.

We can view an Object Request Broker as the back plane (or communication bus) of distributed systems. As a communication bus, the implication is that everything using an ORB can communicate with everything else on the communication bus using an ORB. What advantage is there to using ORBs? ORBs are a flexible construct, but what problems do they solve? The OMG addressed both of these questions in the *Object Management Architecture*.

A typical software system addresses various business needs. *Legacy systems* (i.e., anything system installed earlier than yesterday) are typically separate, distinct and do not share information. They solve a focused problem, even if the solution involves large volumes of data. Over time, as modifications are made to the systems, they become more expensive to enhance. Over the last 30-40 years, these systems became incompatible. The changing hardware, software, and business landscape created a plethora of incompatible systems until the systems-integration field handled this communication problem. The invention of custom solutions to integrate these systems emphasized the need to make the integration less of a duplication of effort and more of an “out-of-the-box” solution. The OMG, together with its member vendors, created the Object Management Architecture (shown in Fig. 26.7).<sup>4</sup>

The Object Management Architecture (OMA) is the OMG’s reference architecture for distributed systems based on the concept of an Object Request Broker. Using object-technology concepts, the OMA defines a plug-and-play framework where publicly defined objects are available for use by any other object or service through an *object broker*. The object broker is a transparent communication mechanism that ensures that objects send messages reliably to one another regardless of their location. The OMA defines an abstraction that hides the fact that various systems use different programming languages or use incompatible versions of the same language.

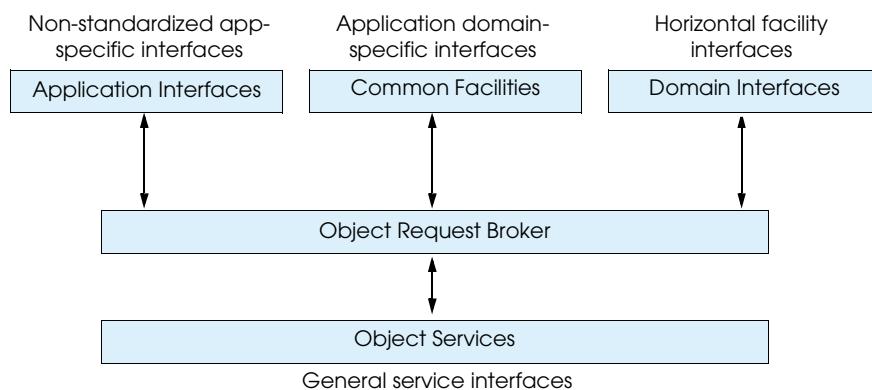
The Common Object Request Broker Architecture specifies how the Object Request Broker behaves and works using different languages. OMA defines a polymorphic framework of common services that appear similar from the outside (their API), but differ on the inside (their implementation).

ORBs can be implemented in one of two ways—as libraries or as daemons. Neither the client nor the servant are concerned with the means of implementation. The creation of an ORB object hides the underlying implementation. Traditionally, the client uses a library-based ORB, whereas the server uses a daemon-based ORB. This is an implementation detail for system administrators to decide. From the perspective of the running process, nothing changes.

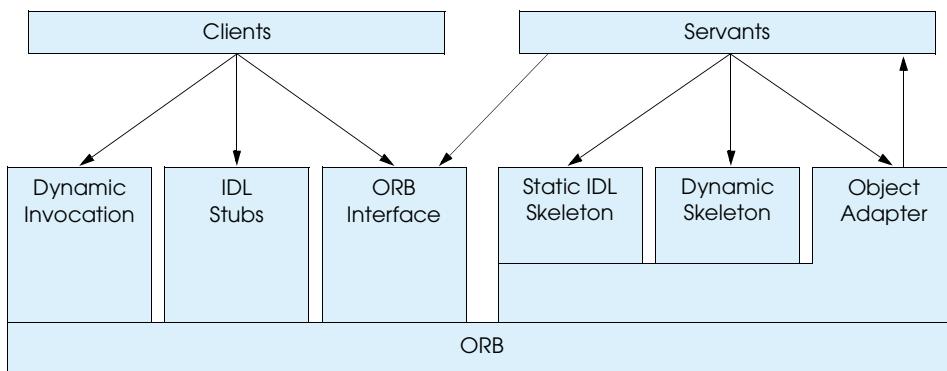
The ORB plays the most fundamental role possible in the OMA. We now examine how both the client and the servant perceive the ORB. The client communicates with the ORB in one of three ways—through a static stub (generated by the IDL compiler), a dynamic interface (using CORBA’s dynamic invocation API) or the ORB’s API. Conceptually, an ORB communicates with a servant in three ways—through a static skeleton, a dynamic interface or the servant’s object adapter (which appears as if the ORB directly interacts with servant). When a servant wants to communicate with another servant, the servant “becomes” a client and all its mechanisms become client-based.

The most straightforward way to communicate with an ORB is through the static stubs and skeletons. They contain the necessary communications code and enables static typing based on the defined IDL. Dynamic invocations (either from a client or a servant) consume

more overhead but are more flexible because they allow developers to control programmatically how remote objects are invoked (Section 27.2 discusses dynamic invocations). Execution of remote methods through direct ORB calls is possible, but not recommended. The indirection that gives CORBA its strength is bypassed and becomes difficult to restore once system implementation is under way. The client/servant communicates with the ORB to access certain actions that are possible only through the ORB—operations on object references and access to the *Interface* and *Implementation Repositories* (two data stores of object meta-data). Low-level CORBA development of that kind is needed only to implement infrastructure support, such as drivers and bridges. Figure 26.8 illustrates the ORB interactions.<sup>5</sup><sup>6</sup>



**Fig. 26.7** Object Management Architecture reference model. Courtesy of Object Management Group, Inc.



**Fig. 26.8** ORB request-interface structure. Courtesy of Object Management Group, Inc.

A CORBA concept discussed earlier was that of *object adapters*—objects that stand between a client and server to control access to the distributed object. The object adapter acts as a “connector” between a client and the servant code that executes when an operation is invoked (the ever-present ORB stands between the client and the object adapter). Prior to CORBA 3.0, the standard object adapter was the *Basic Object Adapter*, or *BOA*. The BOA facilitated binding between a client and a server. CORBA 3.0 defined another object adapter called the *Portable Object Adapter* (*POA*). The POA replaces the BOA as the object adapter of choice. The BOA design did not meet demands required by Internet applications. When the OMG first specified BOAs, what is now considered standard functionality (i.e., better CORBA portability between vendors) was not perceived as a high-priority issue. In the same way that Java has supplanted various technologies, the CORBA specification deprecates the BOA in favor of the POA.

The Portable Object Adapter serves many purposes, including the ability to separate the availability of the servant from the actual servant. When a client needs a service, the client needs particular functionality at a particular time. Several components interact to make this possible. First, the client has an object reference represented by a CORBA object. Using the object reference, this CORBA object contains information to find the object adapter that created it. The object adapter handles the client’s invocation by deciding which entity (or servant) can handle the invocation and completing the invocation as needed (based on various configuration options set when the object adapter was created). If the client, holding onto the object reference it received when it first connected to the servant, does not actually need to call the servant for some extended period, waiting for the client to use the servant should not penalize the servant. Scalability would suffer, making CORBA an ineffective solution for systems-integration. By separating the servant from the client’s handle to the service, different servant objects (controlled through object lifetime and activation patterns) can handle the method calls made on a service. There are a number of issues wrapped up in that last statement. The indirection gained by using a POA means transparent handling of those issues.

Chapter 27 discusses the dynamic interface that the client and server use. *Static stubs* (using the *Static Invocation Interface* or *SII*) have hard-coded object types to perform their type checking at compile time, whereas *dynamic stubs* (using the *Dynamic Invocation Interface* or *DI*) perform their type checking at runtime.

*CORBA services* are the baseline services available to all objects sitting on the ORB communication bus. Because the ORB is the center of a CORBA system, CORBA services can assume the existence of an ORB when they are running. There are sixteen services:<sup>7</sup>

1. Naming Service
2. Event Management Service
3. Life Cycle Service
4. Persistent State Service
5. Transaction Service
6. Concurrency Service
7. Relationship Service
8. Externalization Service

9. Query Service
10. Licensing Service
11. Property Service
12. Time Service
13. Security Service
14. Notification Service
15. Trader Service
16. Collections Service

These services are so fundamental that the Enterprise JavaBeans specification dictates the use of four of them as a requirement (naming, security, persistence and transaction). The CORBAservices all have standard IDL interfaces that describe the functionality that these services offer. The purpose of standard interfaces fits right in with another OMA goal: pluggable services should have standard mechanisms for access.

The *CORBAfacilities* are a step above the intermediate CORBAservices and come in two groups—*horizontal* and *vertical*. The horizontal facilities target client-side functionality, the vertical facilities target domain-specific functionality. The horizontal CORBAfacilities have only three specifications:<sup>8 9</sup>

1. Mobile Agents Facility
2. Printing Facility
3. Internationalization Facility

All three are course-grained enough not to be grouped with CORBAservices, but abstract enough not to conflict with potential vendor offerings that could be built on top of CORBAservices.

The vertical CORBAfacilities—also called *CORBA Domains*—are between the CORBAservices and the Applications Objects (Fig. 26.7). They make use of various CORBAservices and horizontal facilities and define domain-specific services. Eleven domain task forces define the various business areas:<sup>10</sup>

1. Common Enterprise Models
2. Finance/Insurance
3. Electronic Commerce
4. Manufacturing
5. Healthcare
6. Telecommunications
7. Transportation
8. Life Science Research
9. Utilities
10. C4I (Command, Control, Communications, Computers, and Intelligence)
11. Space

The various OMG committees for different industries are creating, enhancing and voting on dozens of specifications. CORBA Domains are worth the effort of a visit to the OMG site ([www.omg.org](http://www.omg.org)).

The Applications Objects are the top layer of the OMA. Relatively speaking, developers find the least amount of reusable code here; the objects at this layer address enterprise-specific domain areas. Applications Objects have the functionality not found at the domain layer, facilities layer or the services layer. Custom applications sit securely in the OMA framework, using existing IDL-defined services or brand new services developers have written in response to design requests.

An understanding of the OMA means a head start in developing an architecture, because so many of the pieces needed in most systems are defined in the OMA. Distributed systems are inherently complex and interesting, but the basic concepts are the same regardless of the designed system's size.

## 26.5 CORBA Basics

Distributed objects need to be defined so they can be discovered and used by other distributed objects. We define the distributed objects in IDL and use the stubs and skeletons generated by the IDL compiler to mediate the invocations in a consistent manner.<sup>1</sup>

ORB vendors ship IDL compilers with their products. As of Java 1.2, Javasoft commoditized the OMG libraries for Java by shipping them with the JDK. Having the CORBA libraries available allows Java/CORBA developers to generate their own stubs and skeletons using the Java-supplied IDL compiler **idlj**. Ideally, the Java stubs generated by the compiler should interoperate with the skeleton code running under another vendor's ORB (and the stub code from other vendor's ORBs should interoperate with the Java skeleton code), but test often and be aware of possible incompatibilities.

OMG document formal/99-07-53 defines the IDL-to-Java mapping and covers everything from package names to **Helpers** to mapping CORBA pseudo objects. Syntactically IDL is similar to C++, but the similarity ends there. Figure 26.9 lists the most frequently used specification mappings.<sup>11</sup>

IDL	Java
<b>module</b>	<b>package</b>
<b>interface</b>	<b>interface</b>
<b>struct</b>	<b>class</b>
<b>const</b>	<b>public static final</b>
<b>boolean</b>	<b>boolean</b>
<b>char</b>	<b>char</b>
<b>wchar</b>	<b>wchar</b>
<b>octet</b>	<b>octet</b>
<b>string</b>	<b>java.lang.String</b>

Fig. 26.9 IDL keywords, types and their mappings to Java keywords (part 1 of 2).

IDL	Java
wstring	<code>java.lang.String</code>
short	<code>short</code>
unsigned short	<code>short</code>
long	<code>int</code>
unsigned long	<code>int</code>
long long	<code>long</code>
unsigned long long	<code>long</code>
float	<code>float</code>
double	<code>double</code>
<b>fixed</b> (not supported in <code>idlj</code> )	<code>java.math.BigDecimal</code>
<b>sequence</b>	<code>[]</code> (array)
<code>[]</code> (array)	<code>[]</code> (array)

Fig. 26.9 IDL keywords, types and their mappings to Java keywords (part 2 of 2).

Packages starting with `org.omg` contain the Java packages that comprise the core CORBA infrastructure. CORBA vendors deliver their version of the CORBA libraries with their Java ORB products.

The following example walks through various IDL keywords and their Java counterparts. The IDL in Fig. 26.10 uses many of the IDL keywords so that we can see how the IDL compiler maps the keywords in the generated files listed in Fig. 26.11–Fig. 26.13.

```

1  /*
2   * Any comments located outside of the module declaration are
3   * ignored by the IDL compiler. This multi-line comment does
4   * not appear in any of the files generated by idlj.
5   */
6
7 // This single-line comment is also ignored by the IDL compiler
8
9 module maptest {
10
11    // This comment appears in the generated files for StructMap
12    struct StructMap {
13
14      // This comment appears at start of the type declarations
15      boolean boolValue;
16      char charValue;
17      wchar wCharValue;
18      octet octetValue;
19      string stringValue;
20      wstring wStringValue;
21      short shortValue;
```

Fig. 26.10 IDL file testing many of the IDL keywords and types (part 1 of 2).

```

22     unsigned short uShortValue;
23     long longValue;
24     unsigned long uLongValue;
25     long long longLongValue;
26     unsigned long long uLongLongValue;
27     float floatValue;
28     double doubleValue;
29
30     // fixed fixedValue; not supported by JavaIDL
31 };
32
33     typedef sequence <StructMap> StructMapSeq;
34     typedef sequence <StructMap, 5> BoundStructMapSeq;
35
36     typedef long IntArray[ 5 ];
37
38     // This comment appears above
39     // the interface declaration for interfaceName
40     interface interfaceName {
41
42         // comment above the readwrite attribute
43         attribute long anAttribute;
44         readonly attribute long roAttribute;
45         const long constantValue = 42;
46
47         // comment above the methods
48         void seqMethod( in StructMapSeq seq );
49         void boundSeqMethod( in BoundStructMapSeq seq );
50         void arrayMethod( in IntArray array );
51         void intOutMethod( inout long intValue );
52     };
53 } // end module maptest

```

Fig. 26.10 IDL file testing many of the IDL keywords and types (part 2 of 2).

File **maptest.idl** starts with two different types of comments—one multi-line block (lines 1–5), and a single-line comment (line 7). These comments do not appear in the generated files created by the IDL compiler. The comments are for the author and maintainers of the **.idl** file as a documentation aid. Comments placed in an IDL file appear in the generated files only if they are within the **module** scope. Therefore, lines 1–5 and line 7 from **maptest.idl** are extraneous to the **.java** files but not to the **.idl** file.

The **module** name **maptest** (line 9) maps directly to a **package** named **maptest** (however, the compiler can handle the prepending of a **package** name using the **-pkg-Prefix** command line option as we did in the **SystemClock** example). The **module** and its curly braces represent the highest level of symbol scope in IDL.

The comment on line 11 appears in the generated file so any documentation appropriate to the Java code can be included (it is within the scope of the **module**). Lines 12–31 declare **struct StructMap**. **StructMap** uses the bulk of the IDL data types to observe how they map to Java data types. Line 31 completes **struct StructMap** with a closing brace and a semicolon.

It would seem, from the table listing the translation points, that IDL does not handle complex types. In fact, **structs** allow for the complex aggregation of primitives and

object references. However, because a **struct** is not really a class (even though it gets converted into one), the compiler generates a **public final** class to prevent the creation of derived classes from the **struct**. A **struct** is a collection of data compiled into a class definition that a remote servant can return to, or receive from, a client at runtime. In both cases, a local copy of the data is received (instead of an object reference).

Most of the primitive IDL-to-Java mappings are straightforward. The IDL compiler maps signed primitives to corresponding signed primitive types in Java; unsigned IDL primitives run the risk of truncation, because they are mapped to their signed Java primitive counterparts (a signed short cannot store as large a value as an unsigned short). The IDL compiler also enforces the clean initialization of the instance variables by setting them to integer zero, 0.0, **false** or **null** (casting where necessary). Notice, in the generated Java code from **StructMap.java** (Fig. 26.11) that the declared instance variables are **public**. The IDL-generated code breaks encapsulation. In fact, everything in IDL is **public**, because C, COBOL and other IDL-mapped languages do not support encapsulation concepts.



### Software Engineering Observation 26.3

*Write wrapper classes to surround the **structs**-turned-objects as a way of restoring encapsulation. Wrapper classes define objects that mediate access to another object through a well-defined API. Pass the object representing the CORBA **struct** into the wrapper object's constructor when the wrapper object is instantiated.*

An **interface** (line 40) declares attributes clients can query and methods that clients can invoke on remote objects. A **struct** represents a real chunk of runtime data, whereas an **interface** represents a remote object that might be in a different process space, but appears as a local object. The **interface** represents the remote object because the IDL compiler does not *implement* the distributed object. The developer must take the generated code and implement the actual servant, using the generated definitions. Two of the generated interface files (**InterfaceNameOperations.java** and **InterfaceName.java**) encourage developers to (1) structure the servant in a way that allows polymorphic access to the servant through the parent interface (**InterfaceName**) and (2) inherit the distributed protocol behavior we need from an abstract class (**\_InterfaceNameImplBase**).

The distributed object definition **interface InterfaceName** contains two **attributes**, one constant and four operations. Line 43 declares an **attribute** that can be read and changed while line 44 explicitly defines **attribute roAttribute** to be **readonly**. The **const** keyword on line 45 declares the **constantValue** field unchangeable.

Only an **interface** can have **attribute** declarations. If the **attribute** keyword is used alone, the compiler generates two methods—an *accessor* (*get* method) and a *mutator* (*set* method). Using the **readonly** keyword with **attribute** would generate only the accessor. Originally, the accessor methods looked like JavaBean-style *get* methods (**getAge**, **getAttribute**). In the latest incarnation of the IDL specification, the JavaBeans naming convention is effectively deprecated. Overloaded methods are generated for both the accessor and mutator using the name of the attribute and are different based on their signatures—the accessor method signature for **attribute balance** would return a value while the mutator would take an incoming argument and return nothing. The implication is that CORBA objects cannot be JavaBeans, but that discussion continues in the CORBA components section in Chapter 27.

In IDL, the **const** keyword declares a constant. Syntactically, Java declares constant values using the **final** keyword. Idiomatically, the Java keywords **static** and **final** declare constants as there is no point in having multiple copies of an unchangeable value. The IDL compiler generated code complies with the Java idiom (Fig. 26.13, line 14). The IDL compiler also acknowledges the fact that integral values in Java start out as **longs** and so casts the literal to the smaller type.

The mapping of methods, the parameter-passing modes, holders and arrays represent the remaining concepts needed to define server-side objects and the services they provide. Java developers take many of these features for granted as Java defines cross-platform data sizes and mechanisms to invoke operations on objects in the Java Language Specification. CORBA IDL mappings make the same guarantees for data and invocations between any CORBA-supported languages.

Note the use of the **in** keyword in the method declaration in Fig. 26.10, line 48. IDL includes keywords **in**, **out** and **inout** to describe method arguments. A variable declared as **in** has a copy of itself passed to the called method. The scope of a change made by the servant is visible only to the servant (similar to call-by-value). When the method returns, the client will not see any changes. An **out** variable must be a reference to a Java object containing another Java object where the contained Java object may be substituted with another Java object and the change is visible to the client (similar to call-by-reference). A variable declared as **inout** uses both semantics. Java has two value types—primitives and object references. An object reference is, by definition, a call-by-reference. Use of a primitive, on the other hand, is only as a value. CORBA uses **Holder** objects to make the changing of values by a server-side object similar for both primitives and references. A **Holder** can have its values modified and the client can see the modification. In fact, this works similar to Java **Number** objects that wrap primitive values—however, Java **Number** objects are immutable while **Holderrs** are mutable (modifiable).

Every time a **struct** or **interface** is declared, the IDL compiler generates an associated **Holder** class for use when the **struct** or **interface** is an **inout** or **out** variable. If a servant needs to read a value (whether primitive or object), send the value as an **in** variable. If a servant needs to send a value to a client (whether primitive or object), send the value as an **out** (or **inout**) variable, and use the **Holder** objects to transport them across the network safely. All of the Java primitives have **Holder** classes available for them in the **org.omg.CORBA** package and the IDL compiler generates the proper method signature in the **Operations** interface defining the **Holder** object needed.

Lines 33 and 36 present the two ways to declare arrays in IDL—using the keyword **sequence** and the use of open-and-close square brackets (**[]**). The **sequence** keyword or **[]** are not used alone in either case. The IDL writer must declare a type definition (a **typedef**) using **sequence** or **[]** to declare the array as a simple name. For example, the type **StructMapSeq** is a **sequence** (array) of type **struct StructMap**.



### Common Programming Error 26.1

*The symbol **sequence <StructMap>** cannot define an array identifier; the IDL compiler requires a **typedef**-defined identifier for array types or the compiler generates a syntax error. Renaming the array declaration makes the new symbol become an additional object type.*

The **sequence** keyword can be used in one of two ways—*bounded* or *unbounded*. When a length is given, the **sequence** is considered bounded (line 34); otherwise, it is

considered unbounded (line 33). In both cases, the IDL-to-Java compiler unrolls the **typedef** back to an actual array declaration and generates **Helper** and **Holder** types for those array types (in this case, **StructMapSeqHelper**, **StructMapSeqHolder**, **BoundStructMapSeqHelper**, and **BoundStructMapSeqHolder**). We examine the **Holders** when we discuss *parameter passing* modes.

The standard square brackets notation also can declare arrays. However, the use of IDL arrays is non-standard to Java. In Java, lengths are not part of the intrinsic definition of a data type. In IDL, the new array (using **[1]**) defined using **typedef** has a bounded length enforced in the stub/skeleton proxies. The **typedef** keyword defines an array of a particular data type using a new data type name and the array length. A **typedef** in IDL is similar to a **typedef** in C and C++—a new data type appears to exist, but the data type is an alias for use by the compiler. Using a **typedef** allows the IDL developer to define new data types without the implementation issues involved in the declaration. In **maptest.idl**, (Fig. 26.10) an array of **struct StructMap** is declared using the keyword **typedef**, the type to be redefined and the new name, which is surrounded by **<>** (lines 33–34). The array’s length (its bound) is declared in the name, but is not used anywhere else; the array is bounded.

Figure 26.11 is the listing for **StructMap.java**—one of the generated files from **maptest.idl**. Line 1 (and the first line in each upcoming generated file) declares the **package** name as **maptest**. Lines 12 and 17 are the comments listed in Fig. 26.10 at lines 11 and 14. IDL authors and maintainers are responsible for including information on the IDL and its intended use, rather than including information on implementation specific details that can change.

The instance variables declared in lines 18–31 of Fig. 26.11 are the declared **struct** variables from Fig. 26.10. The Java code initializes the instance variables to include the use of explicit casting. The Java class mapped from the **struct** has two constructors available for object instantiation—a zero-argument constructor, and a constructor with all of the **struct**’s field types as arguments. Creating objects of this type can have default values (using the zero-argument constructor) or pre-defined values (using the second constructor).

**InterfaceNameOperations.java** (Fig. 26.12) contains the **interface** information declared in Fig. 26.10 at lines 40–52. The IDL compiler translated the operations into Java syntax and the comments from the IDL file are visible in the generated code at lines 12, 15, 18 and 22. A Java **interface** cannot contain any instance variables or implementation code, which makes an **interface** a perfect choice for declaring the visible structure for the implementation object. Note that **InterfaceNameOperations.java** does not declare the **attributes** defined in Fig. 26.10 lines 43–44, except indirectly through the available accessor and mutator (lines 16, 19 and 20). The IDL does not dictate the implementation of the **attributes**—the IDL dictates that they be available through a particular **interface**.

```
1 package maptest;
2
3
4 /**
5  * maptest/StructMap.java
```

Fig. 26.11 IDL-generated file **StructMap.java** (re-formatted for clarity)  
(part 1 of 3).

```
6  * Generated by the IDL-to-Java compiler (portable), version "3.0"
7  * from maptest.idl
8  * Monday, May 14, 2001 4:18:09 PM PDT
9  */
10
11
12 // This comment appears in the generated files for StructMap
13 public final class StructMap implements
14     org.omg.CORBA.portable.IDLEntity
15 {
16
17     // This comment appears at start of the type declarations
18     public boolean boolValue = false;
19     public char charValue = ( char ) 0;
20     public char wCharValue = ( char ) 0;
21     public byte octetValue = ( byte ) 0;
22     public String stringValue = null;
23     public String wStringValue = null;
24     public short shortValue = ( short ) 0;
25     public short uShortValue = ( short ) 0;
26     public int longValue = ( int ) 0;
27     public int uLongValue = ( int ) 0;
28     public long longLongValue = ( long ) 0;
29     public long uLongLongValue = ( long ) 0;
30     public float floatValue = ( float ) 0;
31     public double doubleValue = ( double ) 0;
32
33     public StructMap ()
34     {
35         // ctor
36
37     public StructMap( boolean _boolValue, char _charValue,
38                     char _wCharValue, byte _octetValue, String _stringValue,
39                     String wStringValue, short _shortValue,
40                     short _uShortValue, int _longValue, int _uLongValue,
41                     long _longLongValue, long _uLongLongValue,
42                     float _floatValue, double _doubleValue )
43     {
44         boolValue = _boolValue;
45         charValue = _charValue;
46         wCharValue = _wCharValue;
47         octetValue = _octetValue;
48         stringValue = _stringValue;
49         wStringValue = _wStringValue;
50         shortValue = _shortValue;
51         uShortValue = _uShortValue;
52         longValue = _longValue;
53         uLongValue = _uLongValue;
54         longLongValue = _longLongValue;
55         uLongLongValue = _uLongLongValue;
```

Fig. 26.11 IDL-generated file **StructMap.java** (re-formatted for clarity)  
(part 2 of 3).

---

```

56     floatValue = _floatValue;
57     doubleValue = _doubleValue;
58 } // ctor
59
60 } // class StructMap

```

---

Fig. 26.11 IDL-generated file **StructMap.java** (re-formatted for clarity)  
(part 3 of 3).

```

1 package maptest;
2
3
4 /**
5  * maptest/InterfaceNameOperations.java
6  * Generated by the IDL-to-Java compiler (portable), version "3.0"
7  * from maptest.idl
8  * Monday, May 14, 2001 4:18:09 PM PDT
9  */
10
11
12 // the interface declaration for InterfaceName
13 public interface InterfaceNameOperations
14 {
15     // comment above the readwrite attribute
16     int anAttribute();
17
18     // comment above the readwrite attribute
19     void anAttribute(int newAnAttribute);
20     int roAttribute();
21
22     // comment above methods
23     void seqMethod( maptest.StructMap[] seq );
24     void boundSeqMethod( maptest.StructMap[] seq );
25     void arrayMethod( int[] array );
26     void intOutMethod( org.omg.CORBA.IntHolder intValue );
27 } // interface InterfaceNameOperations

```

---

Fig. 26.12 IDL-generated file **InterfaceNameOperations.java**  
(re-formatted for clarity).

The final generated file discussed is **InterfaceName.java** in Fig. 26.13. The declaration of **interface InterfaceName** extends three **interfaces** and declares the constant **constantValue** at line 14 (otherwise, the interface is empty). Constants always appear in the file named after the **interface** declared in the IDL file.

When the IDL compiler processes an IDL file, primary responsibilities for the compiler is to generate these two proxy classes (one for the server, and one for the client). These proxies do not contain any application-specific functionality—they handle only connecting the client to the server. The stub, which directly reflects the API of the server declared in the IDL, can have any of the **public** methods of the server called from it. In the **SystemClock** example, when the client makes a call to **currentTimeMillis**, the client calls a method in the stub that handles calling method **\_invoke** in the stub's abstract parent (**org.omg.CORBA.portable.ObjectImpl**). **ObjectImpl**'s **\_invoke**

method marshals any incoming values (in this case there are none), and the stub code takes care of unmarshaling any return values (which in this case is a **long** value). From the client's perspective, it makes a method call on the server and blocks until the method returns with a value. In reality, the ORB makes the request by calling **\_invoke** on the stub to handle the method call. The **\_invoke** method calls the proper method on the servant, waits for the method to return and unmarshals any return values.

Prior to CORBA 3, there were two types of static invocations—*synchronous* and *oneway* (there was also one for dynamic invocation, but more on that later). When a client makes a *synchronous method call* to a server, the client *blocks* (does not return) until the server's method completes. The **oneway** modifier declared an invoked method as returning immediately—but did not declare any *quality-of-service* options. *Quality of Service* (known as *QoS*) defines the policy assigned to a particular task allowing the task to complete within a reasonable length of time.<sup>12</sup> The OMG considered QoS so important a separate QoS framework specification exists to allow developers to control QoS at various levels (generally speaking they are *ORB level*, *thread level* and *object-reference level*). Object reference level QoS overrides thread level QoS and thread level QoS overrides ORB level QoS.<sup>13</sup> QoS makes CORBA 3 invocation choices much more symmetrical—they can be synchronous (*normal* or **oneway**) or asynchronous (*callback* or *polling*). A callback is an invocation made from the server, whereas polling is an invocation made from the client—in either case, a method is being invoked based on the needs of the calling object. From an implementation perspective, a callback has more overhead as the callback object (the client) needs to use CORBA libraries to behave as a CORBA server. A polling client has no additional overhead to make repeated calls to a server. The distinction has to do with a met condition (a server alerts a callback object) or an expected condition (a client polls an object to check on state changes).



### Portability Tip 26.2

The OMG has not yet decided on standard default values for QoS, ORB vendors can define nonportable values. If you use these values, place them in a separate **.properties** file for the system to read on start-up.

```

1 package maptest;
2
3 /**
4  * maptest/InterfaceName.java
5  * Generated by the IDL-to-Java compiler (portable), version "3.0"
6  * from maptest.idl
7  * Monday, May 14, 2001 4:18:09 PM PDT
8  */
9
10 // the interface declaration for InterfaceName
11 public interface InterfaceName extends InterfaceNameOperations,
12     org.omg.CORBA.Object, org.omg.CORBA.portable.IDLEntity
13 {
14     public static final int constantValue = ( int ) ( 42 );
15 } // interface InterfaceName

```

Fig. 26.13 IDL-generated file **InterfaceName.java** (re-formatted for clarity).

A synchronous call is a standard method invocation—a client invokes a method and blocks until the call completes. If an IDL method signature includes the **oneway** keyword, the compiler generates code that does not block on the invocation and returns based on the QoS settings. To return immediately, the method must receive only **in** arguments, must not return values and cannot throw exceptions. The caller does not need to wait for a response (it notifies the server something has happened and does not care what happens next) or the client wants to make itself available as soon as possible to other callers. In either case, a synchronous call is client-initiated.

An asynchronous call differs from a synchronous call. In a callback situation, the server can call a client at any time. In many cases, a server calling a client asynchronously works fine (e.g., listeners in the Java event model), but consider when a client needs the server to notify it in a more controlled fashion? The CORBA *Asynchronous Method Invocation* specification supports both callback and polling models. The callback model supports (with various QoS options) the ability of a servant to call a client arbitrarily at the discretion of the servant. In the polling model, the client decides when to retrieve a possible result based on a call to a **oneway** method. In standard polling, there may be nothing to retrieve, so the client continues polling until it receives a valid value or decides to stop.

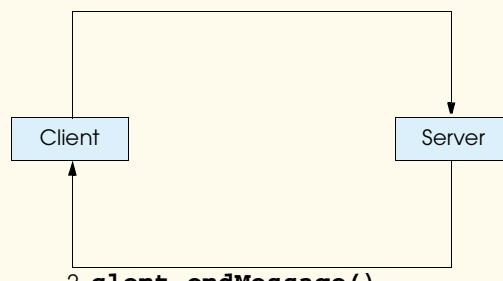
As a matter of convention, passing an object reference to another distributed object (especially for the express intent of callbacks) demands declaring its registration method as **oneway**. The **oneway** keyword tells the IDL compiler to generate code that does not block on the invocation waiting for the called operation to return. This nonblocking behavior prevents the registration method from making method calls on the incoming object reference. If neither object is multithreaded, a server calling a client can cause deadlock. Without the use of **oneway**, the client would wait for the server to return, and the server would wait for the client method to return (Fig. 26.14). Section 26.6 presents an explicit example of the use of the **oneway** keyword.



#### Good Programming Practice 26.4

To avoid deadlock, use the **oneway** keyword whenever passing an object reference to a client through a server method.

1. **registerClient( this )**



Client and server are now deadlocked.

**Fig. 26.14** Deadlock caused by client calling a server that calls the client.

## 26.6 Example: AlarmClock

The **AlarmClock** example is a different type of application from the **SystemClock** example. **SystemClock** is a typical *pull-model application*—the client decides when to retrieve information from the server. The **AlarmClock** example, on the other hand, is a typical *push-model application*—the server decides when to send information to the client. In **AlarmClock**, the client sets a server-side “alarm,” then waits for the server to wake it up when the alarm sounds. In this example, the client generates a random sleep time with which to set the alarm clock. When the alarm goes off, the server notifies the client and the awakened client displays a new sleep time and resets the alarm.

### 26.6.1 AlarmClock.idl

Figure 26.15 is the IDL declaring the two servers.

Line 4 declares the **module** name, and lines 5 and 9 declare the names of the server types. The **module** has two **interface** declarations—the server **interface** and the callback **interface**. The main server is **AlarmClock**, and **AlarmListener** is the callback definition. Using the keyword **const**, line 10 defines a constant called **NAME** for the implementation code when we bind to the Naming Service. **AlarmClock** method **addAlarmListener** at line 12–13 adds **AlarmListener** objects to a list of callback objects—any object holding a reference to an **AlarmListener** can call method **updateTime**. The caller sends in an arbitrary name for the server to associate the caller’s object reference with the name as a primary key. An **AlarmListener** object is a reference to a listener, so we add keyword **oneway** to make sure the compiler generates nonblocking code for this operation. The object implementing the **AlarmListener** interface can register itself with **AlarmClock** and then wait until the alarm expires. Figure 26.16 is the implementation of the “real” server.

---

```

1 // Fig. 26.15: alarmclock1.idl
2 // The IDL for the AlarmClock example
3
4 module alarm {
5     interface AlarmListener {
6         void updateTime( in long long newTime );
7     };
8
9     interface AlarmClock {
10        const string NAME = "AlarmClock";
11
12        oneway void addAlarmListener( in string listenerName,
13            in AlarmListener listener );
14
15        void setAlarm( in string listenerName,
16            in long long seconds );
17    };
18 };

```

---

Fig. 26.15 **alarmclock1.idl**.

## 26.6.2 AlarmClockImpl.java

In Fig. 26.16, lines 21–52 are the same as method **register** in **SystemClockImpl** (Fig. 26.4, lines 26–59). Lines 26–29 check the incoming arguments. Line 32 creates an ORB using the **ORB.init** factory method, and line 35 connects with the ORB. Lines 38–41 find a reference to a Naming Service. Lines 45–47 create a **NameComponent** object, and line 50 sends this **NameComponent** object to the Naming Service using method **rebind**.

Lines 56–77 declares the **addAlarmListener** registration method. After the standard argument checks, Line 76 stores the listener the incoming name in a **Hashtable**, if the name and listener had not been saved. The **Hashtable** contains the listener name and an **AlarmTimer** object that sleeps the required number of seconds, then notifies the listener that the alarm has sounded (**AlarmTimer** inherits from **java.util.Timer** which handles the threading for calling the client independent of the main thread). Inner class **TaskWrapper** (registered with the **AlarmTimer** at lines 90 and 91) calls the listener method **updateTime** in method **TaskWrapper.run** (lines 143–151) and promptly removes itself as an alarm. Every time a client sets an alarm using method **setAlarm** (lines 81–92), we create a new **TaskWrapper** and return to the caller as fast as we can.

```

1 // Fig. 26.16: AlarmClockImpl.java
2 // Implementation of AlarmClock server.
3
4 package com.deitel.advjhtp1.idl.alarm;
5
6 // Java core packages
7 import java.util.*;
8
9 // Java extension packages
10 import org.omg.CORBA.ORB;
11 import org.omg.CosNaming.*;
12 import org.omg.CosNaming.NamingContextPackage.*;
13
14 public class AlarmClockImpl extends _AlarmClockImplBase {
15
16     // list contains name/alarm pairs of
17     // registered objects waiting for an alarm
18     private Hashtable alarmList = new Hashtable();
19
20     // register AlarmClockImpl object with Naming Service
21     public void register( String corbaName, String params[] ) 
22         throws org.omg.CORBA.ORBPackage.InvalidName,
23             org.omg.CosNaming.NamingContextPackage.InvalidName,
24             CannotProceed, NotFound
25     {
26         if ( ( corbaName == null ) ||
27             ( corbaName.trim().length() == 0 ) )
28             throw new IllegalArgumentException(
29                 "Registration name cannot be null or blank");
30

```

Fig. 26.16 **AlarmClockImpl** is the **AlarmClock** server implementation (part 1 of 4).

```

31     // create and initialize ORB
32     ORB orb = ORB.init( params, null );
33
34     // register this object with ORB
35     orb.connect( this );
36
37     // retrieve reference to Naming Service
38     org.omg.CORBA.Object corbaObject =
39         orb.resolve_initial_references( "NameService" );
40     NamingContext naming =
41         NamingContextHelper.narrow( corbaObject );
42
43     // create NameComponent array with path information to
44     // find this object
45     NameComponent namingComponent =
46         new NameComponent( corbaName, "" );
47     NameComponent path[] = { namingComponent };
48
49     // bind AlarmClockImpl object with ORB
50     naming.rebind( path, this );
51     System.out.println( "Rebind complete" );
52 }
53
54 // method used by clients wanting to register
55 // as callback/listener objects
56 public void addAlarmListener( String listenerName,
57     AlarmListener listener )
58     throws DuplicateNameException
59 {
60     if ( listenerName == null ||
61         listenerName.trim().length() == 0 )
62         throw new IllegalArgumentException(
63             "Name cannot be null or blank");
64     else
65
66         if ( alarmList.get( listenerName ) != null )
67             throw new IllegalArgumentException(
68                 "Name is already registered, please choose another" );
69         else
70
71             if ( listener == null )
72                 throw new IllegalArgumentException(
73                     "Listener cannot be null" );
74
75         // create new Timer and save it under listener name
76         alarmList.put( listenerName, new AlarmTimer( listener ) );
77     }
78 }
```

Fig. 26.16 **AlarmClockImpl** is the **AlarmClock** server implementation (part 2 of 4).

```

79     // Set an alarm for a client.  If client not registered
80     // throw a runtime exception.
81     public void setAlarm( String name, long seconds )
82     {
83         // get alarm for particular client
84         AlarmTimer timer = ( AlarmTimer ) alarmList.get( name );
85
86         if ( timer == null )
87             throw new IllegalArgumentException(
88                 "No clock found for the incoming name" );
89         else
90             timer.schedule( new TaskWrapper(timer.getListener(),
91                             seconds), seconds * 1000 );
92     }
93
94     // main method to execute AlarmClock server
95     public static void main( String args[] ) throws Exception
96     {
97         AlarmClockImpl alarm = new AlarmClockImpl();
98         alarm.register( AlarmClock.NAME, args );
99
100        java.lang.Object object = new java.lang.Object();
101
102        // keep server alive
103        synchronized( object ) {
104            object.wait();
105        }
106    }
107
108    // Every listener get an AlarmTimer assigned to them.
109    private class AlarmTimer extends Timer {
110
111        // The listener this Timer is assigned to.
112        private AlarmListener listener;
113
114        public AlarmTimer( AlarmListener l )
115        {
116            listener = l;
117        }
118
119        // Accessor method so we can get to the listener
120        // // object reference.
121        public AlarmListener getListener()
122        {
123            return listener;
124        }
125    } // end of private inner class TaskWrapper
126

```

Fig. 26.16 **AlarmClockImpl** is the **AlarmClock** server implementation (part 3 of 4).

```

127 // TaskWrapper takes care of calling our clients
128 // when their alarm expires.
129 private class TaskWrapper extends TimerTask {
130
131     // The reference to our listener
132     private AlarmListener listener;
133     private long seconds;
134
135     // TaskWrapper needs to know who to call and
136     // how long was the alarm set (in seconds).
137     public TaskWrapper( AlarmListener l, long s )
138     {
139         listener = l;
140         seconds = s;
141     }
142
143     public void run()
144     {
145         // Go wake them up!
146         listener.updateTime(seconds);
147
148         // Discard this TaskWrapper. When the client
149         // wants a new alarm we create a new TaskWrapper.
150         this.cancel();
151     }
152 } // end private inner class TaskWrapper
153 } // end class AlarmClockImpl

```

Fig. 26.16 **AlarmClockImpl** is the **AlarmClock** server implementation (part 4 of 4).

### 26.6.3 **AlarmClockClient.java**

Figure 26.17 is a simple GUI for the application. The GUI consists of a **JFrame** that displays a **String** informing the user when the alarm has sounded.

```

1 // Fig. 26.17: ClockClientGUI.java
2 // GUI used by the AlarmClockClient.
3
4 package com.deitel.advjhtp1.idl.alarm;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 public class ClockClientGUI extends JFrame {
14     private JLabel outputLabel;
15

```

Fig. 26.17 **ClockClientGUI** informs the user when the alarm has sounded (part 1 of 2).

```

16    // set up GUI
17    public ClockClientGUI()
18    {
19        super( "Clock GUI" );
20
21        outputLabel =
22            new JLabel( "The alarm has not gone off..." );
23        getContentPane().add( outputLabel, BorderLayout.NORTH );
24
25        setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
26        setResizable( false );
27        Dimension screenSize =
28            Toolkit.getDefaultToolkit().getScreenSize();
29        setSize( new Dimension( 450, 100 ) );
30        setLocation( ( screenSize.width - 450 ) / 2,
31                      ( screenSize.height - 100 ) / 2 );
32    }
33
34    // set label's text
35    public void setText( String message )
36    {
37        outputLabel.setText( message );
38    }
39
40 } // end of class ClockClientGUI

```

**Fig. 26.17** **ClockClientGUI** informs the user when the alarm has sounded (part 2 of 2).

**AlarmClockClient** (Fig. 26.18) is the client for the **AlarmClock** service. Lines 22–38 define the **AlarmClockClient** constructor. Using the system time, **AlarmClockClient** gives itself a name and, after creating the GUI, passes the name to method **connectToAlarmServer** (lines 41–68) along with any incoming parameters. **AlarmClockClient** connects to the **AlarmClock** the same way **SystemClockClient** connects to the **TimeServer**. Line 48 creates an ORB object, using the ORB factory method **init**. By passing the client reference in as the second argument, **AlarmClockClient** registers itself with the ORB. The newly instantiated ORB handles mediating all calls made from and sent to the client. The ORB, created as an object separate from the **AlarmClockClient**, can control access to and from the **AlarmClockClient**, but only if the ORB has a usable reference to complete invocations started (or ending) in the stub client code. Method **init** makes the **AlarmClockClient** ORB-enabled. Using the same ORB, **AlarmClockClient** can obtain a reference to the Naming Service. As in the example from Fig. 26.5, ORBs have mini-naming services that allow them to bootstrap with a predefined list of external services (naming being one of them). Using the **NamingContextHelper.narrow** method, line 55 downcasts the CORBA object returned from **resolve\_initial\_references** to an object of type **NamingContext**. Figure 26.18 displays the output when the client and server connected.

**NameComponents** allow clients to traverse the Naming Service to look for needed services. Lines 58–59 create a **NameComponent** object that the Naming Service uses to find the **AlarmClock** service. When the **AlarmClockClient** calls the Naming Service methods **resolve** and downcasts the returned object reference into an object of type

**AlarmClock** (lines 61–62), the **AlarmClockClient** can make a remote method call. Line 65 registers the client with the **AlarmClock** as an **AlarmListener**, making itself an asynchronous callback object. The **AlarmClockClient** finishes method **connectToAlarmServer** after displaying the GUI and setting the alarm through method **updateTime** (lines 71–80)—this method (declared in the IDL interface **AlarmListener**) resets the alarm after every call from the server, allowing the client to sleep until the time expires. The main difference between this code and that of **SystemClockClient** is the client behavior after finding the Naming Service. The **AlarmClockHelper.narrow** method is the only nonreusable code.

```

1 // Fig. 26.18: AlarmClockClient.java
2 // Client of the AlarmClock service
3
4 package com.deitel.advjhtp1.idl.alarm;
5
6 // OMG CORBA packages
7 import org.omg.CORBA.ORB;
8 import org.omg.CosNaming.*;
9 import org.omg.CosNaming.NamingContextPackage.*;
10
11 public class AlarmClockClient extends _AlarmListenerImplBase {
12
13     // Reference to the GUI to be displayed
14     private ClockClientGUI gui;
15
16     // Reference to the alarm clock server we connect to
17     private AlarmClock alarmClock;
18
19     // Name of this client used by server to make proper callback
20     private String name;
21
22     public AlarmClockClient( String params[] ) throws Exception
23     {
24         // create displayable name that is unique among VMs
25         // running on same computer (or at least randomly unique)
26         name = new Long(
27             System.currentTimeMillis() % 10000 ).toString();
28
29         // create GUI to display name and
30         // number of seconds before alarm expires
31         gui = new ClockClientGUI();
32
33         // connect to TimeService
34         connectToAlarmServer( name, params );
35
36         // display GUI and wait for user to terminate app.
37         gui.show();
38     }
39

```

Fig. 26.18 **AlarmClockClient** is the **AlarmClock** client (part 1 of 3).

```

40     // perform connection to AlarmServer
41     private void connectToAlarmServer(
42         String name, String params[] )
43         throws org.omg.CORBA.CORBAPackage.InvalidName,
44             org.omg.CosNaming.NamingContextPackage.InvalidName,
45             NotFound, CannotProceed
46     {
47         // connect AlarmClockClient to an ORB
48         ORB orb = ORB.init( params, null );
49
50         // connect to Naming Service and find object
51         // reference for AlarmClock service
52         org.omg.CORBA.Object corbaObject =
53             orb.resolve_initial_references( "NameService" );
54         NamingContext naming =
55             NamingContextHelper.narrow( corbaObject );
56
57         // resolve object reference in naming
58         NameComponent nameComponent =
59             new NameComponent( AlarmClock.NAME, "" );
60         NameComponent path[] = { nameComponent };
61         alarmClock =
62             AlarmClockHelper.narrow( naming.resolve( path ) );
63
64         // register this object with AlarmClock service
65         alarmClock.addAlarmListener( name, this );
66         gui.show();
67         updateTime( 0 );
68     }
69
70     // The callback method defined in AlarmListener.
71     public void updateTime( long seconds )
72     {
73         // Make up a length of time to use for the alarm setting.
74         int newTime = ( int )( Math.random() * 10.0 ) + 1;
75         gui.setText( "Alarm " + name + " came in at " + seconds +
76             " seconds. Resetting to " + newTime + " seconds" );
77         alarmClock.setAlarm( name, newTime );
78     }
79
80     // main method to execute client
81     public static void main( String args[] ) throws Exception
82     {
83         // create client
84         try {
85             AlarmClockClient client = new AlarmClockClient( args );
86         }
87
88         // process exceptions that occur while client executes
89         catch ( Exception exception ) {
90             System.out.println(
91                 "Exception thrown by AlarmClockClient:" );

```

Fig. 26.18 **AlarmClockClient** is the **AlarmClock** client (part 2 of 3).

```

92         exception.printStackTrace();
93     }
94   }
95 }
96 } // end of class AlarmClockClient

```

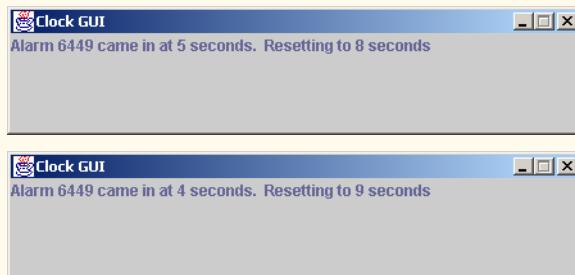


Fig. 26.18 **AlarmClockClient** is the **AlarmClock** client (part 3 of 3).

## 26.7 Distributed Exceptions

Exceptions in an object-oriented environment are the preferred means of handling error situations. Java's exception-handling mechanism works at two levels—*compile-time* and *runtime*. Developers can handle exceptions at compile-time using **try** blocks or by expanding method signatures to include any exceptions they **throw**. If a particular exception is so general that code is written solely to provide specialized error recovery, the exception can inherit from **RuntimeException**—the developer then decides explicitly when the exception should be handled. At runtime, the code is already set to handle normal exceptions, and any code that could throw a **RuntimeException** has to be carefully scrutinized prior to being called to minimize the risk of abnormal code termination. We must consider the happenings when Java code throws exceptions across the network. In CORBA, the server with which a client is communicating might be in a different language. Does this result in using antiquated methods to check status codes?

CORBA specifies two exception types—system exceptions and user exceptions. System exceptions are defined for use by CORBA infrastructure and all operations defined using IDL. User exceptions are CORBA exceptions defined using IDL by the developers of a CORBA system. Every call to a distributed object can throw an exception. Every operation on a CORBA object can throw a CORBA **SystemException**—developers then write code that handle these exceptions. However, even runtime exceptions need attention occasionally, so consider writing additional **try** blocks or wrappers around the stub of a distributed object so that the client does not have to know there is additional error handling occurring when an exception is thrown.

Developers can find the exceptions thrown by a CORBA object by looking in the object's associated IDL file. For example, the Naming Service declares the **rebind** method in **CosNaming.idl**:<sup>14</sup>

```

void rebind( in Name n, in Object obj )
    raises( NotFound, CannotProceed,
           InvalidName );

```

The keyword **raises** maps to the Java keyword **throws**. Method **rebind** **raises** three exceptions—**NotFound**, **CannotProceed** and **InvalidName**. **Cos-Naming.idl** defines them as<sup>15</sup>

```

enum NotFoundReason {
    missing_node,
    not_context,
    not_object
};

exception NotFound {
    NotFoundReason why;
    Name rest_of_name;
};

exception CannotProceed {
    NamingContext ctxt;
    Name rest_of_name;
};

exception InvalidName{};

```

Note the use of the keyword **exception**. IDL **exceptions** map to Java exceptions inheriting indirectly from **java.lang.Exception** (they inherit directly from **User-Exception**). The **InvalidName** exception—a **java.lang.Exception** subclass—is closer to standard Java practice, but only as a means of specifying a particular problem area. Exception **CannotProceed** defines additional attributes available to anyone receiving the exception object, but the attributes are all **public**.

By definition, standard CORBA exceptions map to Java exceptions as **final** classes. If a CORBA exception inherits from **SystemException**, it is also a **RuntimeException**. All CORBA exceptions are available for use by developers in the various **org.omg** packages shipped with the JDK. Use CORBA exceptions within a server when appropriate; throw CORBA exceptions only when a CORBA problem has surfaced. Define custom distributed exceptions for service-specific problems that need the attention of the remote caller.

Defining custom exceptions in IDL is straightforward. In Fig. 26.19, lines 2–4 declare an **exception** useful in alerting a caller that a problem occurred when trying to retrieve a customer record. The **find** operation (line 7) declares its intention to throw a **DatabaseException** by using keyword **raises**.

The IDL compiler generates the exception class definition and needs no further work on the developer's part. The generated **DatabaseException** class appears in Fig. 26.20.

To make the **AlarmClock** more client-friendly, we can add user-defined **Duplicate-eNameException** to method **addAlarmListener** (lines 16–18) in Fig. 26.21. Adding the exception to the signature of **addAlarmListener** also removes keyword **oneway**, which does not allow the use of **out** or **inout** return values or the throwing of exceptions.

---

```

1 module domain {
2     exception DatabaseException {
3         string msg;
4     };

```

**Fig. 26.19** A user-defined CORBA exception (**DatabaseException**) and an operation capable of throwing the exception (part 1 of 2).

```

5
6     interface CustomerHome {
7         void find( in long key ) raises ( DatabaseException );
8     };
9 }

```

Fig. 26.19 A user-defined CORBA exception (**DatabaseException**) and an operation capable of throwing the exception (part 2 of 2).

```

1  public final class DatabaseException
2      extends org.omg.CORBA.UserException
3      implements org.omg.CORBA.portable.IDLEntity
4  {
5      public String msg = null;
6
7      public DuplicateNameException ()
8      {
9          // ctor
10
11     public DuplicateNameException( String _msg )
12     {
13         msg = _msg;
14     } // ctor
15 } // class DatabaseException

```

Fig. 26.20 The generated **DatabaseException.java** file (reformatted for clarity).

```

1 // Fig. 26.21: alarmclock2.idl
2 // The IDL for the AlarmClock example
3
4 module alarm {
5     exception DuplicateNameException {
6         string msg;
7     };
8
9     interface AlarmListener {
10         void updateTime( in long long newTime );
11     };
12
13     interface AlarmClock {
14         const string NAME = "AlarmClock";
15
16         void addAlarmListener( in string listenerName,
17             in AlarmListener listener )
18             raises( DuplicateNameException );
19
20         void setAlarm( in string listenerName,
21             in long long seconds );
22     };
23 }

```

Fig. 26.21 **alarmclock2.idl** is the IDL for the **AlarmClock** example.

With the addition of the exception to method `addAlarmListener`, clients cannot register to set alarms if they have the same name. This should be a precondition for this method in any case, but the sentiment is the same. The only changes we need to make to method `addAlarmListener` (Fig. 26.16) are shown in Fig. 26.22 (lines 57 and 66). Line 57 adds the `throws DuplicateNameException` clause to match the method declaration in `AlarmClockOperations.java` (the interface generated when we compiled `alarmclock2.idl`). Line 65 performs the duplicate name check, and line 66 `throws` the exception if there is an existing listener registered using the incoming name.

Adding `DuplicateNameException` to `addAlarmListener`'s signature has an impact on any methods that call it. In this case, method `connectToAlarmServer` (Fig. 26.18) must add `DuplicateNameException` to its method signature. Making this change to the signature of `connectToAlarmServer` requires any callers either to catch the exception or pass it on to their callers (this example catches everything in method `main`).

Extending Java exceptions by making them distributed does not imply that all Java mechanisms have the same additional capabilities. An area not discussed in CORBA is *garbage collection*—the reclamation of allocated memory. CORBA does not handle the allocation and deallocation of objects directly. CORBA does not dictate implementation, so we discuss garbage collection in the context of Java in a CORBA environment. Non-Java languages have their own mechanisms for memory allocation and deallocation—these mechanisms create objects for remote use or create `structs` given to another process somewhere “out there.” Java does not force developers to perform memory deallocation. The same features that attracted millions of developers to Java in the first place are still available even when used in conjunction with legacy languages glued together using CORBA.

```

1 public void addAlarmListener( String listenerName,
2     AlarmListener listener ) throws DuplicateNameException
3 {
4     if ( listenerName == null ||
5         listenerName.trim().length() == 0 )
6         throw new IllegalArgumentException(
7             "Name cannot be null or blank" );
8     else
9
10    if ( list.get( listenerName ) != null )
11        throw new DuplicateNameException(
12            "Name is already registered, please choose another" );
13    else
14
15    if ( listener == null )
16        throw new IllegalArgumentException(
17            "Listener cannot be null" );
18
19    // Create a new Timer and save it under the listener name
20    alarmList.put( listenerName, new AlarmTimer( listener ) );
21 }
```

Fig. 26.22 Excerpt from `AlarmClockImpl.java`.

When **structs** are instantiated in Java, as we have stated before, all of the instance variables are **public**, leaving us with an exposed object. When a client sends a **struct** object as an argument to a remote operation, the skeleton makes a copy on the server side for use as a local object. What happens to the original data object on the client side? As long as some variable has a handle to the reference, the **struct** object is not deallocated. As soon as no more variables are pointing to the object (the reference count has become zero) the object is garbage collected. Server-side Java behaves the same way—incoming objects (i.e., references or data objects) exist for as long as a server-side resource has a handle to it—otherwise, these objects are marked for garbage collection.

## 26.8 Case Study: Chat

Chapter 13 presented a straightforward implementation of the RMI Messenger example. This next example ports the RMI Messenger to CORBA using the concepts discussed in the **SystemClock** and **AlarmClock** examples. A chat program is a natural application for distributed system technologies like RMI and CORBA. **Chat** is a basic network application using a central broadcasting point where a collection of clients pushes in messages and the middleware pushes out messages.

The architectural model for CORBA Messenger begins with determining large, transactional, visible (to the user) functionality offered by the application. The Unified Modeling Language calls the list and description of user-visible functionality *use cases*. CORBA Messenger has the following use cases:

1. Connect: A client finds and connects to a chat server.
2. Disconnect: A client completes a chat session by disconnecting from the chat server.
3. Send message: A connected client creates a chat message and gives the message to the chat server.
4. Receive message: A connected client receives messages delivered by the chat server. All clients connected to the chat server receive the same message.



### Testing and Debugging Tip 26.1

---

*Create test objects as soon as possible in the development cycle of the distributed object. Test the load-bearing capabilities expected of the server on a regular basis.*

The Naming Service is a fundamental implementation point for a CORBA system. Naming is the standard way clients can find the service(s) they need to accomplish their tasks. The name for the CORBA Messenger chat server is “**ChatServer**”. When requested, the Naming Service returns the Interoperable Object Reference (IOR) associated with the chat server name (which the server gave the Naming Service when the server was first started).

Another way for a client to find a service is to use a *stringified* version of the service’s Interoperable Object Reference. As we mentioned earlier, an object reference contains network information needed by an ORB to find a distributed object. When discovered from a Naming Service, the object reference (in the form of an IOR) is valid for the activation lifetime of the remote object through a particular ORB. The stringified IOR is valid as long as

a server is available to handle any invocations (this is subject to the servant's POA's quality of service settings). If desired, an external file can save the IOR for future use.

The object reference of every distributed object can be returned as a **string** for external use by clients using ORB method **object\_to\_string**, but using the stringified IOR is not a guarantee that the object is available for use. What a stringified IOR does guarantee is a valid object reference for any session where the object is alive (going through the ORB at the location stated in the object reference). However, clients always expect the Naming Service to have the latest path to a particular object, while there can be no guarantees as to the validity of a stringified IOR. This is similar to the process of starting a car—knowing how to hot wire a vehicle means all cars are available for use, but hot wiring is harder than simply using the ignition key of a particular car.

Abstractions such as the IOR give developers more implementation flexibility. At first glance, passing the message as a **string** to the **ChatServer** appears sufficient to allow the server to send messages to all clients. However, modeling the problem domain enables us to abstract the **string** into a **Message**, allowing us to do more with the value object being passed between client and server (for example, sending the originating chat name along with the message). Making the **ChatMessage** a **struct** means all connected clients receive their own copy of the message for local manipulation rather than sharing one central object (lines 6–11 of Fig. 26.23). The simultaneous access of one shared **ChatMessage** object among all the users of the system would create a severe bottleneck in the system when all of the clients try to read the object's contents at the same time.

The use of **structs** in IDL is an ongoing issue from an object-oriented implementation perspective. A **struct** is useful for sending collections of data across the network due to a design decision such as performance (i.e., sending 10 **struct**-like objects between a client and a server offers better performance than sending 10 object references as individual data-member accesses). However, when mapping a non-object-oriented construct (e.g., a **struct**) to an object-oriented target language, the mapping will not be fully object-oriented without raising more issues than are being solved. In the case of **structs**, the data becomes unencapsulated. CORBA is language-neutral, and IDL is not an implementation language. As mentioned earlier, everything in IDL is **public** because C, COBOL and other languages do not support encapsulation concepts. If the middleware were a C server, the stubs and skeletons involved would have to know how to map the proper Java object into a proper C **struct**. This mapping can be handled by the code generated using the IDL compiler. However, making the generated code more complex raises other issues, such as how the object scope can be opened to allow for the marshaling of these now properly encapsulated values. Remember, CORBA is the glue used to enable systems integration, not an object-oriented solution to domain problems.

Developers do not have to do anything with the code generated to represent **structs** (they just have to be careful with using unencapsulated values). If **ChatMessage** were going to be a distributed object, we would have to define **ChatMessage** as an IDL **interface**, which developers would have to implement.

### 26.8.1 **chat.idl**

The server needs server-side interfaces to register and unregister a client and deliver messages to all clients. The client uses its own server-side interfaces to accept messages (after registering with the server).

Figure 26.23 defines the two server **interfaces** for the **Chat** application. Lines 29–44 reflect the IDL of the three services (operations) offered in **interface ChatServer**. The nested **module** names **client** (line 13) and **server** (line 24) create new scope levels. Line 33 references type **client::ChatClient** for use with method **registerClient** (the double colons resolve IDL namespace the same way the dot resolves Java package/class namespace). Lines 14–21 define the **ChatClient** and its service of delivering incoming messages to a user. **ChatServer**'s knowledge of the symbol **ChatClient** defines the symbol linkage for the callback. The IDL gives no indication that **ChatClient** needs to know anything but the symbol **ChatMessage**.

```

1 // Chat.idl
2 // This file contains the IDL defining the API to the ChatServer
3 // as well as the ChatClient and ChatMessage.
4
5 module corba {
6     struct ChatMessage {
7
8         // ChatMessage properties
9         string from;
10        string message;
11    };
12
13    module client {
14        interface ChatClient {
15
16            // receive new message
17            void deliverMessage( in ChatMessage message );
18
19            // method called when server shutting down
20            void serverStopping();
21        };
22    };
23
24    module server {
25        interface StoppableChatServer {
26            void stopServer();
27        };
28
29        interface ChatServer {
30            const string NAME = "ChatServer";
31
32            // register new ChatClient with ChatServer
33            oneway void registerClient( in client::ChatClient client );
34
35            // unregister ChatClient with ChatServer
36            void unregisterClient( in client::ChatClient client );
37
38            // post new message to ChatServer
39            void postMessage( in ChatMessage message );
40        };
}

```

Fig. 26.23 **ChatServer**, **ChatClient** and **ChatMessage** interface definitions (part 1 of 2).

```

41
42     // Create a combination interface
43     interface ChatService : ChatServer, StoppableChatServer {
44         ;
45     };
46
47 } // end module corba

```

Fig. 26.23 **ChatServer**, **ChatClient** and **ChatMessage** interface definitions (part 2 of 2).

### 26.8.2 ChatServerImpl.java

The IDL compiler generated the following files for server-side use when we compile **chat.idl**:

- messenger\client\\_ChatClientImplBase.java
- messenger\server\\_ChatServerImplBase.java
- messenger\client\ChatClient.java
- messenger\client\ChatClientOperations.java
- messenger\ChatMessage.java
- messenger\server\ChatServer.java
- messenger\server\ChatServerOperations.java

In addition, the compiler generated two class files that are not used directly:

- messenger\ChatMessageHelper.java
- messenger\ChatMessageHolder.java

The **ImplBase** classes use **ChatMessageHelper** to read and write from the **Stream** for sending objects. Developers never see this use of **ChatMessageHelper** unless they look at the generated files. On the other hand, developers will use **ChatMessageHolder** directly if they had declared **ChatMessage** an **out** variable. (**ChatMessage** is used only as an **in** variable, so **ChatMessageHolder** is unused.)

Note that **ChatClient**, **ChatClientOperations** and **\_ChatClientImplBase** seem to refer to a client—from the **ChatServer**'s perspective, **ChatClient** is another server (which makes **ChatServer** a client during calls to **ChatClient**). We revisit these files in the client-implementation discussion.

The **ChatServer** is responsible for keeping a list of clients that want to be part of the broadcast of messages filtering through the server. For simplicity, we use a **Hashtable** with the user name as the key and the object reference to the **ChatClient** as the value. In general, method **registerClient** saves the user name and object reference to the **ChatClient** in the **Hashtable**, method **removeClient** removes the object reference using the user name as the key into the **Hashtable** and method **postMessage** iterates the list of object references and calls **deliverMessage** on each registered client.

In Fig. 26.24, lines 11–13 import the standard packages that contain the symbols for the CORBA classes. At line 19, **ChatServerImpl** inherits from **\_ChatServerImplBase**. Abstract class **\_ChatServerImplBase** implements

**interface ChatServer**, which extends **ChatServerOperations** and requires that **ChatServerImpl** implement the methods defined in interface **ChatServerOperations**. The implementation of the three methods is straightforward and is not significantly different from the original **ChatServerImpl** found in Chapter 13 (which used a **Vector** instead of a **Hashtable**). Line 25 defines the **HashMap** to hold the references to registered clients (the **HashMap** is also instantiated).

Method **register** (lines 81–106) looks similar to the **register** methods from other examples. In this case, we are close enough to the top of the call stack that having a **RuntimeException** thrown keeps us from continuing if we do not successfully bind to the Naming Service.



#### Software Engineering Observation 26.4

A good habit to get into is placing **try** blocks at strategic locations for easier recovery to catch thrown **RuntimeExceptions** (even if that location is **main**).

At line 41 of method **registerClient**, we store the reference to the listener, using the client's stringified IOR as a key in the **Hashtable**. Method **unregisterClient** (lines 49–59) removes listeners at line 75. Other than storing (or removing) the IOR of the incoming client, we have kept CORBA use to a minimum.

Method **postMessage** (lines 62–78) is the only use of the saved IOR. Line 68 retrieves an **Enumeration** of the clients in the **HashSet**, and lines 72–75 loops through the clients and calls method **deliverMessage** on each of them.

```

1 // ChatServerImpl.java
2 // ChatServerImpl implements the CORBA ChatServer.
3 package com.deitel.messenger.corba.server;
4
5 // Java core packages
6 import java.io.*;
7 import java.util.*;
8 import java.net.MalformedURLException;
9
10 // Java extension packages
11 import org.omg.CosNaming.*;
12 import org.omg.CosNaming.NamingContextPackage.*;
13 import org.omg.CORBA.*;
14
15 // Deitel packages
16 import com.deitel.messenger.corba.ChatMessage;
17 import com.deitel.messenger.corba.client.ChatClient;
18
19 public class ChatServerImpl extends _ChatServerImplBase {
20
21     // The ORB that connects us to the network
22     private ORB orb;
23
24     // Map of ChatClient references
25     private Map clients = new HashMap();
26

```

Fig. 26.24 **ChatServerImpl** implementation of the CORBA **ChatServer** (part 1 of 4).

```

27 // construct new ChatServerImpl
28 public ChatServerImpl( String[] args )
29     throws Exception
30 {
31     super();
32     register( ChatServer.NAME, args );
33 }
34
35 // register new ChatClient with ChatServer
36 public void registerClient( ChatClient client )
37 {
38     // add client to Map of registered clients
39     String key = orb.object_to_string( client );
40     synchronized( clients ) {
41         clients.put( key, client );
42     }
43
44     System.out.println( "Registered Client: " + key );
45
46 } // end method registerClient
47
48 // unregister client with ChatServer
49 public void unregisterClient( ChatClient client )
50 {
51     // remove client from Map of registered clients
52     String key = orb.object_to_string( client );
53     synchronized( clients ) {
54         clients.remove( key );
55     }
56
57     System.out.println( "Unregistered Client: " + key );
58
59 } // end method unregisterClient
60
61 // post new message to ChatServer
62 public void postMessage( ChatMessage message )
63 {
64     Iterator iterator = null;
65
66     // get Iterator for Set of registered clients
67     synchronized( clients ) {
68         iterator = new HashSet( clients.entrySet() ).iterator();
69     }
70
71     // send message to every ChatClient
72     while ( iterator.hasNext() ) {
73         ChatClient client =
74             ( ChatClient ) ( ( Map.Entry ) iterator.next() ).getValue();
75         client.deliverMessage( message );
76     }
77
78 } // end method postMessage

```

Fig. 26.24 ChatServerImpl implementation of the CORBA ChatServer (part 2 of 4).

```

79
80     // Register ChatServerImpl object with Naming Service
81     public void register( String serverName, String[] parameters )
82         throws NotFound, CannotProceed,
83             org.omg.CosNaming.NamingContextPackage.InvalidName,
84             org.omg.CORBA.ORBPackage.InvalidName
85     {
86         if ( serverName == null )
87             throw new IllegalArgumentException(
88                 "Registration name can not be null" );
89
90         // Bind ChatServerImpl object to Naming Service.
91         // Create and initialize ORB.
92         orb = ORB.init( parameters, null );
93
94         // create servant and register it with ORB
95         orb.connect( this );
96
97         org.omg.CORBA.Object corbaObject =
98             orb.resolve_initial_references( "NameService" );
99         NamingContext naming =
100            NamingContextHelper.narrow( corbaObject );
101        NameComponent namingComponent =
102            new NameComponent( serverName, "" );
103        NameComponent path[] = { namingComponent };
104        naming.rebind( path, this );
105        System.out.println( "Server bound to naming" );
106    }
107
108   // notify each client that server is shutting down and
109   // terminate server application
110   public void stopServer()
111   {
112       System.out.println( "Terminating server ..." );
113
114       Iterator iterator = null;
115
116       // get Iterator for Set of registered clients
117       synchronized( clients ) {
118           iterator = new HashSet( clients.entrySet() ).iterator();
119       }
120
121       // send serverStopping message to every ChatClient
122       while ( iterator.hasNext() ) {
123           ChatClient client = ( ChatClient ) iterator.next();
124           client.serverStopping();
125           System.err.println( "Disconnected: " + client );
126       }
127

```

Fig. 26.24 ChatServerImpl implementation of the CORBA ChatServer (part 3 of 4).

```

128     // create Thread to terminate application after
129     // stopServer method returns to caller
130     Thread terminator = new Thread(
131         new Runnable() {
132
133             // sleep for 5 seconds, print message and terminate
134             public void run()
135             {
136                 // sleep
137                 try {
138                     Thread.sleep( 5000 );
139                 }
140
141                 // ignore InterruptedExceptions
142                 catch ( InterruptedException exception ) {}
143
144                 System.err.println( "Server terminated" );
145                 System.exit( 0 );
146             }
147         }
148     );
149
150     terminator.start(); // start termination thread
151
152 } // end method stopServer
153
154 // main method to execute ChatServerImpl
155 public static void main( String[] args )
156 {
157     // set up ChatServerImpl object and bind to Naming Service
158     try {
159
160         // create ChatServerImpl object
161         ChatServerImpl chatServerImpl =
162             new ChatServerImpl( args );
163
164         java.lang.Object object = new java.lang.Object();
165
166         // keep server alive
167         synchronized( object ) {
168             object.wait();
169         }
170     }
171
172     // process problems setting up ChatServerImpl object
173     catch ( Exception exception ) {
174         exception.printStackTrace();
175         System.exit( 1 );
176     }
177
178 } // end method main
179 }
```

Fig. 26.24 ChatServerImpl implementation of the CORBA ChatServer (part 4 of 4).

Method **main** (lines 155–178) creates the server at lines 161–162. Once again, **main** creates an object named **object** (line 164) and calls **object.wait** (line 168) to keep the server alive by keeping **object** sitting in the thread queue. A **try** block surrounds the core logic in **main** to control the handling of any thrown **exceptions**.

### 26.8.3 DeitelMessenger.java

The following generated files are available for client-side use after the compile of **chat.idl**:

1. messenger\client\\_ChatClientStub.java
2. messenger\server\\_ChatServerStub.java
3. messenger\client\ChatClient.java
4. messenger\client\ChatClientOperations.java
5. messenger\ChatMessage.java
6. messenger\server\ChatServer.java
7. messenger\server\ChatServerHelper.java
8. messenger\server\ChatServerOperations.java

However, as we mentioned before, the following generated server-side files are available for the client to accept callback invocations from the server:

1. messenger\client\\_ChatClientImplBase.java
2. messenger\client\ChatClient.java
3. messenger\client\ChatClientOperations.java

In addition, the following Java source files were generated and not used explicitly:

1. messenger\client\ChatClientHelper.java
2. messenger\client\ChatClientHolder.java
3. messenger\ChatMessageHelper.java
4. messenger\ChatMessageHolder.java
5. messenger\server\ChatServerHolder.java

The *<data type name>Helper* classes are for the direct manipulation of mechanisms like the ORB's object stream. The *<data type name>Holder* classes are for **out** and **inout** variable use as dictated in the code generated by the IDL compiler.

A standard CORBA client is concerned with connecting to the Naming Service, getting the object reference to a server (i.e., the **ChatServer**) and making calls to the server. In this case, the client also takes on the role of a server. To be a proper CORBA server the client must inherit from **\_ChatClientImplBase** and implement any methods declared in **ChatClientOperations**. Class **\_ChatClientImplBase** implements class **ChatClient**, which extends **ChatClientOperations** so the **ChatClient** server implementation has to implement method **deliverMessage**. Figure 26.25, line 23 declares the inheritance to **\_ChatClientImplBase** which implies the client must implement method **deliverMessage** somewhere. The client is an implementation of

**MessageManager** (line 24)—an interface that represents the connectivity portion of the **DeitelMessenger** GUI client.

```
1 // CORBAMessageManager.java
2 // CORBAMessageManager implements the ChatClient remote
3 // interface and manages incoming and outgoing chat messages
4 // using CORBA.
5 package com.deitel.messenger.corba.client;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.util.*;
11
12 // Java extension packages
13 import org.omg.CosNaming.*;
14 import org.omg.CosNaming.NamingContextPackage.*;
15 import org.omg.CORBA.*;
16
17 // Deitel packages
18 import com.deitel.messenger.*;
19 import com.deitel.messenger.corba.client.ChatClient;
20 import com.deitel.messenger.corba.ChatMessage;
21 import com.deitel.messenger.corba.server.*;
22
23 public class CORBAMessageManager extends _ChatClientImplBase
24     implements MessageManager {
25
26     // incoming ORB configuration parameters
27     private String[] configurationParameters;
28
29     // listeners for incoming messages and disconnect notifications
30     private MessageListener messageListener;
31     private DisconnectListener disconnectListener;
32
33     // ChatServer for sending and receiving messages
34     private ChatServer chatServer;
35
36     // CORBAMessageManager constructor
37     public CORBAMessageManager( String[] parameters )
38     {
39         configurationParameters = parameters;
40     }
41
42     // connect to ChatServer
43     public void connect( MessageListener listener )
44         throws Exception
45     {
46
47         // find ChatServer remote object
48         ORB orb = ORB.init( configurationParameters, null );
```

Fig. 26.25 CORBAMessageManager implementation of interface **MessageManager** using CORBA (part 1 of 3).

```
49     org.omg.CORBA.Object corbaObject =
50         orb.resolve_initial_references( "NameService" );
51     NamingContext naming =
52         NamingContextHelper.narrow( corbaObject );
53
54     // Resolve the object reference in naming
55     NameComponent nameComponent =
56         new NameComponent( ChatServer.NAME, "" );
57     NameComponent path[] = { nameComponent };
58     chatServer =
59         ChatServerHelper.narrow( naming.resolve( path ) );
60
61     // register client with ChatServer to receive messages
62     chatServer.registerClient( this );
63
64     // set listener for incoming messages
65     messageListener = listener;
66
67 } // end method connect
68
69 // disconnect from ChatServer
70 public void disconnect( MessageListener listener )
71     throws Exception
72 {
73     if ( chatServer == null )
74         return;
75
76     chatServer.unregisterClient( this );
77     messageListener = null;
78
79     // notify listener of disconnect
80     fireServerDisconnected( "" );
81
82 } // end method disconnect
83
84 // send ChatMessage to ChatServer
85 public void sendMessage( String fromUser, String message )
86     throws Exception
87 {
88     if ( chatServer == null )
89         return;
90
91     // create ChatMessage with message text and user name
92     ChatMessage chatMessage =
93         new ChatMessage( fromUser, message );
94
95     // post message to ChatServer
96     chatServer.postMessage( chatMessage );
97
98 } // end method sendMessage
99
```

Fig. 26.25 CORBAMessageManager implementation of interface **MessageManager** using CORBA (part 2 of 3).

```

100    // process delivery of ChatMessage from ChatServer
101    public void deliverMessage( ChatMessage message )
102    {
103        if ( messageListener != null )
104            messageListener.messageReceived( message.from,
105                message.message );
106    }
107
108    // process server shutting down notification
109    public void serverStopping()
110    {
111        chatServer = null;
112        fireServerDisconnected( "Server shut down." );
113    }
114
115    // register listener for disconnect notifications
116    public void setDisconnectListener(
117        DisconnectListener listener )
118    {
119        disconnectListener = listener;
120    }
121
122    // send disconnect notification
123    private void fireServerDisconnected( String message )
124    {
125        if ( disconnectListener != null )
126            disconnectListener.serverDisconnected( message );
127    }
128 }

```

Fig. 26.25 CORBAMessageManager implementation of interface **MessageManager** using CORBA (part 3 of 3).

The GUI client is not concerned with registering with the Naming Service. **ChatServer** has the client-registration method **registerClient**, so the **ChatClient (CorbaMessageManager)** passes itself in and makes itself available to the server.

Let us now look at the chat client as a client. The relevant methods for the client are **connect**, **disconnect** and **sendMessage**.

Method **connect** (lines 43–67) initializes an ORB, gets the Naming Service object reference and asks for the **ChatServer** reference from the Naming Service. Line 62 passes the client to the server for callback invocations (as in the **AlarmClock** example—view the client as a listener, the **ChatServer** as an event generator and the **ChatMessage** as an event object passed to the listener). If we execute the call to method **registerClient** successfully, the client is now ready to receive messages from any clients connected to the **ChatServer**.

Method **deliverMessage** (lines 101–106), which implements the operation declared in **chat.idl**, takes the incoming message, and sends it to objects registered with the **MessageManager** to receive messages. There is no indication of CORBA at work except for the direct access of fields **from** and **message** at lines 104–105. Knowing that **ChatMessage** is an IDL **struct** allows us to understand why we are violating encapsulation, but does not make the transgression any easier to accept. The good news is that

changing either of the two fields has no impact on the other clients receiving the message (the object is local), but leaves open the possibility of another object in any particular chat client changing the information in an uncontrolled fashion. From a design perspective, **ChatMessage** should be a read-only (immutable) object. Once the server has sent a message, there is no reason to update the message; the other clients cannot see the change. A possible solution is to wrap the **ChatServer** in a client-side proxy object (which would allow us to handle client-side CORBA exceptions in a transparent way) and have the **ChatServer** proxy instantiate a read-only wrapper around the **ChatMessage** before sending it to the chat client. The implementation issues become problematic at that point, however, because the proxy would have to register itself with the real **ChatServer** as the callback target instead of the client registering itself with the **ChatServer**. The client would become the callback target of the chat server proxy when the proxy decides to call the client's **deliverMessage** method.

**DeitelMessenger** (Fig. 26.26), as the entry point to the client-state implementation, controls the instantiation of the **CORBAMessageManager** (lines 15–16) and the **ClientGUI** objects (line 19).

## 26.8.4 Running Chat

The steps for running this example are as follows:

1. Compile the IDL file using **idlj**—for example (all on one line):

```
idlj -pkgPrefix chat com.deitel.advjhttp1.idl -td c:\src
      -fall chat.idl
```

2. Implement and compile the server class (Fig. 26.24).
3. Implement and compile the client class (Fig. 26.26).
4. Open a window and run the **tnameserver** Naming Service:

```
tnameserv -ORBInitialPort 1050
```

5. Open a window and run the server:

```
java com.deitel.messenger.corba.server.ChatServerImpl
      -ORBInitialPort 1050
```

6. Open a window and run the client (then open another window and run another client):

```
java com.deitel.messenger.corba.client.DeitelMessenger
      -ORBInitialPort 1050
```

## 26.8.5 Issues

**CORBAMessenger** was a straightforward port of **RMIMessenger**. The differences between the two versions are minimal, with the largest being the use of a CORBA **struct** compared to the use of a serialized object. The number of remote objects, the operations and the result (broadcasting messages to registered clients) are identical in both cases.

Why use a local object for the messages received by the clients? How would making **ChatMessage** a distributed object alter the application's complexity?

```

1 // DeitelMessenger.java
2 // DeitelMessenger uses ClientGUI and CORBAMessageManager to
3 // implement an CORBA chat client.
4 package com.deitel.messenger.corba.client;
5
6 // Deitel packages
7 import com.deitel.messenger.*;
8
9 public class DeitelMessenger {
10
11     // launch DeitelMessenger application
12     public static void main( String args[] ) throws Exception
13     {
14         // create CORBAMessageManager for communicating with server
15         MessageManager messageManager =
16             new CORBAMessageManager( args );
17
18         // configure and display chat window
19         ClientGUI clientGUI = new ClientGUI( messageManager );
20         clientGUI.setSize( 300, 400 );
21         clientGUI.setResizable( false );
22         clientGUI.setVisible( true );
23     }
24 }

```

Fig. 26.26 **DeitelMessenger** application for launching the CORBA chat client.

The current schema of a **ChatMessage** object is a **struct** holding two strings. For the client to use this object that contains two **public** data members with no accessor/mutator methods, it creates a **String** that accesses first the instance variable **from**, then variable **message**. If this **struct** were changed into an **interface** and the **from** and **message** fields turned into **interface attributes**, the advantages are the following:

1. The proper encapsulation of **ChatMessage**. **ChatMessage** would not have to reveal its complexity to any callers.
2. **ChatMessage** would be a remote object. All clients, once given the **ChatMessage** object reference, could inspect the message object and would see changes to the object immediately. In addition, the **ChatMessage** data would not have to be unmarshaled upon arrival to the client.
3. The client would have a clearly defined API with which to work. Having no **public** data members means the object can properly offer services through its operations rather than direct data access.
4. All connected clients could share a single **ChatMessage**. **ChatMessage** would be a direct open pipeline to the clients. If the server makes a change, the clients see the change immediately and can access the message when appropriate.

The disadvantages of turning **ChatMessage** into an **interface** (i.e., a true distributed object) are the following:

1. **ChatMessage** would be a remote object. As a distributed object, all the registered clients would share a single **ChatMessage**, creating a massive network bottleneck at the server. If a particular object has a substantial amount of information to share with clients, consider putting the information inside a **struct**. This is important because of one fact—during the access of a distributed object, there is marshaling of data, protocol mapping, and unmarshaling of data when the call completes (if the operation has data to return). The overhead to deliver a **ChatMessage struct** (a complete round-trip network call) occurs once. The overhead of a distributed **ChatMessage** starts with the first network call to receive the object reference, accessing the **from** attribute involves another network call and accessing the **message** attribute yet another, bringing the total number of network calls up to three. **ChatMessage**, as a **struct**, has trivial network overhead when it arrives—the unmarshaling of the data. Additional overhead is the creation of an object to hold the data, but this represents a fixed startup cost in addition to the single network call. The more data in the object, the greater the advantage to having a local copy.
2. All connected clients could share **ChatMessage**. In many situations, having numerous clients sharing a distributed object is a valid practice. However, in this case, not giving the clients their own copy means dealing with data locking issues. When do we know that no one is accessing the message? Behavior similar to Java **synchronized** is advantageous, but CORBA does not directly support this behavior (the developer is always free to programmatically support this behavior). In addition, giving others the ability to change shared data (or data with the potential to be shared) without some straightforward mechanism for notifying interested parties of the change is not a good idea.

Sending a local object to a client circumvents all of the preceding problems.



### Performance Tip 26.2

*Use **structs** or **valuetypes** whenever passing data around from a client to a server or vice versa. An object reference is convenient for communication purposes, but can have significant overhead if used solely for the transmission of data. Not only are **structs** and **valuetypes** an optimal way to pass around presentation information, but the distributed service that generated the data can also continue to respond to service requests in a timely fashion.*

In RMI, when an object is serializable, it is streamed across the network and reassembled in the JVM of the caller. The reason to send an object by value is the same as the reason to use **structs**—a local copy of an object has less access overhead than a remote object that needs repeated access. A serialized object in RMI is a real object with all of the standard advantages inherent to an object. A CORBA **struct** has no behavior. The target language of the mapped **struct** adds some overhead (in a non-object-oriented target language, the overhead is almost nonexistent), but beyond that, the ORB adds nothing. Structurally, all IDL **structs** mapped to Java classes implement **org.omg.CORBA.portable.IDLEntity** but do not inherit behavior or structure from any classes (except for **java.lang.Object**). Is there a CORBA mechanism that works like RMI, but maintains the language neutrality of CORBA? The answer is “yes.”

The *Objects-by-Value (OBV)* specification defines a new kind of **interface** type—a **struct** with behavior semantics (the ability to support the declaration of operations)

called a **valuetype**. The advantage of **valuetypes** is the ability to pass copies of “objects” around a distributed system that contain behavior in addition to data. This maps indirectly with Java serialized objects, yet continues to support language neutrality. As a matter of record, the OBV specification had to support the concept of objects-by-value in all the target languages approved by the OMG.

Implementing objects-by-value is not a trivial undertaking. Declaring a **valuetype** is straightforward, as is seen in Fig. 26.27, lines 7–17.

To create a Java **valuetype** object, define the **valuetype** in an IDL file and compile the definition using **idlj** (or a vendor-supplied IDL compiler). Derive a new class from the base **valuetype** class definition, and make sure there is a no-argument constructor as well as a constructor capable of receiving each of the fields belonging to the **valuetype** defined in the IDL. In addition to the generated **valuetype** files, the compiler creates a **<valuetype>DefaultFactory** source file. If necessary, subclass the **<valuetype>DefaultFactory** generated by the IDL, and add any addition operations included in the IDL file. Use of an object instantiated from a **valuetype** is the same as the use of any other Java object. Figure 26.28 lists some keywords added to IDL to support **valuetypes**.

```

1 // Fig. 26.27: Chat.idl
2 // This file contains the IDL defining the
3 // API to the ChatServer as well as the
4 // ChatClient and ChatMessage.
5
6 module obvcorba {
7     valuetype ChatMessage {
8
9         // ChatMessage properties
10        private string from;
11        private string message;
12
13        string getSenderName();
14        string getMessage();
15
16        factory create( in string from, in string message );
17    };
18
19    module client {
20        interface ChatClient {
21
22            // receive new message
23            void deliverMessage( in ChatMessage message );
24        };
25    };
26
27    module server {
28        interface ChatServer {
29            const string NAME = "ChatServer";
30    };

```

Fig. 26.27 **chat.idl** with **ChatMessage** changed to be a **valuetype** (part 1 of 2).

```

31      // register new ChatClient with ChatServer
32      void registerClient( in string chatName,
33                          in client::ChatClient client );
34
35      // unregister ChatClient with ChatServer
36      void unregisterClient( in string chatName );
37
38      // post new message to ChatServer
39      void postMessage( in ChatMessage message );
40  };
41 };
42 }; // end of module obvmessenger

```

Fig. 26.27 `chat.idl` with `ChatMessage` changed to be a `valuetype` (part 2 of 2).

The keyword `private` is misleading—`private valuetype` fields become `protected` Java instance variables. This allows the derived class to access the variables, but outside callers cannot (at least non-package-level outside callers). Java scope rules allow objects defined in a package to access the `protected` fields of the other objects defined in the same package.)

Generated code handles everything else. The server creates the `valuetype` object the way the server always creates objects (using `new` or factory methods, but using the derived class definition). The client receives a `valuetype` object and treats it as a local object. The stubs and skeletons call the `DefaultFactory` when a `valuetype` arrives.

`ChatMessage`, instead of being complete when we compile the IDL, is now a base class for us to derive. `ChatMessageImpl.java` (Fig. 26.29) is the class definition to use to instantiate a `valuetype` object.

#### Keywords specific to `valuetypes`

```

valuetype
private
public
factory
custom
supports
truncatable

```

Fig. 26.28 Keywords specific to `valuetypes`.

```

1 // Fig. 26.29: ChatMessageImpl.java
2 package com.deitel.messenger.obvcorba;
3

```

Fig. 26.29 `ChatMessageImpl` is the `ChatMessage` implementation (part 1 of 2).

```

4  public class ChatMessageImpl extends ChatMessage {
5
6      // default constructor for empty ChatMessageImpl object
7      public ChatMessageImpl()
8      {
9          this( "", "" );
10     }
11
12     // constructor to initialize from and message properties
13     public ChatMessageImpl( String sender, String text )
14     {
15         from = sender;
16         message = text;
17     }
18
19     // return name of sender
20     public String getSenderName()
21     {
22         return from;
23     }
24
25     // get message
26     public String getMessage()
27     {
28         return message;
29     }
30 }

```

Fig. 26.29 `ChatMessageImpl` is the `ChatMessage` implementation (part 2 of 2).

`ChatServerImpl` does not change. The server receives an object of type `ChatMessage` (i.e., `ChatMessageImpl`) and sends that object to the registered clients. `DeitelMessenger` has two changes at lines 92–93:

```

ChatMessage message =
    new ChatMessageImpl( userName, messageToSend );

```

and at lines 245–246:

```

messageArea.append( "\n" + message.getSenderName() +
    "> " + message.getMessage() );

```

Everything else happens via standard CORBA mechanisms, so `DeitelMessenger` and `ChatServerImpl` objects continue to work as written.

At `CORBAMessageManager` time of this writing, the `idlj` delivered with JDK 1.3.0\_02 does not support the `valuetypes` as specified in the OBV specification. The code presented works under the Java 2 Software Development Kit. Updated code examples will be available at [www.deitel.com](http://www.deitel.com) when `idlj` complies more closely with the OBV specification.

## 26.9 Comments and Comparisons

Comparing the RMI version of the chat example to the CORBA version raises a couple of interesting questions not the least of which is the use of a **Hashtable** instead of a **Vector** in the CORBA version of the server. Using a **Vector** is much simpler than using a **Hashtable** (but bear in mind that this is an implementation detail. The type of object used to hold a collection can change many times during the design of a sub-system). In this particular case, **Hashtables** allow a lookup by primary key, whereas **Vectors** do not. Primary key lookup is important because of the way RMI communicates with remote objects compared to CORBA. In the beginning, RMI required both stubs and skeletons to communicate, but switched over to a *skeleton-optimal* implementation protocol in JDK 1.2. When a client passes its remote object reference, the client-side Java object that contains the RMI object reference communicates directly with the server (in effect, “pretending” to be the server’s skeleton code). The underlying RMI mechanism matches the remote object reference with the Java object on the server-side that contains the object reference.

CORBA, on the other hand, has the *stub* communicating with the *skeleton* before going to the server. The CORBA object reference is always the same, but the Java object holding the reference is different. The skeleton is responsible for unmarshaling all incoming arguments, so a Java object is always created for non-primitive argument values. Also, the current version of JavaIDL supports only BOAs and does not support POAs, which would have offered slightly different behavior. In RMI, the Java object is always identical for each client because there is no skeleton between the stub and the server.

More fundamentally, is this the best design for a chat application? OMA has the final answer—use services whenever possible. CORBA specifies a *Notification Service* that delivers messages synchronously and asynchronously. Using the Notification Service as the messaging middleware makes the chat-application implementation even simpler.

CORBA is a powerful means of designing robust distributed systems. Legacy applications have become valuable long-term assets, and new applications have become reusable services that can exchange data in a platform-neutral fashion. IIOP allows ORBs to communicate in a predictable and robust way, and the Object Management Architecture gives developers a roadmap to follow as they design and implement systems to accomplish tasks of substantial complexity. The OMG continues to push the boundaries of system design and integration with specifications in areas where commonality of purpose and design give developers more leverage to build larger systems. In Chapter 27, we present an in-depth look at system architecture, including CORBAservices, the CORBA Component Model, Enterprise JavaBeans and an assessment of CORBA and RMI.

## 26.10 Internet and World Wide Web Resources

[java.sun.com/products/jdk/idl/index.html](http://java.sun.com/products/jdk/idl/index.html)

The *JavaIDL Home Page* lists various documents relating to JavaIDL and Javasoft’s implementation of various OMG specifications.

[www.omg.org](http://www.omg.org)

The *Object Management Group* home page. This is the ultimate portal for CORBA information. The OMG home page lists membership information as well as information on the latest happenings in the distributed systems world.

[www.omg.org/technology/documents/formal/object\\_management\\_architecture.htm](http://www.omg.org/technology/documents/formal/object_management_architecture.htm)

Download the *Object Management Architecture Specification* from this HTML page as either a PDF or a postscript file.

[www.omg.org/technology/documents/formal/index.htm](http://www.omg.org/technology/documents/formal/index.htm)

*OMG Formal Documentation.* All of the approved specifications in the various areas the OMG is involved in are at this location. The latest CORBA, CORBAservices and IDL mapping specifications have their own link.

[www.omg.org/technology/documents/formal/corbaiop.htm](http://www.omg.org/technology/documents/formal/corbaiop.htm)

The *CORBA 2.4 specification* describes the mappings and functionality required for a product to be considered CORBA-compliant.

[www.omg.org/technology/documents/formal/omg\\_idl\\_to\\_java\\_language\\_mapping.htm](http://www.omg.org/technology/documents/formal/omg_idl_to_java_language_mapping.htm)

The *OMG IDL-to-Java Mapping Specification* explains how IDL-described services translate into Java. This specification is the definitive source for mapping information.

[www.omg.org/technology/documents/formal/naming\\_service.htm](http://www.omg.org/technology/documents/formal/naming_service.htm)

The *Naming Service Specification* describes the baseline functionality needed by a distributed naming service to be useful to a distributed architecture. The specification explains definitions and Naming Service IDL in detail.

[www.omg.org/cgi-bin/doc?orbos/98-01-18](http://www.omg.org/cgi-bin/doc?orbos/98-01-18)

This link has the February 1998 paper *Objects-by-Value, Joint Revised Submission - w/Errata*.

[www.omg.org/cgi-bin/doc?formal/98-12-09](http://www.omg.org/cgi-bin/doc?formal/98-12-09)

This link on the Object Management Group Web site has the *CORBAservices: Common Object Services Specification* document.

[www.corba.net](http://www.corba.net)

The *CORBAnet* site, sponsored by the OMG and the Distributed Systems Technology Centre in Australia, showcases CORBA technology in concrete ways, including a web-based application showing interoperability between different vendor's ORBs.

### ***Open Source ORBs***

[openorb.exolab.org](http://openorb.exolab.org)

*ExoLab Group's OpenORB* is an open source implementation of the CORBA specification. OpenORB is at CORBA 2.4.1 compliance and includes many of the standard tools developers expect from a full-fledged CORBA product.

[www.cs.wustl.edu/~schmidt/TAO.html](http://www.cs.wustl.edu/~schmidt/TAO.html)

The *Ace ORB (TAO)*. The ACE project is a collection of frameworks and CORBA concepts implemented in an open source ORB reflecting high quality and best practice.

### ***CORBA Vendors***

The following vendors sell ORBs or products built on ORBs. The following is not a comprehensive list.

[www.iona.com](http://www.iona.com)

Iona.

[www.inprise.com/visibroker](http://www.inprise.com/visibroker)

Inprise.

[www.capeclear.com](http://www.capeclear.com)

Cape Clear.

**[www.vertel.com](http://www.vertel.com)**

Vertel.

***CORBA services Vendors*****[www.prismtechnologies.com](http://www.prismtechnologies.com)**

Prism Technologies is a commercial CORBA vendor that has implemented many of the defined CORBA services.

**[www.ooc.com](http://www.ooc.com)**

Object Oriented Concepts, Inc. (an Iona company) is also a commercial ORB vendor. OOC's free (for non-commercial use) download includes a handful of CORBA services with their ORBacus product.

**[openorb.exolab.org/services.html](http://openorb.exolab.org/services.html)**

The same ExoLab Group folks that implemented OpenORB also have implemented many of the standard CORBA services. These CORBA services are available for free download.

**SUMMARY**

- CORBA stands for the Common Object Request Broker Architecture.
- The reason CORBA exists is to allow programs written in various languages, with varying implementations running in disparate locations, to communicate with each other as easily as if they were in the same process address space.
- Transparency is a crucial goal of CORBA.
- Invocation transparency defines the viewpoint of a client sending a message to a server.
- Implementation transparency is a standard object concept (encapsulation) applied to distributed systems.
- Location transparency allows a client to invoke CORBA-enabled code that could be executing anywhere on the network without worrying about where the method call is happening.
- The Object Management Architecture (OMA) is one of the defining features that distinguish CORBA from other distributed system technologies.
- The OMA (as a reference architecture) defines a system consisting of cooperating services solving a domain problem.
- IDL, the Interface Definition Language, allows developers to describe the interface (or API) of the data type they wish to use remotely in a language-independent fashion.
- IDL is a pure description language—no implementation details are included in IDL files.
- An IDL compiler creates a number of language-dependent files. A project would need as many IDL compilers as target languages in the system to be developed.
- Any CORBA-enabled objects must use an ORB to make or receive method requests, but those same objects rarely see the ORB.
- When a client using an ORB connects to a distributed object, the ORB returns an object reference to the object in question.
- CORBA defines an object reference as being an Interoperable Object Reference (IOR). The IOR contains three important pieces of information—the distributed object's location (an address, but not a memory address), a reference to the adapter that created the IOR and an object ID for the servant.
- IIOP is the standard ORB protocol that all vendors must support for their ORB's to be considered CORBA-compliant.

- IIOP is the concrete implementation of another OMG standard—the General Inter-ORB Protocol, or GIOP. GIOP defines the messages needed by ORBs to communicate with each other as well as support for the underlying transport mechanism of the platform on which the ORB is running.
- Java 2 was the first official JavaSoft release to support the OMG mappings directly.
- The steps necessary to implement a distributed system using Java and CORBA are: 1) perform analysis and design, 2) define the IDL, 3) implement the servant using files generated by the IDL compiler, 4) implement a client using the stub files generated by the IDL compiler, 5) execute a CORBA Naming Service, 6) execute the servant implementation, 7) execute the client.
- IDL follows standard C++ syntax with the double slash (//) denoting a single-line comment.
- The **module** keyword maps a given name directly to a Java package. Nested **module** names concatenated together create a complete package name.
- Curly braces denote the boundaries of a scope block and always end with a semicolon.
- The keyword **interface** defines a CORBA-enabled object.
- Everything declared in IDL is public so there are no special keywords to denote public, private or protected declarations.
- Conventionally, the concrete class that implements the interface that defines the public API to a CORBA distributed object is named *<interface name>Impl*.
- Once the ORB has the implementation object, no one accesses the object except through the ORB.
- A standard CORBA directory service is the Naming Service. It exists for the sole purpose of listing resources for future use by clients.
- Method **resolve\_initial\_references** knows a select list of services reachable directly from the ORB. The ORB effectively has a mini-naming service with which it can perform the lookup of base services.
- For a name to be properly registered (or bound, in CORBA terminology) the resource must set up a naming context using a **NameComponent** object.
- The **tnameserv** tool is a basic implementation of the CORBA Object Service (COS) Naming Service.
- We can think of an Object Request Broker as the back plane (or communication bus) of distributed systems.
- The Object Management Architecture is the OMG's reference architecture for distributed systems based on the concept of an Object Request Broker.
- The OMA defines a plug-and-play framework where publicly defined objects are available for use by any other object or service through an object broker.
- The Common Object Request Broker Architecture defines how the Object Request Broker behaves and how it works using different languages.
- ORBs can be implemented in one of two ways—as libraries, or as standalone processes known as daemons.
- The client can talk to the ORB either through a static stub, a dynamic interface or directly.
- An ORB can talk to a servant in one of three ways—through a static skeleton, a dynamic interface or directly.
- Object adapters are objects that stand between a client and server to control access to the actual distributed object.
- CORBA 3.0 defined an object adapter called the Portable Object Adapter (POA).

- The Portable Object Adapter serves a number of purposes, including the ability to separate the availability of the servant from the actual servant itself.
- Static stubs (using the Static Invocation Interface or SII) have hard-coded object types to allow for compile-time type checking while dynamic stubs (the Dynamic Invocation Interface or DII) perform their type checking at runtime.
- CORBAservices are the baseline services available to all objects sitting on the ORB communication bus.
- The ORB is the central core of a CORBA system, so the CORBAservices can assume the existence of an ORB when they are running.
- The CORBAservices all have standard IDL interfaces that describe what the various services offer in the way of functionality.
- The CORBAfacilities are a step above the intermediate CORBAservices and come in two groups—horizontal and vertical.
- The horizontal facilities target client-side functionality.
- The vertical CORBAfacilities—also called CORBA Domains—are between the CORBAservices and the Applications Objects.
- The Applications Objects are the top layer of the OMA. They have functionality not found at the domain layer, facilities layer or the services layer.
- Distributed objects need to be defined in a manner that allows them to be discovered and used by others distributed objects.
- OMG document formal/99-07-53 defines the IDL-to-Java mapping and covers everything from package names to helpers to mapping CORBA pseudo objects.
- The Java packages that constitute the core CORBA infrastructure are located in the packages that start with **org.omg.\***.
- Comments placed in an IDL file appear in the generated files only if they are within the **module** scope. Any other comments are purely for the maintainer of the IDL file.
- A **struct** is the definition of a collection of data compiled into a class definition that a remote servant can return to or receive from a client at runtime.
- Most of the primitive IDL-to-Java mappings are straightforward. Signed primitives stay that way (except there is no keyword **int** in IDL); unsigned IDL primitives run the risk of truncation when they are mapped to their signed Java primitive counterparts (a signed short cannot store as large a value as a unsigned short).
- The IDL compiler also initializes the instance variables by setting them to integer zero, 0.0, **false** or **null** (casting where necessary).
- There are two ways to declare arrays in IDL—using the keyword **sequence** or by the use of open-and-close square brackets.
- The **sequence** keyword can be used in two ways—bounded and unbounded. When a length is given, the **sequence** is considered bounded, otherwise it is considered unbounded.
- The more standard square brackets notation can also declare arrays. However, the use of IDL arrays is nonstandard to Java. The **typedef** keyword would define an array of a particular data type, using a new data type name and the array length.
- IDL includes keywords **in**, **out** and **inout** to describe method arguments. A variable declared as **in** has a copy of itself passed to the called method. An **out** variable must be a reference to an object containing another object where the contained object may be substituted with another object

and the change is visible to the client (mimicking call-by-reference). A variable declared as **in-out** uses both semantics.

- Every time a **struct** or **interface** is declared, the IDL compiler generates an associated **Holder** class for use when the **struct** or **interface** is an **out** variable.
- All of the Java primitives have **Holder** classes available for them in the **org.omg.CORBA** package, and the IDL generates an **Operations** interface defining the **Holder** object needed.
- Only an **interface** can have **attribute** declarations.
- If the **attribute** keyword is used alone the compiler generates two methods—an accessor (*get* method) and a mutator (*set* method).
- Using the **readonly** keyword with **attribute** would generate only the accessor.
- In IDL, the **const** keyword declares a constant.
- Proxies are stand-ins for other objects. They allow a client to believe it is sending a message to one object when the client is really sending the message to another object.
- CORBA defines two related proxies—a stub and a skeleton. A stub is the client-side proxy and a skeleton is the server-side proxy. Both proxies hide the use of the ORB from the client and the server.
- In CORBA 3, static invocation choices can be synchronous (normal or **oneway**) or asynchronous (callback or polling).
- The use of a callback or polling mechanism is purely one of perspective—a callback is an invocation made from the server while polling is an invocation made from the client. The distinction has to do with a met condition (a server alerts a callback object) or an expected condition (a client poll an object to check on state changes).
- A normal synchronous call is a standard method invocation—a client invokes a method and blocks until the call completes.
- If an IDL method signature includes the **oneway** keyword, the compiler generates code that does not block on the invocation and returns based on the QoS settings.
- The CORBA Asynchronous Method Invocation specification supports both callback and polling models.
- The callback model supports (with various QoS options) the ability of a servant to call a client at arbitrary times at the discretion of the servant.
- In the polling model the client decides when to retrieve a possible result based on a call to a **one-way** method.
- When **structs** are instantiated in Java, all of the instance variables are **public**.
- Another way for a client to find a service is to use a stringified version of the service's Interoperable Object Reference.
- The **<data type name>Helper** classes are for the direct manipulation of mechanisms like the ORB's object stream.
- The **<data type name>Holder** classes are for **out** and **inout** variable use as dictated in the code generated by the IDL compiler.
- Every call to a distributed object can throw an exception.
- Developers can find the exceptions thrown by a CORBA object by looking in the object's associated IDL file.

- The keyword **raises** maps to the Java keyword **throws**.
- IDL **exceptions** map indirectly to Java exceptions inheriting from **java.lang.Exception** (they directly inherit from **UserException**).
- Standard CORBA exceptions map to Java exceptions as **final** classes.
- If a CORBA exception inherits from **SystemException**, then it is also a **RuntimeException**.
- The reason to send an object by value is the same as the reason to use **structs**—a local copy of an object has less access overhead than a remote object that needs repeated access.
- The target language of the mapped **struct** adds some overhead (in a nonobject-oriented target language, the overhead is almost nonexistent), but beyond that, the ORB adds nothing.
- Structurally, all IDL **structs** mapped to Java classes implement **org.omg.CORBA.portable.IDLEntity**, but do not inherit behavior or structure from any classes (except for the ubiquitous **java.lang.Object**).
- The Objects-by-Value (OBV) specification defines a new kind of **interface** type—a **struct** with behavior semantics (the ability to support the declaration of operations) called a **valuetype**.
- The advantage of **valuetypes** is the ability to pass copies of “objects” around a distributed system that contain not just data, but behavior.
- In the beginning, RMI required both stubs and skeletons to communicate, but, in JDK 1.2, RMI switched over to a skeleton-optional implementation protocol.
- CORBA specifies a Notification Service that delivers messages synchronously and asynchronously.

## TERMINOLOGY

<b>activation</b>	<b>interface</b>
Architecture (CORBA)	Interface Definition Language (IDL)
Asynchronous Method Invocation (AMI)	Internet Inter-ORB Protocol (IIOP)
<b>attribute</b>	Interoperable Object Reference (IOR)
Basic Object Adapter (BOA)	invocation transparency
client	location transparency
Common Object Request Broker	marshaling
<b>const</b>	<b>module</b>
CORBA Component Model (CCM)	Naming Service
CORBAfacilities	object activation
CORBAservices	Object Management Architecture (OMA)
distributed computing	Object Management Group (OMG)
Dynamic Invocation Interface (DII)	Object Request Broker (ORB)
<b>exception</b>	objects-by-reference
factory	objects-by-value
General Inter-ORB Protocol (GIOP)	<b>oneway</b>
Helper	opaque network reference
Holder	<b>out</b>
<b>idlj</b>	Portable Object Adapter (POA)
IIOP (Internet Inter-ORB Protocol)	proxy
implementation transparency	Quality of Service (QoS)
<b>in</b>	<b>readonly</b>
<b>inout</b>	

Remote Method Invocation (RMI)	stringified IOR
RMI (Remote Method Invocation)	<b>struct</b>
<b>sequence</b>	stub
servant	<b>SystemException</b>
singleton	<b>typedef</b>
skeleton	unmarshaling
Static Invocation Interface (SII)	<b>valuetype</b>

## SELF-REVIEW EXERCISES

**26.1** Fill in the blanks in each of the following statements:

- a) \_\_\_\_\_ is the highest-level scope in an IDL file.
- b) In an IDL file, declarations of data without operations appear in a \_\_\_\_\_.
- c) An IDL **interface** maps to a Java \_\_\_\_\_.
- d) An IDL operation uses the keyword \_\_\_\_\_ to declare its use of an exception.
- e) A client would use the \_\_\_\_\_ service to retrieve a server's IOR.
- f) The CORBA proxy used by a client is called a \_\_\_\_\_, and the proxy used by a server is called a \_\_\_\_\_.
- g) To find the initial object reference to standard services like the Naming Service, use the ORB method \_\_\_\_\_.

**26.2** State whether each of the following is *true* or *false*. If *false*, explain why.

- a) An IDL **interface** maps to a Java **interface** of the same name.
- b) An IDL **struct** can declare operations.
- c) An IDL **valuetype** can declare operations.
- d) The only way a client can get an object reference to a server is by using a Naming Service.
- e) IDL is an implementation language.

## ANSWERS TO SELF-REVIEW EXERCISES

**26.1** a) **module**. b) **struct**. c) **interface**. d) **raises**. e) Naming. f) stub, skeleton.  
g) **resolve\_initial\_reference( String serviceName )**.

**26.2**

- a) True.
- b) False. An IDL **struct** only contains data definitions.
- c) True.
- d) False. A client can read an object reference from a stringified IOR.
- e) False. IDL defines data, structures of data and interfaces to distributed objects, not their implementation.

## EXERCISES

**26.3** Write the IDL for a server named **Server** with one operation called **getString** and have the operation return a **string**. Implement the server. Write a client named **Client** that requests the string and displays the returned value.

**26.4** Modify Exercise 26.3 to do the following:

- a) Return a **struct** containing the string.
- b) Change the **get** operation of the server. Have the client give the server the **struct**.
- c) Modify part a) above to have the client modify the **struct** object given to it by the server and have the client send the object back to the server.

- d) Wrap the creation of the server (including the code to **resolve** the object reference) inside a client-side proxy. The client-side server proxy constructor should not throw any CORBA exceptions.
  - e) Wrap the **struct** in an object created in the proxy implemented in part d), using a factory method.
- 26.5** Create a service that returns object references to a **Customer** (do not make the **Customer** a **struct**). This service is the implementation of the factory design pattern as it creates and returns objects of a given type without revealing their actual type. Give the **Customer** two attributes and have a test client display the attributes (a primary key and an attribute).
- 26.6** Write a server with an operation that returns an IDL **unsigned short**. Have the server return **Short.MAX\_VALUE + 1**. Display the value returned by the server in a **JOptionPane**. How does Java's lack of support for **unsigned** values affect its interaction with servers that return values larger than Java can handle for certain data types?
- 26.7** Write a class named **FileServer** that returns a file requested by a client (use an array of IDL type **octet**). The client can display the file in a **JTextArea**. What limitations are there in the use of an IDL array?
- 26.8** Modify the **FileServer** to return a **FileStream** object. **FileStream** should cache the file on the server side until the client makes a request. **FileStream** should have an operation to return one line at a time.

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# Common Object Request Broker Architecture (CORBA): Part 2

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## Objectives

- To introduce the Dynamic Invocation Interface (DII).
- To understand the differences among BOAs, POAs and TIEs.
- To introduce CORBAservices, including Naming, Security, Object Transaction and Persistent State services.
- To understand the differences between RMI and CORBA.
- To introduce RMI-IIOP for integrating RMI with CORBA.

*Two elements are needed to form a truth—a fact and an abstraction.*

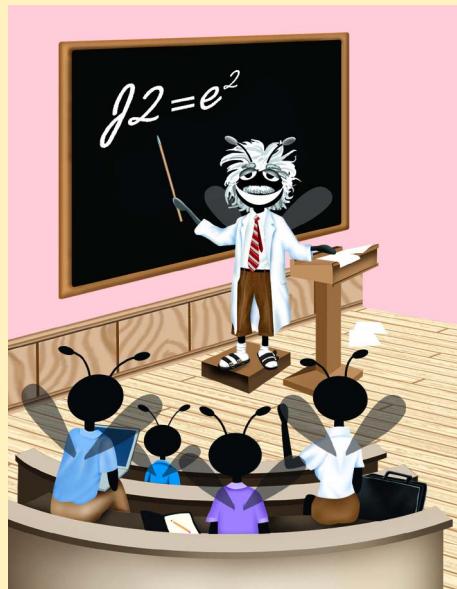
Remy de Gourmont

*If two friends ask you to judge a dispute, don't accept, because you will lose one friend; on the other hand, if two strangers come with the same request, accept because you will gain one friend.*

Saint Augustine

*The profoundest thought or passion sleeps as in a mine, until an equal mind and heart finds and publishes it.*

Ralph Waldo Emerson



## Outline

- 27.1 Introduction**
- 27.2 Static Invocation Interface (SII), Dynamic Invocation Interface (DII) and Dynamic Skeleton Interface (DSI)**
- 27.3 BOAs, POAs and TIEs**
- 27.4 CORBAservices**
  - 27.4.1 Naming Service**
  - 27.4.2 Security Service**
  - 27.4.3 Object Transaction Service**
  - 27.4.4 Persistent State Service**
  - 27.4.5 Event and Notification Services**
- 27.5 EJBs and CORBAComponents**
- 27.6 CORBA vs. RMI**
  - 27.6.1 When to Use RMI**
  - 27.6.2 When to Use CORBA**
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- 27.7 RMI-Messenger Case Study Ported to RMI-IIOP**
  - 27.7.1 ChatServer RMI-IIOP Implementation**
  - 27.7.2 ChatClient RMI-IIOP Implementation**
  - 27.7.3 Compiling and Running the ChatServer and ChatClient**
- 27.8 Future Directions**
- 27.9 Internet and World Wide Web Resources**

*Summary • Terminology • Internet and World Wide web Resources • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Works Cited • Bibliography*

## 27.1 Introduction\*

The previous chapter introduced the world of distributed systems through the eyes of the OMG (Object Management Group). This is a group vision (the OMG has approximately 800 members at last count), and the architectural issues are all relevant and practical—these are vendors who have been building (and in some cases rebuilding) systems of this kind for years. Their combined expertise and resolve have produced far-reaching, influential specifications that have made huge enterprise-level systems possible. Their goal of an object marketplace is coming closer.

JavaIDL is the first step into the world of CORBA and distributed systems. Understanding of CORBA concepts at both the low level (i.e., object adapters) and high level (CORBAservices and CORBAComponents) is important.

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\*. This chapter was co-authored by Carlos Valcarcel of EinTech, Inc.

## 27.2 Static Invocation Interface (SII), Dynamic Invocation Interface (DII) and Dynamic Skeleton Interface (DSI)

There are two ways to invoke a request in CORBA—statically and dynamically. All of the examples presented up to this point use the *Static Invocation Interface* or *SII*.

SII relies on the compile-time definition of an object type (an IDL interface) and the object operations (IDL methods within an IDL interface). When the IDL compiler generates the client-side stub and server-side skeleton, there is no question what the contract is on both sides of the invocation. The generated stub/skeleton code defines the *static type* of the interface in an IDL file. From the server's perspective, the server receives a request and, using any incoming parameters, executes code and returns any values necessary. The server-side ORB receives the pieces needed to complete a request, but does not know about the process that created the request.

The server-side skeleton's ability to receive an invocation request that is independent of the mechanism to create the request makes a *dynamically typed* call to a server possible. A client has two choices available to make an invocation on a server: use the static stubs generated by the IDL compiler or manually create an invocation request programmatically. A client uses the *Dynamic Invocation Interface (DII)* API create and send an execution request directly to the server-side ORB without the assistance of a stub. The code written by a developer using the DII API looks similar to the code generated for the stub; the difference is the additional flexibility of programmatic control over the API instead of the hard-coded instructions found in the stubs.

On the other side of the invocation, the server can process the request in one of two ways: the static skeleton generated by the IDL compiler can process the incoming request or the servant (the object implementation under the control of an object adapter) can process the request manually. When a servant receives an invocation and manually extracts the data needed from the incoming request the servant uses the *Dynamic Skeleton Interface (DSI)*. Clients and servers can use DII and DSI together or separately. Clients using the invocation interface can invoke operations on a server regardless of that server's use of static or dynamic skeletons. Servers can accept incoming invocation requests from clients regardless of a client's use of static stubs or dynamic invocations. Developers are responsible for passing and guaranteeing the proper type and number of arguments to the invocation.

The *Interface Repository (IR)* contains descriptive information about distributed objects. Such information includes the modules available, the interfaces defined within the modules, the names of the operations defined within the interfaces, the argument types acceptable to the operations, the return types of the operations and any exceptions raised. A client can discover this information about an object by retrieving metadata from the Interface Repository.

JavaIDL does not ship with an Interface Repository, so a truly dynamic working DII example is not possible with the ORB shipped with JDK 1.3. A basic code example is possible—we can bind directly to a remote object and, using a known operation signature, make a dynamic invocation to the object's operation.

The steps needed to make a DII call (without using the Interface Repository) are as follows:

1. Obtain an object reference to the server object.
2. Create and initialize a **Request** object.

3. Invoke the **Request** and wait for the call to unblock (return).
4. Get the results.

Using the Interface Repository entails finding the Interface Repository entry for the object type in question after getting the object's reference to the server object. The following are the new steps:

1. Obtain an object reference to the server object.
2. Look up the desired method in the Interface Repository.
3. Build the argument list for the target operation using the Interface Repository's **OperationDef**.
4. Create and initialize a **Request** object.
5. Invoke the **Request** and wait for the call to unblock (return).
6. Get the results.

With the level of control possible using DII comes the high price of code complexity. Developers must craft every method invocation carefully, and the amount of custom code varies based on the complexity of the arguments, result types and exceptions. However, developers often find that the control that DII offers makes learning DII worthwhile. System-framework architects find DII useful in implementing hot-swappable components, administrative plugins and more. The Interface Repository becomes the central data store for finding registered object types—CORBA vendors are responsible for implementing robust, multiuser repositories that support the high-bandwidth, global distributed systems being developed today.

We have modified the **SystemClock** example to support DII. The files needed for **SystemClock** are **clock.idl**, **SystemClock.java**, **SystemClockOperations.java**, **\_SystemClockImplBase.java**, **SystemClockImpl.java** and **SystemClockClient.java**. The only generated files needed are the server-side files, so **idlj** needs just the **-fserver** option set instead of **-fall**. The **Helper** and **Holder** files are unnecessary. **SystemClockClient.java** (Fig. 27.1) is the only file that needs updating.

```

1 // SystemClockClient.java
2 // Client that uses DII to request the system time from a servant.
3 package com.deitel.advjhttp1.idl.dii;
4
5 // Java core packages
6 import java.text.DateFormat;
7 import java.util.*;
8
9 // Java extension packages
10 import javax.swing.JOptionPane;
11
12 // OMG CORBA packages
13 import org.omg.CORBA.ORB;
14 import org.omg.CosNaming.*;
15 import org.omg.CosNaming.NamingContextPackage.*;
```

Fig. 27.1 **SystemClockClient** modified to support DII (part 1 of 3).

```
16
17 public class SystemClockClient implements Runnable {
18
19     // object reference to desired server
20     private org.omg.CORBA.Object timeServer;
21     private ORB orb;
22
23     // initialize client
24     public SystemClockClient( String[] params ) throws Exception
25     {
26         connectToTimeServer( params );
27         startTimer();
28     }
29
30     // use NameService to connect to time server
31     private void connectToTimeServer( String [] params )
32             throws org.omg.CORBA.ORBPackage.InvalidName,
33                     org.omg.CosNaming.NamingContextPackage.InvalidName,
34                     NotFound, CannotProceed
35     {
36         // Connect to the SystemClock server
37         orb = ORB.init( params, null );
38
39         org.omg.CORBA.Object corbaObject =
40             orb.resolve_initial_references( "NameService" );
41         NamingContext naming =
42             NamingContextHelper.narrow( corbaObject );
43
44         // Resolve the object reference in naming
45         NameComponent nameComponent =
46             new NameComponent( "TimeServer", "" );
47         NameComponent path[] = { nameComponent };
48         timeServer = naming.resolve( path );
49     }
50
51     // start timer thread
52     private void startTimer()
53     {
54         Thread thread = new Thread( this );
55         thread.start();
56     }
57
58     // talk to server on a regular basis and display the results
59     public void run()
60     {
61         long time = 0;
62         Date date = null;
63         DateFormat format =
64             DateFormat.getTimeInstance( DateFormat.LONG );
65         String timeString = null;
66         int response = 0;
67     }
```

Fig. 27.1 **SystemClockClient** modified to support DII (part 2 of 3).

```

68     org.omg.CORBA.Request request =
69         timeServer._request( "currentTimeMillis" );
70     request.set_return_type( orb.get_primitive_tc(
71         org.omg.CORBA.TCKind.tk_longlong ) )
72     );
73
74     while( true ) {
75
76         // invoke method currentTimeMillis using the request object
77         // time = timeServer.currentTimeMillis();
78         request.invoke();
79
80         // get time value from request object
81         time = request.result().value().extract_longlong();
82         date = new Date( time );
83         timeString = format.format( date );
84
85         response = JOptionPane.showConfirmDialog( null, timeString,
86             "SystemClock Example", JOptionPane.OK_CANCEL_OPTION );
87
88         if ( response == JOptionPane.CANCEL_OPTION )
89             break;
90     }
91
92     System.exit( 0 );
93 }
94
95 // main method to execute client application
96 public static void main( String args[] )
97 {
98     // create client
99     try {
100         new SystemClockClient( args );
101     }
102
103     // process exceptions that occur while client executes
104     catch ( Exception exception ) {
105         System.out.println(
106             "Exception thrown by SystemClockClient:" );
107         exception.printStackTrace();
108     }
109 }
110 }
```

Fig. 27.1 **SystemClockClient** modified to support DII (part 3 of 3).

First, we need two instance variables to use in the client. Line 20 declares a reference to a generic CORBA object called **timeServer**, which will hold the reference to the remote server. The **orb** variable (line 22) holds the ORB reference used in both methods **connectToTimeServer** (lines 31–49) and **run** (lines 59–93) to connect the client to the server and to create support objects for the invocation to the server. Method **connectToTimeServer** places the newly created ORB object in variable **orb** and binding the client to server **timeServer**.

The invocation of server method **currentTimeMillis** occurs at line 78 (the original code is commented out at line 77). Prior to the **while** loop, the client asked the **CORBA.Object** returned by the call to **resolve** (saved in variable **timeServer**) to create and return a **Request** object. This **CORBA.Object** (the client-side construct that holds the server object reference) returns a **Request** object that the client uses to call the server. The client's sole task is to set the **request** return type to an IDL **long long** (**TCKind.tk\_longlong**). The call to **currentTimeMillis** does not need any incoming arguments, so the preparation of the dynamic call is complete once the return type of the method is set in the **request** (lines 70–71).

The call to **currentTimeMillis** becomes a multiline dynamic call to the target method of the **timeServer** (line 78 invokes the method and line 81 unmarshals the return value). The call to **invoke** sends the **request** object to our bound server and blocks until the operation returns. The client queries the **request** object for the **result**, queries the **result** for the **result**'s internal **value** and requests the value of the **result** as an IDL **long long** (line 81).

Running the transient Naming Service (**tnameserv**), **SystemClockImpl** and **SystemClockClient** should produce the same results as the **SystemClock** example in Chapter 26 with minimal additional overhead. The indirect call to **currentTimeMillis** did not receive any arguments, and the example does not need to reconstruct the **Request** object repeatedly to invoke the method on the remote object.

DII is composed of a number of useful technologies. Using the Interface Repository enables flexibility at runtime to discover more about the types available in a distributed system and yields options for a client to interact with future distributed objects. Think of the Interface Repository (and the API to access it) as a distributed version of the Java reflection mechanism. Highly-flexible frameworks can take advantage of the information contained within the IR as well as interested clients who need type information about a particular CORBA object they are working with at a particular moment in time.

JavaIDL is not a complete implementation of CORBA. The Javadocs for package **org.omg.CORBA** list the various parts of the JavaIDL packages defined in the API but not implemented in JavaIDL. Rather than work against Sun's implementation, we recommend using a commercial ORB vendor's CORBA implementation when the modeling and analysis of a Java-based distributed system are complete. Open-source implementations of CORBA for Java are also available that include a working Interface Repository.

### 27.3 BOAs, POAs and TIEs

When a client interacts with a distributed object, more than just a pair of ORBs are involved. When we consider implementation in a CORBA system, clients are made thin purposefully. Distributed systems are weighed heavily on the server, while client-side invocation issues are taken care of by the IDL generated stubs. Clients do not worry about issues such as load balancing or persistence—these are server-side issues. The indirection that enables this lopsided view is the *object adapter*, which stands between a distributed object and its ORB (Fig. 26.8). Many ORB services of use to a distributed object are accessed through its object adapter.<sup>1</sup> Some of the ORB services the object adapter transparently performs are IOR generation, security and activation/deactivation. The first adapter type specified by the OMG was the *Basic Object Adapter* or *BOA*. In CORBA 2.0, the definition of a BOA was

vague, so incongruities existed among various BOA implementations, which hindered the portability and interoperability of generated code that used ORBs from different vendors. To resolve these problems, the OMG deprecated the use of BOAs in favor of the *POA*, the *Portable Object Adapter*. The indirection introduced with POAs opens up many more possibilities and makes interoperability easier to guarantee. From one perspective, BOAs are easier to use (even if their behavior is inconsistent), but POAs are more widely employed.

A POA connects an object reference to developer-written code using the code found in the skeleton generated by the IDL compiler. As configurable objects, POAs allow fine-grained control over the object implementation (called a *servant* when attached to a POA). In the same fashion that our server inherited from the **ImplBase** definition (Fig. 26.4, line 11), a servant inherits from the POA base definition generated by the IDL compiler. In this case, our distributed object inherits the structure needed to be an object usable by a POA, and the POA controls all access to the servant based on various *policies* set within the POA. Policies describe characteristics of the objects under the control of a particular POA. These policies, once set, are immutable.

Three POA policies are **ImplicitObjectActivation**, **IDAssignmentPolicy**, and **RequestProcessingPolicy** (there are seven policy types all together). The POA **ImplicitObjectActivation** policy of **NO\_IMPLICIT\_ACTIVATION** tells the POA an outside object created the servant under the POA's control and passed the object to the POA using method **activate\_object** or **activate\_object\_with\_id**. An *object id* is a unique identifier that can be defined by either the developer or the system. Each object id is associated with a particular servant. *Activating* an object within a POA makes it available for use by clients. *Deactivating* an object makes the object unavailable, although the object may be activated again at a later time. The use of method **activate\_object** or **activate\_object\_with\_id** rests on the use of POA policy **IDAssignmentPolicy**, which can be set to either **USER\_ID** or **SYSTEM\_ID**. A POA policy of **IDAssignmentPolicy USER\_ID** implies that a caller needing to associate a servant with a POA will define the servant's unique identifier rather than letting the POA generate the object id (which would be the case if **IDAssignmentPolicy SYSTEM\_ID** were used). Together with **RequestProcessingPolicy USE\_DEFAULT\_SERVANT** (and method **set\_servant**) the above mentioned policies will configure a POA that will not create servants (however, the POA will route invocations to them), associate user-supplied object ids with various servants and route all invocations to a default servant if the incoming object id does not match an already active object. An example of this interaction is as follows: a client makes a request to a particular server using that server's object reference. One of the pieces of information contained within an object reference is the servant's object id. The POA, processing the invocation using the **RequestProcessingPolicy**, uses the object id either to find the servant that matches the object id or to invoke the default servant that uses the object id to perform a lookup in a database. If the default servant is called, it can create the requested object, returns the new object to the POA, and the POA would pass it on to the ORB for delivery to the client.

If there is no explicit need for an id, the POA can generate an id for internal use. In either case, when a request comes in for a particular servant, the POA uses a combination of policies and object ids to connect the request to a particular object. The indirection created by the use of a POA allows one POA to control one servant or many servants.

Although the combination of POA policies can be confusing, it enables various levels of QoS and scalability.

Another way for developers to use a POA is to wrap their servants in a *TIE*. TIEs enable interaction with a POA without having the servant's object implementation inherit structure from a **POAImpl**. By delegating the CORBA functionality to the TIE object, the servant can inherit from some other base class freely (in Java, we want to inherit only when appropriate). A TIE object that mimics the servant's API contains the created servant and invokes the proper operation at runtime.



### Good Programming Practice 27.1

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*When using POAs, consider using TIE POAs. The potential distributed object can inherit from the **Operations** interface and gain CORBA functionality in a transparent fashion from the TIE POA wrapper class.*

BOAs, POAs and TIEs rely on the code generated by the IDL compiler. The JDK-supplied IDL compiler, **idl-j**, does not yet support the generation of POAs and TIEs, so developers are recommended to seek out 3<sup>rd</sup> party CORBA implementations if their system design warrants the use of POAs or TIEs.

## 27.4 CORBAservices

*CORBAservices* are the *Object Services* of the Object Management Architecture (Fig. 26.7). CORBAservices define base services and a support structure useful to a wide range of applications. The 16 services mentioned in Section 26.4 offer a wide range of functionality. The five services described in this section are the most commonly used (and are already the specified services for the CORBA equivalent of Enterprise JavaBeans, the *CORBA Components Model*, or *CCM*).

### 27.4.1 Naming Service

The *Naming Service* associates name objects with an arbitrary value (known as *name bindings*). Any arbitrary value can be used, as long as it inherits from **org.omg.CORBA.Object**. In the context of a CORBA system, the association is between a name and an object reference. However, there are no restrictions as to the use of a Naming Service nor that the collection of objects the Naming Service contains must be homogeneous. A path to a name binding consists of zero or more *naming contexts* (a collection of unique name bindings). *Resolving* a name binding from within the Naming Service returns the object associated with the name. *Binding* a name to the Naming Service creates the association between a name and an object. Associating names to naming contexts creates a *naming graph* that represents the various paths available to the nodes holding a name binding. Multiple name bindings can point to a single object.

Naming represents a fundamental service in CORBA. Some of the CORBAservices inherit IDL interfaces from other CORBAservices, both for backward compatibility and for consistency of their APIs. Naming does not rely on other IDL interfaces, nor does the specification dictate administration of the service or what the name bindings mean. Anything that a client can associate with a name can be contained in the Naming Service. In addition, a group of Naming Services can participate as part of a naming graph to support the distributed discovery of name bindings.

## 27.4.2 Security Service

The *Security Service* is one of the more complex CORBA services. It consists of two levels. Level 1 provides basic security for:

1. User authentication.
2. Invocation security.
3. Availability of authentication principals to security-aware applications.

Level 1 allows applications to ignore the system-security requirements. The security needs are limited in scope, and the ORB will usually handle these needs to the total ignorance of the objects involved in an invocation. A normal ORB does not care about additional processing of object invocations. However, for security to work pervasively, a security-enabled ORB must support the passing of credentials from an initial caller (and any intermediate objects) to a target object.

Level 1 security requires support for the *no delegation* and the *simple delegation* models among a client, an invoked object and a final target object. In the *no delegation* model, a client passes credentials to an intermediate object—this object creates intermediate credentials for use in calling the final target object. In the *simple delegation* model, an intermediate object can use the client’s credentials to make invocations on a target object. If there are no restrictions on how an intermediate object can call the target using the client’s credentials, the intermediate object impersonates the client.<sup>2</sup>

Level 2 is everything Level 1 provides plus the following security areas:

1. More fine-grained user authentication (i.e., user authentication can be checked at method invocation).
2. Greater invocation security.
3. Auditing.
4. Finer control over secure invocations.
5. Delegation.
6. Administrators can set security policies.
7. Discovery of security policies by security-aware applications.
8. Discovery of security policies by ORBs and other services.

Security level 2 gives a system full use of all the functionality listed previously (through the use of APIs defined by the various Security Service interfaces). Separate administration programs modify security policies.<sup>3</sup>

## 27.4.3 Object Transaction Service

The *Object Transaction Service (OTS)* enables CORBA objects to execute as parts of distributed transactions. The OTS specification was one of the first of the CORBA services specifications and has undergone recent changes to increase its flexibility and to fix various implementability issues. A transaction describes a collection of interactions where multiple users may access and/or modify data and the data’s integrity is guaranteed (a transaction is also known in the database world as a *unit of work*). The acronym ACID describes the four standard requirements for reliable transactions:

- Atomic—the completion of the transaction signals either full success or complete failure; if five steps were to be completed within the course of a transaction, then all five steps must terminate successfully or the changes made in each step must be undone. In an atomic transaction, there will never be a situation where some of the steps completed, but others did not.
- Consistent—the effects of the transaction are repeatable and predictable. Executing the same steps on the same data set will always return the same result (also known as preserving invariants).
- Isolated—the transaction is not interruptible from the outside and gives no indication if execution is proceeding serially or concurrently.
- Durable—short of a catastrophic failure (power outage, earthquake etc.), the transaction results are persistent.

A transaction completes in one of two ways—*committed* (the changes made persist) or *rolled back* (all changes made to the data are discarded). The OTS adds to the properties of a reliable transaction service the ability to control transactions across a distributed system.

Functionally, the Object Transaction Service supports flat and (optionally) nested transactions. Flat transactions are the most common type. Nested transactions support ACID for the duration of a child transaction, yet allow for a partial rollback if a child transaction fails. A complete rollback of child transactions occurs when the parent transaction fails. When the top-level transaction—the transaction with no parent—fails, the entire transaction rolls back.

The OTS allows developers to add distributed transactions to existing systems. CORBA facilitates the joining of heterogeneous systems. The OTS, in conjunction with standards such as the Open Group's XA Specification,<sup>4</sup> enables a client to use transactions implicitly or explicitly. An implicit use of a transaction sends the transaction context transparently from ORB to ORB once the transaction is created. An explicit transaction passes the transaction context as a parameter to any called methods. OTS also allows servers to register with the transaction service. To enable the joining of heterogeneous systems, the OTS also supports the X/Open Distributed Transaction Processing model, which allows OTS to communicate with procedural transaction systems.

In CORBA 3, the *Asynchronous Method Invocation (AMI)* specification dictates the behavior of asynchronous calls in a distributed system. In a CORBA system the behavior of asynchronous invocations is almost purely a client-side issue; servants have their transactional requirements set through their POA, and clients making asynchronous calls must have their invocations handled by intermediate routers that will create a new transaction context involving the servant.

POAs dictate the transaction types supported by servants—allow or require only shared transactions, allow or require only unshared transactions, or allow or require either transaction type. If the transaction policy is set at the POA level, that means every object (servant) under the control of the POA has the same transaction policy. A POA can control more than one object at a time, so the objects under the POA's control have the same transactional requirements.

The concepts of *transactional clients*, *transactional objects* and *recoverable objects* define the OTS. A Transactional Client interacts with the OTS to create and commit or rollback a transaction. A transactional object's behavior varies when invoked within a transac-

tion, but object's data may not be recoverable. A recoverable object is a transactional object in which data is recoverable (e.g., an object that represents a row in a database). Recoverable objects maintain their data and, in the event of a persistence failure, assist in restoring their lost state. Two types of application servers that use transactional objects are transactional and recoverable servers. A transactional server has no recoverable objects, whereas a recoverable server has at least one recoverable object. The OTS specifies that both server types can roll back a transaction, but only the recoverable server can participate in the commit.<sup>5</sup>

The *Java Transaction Service (JTS)* is the Java implementation of the distributed transaction service. The API of the JTS is defined by the *Java Transaction API (JTA)*. The JTS uses the CORBA OTS specifications to define the protocol between transaction managers during the exchange of transaction contexts.

#### 27.4.4 Persistent State Service

The *Persistent State Service (PSS)* stores and retrieves objects. In conjunction with an OTS, the PSS abstracts the interaction between objects and datastores. Ideally, systems should persist their objects into object datastores. However, relational databases dominate the marketplace—mapping objects into these databases in a consistent, predictable manner is not trivial. The Persistent State Service relies on the Object Transaction Service and Security Service to maintain transactional integrity and access control.

In the same way that IDL defines the interface of a distributed object, a new *Persistent State Definition Language (PSDL)* defines a distributed object schema in a portable fashion (PSDL is a superset of IDL). Two new constructs are **storagetype** and **storagehome** (usable with or without the keyword **abstract**). A PSDL file contains two definition types: an abstract definition and a concrete definition. In addition, a *factory* (or *home*) can be declared that creates objects of the newly defined type. The **abstract storagetype** or **abstract storagehome** do not define concrete object definitions—rather, they define the portable definition of the persistable state of a CORBA object. The concepts and constructs of an object factory and factory-created objects should look familiar to anyone working with Enterprise JavaBeans (Java interfaces **EJBHome** and **EJBObject** are the corresponding base classes used in the definition of EJBs). Figure 27.2 shows an example of PSDL for a customer **storagehome** and **storagetype**.

```

1 // The schema for a domain object. This is the abstract definition
2 // needed by the PSS. The concrete definition of Customer is below.
3 abstract storagetype Customer {
4     // The accountNumber is our primary key
5     readonly state string accountNumber;
6     state string name;
7 };
8
9 // The factory to be used to retrieve Customer objects
10 abstract storagehome CustomerHome of Customer {
11     // The creation method will create persistent Customers
12     Customer create( in string accountNumber );
13 };
14

```

Fig. 27.2 Persistent State Definition Language example (part 1 of 2).

```

15 // Our factory finder. Use the CustomerDirectory to
16 // find any factories used by the system to create
17 // domain objects like Customer
18 catalog CustomerDirectory {
19     provides CustomerHome customerHome;
20 };
21
22 // This is the concrete declaration of the Customer defined
23 // above. These declarations are empty as we are not adding
24 // any addition structure to Customer or its factory.
25 storageType CustomerImpl implements Customer {};
26
27 storagehome CustomerHomeImpl of CustomerImpl
28     implements CustomerHome {};

```

Fig. 27.2 Persistent State Definition Language example (part 2 of 2).

Line 3 declares the **abstract storageType** for the **Customer**. In addition, Lines 5–6 declare a read-only **accountNumber** and readable/writable **name** using the keyword **state** to notify the PSDL compiler of which fields to persist. The **Customer** is instantiated by a factory, so there should be a declaration of an **abstract CustomerHome** factory.

Lines 10–13 declare **storagehome CustomerHome**. This factory creates **Customers** using method **create**, each with an **accountNumber** as the primary key. A developer does not implement the home class. The PSS software generates the code needed to map the data store to the declared definition of the object. The PSS vendor is responsible for delivering a tool that maps these objects to the data store in which the objects persist.

The two abstract declarations (lines 3 and 10) and the two concrete declarations (lines 25 and 27) are enough information for the PSDL compiler to generate the code creating **CustomerHomeImpl** and **CustomerImpl** classes along with any needed supporting **interfaces** and **abstract classes**.

#### 27.4.5 Event and Notification Services

The *Event Service* defines the mechanism that decouples the delivery of events (messages) from the source of the events. The Event Service is responsible for keeping track of such as **ActionEvent** and **ActionListener** for use by objects that want to send or receive events. In a similar fashion, **EventChannels** use the CORBA data type **Any** to send an event of any type (either primitive or object) across the network in a consistent fashion, as there are no predefined event types in the Event Service specification. However, there is no distributed Java event model, whereas the CORBA model is distributed.

In general, a *supplier* creates events that are processed by a *consumer*. In a *push model*, a supplier sends event messages asynchronously to all consumers registered to receive the messages. In a *pull model*, the consumer polls the supplier for events—if none are available, the consumer may block until events become available. A nonblocking consumer looking for events has to poll the supplier on a regular basis for events. For example, Java uses the push model for Swing and AWT events. A handler object implements the **ActionListener** interface and registers with a Swing component, which notifies the handler of state changes to the GUI component by calling the handler's **actionPerformed** method with an

**ActionEvent.** The GUI component sends the event to the handler object asynchronously. However, Java events are different than Event Service events—the Event Service does not define an event type. Java events are strongly typed, whereas CORBA Event Service events can be typed or untyped, based on the kind of event channel used.

Suppliers and consumers can be either *pull* or *push*, and the type of model they use does not have to match. A push supplier can create messages for consumption by a pull consumer, and a push consumer can wait passively for messages to arrive from a pull supplier. The Event Service acts as the queue (also called the *channel*) where events wait for their consumers. The supplier can either push events into the event channel or have events pulled by the event channel. Once the event is sitting in the queue, the channel pushes the event to a push consumer or waits for the pull consumer to ask for the event. There is no mechanism for finding particular event channels and no defined quality of service in the Event Service, but these important capabilities are added by the Notification Service.

The *Notification Service* is the industrial-strength Event Service. The Notification Service is a direct extension of the Event Service, as it inherits from the original Event Service IDL interfaces. Objects can create and destroy event channels arbitrarily and can filter their output using *Filter Objects* and the *Object Constraint Language* grammar (originally defined for the *Trader* service and known as the *Trader Constraint Language* or *TCL*). The Notification Service provides full support for the Event Service. Method **EventServiceHelper.narrow** safely converts the object reference of a Notification Service into an Event Service object reference. In addition, the Notification Service also defines an event type named **StructuredEvent**.

Figure 27.3 depicts the levels of indirection inherent in the CORBA Event/Notification Service and shows how the decoupling of the event's supplier from the event's consumer adds flexibility as additional objects come into play. The standard flow of a **StructuredEvent** starts with the supplier finding the object reference to the Notification Service (an object of type **EventChannelFactory**). The **EventChannelFactory** creates an **EventChannel**, and the supplier asks the **EventChannel** to return a **SupplierAdmin** object. The **SupplierAdmin** returns one of many **Consumer** proxy types (such as **StructuredProxyPushConsumer**), and the supplier uses this consumer proxy. A **StructuredProxyPushConsumer** is a proxy to an event channel that accepts **StructuredEvents** from a supplier. The **EventChannel** created for the **SupplierAdmin** created the **StructuredProxyPushConsumer**, so all the objects in this chain communicate on the same event channel. Using a non-blocking push method, the supplier can create and push **StructuredEvents** into the channel and prepare to send more events as appropriate.

The consumer does the same from the opposite side. The consumer finds the reference to the Notification Service, **narrow**s the object reference to an **EventChannelFactory** reference, gets a known channel, retrieves a **ConsumerAdmin** object, retrieves a **StructuredProxyPushSupplier**, connects to the supplier and waits for events to arrive.

A concrete use of the Notification Service is a chat application. A chat object that sends a message is a supplier. A chat object that receives that message is the consumer. Traditionally, chat applications use a pure push model (the chat message supplier pushing messages to the chat message consumer waiting to be pushed). The application does not need to use custom IDL if the event had carried standard CORBA data types. If custom data types are needed (for example, **struct** or **valuetype TextMessage**), the developer has to

write the appropriate IDL. A chat application using the Notification Service is an example of a *peer-to-peer* application—an application in which clients communicate with each other directly, without going through a central server.

## 27.5 EJBs and CORBA Components

*Enterprise JavaBeans (EJBs)* define “a standard component architecture for building distributed object-oriented business applications in the Java™ programming language.”<sup>6</sup> The OMG released the *CORBA Component Model (CCM) Request for Proposal (RFP)*, which recommended the JavaBeans component model as the basis of a server-side framework. During the analysis and design of a pure Java server-side component framework, Sun decided not to use JavaBeans as the basis for a server-side distributed component architecture—instead, Sun decided to use Enterprise JavaBeans (EJBs are JavaBeans in name alone—JavaBeans support the throwing of events while EJBs are not required to support events). The CORBA Component Model submitter companies chose to follow and based their component architecture on many of the ideas from EJB, while taking advantage of the advanced features already found in CORBA.

Conceptually, a Supplier sends an Event to a Consumer.



An **EventChannel** decouples the Supplier from the Consumer.



Adding a **ProxyConsumer** and **ProxySupplier** enables further decoupling and makes it possible to support both the push and pull models.

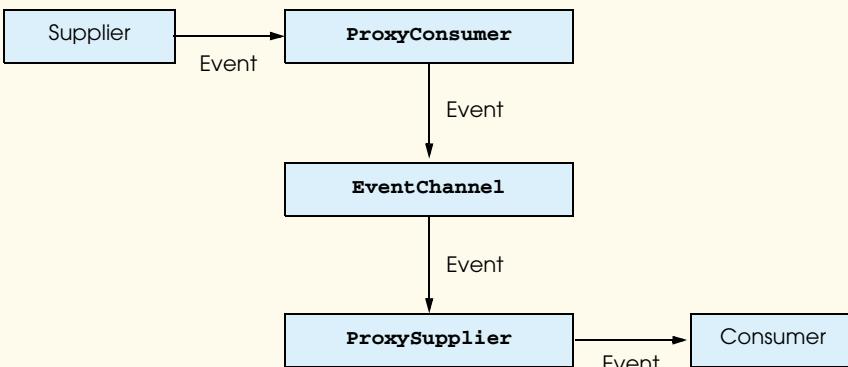


Fig. 27.3 Supplier-to-consumer flow using the Event/Notification Service.

The OMG defines technology standards to support an object marketplace, thus facilitating the construction of object-oriented systems. Components, as coarse-level objects, bring this marketplace one step closer to reality. The use of encapsulation, inheritance, polymorphism and dynamic binding enables reusable architectural frameworks. The designers of CCM based CORBA components on the *Component Implementation Framework (CIF)* architecture. CIF specifies a successful architectural pattern based on CORBA and CORBA technologies. CIF defines a superset of the Persistent State Definition Language called *Component IDL (CIDL)* a component model for CORBA objects and a container-programming model where CORBA components exist at runtime.

The CCM defines several additions and extensions to CORBA to make CCM possible. An understanding of Enterprise JavaBeans facilitates understanding these concepts. The CCM specification extends IDL with the keywords listed in Fig. 27.4.

These keywords enable developers to define components in a high-level fashion, allow for single-class inheritance and multiple-interface inheritance (for those mapped languages that support an inheritance model) and support all the normal attribute and operation syntax found in IDL interfaces (including the recently added keywords **private**, **public**, **attribute** etc.).

The *Component Interface Definition Language (CIDL)* is a superset of the Persistent State Definition Language introduced in Section 27.4.4. As a superset of PSDL, CIDL defines components in a way that enables the automatic generation of the component's persistence code. CIDL also defines component implementation as well as state management. A developer compiles a **.cidl** file with a CIDL compiler.

When a collection of components is complete, the developer organizes the components as an assembly together with a *descriptor* that describes how the components are deployed. The descriptor is an extension of the *Open Software Description (OSD)* Format (an XML vocabulary). OSD describes the installation and distribution rules of software for the desktop.<sup>7</sup> CCM defines a modified version of OSD to support component packaging.

The most interesting parts of CCM are its container programming model, how the POA fits into CCM and EJB interoperability. Commercial CCM implementations are expected any day, but for now, the OpenCCM Platform out of the Université des Sciences et Technologies de Lille (LIFL) is available. OpenCCM is a work in progress and is free.

A **Container** class creates a containment hierarchy grouping components and other containers together (such as a **Panel** from the Java AWT package). The Container programming model is a runtime environment in which component implementations use their enclosing containers to access various services the container provides. The containers use the implementation of services available to them by their deployment environment (an application server, for example). Four key areas make up the CCM container programming model:

#### IDL keywords to support the CORBA Component Model (CCM)

**component**  
**consumes**

**home**  
**import**

**provides**  
**setRaises**

Fig. 27.4 IDL keywords to support the CORBA Component Model (part 1 of 2).

**IDL keywords to support the CORBA Component Model (CCM)**

<b>emits</b>	<b>local</b>	<b>supports</b>
<b>finder</b>	<b>multiple</b>	<b>typeId</b>
<b>getRaises</b>	<b>primaryKey</b>	<b>typePrefix</b>

Fig. 27.4 IDL keywords to support the CORBA Component Model (part 2 of 2).

- External types—the interfaces seen by a client wanting to communicate with a component.
- Container types—the API that the component uses to communicate with the runtime container.
- Container Implementation types—different containers have different relationships with the surrounding system. The three CORBA containers types available are *stateless*, *conversational* and *durable*. Each container type defines its system support.
- Component Category—where a component fits in the overall framework. The *external types* and *container types* define this view.

The three container implementation types are subtly different from one another. A *stateless container* expects to call the servant referenced by a POA regardless of the object id used to make the invocation. A *conversational container* expects a transient servant referenced with a particular object id to handle the operation. A *durable container* has a persistent servant that answers to a particular object ID to handle invocations. These container types directly reflect a subset of the policies used by POAs, because CCM containers can be viewed as specialized POAs. POAs are associated with containers and the POAs are configured based on their associated container type.

The container defines the API for component security, persistence, transactions, events and lifecycle (creation, persistence, etc.). Using a container's internal interfaces, a component has full access to the services a container supports. The component implements callback interfaces to allow container-to-component communication. Containers can create either transient components or persistent components. A component is associated with only one container type (stateless, conversational or durable).

CCM containers support both single and multithreaded models (serial or concurrent access). A container with a policy of *serialize* forces all invocations on a component to be handled sequentially. A policy of *multithreaded* advises the container as to the component's ability to handle multithreaded access to the component's state. The deployment descriptor specifies the component's threading policy.

Components can be either *transient* or *persistent*. Factories provide creation points for components, which may or may not have primary keys. Finder methods do not create objects; they simply find requested objects using some arbitrary key criteria. When a factory client requests an object to be found at runtime the object may be instantiated to complete the request. From the client's perspective the object was found from an existing data store and did not need to be created. Logically, an object is only “created” when a

factory **create** method is invoked. CIDL defines factories and finders as the creation point for our components, but transient components can only be created by factories while persistent components can be created by factories and located by finders. Transient components do not have primary keys (or at least not primary keys available outside the container where the component exists), so finder methods have no key with which to search for them. Persistent components, having primary keys attached, support two kinds of persistence—container-managed and component-managed. *Container-managed persistence* is maintenance and administration intensive, while *component-managed persistence* is developer intensive. Figure 27.5 lists the CORBA component types and their descriptions.<sup>8</sup>

*Activation* and *passivation* are actions around the invocation boundaries of an object operation. When a request comes in to an ORB to invoke an operation on an object, the ORB sends the request to the POA. The POA sends the request to the container managing a particular component, and the container activates the object. The object's deployment information defines the passivation policy of the object. The passivation policies are *method* (passivate when the operation completes), *transaction* (passivate at the conclusion of the transaction), *component* (passivate at the request of the component) or *container* (passivate at the container's discretion). Activation and passivation occur when a container calls a component using one of the component's callback interfaces.

In distributed systems, clients do not create objects directly; they discover the objects needed. The discovery process can be either through a file containing the object's IOR or through a Naming Service. Factories create our components, or, in CCM terminology, **ComponentHome** objects create our components. A component definition must also define the component's factory and, if the component is persistent, a **find** method using the component's primary key.

CORBAservices use a subset of CORBAservices for the Component Implementation Framework. These include security, transaction, persistence and notification services.

The Security Service defines authorization based on roles. Every component can have differing security requirements (defined in the component's deployment descriptor), but the container is responsible for keeping them consistent. If the container updates the security of a component, the new policy stays in effect until the invocation of another component occurs and that component's security policy becomes active. The standard Security Service specification did not change to support these requirements.

The CCM allows the use of a lite version of the Object Transaction Service. The Persistent State Service specification defines the lite version of OTS to allow the use of smaller implementations of the OTS (one which allows the underlying datastore to be responsible for all transactional access). The OTS interfaces do not change in any way, which means replacing the underlying OTS does not change code using the OTS. In addition, the container can control the transaction boundaries or the component can. An example transaction boundary is at the activation/passivation point.

The Persistent State Service manages object persistence. In container-managed persistence, the use of PSS is transparent to the component. This might seem like the most convenient method for persistence—container-managed persistence is not necessarily ideal for every design situation. Components managing their own persistence should still use the PSS to save their state, but this comes at the price of future maintenance.

Component Type	Description
Service	<ul style="list-style-type: none"> <li>• Does not maintain state information (completely stateless)</li> <li>• Does not have a unique id (primary key)</li> <li>• Implements needed behavior (e.g., <code>calculateInterest</code>, <code>addItemToShoppingCart</code>, etc.)</li> <li>• Can use transactions, is not included in the current transaction</li> </ul>
Session	<ul style="list-style-type: none"> <li>• Maintains internal-state information</li> <li>• Has a unique id that is usable only by its container</li> <li>• Implements needed behavior</li> <li>• Can use transactions, but is not included in the current transaction</li> <li>• Maps to Session EJBs</li> </ul>
Entity	<ul style="list-style-type: none"> <li>• Container- or component-managed persistent state</li> <li>• Has a unique id (primary key)</li> <li>• Implements needed behavior that is optionally transactional</li> <li>• Maps to Entity EJBs</li> </ul>
Process	<ul style="list-style-type: none"> <li>• Container-managed or component-managed persistent state that is inaccessible to clients</li> <li>• Container-managed or component-managed persistence of the component's primary key (identity) with visibility of the primary key through user-defined methods</li> <li>• Implements needed behavior and the behavior is optionally transactional</li> </ul>

Fig. 27.5 CORBA component types and descriptions.

CCM components access an event service indirectly based on whether or not they use the IDL keywords **publishes** and **emits**. The container in which the component runs mediates use of the event service by the component. The notification Quality-of-Service settings needed by a particular component are also set by the container. The notification and event services supported by the container have to support only the notification and event service subsets defined by the CCM specification, respectively. Using the generated component API does not preclude the direct use of the Notification Service, but component developers are encouraged to define the events in the IDL as a way of keeping the component's functional description in one location.

The keywords **publishes** and **emits** are similar. The difference is in the number of consumers allowed to receive events sent by components. Any number of consumers can

subscribe to an event that a component **`publishes`**, whereas only one consumer can subscribe to an event a component **`emits`**. Events declared using **`publishes`** are expected to be part of the shared interface of the component (the API available to all clients). The event channel created for **`emits`** is expected to be a private channel used internally by the system. Figure 27.6 declares a **`Customer`** component that **`publishes`** a **`PropertyEvent`** to multiple consumers if the **`Customer`** has exceeded their credit limit and **`emits`** an **`InvariantEvent`** to one particular event consumer if the **`Customer`**'s internal state has been set improperly.

Components, like other CORBA objects, can communicate with CORBA services. Components use ORBs to discover available services. This discovery process implies the use of the Naming Service, but CCM introduces a **`HomeFinder`** service for components to discover **`ComponentHomes`** for other components. **`HomeFinder`** is a kind of Naming Service strictly for discovering **`ComponentHomes`**.

CCM defines a framework for implementing enterprise-level distributed objects using CORBA. The CCM infrastructure enables the use of a subset of CORBA services (Naming, Security, Transaction, Persistence and Event). The IDL-defined component factories subclass **`ComponentHome`**. These component factories are found using **`HomeFinders`**—this is another use of the Naming Service. CCM components come in four types—service, session, entity and process. Based on the amount of state the components declare and whether any of the state needs to persist, these components can delegate persistence to the container in which they exist (container-managed persistence) or can handle the persistence on their own (component-managed persistence). CCM containers can be single-threaded or multithreaded, based on whether the CCM component can handle multithreaded access. Clients access the components through the container in which the components execute.

Enterprise JavaBeans (Chapters 14 and 15) and CORBA components share a significant amount of lineage. A design point in the CCM specification is that CORBA components-programming model (they run in the process space of a runtime environment, either an application or EJB server). The EJB specification dictates that the runtime environment must support Naming, Security, Persistence and Transaction services. The EJB distributed-object framework uses RMI as the client-side/server-side glue, defines **`EJBHome`** as the base interface for component factories and defines **`EJBObject`** as the base interface for components. EJBs come in two types—*session* (stateless and stateful) and *entity* (stateful). Stateless session beans never persist, stateful session beans are persisted based on the container's policies and entity beans always persist. EJBs should be single threaded; the containers are not specified as having configurable threading policies. Clients access EJBs through the EJB container.<sup>9</sup>

---

```

1 // Our Customer can send two events:
2 // creditEvent if the customer's credit limit has been exceeded
3 // and internalStateEvent if the some data in the customer
4 // has not been updated properly
5 component Customer {
6     publishes PropertyEvent creditEvent;
7     emits InvariantEvent internalStateEvent;
8 };

```

---

Fig. 27.6 **`Customer`** component IDL definition demonstrating keywords **`publishes`** and **`emits`** for issuing events.

The CCM and EJB models are quite similar. The CCM specification defines two levels of components—*basic* and *extended*. A *basic* component mirrors the EJB model almost exactly. A basic component lives in a container that supports only single threading; the component uses only the security, transaction and persistence services; the component exposes only a single interface to clients. An *extended* component supports multiple interfaces. The CCM defines advanced storage types and allows them to be properly persisted. An extended component also supports the use of event services.

Sun developed Enterprise JavaBeans independently of the CORBA components architecture. However, the OMG and Sun worked closely in joining the two architectures during the design of CCM. Enterprise JavaBeans is now an official subset of the CCM architecture. Ideally, an EJB implementation built on top of a CCM system would be a much more extensible system than an EJB system built from scratch. The EJB Specification, Version 2.0 requires support for IIOP. Vendors who ship EJB 2.0-compliant products must support the CORBA protocol. IIOP support does not mean that EJB containers can handle CCM components. Developers can write CCM components in any language for which the CORBA CCM mappings exist. The implication is that EJB is the first real introduction of a distributed components architecture (not just distributed objects). Systems integration is entering a mature phase of development, in which COBOL components can interact side-by-side with Java components or C++ components in software frameworks that use similar concepts and APIs.

## 27.6 CORBA vs. RMI

CORBA is a comprehensive view of distributed systems architecture, whereas RMI describes only the communication proxies and protocols between a client object and server object. The OMA specification defines a road map for integrating systems that use object technology and system architecture concepts. CORBA follows the OMA specification and benefits from the breadth of industry expertise that created it. The member organizations of the OMG have evolved CORBA into a useful and robust technology.

### 27.6.1 When to Use RMI

RMI is suitable for smaller distributed applications in which scalability, architecture, heterogeneity, and extensibility are not major concerns. For a time, there was no long-range architecture road map for RMI the way CORBA has the OMA. Architecturally, building the infrastructure for an RMI system is not a trivial undertaking. A mapping of RMI and RMI capabilities to the OMA encompasses only Applications Objects and the ORB. Applications Objects are specific to the application or system and therefore have no formal specification. The RMI communications infrastructure mimics an ORB (with the RMIRegistry used as a naming service). In addition to missing standard infrastructure—e.g., such as that defined by the CORBAservices and CORBAfacilities—RMI does not define Quality of Service or asynchronous invocations. RMI has no equivalent to the Portable Object Adapter and the range of control afforded through use of a POA. In addition, RMI automatic and dynamic class loading permits a client to perform some operations locally rather than via network calls. CORBA has the **struct** keyword, but this places the burden of implementation and binding on the client, which is not ideal for some applications.

Enterprise JavaBeans, on the other hand, is a larger view of systems and where technology such as Java is heading to address the concerns of customers with large-scale, real-world problems. Security and data manipulation are the highest risk elements of many systems, implying the need for specialized subsystems to mitigate those risks. These subsystems (i.e., security and persistence) and others (for example, transactions and messaging) appear repeatedly as standard players in nontrivial systems. Prior to CORBA, systems integrators built custom (sometimes brittle) frameworks to accomplish reliable communications between heterogeneous systems and standard services. Once CORBA and RMI standardized the communications infrastructure, frameworks began to grow around them. A framework such as Enterprise JavaBeans is a reliable and cost-effective way to build large-scale distributed systems. EJB is the Java implementation of a first-generation framework with direct lineage to CORBA.

RMI allows objects to participate in distributed systems consistently and predictably. RMI is a natural choice for distributed systems built in Java. RMI is inappropriate for system architectures that require container services, load balancing or other framework functionality without custom development. A pure Java-distributed system needs to be considered from an architectural perspective where the distributed issues can be discovered and resolved before the implementation issues are decided. Too often, the question of where to use RMI becomes the issue, when a more appropriate question is “what design problems are best solved using RMI?”

## 27.6.2 When to Use CORBA

If developers should not use custom RMI except for small projects, this leaves IDL in an awkward position. IDL is not difficult to learn, but it is not a trivial undertaking for developers who are unfamiliar with C/C++ syntax. CORBA can have a steep learning curve for those starting to learn object technology. Yet CORBA is still an excellent way to develop the full range of distributed systems, even without a framework like CORBA components. The reason CORBA is a good choice in the design of nontrivial systems has to do with implementation concepts (e.g., OMA). In the area of connectivity, both RMI and CORBA share the same protocol (IIOP), but RMI falls short in many other areas compared to CORBA.

- **Architecture:** RMI does not define an architecture in any way, shape or form. CORBA has defined an established distributed-systems architecture since the 1980s. Moving to distributed component architectures similar to Enterprise JavaBeans had always been in the road map. Proven architecture, like EJB (which uses mechanisms such as RMI), helps the OMG continue standardizing accepted/existing practice.
- **Quality of Service (QoS):** The Quality-of-Service specification establishes policies for distributed-object behavior at many levels. There are no programmatic QoS concepts in Java, RMI or EJB yet.
- **Scalability:** RMI supports the concept of an object adapter but only as a basic mechanism to hide the method-invocation complexity. The concept behind the Portable Object Adapter, which has various selectable policies for activation (including one that allows a single servant to handle calls to different object types) is unknown in RMI.

- Heterogeneity: Java, as an implementation language, runs on many different operating systems and, by extension, several kinds of hardware platforms. This differs from CORBA's view of heterogeneity—CORBA enables interoperability between systems written in different languages and different operating systems and hardware platforms. CORBA has no implementation except that developed by various vendors. CORBA encourages vendors to port CORBA's technology to many platforms and languages.
- Extensibility: Being hardware-neutral, language-neutral, and location-transparent keeps CORBA in the forefront of many system-integration projects.

### 27.6.3 RMI-IIOP

In a joint effort, Sun and IBM implemented *RMI-over-IIOP (RMI-IIOP)* to replace RMI's underlying communication protocol (*Java Remote Method Protocol* or *JRMP*) with CORBA's IIOP. Inprise, Netscape, and Oracle, working with Sun and IBM, specified a reverse mapping of Java-to-IDL to allow the RMI compiler (**rmic**) to output IDL, stubs and skeletons needed by a server to accept invocations and a client to make the invocations. Restrictions in the reverse mapping include the following<sup>10</sup>:

1. Constants can be of primitive types or of class **java.lang.String** only.
2. IDL normally does not support overloading of method names.
3. A class cannot inherit a method with the same signature from two different interfaces.
4. Interfaces and value types must be **public**.
5. The compiler considers packages and interface names to be identical if the only difference is case sensitivity.

The mapping also identifies four runtime limitations:<sup>11</sup>

1. Sending a tree graph (an object containing references to other objects) from ORB to ORB may be problematic if multiple nodes point to one object (copies will probably be sent instead).
2. CORBA does not define distributed garbage collection.
3. Casting stubs may not work properly, so using the static method **narrow** of class **java.rmi.PortableRemoteObject** is encouraged. RMI downloads the stubs needed by the client to communicate with a server, but CORBA does not support that behavior.

Writing a distributed application using RMI-IIOP involves the standard RMI development steps (Chapter 13, Remote Method Invocation) with a small number of changes:

1. Use **javax.rmi.PortableRemoteObject** instead of using **java.rmi.UnicastRemoteObject**. A workaround would be to use *value-types* (discussed in Chapter 26).
2. Use the *JNDI (Java Naming and Directory Interface)* instead of the RMI Registry.
3. Do not downcast remote objects to subclass types; use method **narrow** of class **PortableRemoteObject** to cast distributed objects as subclass types.

## 27.7 RMIMessenger Case Study Ported to RMI-IIOP

In this section, we modify the RMI messenger program of Chapter 13 to use RMI-IIOP. Porting the RMI messenger to RMI-IIOP is easier than porting the application to CORBA (Chapter 26). The remote interfaces (**ChatServer**, **StoppableChatServer** and **ChatClient**) remain the same. The modular approach we used to design the Deitel messenger system enables us to reuse the supporting classes and interfaces (**ChatMessage**, **ClientGUI**, **MessageListener**, **MessageManager** and **DisconnectListener**) also without modification.

For the RMI-IIOP messenger, we provide new implementations of the **ChatServer** remote interface (**ChatServerImpl**), the **ChatServerAdministrator**, the **MessageManager** interface (**RMIIOPMessageManager**) and the client launcher (**DeitelMessenger**).

### 27.7.1 ChatServer RMI-IIOP Implementation

Class **ChatServerImpl** (Fig. 27.7) implements the **ChatServer** remote interface as a subclass of class **javax.rmi.PortableRemoteObject** (line 20), which is the base class for RMI-IIOP remote objects. No changes are required in either the **ChatServer** or **StoppableChatServer** remote interfaces, which class **ChatServerImpl** implements (line 21). Class **ChatServerImpl** does not implement method **register**, which registered the **Activatable RMI ChatServer** with the RMI registry. Instead, the RMI-IIOP version of class **ChatServerAdministrator** (Fig. 27.8) handles registration with name services. The remainder of the RMI-IIOP **ChatServerImpl** is identical to its RMI counterpart.

Class **ChatServerAdministrator** (Fig. 27.8) is a utility program for starting and stopping the RMI-IIOP **ChatServer** implementation. Method **startServer** (lines 21–53) creates an instance of **ChatServerImpl** (line 27) and registers this **ChatServer** with a naming service (lines 30–35). The RMI-IIOP equivalent to the RMI registry is the CORBA Naming Service. Instead of connecting to a naming service in a CORBA-specific way, Java recommends using the *Java Naming and Directory Interface (JNDI)*, which abstracts the concept of naming and directory services. Package **javax.naming** (line 13) contains JNDI classes and interfaces. Line 30 creates an **InitialContext**, which represents the naming service. Line 35 invokes method **rebind** of interface **Context** to bind the **ChatServerImpl** object to the name “**ChatServer**” in the naming service, thus making the **ChatServer** available to clients. At runtime, the **InitialContext** uses two system properties to discover the underlying naming service (the Javadocs for **javax.naming.InitialContext** and **javax.naming.Context** specify the system-naming properties and useful default values). Property **java.naming.factory.initial** defines the class name of the factory that will create the **InitialContext** object. Class **com.sun.jndi.cosnaming.CNCtxFactory** is the default factory class for connecting to CORBA Naming Services. Property **java.naming.provider.url** specifies the URL for the Naming Service, including the port to which the Naming Service is attached (e.g., **iiop://localhost:1050**).

Method **terminateServer** (lines 56–91) locates and stops the running **ChatServer** and removes the **ChatServer** registration from the naming service. Line 62

creates an **InitialContext** for the naming service in which the **ChatServer** is registered. Lines 65–66 invoke method **lookup**, passing as an argument the name under which the **ChatServer** registered. Method **lookup** returns an **Object** reference to the **ChatServer** remote object. Lines 69–71 create a **StoppableChatServer** reference to the **ChatServer** remote object. Recall that RMI-IIOP requires that remote objects be converted to specific types using method **narrow** of class **PortableRemoteObject**, as opposed to using casting. Method **narrow** takes as arguments an **Object** reference to the remote object and the **Class** object for the target reference type. Line 71 passes **remoteObject** and the **Class** object for interface **StoppableChatServer** to method **narrow**. Line 74 invokes method **stopServer** of interface **StoppableChatServer** to terminate the **ChatServer**. Line 77 invokes method **unbind** of interface **Context** to remove the **ChatServer**'s registration from the naming service. Lines 82–84 **catch** a **NamingException** if the **ChatServer** is not found in the naming service. Lines 87–89 **catch** a **RemoteException** if there is a problem obtaining the **ChatServer** remote object or invoking its remote methods.

```

1 // ChatServerImpl.java
2 // ChatServerImpl implements the ChatServer and StoppableChatServer
3 // remote interfaces using RMI over IIOP.
4 package com.deitel.messenger.rmi_iip.server;
5
6 // Java core packages
7 import java.io.*;
8 import java.util.*;
9 import java.net.MalformedURLException;
10 import java.rmi.*;
11
12 // Java extension packages
13 import javax.rmi.*;
14
15 // Deitel packages
16 import com.deitel.messenger.rmi.ChatMessage;
17 import com.deitel.messenger.rmi.client.ChatClient;
18 import com.deitel.messenger.rmi.server.*;
19
20 public class ChatServerImpl extends PortableRemoteObject
21     implements ChatServer, StoppableChatServer {
22
23     // Set of ChatClient references
24     private Set clients = new HashSet();
25
26     // construct new ChatServerImpl
27     public ChatServerImpl() throws RemoteException
28     {
29         super();
30     }
31

```

**Fig. 27.7** **ChatServerImpl** implements the Deitel messenger **ChatServer** using RMI-IIOP (part 1 of 3).

```

32     // register new ChatClient with ChatServer
33     public void registerClient( ChatClient client )
34         throws RemoteException
35     {
36         // add client to Set of registered clients
37         synchronized( clients ) {
38             clients.add( client );
39         }
40
41         System.out.println( "Registered Client: " + client );
42     } // end method registerClient
43
44     // unregister client with ChatServer
45     public void unregisterClient( ChatClient client )
46         throws RemoteException
47     {
48         // remove client from Set of registered clients
49         synchronized( clients ) {
50             clients.remove( client );
51         }
52
53         System.out.println( "Unregistered Client: " + client );
54     } // end method unregisterClient
55
56     // post new message to ChatServer
57     public void postMessage( ChatMessage message )
58         throws RemoteException
59     {
60         Iterator iterator = null;
61
62         // get Iterator for Set of registered clients
63         synchronized( clients ) {
64             iterator = new HashSet( clients ).iterator();
65         }
66
67         // send message to every ChatClient
68         while ( iterator.hasNext() ) {
69             ChatClient client = ( ChatClient ) iterator.next();
70             client.deliverMessage( message );
71         }
72
73     } // end method postMessage
74
75     // notify each client that server is shutting down and
76     // terminate server application
77     public void stopServer() throws RemoteException
78     {
79         System.out.println( "Terminating server ..." );
80
81         Iterator iterator = null;

```

Fig. 27.7 **ChatServerImpl** implements the Deitel messenger **ChatServer** using RMI-IIOP (part 2 of 3).

```

84     // get Iterator for Set of registered clients
85     synchronized( clients ) {
86         iterator = new HashSet( clients ).iterator();
87     }
88
89     // send serverStopping message to every ChatClient
90     while ( iterator.hasNext() ) {
91         ChatClient client = ( ChatClient ) iterator.next();
92         client.serverStopping();
93         System.err.println( "Disconnected: " + client );
94     }
95
96
97     // create Thread to terminate application after
98     // stopServer method returns to caller
99     Thread terminator = new Thread(
100         new Runnable() {
101
102             // sleep for 5 seconds, print message and terminate
103             public void run()
104             {
105                 // sleep
106                 try {
107                     Thread.sleep( 5000 );
108                 }
109
110                 // ignore InterruptedExceptions
111                 catch ( InterruptedException exception ) {}
112
113                 System.err.println( "Server terminated" );
114                 System.exit( 0 );
115             }
116         }
117     );
118
119     terminator.start(); // start termination thread
120
121 } // end method stopServer
122 }
```

**Fig. 27.7** **ChatServerImpl** implements the Deitel messenger **ChatServer** using RMI-IIOP (part 3 of 3).

```

1 // ChatServerAdministrator.java
2 // ChatServerAdministrator is a utility for starting and stopping
3 // the RMI-IIOP ChatServer implementation.
4 package com.deitel.messenger.rmi_iip.server;
5
6 // Java core packages
7 import java.rmi.*;
8 import java.rmi.activation.*;
```

**Fig. 27.8** **ChatServerAdministrator** application for starting and stopping RMI-IIOP **ChatServer** (part 1 of 4).

```
9 import java.util.*;
10 // Java extension packages
11 import javax.rmi.*;
12 import javax.naming.*;
13
14 // Deitel packages
15 import com.deitel.messenger.rmi.server.StoppableChatServer;
16
17 public class ChatServerAdministrator {
18
19     // set up ChatServer object
20     private static void startServer()
21     {
22         {
23             // register ChatServer in Naming Service
24             try {
25
26                 // create ChatServerImpl object
27                 ChatServerImpl chatServerImpl = new ChatServerImpl();
28
29                 // create InitialContext for naming service
30                 Context namingContext = new InitialContext();
31
32                 System.err.println( "Binding server to naming service..");
33
34                 // bind ChatServerImpl object to naming service
35                 namingContext.rebind( "ChatServer", chatServerImpl );
36
37                 System.out.println( "Server bound to naming service" );
38
39         } // end try
40
41         // handle exception registering ChatServer
42         catch ( NamingException namingException ) {
43             namingException.printStackTrace();
44             System.exit( 1 );
45         }
46
47         // handle exception creating ChatServer
48         catch ( RemoteException remoteException ) {
49             remoteException.printStackTrace();
50             System.exit( 1 );
51         }
52
53     } // end method startServer
54
55     // terminate server
56     private static void terminateServer()
57     {
58         // look up and terminate ChatServer
59         try {
60
```

Fig. 27.8 **ChatServerAdministrator** application for starting and stopping RMI-IIOP **ChatServer** (part 2 of 4).

```
61      // create naming Context for looking up server
62      Context namingContext = new InitialContext();
63
64      // find ChatServer remote object
65      Object remoteObject =
66          namingContext.lookup( "ChatServer" );
67
68      // narrow remoteObject to StoppableChatServer
69      StoppableChatServer chatServer =
70          ( StoppableChatServer ) PortableRemoteObject.narrow(
71              remoteObject, StoppableChatServer.class );
72
73      // stop ChatServer
74      chatServer.stopServer();
75
76      // remove ChatServer from Naming Service
77      namingContext.unbind( "ChatServer" );
78
79  } // end try
80
81      // handle exception looking up ChatServer
82  catch ( NamingException namingException ) {
83      namingException.printStackTrace();
84  }
85
86      // handle exception communicating with ChatServer
87  catch ( RemoteException remoteException ) {
88      remoteException.printStackTrace();
89  }
90
91 } // end method terminateServer
92
93 // launch ChatServerAdministrator application
94 public static void main( String args[] )
95 {
96     // check command-line arguments and start or stop server
97     if ( args[ 0 ].equals( "start" ) )
98         startServer();
99
100    else if ( args[ 0 ].equals( "stop" ) )
101        terminateServer();
102
103    // print usage information
104    else
105        System.err.println(
106            "Usage: java ChatServerAdministrator start | stop" );
107
108 } // end method main
109 }
```

Fig. 27.8 **ChatServerAdministrator** application for starting and stopping RMI-IIOP **ChatServer** (part 3 of 4).

```

Binding server to naming service...
Server bound to naming service
Registered Client:
IOR:0000000000000040524d493a636f6d2e64656974656c2e6d657373656e6765722
e726d692e636c69656e742e43686174436c69656e743a3030303030303030303030303030
3030303000000000010000000000000000540001010000000000d3139322e3136382e312
e3435000005e00000018afabcaff00000002243bba8f000000080000000100000000
0000000100000001000000140000000000010020000000000001010000000000
Registered Client:
IOR:0000000000000040524d493a636f6d2e64656974656c2e6d657373656e6765722
e726d692e636c69656e742e43686174436c69656e743a30303030303030303030303030
3030303000000000010000000000000000540001010000000000d3139322e3136382e312
e3435000005e500000018afabcaff00000002243bbbed000000080000000100000000
0000000100000001000000140000000000010020000000000001010000000000
Registered Client:
IOR:0000000000000040524d493a636f6d2e64656974656c2e6d657373656e6765722
e726d692e636c69656e742e43686174436c69656e743a30303030303030303030303030
3030303000000000010000000000000000540001010000000000d3139322e3136382e312
e3435000005ea00000018afabcaff00000002243bb5c000000080000000100000000
0000000100000001000000140000000000010020000000000001010000000000
Unregistered Client:
IOR:0000000000000040524d493a636f6d2e64656974656c2e6d657373656e6765722
e726d692e636c69656e742e43686174436c69656e743a303030303030303030303030
3030303000000000010000000000000000540001010000000000d3139322e3136382e312
e3435000005e000000018afabcaff00000002243bba8f000000080000000100000000
0000000100000001000000140000000000010020000000000001010000000000
Terminating server ...
Disconnected:
IOR:0000000000000040524d493a636f6d2e64656974656c2e6d657373656e6765722
e726d692e636c69656e742e43686174436c69656e743a303030303030303030303030
3030303000000000010000000000000000540001010000000000d3139322e3136382e312
e3435000005e500000018afabcaff00000002243bbbed000000080000000100000000
0000000100000001000000140000000000010020000000000001010000000000
Disconnected:
IOR:0000000000000040524d493a636f6d2e64656974656c2e6d657373656e6765722
e726d692e636c69656e742e43686174436c69656e743a303030303030303030303030
3030303000000000010000000000000000540001010000000000d3139322e3136382e312
e3435000005ea00000018afabcaff00000002243bb5c000000080000000100000000
0000000100000001000000140000000000010020000000000001010000000000
Server terminated

```

Fig. 27.8 **ChatServerAdministrator** application for starting and stopping RMI-IIOP **ChatServer** (part 4 of 4).

Figure 27.8 shows text output from **ChatServerAdministrator**. In this output, **ChatServerAdministrator** launches the **ChatServer** and binds it to a naming service. Three clients connect to the naming service—the first client then disconnects. The **ChatServerAdministrator** terminates the **ChatServer**, which disconnects the remaining two clients and shuts down the server.

## 27.7.2 ChatClient RMI-IIOP Implementation

To implement a **ChatClient** for the RMI-IIOP messenger, we must provide an RMI-IIOP implementation of interface **MessageManager**. We then must create a new **DeitelMessenger** application for launching **ClientGUI** with the new **MessageManager** implementation.

Class **RMIIOPMessagerManager** (Fig. 27.9) implements the **ChatClient** and **MessageManager** interfaces using RMI-IIOP. Like the **RMIIMessageManager** implementation from Chapter 13, class **RMIIOPMessagerManager** is a remote object that communicates with the **ChatServer** remote object. However, class **RMIIOPMessagerManager** extends class **PortableRemoteObject** for compatibility with IIOP (line 24). Method **connect** (lines 38–57) creates an **InitialContext** for the Naming Service (line 42) and invokes method **lookup** of interface **Context** to retrieve a remote reference to the RMI-IIOP **ChatServer** (lines 45–46). Lines 48–49 invoke method **narrow** of class **PortableRemoteObject** to convert the **Object** remote reference to a **ChatServer** remote reference. Line 52 invokes method **registerClient** of interface **ChatServer** to register the **RMIIOPMessagerManager** as a **ChatServer** client. Line 55 sets the **MessageListener** to which incoming **ChatMessages** should be delivered. The remainder of class **RMIIOPMessagerManager** is identical to class **RMIIMessageManager**.

Class **DeitelMessenger** (Fig. 27.10) launches the Deitel messenger client using classes **ClientGUI** and **RMIIOPMessagerManager**. Line 18 creates an instance of class **RMIIOPMessagerManager** for communicating with the **ChatServer**. Lines 21–24 create a **ClientGUI** for the **RMIIOPMessagerManager** and display the GUI to the user.

```

1 // RMIIOPMessageManager.java
2 // RMIIOPMessageManager implements the ChatClient remote
3 // interface and manages incoming and outgoing chat messages
4 // using RMI over IIOP.
5 package com.deitel.messenger.rmi_iop.client;
6
7 // Java core packages
8 import java.awt.*;
9 import java.awt.event.*;
10 import java.rmi.*;
11 import java.rmi.server.*;
12 import java.util.*;
13
14 // Java extension packages
15 import javax.rmi.*;
16 import javax.naming.*;

```

Fig. 27.9 **RMIIOPMessagerManager** implements the **ChatClient** and **MessageManager** interfaces using RMI-IIOP (part 1 of 3).

```
17
18 // Deitel packages
19 import com.deitel.messenger.*;
20 import com.deitel.messenger.rmi.client.ChatClient;
21 import com.deitel.messenger.rmi.ChatMessage;
22 import com.deitel.messenger.rmi.server.ChatServer;
23
24 public class RMIIIOPMessageManager extends PortableRemoteObject
25     implements ChatClient, MessageManager {
26
27     // listeners for incoming messages and disconnect notifications
28     private MessageListener messageListener;
29     private DisconnectListener disconnectListener;
30
31     // ChatServer for sending and receiving messages
32     private ChatServer chatServer;
33
34     // RMIMessageManager constructor
35     public RMIIIOPMessageManager() throws RemoteException {}
36
37     // connect to ChatServer
38     public void connect( MessageListener listener )
39         throws Exception
40     {
41         // create naming Context for looking up server
42         Context namingContext = new InitialContext();
43
44         // find ChatServer remote object
45         Object remoteObject =
46             namingContext.lookup( "ChatServer" );
47
48         chatServer = ( ChatServer ) PortableRemoteObject.narrow(
49             remoteObject, ChatServer.class );
50
51         // register client with ChatServer to receive messages
52         chatServer.registerClient( this );
53
54         // set listener for incoming messages
55         messageListener = listener;
56
57     } // end method connect
58
59     // disconnect from ChatServer
60     public void disconnect( MessageListener listener )
61         throws Exception
62     {
63         if ( chatServer == null )
64             return;
65
66         chatServer.unregisterClient( this );
67         messageListener = null;
68 }
```

Fig. 27.9 **RMIIIOPMessageManager** implements the **ChatClient** and **MessageManager** interfaces using RMI-IIOP (part 2 of 3).

```
69      // notify listener of disconnect
70      fireServerDisconnected( "" );
71
72  } // end method disconnect
73
74 // send ChatMessage to ChatServer
75 public void sendMessage( String fromUser, String message )
76     throws Exception
77 {
78     if ( chatServer == null )
79         return;
80
81     // create ChatMessage with message text and user name
82     ChatMessage chatMessage =
83         new ChatMessage( fromUser, message );
84
85     // post message to ChatServer
86     chatServer.postMessage( chatMessage );
87
88 } // end method sendMessage
89
90 // process delivery of ChatMessage from ChatServer
91 public void deliverMessage( ChatMessage message )
92     throws RemoteException
93 {
94     if ( messageListener != null )
95         messageListener.messageReceived( message.getSender(),
96                                         message.getMessage() );
97 }
98
99 // process server shutting down notification
100 public void serverStopping() throws RemoteException
101 {
102     chatServer = null;
103     fireServerDisconnected( "Server shut down." );
104 }
105
106 // register listener for disconnect notifications
107 public void setDisconnectListener(
108     DisconnectListener listener )
109 {
110     disconnectListener = listener;
111 }
112
113 // send disconnect notification
114 private void fireServerDisconnected( String message )
115 {
116     if ( disconnectListener != null )
117         disconnectListener.serverDisconnected( message );
118 }
119 }
```

Fig. 27.9 **RMI-IIOPMessageManager** implements the **ChatClient** and **MessageManager** interfaces using RMI-IIOP (part 3 of 3).

```

1 // DeitelMessenger.java
2 // DeitelMessenger uses ClientGUI and RMIIIOPMessageManager to
3 // implement an RMI over IIOP chat client.
4 package com.deitel.messenger.rmi_iop.client;
5
6 // Java core packages
7 import java.rmi.RMISecurityManager;
8
9 // Deitel packages
10 import com.deitel.messenger.*;
11
12 public class DeitelMessenger {
13
14     // launch DeitelMessenger application
15     public static void main( String args[] ) throws Exception
16     {
17         // create RMIIIOPMessageManager for communicating with server
18         MessageManager messageManager = new RMIIIOPMessageManager();
19
20         // configure and display chat window
21         ClientGUI clientGUI = new ClientGUI( messageManager );
22         clientGUI.setSize( 300, 400 );
23         clientGUI.setResizable( false );
24         clientGUI.setVisible( true );
25     }
26 }
```

**Fig. 27.10** `DeitelMessenger` creates a `ClientGUI` and `RMIIIOPMessageManager` to launch the RMI-IIOP messenger client.

### 27.7.3 Compiling and Running the ChatServer and ChatClient

Compile `ChatServerImpl`, `ChatServerAdministrator`, `RMIIIOPMessageManager` and `DeitelMessenger` using the Java compiler. You must also compile the RMI-IIOP stub classes for the `ChatServerImpl` and `RMIIIOPMessageManager` remote objects. Use the `rmic` tool with the `-iiop` command-line option to generate the appropriate stubs, for example,

```
rmic -iiop com.deitel.messenger.rmi_iop.server.ChatServer-
Impl
```

Running the RMI-IIOP Deitel messenger system requires a CORBA Naming Service. For this example, we use `tnameserv`, which we used for the examples in Chapter 26. Start `tnameserv` by typing the following at a command prompt:

```
tnameserv -ORBInitialPort 1050
```

Class `ChatServerAdministrator` launches the `ChatServer` and registers the server with the Naming Service. To start `ChatServer`, type the following at a command prompt:

```
java -Djava.naming.factory.initial=com.sun.jndi.cos-
naming.CNCtxFactory
-Djava.naming.provider.url=iiop://localhost:1050
com.deitel.messenger.rmi_iiop.server.ChatServerAdministra-
tor start
```

The **-D** command-line option specifies system properties for the virtual machine. Recall that property **java.naming.factory.initial** specifies the class that implements the Naming Service's **InitialContext**. Property **java.naming.provider.url** specifies the location and port where the Naming Service is running. For this example, the Naming Service runs on the local machine on port **1050**.

Once **ChatServer** is running and bound to the Naming Service, launch several clients by typing the following at a command prompt and executing repeatedly:

```
java -Djava.naming.factory.initial=com.sun.jndi.cos-
naming.CNCtxFactory
-Djava.naming.provider.url=iiop://localhost:1050
com.deitel.messenger.rmi_iiop.client.DeitelMessenger
```

## 27.8 Future Directions

The Object Management Architecture defined the various levels of object services in the first version of a full CORBA architecture back in 1990. The OMA is the guiding document for the design of many CORBA systems, yet falls short in average-size systems that still have needs for distributed system concepts. CORBA and OMA expect developers to use the reference architecture's flexibility to make the same fine-grained decisions for each system being built. (How should the POAs be configured? What activation policies should be enabled and when? Is there a process for choosing the proper CORBAservices and integrating them into a general, reusable framework?)

The CORBA Component Model and Enterprise JavaBeans abstract many system issues through programming constructs such as containers and subsystems. CCM guarantees Enterprise JavaBeans' place in the future by allowing future programming languages to interoperate with Java transparently, so Java can interoperate with COBOL, C, C++ and other IDL-mapped languages.

OMG is now working on an architectural process called the Model Driven Architecture™ (MDA). In late 2000 and early 2001, OMG members noticed that the occasional introduction of new middleware platforms turned into a steady stream which was not likely to slow or stop anytime in the foreseeable future. To restore stability to standards and the enterprise development process, OMG created and adopted the MDA as the basis for its future specifications. In the MDA, a specification or application is defined first and fundamentally as a Platform-Independent Model (PIM) in the Unified Modeling Language (UML). MDA tools generate one or more Platform-Specific Models (PSM) from the application's PIM, following OMG-standardized mappings. In a third step, the MDA tool generates interfaces, stub and template code, configuration files, build and deployment files and application code from the PSM. MDA supports, and OMG will publish standards in, many middleware platforms such as EJB, XML/SOAP, C#/.NET and CORBA. Interoperability is provided by bridges or by bridging code generated by MDA tools from models. The PIM retains its value as the technology around it shifts over time. Industry standards groups, including especially OMG's Domain Task Forces, shifted quickly to MDA for their

work because specifications formulated as PIMs embody only business functionality and behavior, and so outlast individual technologies and trends.

This expansion of OMG's architecture beyond CORBA (which receives the same level of support as before MDA) is giving new vitality to OMG and its commitment to technology-independent domain standards.

## 27.9 Internet and World Wide Web Resources

### **[www.omg.org/cgi-bin/doc?formal/99-07-59](http://www.omg.org/cgi-bin/doc?formal/99-07-59)**

The OMG Java-to-IDL Specification describes in detail the various mappings and limitations inherent in using this reverse IDL mapping. This document is also available in Postscript and PDF.

### **[www.omg.org/technology/documents/formal/corba\\_services\\_available\\_electro.htm](http://www.omg.org/technology/documents/formal/corba_services_available_electro.htm)**

This OMG page lists the CORBAservices specifications that are available electronically. Downloads of each specification are available as Postscript and PDF files.

### **[www.omg.org/cgi-bin/doc?orbos/98-01-18](http://www.omg.org/cgi-bin/doc?orbos/98-01-18)**

Objects-by-Value, as a distinguishing characteristic between RMI and CORBA, is explained in this document. The specification describes applicable keywords, mechanism concepts and how OBV applies to Java.

### **[www.w3.org/TR/NOTE-ice](http://www.w3.org/TR/NOTE-ice)**

This site gives the definitive description and thinking of Open Software Description Format. An understanding of XML and Web technologies is necessary to appreciate what OSD (and by extension the Information and Content Exchange Protocol) is trying to do.

### **[openorb.exolab.org/openorb.html](http://openorb.exolab.org/openorb.html)**

In the spirit of open source, ExoLab Group has released (and updates) a full, open-source implementation of CORBA 2.4.1 for the development of distributed systems. OpenORB supports both POAs and BOAs and includes various tools (such as IDL compilers).

### **[openorb.exolab.org/services.html](http://openorb.exolab.org/services.html)**

Although not a full set of CORBAservices, this open-source alternative offers a collection of useful services for developers building CORBA frameworks. Naming, Persistence and Transaction are available (to name a few). Follow the Extensions link to find their implementation of RMI-IIOP.

### **[www.omg.org/cgi-bin/doc?formal/01-06-07](http://www.omg.org/cgi-bin/doc?formal/01-06-07)**

This Web page provides a link to the June 2001 paper, *Java Language to IDL Mapping*.

### **[www.omg.org/cgi-bin/doc?formal/98-12-09](http://www.omg.org/cgi-bin/doc?formal/98-12-09)**

Object Management Group, *CORBAservices: Common Object Services Specification*, December 1998.

### **[www.omg.org/cgi-bin/doc?ptc/99-10-03](http://www.omg.org/cgi-bin/doc?ptc/99-10-03)**

This page on the Object Management Group's Web site offers the *Component FTF Edited Drafts of CORBA Core Chapters*, originally published October 1999.

### **[www.omg.org/technology/documents/formal/internationalization\\_and\\_time.htm](http://www.omg.org/technology/documents/formal/internationalization_and_time.htm)**

The January 2000 paper, *Internationalization, Time Operations, and Related Facilities*, is available on this page.

### **[www.omg.org/technology/documents/formal/mobile\\_agent\\_facility.htm](http://www.omg.org/technology/documents/formal/mobile_agent_facility.htm)**

The *Mobile Agent Facility Specification* is available at this link.

### **[www.cs.wustl.edu/~schmidt/PDF/CBSE.pdf](http://www.cs.wustl.edu/~schmidt/PDF/CBSE.pdf)**

This site contains an excellent collaborative work, *Overview of the CORBA Component Model*.

[java.sun.com/j2se/1.3/docs/guide/rmi-iiop/rmi\\_iiop\\_pg.html](http://java.sun.com/j2se/1.3/docs/guide/rmi-iiop/rmi_iiop_pg.html)

Learn-by-doing is the approach taken by this well-written tutorial explaining how to use RMI-IIOP. The RMI-IIOP Programmer's Guide includes many links for background information useful to developers new to RMI, CORBA and IIOP.

### **CORBA Component Model Resources**

[corbaweb.lifl.fr/OpenCCM/](http://corbaweb.lifl.fr/OpenCCM/)

The OpenCCM Platform is an open-source implementation of the CORBA Component Model. Sponsored by the *Laboratoire de Recherche en Informatique de l'Université des Sciences et Technologies de Lille* (LIFL) in France, this open-source implementation of the CORBA Component Model is a worthwhile place for CORBA developers to inexpensively try out CCM technology.

[www.cs.wustl.edu/~schmidt/PDF/CBSE.pdf](http://www.cs.wustl.edu/~schmidt/PDF/CBSE.pdf)

This document is an overview of the CORBA Component Model and why it is a worthwhile addition to the CORBA marketplace. This well-written overview goes into more detail about containers, components, deployment and the runtime environment a developer can expect from CCM.

### **Model Driven Architecture™ Resources**

[www.omg.org/mda/index.htm](http://www.omg.org/mda/index.htm)

Model Driven Architecture promises to leverage many existing technologies into a cohesive view allowing the development of large-grained systems. The documents at this link explain the direction in which the OMG expects MDA to go.

## **TERMINOLOGY**

**abstract**

ACID

activation

Asynchronous Method Invocation (AMI)

Basic Object Adapter (BOA)

call-by-value

**catalog**

Component Implementation Framework (CIF)

Component Interface Definition Language (CIDL)

**ComponentHome**

component-managed persistence

**ConsumerAdmin**

Container programming model

container-managed persistence

conversational container

CORBA Component Model (CCM)

CORBAservices

durable container

Dynamic Invocation Interface (DII)

Dynamic Skeleton Interface (DSI)

**emits**

Enterprise JavaBeans

**entity** component

**EventChannel**

**EventChannelFactory**

Event Service

flat transactions

**HomeFinder**

Interface Repository (IR)

Java Naming and Directory Interface (JNDI)

Model Driven Architecture™

**NameComponent**

**Naming**

**NamingContext**

nested transactions

Notification Service

Object activation

Object Constraint Language (OCL)

Object Transaction Service (OTS)

Object-by-Reference

Object-by-Value

Open Software Description Format (OSD)

**OperationDef**

passivation

Persistent State Definition Language (PSDL)

Persistent State Service (PSS)

Portable Object Adapter (POA)

<b>PortableRemoteObject</b>	<b>storagehome</b>
<b>process</b> component	<b>storagetype</b>
<b>publishes</b>	<b>StructuredEvent</b>
pull model	<b>StructuredProxyPushConsumer</b>
push model	<b>StructuredProxyPushSupplier</b>
recoverable object	<b>SupplierAdmin</b>
recoverable server	TIE (Object Adapter in delegation model)
<b>Request</b>	Trader Constraint Language (TCL)
Request for Proposal (RFP)	Transactional client
RMI-IIOP	Transactional objects
Security Service	Transactional server
servant	Unified Modeling Language (UML)
<b>service</b> component	unit of work
<b>session</b> component	Unshared transaction
shared transaction	XML Metadata Interchange (XMI <sup>TM</sup> )
stateless container	

## SELF-REVIEW EXERCISES

**27.1** Fill in the blanks in each of the following statements:

- An association between a name and a value is called a \_\_\_\_\_.
- In the context of transaction processing, ACID stands for \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- Use of the Event Service is done through the \_\_\_\_\_.
- In RMI-IIOP, the \_\_\_\_\_ is used in place of the **java.rmi.UnicastRemoteObject**.
- The DII allows \_\_\_\_\_-typed calls to be made from a client.
- \_\_\_\_\_ give components an environment to exist in and available services to use.

**27.2** State whether each of the following is *true* or *false*. If *false*, explain why.

- RMI uses the same underlying communication protocol as CORBA.
- TIEs are POAs that use the delegation model.
- The Event Service allows only one delivery model at a time: Either pull or push, but not both.
- Session CORBA components are equivalent to EJB stateless session beans.
- Session CORBA components are equivalent to EJB stateful session beans.
- Enterprise JavaBeans specify the use of an Event Service.
- CCM supports multithreaded containers.

## ANSWERS TO SELF-REVIEW EXERCISES

**27.1** a) name binding. b) Atomic, Consistent, Isolated, Durable. c) **EventChannelFactory**. d) **javax.rmi.PortableRemoteObject**. e) dynamically. f) Containers.

**27.2** a) False. RMI uses the Java Remote Method Protocol (JRMP), CORBA uses the Internet Inter-ORB Protocol (IIOP). RMI-IIOP uses IIOP. b) True. c) False. The Event Service allows a mix of either pull or push in any combination by the suppliers and consumers. d) True. e) True. f) False. The EJB specification requires only Naming, Security, Persistence and Transaction. g) True.

## EXERCISES

**27.3** Write a **QuoteService** that works in either a push or pull model: define an operation to allow clients to register and receive **Quotes** (push) and define another operation to return a **Quote** for a specific **Symbol** (pull). Write a test client that gets pushed by the server and also pulls **Quotes** from the server.

**27.4** Write a GUI client that displays the **Quote** information in a **JTable**. Use a **TableModel** to mediate access to the **Quote** data. Use a client-side proxy to wrap the remote **QuoteService**. Use a client-side proxy to wrap the **Quote** object (if necessary).

**27.5** Modify the **QuoteService** to return an array of **Quotes** based on an array of incoming **Symbol** names.

**27.6** Write a **LoggingService**. One model for logging messages is to connect to an object that would deliver messages in an appropriate fashion based on how important they are. The API should take into account the source, priority, topic and contents. System architecture would consider priority a quality-of-service attribute. The **LoggingService** should be a write-only service (messages go in, but not out). Take multiuser access into account in the API. What kind of activation policies can a POA be assigned to handle some of these issues?

**27.7** From an implementation perspective, the **LoggingService** could distribute the delivery of the message in a number of ways. This is a classic trade-off between making the API straightforward (connect to the service and post messages directly to it) or making its use more complex, but more flexible (make the service more of a pool of connections usable by many clients). Change the name of the **LoggingService** to **LoggingConnection** and have it return a **LogStream** object. The **LogStream** takes the source, priority, topic and contents of the message into account (just as the previous example did), only now the load balancing is more explicit.

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# Peer-to-Peer Applications and JXTA

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## Objectives

- To understand peer-to-peer application architectures.
- To understand how various popular peer-to-peer applications work.
- To create a complete P2P instant-messenger application using RMI and Jini technologies.
- To create a complete P2P instant-messenger application using Multicast Sockets and RMI.
- To introduce the emerging JXTA peer-to-peer technology.

*No! let me taste the whole of it, fare like my peers,  
The heroes of old,*

*Bear the brunt, in a minute pay glad life's arrears  
Of pain, darkness, and cold.*

Robert Browning

*If we do not lay out ourselves in the service of mankind whom  
should we serve?*

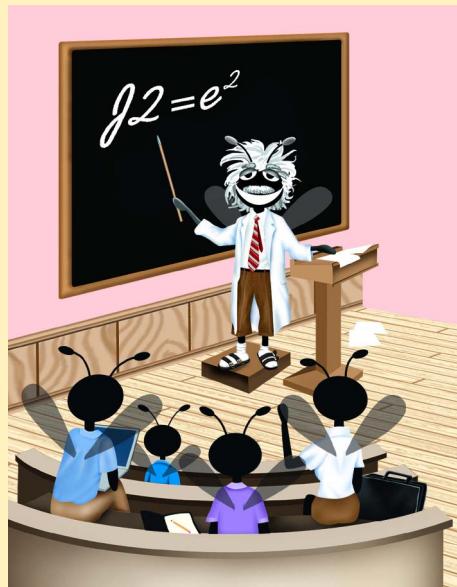
John Adams

*We are as much as we see...*

Henry David Thoreau

*Good counselors lack no clients.*

William Shakespeare



## Outline

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- 28.1 Introduction**
  - 28.2 Client/Server and Peer-to-Peer Applications**
  - 28.3 Centralized vs. Decentralized Network Applications**
  - 28.4 Peer Discovery and Searching**
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    - 28.12.1 Registering the Peer**
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  - 28.13 Introduction to JXTA**
  - 28.14 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 28.1 Introduction

Instant-messaging systems and document-sharing applications such as AOL Instant Messenger™ and Gnutella have exploded in popularity, transforming the way users interact with one another over networks. In a *peer-to-peer (P2P) application*, each node performs both client and server functions. Such applications distribute processing responsibilities and information to many computers, thus reclaiming otherwise wasted computing power and storage space, and eliminating central points of failure.

In this chapter, we introduce the fundamental concepts of peer-to-peer applications. Using Jini (Chapter 22), RMI (Chapter 13) and multicast sockets, we present two peer-to-peer application case studies. We first implement an instant-messaging application with Jini and RMI to demonstrate a more substantial Jini application and show the benefits of integrating Jini with other technologies. We then implement the same instant-messaging application using multicast sockets and RMI. Finally, we introduce JXTA (short for “juxtapose”—a new open-source technology from Sun Microsystems™ that defines common protocols for implementing peer-to-peer applications).

### 28.2 Client/Server and Peer-to-Peer Applications

Many network applications operate on the principle that computers should be segregated by function. Some computers—called *servers*—offer common stores of programs and data. Other computers—called *clients*—access the data provided by the servers. The Yahoo!™ search engine ([www.yahoo.com](http://www.yahoo.com)) is an example of a *client/server application*. Client send queries to the central servers, which have pre-compiled catalogs of the Internet. The central servers refer to their databases and respond with the requested information.

P2P applications are different than client/server applications. Instead of segregating computers by function, all computers act as both clients and servers. P2P applications are similar to the telephone system—a single user can both speak (send information) and listen (receive information).<sup>1</sup> Figure 28.1 lists some common peer-to-peer applications.

### 28.3 Centralized vs. Decentralized Network Applications

An application that uses a *centralized server* exemplifies the client/server relationship. One major weakness of this centralized system is the dependency on the central server. If the central node (i.e., server) fails, the entire application also fails. The server's capabilities limit the application's overall performance. For instance, Web sites can fail when malicious users overload the Web server(s) with an excessive number of requests. However, centralized architectures also have advantages, such as simplifying management tasks (e.g., monitoring user access by providing single points of network control).

True P2P applications are completely decentralized and do not suffer from the same deficiencies as applications that depend on centralized servers. If nodes in a P2P application fail, well-designed P2P applications continue to function. P2P applications often leverage distributed computational power. *Freenet*, for instance, allows users to share documents in a way that precludes censorship. Peer-to-peer architectures allow real-time searches that return up-to-date results. Centralized search engines today are slow to incorporate recently created Web data into these catalogs. Peer-to-peer searches accurately reflect the network status at the time of the query.<sup>2</sup>

Distributed Applications	Description
Gnutella	A P2P technology that does not use any central servers. There is no authentication, and peers search for files via a distributed-search mechanism.
KaZaA	A file-sharing application that is a hybrid between Gnutella and centralized applications. A central server authenticates all users. Certain peers serve as <i>search hubs</i> , which catalog the files of peers connected to them. Searches are distributed to each search hub, which then respond with results that allow direct connections for file transfers.
Instant Messengers	Peer-to-peer applications that enable users to send short text messages and files to one another. Most instant messengers use central servers that authenticate all users and route messages between peers.
Telephone System	A peer-to-peer application that enables users to conduct voice conversations remotely.

Fig. 28.1 Common P2P applications.

1. E. Harold, *JAVA Network Programming*. Sebastopol: O'Reilly & Associates, Inc., 1997: 26–27.
2. S. Waterhouse, “JXTA Search: Distributed Search for Distributed Networks,” May, 2001. [search.jxta.org/JXTAsearch.pdf](http://search.jxta.org/JXTAsearch.pdf)

Peer-to-peer applications have disadvantages as well. Anyone with the appropriate software can join the network of peers and often remain anonymous—for this reason, determining who is on the network at any instant is difficult. Also, the lack of a central server hinders the enforcement of copyright and intellectual-property laws. Real-time searches can be slow and increase network traffic, because every query must propagate throughout the entire network.

True client/server applications are completely centralized, whereas true peer-to-peer applications are completely decentralized. Many applications adopt aspects of both to achieve specific goals. For example, some file-sharing applications are not true peer-to-peer applications, because they use central servers to authenticate users and index each peer's shared files. However, peers connect directly to one another to transfer files. In such a system, centralization increases search performance but makes the network dependent on a central server. Performing file transfers between peers decreases the load on the central server.

## 28.4 Peer Discovery and Searching

*Peer discovery* is the act of finding peers in a P2P application. Decentralizing an application often slows peer discovery and information searching. Gnutella presents one approach for circumventing these problems. Gnutella is a true peer-to-peer technology that enables distributed information storage and retrieval. Users can search for and download files from any peer on the network. Users first join a Gnutella network by specifying the network address of a known Gnutella peer. Without knowing of at least one peer on the network, a user cannot join the network. Each user's Gnutella software functions as a server and uses the HTTP protocol to search for and transfer files.

To perform a search, a peer sends search criteria to several nearby peers. Those peers then propagate the search throughout the network of peers. If a particular peer can satisfy the search, that peer passes this information back to the originator. The originator then connects directly to the target peer and downloads the information. The peer that made the original query loses anonymity only when it connects directly to the peer with the requested file to begin file transfer.

In the *Freenet* P2P application, files also propagate throughout the network of peers. Each peer that uses Freenet forwards search requests to only one other peer. If the search fails, the peer that received the request forwards the request to the next known peer. If we view the searching peer as the root of a hierarchical structure that represents the Gnutella network, each search request traverses in a breadth-first fashion, because peers forward each search request to several peers at once. Freenet works essentially like Gnutella, except that each search request traverses depth-first.

Searches conducted in both Gnutella and Freenet are called *distributed searches*. Distributed searches make networks more robust by removing single points of failure, such as central servers. Information found via distributed searches is current because it reflects the current state of the network. Not only can peers find information in this way, but peers can search for other peers via distributed searches as well.

## 28.5 Case Study: Deitel Instant Messenger

In the next several sections, we present a peer-to-peer application that allows users to send instant messages to one other. The Deitel Instant Messenger application uses Jini to boot-

*strap*—or register—users onto the peer-to-peer network. Jini lookup services store remote references to peers on the network. Peers use RMI to connect to one another directly and converse. Although we sometimes refer to an instance of the application as a client, each application instance is both a client and a server.

The application's main window (Fig. 28.2, left-side image) displays a list of peers running Deitel Instant Messenger on the local network. To send an instant message, the user selects a name and clicks the **Connect** button. The conversation window (Fig. 28.2, right-side image) appears with the selected peer's name as the title. The user can type a message, then send it by clicking **Send**.

Deitel Instant Messenger uses Sun's Jini technology, which requires at least one lookup service. However, with only one lookup service, the application acts as a hybrid between P2P and client/server applications. The lookup service is centralized to enable peers to find other peers easily. Peers use RMI to connect to one another directly. A setup with only one lookup service is similar to the setup that many instant messaging applications use today.

For Deitel Instant Messenger to be truly peer-to-peer, each node must run its own lookup service. However, running a lookup service on each peer is inefficient and could generate extensive network traffic. Thus, a compromise between using only one lookup service and using a lookup service for every node balances both reliability and robustness with speed and efficiency.

If a node does not run a lookup service, that node depends on the existing lookup services on the network—this results in centralization. Each client consists of a Jini-service proxy and an RMI object that enables the peer-to-peer communication. The application registers with all known lookup services, which includes those found through both multicast and unicast discovery. Users can add lookup services to the program by selecting the **Add Locator** item in the **File** menu and supplying the lookup service's URL.

After registering the client's proxy with the lookup service, the Deitel Instant Messenger client retrieves all other proxies in the Jini lookup service. These proxies represent all known peers. To send messages, a client must hold a remote reference to the other peer. Therefore, to begin a conversation, a client sends a reference to itself through the service proxy to the other peer. The other peer responds by sending a remote reference back to the peer that initiated the conversation. When each party has a reference to the other, they can both send and receive messages.



Fig. 28.2 Sample windows of Deitel Instant Messenger.

The major steps in this example are as follows:

1. define a *service interface* that contains a remote reference to the service implementation,
2. define the service implementation,
3. provide methods for bootstrapping the service into the peer group and
4. compile and run the P2P application.

We discuss each step in detail in the next several sections, as we implement the Deitel Instant Messenger application.

## 28.6 Defining the Service Interface

The first step in the example is to define the service interface—**IMService** (Fig. 28.3). Method **connect** (lines 16–17) enables remote users to send a remote reference to an **IMPeer** (the instant-messenger peer). A remote reference enables one-way communication. To establish two-way communication, each client must have a remote reference to the other client's **IMPeer** objects.

**IMPeer** (Fig. 28.4) specifies the interface for communicating between peers. Method **connect** (line 16) takes as an argument an **IMPeer** and returns an **IMPeer** reference. Remote interface **IMPeer** describes the basic methods for interacting with an **IMPeer**.

```
1 // IMService.java
2 // IMService interface defines the methods
3 // through which the service proxy
4 // communicates with the service.
5 package com.deitel.advjhttp1.jini.IM.service;
6
7 // Java core packages
8 import java.rmi.*;
9
10 // Deitel packages
11 import com.deitel.advjhttp1.jini.IM.IMPeer;
12
13 public interface IMService extends Remote {
14
15     // return RMI reference to a remote IMPeer
16     public IMPeer connect( IMPeer sender )
17         throws RemoteException;
18 }
```

Fig. 28.3 Interface **IMService** specifies how service proxy interacts with the service.

```
1 // IMPeer.java
2 // Interface that all Peer to Peer apps must implement
3 package com.deitel.advjhttp1.jini.IM;
4
```

Fig. 28.4 Interface **IMPeer** specifies interaction between peers (part 1 of 2).

```
5 //java core packages
6 import java.rmi.*;
7 import java.util.*;
8
9 public interface IMPeer extends Remote
10 {
11     // posts Message to peer
12     public void sendMessage( Message message )
13         throws RemoteException;
14
15     // information methods
16     public String getName() throws RemoteException;
17 }
```

Fig. 28.4 Interface **IMPeer** specifies interaction between peers (part 2 of 2).

In line 9, **IMPeer** extends interface **java.rmi.Remote**, because **IMPeers** are remote objects. The Deitel Instant Messenger client sends a message to a peer by calling that peer's **sendMessage** method (line 12–13) and passing a **Message** object as an argument. Class **Message** (Fig. 28.5) represents a message that **IMPeers** can send to one another.

```
1 // Message.java
2 // Message represents an object that can be sent to an IMPeer;
3 // contains the sender and content of the message.
4 package com.deitel.advjhttp1.jini.IM;
5
6 // Java core package
7 import java.io.Serializable;
8
9 public class Message implements Serializable
10 {
11     private static final long serialVersionUID = 20010808L;
12     private String from;
13     private String content;
14
15     // Message constructor
16     public Message( String messageSenderName,
17                     String messageContent )
18     {
19         from = messageSenderName;
20         content = messageContent;
21     }
22
23     // get String representation
24     public String toString()
25     {
26         return from + ": " + content + "\n";
27     }
28 }
```

Fig. 28.5 Class **Message** defines an object for sending and receiving messages between peers (part 1 of 2).

```
29 // get Message sender's name
30 public String getSenderName()
31 {
32     return from;
33 }
34
35 // get Message content
36 public String getContent()
37 {
38     return content;
39 }
40 }
```

Fig. 28.5 Class **Message** defines an object for sending and receiving messages between peers (part 2 of 2).

In the upcoming exercises, we ask you to extend this class to allow more complex types of communication. Line 10 specifies that class **Message** implements interface **Serializable**, because **Messages** must be serialized for delivery over RMI. The **Message** constructor (lines 16–21) takes as arguments the sender’s name and the content of the message.

## 28.7 Defining the Service implementation

The second step in the example is defining the service implementation—**IMService-Impl** (Fig. 28.6), which implements interface **IMService**. Lines 18–19 declare that class **IMServiceImpl** extends **UnicastRemoteObject**, which facilitates exporting the **IMServiceImpl** as a remote object.

```
1 // IMServiceImpl.java
2 // IMServiceImpl implements IMService interface
3 // is service side of IM application
4 package com.deitel.advjhttp1.jini.IM.service;
5
6 // Java core packages
7 import java.io.*;
8 import java.rmi.server.UnicastRemoteObject;
9 import java.rmi.RemoteException;
10 import java.util.StringTokenizer;
11
12 // Deitel packages
13 import com.deitel.advjhttp1.jini.IM.IMPeer;
14 import com.deitel.advjhttp1.jini.IM.IMPeerImpl;
15 import com.deitel.advjhttp1.jini.IM.Message;
16 import com.deitel.advjhttp1.jini.IM.client.IMPeerListener;
17
18 public class IMServiceImpl extends UnicastRemoteObject
19     implements IMService, Serializable {
20 }
```

Fig. 28.6 **IMService-Impl** service implementation for our case study (part 1 of 2).

```

21  private static final long serialVersionUID = 20010808L;
22  private String userName = "Anonymous";
23
24  // IMService no-argument constructor
25  public IMServiceImpl() throws RemoteException{}
26
27  // IMService constructor takes userName
28  public IMServiceImpl( String name ) throws RemoteException
29  {
30      userName = name;
31  }
32
33  // sets service's userName
34  public void setUserName( String name )
35  {
36      userName = name;
37  }
38
39  // return RMI reference to an IMPeer on the receiver side
40  public IMPeer connect( IMPeer sender )
41      throws RemoteException
42  {
43      // Make a GUI and IMPeerImpl to be sent to remote peer
44      IMPeerListener listener =
45          new IMPeerListener( userName );
46
47      IMPeerImpl me = new IMPeerImpl( userName );
48      me.addListener( listener );
49
50      // add remote peer to my GUI
51      listener.addPeer( sender );
52
53      // send my IMPeerImpl to him
54      return me;
55
56  } // end method connect
57 }

```

Fig. 28.6 **IMServiceImpl** service implementation for our case study (part 2 of 2).

The second constructor (lines 28–31) takes as a **String** argument the user’s name. This name appears in the **PeerList** window. Lines 40–56 implement method **connect**.

For two peers to communicate, each peer requires a remote reference to the other peer. The following steps summarize the connection process:

1. Peer A sends a reference to itself to peer B by invoking **IMService** method **connect**.
2. Peer B stores that reference (line 51) to peer A for use when conversation starts.
3. Peer B returns a reference to itself (line 54) to peer A.

The Deitel Instant Messenger creates an object of class **IMPeerListener** (Fig. 28.7)—the GUI that starts the peer communication. The upper text area outputs messages sent via the remote reference to an **IMPeer**. The bottom text area contains text to be sent via a remote method call.

```
1 // IMPeerListener.java
2 // IMPeerListener extends JFrame and provides GUI for
3 // conversations with other peers
4 package com.deitel.advjhttp1.jini.IM.client;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.rmi.RemoteException;
10
11 // Java extension packages
12 import javax.swing.*;
13 import javax.swing.text.*;
14 import javax.swing.border.*;
15
16 // Deitel Packages
17 import com.deitel.advjhttp1.jini.IM.IMPeer;
18 import com.deitel.advjhttp1.jini.IM.Message;
19
20 public class IMPeerListener extends JFrame {
21
22     // JTextAreas for displaying and inputting messages
23     private JTextArea messageArea;
24     private JTextArea inputArea;
25
26     // Actions for sending messages, etc.
27     private Action sendAction;
28
29     // userName to add to outgoing messages
30     private String userName = "";
31
32     // IMPeer to send messages to peer
33     private IMPeer remotePeer;
34
35     // constructor
36     public IMPeerListener( String name )
37     {
38         super( "Conversation Window" );
39
40         // set user name
41         userName = name;
42
43         // init sendAction
44         sendAction = new SendAction();
45
46         // create JTextArea for displaying messages
47         messageArea = new JTextArea( 15, 15 );
48
49         // disable editing and wrap words at end of line
50         messageArea.setEditable( false );
51         messageArea.setLineWrap( true );
52         messageArea.setWrapStyleWord( true );
```

Fig. 28.7 Class **IMPeerListener** is the GUI that starts peer communication (part 1 of 4).

```
53     JPanel panel = new JPanel();
54     panel.setLayout( new BorderLayout( 5, 5 ) );
55     panel.add( new JScrollPane( messageArea ),
56                BorderLayout.CENTER );
57
58
59     // create JTextArea for entering new messages
60     inputArea = new JTextArea( 4, 12 );
61     inputArea.setLineWrap( true );
62     inputArea.setWrapStyleWord( true );
63
64     // map Enter key in inputArea area to sendAction
65     Keymap keyMap = inputArea.getKeymap();
66     KeyStroke enterKey = KeyStroke.getKeyStroke(
67         KeyEvent.VK_ENTER, 0 );
68     keyMap.addActionForKeyStroke( enterKey, sendAction );
69
70     // lay out inputArea and sendAction JButton in Box
71     Box box = Box.createVerticalBox();
72     box.add( new JScrollPane( inputArea ) );
73     box.add( new JButton( sendAction ) );
74
75     panel.add( box, BorderLayout.SOUTH );
76
77     // lay out components
78     Container container = getContentPane();
79     container.add( panel, BorderLayout.CENTER );
80
81     setSize( 200, 400 );
82     setVisible( true );
83 }
84
85 // Action for sending messages
86 private class SendAction extends AbstractAction {
87
88     // configure SendAction
89     public SendAction()
90     {
91         putValue( Action.NAME, "Send" );
92         putValue( Action.SHORT_DESCRIPTION,
93                  "Send Message" );
94         putValue( Action.LONG_DESCRIPTION,
95                  "Send an Instant Message" );
96     }
97
98     // send message and clear inputArea
99     public void actionPerformed( ActionEvent event )
100    {
101        // send message to server
102        try {
103            Message message = new Message( userName,
104                                         inputArea.getText() );
```

Fig. 28.7 Class **IMPeerListener** is the GUI that starts peer communication (part 2 of 4).

```
105         // use RMI reference to send a Message
106         remotePeer.sendMessage( message );
107
108         // clear inputArea
109         inputArea.setText( "" );
110         displayMessage( message );
111     }
112
113
114         // catch error sending message
115         catch( RemoteException remoteException ) {
116             JOptionPane.showMessageDialog( null,
117                 "Unable to send message." );
118
119             remoteException.printStackTrace();
120         }
121     } // end method actionPerformed
122
123 } // end sendAction inner class
124
125 public void displayMessage( Message message )
126 {
127     // displayMessage uses SwingUtilities.invokeLater
128     // to ensure thread-safe access to messageArea
129     SwingUtilities.invokeLater(
130         new MessageDisplayer(
131             message.getSenderName(), message.getContent() ) );
132     }
133
134 // MessageDisplayer displays a new message by appending
135 // the message to the messageArea JTextArea. This Runnable
136 // object should be executed only on the event-dispatch
137 // thread, as it modifies a live Swing component.
138 private class MessageDisplayer implements Runnable {
139
140     private String fromUser;
141     private String messageBody;
142
143     // MessageDisplayer constructor
144     public MessageDisplayer( String from, String body )
145     {
146         fromUser = from;
147         messageBody = body;
148     }
149
150     // display new message in messageArea
151     public void run()
152     {
153         // append new message
154         messageArea.append( "\n" + fromUser + "> " +
155             messageBody );
```

Fig. 28.7 Class **IMPeerListener** is the GUI that starts peer communication (part 3 of 4).

```

157         // move caret to end of messageArea to ensure new
158         // message is visible on screen
159         messageArea.setCaretPosition(
160             messageArea.getText().length() );
161     }
162
163 } // end MessageDisplayer inner class
164
165 // addPeer takes IMPeer as arg
166 // associates IMPeer with sendAction to send messages
167 public void addPeer( IMPeer peer ) throws RemoteException
168 {
169     remotePeer = peer;
170
171     // change title of window to name of peer
172     setTitle( remotePeer.getName() );
173 }
174 }
```

Fig. 28.7 Class **IMPeerListener** is the GUI that starts peer communication (part 4 of 4).

In Fig. 28.6, line 48 adds an **IMPeerListener** object to an **IMPeerImpl** object using method **addListener**. **IMPeerImpl** method **sendMessage** sends **Message** objects to the **IMPeerListener**.

Line 51 calls method **addPeer** to add a reference to a remote **IMPeer** object to the **IMPeerListener**. This allows the **IMPeerListener** to send messages to the remote peer. Notice the symmetry: **IMPeerListener** is also client/server, because the application itself is client/server. Just as each peer must provide a reference to itself and store references to the remote party, so must the **IMPeerListener**. **IMPeerListener** mediates between the two peers.

**IMPeerListener** (Fig. 28.7) is the GUI for communication between peers. Method **addPeer** (lines 167–173) stores a reference to the remote **IMPeer** and sets the title of the conversation window to the name of the remote **IMPeer**. When the user presses the **JButton** on the GUI, line 107 calls method **sendMessage** of the remote **IMPeer**, passing the contents of **inputArea** as the argument. This is how the client sends messages to remote peers. On the receiving end, the remote **IMPeerImpl** (Fig. 28.8) calls **IMPeerListener** method **displayMethod** to display the message.

```

1 // IMPeerImpl.java
2 // Implements the IMPeer interface
3 package com.deitel.advjhttp1.jini.IM;
4
5 // Java core packages
6 import java.io.*;
7 import java.net.*;
8 import java.rmi.*;
9 import java.rmi.server.*;
10 import java.util.*;
```

Fig. 28.8 Class **IMPeerImpl** is the **IMPeer** implementation (part 1 of 2).

```
11 // Deitel Packages
12 import com.deitel.advjhttp1.jini.IM.Message;
13 import com.deitel.advjhttp1.jini.IM.client.IMPeerListener;
14
15
16
17 public class IMPeerImpl extends UnicastRemoteObject
18 implements IMPeer {
19
20     private String name;
21     private IMPeerListener output;
22
23     // No argument constructor
24     public IMPeerImpl() throws RemoteException
25     {
26         super();
27         name = "anonymous";
28     }
29     // constructor takes userName
30     public IMPeerImpl( String myName ) throws RemoteException
31     {
32         name = myName;
33     }
34
35     public void addListener( IMPeerListener listener )
36     {
37         output = listener;
38     }
39
40     // send message to this peer
41     public void sendMessage( Message message )
42         throws RemoteException
43     {
44         output.displayMessage( message );
45     }
46
47     // accessor for name
48     public String getName() throws RemoteException
49     {
50         return name;
51     }
52 }
```

Fig. 28.8 Class **IMPeerImpl** is the **IMPeer** implementation (part 2 of 2).

Class **IMPeerImpl** implements the **IMPeer** interface. An **IMPeerImpl** instance represents each peer in conversations with other peers and allows peers to communicate with one another. Lines 17–18 declare that **IMPeerImpl** extends **UnicastRemoteObject**, to facilitate exporting the **IMPeerImpl** as a remote object. Method **addListener** (lines 35–38) adds an object of type **IMPeerListener** that will display the **IMPeerImpl**'s actions. Method **sendMessage** (lines 41–45) calls method **displayMessage** of interface **IMPeerListener** to display the message.

## 28.8 Registering the Service

The third step in the example is registering (bootstrapping) the service with the peer group. Class **IMServiceManager** (Fig. 28.9) takes the user's name as a **String** argument and uses the Jini's **JoinManager** class to register the service with all known lookup services. The code is similar to the **JoinManager** version of the **SeminarInfo** program in Chapter 22. One difference is that the constructor (lines 33–65) takes a **String** that specifies the **Name Entry** for the service.

```
1 // IMServiceManager.java
2 // IMServiceManager uses JoinManager to find Lookup services,
3 // registers the IMService with the Lookup services,
4 // manages lease renewal
5 package com.deitel.advjhttp1.jini.IM;
6
7 // Java core packages
8 import java.rmi.RMISecurityManager;
9 import java.rmi.RemoteException;
10 import java.io.IOException;
11
12 // Jini core packages
13 import net.jini.core.lookup.ServiceID;
14 import net.jini.core.entry.Entry;
15
16 // Jini extension packages
17 import net.jini.lookup.entry.Name;
18 import net.jini.lease.LeaseRenewalManager;
19 import net.jini.lookup.JoinManager;
20 import net.jini.discovery.LookupDiscoveryManager;
21 import net.jini.lookup.ServiceIDListener;
22
23 // Deitel packages
24 import com.deitel.advjhttp1.jini.IM.service.*;
25
26 public class IMServiceManager implements ServiceIDListener {
27
28     JoinManager manager;
29     LookupDiscoveryManager lookupManager;
30     String serviceName;
31
32     // constructor takes name of the service
33     public IMServiceManager( String screenName )
34     {
35         System.setSecurityManager( new RMISecurityManager() );
36
37         // sets the serviceName of this service
38         serviceName = screenName;
39     }
```

Fig. 28.9 Class **IMServiceManager** registers **IMServiceImpl** with lookup services (part 1 of 3).

```
40     // use JoinManager to register SeminarInfo service
41     // and manage lease
42     try {
43
44         // create LookupDiscoveryManager for discovering
45         // lookup services
46         lookupManager =
47             new LookupDiscoveryManager( new String[] { "" },
48                                         null, null );
49
50         // create and set Entry name for service
51         // name used from constructor
52         Entry[] entries = new Entry[ 1 ];
53         entries[ 0 ] = new Name( serviceName );
54
55         // create JoinManager
56         manager = new JoinManager( createProxy(),
57                                     entries, this, lookupManager,
58                                     new LeaseRenewalManager() );
59     }
60
61     // handle exception creating JoinManager
62     catch ( IOException exception ) {
63         exception.printStackTrace();
64     }
65 } // end SeminarInfoJoinService constructor
66
67 // return the LookupDiscoveryManager created by JoinManager
68 public LookupDiscoveryManager getDiscoveryManager()
69 {
70     return lookupManager;
71 }
72
73 // create service proxy
74 private IMService createProxy()
75 {
76     // get SeminarProxy for SeminarInfo service
77     try {
78         return( new IMServiceImpl( serviceName ) );
79     }
80
81     // handle exception creating SeminarProxy
82     catch ( RemoteException exception ) {
83         exception.printStackTrace();
84     }
85
86     return null;
87 }
88 } // end method createProxy
89
```

Fig. 28.9 Class **IMServiceManager** registers **IMServiceImpl** with lookup services (part 2 of 3).

```

90     // receive notification of ServiceID assignment
91     public void serviceIDNotify( ServiceID serviceID )
92     {
93         System.err.println( "Service ID: " + serviceID );
94     }
95
96     // informs all lookup services that service is ending
97     public void logout()
98     {
99         manager.terminate();
100    }
101 }
```

Fig. 28.9 Class **IMServiceManager** registers **IMServiceImpl** with lookup services (part 3 of 3).

## 28.9 Find Other Peers

Class **PeerList** (Fig. 28.10)—the main window of the Deitel Instant Messenger—lists peers to whom the user can send instant messages. Line 264 creates a new **IMServiceManager**, passing **String userName** as an argument to the **IMServiceManager** constructor to name the peer.

**IMPeer** (Fig. 28.4) specifies the interface for communicating between peers. Method **connect** (line 16) takes as an argument an **IMPeer** and returns an **IMPeer** reference. Remote interface **IMPeer** describes the basic methods for interacting with an **IMPeer**.

A **LookupCache** also allows an application to respond to services being added, removed, or changed without constantly polling lookup services. The Peer List uses a **LookupCache** to determine when other peers join and leave the network. To use this functionality, an application must pass a **ServiceDiscoveryListener** object to method **createLookupCache**. **PeerList** implements **ServiceDiscoveryListener** (lines 33–34), so line 276 passes the **this** reference to method **createLookupCache**. **ServiceDiscoveryManager** uses remote events registered with lookup services to implement asynchronous notification of **ServiceDiscoveryEvents**. Therefore, we must provide lookup services with a way to download the stub class files for the **RemoteEvent** handlers. Section 28.10 explains how to do this.

```

1 // PeerList.java
2 // Initializes ServiceManager, starts service discovery
3 // and lists all IM services in a window
4 package com.deitel.advjhtpl.jini.IM;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.net.MalformedURLException;
10 import java.util.*;
11 import java.util.List;
12 import java.io.IOException;
13 import java.rmi.*;
```

Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 1 of 7).

```
14 // Java extension packages
15 import javax.swing.*;
16 import javax.swing.event.*;
17
18
19 // Jini core packages
20 import net.jini.core.lookup.ServiceItem;
21 import net.jini.core.lookup.ServiceTemplate;
22 import net.jini.lookup.*;
23 import net.jini.discovery.LookupDiscoveryManager;
24 import net.jini.lease.LeaseRenewalManager;
25 import net.jini.lookup.entry.Name;
26 import net.jini.core.entry.Entry;
27 import net.jini.core.discovery.LookupLocator;
28
29 // Deitel Packages
30 import com.deitel.advjhttp1.jini.IM.service.IMService;
31 import com.deitel.advjhttp1.jini.IM.client.IMPeerListener;
32
33 public class PeerList extends JFrame
34     implements ServiceDiscoveryListener {
35
36     private DefaultListModel peers;
37     private JList peerList;
38     private List serviceItems;
39     private ServiceDiscoveryManager serviceDiscoveryManager;
40     private LookupCache cache;
41     private IMServiceManager myManager;
42     private LookupDiscoveryManager lookupDiscoveryManager;
43
44     // initialize userName to anonymous
45     private String userName = "anonymous";
46
47     // method called when ServiceDiscoveryManager finds
48     // IM service adds service proxy to serviceItems
49     // adds Service name to ListModel for JList
50     public void serviceAdded( ServiceDiscoveryEvent event )
51     {
52         // get added serviceItem
53         ServiceItem item = event.getPostEventServiceItem();
54         Entry attributes[] = item.attributeSets;
55
56         // iterates through attributes to find name
57         for( int i = 0; i < attributes.length; i++ )
58
59             if ( attributes[ i ] instanceof Name ) {
60                 System.out.println( "Added: " + item );
61                 serviceItems.add( item.service );
62                 peers.addElement(
63                     ( ( Name )attributes[ i ] ).name );
64                 break;
65             }
66     } // end method serviceAdded
```

Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 2 of 7).

```
67
68     // empty method ignores serviceChanged event
69     public void serviceChanged( ServiceDiscoveryEvent event )
70     {}
71
72     // removes services from PeerList GUI and data structure
73     // when serviceRemoved event occurs
74     public void serviceRemoved( ServiceDiscoveryEvent event )
75     {
76         // getPreEvent because item has been removed
77         // getPostEvent would return null
78         ServiceItem item = event.getPreEventServiceItem();
79         Entry attributes[ ] = item.attributeSets;
80
81         // debug
82         System.out.println( "Remove Event!" );
83
84         // remove from arraylist and DefaultListModel
85         int index = serviceItems.indexOf( item.service );
86
87         // print name of person removed
88         if ( index >= 0 )
89         {
90             System.out.println( "Removing from List:" +
91                 serviceItems.remove( index ) );
92
93             System.out.println( "Removing from DefList" +
94                 peers.elementAt( index ) );
95
96             peers.removeElementAt( index );
97         }
98     } // end method ServiceRemoved
99
100    // constructor
101    public PeerList()
102    {
103        super( "Peer List" );
104
105        System.setSecurityManager( new RMISecurityManager() );
106
107        // get desired userName
108        userName = JOptionPane.showInputDialog(
109            PeerList.this, "Please enter your name: " );
110
111        // change title of window
112        setTitle( userName + "'s Peer List Window" );
113
114        // Init Lists
115        serviceItems = new ArrayList();
116
117        Container container = getContentPane();
118        peers = new DefaultListModel();
119    }
```

Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 3 of 7).

```
120     // init components
121     peerList = new JList( peers );
122     peerList.setVisibleRowCount( 5 );
123     JButton connectButton = new JButton( "Connect" );
124
125     // do not allow multiple selections
126     peerList.setSelectionMode(
127         ListSelectionModel.SINGLE_SELECTION );
128
129     // set up event handler for connectButton
130     connectButton.addActionListener(
131         new ActionListener() {
132
133             public void actionPerformed( ActionEvent event )
134             {
135                 int itemIndex = peerList.getSelectedIndex();
136
137                 Object selectedService =
138                     serviceItems.get( itemIndex );
139                 IMService peerProxy =
140                     ( IMService )selectedService;
141
142                 // send info to remote peer
143                 // get RMI reference
144                 try {
145
146                     // set up gui and my peerImpl
147                     IMPeerListener gui =
148                         new IMPeerListener( userName );
149                     IMPeerImpl me =
150                         new IMPeerImpl( userName );
151                     me.addListener( gui );
152
153                     // Connect myGui to remote IMPeer object
154                     IMPeer myPeer = peerProxy.connect( me );
155                     gui.addPeer( myPeer );
156                 }
157
158                 // connecting may cause RemoteException
159                 catch( RemoteException re ) {
160                     JOptionPane.showMessageDialog(
161                         null, "Couldn't Connect" );
162                     re.printStackTrace();
163                 }
164             }
165         }
166     ); // end connectButton actionPerformed
167
168     // set up File menu
169     JMenu fileMenu = new JMenu( "File" );
170     fileMenu.setMnemonic( 'F' );
171
```

Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 4 of 7).

```
172     // about Item
173     JMenuItem aboutItem = new JMenuItem( "About..." );
174     aboutItem.setMnemonic( 'A' );
175     aboutItem.addActionListener(
176         new ActionListener() {
177             public void actionPerformed( ActionEvent event )
178             {
179                 JOptionPane.showMessageDialog( PeerList.this,
180                     "Deitel Instant Messenger",
181                     "About", JOptionPane.PLAIN_MESSAGE );
182             }
183         }
184     );
185
186     fileMenu.add( aboutItem );
187
188     // AddLocator item
189     JMenuItem federateItem =
190         new JMenuItem( "Add Locators" );
191     federateItem.setMnemonic( 'L' );
192     federateItem.addActionListener(
193
194         new ActionListener() {
195             public void actionPerformed( ActionEvent event )
196             {
197                 // get LookupService url to be added
198                 String locator =
199                     JOptionPane.showInputDialog(
200                         PeerList.this,
201                         "Please enter locator in this" +
202                         "form: jini://host:port/" );
203
204                 try {
205                     LookupLocator newLocator =
206                         new LookupLocator( locator );
207
208                     // make one element LookupLocator array
209                     LookupLocator[] locators = { newLocator };
210
211                     // because addLocators takes array
212                     lookupDiscoveryManager.addLocators( locators );
213                 }
214
215                 catch( MalformedURLException urlException ) {
216
217                     JOptionPane.showMessageDialog(
218                         PeerList.this, "invalid url" );
219                 }
220             }
221         }
222     );
223     fileMenu.add( federateItem );
224 }
```

Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 5 of 7).

```
225     // set up JMenuBar and attach File menu
226     JMenuBar menuBar = new JMenuBar();
227     menuBar.add( fileMenu );
228     setJMenuBar( menuBar );
229
230     // handle window closing event
231     addWindowListener(
232         new WindowAdapter(){
233             public void windowClosing( WindowEvent w )
234             {
235                 System.out.println( "CLOSING WINDOW" );
236
237                 // disconnects from lookup services
238                 myManager.logout();
239                 System.exit( 0 );
240             }
241         }
242     );
243
244     // lay out GUI components
245     peerList.setFixedCellWidth( 100 );
246     JPanel inputPanel = new JPanel();
247     inputPanel.add( connectButton );
248
249     container.add( new JScrollPane( peerList ) ,
250                     BorderLayout.NORTH );
251     container.add( inputPanel, BorderLayout.SOUTH );
252
253     setSize( 100, 170 );
254     setVisible( true );
255
256     // peer list displays only other IMServices
257     Class[] types = new Class[] { IMServices.class };
258     ServiceTemplate IMTemplate =
259         new ServiceTemplate( null, types, null );
260
261     // Initialize IMServicesManager, ServiceDiscoveryManager
262     try {
263         myManager = new IMServicesManager( userName );
264
265         // store LookupDiscoveryManager
266         // generated by IMServicesManager
267         lookupDiscoveryManager = myManager.getDiscoveryManager();
268
269         // ServiceDiscoveryManager uses lookupDiscoveryManager
270         serviceDiscoveryManager =
271             new ServiceDiscoveryManager( lookupDiscoveryManager,
272                                         null );
273
274         // create a LookupCache
275         cache = serviceDiscoveryManager.createLookupCache(
276             IMTemplate, null, this );
277     }
```

Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 6 of 7).

```

278     // catch all exceptions and inform user of problem
279     catch ( Exception managerException ) {
280         JOptionPane.showMessageDialog( null,
281             "Error initializing IMServiceManger" +
282             "or ServiceDiscoveryManager" );
283         managerException.printStackTrace();
284     }
285 }
286 }
287
288 public static void main( String args[] )
289 {
290     new PeerList();
291 }
292 }

```

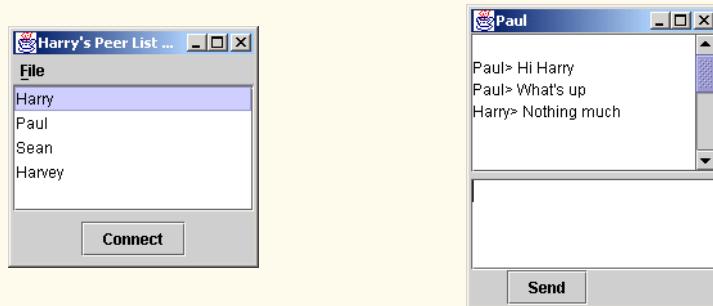


Fig. 28.10 Class **PeerList** is the GUI for finding peers (part 7 of 7).

The methods required to implement **ServiceDiscoveryListener** are **serviceAdded** (lines 50–66), **serviceChanged** (lines 69–70) and **serviceRemoved** (lines 74–98). Method **ServiceAdded** calls method **getPostEventServiceItem** of the **ServiceDiscoveryEvent** to obtain a **ServiceItem** that represents the added service. Lines 57–65 cycle through all the attributes of the **ServiceItem**. If line 59 finds a **Name** entry, line 61 adds the service proxy to a **List**, and lines 62–63 add the service **Name** to a **DefaultListModel**. Method **serviceChanged** is an empty method, because we are not concerned whether services change their attributes. Method **serviceRemoved** invokes method **getPreEventServiceItem** of the **ServiceDiscoveryEvent** to obtain a **ServiceItem** that represents the removed service.

The **ActionListener** (lines 130–167) of the **connectButton** object gets the index of the selected item in the **JList** and retrieves the **IMService** proxy associated with that index from **List serviceItems** (lines 138–141). Lines 147–148 create an **IMPeerListener** object, and lines 149–150 create an **IMPeerImpl** object. Line 151 adds the **IMPeerListener** to the **IMPeerImpl**. The **IMPeerImpl** will post all messages sent by the remote peer to the **IMPeerListener**. Using method **connect** of the **IMService**, line 154 sends a remote reference to the **IMPeerImpl** to the remote peer. Line 155 adds the returned **IMPeer** remote reference to the **IMPeerListener**—this allows the local peer to send messages to remote peer. If this sequence of events throws a **RemoteException**, lines 160–162 inform the user of the error. If the connection succeeds, the service returns an **IMPeer**, and communication occurs as described in earlier sections.

Lines 189–223 create the **Add Locator** menu item in the **File** menu. Selecting this menu item launches a dialog box that prompts the user for the URL of a Jini lookup service to add via unicast discovery. Lines 204–213 add this URL to the list of **LookupLocators**—this results in the client’s registering with the newly added lookup service, and the **PeerList** window lists all other peers registered with the new lookup service.

## 28.10 Compiling and Running the Example

Finally, we can compile and run the peer-to-peer application. This requires several steps. First, compile the classes using **javac**.

Next, compile the remote classes **IMServiceImpl** and **IMPeerImpl** using the **rmic compiler** to produce stub classes (see Chapter 13). Next, place the RMI stub classes that need to be available to other Deitel Instant Messenger clients and lookup services (**IMServiceImpl\_Stub** and **IMPeerImpl\_Stub**) in a JAR file (e.g., **DIM\_dl.jar**) with the proper package structure.

For lookup services to notify our application when services are added or removed, the **ServiceDiscoveryManager** needs to upload a remote-event listener. Change to the root directory of your Web server and execute the following command lines:

```
jar xvf C:\jini1_1\lib\jini-ext.jar net\jini\lookup\Service-
DiscoveryManager$LookupCacheImpl$LookupListener_Stub.class

jar xvf C:\jini1_1\lib\jini-core.jar
net\jini\core\event\RemoteEventListener.class
```

This creates a **net** subdirectory in your Web server’s root directory.

To use the Deitel Instant Messenger, first start the RMI activation daemon, an HTTP Server, and a lookup service (see Chapter 22). To start Deitel Instant Messenger, change to the directory that contains the application’s package structure and execute the following command line:

```
java -Djava.security.policy=policy.all
-Djava.rmi.server.codebase=http://host:port/DIM_dl.jar
com.deitel.advjhttp1.jini.IM.PeerList
```

Substitute the appropriate values for the *host*, *port* and JAR file name (e.g., **DIM\_dl.jar**). The codebase provides the location of the JAR file which contains the RMI stub files that remote peers and lookup services must download.

## 28.11 Improving Deitel Instant Messenger

The Deitel Instant Messenger Jini implementation does not address issues of security and scalability. The **ServiceDiscoveryManager** downloads proxies for every user listed on every known lookup service. As more users and lookup services join the network, network overhead becomes overwhelming. The lack of security and authentication mechanisms forces anonymity on clients, because there is no absolute way of verifying that users are who they claim to be.

There are various ways to address these problems. Filters can limit the number of service proxies that the **ServiceDiscoveryManager** downloads. Lookup services can limit the number of services they manage. The application also could use distributed searches to locate peers (see Section 28.4). This involves sending a request to a known search service, which forwards the request if unable to find the user. The ubiquitous use of digital signatures and public and private keys can enable security and authentication—however, this does not solve the problem of having duplicate user names in a large-scale peer-to-peer network. These solutions are incomplete.

## 28.12 Deitel Instant Messenger with Multicast Sockets

The Deitel Instant messenger uses Jini's **JoinManager** and **ServiceDiscoveryManager** to advertise the existence of each peer and discover other peers. With Jini, a few lines of code implemented this functionality. To adhere to a true peer-to-peer architecture, each peer must run a lookup service. Lookup services require significant amounts of memory and processor time. Because of these performance and memory concerns, we introduce an improved implementation of the Deitel Instant Messenger that uses multicast sockets and a simple, text-based protocol to advertise and find peers in the network.

### 28.12.1 Registering the Peer

In the Jini implementation of the Deitel Instant Messenger, Jini provided the mechanism that allowed peers to sign onto the network and find other peers. If a peer loses its connection without explicitly disconnecting (e.g., by calling method **terminate** of a **JoinManager** instance), the Jini lookup services remove the peer after the service's lease expires. When a peer's lease expires, the Jini lookup service removes the peer's service from the registry—in the Deitel Instant Messenger, the peer disappears from the Peer-List window. Because we are removing Jini from this application, we must implement these mechanisms ourselves.

The first mechanism we implement is class **MulticastSendingThread** (Fig. 28.11). **MulticastSendingThread** multicasts a peer's presence. **MulticastSendingThread** periodically sends multicast packets throughout the network to notify other peers that this peer is still available. Each peer on the receiving end renew's the lease for the multicasting peer. In the event that the multicasting peer stops advertising its presence (e.g., the user quits the peer application), that peer's lease expires. Essentially, the peer ceases to exist on the network.

```
1 // MulticastSendingThread.java
2 // Sends a multicast periodically containing a remote reference
3 // to the IMServiceImpl object
4 package com.deitel.advjhttp1.p2p;
5
6 // Java core packages
7 import java.net.MulticastSocket;
8 import java.net.*;
9 import java.rmi.*;
```

Fig. 28.11 **MulticastSendingThread** broadcasts **DatagramPackets** (part 1 of 4).

```
10 import java.rmi.registry.*;
11 import java.io.*;
12
13 // Deitel core packages
14 import com.deitel.advjhttp1.jini.IM.service.IMServiceImpl;
15 import com.deitel.advjhttp1.jini.IM.service.IMService;
16
17 public class MulticastSendingThread extends Thread
18     implements IMConstants {
19
20     // InetAddress of group for messages
21     private InetAddress multicastNetAddress;
22
23     // MulticastSocket for multicasting messages
24     private MulticastSocket multicastSocket;
25
26     // Datagram packet to be reused
27     private DatagramPacket multicastPacket;
28
29     // stub of local peer
30     private IMService peerStub;
31
32     // flag for terminating MulticastSendingThread
33     private boolean keepSending = true;
34
35     private String userName;
36
37     // MulticastSendingThread constructor
38     public MulticastSendingThread( String myName )
39     {
40         // invoke superclass constructor to name Thread
41         super( "MulticastSendingThread" );
42
43         userName = myName;
44
45         // create a registry on default port 1099
46         try {
47             Registry registry =
48                 LocateRegistry.createRegistry( 1099 );
49             peerStub = new IMServiceImpl( userName );
50             registry.rebind( BINDING_NAME, peerStub );
51         }
52         catch ( RemoteException remoteException ) {
53             remoteException.printStackTrace();
54         }
55
56         try {
57
58             // create MulticastSocket for sending messages
59             multicastSocket =
60                 new MulticastSocket ( MULTICAST_SENDING_PORT );
61
62         }
63
64         catch ( IOException ioException ) {
65             ioException.printStackTrace();
66         }
67
68         // start sending messages
69         start();
70     }
71
72     public void run()
73     {
74         while ( keepSending ) {
75             // create a DatagramPacket to send
76             ...
77
78             // broadcast the DatagramPacket
79             ...
80
81             // sleep for a short time
82             ...
83         }
84     }
85
86     public void stop()
87     {
88         keepSending = false;
89     }
90 }
```

Fig. 28.11 **MulticastSendingThread** broadcasts **DatagramPackets** (part 2 of 4).

```
62         // set TTL for Multicast Socket
63         multicastSocket.setTimeToLive( MULTICAST_TTL );
64
65         // use InetAddress reserved for multicast group
66         multicastNetAddress = InetAddress.getByName(
67             MULTICAST_ADDRESS );
68
69         // create greeting packet
70         String greeting = new String( HELLO_HEADER + userName );
71
72         multicastPacket = new DatagramPacket(
73             greeting.getBytes(), greeting.getBytes().length,
74             multicastNetAddress, MULTICAST_LISTENING_PORT );
75     }
76
77     // MULTICAST_ADDRESS IS UNKNOWN HOST
78     catch ( java.net.UnknownHostException unknownHostException )
79     {
80         System.err.println( "MULTICAST_ADDRESS is unknown" );
81         unknownHostException.printStackTrace();
82     }
83
84     // any other exception
85     catch ( Exception exception )
86     {
87         exception.printStackTrace();
88     }
89 }
90
91 // deliver greeting message to peers
92 public void run()
93 {
94     while ( keepSending ) {
95
96         // deliver greeting
97         try {
98
99             // send greeting packet
100            multicastSocket.send( multicastPacket );
101
102            Thread.sleep( MULTICAST_INTERVAL );
103        }
104
105        // handle exception delivering message
106        catch ( IOException ioException ) {
107            ioException.printStackTrace();
108            continue;
109        }
110        catch ( InterruptedException interruptedException ) {
111            interruptedException.printStackTrace();
112        }
113 }
```

Fig. 28.11 **MulticastSendingThread** broadcasts **DatagramPackets** (part 3 of 4).

```

114      } // end while
115
116      multicastSocket.close();
117
118  } // end method run
119
120 // send goodbye message
121 public void logout()
122 {
123     String goodbye = new String( GOODBYE_HEADER + userName );
124     System.out.println( goodbye );
125     multicastPacket = new DatagramPacket(
126         goodbye.getBytes(), goodbye.getBytes().length,
127         multicastNetAddress, MULTICAST_LISTENING_PORT );
128
129     try {
130         multicastSocket.send( multicastPacket );
131
132         Naming.unbind( BINDING_NAME );
133     }
134
135     // error multicasting
136     catch ( IOException ioException ) {
137         System.err.println("Couldn't Say Goodbye");
138         ioException.printStackTrace();
139     }
140
141     // unbinding may cause many possible exceptions
142     catch ( Exception unbindingException ) {
143         unbindingException.printStackTrace();
144     }
145
146     keepSending = false;
147
148 }
149 }
```

**Fig. 28.11 MulticastSendingThread** broadcasts **DatagramPackets** (part 4 of 4).

**MulticastSendingThread** extends class **Thread**. Lines 47–48 calls method **createRegistry** of class **LocateRegistry** to instantiate an RMI registry on port 1099—the port that **rmiregistry** application normally uses. Line 49 creates a new **IMServiceImpl** object. Line 50 **rebinds** the **IMServiceImpl** object to the RMI registry, using **BINDING\_NAME**—one of many constants defined in interface **IMConstants** (Fig. 28.12), which class **MulticastSendingThread** implements. Figure 28.12 shows the interface **IMConstants**, which defines all the constants used by Deitel Instant Messenger.

```

1 // IMConstants.java
2 // contains constants used by IM application
```

**Fig. 28.12** Interface **IMConstants** defines Deitel-Instant-Messenger constants (part 1 of 2).

```

3  package com.deitel.advjhttp1.p2p;
4
5  public interface IMConstants {
6
7      public static final String MULTICAST_ADDRESS = "228.5.6.10";
8
9      public static final int MULTICAST_TTL = 30;
10
11     // port on local machine for broadcasting
12     public static final int MULTICAST_SENDING_PORT = 6800;
13
14     // port on local machine for receiving broadcasts
15     public static final int MULTICAST RECEIVING_PORT = 6789;
16
17     // port on multicast ip address to send packets
18     public static final int MULTICAST_LISTENING_PORT = 6789;
19
20     public static final String HELLO_HEADER = "HELLOIM: ";
21
22     public static final String GOODBYE_HEADER = "GOODBYE: ";
23
24     // time in milliseconds to wait between each multicast
25     public static final int MULTICAST_INTERVAL = 10000;
26
27     // how many MULTICAST_INTERVALS before LEASE EXPIRATION
28     public static final int PEER_TTL = 5;
29
30     public static final int MESSAGE_SIZE = 256;
31
32     public static String BINDING_NAME = "IMSERVICE";
33
34 }

```

Fig. 28.12 Interface **IMConstants** defines Deitel-Instant-Messenger constants (part 2 of 2).

Lines 59–60 of Fig. 28.11 create a **MulticastSocket** on the port number that constant **MULTICAST\_SENDING\_PORT** defines. Line 63 sets the default *Time To Live (TTL)* for **DatagramPackets** sent through the **MulticastSocket**. Lines 66–67 create an **InetAddress** with the multicast IP address specified by constant **MULTICAST\_ADDRESS**.

Lines 70–74 create a **DatagramPacket** that contains a **String** with the peer's name. **HELLO\_HEADER** informs all peers listening on the multicast port that this peer can receive messages. **MULTICAST\_LISTENING\_PORT** specifies the port on the multicast IP address on which all peers listen. Lines 78–82 catch an **UnknownHostException** if **MULTICAST\_ADDRESS** is an invalid multicast IP address.

Line 100 multicasts the **MulticastPacket** that the constructor generated. Line 102 specifies that the thread should wait **MULTICAST\_INTERVAL** milliseconds between each multicast. Line 116 closes the **MulticastSocket** when the user exits the application.

Lines 123–127 create a **DatagramPacket** that contains a **String** with the **GOODBYE\_HEADER** and the peer's user name. **GOODBYE\_HEADER** indicates that the peer is leaving the network. Lines 130–133 send this **DatagramPacket** and **unbind** the

**IMServiceImpl** associated with **BINDING\_NAME** from the RMI registry. Line 146 sets **boolean keepSending** to **false** to terminate the thread.

### 28.12.2 Finding Other Peers

In the Jini implementation of the Deitel Instant Messenger, the Jini lookup service listed new peers and removed peers that left the network. Class **ServiceDiscoveryManager** updated the application when peers were either added or removed. To implement these mechanisms, we create class **MulticastReceivingThread** (Figure 28.13), which listens for **DatagramPackets** that contain notifications of peers joining and leaving the network.

Lines 48–55 create a **MulticastSocket** on port **MULTICAST RECEIVING\_PORT** and join the multicast group. Line 58 specifies that the **MulticastSocket** should time out receiving a packet takes longer than five seconds. Lines 69–71 start the **LeasingThread** as a daemon thread. We explain **LeasingThread** in greater detail later in this section.

Line 89 receives a **DatagramPacket** from the **MulticastSocket** using by invoking method **receive**. If the call to **receive** times out, lines 93–97 catch the **InterruptedException** that is thrown. Lines 106–107 retrieve the message **String** stored in the received **DatagramPacket**.

```
1 // MulticastReceivingThread.java
2 // Receive and process multicasts from multicast group
3 package com.deitel.advjhttp1.p2p;
4
5 // Java core packages
6 import java.net.MulticastSocket;
7 import java.net.*;
8 import java.io.*;
9 import java.util.*;
10
11 // Deitel packages
12 import com.deitel.advjhttp1.p2p.PeerDiscoveryListener;
13
14 public class MulticastReceivingThread extends Thread
15     implements IMConstants {
16
17     // HashMap containing peer names and time to live
18     // used to implement leasing
19     private HashMap peerTTLMap;
20
21     // LeasingThread reference
22     private LeasingThread leasingThread;
23
24     // object that will respond to peer added or removed events
25     private PeerDiscoveryListener peerDiscoveryListener;
26 }
```

Fig. 28.13 Class **MulticastReceivingThread** uses threads to add and remove peers (part 1 of 6).

```
27 // MulticastSocket for receiving broadcast messages
28 private MulticastSocket multicastSocket;
29
30 // InetAddress of group for messages
31 private InetAddress multicastNetAddress;
32
33 // flag for terminating MulticastReceivingThread
34 private boolean keepListening = true;
35
36 // MulticastReceivingThread constructor
37 public MulticastReceivingThread( String userName,
38     PeerDiscoveryListener peerEventHandler )
39 {
40     // invoke superclass constructor to name Thread
41     super( "MulticastReceivingThread" );
42
43     // set peerDiscoveryListener
44     peerDiscoveryListener = peerEventHandler;
45
46     // connect MulticastSocket to multicast address and port
47     try {
48         multicastSocket =
49             new MulticastSocket( MULTICAST_RECEIVING_PORT );
50
51         multicastNetAddress =
52             InetAddress.getByName( MULTICAST_ADDRESS );
53
54         // join multicast group to receive messages
55         multicastSocket.joinGroup( multicastNetAddress );
56
57         // set 5 second time-out when waiting for new packets
58         multicastSocket.setSoTimeout( 5000 );
59     }
60
61     // handle exception connecting to multicast address
62     catch( IOException ioException ) {
63         ioException.printStackTrace();
64     }
65
66     peerTTLMap = new HashMap();
67
68     // create Leasing thread which decrements TTL of peers
69     leasingThread = new LeasingThread();
70     leasingThread.setDaemon( true );
71     leasingThread.start();
72
73 } // end MulticastReceivingThread constructor
74
75 // listen for messages from multicast group
76 public void run()
77 {
```

Fig. 28.13 Class **MulticastReceivingThread** uses threads to add and remove peers (part 2 of 6).

```
78     while( keepListening ) {
79
80         // create buffer for incoming message
81         byte[] buffer = new byte[ MESSAGE_SIZE ];
82
83         // create DatagramPacket for incoming message
84         DatagramPacket packet = new DatagramPacket( buffer,
85             MESSAGE_SIZE );
86
87         // receive new DatagramPacket (blocking call)
88         try {
89             multicastSocket.receive( packet );
90         }
91
92         // handle exception when receive times out
93         catch ( InterruptedIOException interruptedIOException ) {
94
95             // continue to next iteration to keep listening
96             continue;
97         }
98
99         // handle exception reading packet from multicast group
100        catch ( IOException ioException ) {
101            ioException.printStackTrace();
102            break;
103        }
104
105        // put message data into String
106        String message = new String( packet.getData(),
107            packet.getOffset(), packet.getLength() );
108
109        // ensure non-null message
110        if ( message != null ) {
111
112            // trim extra whitespace from end of message
113            message = message.trim();
114
115            System.out.println( message );
116
117            // decide if goodbye or hello
118            if ( message.startsWith( HELLO_HEADER ) ) {
119                processHello(
120                    message.substring( HELLO_HEADER.length() ),
121                    packet.getAddress().getHostAddress()
122                );
123            }
124
125            else if ( message.startsWith( GOODBYE_HEADER ) ) {
126                processGoodbye( message.substring(
127                    GOODBYE_HEADER.length() ) );
128            }
129        } // end if
```

Fig. 28.13 Class **MulticastReceivingThread** uses threads to add and remove peers (part 3 of 6).

```
130         } // end while
131
132     // leave multicast group and close MulticastSocket
133     try {
134         multicastSocket.leaveGroup( multicastNetAddress );
135         multicastSocket.close();
136     }
137
138     // handle exception leaving group
139     catch ( IOException ioException ) {
140         ioException.printStackTrace();
141     }
142
143 }
144
145
146 // process hello message from peer
147 public void processHello( String peerName,
148     String registryAddress )
149 {
150     registryAddress += ( "/" + BINDING_NAME );
151     synchronized( peerTTLMap )
152     {
153
154         // if it is a new peer, call peerAdded event
155         if ( !peerTTLMap.containsKey( peerName ) ) {
156             peerDiscoveryListener.peerAdded( peerName,
157                 registryAddress );
158         }
159
160         // add to map or if present, refresh TTL
161         peerTTLMap.put( peerName, new Integer( PEER_TTL ) );
162     }
163 }
164
165
166 // process goodbye message from peer
167 public void processGoodbye( String peerName )
168 {
169     synchronized( peerTTLMap )
170     {
171         System.out.println( "Removing peer" + peerName );
172         if ( peerTTLMap.containsKey( peerName ) ) {
173             peerDiscoveryListener.peerRemoved( peerName );
174             peerTTLMap.remove( peerName );
175         }
176     }
177 }
178
179 // periodically decrements the TTL of peers listed
180 private class LeasingThread extends Thread
181 {
```

Fig. 28.13 Class **MulticastReceivingThread** uses threads to add and remove peers (part 4 of 6).

```
182     public void run()
183     {
184         while ( keepListening )
185         {
186             // sleep
187             try {
188                 Thread.sleep( MULTICAST_INTERVAL );
189             }
190
191             // InterruptedException may interrupt Thread Sleep
192             catch ( InterruptedException interruptedException ) {
193                 interruptedException.printStackTrace();
194             }
195
196             // lock hashmap while decrementing TTL values
197             synchronized( peerTTLMap ) {
198
199                 // decrement peers
200                 Iterator peerIterator =
201                     peerTTLMap.entrySet().iterator();
202
203                 while ( peerIterator.hasNext() ) {
204                     // make new TTL of peer
205                     Map.Entry tempMapEntry =
206                         ( Map.Entry ) peerIterator.next();
207
208                     Integer tempIntegerTTL =
209                         ( Integer ) tempMapEntry.getValue();
210                     int tempIntTTL = tempIntegerTTL.intValue();
211
212                     // decrement TTL
213                     tempIntTTL--;
214
215                     // if lease expired, remove peer
216                     if ( tempIntTTL < 0 ) {
217                         peerDiscoveryListener.peerRemoved(
218                             ( String ) tempMapEntry.getKey() );
219                         peerIterator.remove();
220                     }
221
222                     // otherwise set TTL of peer to new value
223                     else
224                         tempMapEntry.setValue(
225                             new Integer( tempIntTTL ) );
226
227                 } // end while iterating through peers
228
229             } // end synchronized
230
231         } // end while in run method
232
233     } // end run method
```

Fig. 28.13 Class **MulticastReceivingThread** uses threads to add and remove peers (part 5 of 6).

```

234     } // end class LeasingThread
235
236     // stop listening for multicasts
237     public void logout()
238     {
239         {
240             // terminate thread
241             keepListening = false;
242         }
243     }

```

**Fig. 28.13** Class **MulticastReceivingThread** uses threads to add and remove peers (part 6 of 6).

Lines 118–123 call method **processHello** (lines 147–164) if the message **String** begins with constant **HELLO\_HEADER**. Lines 125–127 call method **processGoodbye** (lines 167–177) if the message starts with **GOODBYE\_HEADER**. When the **while** loop terminates, lines 134–187 unsubscribe from the multicast group and close the socket.

Method **processHello** handles messages that contain the **HELLO\_HEADER**. Line 150 appends **BINDING\_NAME** to the given **String** containing the IP address of the peer that sent the “hello” message. This forms an RMI URL with which the peer can connect to the newly joined peer. Line 151 synchronizes object **HashMap peerTTLMap**, to prevent other threads from accessing and modifying **peerTTLMap**. This **HashMap** stores peer names as keys and stores the peer lease-expiration times as values. Line 155 tests if the peer name specified in the “hello” message is in **peerTTLMap**. If the peer is not in **peerTTLMap**, line 156 calls method **peerAdded** of the **peerDiscoveryListener** object. Each **MulticastReceivingThread** contains a reference of an object that implements interface **PeerDiscoveryListener** (Fig. 28.14).

Methods **peerAdded** (line 8) and **peerRemoved** (line 11) inform the **PeerDiscoveryListener** implementation that a peer has entered, or has been removed from, the multicast group, respectively. Line 161 of class **MulticastReceivingThread** **puts** an entry into **peerTTLMap** that contains the peer’s name and TTL (specified by **PEER\_TTL**). If the peer is already in **peerTTLMap**, line 161 replaces the pre-existing entry with a new entry, which renews the peer’s lease by resetting its Time to Live (TTL). Line 174 of class **MulticastReceivingThread** removes a peer from **peerTTLMap**. Because every peer continuously multicasts “hello” packets, datagram packets may be duplicated. Therefore, line 172 first checks if the given peer is in **peerTTLMap** before attempting to remove it. Line 173 calls method **peerRemoved** on the registered **PeerDiscoveryListener** to inform it that a peer has left the multicast group.

```

1 // PeerDiscoveryListener.java
2 // Interface for listening to peerAdded or peerRemoved events
3 package com.deitel.advjhtp1.p2p;
4
5 public interface PeerDiscoveryListener {
6

```

**Fig. 28.14** Interface **PeerDiscoveryListener** listens for when peers are added and removed from peer groups (part 1 of 2).

```

7  // add peer with given name and ip address
8  public void peerAdded( String name, String peerStubAddress );
9
10 // remove peer with given name
11 public void peerRemoved( String name );
12
13 }

```

Fig. 28.14 Interface **PeerDiscoveryListener** listens for when peers are added and removed from peer groups (part 2 of 2).

Lines 180–235 define inner class **LeasingThread**. A single-leasing-thread instance periodically decrements the TTL of each peer in the **peerTTLMap**. Line 197 synchronizes **peerTTLMap** to prevent modification conflicts between threads trying to access **peerTTLMap** concurrently. Lines 200–201 obtain an **Iterator** object of **peerTTLMap**'s entries. Lines 203–227 decrement the TTL of each entry in **peerTTLMap**. Lines 208–210 obtains an **int** that contains a peer's TTL—line 213 decrements the TTL value. Line 216 checks if the modified TTL is less than zero, which indicates that the peer's lease has expired. Lines 217–218 then pass the expired peer's name as an argument to method **peerRemoved** of the **PeerDiscoveryListener** object. Line 219 calls **Iterator** method **remove**, which removes the current entry from **peerTTLMap**. If the modified TTL is greater than (or equal to) zero, the peer's lease is still active, so lines 224–225 set the peer's TTL to the newly decremented value. Method **logout** (lines 238–242) enables an outside object to terminate the **MulticastReceivingThread**.

To use classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger, we had to modify class **PeerList** from our Instant Messenger Jini implementation. Figure 28.15 contains the modified **PeerList** listing.

```

1 // PeerList.java
2 // Starts broadcasting and receiving threads
3 // and lists all IM peers in a window
4 package com.deitel.advjhttp1.p2p;
5
6 // Java core packages
7 import java.awt.*;
8 import java.awt.event.*;
9 import java.net.MalformedURLException;
10 import java.util.*;
11 import java.util.List;
12 import java.io.IOException;
13 import java.rmi.*;
14
15 // Java extension packages
16 import javax.swing.*;
17 import javax.swing.event.*;
18

```

Fig. 28.15 Modified **PeerList** enables the use of classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger (part 1 of 6).

```
19 // Deitel Packages
20 import com.deitel.advjhttp1.jini.IM.service.IMService;
21 import com.deitel.advjhttp1.jini.IM.client.IMPeerListener;
22 import com.deitel.advjhttp1.jini.IM.IMPeerImpl;
23 import com.deitel.advjhttp1.jini.IM.IMPeer;
24
25 public class PeerList extends JFrame
26     implements PeerDiscoveryListener, IMConstants {
27
28     // initialize userName to anonymous
29     private String userName = "anonymous";
30     private MulticastSendingThread multicastSender;
31     private MulticastReceivingThread multicastReceiver;
32
33     // list variables
34     private DefaultListModel peerNames;      // contains peer names
35     private List peerStubAddresses;          // contains peer stubs
36     private JList peerJList;
37
38     // add peer name and peer stub to lists
39     public void peerAdded( String name, String peerStubAddress )
40     {
41         // add name to peerNames
42         peerNames.addElement( name );
43
44         // add stub to peerStubAddresses
45         peerStubAddresses.add( peerStubAddress );
46
47     } // end method peerAdded
48
49
50     // removes services from PeerList GUI and data structure
51     public void peerRemoved( String name )
52     {
53         // remove name from peerNames
54         int index = peerNames.indexOf( name );
55         peerNames.removeElementAt( index );
56
57         // remove stub from peerStubAddresses
58         peerStubAddresses.remove( index );
59
60     } // end method peerRemoved
61
62     // constructor
63     public PeerList()
64     {
65         super( "Peer List" );
66
67         // get desired userName
68         userName = JOptionPane.showInputDialog(
69             PeerList.this, "Please enter your name: " );
```

Fig. 28.15 Modified **PeerList** enables the use of classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger (part 2 of 6).

```
70      // change title of window
71      setTitle( userName + "'s Peer List Window" );
72
73
74      // Init List data structures
75      peerNames = new DefaultListModel();
76      peerStubAddresses = new ArrayList();
77
78      // init components
79      Container container = getContentPane();
80      peerJList = new JList( peerNames );
81      peerJList.setVisibleRowCount( 5 );
82      JButton connectButton = new JButton( "Connect" );
83
84      // do not allow multiple selections
85      peerJList.setSelectionMode(
86          ListSelectionModel.SINGLE_SELECTION );
87
88      // set up event handler for connectButton
89      connectButton.addActionListener(
90          new ActionListener() {
91
92              public void actionPerformed( ActionEvent event )
93              {
94                  int itemIndex = peerJList.getSelectedIndex();
95
96                  String stubAddress =
97                      ( String ) peerStubAddresses.get( itemIndex );
98
99                  // get RMI reference to IMService and IMPeer
100                 try {
101
102                     IMService peerStub =
103                         ( IMService ) Naming.lookup( "rmi://" +
104                             stubAddress );
105
106                     // set up gui and my peerImpl
107                     IMPeerListener gui =
108                         new IMPeerListener( userName );
109                     IMPeerImpl me =
110                         new IMPeerImpl( userName );
111                     me.addListener( gui );
112
113                     // Connect myGui to remote IMPeer object
114                     IMPeer myPeer = peerStub.connect( me );
115                     gui.addPeer( myPeer );
116                 }
117             }
```

Fig. 28.15 Modified **PeerList** enables the use of classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger (part 3 of 6).

```
118         // malformedURL passed to lookup
119         catch( MalformedURLException exception ) {
120             JOptionPane.showMessageDialog(
121                 null, "Stub address incorrectly formatted" );
122             exception.printStackTrace();
123         }
124
125
126         // Remote object not bound to remote registry
127         catch ( NotBoundException notBoundException ) {
128             JOptionPane.showMessageDialog(
129                 null, "Remote object not present in Registry" );
130             notBoundException.printStackTrace();
131         }
132
133         // connecting may cause RemoteException
134         catch ( RemoteException remoteException ) {
135             JOptionPane.showMessageDialog(
136                 null, "Couldn't Connect" );
137             remoteException.printStackTrace();
138         }
139
140     } // end method actionPerformed
141
142 } // end ActionListener anonymous inner class
143
144 ); // end connectButton actionPerformed
145
146 // set up File menu
147 JMenu fileMenu = new JMenu( "File" );
148 fileMenu.setMnemonic( 'F' );
149
150 // about Item
151 JMenuItem aboutItem = new JMenuItem( "About..." );
152 aboutItem.setMnemonic( 'A' );
153 aboutItem.addActionListener(
154     new ActionListener() {
155         public void actionPerformed( ActionEvent event )
156         {
157             JOptionPane.showMessageDialog( PeerList.this,
158                 "Deitel Instant Messenger",
159                 "About", JOptionPane.PLAIN_MESSAGE );
160         }
161     }
162 );
163
164 fileMenu.add( aboutItem );
165
166 // set up JMenuBar and attach File menu
167 JMenuBar menuBar = new JMenuBar();
168 menuBar.add ( fileMenu );
```

Fig. 28.15 Modified **PeerList** enables the use of classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger (part 4 of 6).

```
169     setJMenuBar( menuBar );
170
171     // handle window closing event
172     addWindowListener(
173
174         new WindowAdapter() {
175
176             public void windowClosing( WindowEvent w )
177             {
178                 System.out.println( "CLOSING WINDOW" );
179
180                 // disconnects from lookup services
181                 multicastSender.logout();
182                 multicastReceiver.logout();
183
184                 // join threads
185                 try {
186                     multicastSender.join();
187                     multicastReceiver.join();
188                 }
189                 catch( InterruptedException interruptedException ) {
190                     interruptedException.printStackTrace();
191                 }
192
193                 System.exit( 0 );
194             }
195         );
196     );
197
198     // lay out GUI components
199     peerJList.setFixedCellWidth( 100 );
200     JPanel inputPanel = new JPanel();
201     inputPanel.add( connectButton );
202
203     container.add( new JScrollPane( peerJList ) ,
204         BorderLayout.NORTH );
205     container.add( inputPanel, BorderLayout.SOUTH );
206
207     // Initialize threads
208     try {
209
210         multicastReceiver =
211             new MulticastReceivingThread( userName, this );
212         multicastReceiver.start();
213
214         multicastSender =
215             new MulticastSendingThread( userName );
216         multicastSender.start();
217
218     }
219 }
```

Fig. 28.15 Modified **PeerList** enables the use of classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger (part 5 of 6).

```

220     // catch all exceptions and inform user of problem
221     catch ( Exception managerException ) {
222         JOptionPane.showMessageDialog( null,
223             "Error initializing MulticastSendingThread" +
224             "or MulticastReceivingThread" );
225         managerException.printStackTrace();
226     }
227 }
228
229 public static void main( String args[] )
230 {
231     PeerList peerlist = new PeerList();
232     peerlist.setSize( 100, 170 );
233     peerlist.setVisible( true );
234 }
235 }
```

**Fig. 28.15** Modified **PeerList** enables the use of classes **MulticastReceivingThread** and **PeerDiscoveryListener** in the Deitel Instant Messenger (part 6 of 6).

Class **PeerList** implements interface **PeerDiscoveryListener**—the Jini version implemented interface **ServiceDiscoveryListener**. Lines 210–211 create a **MulticastReceivingThread** and passes the **this** reference as a **PeerDiscoveryListener**—line 212 starts this thread. Lines 214–215 create a **MulticastSendingThread** specifying the user name—line 216 starts this thread.

Lines 39–47 implement method **PeerAdded**, which takes two **Strings**—**name** and **peerStubAddress**. Parameter **name** specifies the peer’s name. Parameter **peerStubAddress** is a URL-formatted **String** that contains the information needed to make a **Naming.lookup** call on the remote peer. The **Naming.lookup** call obtains an **IMService** remote reference. Lines 42–45 store the **IMService** remote reference.

Lines 51–60 implement method **peerRemoved**. Lines 54–58 remove the information of the given peer from **peerNames** and **peerStubAddresses**.

Lines 89–141 specify the **ActionListener** for the **JButton** that we use to connect peers. Line 96–97 obtains the **peerStubAddress** of the selected peer in the **JList**. Lines 102–104 calls method **Naming.lookup** to obtain a reference to the remote peer’s **IMService** object from the RMI registry. The code in lines 106–140 works similarly to that of the previous Deitel Instant Messenger implementation.

Lines 176–194 specify instructions to execute when the user closes the **PeerList** window. Lines 180–181 terminate each thread by calling method **logout**. Lines 186–187 **join** each thread, thereby blocking until each thread terminates. Line 193 exits the program.

## 28.13 Introduction to JXTA

Sun Microsystems, Inc. created Project JXTA<sup>3</sup> as a response to the growing popularity of peer-to-peer applications. Project JXTA strives to create a standard, low-level, platform and language-independent protocol that promotes interoperability among peer-to-peer applications. The current JXTA implementation is written in Java, but developers can imple-

3. For more information, see [www.jxta.org](http://www.jxta.org).

ment JXTA in any programming language. JXTA provides a foundation from which developers can build any type of P2P application.

JXTA attempts to solve the following problems of peer-to-peer applications:

1. Security/Authentication—Large peer-to-peer network applications, such as AOL Instant Messenger and MSN Instant Messenger, use central servers to bootstrap users onto the network. This bootstrapping ensures, to some degree, that the same person uses a particular online identity.
2. Peer Discovery—Without a central server, it is difficult to realize the presence of other peers on the network. Multicasting, as used by Jini, is not a viable solution outside the LAN setting.
3. Network Incompatibility—Currently, each popular peer-to-peer application yields a set of proprietary protocols that prevent compatibility with other peer-to-peer networks. For example, the millions of users on the AIM platform cannot communicate with Yahoo Instant Messenger users. Most new users opt for the peer-to-peer application with the largest following.
4. Platform Incompatibility—Software developers must rewrite the low-level core aspects of their peer-to-peer applications for each platform they wish to support. Wireless phones and other mobile devices usually have a limited selection of P2P applications, if any.

JXTA attempts to solve these problems by standardizing the low-level protocols that govern peer-to-peer applications. JXTA is designed to be a general infrastructure, rather than a special-purpose one. Therefore, developers can use JXTA to implement virtually any type of P2P application. Because all JXTA-based P2P applications use identical low-level protocols, they will be compatible with one another.

Networks built with the JXTA protocols consist of three basic types of entities—*peer/peer groups, advertisements and pipes/messages*. Each JXTA runtime environment associates each entity's name and network address with a unique 128-bit identifier.

A *peer* is any entity that uses JXTA protocols (Fig. 28.16) to communicate with other peers. Each peer need support only some of the protocols, so devices with low processing power and memory can participate in JXTA networks (albeit with limited functionality). *Peer groups* are logical constructs that represent sets of peers. JXTA specifies only two rules regarding peer groups

1. peers can join or leave groups
2. the group administrator, if the group has one, controls access to the group.

All peers are part of the World Peer Group. Membership in the World Peer Group does not imply that each peer can discover and communicate with every other peer on the network.

*Advertisements* are XML documents that perform a function similar to that of multicast packets in Jini. An entity in the JXTA network advertises itself to notify others of its existence by sending XML documents formatted according to JXTA specifications.

At the simplest level, *pipes* are unreliable one-way communication channels. More sophisticated pipes may be reliable and multi-directional. Earlier in the chapter, we mentioned that an RMI peer reference allows one-way communication with that peer. Pipes perform similarly. Two peers communicate by configuring two pipes that “flow” in opposite directions. Each peer communicates by sending *Messages* to the other peer through the

pipe. JXTA specifies the Messages' structure. The most recent JXTA implementation uses XML Messages. The developers of JXTA use XML because of its portability. However, JXTA does not restrict the Message format to XML.

JXTA is still in development and has not yet resolved all of the problems with peer-to-peer applications. The implementation of peer discovery and security measures continues to progress. JXTA suggests that peer discovery use a combination of *LAN-based discovery*, *discovery through invitation*, *cascaded discovery* and *rendezvous discovery*. Jini illustrates one means of LAN-based discovery. In LAN-based discovery, peers in a local network discover each other automatically by multicasting. Discovery through invitation occurs when a peer receives a message from a previously unknown peer. Cascaded discovery is a distributed-search mechanism—similar to that of Gnutella. Rendezvous discovery is the creation of certain well-known sites that provide network addresses of many users on the network to bootstrap new users.

For further information on the current state of JXTA and other P2P technologies, see the resources provided in Section 28.14.

## 28.14 Internet and World Wide Web Resources

### [www.openp2p.com](http://www.openp2p.com)

*openp2p.com* is a Web site that is part of the O'Reilly Network. This online resource provides articles and links about peer-to-peer technologies.

### [www.clip2.com](http://www.clip2.com)

This site provides information and statistics regarding the popular and upcoming peer-to-peer technologies. This site also provides columns that explain how various peer-to-peer protocols work.

### [www.peer-to-peerwg.org](http://www.peer-to-peerwg.org)

This page is published by the peer-to-peer working group.

Protocol	Function
Peer Discovery	Peers use this protocol to find other entities in the JXTA network by searching for advertisements.
Peer Resolver	Peers that help a search process (e.g., higher bandwidth, capacity storage, etc.) implement this protocol.
Peer Information	Peers obtain information about other peers via this protocol.
Peer Membership	Peers use this protocol to learn about the requirements of groups, how to apply for membership, how to modify their membership and how to quit a group. Authentication and security are implemented through this protocol.
Pipe Binding	Peers can connect pipes to one another, via advertisements, through this protocol.
Endpoint Routing	Peer routers implement this protocol to provide other routing services to other peers (e.g., tunneling through a firewall).

Fig. 28.16 JXTA low-level protocols.

**[www.jxta.org](http://www.jxta.org)**

This is the official Web site for Project JXTA and contains the newest downloads of the source code and opportunities to participate in developing JXTA.

**[www.peerintelligence.com](http://www.peerintelligence.com)**

This Web site publishes columns that discuss how peer-to-peer technologies are being developed into enterprise solutions. This site focuses on how businesses can use peer-to-peer applications.

**[www.peertal.com](http://www.peertal.com)**

This site presents columns that discuss peer-to-peer technologies.

## SUMMARY

- In a peer-to-peer (P2P) network architecture, each node can perform both client and server functions. Such networks distribute processing and information to many computers, thus reclaiming otherwise wasted computing power and storage space and eliminating central points of failure.
- Developers may implement P2P applications using various technologies, such as multicast sockets.
- Many networks operate on the principle that computers should be segregated by function.
- Instead of segregating computers by function, in P2P networks all computers act as both clients and servers.
- The concept of P2P applications is similar to that of the telephone system—a single user can both speak (send information) and listen (receive information).
- Many network applications do not fall neatly into either client/server or peer-to-peer categories.
- One major weakness of this centralized system is the dependency on the central server. If the central node (i.e., server) fails, so does the entire application.
- The capabilities of the server limit the overall performance of the application.
- Centralized architectures simplify management tasks, such as monitoring user access, by providing single points of network control.
- True P2P applications are completely decentralized and do not suffer from the same deficiencies as applications that depend on centralized servers.
- Some P2P applications leverage distributed computational power.
- Peer-to-peer architectures allow real-time searches that return up-to-date results.
- Peer-to-peer searches reflect the status of the network at the time of the query.
- In peer-to-peer networks determining who is on the network at any instant is difficult.
- Real-time searches are slower and increase network traffic, because every query must propagate throughout the entire network.
- A true client/server network is completely centralized, whereas a true peer-to-peer application is completely decentralized.
- Many applications adopt aspects of both networking styles to achieve specific goals.
- Peer discovery is the act of finding peers in a P2P application.
- Decentralizing an application makes peer discovery and searching for information difficult.
- Distributed searches make networks more robust by removing single points of failure, such as central servers.
- Information found via distributed searches is up-to-date because it reflects the current state of the network.

## TERMINOLOGY

authentication	P2P (peer-to-peer) application
bootstrapping	peer
central server	peer discovery
centralization	peer group
client/server computing	pipe
decentralization	proxy
distributed search	real-time search
Freenet	Remote Method Invocation (RMI)
Gnutella	search engine
Jini	search hub
JXTA	Time to Live (TTL)
lookup service	unicast discovery
multicast socket	

## SELF-REVIEW EXERCISES

**28.1** Fill in the blanks in each of the following statements:

- For the Deitel Instant Messenger to send a message to a remote peer, it must hold a \_\_\_\_\_ to the remote peer.
- Pipes are \_\_\_\_\_ one-way communication channels.
- Large peer-to-peer networks, such as AOL Instant Messenger and MSN Instant Messenger, use \_\_\_\_\_ to bootstrap users onto the network.
- Peer discovery is the act of \_\_\_\_\_ and \_\_\_\_\_ with other peers.
- Class \_\_\_\_\_ can be used to cache proxies of all services listed in known lookups services.

**28.2** State whether each of the following is *true* or *false*. If *false*, explain why.

- In a peer-to-peer application, each peer performs both client and server functions.
- One remote reference provides one-way communication.
- Jini is the best tool for designing peer-to-peer applications.
- Client/Server network architecture is the most efficient way of organizing groups of computers.
- The **ServiceDiscoveryManager** needs to export certain classes to asynchronously notify **ServiceDiscoveryListeners** of **ServiceDiscoveryEvents**.
- Broadcasting is a viable solution to the problem of discovering other peers on a large-scale peer-to-peer network.
- All network applications are either peer-to-peer or client/server.

## ANSWERS TO SELF-REVIEW EXERCISES

**28.1** a) reference.      b) unreliable.      c) central servers.      d) finding, connecting.  
e) **ServiceDiscoveryManager**.

- 28.2** a) True.  
b) True.  
c) False. Implementing authentication, security and large-scale networks is difficult in Jini. There is no automatic means of peer discovery by distributed search.  
d) False. Client/server computing wastes the unused processing power and storage space of the client computers.  
e) True.

- f) False. Broadcasting is an inefficient way for computers to announce their existence in a large network. As the number of computers in a network grow, broadcasting creates too much network traffic to be a viable solution.
- g) False. Many applications include elements of both peer-to-peer applications and client/server applications.

## EXERCISES

**28.3** Modify Deitel Instant Messenger so that it can be used to send image files and display them on the remote computer.

**28.4** Modify Deitel Instant Messenger so that it plays a user-selected sound file when an incoming message is received.

**28.5** Deitel Instant Messenger can create multiple conversations with the same person. Modify Deitel Instant Messenger so that it will not allow multiple conversations with the same person simultaneously.

**28.6** Modify Deitel Instant Messenger so that peers notify any peers with whom they are speaking when they close the conversation window. Remote peers will reconnect to continue sending messages.

**28.7** Expand Deitel Instant Messenger so that users can have a user profile. Enable users to search for users with keywords.

# 29

## Introduction to Web Services and SOAP

### Objectives

- To understand the Simple Object Access Protocol (SOAP) and how it uses XML.
- To understand the structure of a SOAP message.
- To be able to write Java applications that send and receive SOAP messages.

*Nothing happens until something is sold.*

Arthur H. Motley

*Men are going to have to learn to be managers in a world where the organization will come close to consisting of all chiefs and one Indian. The Indian, of course, is the computer.*

Thomas L. Whisler

*...it is always the simple that produces the marvelous.*

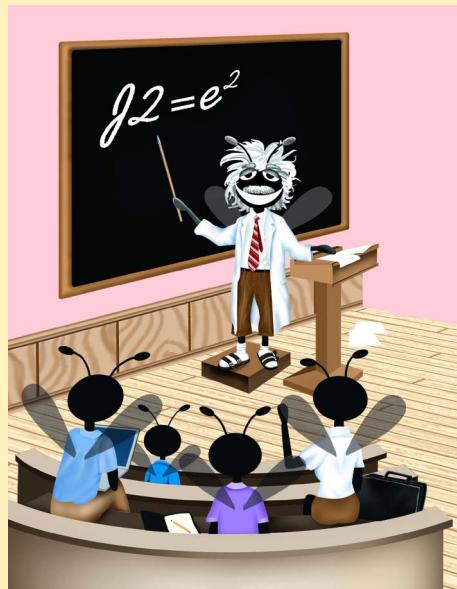
Amelia Barr

*Resemblance reproduces the formal aspect of objects...*

Ching Hao

*...if the simple things of nature have a message that you understand, rejoice, for your soul is alive...*

Eleonora Duse



## Outline

- 29.1 Introduction**
- 29.2 Simple Object Access Protocol (SOAP)**
- 29.3 SOAP Weather Service**
- 29.4 Internet and World Wide Web Resources**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### 29.1 Introduction

*Interoperability*, or seamless communication and interaction between different software systems, is a primary goal of many businesses and organizations that rely heavily on computers and electronic networks. Many applications use the Internet to transfer data. Some of these applications run on client systems with little processing power, so they invoke method calls on remote machines to process data. Many applications use proprietary data specifications, which makes communication with other applications difficult, if not impossible. The majority of applications also reside behind *firewalls*—security barriers that restrict communication between networks. The *Simple Object Access Protocol (SOAP)* is a protocol that addresses these problems. Combining the powers of HTTP and XML, it provides a fully extensible mode of communication between software systems.

*Web Services* are an emerging area of distributed computing. Sun Microsystems' *Open Net Environment (ONE)* and Microsoft Corporation's *.NET* initiative are frameworks for writing and deploying Web services. There are several definitions of a Web service. A Web service can be any Web-accessible application, such as a Web page with dynamic content. A narrower definition of a Web service is an application that exposes a public interface usable by other applications over the Web. Sun's ONE requires Web services to be accessible through HTTP and other Web protocols, to communicate with XML-based messages and to be available through lookup services. SOAP provides the XML communication in many Web services. Web services can provide great interoperability between diverse systems.<sup>1</sup>

A hypothetical Web service designed for the Sun ONE architecture might take a form in which a service registry publishes a description of the Web service as a *Universal Description, Discovery and Integration (UDDI)* document. The client, such as a Web browser or Java GUI client, searches a directory service for a needed Web service. The client uses the information it receives through the lookup service to send an XML message via HTTP to the Web server hosting the Web service. A servlet processes the client request. The servlet then accesses an application server that provides Enterprise Java Beans. The EJBs in turn access a database that stores the Web service's information. After accessing the database, the EJB responds to the servlet with the requested information. The servlet formats the information for the client (e.g. creates a JavaServer Page). The HTTP server sends an XML response back to the client. The client then parses the response and displays the information for the user.<sup>1</sup>

The great potential of Web services does not lie with the technology used to create them. HTTP, XML and the other protocols used by Web services are not new. The interoperability and scalability of Web services means developers can rapidly create large applications and larger Web services from small Web services. Sun's Open Net Environment describes an architecture for creating *smart Web services*. Smart Web services share a common operating environment with one another. By sharing context, smart Web services can perform common

authentication for financial transactions, provide location-specific recommendations and directions, etc., among e-businesses. At the time of this writing, there are two major obstacles in the way of developing smart Web services. There do not yet exist widely accepted standards for sharing context between Web services or ensuring the security and privacy of Web-service transactions.

## 29.2 Simple Object Access Protocol (SOAP)

IBM, Lotus Development Corporation, Microsoft, DevelopMentor and Userland Software developed and drafted SOAP, which is an HTTP-XML-based protocol that enables applications to communicate over the Internet, by using XML documents called *SOAP messages*. SOAP is compatible with any object model, because it includes only functions and capabilities that are absolutely necessary for defining a communication framework. Thus, SOAP is both platform and software independent, and any programming language can implement it. SOAP supports transport using almost any conceivable protocol. For example, SOAP binds to HTTP and follows the HTTP request-response model. SOAP also supports any method of encoding data, which enables SOAP-based applications to send virtually any type information (e.g., images, objects, documents, etc.) in SOAP messages.

A SOAP message contains an *envelope*, which describes the content, intended recipient and processing requirements of a message. The optional **header** element of a SOAP message provides processing instructions for applications that receive the message. For example, for implementations that support transactions, the header could specify details of that transaction. The header also can incorporate routing information. Through the header, more complex protocols can be built onto SOAP. Header entries can modularly extend the message for purposes such as authentication, transaction management and payment. The body of a SOAP message contains application-specific data for the intended recipient of the message.

SOAP has the ability to make a *Remote Procedure Call (RPC)*, which is a request made to another machine to run a task. The RPC uses an XML vocabulary to specify the method to be invoked, any parameters the method takes and the Universal Resource Identifier (URI) of the target object. An RPC call naturally maps to an HTTP request, so an HTTP **post** sends the message. A SOAP-response message is an HTTP-response document that contains the results of the method call (e.g., returned values, error messages, etc.). SOAP also supports *asynchronous RPC*, in which program that invokes the RPC does not wait for a response from the remote procedure.

At the time of this writing, SOAP is still under development, and many of the technologies that build on it are in the early stages of development. To realize the benefits of SOAP, industry must establish higher-level specifications and standards that use this technology. Nevertheless, SOAP is the leading industry standard for an XML-distributed computing infrastructure, providing previously nonexistent extensibility and interoperability.

Figure 29.1–Fig. 29.4 present a SOAP example using Apache's SOAP implementation API, version 2.2 (available at [xml.apache.org/soap](http://xml.apache.org/soap)). The SOAP RPC requires a servlet engine, such as Tomcat ([jakarta.apache.org](http://jakarta.apache.org)) and Apache's Xerces parser for Java (available at [xml.apache.org/xerces-j/index.html](http://xml.apache.org/xerces-j/index.html)). The SOAP documentation ([docs/install/index.html](http://docs.install/index.html)) includes installation instructions for both the server and the client.

Figure 29.1 shows class **SimpleService**, which resides on the server and contains method **getWelcome**. The Java application in Fig. 29.4 invokes this method using an RPC.

```
1 // Fig. 29.1: SimpleService.java
2 // Implementation for the requested method on the server
3
4 public class SimpleService {
5
6     public String getWelcome( String message ) throws Exception
7     {
8         String text =
9             "Welcome to SOAP! \nHere is your message: " + message;
10
11        return text;    // response
12    }
13 }
```

Fig. 29.1 Class **SimpleService**.

Method **getWelcome** (lines 6–12) returns a **String** when invoked. To make this method available to clients (i.e., to facilitate RPC), we need to provide the server with the name of the method that processes the request—i.e., we must *deploy the service*.

To deploy the service, first copy the **SimpleService.class** file into the **jakarta-tomcat/classes** directory. If you created a Java Archive (JAR) file, copy the JAR file into the **jakarta-tomcat/lib** directory. Create the **classes** or **lib** directories if they do not exist. Jakarta-Tomcat includes files in these directories in the **CLASSPATH**.

Deploy the service with the XML-SOAP administration tool included in the SOAP package (located in the directory **webapps/soap**). To run this application, type the URL **localhost:8080/soap/admin** into a Web browser. Figure 29.2 and Fig. 29.3 show the administration tool that allows you to deploy, remove and list services. The **ID** field in Fig. 29.2 contains a URI (**urn:xml-simple-message**) that identifies the service to the client. This URI is programmer defined. If one service has the same URI as another, the client cannot differentiate between them; consequently, errors may occur. The **Scope** field specifies the lifetime of the object created (on the server) for serving the SOAP request. The object can exist for the duration of the **Request**, **Session** or **Application**. **Request** denotes that the server deletes the object after it sends the response, **Session** indicates that the object persists for the duration of the client’s session with the server. **Application** signifies that the object is available for all requests throughout the lifetime of the application. The **Methods** field (Fig. 29.2) specifies the methods available for a SOAP request—in this case, method **getWelcome**. The **Provider Type** field specifies the service implementation language. Languages supported include Java, JavaScript, Perl and Bean Markup Language (BML). For the examples in this chapter, we use Java. In the **Provider Class** field we specify the class that implements the service—**SimpleService**. The **Script Language**, **Script File** and **Script** fields are used only for services implemented in a supported scripting language. The **Type Mapping** field allows manual mapping of Java types to XML. The Apache SOAP implementation provides default mappings for most Java types and for Java classes that follow the JavaBeans design patterns. After completing the form, click the **Deploy** button on the bottom of the form to deploy the service. Click the **List** button, which lists the services, to confirm that the service deployed successfully (Fig. 29.3). Instructions for other methods of deployment (such as using the command line) are provided in **docs/guide/index.html**.

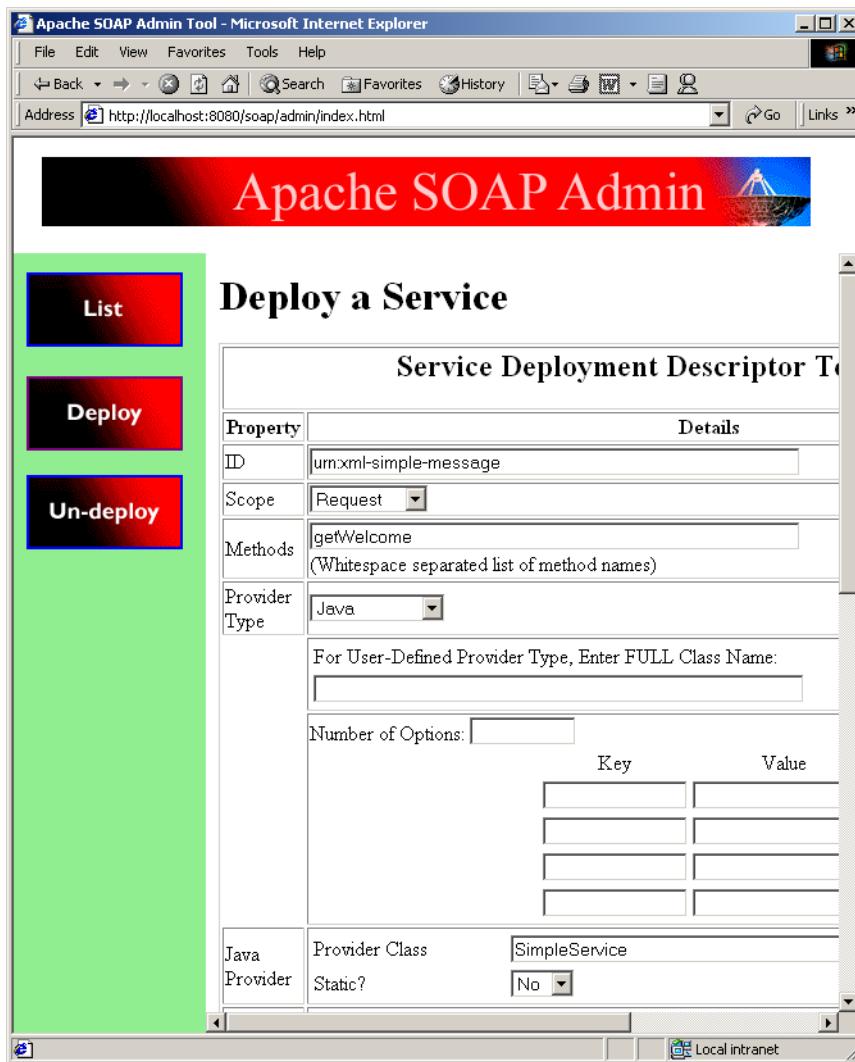


Fig. 29.2 SOAP package administration tool.

Figure 29.4 lists the client-side code for the RPC. When executed, the program sends a SOAP request to the server, which in our case is the same machine, the local host. The client sends a message as a parameter to the remote method. (This message can be from the command line; by default, the application uses the message **Thanks!**) When the server invokes the method, it sends back the message

```
Welcome to SOAP!
Here is your message: Thanks!
```

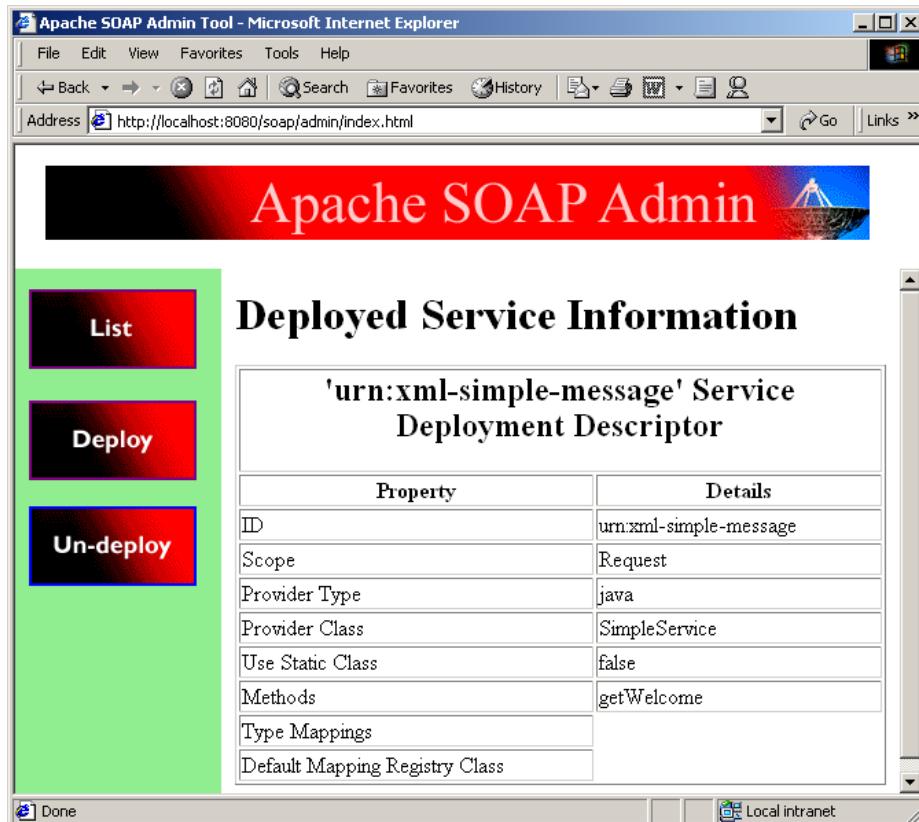


Fig. 29.3 Description of deployed service.

```
1 // Fig. 29.4 : GetMessage.java
2 // Program that makes a SOAP RPC
3
4 // import Java packages
5 import java.io.*;
6 import java.net.*;
7 import java.util.*;
8
9 // import third-party packages
10 import org.apache.soap.*;
11 import org.apache.soap.rpc.*;
12
13 public class GetMessage {
14
15     // main method
16     public static void main( String args[] ) {
17         String encodingStyleURI = Constants.NS_URI_SOAP_ENC;
18         String message;
```

Fig. 29.4 Client making a SOAP request (part 1 of 3).

```
19
20     if ( args.length != 0 )
21         message = args[ 0 ];
22     else
23         message = "Thanks!";
24
25     // attempt SOAP remote procedure call
26     try {
27         URL url = new URL(
28             "http://localhost:8080/soap/servlet/rpcrouter" );
29
30         // build call
31         Call remoteMethod = new Call();
32         remoteMethod.setTargetObjectURI(
33             "urn:xml-simple-message" );
34
35         // set name of remote method to be invoked
36         remoteMethod.setMethodName( "getWelcome" );
37         remoteMethod.setEncodingStyleURI( encodingStyleURI );
38
39         // set parameters for remote method
40         Vector parameters = new Vector();
41
42         parameters.addElement( new Parameter( "message",
43             String.class, message, null ) );
44         remoteMethod.setParams( parameters );
45         Response response;
46
47         // invoke remote method
48         response = remoteMethod.invoke( url, "" );
49
50         // get response
51         if ( response.generatedFault() ) {
52             Fault fault = response.getFault();
53
54             System.err.println( "CALL FAILED:\nFault Code = "
55                 + fault.getFaultCode() + "\nFault String = "
56                 + fault.getFaultString() );
57         }
58
59         else {
60             Parameter result = response.getReturnValue();
61
62             // display result of call
63             System.out.println( result.getValue() );
64         }
65     }
66
67     // catch malformed URL exception
68     catch ( MalformedURLException malformedURLException ) {
69         malformedURLException.printStackTrace();
70         System.exit( 1 );
71     }
```

Fig. 29.4 Client making a SOAP request (part 2 of 3).

```
72         // catch SOAPException
73     catch ( SOAPException soapException ) {
74         System.err.println( "Error message: " +
75             soapException.getMessage() );
76         System.exit( 1 );
77     }
78 }
79 }
80 }
```

```
java GetMessage
Welcome to SOAP!
Here is your message: Thanks!
```

```
java GetMessage "my message"
Welcome to SOAP!
Here is your message: my message
```

Fig. 29.4 Client making a SOAP request (part 3 of 3).

Line 10 **imports** the SOAP package that provides the API for the SOAP implementation. The package **org.apache.soap.rpc** in line 11 provides the implementation for RPC using SOAP. Line 17 specifies the encoding style used for the message. SOAP, which has no default encoding style, supports many encoding styles—we use the standard RPC encoding (**WS\_URI\_SOAP\_ENC**). Lines 27–28 specify the server-side URL to which the client sends **message**'s value, **rpcrouter**. This document, a Java servlet, receives the SOAP envelope through the HTTP **post** method. Using the URI specified in the SOAP message, it looks up the services deployed on the server in order to instantiate the appropriate object, in this case a **SimpleService** object.

Objects of class **Call** invoke remote methods. Line 31 instantiates a **Call** object and assigns it to reference **remoteMethod**, and lines 32–33 set the remote method's URI. Line 36 specifies the name of the method to be invoked, **getWelcome**. We then set the encoding style for the message on line 37. Lines 40–44 build the parameters passed to the remote method for processing. Each parameter must be in its own object, and the parameter objects must be placed in a **Vector**.

Lines 42–43 build a new parameter for the method by constructing a **Parameter object**. The first constructor argument is the name of the variable or reference (**message**), the second argument is the class to which the **Parameter** object belongs (**String**), the third argument is the value of the parameter (the object **message**) and the fourth argument specifies the parameter's encoding. (**null** specifies the application's default encoding.) Method **setParams** in line 44 sets the parameters of the **remoteMethod** object.

We invoke the remote method by calling method **invoke** in line 48. It takes two arguments: the server URL to which the SOAP message is being sent and the value of the **SOAPAction** header, which specifies the intent of the request. The second argument can take a **null** string if a **SOAPAction** header is not being used. Method **invoke** throws a **SOAPException** (lines 74–78) if any network error occurs while the SOAP request is being sent. Once the method is invoked on the server, the result is sent back to the client

and stored in the object referenced by **response** (line 48). This object receives an error message if a server error, such as a failure to locate the appropriate services, occurs. Lines 51–57 determine whether the received message is an error message. Lines 59–64 print the output if no error has been received.

### 29.3 SOAP Weather Service

This section describes a simple Web service implemented with Java and SOAP. The Web service is a modified version of the weather service implemented with RMI in Chapter 13. The weather service now uses SOAP RPC instead of Java RMI to send information from the server to the client. The required software components are the same as the previous section.

The SOAP weather service uses classes **WeatherBean**, **WeatherCellRenderer**, **WeatherItem** and **WeatherListModel** from the RMI weather service without modification. SOAP RPC does not require a Java interface like RMI, so this example does not use interface **WeatherService** and class **WeatherServiceImpl**. For this example, class **WeatherService** uses most of **WeatherServiceImpl**'s code and exposes method **getWeatherInformation** via SOAP. Class **WeatherServiceClient** now uses SOAP RPC instead of Java RMI.

Class **WeatherService** (Fig. 29.5) provides method **getWeatherInformation** that class **WeatherServiceClient** calls through a SOAP RPC. **WeatherService** must be in the **classes** directory of the Tomcat servlet engine for the call to be successful. The RMI version of method **getWeatherInformation** returns a **List** of **WeatherBean** objects. SOAP does not support direct transmission of these Java objects, so the SOAP RPC version of **getWeatherInformation** returns a **Vector** of **Strings**. Lines 66–71 add the **Strings** parsed from the *Traveler's Forecast* Web page to **Vector weatherInformation** (line 13). Line 99 returns **Vector weatherInformation**. The rest of class **WeatherService** is identical to class **WeatherServiceImpl** from Chapter 13.

```
1 // Fig. 29.5: WeatherService.java
2 // WeatherService provides a method to retrieve weather
3 // information from the National Weather Service.
4 package com.deitel.advjhtp1.soap.weather;
5
6 // Java core packages
7 import java.io.*;
8 import java.net.URL;
9 import java.util.*;
10
11 public class WeatherService {
12
13     private Vector weatherInformation; // WeatherBean objects
14
15     // get weather information from NWS
16     private void updateWeatherConditions()
17     {
18         try {
19             System.out.println( "Update weather information..." );
```

Fig. 29.5 SOAP implementation of class **WeatherService** (part 1 of 3).

```
20      // National Weather Service Travelers Forecast page
21      URL url = new URL(
22          "http://iwin.nws.noaa.gov/iwin/us/traveler.html" );
23
24      // set up text input stream to read Web page contents
25      BufferedReader in = new BufferedReader(
26          new InputStreamReader( url.openStream() ) );
27
28      // helps determine starting point of data on Web page
29      String separator = "TAV12";
30
31      // locate separator string in Web page
32      while ( !in.readLine().startsWith( separator ) )
33          ;      // do nothing
34
35
36      // strings representing headers on Travelers Forecast
37      // Web page for daytime and nighttime weather
38      String dayHeader =
39          "CITY           WEA     HI/LO    WEA     HI/LO";
40      String nightHeader =
41          "CITY           WEA     LO/HI    WEA     LO/HI";
42
43      String inputLine = "";
44
45      // locate header that begins weather information
46      do {
47          inputLine = in.readLine();
48      } while ( !inputLine.equals( dayHeader ) &&
49                  !inputLine.equals( nightHeader ) );
50
51      weatherInformation = new Vector(); // create Vector
52
53      // create WeatherBeans containing weather data and
54      // store in weatherInformation Vector
55      inputLine = in.readLine(); // get first city's data
56
57      // The portion of inputLine containing relevant data
58      // is 28 characters long. If the line length is not at
59      // least 28 characters long, then done processing data.
60      while ( inputLine.length() > 28 ) {
61
62          // Prepare strings for WeatherBean for each city.
63          // First 16 characters are city name. Next, six
64          // characters are weather description. Next six
65          // characters are HI/LO or LO/HI temperature.
66          weatherInformation.add(
67              inputLine.substring( 0, 16 ) );
68          weatherInformation.add(
69              inputLine.substring( 16, 22 ) );
70          weatherInformation.add(
71              inputLine.substring( 23, 29 ) );
72
```

Fig. 29.5 SOAP implementation of class **WeatherService** (part 2 of 3).

```

73         inputLine = in.readLine(); // get next city's data
74     }
75
76     in.close(); // close connection to NWS Web server
77
78     System.out.println( "Weather information updated." );
79 }
80
81 // process failure to connect to National Weather Service
82 catch( java.net.ConnectException connectException ) {
83     connectException.printStackTrace();
84     System.exit( 1 );
85 }
86
87 // process other exceptions
88 catch( Exception exception ) {
89     exception.printStackTrace();
90     System.exit( 1 );
91 }
92 }
93
94 // implementation for WeatherService interface method
95 public Vector getWeatherInformation()
96 {
97     updateWeatherConditions();
98
99     return weatherInformation;
100 }
101 }
```

Fig. 29.5 SOAP implementation of class **WeatherService** (part 3 of 3).

Class **WeatherServiceClient** (Fig. 29.6) makes a SOAP remote procedure call to method **getWeatherInformation** of class **WeatherService**. Lines 14–15 **import** the Apache SOAP packages. Lines 31–32 set the SOAP service's URL. Line 35 creates a new **Call** object, which stores information needed to perform the remote procedure call. Lines 36–37 set the URI that uniquely identifies the weather service in the servlet engine. Lines 40–41 specify the method name for the RPC. Lines 42–43 set the encoding for the call. Line 46 creates a **Response** object and calls method **invoke** on the **Call** object with a URL as an argument. The **Response** object holds the response to the remote procedure call. Line 49 determines if the response generates a **Fault**. If a **Fault** occurs, lines 52–54 print the error code. If no **Fault** occurs, line 58 gets the object returned by the remote procedure call. Lines 60–61 cast the **Object** to a **Vector**. Lines 64–65 create a **List** and call method **createBeans** (lines 95–107) with the **Vector** of **Strings** as a parameter. Method **createBeans** turns the **Vector** of **Strings** into a **List** of **WeatherBeans**. Lines 68–69 create a **ListModel** of the **List** of **WeatherBeans**. Lines 73–77 create a **JList** of the information obtained from the remote procedure call and display the **JList** in a **JFrame**.

The weather service deploys in the same manner as the simple message service. Start the Tomcat servlet engine and go to the SOAP administration tool (**localhost:8080/soap/admin**) as shown in Fig. 29.7. Click **Deploy** and fill in the information in the form

```
1 // Fig. 29.6: WeatherServiceClient.java
2 // WeatherServiceClient accesses the WeatherService remote
3 // object via SOAP to retrieve weather information.
4 package com.deitel.advjhttp1.soap.weather;
5
6 // Java core packages
7 import java.util.*;
8 import java.net.*;
9
10 // Java extension packages
11 import javax.swing.*;
12
13 // third-party packages
14 import org.apache.soap.*;
15 import org.apache.soap.rpc.*;
16
17 // Deitel packages
18 import com.deitel.advjhttp1.rmi.weather.*;
19
20 public class WeatherServiceClient extends JFrame {
21
22     // WeatherServiceClient constructor
23     public WeatherServiceClient( String server )
24     {
25         super( "SOAP WeatherService Client" );
26
27         // connect to server and get weather information
28         try {
29
30             // URL of remote SOAP object
31             URL url = new URL( "http://" + server + ":8080/soap/" +
32                 + "servlet/rpcrouter" );
33
34             // build SOAP RPC call
35             Call remoteMethod = new Call();
36             remoteMethod.setTargetObjectURI(
37                 "urn:xml-weather-service" );
38
39             // set name of remote method to be invoked
40             remoteMethod.setMethodName(
41                 "getWeatherInformation" );
42             remoteMethod.setEncodingStyleURI(
43                 Constants.NS_URI_SOAP_ENC );
44
45             // invoke remote method
46             Response response = remoteMethod.invoke( url, "" );
47
48             // get response
49             if ( response.generatedFault() ) {
50                 Fault fault = response.getFault();
```

Fig. 29.6 SOAP implementation of class **WeatherServiceClient**.

```
52         System.err.println( "CALL FAILED:\nFault Code = "
53             + fault.getFaultCode() + "\nFault String = "
54             + fault.getFaultString() );
55     }
56
57     else {
58         Parameter result = response.getReturnValue();
59
60         Vector weatherStrings = ( Vector )
61             result.getValue();
62
63         // get weather information from result object
64         List weatherInformation = createBeans(
65             weatherStrings );
66
67         // create WeatherListModel for weather information
68         ListModel weatherListModel =
69             new WeatherListModel( weatherInformation );
70
71         // create JList, set its CellRenderer and add to
72         // layout
73         JList weatherJList = new JList( weatherListModel );
74         weatherJList.setCellRenderer( new
75             WeatherCellRenderer() );
76         getContentPane().add( new
77             JScrollPane( weatherJList ) );
78     }
79
80 } // end try
81
82 // handle bad URL
83 catch ( MalformedURLException malformedURLException ) {
84     malformedURLException.printStackTrace();
85 }
86
87 // handle SOAP exception
88 catch ( SOAPException soapException ) {
89     soapException.printStackTrace();
90 }
91
92 } // end WeatherServiceClient constructor
93
94 // create List of WeatherBeans from Vector of Strings
95 public List createBeans( Vector weatherStrings )
96 {
97     List list = new ArrayList();
98     for ( int i = 0; ( weatherStrings.size() - 1 ) > i;
99         i += 3 ) {
100         list.add( new WeatherBean(
101             ( String ) weatherStrings.elementAt( i ),
102             ( String ) weatherStrings.elementAt( i + 1 ),
103             ( String ) weatherStrings.elementAt( i + 2 ) ) );
104     }
}
```

Fig. 29.6 SOAP implementation of class **WeatherServiceClient**.

```
105     return list;
106 }
108
109 // execute WeatherServiceClient
110 public static void main( String args[] )
111 {
112     WeatherServiceClient client = null;
113
114     // if no server IP address or host name specified,
115     // use "localhost"; otherwise use specified host
116     if ( args.length == 0 )
117         client = new WeatherServiceClient( "localhost" );
118     else
119         client = new WeatherServiceClient( args[ 0 ] );
120
121     // configure and display application window
122     client.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
123     client.pack();
124     client.setResizable( false );
125     client.setVisible( true );
126 }
127 }
```

Fig. 29.6 SOAP implementation of class **WeatherServiceClient**.

as it appears in Fig. 29.8. Be sure to enter the fully qualified package name of **WeatherService**. Once the service is deployed, run **WeatherServiceClient**. The remote procedure call retrieves the weather information and, the client displays it (Fig. 29.9).

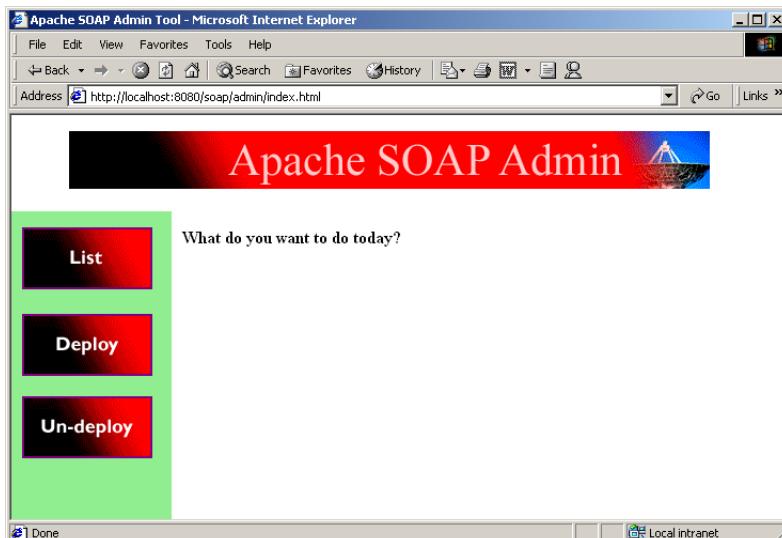


Fig. 29.7 Apache SOAP Admin page.

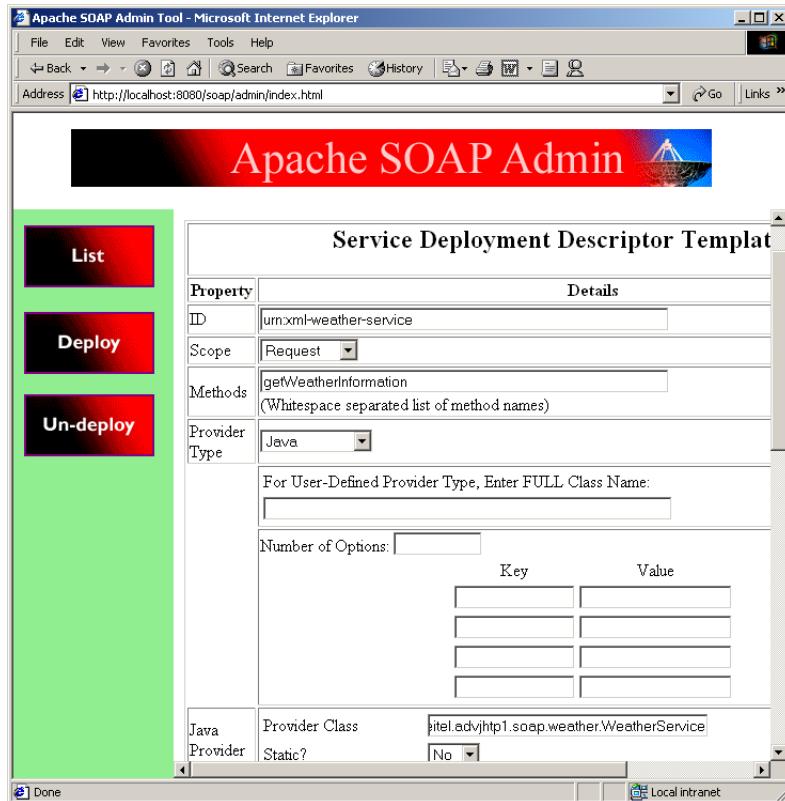


Fig. 29.8 Apache SOAP Service Deployment Descriptor Template.

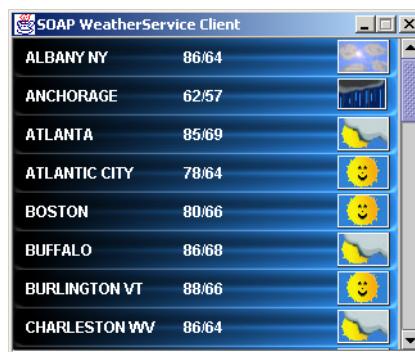


Fig. 29.9 SOAP WeatherService Client.

## 29.4 Internet and World Wide Web Resources

[www.sun.com/software/sunone/index.html](http://www.sun.com/software/sunone/index.html)

This is Sun Microsystem's site for the Open Net Environment Web services architecture.

**xml.apache.org/soap**

Apache's SOAP implementation can be downloaded from this site, which also provides information and documentation.

**xml.apache.org/xerces-j/index.html**

Apache's Xerces parser for Java can be downloaded from this site, along with documentation.

**jakarta.apache.org**

Web site for Apache's Jakarta-Tomcat servlet engine.

## SUMMARY

- A Web service can be any Web-accessible application, such as a Web page with dynamic content.
- A narrower definition of a Web service is an application that exposes a public interface usable by other applications over the Web.
- Sun's ONE requires a Web service to be accessible through HTTP and other Web protocols, to communicate using XML-based messages and to be registered with a lookup service.
- Web services can provide great interoperability between diverse systems. The interoperability and scalability of Web services means developers can rapidly create large applications and larger Web services from small Web services.
- Sun's Open Net Environment describes an architecture for creating *smart Web services*. According to Sun, smart Web services share a common operating environment with other services.
- SOAP is an HTTP–XML-based protocol that allows applications to communicate over the Internet, using XML documents called SOAP messages.
- SOAP is both platform and software independent and can be implemented in any programming language. SOAP supports transport using almost any conceivable protocol.
- A SOAP message contains an envelope, which describes the content, intended recipient and processing requirements of a message. The optional **header** element of a SOAP message specifies additional processing information for applications that receive the SOAP message.
- Through the header, more complex protocols can be built onto SOAP. The body of a SOAP message contains application-specific data for the intended recipient of the message.
- SOAP can be used to make a Remote Procedure Call (RPC), which is a request made to another machine to run a task. The RPC uses an XML vocabulary to specify the method to be invoked, any parameters the method takes and the URI of the target object.
- Because businesses use different platforms, applications and data specifications, exchanging data can be difficult. Business partners therefore establish protocols and data formats to engage in electronic commerce.

## TERMINOLOGY

application-to-application (A2A) integration

asynchronous RPC

**Call** class

deploying a service

distributed object architecture

**Fault** class

firewall

Hypertext Transfer Protocol (HTTP)

**invoke** method of class **Call**

loosely coupled messaging

messaging

**org.apache.soap.rpc**

**Parameter** class

Remote Procedure Call (RPC)

request-response

schema

**setMethodName** method of class **Call**

**setParams** method of class **Call**

Simple Object Access Protocol (SOAP)

Sun Open Net Environment

synchronous RPC  
Universal Description, Discovery and  
Integration (UDDI)

Web services  
XML-SOAP admin tool

## SELF-REVIEW EXERCISES

- 29.1** State whether each of the following is *true* or *false*. If *false*, explain why.
- SOAP is a technology for facilitating data transfer across a network.
  - SOAP must be bound to HTTP in order to work.
  - In order to communicate with SOAP, software systems must have the same distributed object architecture.
  - The body of a SOAP message can contain a Remote Procedure Call.
- 29.2** Fill in the blanks in each of the following statements:
- A SOAP RPC requires the name of the method being called, its parameters and \_\_\_\_\_.
  - A SOAP \_\_\_\_\_ contains information that describes the content, recipient and processing requirements of a SOAP message.
  - SOAP can pass through most firewalls because \_\_\_\_\_ is its transport mechanism.
  - SOAP RPCs use the HTTP \_\_\_\_\_ model.

## ANSWERS TO SELF-REVIEW EXERCISES

- 29.1** a) True. b) False. SOAP can be bound to other protocols. c) False. SOAP is platform independent. d) True.
- 29.2** a) the processing requirements of the message. b) envelope. c) HTTP. d) request-response.

## EXERCISES

- 29.3** Write a server-side class with a **sort** method that can sort given numbers. Write a client-side program that can make SOAP RPC invoke the **sort** method by sending a set of unsorted numbers. Display the results of sorting on the client.
- 29.4** Rewrite class **WeatherServiceClient** to update its information at a user-defined interval. Change the settings of Tomcat to make the **WeatherService** object persistent. This makes the updates more efficient.
- 29.5** Write a client and server with a similar architecture to the weather service, but that obtains pricing information from a price-comparison site, such as **shopper.cnet.com**.
- 29.6** Write a server-side class that stores and retrieves **Strings**. Deploy the class so it is persistent on the server. Then write a client that stores and retrieves **Strings** from the server.
- 29.7** Write a simple peer-to-peer instant-messaging service. Write a server class with a method that opens a window with a text message when it is called by a client. The client allows the user to enter a text message and call the method on the server class to display the message on the other machine.

## WORKS CITED

- D. Savarese, "ONEWeb to Rule Them ALL," Java Pro August 2001: pg 58.



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# Creating Markup with XML

---

## Objectives

- To create custom markup using XML.
- To understand the concept of an XML parser.
- To use elements and attributes to mark up data.
- To understand the difference between markup text and character data.
- To understand the concept of a well-formed XML document.
- To understand the concept of an XML namespace.
- To be able to use **CDATA** sections and processing instructions.

*The chief merit of language is clearness, and we know that nothing detracts so much from this as do unfamiliar terms.*  
Galen

*Every country has its own language, yet the subjects of which the untutored soul speaks are the same everywhere.*

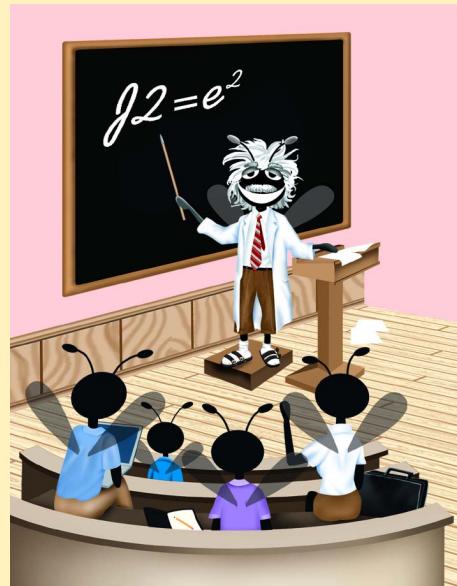
Tertullian

*The historian, essentially, wants more documents than he can really use; the dramatist only wants more liberties than he can really take.*

Henry James

*Entities should not be multiplied unnecessarily.*

William of Occam



## Outline

- A.1 Introduction
- A.2 Introduction to XML Markup
- A.3 Parsers and Well-Formed XML Documents
- A.4 Characters
  - A.4.1 Characters vs. Markup
  - A.4.2 White Space, Entity References and Built-In Entities
- A.5 CDATA Sections and Processing Instructions
- A.6 XML Namespaces
- A.7 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises*

## A.1 Introduction

The Extensible Markup Language (XML) is a technology for marking up structured data so that any software with an XML parser can understand and use its content. Data independence, the separation of content from its presentation, is the essential characteristic of XML. XML documents are simply text files that are marked up in a special way, so XML is intelligible to both humans and machines. Any application can conceivably process XML data. This makes XML ideal for data exchange.

Platform independence, the separation of an application from the platform on which it runs, is the essential characteristic of Java. With Java, software developers can write a program once, and it will run on any platform that has an implementation of the Java virtual machine. Java and XML have common goals. Java allows the portability of executable code across platforms. Likewise, XML allows the portability of structured data across applications. When used together, these technologies allow applications and their associated data to work on any computer. Recognizing this fact, software developers across the world are integrating XML into their Java applications to gain Web functionality and interoperability.

In this appendix, we show how to incorporate XML into Java applications. We use a Java application we created, named **ParserTest**, to output an XML document's contents. This application is included in the Appendix A examples directory on the CD-ROM that accompanies this book.

## A.2 Introduction to XML Markup

In this section, we begin marking up data using XML. Consider a simple XML document (**first.xml**) that marks up a message (Fig. A.1). We output the entire XML document to the command line.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. A.1 : first.xml -->
4 <!-- Simple introduction to XML markup -->
5
6 <myMessage id = "643070">
7   <message>Welcome to XML!</message>
8 </myMessage>
```

```
C:\>java -jar ParserTest.jar first.xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. A.1 : first.xml -->
<!-- Simple introduction to XML markup -->
<myMessage id="T643070">
  <message>Welcome to XML!</message>
</myMessage>
```

Fig. A.1 Simple XML document containing a message .

The document begins with the optional *XML declaration* in line 1. This declaration identifies the document as an XML document. The **version** information parameter specifies the version of XML used in the document.



### Portability Tip A.1

Although the XML declaration is optional, it should be used to identify the XML version to which the document conforms. Otherwise, in the future, a document without an XML declaration might be assumed to conform to the latest version of XML. Errors or other serious problems may result.



### Common Programming Error A.1

Placing anything, including whitespace (i.e., spaces, tabs and newlines), before an XML declaration is an error.

Lines 3–4 are comments, which begin with `<!--` and end with `-->`. Comments can be placed almost anywhere in an XML document and can span multiple lines. For example, we could have written lines 3–4 as

```
<!-- Fig. A.1 : first.xml
    Simple introduction to XML markup -->
```



### Common Programming Error A.2

Placing `--` between `<!--` and `-->` is an error.

In XML, data are marked up using *tags*, which are names enclosed in *angle brackets* (`< >`). Tags are used in pairs to delimit the beginning and end of markup. A tag that begins markup is called a *start tag* and a tag that terminates markup is called an *end tag*. Examples of start tags are `<myMessage>` and `<message>` (lines 6–7). End tags differ from start tags in that they contain a *forward slash* (/) character. Examples of end tags are `</message>` and `</myMessage>` in lines 7–8. XML documents can contain any number of tags.



### Good Programming Practice A.1

XML elements and attribute names should be meaningful. For example, use `<address>` instead of `<adr>`.



### Common Programming Error A.3

Using spaces in an XML element name or attribute name is an error.

Individual units of markup (i.e., everything from a start tag to an end tag, inclusive) are called *elements*, which are the most fundamental building blocks of an XML document. XML documents contain exactly one element—called a *root element* (e.g., **myMessage** in lines 6–8)—that contains all other elements in the document. Elements are embedded or nested within each other to form hierarchies—with the root element at the top of the hierarchy. This practice allows document authors to create explicit relationships between data.



### Common Programming Error A.4

Improperly nesting XML tags is an error. For example, `<x><y>hello</x></y>` is an error; here the nested `<y>` tag must end before the `</x>` tag.



### Good Programming Practice A.2

When creating an XML document, add whitespace to emphasize the document's hierarchical structure. This makes documents more readable to humans.



### Common Programming Error A.5

Attempting to create more than one root element in an XML document is an error.

Elements, such as the root element, that contain other elements are called *parent elements*. Elements nested within a parent element are called *children*. Parent elements can have any number of children, but an individual child element can have only one parent. As we will see momentarily, it is possible for an element to be both a parent element and a child element. Element **message** is an example of a child element and element **myMessage** is an example of a parent element.



### Common Programming Error A.6

XML element names are case sensitive. Using the wrong mixture of case is an error. For example, using the start tag `<message>` and end tag `</Message>` is an error.

In addition to being placed between tags, data can be placed in *attributes*, which are name-value pairs in start tags. Elements can have any number of attributes. In Fig. A.1, attribute **id** is assigned the value **"643070"**. XML element and attribute names can be of any length and may contain letters, digits, underscores, hyphens and periods; they must begin with a letter or an underscore.



### Common Programming Error A.7

Not placing an attribute's value in either single or double quotes is a syntax error.

Notice that the XML declaration output differs from the XML declaration in line 1. The optional **encoding** declaration specifies the method used to represent characters electronically. **UTF-8** is a character encoding typically used for Latin-alphabet characters

(e.g., English) that can be stored in one byte. When present, this declaration allows authors to specify a character encoding explicitly. When omitted, either UTF-8 or *UTF-16* (a format for encoding and storing characters in two bytes) is the default. We discuss character encoding in Section A.4.



### Portability Tip A.2

The **encoding** declaration allows XML documents to be authored in a wide variety of human languages.

## A.3 Parsers and Well-Formed XML Documents

A software program called an *XML parser* (or an *XML processor*) is required to process an XML document. XML parsers read the XML document, check its syntax, report any errors and allow programmatic access to the document's contents. An XML document is considered *well formed* if it is syntactically correct (i.e., errors are not reported by the parser when the document is processed). Figure A.1 is an example of a well-formed XML document.

If an XML document is not well formed, the parser reports errors. For example, if the end tag (line 8) in Fig. A.1 is omitted, the error message shown in Fig. A.2 is generated by the parser.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. A.2 : error.xml           -->
4 <!-- XML document missing an end tag -->
5
6 <myMessage id = "643070">
7   <message>Welcome to XML!</message>
```

```
C:\>java -jar ParserTest.jar error.xml
Exception in thread "main" org.xml.sax.SAXParseException: End of entity
not allowed; an end tag is missing.
    at org.apache.crimson.parser.Parser2.fatal(Parser2.java:3035)
    at org.apache.crimson.parser.Parser2.fatal(Parser2.java:3023)
    at org.apache.crimson.parser.Parser2.content(Parser2.java:1758)
    at org.apache.crimson.parser.Parser2.maybeElement(Parser2.ja-
va:1468)
    at org.apache.crimson.parser.Parser2.parseInternal(Parser2.ja-
va:499)
    at org.apache.crimson.parser.Parser2.parse(Parser2.java:304)
    at org.apache.crimson.parser.XMLReaderImpl.parse(XMLReaderImpl.ja-
va:433)

    at org.apache.crimson.jaxp.DocumentBuilderImpl.parse(DocumentBuild-
erImpl.java:179)
    at javax.xml.parsers.DocumentBuilder.parse(DocumentBuilder.ja-
va:161)
    at ParserTest.main(ParserTest.java:42)
```

Fig. A.2 XML document missing an end tag.

Most XML parsers can be downloaded at no charge. Several Independent Software Vendors (ISVs) have developed XML parsers, which can be found at [www.oasis-open.org/cover/xml.html#xmlparsers](http://www.oasis-open.org/cover/xml.html#xmlparsers). In this appendix, we will use the reference implementation for the Java API for XML Processing 1.1 (JAXP).

Parsers can support the *Document Object Model (DOM)* and/or the *Simple API for XML (SAX)* for accessing a document's content programmatically, using languages such as Java™, Python, and C. A DOM-based parser builds a tree structure containing the XML document's data in memory. A SAX-based parser processes the document and generates *events* (i.e., notifications to the application) when tags, text, comments, etc., are encountered. These events return data from the XML document. Software programs can "listen" for the events to obtain data from the XML document.

The examples we present use DOM-based parsing. In Appendix C, we provide a detailed discussion of the DOM. We do not discuss SAX-based parsing in these appendices.

## A.4 Characters

In this section, we discuss the collection of characters—called a *character set*—permitted in an XML document. XML documents may contain: carriage returns, line feeds and *Unicode*® characters. Unicode is a character set created by the *Unicode Consortium* ([www.unicode.org](http://www.unicode.org)), which encodes the vast majority of the world's commercially viable languages. We discuss Unicode in detail in Appendix I.

### A.4.1 Characters vs. Markup

Once a parser determines that all characters in a document are legal, it must differentiate between markup text and *character data*. Markup text is enclosed in angle brackets (< and >). Character data (sometimes called *element content*) is the *text* delimited by the start tag and end tag. Child elements are considered markup—not character data. Lines 1, 3–4 and 6–8 in Fig. A.1 contain markup text. In line 7, the tags <**message**> and </**message**> are the markup text and the text **Welcome to XML!** is character data.

### A.4.2 White Space, Entity References and Built-In Entities

Spaces, tabs, line feeds and carriage returns are characters commonly called *whitespace characters*. An XML parser is required to pass all characters in a document, including whitespace characters, to the application (e.g., a Java application) using the XML document.

Figure A.3 demonstrates that whitespace characters are passed by the parser to the application using the XML document. In this case, we simply print the data returned by the parser.

```
1  <?xml version = "1.0"?>
2
3  <!-- Fig. A.3 : whitespace.xml          -->
4  <!-- Demonstrating whitespace, entities -->
5  <!-- and empty elements                -->
6
```

Fig. A.3 Whitespace characters in an XML document (part 1 of 2).

```
7 <information>
8
9   <!-- empty element -->
10  <company name = "Deitel & Associates, Inc." />
11
12  <!-- start tag contains insignificant whitespace -->
13  <city> Sudbury </city>
14
15
16  <state>Massachusetts</state>
17 </information>
```

```
C:\>java -jar ParserTest.jar whitespace.xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. A.3 : whitespace.xml          -->
<!-- Demonstrating whitespace, entities -->
<!-- and empty elements              -->
<information>
  <!-- empty element -->
  <company name="Deitel & Associates, Inc."/>

  <!-- start tag contains insignificant whitespace -->
  <city> Sudbury </city>

  <state>Massachusetts</state>
</information>
```

Fig. A.3 Whitespace characters in an XML document (part 2 of 2).

A parser can inform an application as to whether individual whitespace characters are *significant* (i.e., need to be preserved) or *insignificant* (i.e., need not be preserved). The output window illustrates that the majority of whitespace characters in the document are considered significant. Line 2 was considered insignificant by the application as well as the extra space characters in the start tag of line 13. In Appendix B, you will see that whitespace may or may not be significant, depending on the Document Type Definition (DTD) that an XML file uses. We will explore the subtleties of whitespace interpretation in greater detail in Appendix B.

XML element markup consists of a start tag, character data and an end tag. The element of line 10 is called an *empty element*, because it does not contain character data between its start and end tags. The forward slash character closes the tag. Alternatively, this empty element can be written as

```
<company name = "Deitel & Associates, Inc."></company>
```

Both forms are equivalent.

Almost any character can be used in an XML document, but the characters *ampersand* (**&**) and *left angle bracket* (**<**) are reserved in XML and may not be used in character data. To use these symbols in character data or in attribute values, *entity references* must be used. Entity references begin with an ampersand (**&**) and end with a *semicolon* (**;**). XML provides entity references (or *built-in entities*) for the ampersand (**&amp;**), left-angle bracket (**&lt;**), right angle bracket (**&gt;**), apostrophe (**&apos;**) and quotation mark (**&quot;**).



### Common Programming Error A.8

Attempting to use the left-angle bracket (<) in character data or in attribute values is an error.



### Common Programming Error A.9

Attempting to use the ampersand (&)—other than in an entity reference—in character data or in attribute values is an error.

## A.5 CDATA Sections and Processing Instructions

In this section, we discuss parts of an XML document, called **CDATA sections**, that can contain text, reserved characters (e.g., <) and whitespace characters. Character data in a **CDATA** section are not processed by the XML parser. A common use of a **CDATA** section is for programming code such as JavaScript and C++, which often include the characters & and <. Figure A.4 presents an XML document that compares text in a **CDATA** section with character data.

The first **sample** element (lines 8–12) contains C++ code as character data. Each occurrence of <, > and & is replaced by an entity reference. Lines 15–20 use a **CDATA** section to indicate a block of text that the parser should not treat as character data or markup. **CDATA** sections begin with <! [CDATA[ and terminate with ]]>. Notice that the < and & characters (lines 18–19) do not need to be replaced by entity references.

```
1  <?xml version = "1.0"?>
2
3  <!-- Fig. A.4 : cdata.xml
4  <!-- CDATA section containing C++ code -->
5
6  <book title = "C++ How to Program" edition = "3">
7
8      <sample>
9          // C++ comment
10         if ( this->getX() &lt; 5 && value[ 0 ] != 3 )
11             cerr << this->displayError();
12     </sample>
13
14     <sample>
15         <! [CDATA[
16
17             // C++ comment
18             if ( this->getX() < 5 && value[ 0 ] != 3 )
19                 cerr << this->displayError();
20         ]]>
21     </sample>
22
23     C++ How to Program by Deitel & Deitel
24
25     <?button cpp = "sample.cpp" ansi = "yes"?>
26   </book>
```

Fig. A.4 Using a **CDATA** section (part 1 of 2).

```
C:\>java -jar ParserTest.jar cdata.xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. A.4 : cdata.xml -->
<!-- CDATA section containing C++ code -->
<book title="C++ How to Program" edition="3">

    <sample>
        // C++ comment
        if ( this->getX() < 5 && value[ 0 ] != 3 )
            cerr << this->displayError();
    </sample>

    <sample>
        <! [CDATA[
            // C++ comment
            if ( this->getX() < 5 && value[ 0 ] != 3 )
                cerr << this->displayError();
        ]]>
    </sample>

    C++ How to Program by Deitel & Deitel

    <button cpp = "sample.cpp" ansi = "yes"?>
</book>
```

Fig. A.4 Using a **CDATA** section (part 2 of 2).



### Common Programming Error A.10

Placing one or more spaces inside the opening `<! [CDATA[` or closing `]]>` is an error.

Because a **CDATA** section is not parsed, it can contain almost any text, including characters normally reserved for XML syntax, such as `<` and `&`. However, **CDATA** sections cannot contain the text `]]>`, because this is used to terminate a **CDATA** section. For example,

```
<! [CDATA[
    The following characters cause an error: ]]>
  ]]>
```

is an error.

Line 25 is an example of a *processing instruction (PI)*. Processing instructions provide a convenient syntax to allow document authors to embed application-specific data within an XML document. Processing instructions have no effect on a document if the application processing the document does not use them. The information contained in a PI is passed to the application that is using the XML document.

Processing instructions are delimited by `<?` and `?>` and consist of a *PI target* and a *PI value*. Almost any name may be used for a PI target, except the reserved word `xml` (in any mixture of case). In the current example, the PI target is named `button` and the PI value is `cpp = "sample.cpp" ansi = "yes"`. This PI might be used by an application to create a button that, when clicked, displays the entire code listing for a file named `sample.cpp`.



### Software Engineering Observation A.1

*Processing instructions provide a means for programmers to insert application-specific information into an XML document without affecting the document's portability.*

## A.6 XML Namespaces

Because XML allows document authors to create their own tags, *naming collisions* (i.e., conflicts between two different elements that have the same name) can occur. For example, we may use the element **book** to mark up data about one of our publications. A stamp collector may also create an element **book** to mark up data about a book of stamps. If both of these elements were used in the same document, there would be a naming collision, and it would be difficult to determine which kind of data each element contained. In this section, we discuss a method for preventing collisions called *namespaces*. In Appendix D, we begin using namespaces.

For example,

```
<subject>Math</subject>
```

and

```
<subject>Thrombosis</subject>
```

use a **subject** element to mark up a piece of data. However, in the first case the subject is something one studies in school, whereas in the second case the subject is in the field of medicine. These two **subject** elements can be differentiated using namespaces. For example

```
<school:subject>Math</school:subject>
```

and

```
<medical:subject>Thrombosis</medical:subject>
```

indicate two distinct **subject** elements. Both **school** and **medical** are *namespace prefixes*. Namespace prefixes are prepended to element and attribute names in order to specify the namespace in which the element or attribute can be found. Each namespace prefix is tied to a uniform resource identifier (URI) that uniquely identifies the namespace. Document authors can create their own namespace prefixes, as shown in Fig. A.5 (lines 6–7). Virtually any name may be used for a namespace, except the reserved namespace **xml**.

```
1  <?xml version = "1.0"?>
2
3  <!-- Fig. A.5 : namespace.xml -->
4  <!-- Namespaces           -->
5
6  <text:directory xmlns:text = "urn:deitel:textInfo"
7    xmlns:image = "urn:deitel:imageInfo">
8
```

Fig. A.5 Demonstrating XML namespaces (part 1 of 2).

```
9   <text:file filename = "book.xml">
10    <text:description>A book list</text:description>
11  </text:file>
12
13  <image:file filename = "funny.jpg">
14    <image:description>A funny picture</image:description>
15    <image:size width = "200" height = "100"/>
16  </image:file>
17
18 </text:directory>

<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. A.5 : namespace.xml --&gt;
&lt;!-- Namespaces --&gt;
&lt;text:directory xmlns:text="urn:deitel:textInfo" xmlns:image="urn:deitel:imageInfo"&gt;

  &lt;text:file filename="book.xml"&gt;
    &lt;text:description&gt;A book list&lt;/text:description&gt;
  &lt;/text:file&gt;

  &lt;image:file filename="funny.jpg"&gt;
    &lt;image:description&gt;A funny picture&lt;/image:description&gt;
    &lt;image:size width="200" height="100"/&gt;
  &lt;/image:file&gt;

&lt;/text:directory&gt;</pre>
```

Fig. A.5 Demonstrating XML namespaces (part 2 of 2).

In Fig. A.5, two distinct **file** elements are differentiated using namespaces. Lines 6–7 use the XML namespace keyword **xmlns** to create two namespace prefixes: **text** and **image**. The values assigned to attributes **xmlns:text** and **xmlns:image** are called *Uniform Resource Identifiers (URIs)*. By definition, a URI is a series of characters used to differentiate names.

To ensure that a namespace is unique, the document author must provide a unique URI. Here, we use the text **urn:deitel:textInfo** and **urn:deitel:imageInfo** as URIs. A common practice is to use *Universal Resource Locators (URLs)* for URIs, because the domain names (e.g., **deitel.com**) used in URLs are guaranteed to be unique. For example, lines 6–7 could have been written as

```
<directory xmlns:text = "http://www.deitel.com/xmlns-text"
           xmlns:image = "http://www.deitel.com/xmlns-image">
```

where we use URLs related to the Deitel & Associates, Inc., domain name (**www.deitel.com**). These URLs are never visited by the parser—they only represent a series of characters for differentiating names and nothing more. The URLs need not even exist or be properly formed.

Lines 9–11 use the namespace prefix **text** to describe elements **file** and **description**. Notice that end tags have the namespace prefix **text** applied to them as well. Lines 13–16 apply namespace prefix **image** to elements **file**, **description** and **size**.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. A.6 : defaultnamespace.xml -->
4 <!-- Using Default Namespaces      -->
5
6 <directory xmlns = "urn:deitel:textInfo"
7   xmlns:image = "urn:deitel:imageInfo">
8
9   <file filename = "book.xml">
10    <description>A book list</description>
11   </file>
12
13   <image:file filename = "funny.jpg">
14    <image:description>A funny picture</image:description>
15    <image:size width = "200" height = "100"/>
16   </image:file>
17
18 </directory>
```

```
C:\>java -jar ParserTest.jar defaultnamespace.xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. A.6 : defaultnamespace.xml -->
<!-- Using Default Namespaces      -->
<directory xmlns="urn:deitel:textInfo" xmlns:image="urn:deitel:image-
Info">

  <file filename="book.xml">
    <description>A book list</description>
  </file>

  <image:file filename="funny.jpg">
    <image:description>A funny picture</image:description>
    <image:size width="200" height="100"/>
  </image:file>

</directory>
```

Fig. A.6 Using default namespaces.

To eliminate the need to place a namespace prefix in each element, authors may specify a *default namespace* for an element and all of its child elements. Figure A.6 demonstrates the use of default namespaces.

We declare a default namespace using the **xmlns** attribute with a URI as its value (line 6). Once this default namespace is in place, child elements that are part of the namespace do not need a namespace prefix. Element **file** (line 9) is in the namespace corresponding to the URI **urn:deitel:textInfo**. Compare this usage with that in Fig. A.5, where we prefixed the **file** and **description** elements with the namespace prefix **text** (lines 9–11).

The default namespace applies to all elements contained in the **directory** element. However, we may use a namespace prefix to specify a different namespace for particular

elements. For example, the **file** element on line 13 uses the prefix **image** to indicate that the element is in the namespace corresponding to the URI **urn:deitel:imageInfo**.

## A.7 Internet and World Wide Web Resources

### **www.w3.org/XML**

Worldwide Web Consortium Extensible Markup Language home page. Contains links to related XML technologies, recommended books, a time-line for publications, developer discussions, translations, software, etc.

### **www.w3.org/Addressing**

Worldwide Web Consortium addressing home page. Contains information on URIs and links to other resources.

### **www.xml.com**

This is one of the most popular XML sites on the Web. It has resources and links relating to all aspects of XML, including articles, news, seminar information, tools, Frequently Asked Questions (FAQs), etc.

### **www.xml.org**

“The XML Industry Portal” is another popular XML site that includes links to many different XML resources, such as news, FAQs and descriptions of XML-derived markup languages.

### **www.oasis-open.org/cover**

Oasis XML Cover Pages home page is a comprehensive reference for many aspects of XML and its related technologies. The site includes links to news, articles, software and events.

### **html.about.com/compute/html/cs/xmlandjava/index.htm**

This site contains articles about XML and Java and is updated regularly.

### **www.w3schools.com/xml**

Contains a tutorial that introduces the reader to the major aspects of XML. The tutorial contains many examples.

### **java.sun.com/xml**

Home page of the Sun’s JAXP and parser technology.

## **SUMMARY**

- XML is a technology for creating markup languages to describe data of virtually any type in a structured manner.
- XML allows document authors to describe data precisely by creating their own tags. Markup languages can be created using XML for describing almost anything.
- XML documents are commonly stored in text files that end in the extension **.xml**. Any text editor can be used to create an XML document. Many software packages allow data to be saved as XML documents.
- The XML declaration specifies the version to which the document conforms.
- All XML documents must have exactly one root element that contains all of the other elements.
- To process an XML document, a software program called an XML parser is required. The XML parser reads the XML document, checks its syntax, reports any errors and allows access to the document’s contents.
- An XML document is considered well formed if it is syntactically correct (i.e., the parser did not report any errors due to missing tags, overlapping tags, etc.). Every XML document must be well formed.

- Parsers may or may not support the Document Object Model (DOM) and/or the Simple API for XML (SAX) for accessing a document’s content programmatically by using languages such as Java, Python and C.
- XML documents may contain: carriage return, the line feed and Unicode characters. Unicode is a standard that was released by the Unicode Consortium in 1991 to expand character representation for most of the world’s major languages. The American Standard Code for Information Interchange (ASCII) is a subset of Unicode.
- Markup text is enclosed in angle brackets (i.e., < and >). Character data are the text between a start tag and an end tag. Child elements are considered markup—not character data.
- Spaces, tabs, line feeds and carriage returns are whitespace characters. In an XML document, the parser considers whitespace characters to be either significant (i.e., preserved by the parser) or insignificant (i.e., not preserved by the parser).
- Almost any character may be used in an XML document. However, the characters ampersand (&) and left-angle bracket (<) are reserved in XML and may not be used in character data, except in **CDATA** sections. Angle brackets are reserved for delimiting markup tags. The ampersand is reserved for delimiting hexadecimal values that refer to a specific Unicode character. These expressions are terminated with a semicolon (;) and are called entity references. The apostrophe and double-quote characters are reserved for delimiting attribute values.
- XML provides built-in entities for ampersand (&amp;), left-angle bracket (&lt;), right-angle bracket (&gt;), apostrophe (&apos;) and quotation mark (&quot;).
- All XML start tags must have a corresponding end tag and all start- and end tags must be properly nested. XML is case sensitive, therefore start tags and end tags must have matching capitalization.
- Elements define a structure. An element may or may not contain content (i.e., child elements or character data). Attributes describe elements. An element may have zero, one or more attributes associated with it. Attributes are nested within the element’s start tag. Attribute values are enclosed in quotes—either single or double.
- XML element and attribute names can be of any length and may contain letters, digits, underscores, hyphens and periods; and they must begin with either a letter or an underscore.
- A processing instruction’s (PI’s) information is passed by the parser to the application using the XML document. Document authors may create their own processing instructions. Almost any name may be used for a PI target except the reserved word **xml** (in any mixture of case). Processing instructions allow document authors to embed application-specific data within an XML document. This data are not intended to be readable by humans, but readable by applications.
- **CDATA** sections may contain text, reserved characters (e.g., <), words and whitespace characters. XML parsers do not process the text in **CDATA** sections. **CDATA** sections allow the document author to include data that is not intended to be parsed. **CDATA** sections cannot contain the text ]>.
- Because document authors can create their own tags, naming collisions (e.g., conflicts that arise when document authors use the same names for elements) can occur. Namespaces provide a means for document authors to prevent naming collisions. Document authors create their own namespaces. Virtually any name may be used for a namespace, except the reserved namespace **xml**.
- A Universal Resource Identifier (URI) is a series of characters used to differentiate names. URIs are used with namespaces.

## TERMINOLOGY

<! [CDATA[ and ]]> to delimit a **CDATA**

section

<? and ?> to delimit a processing instruction

ampersand (&amp;)

angle brackets (< and >)

apostrophe (&apos;)

application	parser
ASCII (American Standard Code for Information Interchange)	PI target
attribute	PI value
built-in entity	processing instruction (PI)
<b>CDATA</b> section	quotation mark ( <b>&amp;quot;</b> )
character data	reserved character
child	reserved keyword
child element	reserved namespace
comment	right angle bracket ( <b>&amp;gt;</b> )
container element	root element
content	SAX-based parser
element	significant whitespace character
empty element	Simple API for XML (SAX)
end tag	start tag
entity references	structured data
insignificant whitespace character	tree structure of an XML document
Java API for XML Parsing (JAXP)	Unicode
left angle bracket ( <b>&amp;lt;</b> )	Unicode Consortium
markup language	Universal Resource Identifier (URI)
markup text	XML
namespace	XML declaration
namespace prefix	XML document
namespace <b>xml</b>	XML namespace
naming collision	XML parser
node	XML processor
	XML version

## SELF-REVIEW EXERCISES

- A.1** State whether the following are *true* or *false*. If *false*, explain why.
- XML is a technology for creating markup languages.
  - XML markup text is delimited by forward and backward slashes (/ and \).
  - All XML start tags must have corresponding end tags.
  - Parsers check an XML document's syntax and may support the Document Object Model and/or the Simple API for XML.
  - An XML document is considered well formed if it contains whitespace characters.
  - SAX-based parsers process XML documents and generate events when tags, text, comments, etc., are encountered.
  - When creating new XML tags, document authors must use the set of XML tags provided by the W3C.
  - The pound character (#), the dollar sign (\$), the ampersand (&), the greater-than symbol (>) and the less-than symbol (<) are examples of XML reserved characters.
  - Any text file is automatically considered to be an XML document by a parser.
- A.2** Fill in the blanks in each of the following statements:
- A/An \_\_\_\_\_ processes an XML document.
  - Valid characters that can be used in an XML document are the carriage return, line feed and \_\_\_\_\_ characters.
  - An entity reference must be proceeded by a/an \_\_\_\_\_ character.
  - A/An \_\_\_\_\_ is delimited by <? and ?>.
  - Text in a/an \_\_\_\_\_ section is not parsed.

- f) An XML document is considered \_\_\_\_\_ if it is syntactically correct.
  - g) \_\_\_\_\_ help document authors prevent element-naming collisions.
  - h) A/An \_\_\_\_\_ tag does not contain character data.
  - i) The built-entity for the ampersand is \_\_\_\_\_.
- A.3** Identify and correct the error(s) in each of the following:
- a) <**my Tag**>This is my custom markup<**my Tag**>
  - b) <!PI value!> <!-- a sample processing instruction -->
  - c) <**myXML**>I know XML!!!</**MyXML**>
  - d) <**CDATA**>This is a CDATA section.</**CDATA**>
  - e) <**xml**>x < 5 && x > y</**xml**> <!-- mark up a Java condition \*\*>

## ANSWERS TO SELF-REVIEW EXERCISES

**A.4** a)True. b) False. In an XML document, markup text is any text delimited by angle brackets (< and >), with a forward slash being used in the end tag. c) True. d) True. e) False. An XML document is considered well formed if it is parsed successfully. f) True. g) False. When creating new tags, programmers may use any valid name except the reserved word **xml** (in any mixture of case). h) False. XML reserved characters include the ampersand (&) and the left angle bracket (<), but not the right-angle bracket (>), # and \$. i) False. The text file must be parsable by an XML parser. If parsing fails, the document cannot be considered an XML document.

**A.5** a) parser. b) Unicode. c) ampersand (&). d) processing instruction. e) **CDATA**. f) well formed. g) namespaces. h) empty. i) &**amp**;

**A.6** a) Element name **my tag** contains a space. The forward slash, /, is missing in the end tag. The corrected markup is <**myTag**>This is my custom markup</**myTag**>

- b) Incorrect delimiters for a processing instruction. The corrected markup is  
**<?PI value?> <!-- a sample processing instruction -->**
- c) Incorrect mixture of case in end tag. The corrected markup is  
**<**myXML**>I know XML!!!</**myXML**> or <**MyXML**>I know XML!!!</**MyXML**>**
- d) Incorrect syntax for a **CDATA** section. The corrected markup is  
**<! [CDATA[This is a CDATA section.]]>**
- e) The name **xml** is reserved and cannot be used as an element. The characters <, & and > must be represented using entities. The closing comment delimiter should be two hyphens—not two stars. Corrected markup is  
**<**someName**>x &lt; 5 &amp;&gt; x &gt; y</**someName**>**  
**<!-- mark up a Java condition -->**

# B

---

# Document Type Definition (DTD)

---

## Objectives

- To understand what a DTD is.
- To be able to write DTDs.
- To be able to declare elements and attributes in a DTD.
- To understand the difference between general entities and parameter entities.
- To be able to use conditional sections with entities.
- To be able to use **NOTATIONS**.
- To understand how an XML document's whitespace is processed.

*To whom nothing is given, of him can nothing be required.*

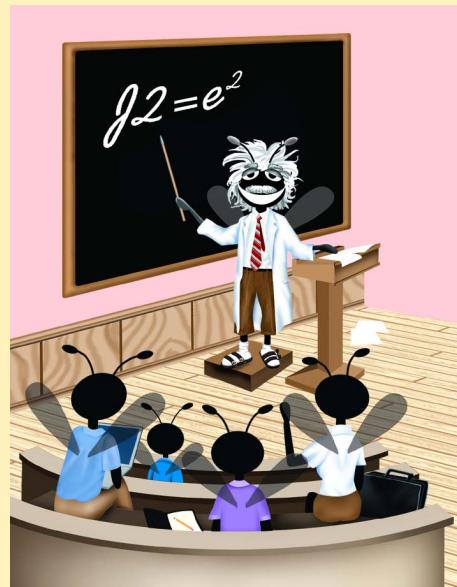
Henry Fielding

*Like everything metaphysical, the harmony between thought and reality is to be found in the grammar of the language.*

Ludwig Wittgenstein

*Grammar, which knows how to control even kings.*

Molière



## Outline

- B.1 Introduction
- B.2 Parsers, Well-Formed and Valid XML Documents
- B.3 Document Type Declaration
- B.4 Element Type Declarations
  - B.4.1 Sequences, Pipe Characters and Occurrence Indicators
  - B.4.2 EMPTY, Mixed Content and ANY
- B.5 Attribute Declarations
- B.6 Attribute Types
  - B.6.1 Tokenized Attribute Type (ID, IDREF, ENTITY, NMTOKEN)
  - B.6.2 Enumerated Attribute Types
- B.7 Conditional Sections
- B.8 Whitespace Characters
- B.9 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises*

### B.1 Introduction

In this appendix, we discuss *Document Type Definitions (DTDs)*, which define an XML document's structure (e.g., what elements, attributes, etc. are permitted in the document). An XML document is not required to have a corresponding DTD. However, DTDs are often recommended to ensure document conformity, especially in business-to-business (B2B) transactions, where XML documents are exchanged. DTDs specify an XML document's structure and are themselves defined using *EBNF (Extended Backus-Naur Form)* grammar—not the XML syntax introduced in Appendix A.

### B.2 Parsers, Well-Formed and Valid XML Documents

Parsers are generally classified as *validating* or *nonvalidating*. A validating parser is able to read a DTD and determine whether the XML document conforms to it. If the document conforms to the DTD, it is referred to as *valid*. If the document fails to conform to the DTD but is syntactically correct, it is well formed, but not valid. By definition, a valid document is well formed.

A nonvalidating parser is able to read the DTD, but cannot check the document against the DTD for conformity. If the document is syntactically correct, it is well formed.

In this appendix, we use a Java program we created to check a document conformance. This program, named **Validator.jar**, is located in the Appendix B examples directory. **Validator.jar** uses the reference implementation for the Java API for XML Processing 1.1, which requires **crimson.jar** and **jaxp.jar**.

## B.3 Document Type Declaration

DTDs are introduced into XML documents using the *document type declaration* (i.e., **DOCTYPE**). A document type declaration is placed in the XML document's *prolog* (i.e., all lines preceding the root element), begins with `<!DOCTYPE` and ends with `>`. The document type declaration can point to declarations that are outside the XML document (called the *external subset*) or can contain the declaration inside the document (called the *internal subset*). For example, an internal subset might look like

```
<!DOCTYPE myMessage [  
    <!ELEMENT myMessage ( #PCDATA )>  
]>
```

The first **myMessage** is the name of the document type declaration. Anything inside the *square brackets* (`[]`) constitutes the internal subset. As we will see momentarily, **ELEMENT** and **#PCDATA** are used in “element declarations.”

External subsets physically exist in a different file that typically ends with the **.dtd** extension, although this file extension is not required. External subsets are specified using either keyword the keyword **SYSTEM** or the keyword **PUBLIC**. For example, the **DOCTYPE** external subset might look like

```
<!DOCTYPE myMessage SYSTEM "myDTD.dtd">
```

which points to the **myDTD.dtd** document. The **PUBLIC** keyword indicates that the DTD is widely used (e.g., the DTD for HTML documents). The DTD may be made available in well-known locations for more efficient downloading. We used such a DTD in Chapters 9 and 10 when we created XHTML documents. The **DOCTYPE**

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"  
    "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
```

uses the **PUBLIC** keyword to reference the well-known DTD for XHTML version 1.0. XML parsers that do not have a local copy of the DTD may use the URL provided to download the DTD to perform validation.

Both the internal and external subset may be specified at the same time. For example, the **DOCTYPE**

```
<!DOCTYPE myMessage SYSTEM "myDTD.dtd" [  
    <!ELEMENT myElement ( #PCDATA )>  
]>
```

contains declarations from the **myDTD.dtd** document, as well as an internal declaration.



### Software Engineering Observation B.1

*The document type declaration's internal subset plus its external subset form the DTD.*



### Software Engineering Observation B.2

*The internal subset is visible only within the document in which it resides. Other external documents cannot be validated against it. DTDs that are used by many documents should be placed in the external subset.*

## B.4 Element Type Declarations

Elements are the primary building blocks used in XML documents and are declared in a DTD with **element** type declarations (**ELEMENTs**). For example, to declare element **myMessage**, we might write

```
<!ELEMENT myElement ( #PCDATA )>
```

The element name (e.g., **myElement**) that follows **ELEMENT** is often called a *generic identifier*. The set of parentheses that follow the element name specify the element's allowed content and is called the *content specification*. Keyword **PCDATA** specifies that the element must contain *parseable character data*. These data will be parsed by the XML parser, therefore any markup text (i.e., <, >, &, etc.) will be treated as markup. We will discuss the content specification in detail momentarily.



### Common Programming Error B.1

Attempting to use the same element name in multiple element type declarations is an error.

Figure B.1 lists an XML document that contains a reference to an external DTD in the **DOCTYPE**. We use **Validator.jar** to check the document's conformity against its DTD.

The document type declaration (line 6) specifies the name of the root element as **MyMessage**. The element **myMessage** (lines 8–10) contains a single child element named **message** (line 9).

Line 3 of the DTD (Fig. B.2) declares element **myMessage**. Notice that the content specification contains the name **message**. This indicates that element **myMessage** contains exactly one child element named **message**. Because **myMessage** can have only an element as its content, it is said to have *element content*. Line 4, declares element **message** whose content is of type **PCDATA**.



### Common Programming Error B.2

Having a root element name other than the name specified in the document type declaration is an error.

If an XML document's structure is inconsistent with its corresponding DTD, but is syntactically correct, the document is only well formed—not valid. Figure B.3 shows the messages generated when the required **message** element is omitted.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. B.1: welcome.xml      -->
4 <!-- Using an external subset -->
5
6 <!DOCTYPE myMessage SYSTEM "welcome.dtd">
7
8 <myMessage>
9   <message>Welcome to XML!</message>
10 </myMessage>
```

Fig. B.1 XML document declaring its associated DTD.

```
1 <!-- Fig. B.2: welcome.dtd -->
2 <!-- External declarations -->
3 <!ELEMENT myMessage ( message )>
4 <!ELEMENT message ( #PCDATA )>
```

```
C:\>java -jar Validator.jar welcome.xml
Document is valid.
```

Fig. B.2 Validation by using an external DTD.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. B.3 : welcome-invalid.xml -->
4 <!-- well-formed, but invalid document -->
5
6 <!DOCTYPE myMessage SYSTEM "welcome.dtd">
7
8 <!-- Root element missing child element message -->
9 <myMessage>
10 </myMessage>
```

```
C:\>java -jar Validator.jar welcome-invalid.xml
error: Element "myMessage" requires additional elements.
```

Fig. B.3 Invalid XML document.

#### B.4.1 Sequences, Pipe Characters and Occurrence Indicators

DTDs allow the document author to define the order and frequency of child elements. The *comma* (,)—called a *sequence*—specifies the order in which the elements must occur. For example,

```
<!ELEMENT classroom ( teacher, student )>
```

specifies that element **classroom** must contain exactly one **teacher** element followed by exactly one **student** element. The content specification can contain any number of items in sequence.

Similarly, choices are specified using the *pipe character* (|), as in

```
<!ELEMENT dessert ( iceCream | pastry )>
```

which specifies that element **dessert** must contain either one **iceCream** element or one **pastry** element, but not both. The content specification may contain any number of pipe character-separated choices.

An element's frequency (i.e., number of occurrences) is specified by using either the *plus sign* (+), *asterisk* (\*) or *question mark* (?) *occurrence indicator* (Fig. B.4).

Occurrence Indicator	Description
Plus sign ( + )	An element can appear any number of times, but must appear at least once (i.e., the element appears one or more times).
Asterisk ( * )	An element is optional, and if used, the element can appear any number of times (i.e., the element appears zero or more times).
Question mark ( ? )	An element is optional, and if used, the element can appear only once (i.e., the element appears zero or one times).

Fig. B.4 Occurrence indicators.

A plus sign indicates one or more occurrences. For example,

```
<!ELEMENT album ( song+ )>
```

specifies that element **album** contains one or more **song** elements.

The frequency of an *element group* (i.e., two or more elements that occur in some combination) is specified by enclosing the element names inside the content specification with parentheses, followed by either the plus sign, asterisk or question mark. For example,

```
<!ELEMENT album ( title, ( songTitle, duration )+ )>
```

indicates that element **album** contains one **title** element followed by any number of **songTitle/duration** element groups. At least one **songTitle/duration** group must follow **title**, and in each of these element groups, the **songTitle** must precede the **duration**. An example of markup that conforms to this is

```
<album>
  <title>XML Classical Hits</title>

  <songTitle>XML Overture</songTitle>
  <duration>10</duration>

  <songTitle>XML Symphony 1.0</songTitle>
  <duration>54</duration>
</album>
```

which contains one **title** element followed by two **songTitle/duration** groups. The asterisk (\*) character indicates an optional element that, if used, can occur any number of times. For example,

```
<!ELEMENT library ( book* )>
```

indicates that element **library** contains any number of **book** elements, including the possibility of none at all. Markup examples that conform to this mark up are

```
<library>
  <book>The Wealth of Nations</book>
  <book>The Iliad</book>
  <book>The Jungle</book>
</library>
```

and

```
<library></library>
```

Optional elements that, if used, may occur only once are followed by a question mark (?). For example,

```
<!ELEMENT seat ( person? )>
```

indicates that element **seat** contains at most one **person** element. Examples of markup that conform to this are

```
<seat>
  <person>Jane Doe</person>
</seat>
```

and

```
<seat></seat>
```

Now we consider three more element type declarations and provide a declaration for each. The declaration

```
<!ELEMENT class ( number, ( instructor | assistant+ ),
  ( credit | noCredit ) )>
```

specifies that a **class** element must contain a **number** element, either one **instructor** element or any number of **assistant** elements and either one **credit** element or one **noCredit** element. Markup examples that conform to this are

```
<class>
  <number>123</number>
  <instructor>Dr. Harvey Deitel</instructor>
  <credit>4</credit>
</class>
```

and

```
<class>
  <number>456</number>
  <assistant>Tem Nieto</assistant>
  <assistant>Paul Deitel</assistant>
  <credit>3</credit>
</class>
```

The declaration

```
<!ELEMENT donutBox ( jelly?, lemon*,
  ( ( creme | sugar )+ | glazed ) )>
```

specifies that element **donutBox** can have zero or one **jelly** elements, followed by zero or more **lemon** elements, followed by one or more **creme** or **sugar** elements or exactly one **glazed** element. Markup examples that conform to this are

```
<donutBox>
  <jelly>grape</jelly>
  <lemon>half-sour</lemon>
  <lemon>sour</lemon>
  <lemon>half-sour</lemon>
  <glazed>chocolate</glazed>
</donutBox>
```

and

```
<donutBox>
  <sugar>semi-sweet</sugar>
  <creme>whipped</creme>
  <sugar>sweet</sugar>
</donutBox>
```

The declaration

```
<!ELEMENT farm ( farmer+, ( dog* | cat? ), pig*,
  ( goat | cow )?, ( chicken+ | duck* ) )>
```

indicates that element **farm** can have one or more **farmer** elements, any number of optional **dog** elements or an optional **cat** element, any number of optional **pig** elements, an optional **goat** or **cow** element and one or more **chicken** elements or any number of optional **duck** elements. Examples of markup that conform to this are

```
<farm>
  <farmer>Jane Doe</farmer>
  <farmer>John Doe</farmer>
  <cat>Lucy</cat>
  <pig>Bo</pig>
  <chicken>Jill</chicken>
</farm>
```

and

```
<farm>
  <farmer>Red Green</farmer>
  <duck>Billy</duck>
  <duck>Sue</duck>
</farm>
```

## B.4.2 EMPTY, Mixed Content and ANY

Elements must be further refined by specifying the types of content they contain. In the previous section, we introduced element content, indicating that an element can contain one or more child elements as its content. In this section, we introduce *content specification types* for describing nonelement content.

In addition to element content, three other types of content exist: **EMPTY**, *mixed content* and **ANY**. Keyword **EMPTY** declares empty elements, which do not contain character data or child elements. For example,

```
<!ELEMENT oven EMPTY>
```

declares element **oven** to be an empty element. The markup for an **oven** element would appear as

```
<oven/>
```

or

```
<oven></oven>
```

in an XML document conforming to this declaration.

An element can also be declared as having mixed content. Such elements may contain any combination of elements and **PCDATA**. For example, the declaration

```
<!ELEMENT myMessage ( #PCDATA | message )*>
```

indicates that element **myMessage** contains mixed content. Markup conforming to this declaration might look like

```
<myMessage>Here is some text, some  
    <message>other text</message>and  
    <message>even more text</message>.  
</myMessage>
```

Element **myMessage** contains two **message** elements and three instances of character data. Because of the **\***, element **myMessage** could have contained nothing.

Figure B.5 specifies the DTD as an internal subset (lines 6–10). In the prolog (line 1), we use the **standalone** attribute with a value of **yes**. An XML document is *standalone* if it does not reference an external subset. This DTD defines three elements: one that contains mixed content and two that contain parsed character data.

```
1 <?xml version = "1.0" standalone = "yes"?>  
2  
3 <!-- Fig. B.5 : mixed.xml -->  
4 <!-- Mixed content type elements -->  
5  
6 <!DOCTYPE format [  
7     <!ELEMENT format ( #PCDATA | bold | italic )*>  
8     <!ELEMENT bold ( #PCDATA )>  
9     <!ELEMENT italic ( #PCDATA )>  
10 ]>  
11  
12 <format>  
13     Book catalog entry:  
14     <bold>XML</bold>  
15     <italic>XML How to Program</italic>  
16     This book carefully explains XML-based systems development.  
17 </format>
```

```
C:\>java -jar Validator.jar mixed.xml  
Document is valid.
```

Fig. B.5 Example of a mixed-content element.

Line 7 declares element **format** as a mixed content element. According to the declaration, the **format** element may contain either parsed character data (**PCDATA**), element **bold** or element **italic**. The asterisk indicates that the content can occur zero or more times. Lines 8 and 9 specify that **bold** and **italic** elements only have **PCDATA** for their content specification—they cannot contain child elements. Despite the fact that elements with **PCDATA** content specification cannot contain child elements, they are still considered to have mixed content. The comma (,), plus sign (+) and question mark (?) occurrence indicators cannot be used with mixed-content elements that contain only **PCDATA**.

Figure B.6 shows the results of changing the first pipe character in line 7 of Fig. B.5 to a comma and the result of removing the asterisk. Both of these are illegal DTD syntax.



### Common Programming Error B.3

*When declaring mixed content, not listing PCDATA as the first item is an error.*

An element declared as type **ANY** can contain any content, including **PCDATA**, elements or a combination of elements and **PCDATA**. Elements with **ANY** content can also be empty elements.



### Software Engineering Observation B.3

*Elements with ANY content are commonly used in the early stages of DTD development. Document authors typically replace ANY content with more specific content as the DTD evolves.*

## B.5 Attribute Declarations

In this section, we discuss *attribute declarations*. An attribute declaration specifies an *attribute list* for an element by using the **ATTLIST** attribute list declaration. An element can have any number of attributes. For example,

```
<!ELEMENT x EMPTY>
<!ATTLIST x y CDATA #REQUIRED>
```

```

1 <?xml version = "1.0" standalone = "yes"?>
2
3 <!-- Fig. B.6 : invalid-mixed.xml -->
4 <!-- Mixed content type elements -->
5
6 <!DOCTYPE format [
7   <!ELEMENT format ( #PCDATA | bold, italic )>
8   <!ELEMENT bold ( #PCDATA )>
9   <!ELEMENT italic ( #PCDATA )>
10 ]>
11
12 <format>
13   Book catalog entry:
14   <bold>XML</bold>
15   <italic>XML How to Program</italic>
16   This book carefully explains XML-based systems development.
17 </format>
```

Fig. B.6 Changing a pipe character to a comma in a DTD (part 1 of 2).

```
C:>java -jar Validator.jar invalid-mixed.xml
fatal error: Mixed content model for "format" must end with ")**", not
",".
```

Fig. B.6 Changing a pipe character to a comma in a DTD (part 2 of 2).

declares **EMPTY** element **x**. The attribute declaration specifies that **y** is an attribute of **x**. Keyword **CDATA** indicates that **y** can contain any character text except for the <, >, &, ' and " characters. Note that the **CDATA** keyword in an attribute declaration has a different meaning than the **CDATA** section in an XML document we introduced in Appendix A. Recall that in a **CDATA** section all characters are legal except the **]]>** end tag. Keyword **#REQUIRED** specifies that the attribute must be provided for element **x**. We will say more about other keywords momentarily.

Figure B.7 demonstrates how to specify attribute declarations for an element. Line 9 declares attribute **id** for element **message**. Attribute **id** contains required **CDATA**. Attribute values are normalized (i.e., consecutive whitespace characters are combined into one whitespace character). We discuss normalization in detail in Section B.8. Line 13 assigns attribute **id** the value **"6343070"**.

DTDs allow document authors to specify an attribute's default value using *attribute defaults*, which we briefly touched upon in the previous section. Keywords **#IMPLIED**, **#REQUIRED** and **#FIXED** are attribute defaults. Keyword **#IMPLIED** specifies that if the attribute does not appear in the element, then the application using the XML document can use whatever value (if any) it chooses.

Keyword **#REQUIRED** indicates that the attribute must appear in the element. The XML document is not valid if the attribute is missing. For example, the markup

```
<message>XML and DTDs</message>
```

```
1  <?xml version = "1.0"?>
2
3  <!-- Fig. B.7: welcome2.xml -->
4  <!-- Declaring attributes -->
5
6  <!DOCTYPE myMessage [
7      <!ELEMENT myMessage ( message )>
8      <!ELEMENT message ( #PCDATA )>
9      <!ATTLIST message id CDATA #REQUIRED>
10 ]>
11
12 <myMessage>
13
14     <message id = "6343070">
15         Welcome to XML!
16     </message>
17
18 </myMessage>
```

Fig. B.7 Declaring attributes (part 1 of 2).

```
C:\>java -jar Validator.jar welcome2.xml
Document is valid.
```

Fig. B.7 Declaring attributes (part 2 of 2).

when checked against the DTD attribute list declaration

```
<!ATTLIST message number CDATA #REQUIRED>
```

does not conform to it because attribute **number** is missing from element **message**.

An attribute declaration with default value **#FIXED** specifies that the attribute value is constant and cannot be different in the XML document. For example,

```
<!ATTLIST address zip #FIXED "02115">
```

indicates that the value **"02115"** is the only value attribute **zip** can have. The XML document is not valid if attribute **zip** contains a value different from **"02115"**. If element **address** does not contain attribute **zip**, the default value **"02115"** is passed to the application that is using the XML document's data.

## B.6 Attribute Types

Attribute types are classified as either *string* (**CDATA**), *tokenized* or *enumerated*. *String attribute* types do not impose any constraints on attribute values, other than disallowing the < and & characters. Entity references (e.g., &lt;, &amp;, etc.) must be used for these characters. *Tokenized attribute types* impose constraints on attribute values, such as which characters are permitted in an attribute name. We discuss tokenized attribute types in the next section. *Enumerated attribute types* are the most restrictive of the three types. They can take only one of the values listed in the attribute declaration. We discuss enumerated attribute types in Section B.6.2.

### B.6.1 Tokenized Attribute Type (**ID**, **IDREF**, **ENTITY**, **NMTOKEN**)

Tokenized attribute types allow a DTD author to restrict the values used for attributes. For example, an author may want to have a unique ID for each element or allow an attribute to have only one or two different values. Four different tokenized attribute types exist: **ID**, **IDREF**, **ENTITY** and **NMTOKEN**.

Tokenized attribute type **ID** uniquely identifies an element. Attributes with type **IDREF** point to elements with an **ID** attribute. A validating parser verifies that every **ID** attribute type referenced by **IDREF** is in the XML document.

Figure B.8 lists an XML document that uses **ID** and **IDREF** attribute types. Element **bookstore** consists of element **shipping** and element **book**. Each **shipping** element describes who shipped the book and how long it will take for the book to arrive.

Line 9 declares attribute **shipID** as an **ID** type attribute (i.e., each **shipping** element has a unique identifier). Lines 27–37 declare **book** elements with attribute **shippedBy** (line 11) of type **IDREF**. Attribute **shippedBy** points to one of the **shipping** elements by matching its **shipID** attribute.



## Common Programming Error B.4

Using the same value for multiple **ID** attributes is a logic error: The document validated against the DTD is not valid.

The DTD contains an *entity declaration* for each of the entities **isbnXML**, **isbnJava** and **isbnCPP**. The parser replaces the entity references with their values. These entities are called *general entities*.

Figure B.9 is a variation of Fig. B.8 that assigns **shippedBy** (line 32) the value "bug". No **shipID** attribute has a value "bug", which results in an invalid XML document.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. B.8: IDEExample.xml -->
4 <!-- Example for ID and IDREF values of attributes -->
5
6 <!DOCTYPE bookstore [
7   <!ELEMENT bookstore ( shipping+, book+ )>
8   <!ELEMENT shipping ( duration )>
9   <!ATTLIST shipping shipID ID #REQUIRED>
10  <!ELEMENT book ( #PCDATA )>
11  <!ATTLIST book shippedBy IDREF #IMPLIED>
12  <!ELEMENT duration ( #PCDATA )>
13  <!ENTITY isbnXML "0-13-028417-3">
14  <!ENTITY isbnJava "0-13-034151-7">
15  <!ENTITY isbnCPP "0-13-0895717-3">
16 ]>
17
18 <bookstore>
19   <shipping shipID = "bug2bug">
20     <duration>2 to 4 days</duration>
21   </shipping>
22
23   <shipping shipID = "Deitel">
24     <duration>1 day</duration>
25   </shipping>
26
27   <book shippedBy = "Deitel" isbn = "&isbnJava;">
28     Java How to Program 4th edition.
29   </book>
30
31   <book shippedBy = "Deitel" isbn = "&isbnXML;">
32     XML How to Program.
33   </book>
34
35   <book shippedBy = "bug2bug" isbn = "&isbnCPP;">
36     C++ How to Program 3rd edition.
37   </book>
38 </bookstore>
```

```
C:\>java -jar Validator.jar IDEExample.xml
Document is valid.
```

Fig. B.8 XML document with **ID** and **IDREF** attribute types (part 1 of 2).

```
C:\>java -jar ParserTest.jar idexample.xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. B.8: IDEExample.xml -->
<!-- Example for ID and IDREF values of attributes -->
<bookstore>
    <shipping shipID="bug2bug">
        <duration>2 to 4 days</duration>
    </shipping>

    <shipping shipID="Deitel">
        <duration>1 day</duration>
    </shipping>

    <book shippedBy="Deitel" isbn="0-13-034151-7">
        Java How to Program 4th edition.
    </book>

    <book shippedBy="Deitel" isbn="0-13-028417-3">
        XML How to Program.
    </book>

    <book shippedBy="bug2bug" isbn="0-13-0895717-3">
        C++ How to Program 3rd edition.
    </book>
</bookstore>
```

Fig. B.8 XML document with **ID** and **IDREF** attribute types (part 2 of 2).



### Common Programming Error B.5

Not beginning a type attribute **ID** 's value with a letter, an underscore (\_) or a colon (:) is an error.



### Common Programming Error B.6

Providing more than one **ID** attribute type for an element is an error.



### Common Programming Error B.7

Declaring attributes of type **ID** as **#FIXED** is an error.

Related to entities are *entity attributes*, which indicate that an attribute has an entity for its value. Entity attributes are specified by using tokenized attribute type **ENTITY**. The primary constraint placed on **ENTITY** attribute types is that they must refer to *external unparsed entities*. An external unparsed entity is defined in the external subset of a DTD and consists of character data that will not be parsed by the XML parser.

Figure B.10 lists an XML document that demonstrates the use of entities and entity attribute types.

```
1  <?xml version = "1.0"?>
2
```

Fig. B.9 Error displayed when an invalid **ID** is referenced (part 1 of 2).

```
3  <!-- Fig. B.9: invalid-IDExample.xml -->
4  <!-- Example for ID and IDREF values of attributes -->
5
6  <!DOCTYPE bookstore [
7    <!ELEMENT bookstore ( shipping+, book+ )>
8    <!ELEMENT shipping ( duration )>
9    <!ATTLIST shipping shipID ID #REQUIRED>
10   <!ELEMENT book ( #PCDATA )>
11   <!ATTLIST book shippedBy IDREF #IMPLIED>
12   <!ELEMENT duration ( #PCDATA )>
13 ]>
14
15 <bookstore>
16   <shipping shipID = "bug2bug">
17     <duration>2 to 4 days</duration>
18   </shipping>
19
20   <shipping shipID = "Deitel">
21     <duration>1 day</duration>
22   </shipping>
23
24   <book shippedBy = "Deitel">
25     Java How to Program 4th edition.
26   </book>
27
28   <book shippedBy = "Deitel">
29     C How to Program 3rd edition.
30   </book>
31
32   <book shippedBy = "bug">
33     C++ How to Program 3rd edition.
34   </book>
35 </bookstore>
```

```
C:\>java -jar Validator.jar invalid-IDExample.xml
error: No element has an ID attribute with value "bug".
```

Fig. B.9 Error displayed when an invalid **ID** is referenced (part 2 of 2).

Line 7 declares a *notation* named **html** that refers to a **SYSTEM** identifier named **"iexplorer"**. Notations provide information that an application using the XML document can use to handle unparsed entities. For example, the application using this document may choose to open Internet Explorer and load the document **tour.html** (line 8).

Line 8 declares an entity named **city** that refers to an external document (**tour.html**). Keyword **NDATA** indicates that the content of this external entity is not XML. The name of the notation (e.g., **html**) that handles this unparsed entity is placed to the right of **NDATA**.

Line 11 declares attribute **tour** for element **company**. Attribute **tour** specifies a required **ENTITY** attribute type. Line 16 assigns entity **city** to attribute **tour**. If we replaced line 16 with

```
<company tour = "country">
```

the document fails to conform to the DTD because entity **country** does not exist. Figure B.11 shows the error message generated when the above replacement is made.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. B.10: entityExample.xml      -->
4 <!-- ENTITY and ENTITY attribute types -->
5
6 <!DOCTYPE database [
7   <!NOTATION XHTML SYSTEM "iexplorer">
8   <!ENTITY city SYSTEM "tour.html" NDATA XHTML>
9   <!ELEMENT database ( company+ )>
10  <!ELEMENT company ( name )>
11  <!ATTLIST company tour ENTITY #REQUIRED>
12  <!ELEMENT name ( #PCDATA )>
13 ]>
14
15 <database>
16   <company tour = "city">
17     <name>Deitel & Associates, Inc.</name>
18   </company>
19 </database>
```

```
C:\>java -jar Validator.jar entityexample.xml
Document is valid.
```

Fig. B.10 XML document that contains an **ENTITY** attribute type.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. B.11: invalid-entityExample.xml -->
4 <!-- ENTITY and ENTITY attribute types      -->
5
6 <!DOCTYPE database [
7   <!NOTATION XHTML SYSTEM "iexplorer">
8   <!ENTITY city SYSTEM "tour.html" NDATA XHTML>
9   <!ELEMENT database ( company+ )>
10  <!ELEMENT company ( name )>
11  <!ATTLIST company tour ENTITY #REQUIRED>
12  <!ELEMENT name ( #PCDATA )>
13 ]>
14
15 <database>
16   <company tour = "country">
17     <name>Deitel & Associates, Inc.</name>
18   </company>
19 </database>
```

Fig. B.11 Error generated when a DTD contains a reference to an undefined entity (part 1 of 2).

```
C:\>java -jar Validator.jar invalid-entityexample.xml
error: Attribute value "country" does not name an unparsed entity.
```

**Fig. B.11** Error generated when a DTD contains a reference to an undefined entity (part 2 of 2).



### Common Programming Error B.8

*Not assigning an unparsed external entity to an attribute with attribute type **ENTITY** results in an invalid XML document.*

Attribute type **ENTITIES** may also be used in a DTD to indicate that an attribute has multiple entities for its value. Each entity is separated by a space. For example

```
<!ATTLIST directory file ENTITIES #REQUIRED>
```

specifies that attribute **file** is required to contain multiple entities. An example of markup that conforms to this might look like

```
<directory file = "animations graph1 graph2">
```

where **animations**, **graph1** and **graph2** are entities declared in a DTD.

A more restrictive attribute type is **NMOKEN** (*name token*), whose value consists of letters, digits, periods, underscores, hyphens and colon characters. For example, consider the declaration

```
<!ATTLIST sportsClub phone NMOKEN #REQUIRED>
```

which indicates **sportsClub** contains a required **NMOKEN** **phone** attribute. An example of markup that conforms to this is

```
<sportsClub phone = "555-111-2222">
```

An example that does not conform to this is

```
<sportsClub phone = "555 555 4902">
```

because spaces are not allowed in an **NMOKEN** attribute.

Similarly, when an **NMOKENS** attribute type is declared, the attribute may contain multiple string tokens separated by spaces.

## B.6.2 Enumerated Attribute Types

*Enumerated attribute types* declare a list of possible values an attribute can have. The attribute must be assigned a value from this list to conform to the DTD. Enumerated type values are separated by pipe characters (|). For example, the declaration

```
<!ATTLIST person gender ( M | F ) "F">
```

contains an enumerated attribute type declaration that allows attribute **gender** to have either the value **M** or the value **F**. A default value of "**F**" is specified to the right of the element attribute type. Alternatively, a declaration such as

```
<!ATTLIST person gender ( M | F ) #IMPLIED>
```

does not provide a default value for **gender**. This type of declaration might be used to validate a marked-up mailing list that contains first names, last names, addresses, etc. The application that uses such a mailing list may want to precede each name by either Mr., Ms. or Mrs. However, some first names are gender neutral (e.g., Chris, Sam, etc.), and the application may not know the **person's** gender. In this case, the application has the flexibility to process the name in a gender-neutral way.

**NOTATION** is also an enumerated attribute type. For example, the declaration

```
<!ATTLIST book reference NOTATION ( JAVA | C ) "C">
```

indicates that **reference** must be assigned either **JAVA** or **C**. If a value is not assigned, **C** is specified as the default. The notation for **C** might be declared as

```
<!NOTATION C SYSTEM
  "http://www.deitel.com/books/2000/chtp3/chtp3_toc.htm">
```

## B.7 Conditional Sections

DTDs provide the ability to include or exclude declarations using conditional sections. Keyword **INCLUDE** specifies that declarations are included, while keyword **IGNORE** specifies that declarations are excluded. For example, the conditional section

```
<! [INCLUDE [
  <!ELEMENT name ( #PCDATA )>
]]>
```

directs the parser to include the declaration of element **name**.

Similarly, the conditional section

```
<! [IGNORE [
  <!ELEMENT message ( #PCDATA )>
]]>
```

directs the parser to exclude the declaration of element **message**. Conditional sections are often used with entities, as demonstrated in Fig. B.12.

---

```

1  <!-- Fig. B.12: conditional.dtd          -->
2  <!-- DTD for conditional section example -->
3
4  <!ENTITY % reject "IGNORE">
5  <!ENTITY % accept "INCLUDE">
6
7  <! [ %accept; [
8    <!ELEMENT message ( approved, signature )>
9  ]]>
10
11 <! [ %reject; [
12   <!ELEMENT message ( approved, reason, signature )>
13 ]]>
14
15 <!ELEMENT approved EMPTY>
16 <!ATTLIST approved flag ( true | false ) "false">
```

---

Fig. B.12 Conditional sections in a DTD (part 1 of 2).

```

17
18  <!ELEMENT reason ( #PCDATA )>
19  <!ELEMENT signature ( #PCDATA )>

```

Fig. B.12 Conditional sections in a DTD (part 2 of 2).

Lines 4–5 declare entities **reject** and **accept**, with the values **IGNORE** and **INCLUDE**, respectively. Because each of these entities is preceded by a *percent (%) character*, they can be used only inside the DTD in which they are declared. These types of entities—called *parameter entities*—allow document authors to create entities specific to a DTD—not an XML document. Recall that the DTD is the combination of the internal subset and external subset. Parameter entities may be placed only in the external subset.

Lines 7–13 use the entities **accept** and **reject**, which represent the strings **INCLUDE** and **IGNORE**, respectively. Notice that the parameter entity references are preceded by %, whereas normal entity references are preceded by &. Line 7 represents the beginning tag of an **IGNORE** section (the value of the **accept** entity is **IGNORE**), while line 11 represents the start tag of an **INCLUDE** section. By changing the values of the entities, we can easily choose which **message** element declaration to allow.

Figure B.13 shows the XML document that conforms to the DTD in Fig. B.12.



#### Software Engineering Observation B.4

Parameter entities allow document authors to use entity names in DTDs without conflicting with entities names used in an XML document.

## B.8 Whitespace Characters

In Appendix A, we briefly discussed whitespace characters. In this section, we discuss how whitespace characters relate to DTDs. Depending on the application, insignificant whitespace characters may be collapsed into a single whitespace character or even removed entirely. This process is called *normalization*. Whitespace is either preserved or normalized, depending on the context in which it is used.

```

1  <?xml version = "1.0" standalone = "no"?>
2
3  <!-- Fig. B.13: conditional.xml -->
4  <!-- Using conditional sections -->
5
6  <!DOCTYPE message SYSTEM "conditional.dtd">
7
8  <message>
9    <approved flag = "true" />
10   <signature>Chairman</signature>
11 </message>

```

```
C:\>java -jar Validator.jar conditional.xml
Document is valid.
```

Fig. B.13 XML document that conforms to **conditional.dtd**.

Figure B.14 contains a DTD and markup that conforms to the DTD. Line 28 assigns a value containing multiple whitespace characters to attribute **cdata**. Attribute **cdata** (declared in line 11) is required and must contain **CDATA**. As mentioned earlier, **CDATA** can contain almost any text, including whitespace. As the output illustrates, spaces in **CDATA** are preserved and passed on to the application that is using the XML document.

Line 30 assigns a value to attribute **id** that contains leading whitespace. Attribute **id** is declared on line 14 with tokenized attribute type **ID**. Because this is not **CDATA**, it is normalized and the leading whitespace characters are removed. Similarly, lines 32 and 34 assign values that contain leading whitespace to attributes **nmtoken** and **enumeration**—which are declared in the DTD as an **NMOKEN** and an enumeration, respectively. Both these attributes are normalized by the parser.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. B.14 : whitespace.xml          -->
4 <!-- Demonstrating whitespace parsing -->
5
6 <!DOCTYPE whitespace [
7   <!ELEMENT whitespace ( hasCDATA,
8     hasID, hasNMTOKEN, hasEnumeration, hasMixed )>
9
10  <!ELEMENT hasCDATA EMPTY>
11  <!ATTLIST hasCDATA cdata CDATA #REQUIRED>
12
13  <!ELEMENT hasID EMPTY>
14  <!ATTLIST hasID id ID #REQUIRED>
15
16  <!ELEMENT hasNMTOKEN EMPTY>
17  <!ATTLIST hasNMTOKEN nmtoken NMTOKEN #REQUIRED>
18
19  <!ELEMENT hasEnumeration EMPTY>
20  <!ATTLIST hasEnumeration enumeration ( true | false )
21    #REQUIRED>
22
23  <!ELEMENT hasMixed ( #PCDATA | hasCDATA )*>
24 ]>
25
26 <whitespace>
27
28   <hasCDATA cdata = "  simple cdata  "/>
29
30   <hasID id = " i20"/>
31
32   <hasNMTOKEN nmtoken = " hello"/>
33
34   <hasEnumeration enumeration = " true"/>
35
36   <hasMixed>
37     This is text.
38     <hasCDATA cdata = " simple      cdata"/>
```

Fig. B.14 Processing whitespace in an XML document (part 1 of 2).

```
39      This is some additional text.  
40  </hasMixed>  
41  
42  </whitespace>
```

```
C:\Documents and Settings\Administrator\My Documents\advanced java\xml  
appendice  
s\appBexamples>java -jar Validator.jar whitespace.xml  
Document is valid.
```

```
C:\>java -jar ParserTest.jar ..\appBexamples\whitespace.xml  
<?xml version="1.0" encoding="UTF-8"?>  
<!-- Fig. B.14 : whitespace.xml -->  
<!-- Demonstrating whitespace parsing -->  
<whitespace>  
  
    <hasCDATA cdata=" simple cdata "/>  
  
    <hasID id="i20"/>  
  
    <hasNMOKEN nmtoken="hello"/>  
  
    <hasEnumeration enumeration="true"/>  
  
    <hasMixed>  
        This is text.  
        <hasCDATA cdata=" simple      cdata"/>  
        This is some additional text.  
    </hasMixed>  
  
</whitespace>
```

Fig. B.14 Processing whitespace in an XML document (part 2 of 2).

## B.9 Internet and World Wide Web Resources

[www.wdvl.com/Authoring/HTML/Validation/DTD.html](http://www.wdvl.com/Authoring/HTML/Validation/DTD.html)

Contains a description of the historical uses of DTDs, including a description of SGML and the HTML DTD.

[www.xml101.com/dtd](http://www.xml101.com/dtd)

Contains tutorials and explanations on creating DTDs.

[www.w3schools.com/dtd](http://www.w3schools.com/dtd)

Contains DTD tutorials and examples.

[wdvl.internet.com/Authoring/Languages/XML/Tutorials/Intro/index3.html](http://wdvl.internet.com/Authoring/Languages/XML/Tutorials/Intro/index3.html)

A DTD tutorial for Web developers.

[www.schema.net](http://www.schema.net)

A DTD repository with XML links and resources.

[www.networking.ibm.com/xml/XmlValidatorForm.html](http://www.networking.ibm.com/xml/XmlValidatorForm.html)

IBM's DOMit XML Validator.

## SUMMARY

- Document Type Definitions (DTDs) define an XML document's structure (e.g., what elements, attributes, etc. are permitted in the XML document). An XML document is not required to have a corresponding DTD. DTDs use EBNF (Extended Backus-Naur Form) grammar.
- Parsers are generally classified as validating or nonvalidating. A validating parser can read the DTD and determine whether or not the XML document conforms to it. If the document conforms to the DTD, it is referred to as valid. If the document fails to conform to the DTD but is syntactically correct, it is well formed but not valid. By definition, a valid document is well formed.
- A nonvalidating parser is able to read a DTD, but cannot check the document against the DTD for conformity. If the document is syntactically correct, it is well formed.
- DTDs are introduced into XML documents by using the document type declaration (i.e., **DOC-TYPE**). The document type declaration can point to declarations that are outside the XML document (called the external subset) or can contain the declaration inside the document (called the internal subset).
- External subsets physically exist in a different file that typically ends with the **.dtd** extension, although this file extension is not required. External subsets are specified using keyword **SYSTEM** or **PUBLIC**. Both the internal and external subset may be specified at the same time.
- Elements are the primary building block used in XML documents and are declared in a DTD with element type declarations (**ELEMENTS**).
- The element name that follows **ELEMENT** is often called a generic identifier. The set of parentheses that follow the element name specify the element's allowed content and is called the content specification.
- Keyword **PCDATA** specifies that the element must contain parsable character data—that is, any text except the characters less than (<) and ampersand (&).
- An XML document is a **standalone** XML document if it does not reference an external DTD.
- An XML element that can have only another element for content is said to have element content.
- DTDs allow document authors to define the order and frequency of child elements. The comma (,),—called a sequence—specifies the order in which the elements must occur. Choices are specified using the pipe character (|). The content specification may contain any number of pipe-character-separated choices.
- An element's frequency (i.e., number of occurrences) is specified by using either the plus sign (+), asterisk (\*) or question mark (?) occurrence indicator.
- The frequency of an element group (i.e., two or more elements that occur in some combination) is specified by enclosing the element names inside the content specification, followed by an occurrence indicator.
- Elements can be further refined by describing the content types they may contain. Content specification types (e.g., **EMPTY**, mixed content, **ANY**, etc.) describe nonelement content.
- An element can be declared as having mixed content (i.e., a combination of elements and **PCDATA**). The comma (,), plus sign (+) and question mark (?) occurrence indicators cannot be used with mixed content elements.
- An element declared as type **ANY** can contain any content including **PCDATA**, elements, or a combination of elements and **PCDATA**. Elements with **ANY** content can also be empty elements.
- An attribute list for an element is declared using the **ATTLIST** element type declaration.
- Attribute values are normalized (i.e., consecutive whitespace characters are combined into one whitespace character).

- DTDs allow document authors to specify an attribute's default value using attribute defaults. Key-words **#IMPLIED**, **#REQUIRED** and **#FIXED** are attribute defaults.
- Keyword **#IMPLIED** specifies that if the attribute does not appear in the element, then the application using the XML document can apply whatever value (if any) it chooses.
- Keyword **#REQUIRED** indicates that the attribute must appear in the element. The XML document is not valid if the attribute is missing.
- An attribute declaration with default value **#FIXED** specifies that the attribute value is constant and cannot be different in the XML document.
- Attribute types are classified as either string (**CDATA**), tokenized or enumerated. String attribute types do not impose any constraints on attribute values, other than disallowing the < and & characters. Entity references (e.g., **&lt;**, **&amp;**, etc.) must be used for these characters. Tokenized attributes impose constraints on attribute values, such as which characters are permitted in an attribute name. Enumerated attributes are the most restrictive of the three types. They can take only one of the values listed in the attribute declaration.
- Four different tokenized attribute types exist: **ID**, **IDREF**, **ENTITY** and **NMTOKEN**. Tokenized attribute type **ID** uniquely identifies an element. Attributes with type **IDREF** point to elements with an **ID** attribute. A validating parser verifies that every **ID** attribute type referenced by **IDREF** is in the XML document.
- Entity attributes indicate that an attribute has an entity for its value and are specified using tokenized attribute type **ENTITY**. The primary constraint placed on **ENTITY** attribute types is that they must refer to external unparsed entities.
- Attribute type **ENTITIES** may also be used in a DTD to indicate that an attribute has multiple entities for its value. Each entity is separated by a space.
- A more restrictive attribute type is attribute type **NMTOKEN** (name token), whose value consists of letters, digits, periods, underscores, hyphens and colon characters.
- Attribute type **NMTOKENS** may contain multiple string tokens separated by spaces.
- Enumerated attribute types declare a list of possible values an attribute can have. The attribute must be assigned a value from this list to conform to the DTD. Enumerated type values are separated by pipe characters (|).
- **NOTATION** is also an enumerated attribute type. Notations provide information that an application using the XML document can use to handle unparsed entities.
- Keyword **NDATA** indicates that the content of an external entity is not XML. The name of the notation that handles this unparsed entity is placed to the right of **NDATA**.
- DTDs provide the ability to include or exclude declarations using conditional sections. Keyword **INCLUDE** specifies that declarations are included, while keyword **IGNORE** specifies that declarations are excluded. Conditional sections are often used with entities.
- Parameter entities are preceded by percent (%) characters and can be used only inside the DTD in which they are declared. Parameter entities allow document authors to create entities specific to a DTD—not an XML document.
- Whitespace is either preserved or normalized, depending on the context in which it is used. Spaces in **CDATA** are preserved. Attribute values with tokenized attribute types **ID**, **NMTOKEN** and enumeration are normalized.

## TERMINOLOGY

**#FIXED**  
**#IMPLIED**

**#PCDATA**  
**#REQUIRED**

<b>.dtd</b> extension	ID tokenized attribute type
<b>ANY</b>	IDREF tokenized attribute type
asterisk (*)	<b>IGNORE</b>
<b>ATTLIST</b> statement	<b>INCLUDE</b>
attribute content	internal subset
attribute declaration	mixed content
attribute default	mixed-content element
attribute list	mixed-content type
attribute name	<b>NCDATA</b>
attribute value	<b>NMTOKEN</b> tokenized attribute type (name token)
<b>CDATA</b>	nonvalid document
character data type	nonvalidating parser
child element	normalization
comma character	<b>NOTATION</b>
conditional section	notation type
content specification	occurrence indicator
content specification type	optional element
declaration	parameter entity
default value of an attribute	parsed character data
<b>DOCTYPE</b> (document type declaration)	parser
document type declaration	percent sign (%)
double quote ("")	period
DTD (Document Type Definition)	pipe character ( )
EBNF (Extended Backus-Naur Form) grammar	plus sign (+)
element	question mark (?)
element content	quote ('')
element name	sequence (,)
<b>ELEMENT</b> statement	<b>standalone</b> XML document
element type declaration (!ELEMENT)	string attribute type
<b>EMPTY</b>	string token
empty element	structural definition
<b>ENTITIES</b>	syntax
entity attribute	<b>SYSTEM</b>
<b>ENTITY</b> tokenized attribute type	text
enumerated attribute type	tokenized attribute type
Extended Backus-Naur Form (EBNF) grammar	type
external subset	valid document
external unparsed entity	validating parser
fixed value	validation
general entity	well-formed document
generic identifier	whitespace character
hyphen (-)	

### SELF-REVIEW EXERCISES

- B.1** State whether the following are *true* or *false*. If the answer is *false*, explain why.
- The document type declaration, **DOCTYPE**, introduces DTDs in XML documents.
  - External DTDs are specified by using the keyword **EXTERNAL**.
  - A DTD can contain either internal or external subsets of declarations, but not both.
  - Child elements are declared in parentheses, inside an element type declaration.
  - An element that appears any number of times is followed by an exclamation point (!).

- f) A mixed-content element can contain text as well as other declared elements.
- g) An attribute declared as type **CDATA** can contain all characters except for the asterisk (\*) and pound sign (#).
- h) Each element attribute of type **ID** must have a unique value.
- i) Enumerated attribute types are the most restrictive category of attribute types.
- j) An enumerated attribute type requires a default value.

**B.2**

Fill in the blanks in each of the following statements:

- a) The set of document type declarations inside an XML document is called the \_\_\_\_\_.
- b) Elements are declared with the \_\_\_\_\_ type declaration.
- c) Keyword \_\_\_\_\_ indicates that an element contains parsable character data.
- d) In an element type declaration, the pipe character (|) indicates that the element can contain \_\_\_\_\_ of the elements indicated.
- e) Attributes are declared by using the \_\_\_\_\_ type.
- f) Keyword \_\_\_\_\_ specifies that the attribute can take only a specific value that has been defined in the DTD.
- g) **ID**, **IDREF**, \_\_\_\_\_ and **NMTOKEN** are all types of tokenized attributes.
- h) The % character is used to declare a/an \_\_\_\_\_.
- i) DTD is an acronym for \_\_\_\_\_.
- j) Conditional sections of DTDs are often used with \_\_\_\_\_.

**ANSWERS TO SELF-REVIEW EXERCISES**

**B.1** a) True. b) False. External DTDs are specified using keyword **SYSTEM**. c) False. A DTD contains both the internal and external subsets. d) True. e) False. An element that appears one or zero times is specified by a question mark (?). f) True. g) False. An attribute declared as type **CDATA** can contain all characters except for ampersand (&), less than (<), greater than (>), quote ('') and double quotes (""). h) True. i) True. j) False. A default value is not required.

**B.2** a) internal subset. b) **ELEMENT**. c) **PCDATA**. d) one. e) **ATTLIST**. f) **#FIXED**. g) **ENTITY**. h) parameter entity. i) Document Type Definition. j) entities.



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# Document Object Model (DOM<sup>TM</sup>)

---

## Objectives

- To understand what the Document Object Model is.
- To understand and be able to use the major DOM features.
- To use Java to manipulate an XML document.
- To become familiar with DOM-based parsers.

*Knowing trees, I understand the meaning of patience.  
Knowing grass, I can appreciate persistence.*

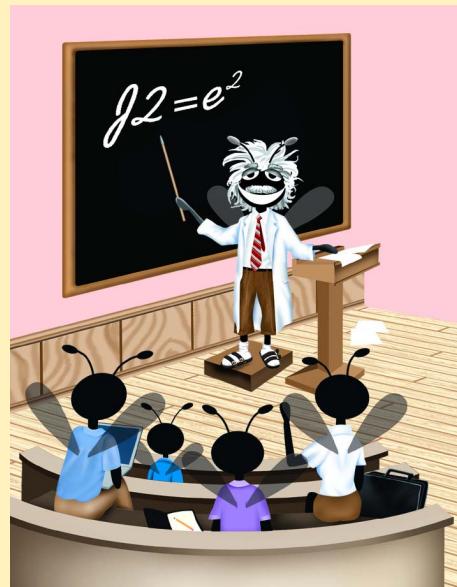
Hal Borland

*There was a child went forth every day,  
And the first object he look'd upon, that object he became.*

Walt Whitman

*I think that I shall never see  
A poem lovely as a tree.*

Joyce Kilmer



## Outline

- C.1 Introduction
- C.2 DOM with Java
- C.3 Setup Instructions
- C.4 DOM Components
- C.5 Creating Nodes
- C.6 Traversing the DOM
- C.7 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises*

## C.1 Introduction

In previous appendices, we concentrated on basic XML markup and DTDs for validating XML documents. In this appendix, we focus on manipulating the contents of an XML document.

XML documents, when parsed, are represented as a hierarchical tree structure in memory. This tree structure contains the document's elements, attributes, content, etc. XML was designed to be a live, dynamic technology—a programmer can modify the contents of the tree structure, which essentially allows the programmer to add data, remove data, query for data, etc. in a manner similar to manipulating a database.

The W3C provides a recommendation for building a tree structure in memory for XML documents. This structure is called the *XML Document Object Model (DOM)*. Any parser that adheres to this recommendation is called a *DOM-based parser*. Each element, attribute, **CDATA** section, etc., in an XML document is represented by a *node* in the DOM tree. For example, the simple XML document

```
<?xml version = "1.0"?>
<message from = "Paul" to = "Tem">
    <body>Hi, Tem!</body>
</message>
```

results in a DOM tree with several nodes. One node is created for the **message** element. This node has a *child node* that corresponds to the **body** element. The **body** element has a child node that corresponds to the text **Hi, Tem!**. The **from** and **to** attributes of the **message** element also have corresponding nodes in the DOM tree as well. An XML declaration is not placed in the tree.

A DOM-based parser *exposes* (i.e., makes available) a programmatic library—called the *DOM Application Programming Interface (API)*—that allows data in an XML document to be accessed and modified by manipulating the nodes in a DOM tree. In this appendix, we use Sun Microsystem's JAXP parsers.



### Portability Tip C.1

*The DOM interfaces for creating and manipulating XML documents are platform and language independent. DOM parsers exist for many different languages, including Java, C, C++, Python and Perl.*

## C.2 DOM with Java

To introduce document manipulation with the XML Document Object Model, we begin with a simple example that uses Java. This example takes an XML document (Fig. C.1) that marks up an article and uses the JAXP API to display the document's element names and values. Figure C.2 lists the Java code that manipulates this XML document and displays its content.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig. C.1: article.xml      -->
4 <!-- Article formatted with XML -->
5
6 <article>
7
8   <title>Simple XML</title>
9
10  <date>July 31, 2001</date>
11
12  <author>
13    <fname>Tem</fname>
14    <lname>Nieto</lname>
15  </author>
16
17  <summary>XML is easy.</summary>
18
19  <content>Once you have mastered XHTML, you can easily learn
20    XML. You must remember that XML is not for
21    displaying information but for managing information.
22  </content>
23
24 </article>
```

Fig. C.1 Article marked up with XML tags.

```
1 // Fig C.2 : XMLInfo.java
2 // Outputs node information
3
4 // Java core libraries
5 import java.io.*;
6
7 // Java standard extensions
8 import javax.xml.parsers.*;
9
10 // third-party libraries
11 import org.w3c.dom.*;
12 import org.xml.sax.*;
13
14 public class XMLInfo {
15
```

Fig. C.2 **XMLInfo** displays information about XML input (part 1 of 3).

```
16    public static void main( String args[] )  
17    {  
18  
19        if ( args.length != 1 ) {  
20            System.err.println( "Usage: java XMLInfo input.xml" );  
21            System.exit( 1 );  
22        }  
23  
24        try {  
25  
26            // create DocumentBuilderFactory  
27            DocumentBuilderFactory factory =  
28                DocumentBuilderFactory.newInstance();  
29  
30            // create DocumentBuilder  
31            DocumentBuilder builder = factory.newDocumentBuilder();  
32  
33            // obtain document object from XML document  
34            Document document = builder.parse(  
35                new File( args[ 0 ] ) );  
36  
37            // get root node  
38            Node root = document.getDocumentElement();  
39  
40            System.out.print( "Here is the document's root node:" );  
41            System.out.println( " " + root.getNodeName() );  
42  
43            System.out.println( "Here are its child elements: " );  
44            NodeList childNodes = root.getChildNodes();  
45            Node currentNode;  
46  
47            for ( int i = 0; i < childNodes.getLength(); i++ ) {  
48  
49                currentNode = childNodes.item( i );  
50  
51                // print node name of each child element  
52                System.out.println( currentNode.getNodeName() );  
53            }  
54  
55            // get first child of root element  
56            currentNode = root.getFirstChild();  
57  
58            System.out.print( "The first child of root node is: " );  
59            System.out.println( currentNode.getNodeName() );  
60  
61            // get next sibling of first child  
62            System.out.print( "whose next sibling is: " );  
63            currentNode = currentNode.getNextSibling();  
64            System.out.println( currentNode.getNodeName() );  
65  
66            // print value of first child's next sibling  
67            System.out.println( "value of " +  
68                currentNode.getNodeName() + " element is: " +
```

Fig. C.2 **XMLInfo** displays information about XML input (part 2 of 3).

```

69         currentNode.getFirstChild().getNodeValue() );
70
71     // print name of next sibling's parent
72     System.out.print( "Parent node of " +
73         currentNode.getNodeName() + " is: " +
74         currentNode.getParentNode().getNodeName() );
75 }
76
77 // handle exception creating DocumentBuilder
78 catch ( ParserConfigurationException parserError ) {
79     System.err.println( "Parser Configuration Error" );
80     parserError.printStackTrace();
81 }
82
83 // handle exception reading data from file
84 catch ( IOException fileException ) {
85     System.err.println( "File IO Error" );
86     fileException.printStackTrace();
87 }
88
89 // handle exception parsing XML document
90 catch ( SAXException parseException ) {
91     System.err.println( "Error Parsing Document" );
92     parseException.printStackTrace();
93 }
94 }
95 }
```

```

Here is the document's root node: article
Here are its child elements:
title
date
author
summary
content
The first child of root node is: title
whose next sibling is: date
value of date element is: July 31, 2001
Parent node of date is: article
```

Fig. C.2 **XMLInfo** displays information about XML input (part 3 of 3).

Lines 7–12 **import** several packages related to XML. Package **javax.xml.parsers** provides classes related to parsing an XML document. Package **org.w3c.dom** provides the DOM-API programmatic interface (i.e., classes, methods, etc.).

Lines 27–28 create a new **DocumentBuilderFactory**. The **DocumentBuilderFactory** is required to produce an appropriate **DocumentBuilder** object for the currently configured XML parser. JAXP can be configured to use many different XML parsers, such as the Apache Group's Xerces and IBM's XML4J. JAXP also has its own parser built in, which is used by default.

Line 31 uses the **DocumentBuilderFactory** class to create a **DocumentBuilder** object. Class **DocumentBuilder** provides a standard interface for loading and parsing XML documents. Lines 34–35 use the **DocumentBuilder** method **parse** to obtain a **document** object from the XML document.

Line 38 retrieves the root node of the XML document via **Document** method **getDocumentElement**. Line 41 retrieves and displays the name of the **Node** via method **getnodeName**. Line 44 calls **Node** method **getChildNodes** to obtain a **NodeList** object, which is list of nodes. The first item added is stored at index 0, the next at index 1, and so forth. This index is used to access an individual item in the **NodeList**.

Line 47 uses **NodeList** method **getLength** to obtain the number of nodes in the list. Lines 47–53 display the name of each **Node** in the **NodeList**, by calling **NodeList** method **item**. This method is passed the index of the desired **Node** in the **NodeList**.

Line 56 calls method **getFirstChild** to obtain a **Node** reference to the first child of **Node root**. Line 59 displays the name of the **Node** stored in **currentNode**. Line 63 calls **Node** method **NextSibling** to obtain a reference to the next sibling of the node. Line 64 displays the sibling **Node**'s name. Lines 67–69 print the value of the first child of **currentNode**. The **Node** method **getNodeValue** returns different objects for different types of nodes. In our XML document (Fig. C.1), the child node happens to be of type **text**, so **getNodeValue** returns the **String** contents of the **text** node. We will explain **Node** types in greater detail later in this appendix. Lines 78–92 **catch Exceptions** that various methods we have used **throw**.

### C.3 Setup Instructions

To manipulate XML within Java, you must properly install the Java API for XML Processing (JAXP). To do so, complete the following steps:

1. Download and run the JAXP 1.1 installer from  
[www.java.sun.com/xml](http://www.java.sun.com/xml)
2. Copy **jaxp.jar**, **crimson.jar**, **xalan.jar** from the **JAXP1.1** directory to the **C:\jdk1.3.1\jre\lib\ext\** directory.
3. Add **C:\jdk1.3.1\jre\bin** to the **PATH** environment variable before **C:\jdk1.3.1\bin**.
4. Run each example as you normally would.

As we present an example, we will discuss any special steps necessary to execute it. However the steps outlined in this section must be followed before attempting to execute any example.

### C.4 DOM Components

In this section, we will use Java, JAXP and interfaces described in Fig. C.3 to manipulate an XML document. Due to the number of DOM interfaces and methods available, we provide only a partial list.

For a complete list of DOM classes and interfaces, browse the HTML documentation (**index.html** in the **api** folder) included with JAXP.

Interface	Description
<b>Document</b> interface	Represents the XML document's top-level node, which provides access to all the document's nodes, including the root element.
<b>Node</b> interface	Represents an XML document node.
<b>NodeList</b> interface	Represents a read-only list of <b>Node</b> objects.
<b>Element</b> interface	Represents an element node. Derives from <b>Node</b> .
<b>Attr</b> interface	Represents an attribute node. Derives from <b>Node</b> .
<b>CharacterData</b> interface	Represents character data. Derives from <b>Node</b> .
<b>Text</b> interface	Represents a text node. Derives from <b>CharacterData</b> .
<b>Comment</b> interface	Represents a comment node. Derives from <b>CharacterData</b> .
<b>ProcessingInstruction</b> interface	Represents a processing instruction node. Derives from <b>Node</b> .
<b>CDataSection</b> interface	Represents a <b>CDATA</b> section. Derives from <b>Text</b> .

**Fig. C.3** DOM classes and interfaces.

The **Document** interface represents the top-level node of an XML document in memory and provides a means of creating nodes and retrieving nodes. Figure C.4 lists some **Document** methods.

Interface **Node** represents an XML document node. Figure C.5 lists the methods of interface **Node**.

Figure C.6 lists some node types that may be returned by method **getNodeType**. Each type in Fig. C.6 is a **static final** (i.e., constant) member of class **Node**.

Method Name	Description
<b>createElement</b>	Creates an element node.
<b>createAttribute</b>	Creates an attribute node.
<b>createTextNode</b>	Creates a text node.
<b>createComment</b>	Creates a comment node.
<b>createProcessingInstruction</b>	Creates a processing instruction node.
<b>createCDataSection</b>	Creates a <b>CDATA</b> section node.
<b>getDocumentElement</b>	Returns the document's root element.
<b>appendChild</b>	Appends a child node.
<b>getchildNodes</b>	Returns the child nodes.

**Fig. C.4** Some **Document** methods.

Method Name	Description
<code>appendChild</code>	Appends a child node.
<code>cloneNode</code>	Duplicates the node.
<code>getAttributes</code>	Returns the node's attributes.
<code>getChildNodes</code>	Returns the node's child nodes.
<code>getNextSibling</code>	Returns the node's next sibling.
<code>getNodeName</code>	Returns the node's name.
<code>getNodeType</code>	Returns the node's type (e.g., element, attribute, text, etc.). Node types are described in greater detail in Fig. C.6.
<code>getNodeValue</code>	Returns the node's value.
<code>getParentNode</code>	Returns the node's parent.
<code>hasChildNodes</code>	Returns <code>true</code> if the node has child nodes.
<code>removeChild</code>	Removes a child node from the node.
<code>replaceChild</code>	Replaces a child node with another node.
<code>setnodeValue</code>	Sets the node's value.
<code>insertBefore</code>	Appends a child node in front of a child node.

Fig. C.5 Node methods.

Node Type	Description
<code>Node.ELEMENT_NODE</code>	Represents an element node.
<code>Node.ATTRIBUTE_NODE</code>	Represents an attribute node.
<code>Node.TEXT_NODE</code>	Represents a text node.
<code>Node.COMMENT_NODE</code>	Represents a comment node.
<code>Node.PROCESSING_INSTRUCTION_NODE</code>	Represents a processing instruction node.
<code>Node.CDATA_SECTION_NODE</code>	Represents a <b>CDATA</b> section node.

Fig. C.6 Some node types.

**Element** represents an element node. Figure C.7 lists some **Element** methods.

Method Name	Description
<code>getAttribute</code>	Returns the value of the attribute with the given name.
<code>getTagName</code>	Returns an element's name.

Fig. C.7 Element methods (part 1 of 2).

Method Name	Description
<b>removeAttribute</b>	Removes an element's attribute.
<b>setAttribute</b>	Sets an attribute's value.

**Fig. C.7** **Element** methods (part 2 of 2).

Figure C.8 lists a Java application that validates **intro.xml** (Fig. C.10) and replaces the text in its **message** element with **New Changed Message!!**.

```

1 // Fig. C.8 : ReplaceText.java
2 // Reads intro.xml and replaces a text node.
3
4 // Java core packages
5 import java.io.*;
6
7 // Java extension packages
8 import javax.xml.parsers.*;
9 import javax.xml.transform.*;
10 import javax.xml.transform.stream.*;
11 import javax.xml.transform.dom.*;
12
13 // third-party libraries
14 import org.xml.sax.*;
15 import org.w3c.dom.*;
16
17
18 public class ReplaceText {
19     private Document document;
20
21     public ReplaceText()
22     {
23         // parse document, find/replace element, output result
24         try {
25
26             // obtain default parser
27             DocumentBuilderFactory factory =
28                 DocumentBuilderFactory.newInstance();
29
30             // set parser as validating
31             factory.setValidating( true );
32
33             // obtain object that builds Documents
34             DocumentBuilder builder = factory.newDocumentBuilder();
35
36             // set error handler for validation errors
37             builder.setErrorHandler( new MyErrorHandler() );
38
39             // obtain document object from XML document
40             document = builder.parse( new File( "c:/intro.xml" ) );

```

**Fig. C.8** Simple example that replaces an existing text node (part 1 of 3).

```
41      // retrieve the root node
42      Node root = document.getDocumentElement();
43
44
45      if ( root.getNodeType() == Node.ELEMENT_NODE ) {
46          Element myMessageNode = ( Element ) root;
47          NodeList messageNodes =
48              myMessageNode.getElementsByTagName( "message" );
49
50          if ( messageNodes.getLength() != 0 ) {
51              Node message = messageNodes.item( 0 );
52
53                  // create text node
54                  Text newText = document.createTextNode(
55                      "New Changed Message!!" );
56
57                  // get old text node
58                  Text oldText =
59                      ( Text ) message.getChildNodes().item( 0 );
60
61                  // replace text
62                  message.replaceChild( newText, oldText );
63          }
64      }
65
66      // output Document object
67
68      // create DOMSource for source XML document
69      Source xmlSource = new DOMSource( document );
70
71      // create StreamResult for transformation result
72      Result result = new StreamResult( System.out );
73
74      // create TransformerFactory
75      TransformerFactory transformerFactory =
76          TransformerFactory.newInstance();
77
78      // create Transformer for transformation
79      Transformer transformer =
80          transformerFactory.newTransformer();
81
82      transformer.setOutputProperty( "indent", "yes" );
83
84      // transform and deliver content to client
85      transformer.transform( xmlSource, result );
86  }
87
88      // handle exception creating DocumentBuilder
89      catch ( ParserConfigurationException parserException ) {
90          parserException.printStackTrace();
91      }
92
93      // handle exception parsing Document
```

Fig. C.8 Simple example that replaces an existing text node (part 2 of 3).

```

94     catch ( SAXException saxException ) {
95         saxException.printStackTrace();
96     }
97
98     // handle exception reading/writing data
99     catch ( IOException ioException ) {
100        ioException.printStackTrace();
101        System.exit( 1 );
102    }
103
104    // handle exception creating TransformerFactory
105    catch ( TransformerFactoryConfigurationError factoryError ) {
106        System.err.println( "Error while creating " +
107            "TransformerFactory" );
108        factoryError.printStackTrace();
109    }
110
111    // handle exception transforming document
112    catch ( TransformerException transformerError ) {
113        System.err.println( "Error transforming document" );
114        transformerError.printStackTrace();
115    }
116
117 }
118
119 public static void main( String args[] )
120 {
121     ReplaceText replace = new ReplaceText();
122 }
123 }
```

**Fig. C.8** Simple example that replaces an existing text node (part 3 of 3).

Lines 27–28 create a new **DocumentBuilderFactory**. Line 31 indicates that a validating parser should be used by passing the value **true** as an argument to method **setValidating**. Line 34 creates a new **DocumentBuilder**. Line 37 specifies that a **MyErrorHandler** (Fig. C.9) object provides methods for handling exceptions related to parsing. Line 40 calls method **parse** to load and parse the XML document stored in the file **intro.xml**. If parsing is successful, a **Document** object is returned that contains nodes representing each part of the **intro.xml** document. If parsing fails, a **SAXException** is thrown.

Line 43 gets the **Document**'s root node. Line 45 calls method **getNodeType** to obtain the root node's type and tests whether the root node is of type element.

Line 46 down casts **root** from a superclass **Node** type to an **Element** derived type. As mentioned earlier, class **Element** inherits from class **Node**. Lines 47–48 get a **NodeList** containing all the **message** elements in the XML document using method **getElementsByTagName**. Line 50 determines whether the **NodeList** contains at least one item. Line 51 retrieves the first **Node** in the **NodeList**.

Lines 54–55 call **createTextNode** to create a text node that contains the text **New Changed Message!!**. This node exists in memory independent of the XML docu-

ment—i.e., it has not been inserted into the document yet. Interface **Text** represents an element or attribute's character data.

Lines 58–59 get the first child node of the **message** element (referenced by **Node message** in line 51), which is a text node containing the text **Welcome to XML!**. Method **item** returns an object of superclass type **Object** which we downcast to **Text**. Line 62 calls method **replaceChild** to replace the **Node** referenced by the second argument with the **Node** referenced by the first argument. The XML document has now been modified—element **message** now contains the text **New Changed Message!!**.

Lines 66–86 output the modified **Document**. Line 69 creates a new **Source** object that wraps the modified **Document** object. Line 72 creates a new **Result** object passing an **OutputStream** as an argument, which in this case is **System.out**. Lines 75–76 create a new **TransformerFactory** by calling **static** method **newInstance**. Lines 79–80 create a new **Transformer** by calling method **newTransformer**.

Line 82 sets the "**indent**" output property to "**yes**," which causes the **Transformer** to add appropriate indentation when it produces the result document. Lines 89–90 handle a **ParserConfigurationException**, which can be thrown by **DocumentBuilderFactory** method **newDocumentBuilder**. Line 89 begins a **catch** block for a **SAXException**. This exception contains information about errors thrown by the parser.

Figure C.9 presents **MyErrorHandler.java**, which provides the implementation for handling errors thrown by the parser in **ReplaceText.java**. By default, JAXP does not throw any exceptions when a document fails to conform to a DTD. The programmer must provide an error handler, which is registered using method **setErrorHandler** (line 38 in Fig. C.8).

```
1 // Fig C.9 : MyErrorHandler.java
2 // Error Handler for validation errors.
3
4 import org.xml.sax.ErrorHandler;
5 import org.xml.sax.SAXException;
6 import org.xml.sax.SAXParseException;
7
8 public class MyErrorHandler implements ErrorHandler
9 {
10
11     // throw SAXException for fatal errors
12     public void fatalError( SAXParseException exception )
13     throws SAXException
14     {
15         throw exception;
16     }
17
18     public void error( SAXParseException errorException )
19     throws SAXParseException
20     {
21         throw errorException;
22     }
23
24     // print any warnings
```

Fig. C.9 Class definition for **MyErrorHandler** (part 1 of 2).

```

25     public void warning( SAXParseException warningError )
26         throws SAXParseException
27     {
28         System.err.println( "Warning: " + warningError.getMessage() );
29     }
30 }
```

Fig. C.9 Class definition for **MyErrorHandler** (part 2 of 2).

Lines 4–6 of Fig. C.9 **import ErrorHandler, SAXException** and **SAXParseException**. Interface **ErrorHandler** provides methods **fatalError**, **error** and **warning** for *fatal errors* (i.e., errors that violate the XML 1.0 recommendation; parsing is halted), *errors* (e.g., validity constraints that do not stop the parsing process) and *warnings* (i.e., not classified as fatal errors or errors and that do not stop the parsing process), respectively. These methods are overridden in lines 12, 18 and 25. Fatal errors and errors are rethrown and warnings are output to the standard error device (**System.err**). To run the example, compile the classes and execute class **ReplaceText**.

Figure C.10 lists the XML document manipulated by the Java application in Fig. C.8. Notice that the **message** element's text has been changed and the comments are missing. The DTD is preserved, because we are using a validating parser—otherwise the DTD would not be included in the file. Figure C.10's output also sets the **encoding** attribute in the XML declaration. The **encoding** specifies the character set used in the document. Recall from Appendix A that XML uses the Unicode character set. Unicode provides characters in most of the world's major languages. Use an **encoding** (e.g., **UTF-8**) to specify a subset of the characters in Unicode that will be used in a document.

```

1 <?xml version = "1.0"?>
2
3 <!-- Fig. C.10 : intro.xml -->
4 <!-- Simple introduction to XML markup -->
5
6 <!DOCTYPE myMessage [
7   <!ELEMENT myMessage ( message )>
8   <!ELEMENT message ( #PCDATA )>
9 ]>
10
11 <myMessage>
12   <message>Welcome to XML!</message>
13 </myMessage>
```

```

<?xml version="1.0" encoding="UTF-8"?>
<!-- Fig. C.10 : intro.xml -->
<!-- Simple introduction to XML markup -->
<myMessage>
  <message>New Changed Message!!</message>
</myMessage>
```

Fig. C.10 Input document (**intro.xml**) and output from **ReplaceText.java**.

## C.5 Creating Nodes

The majority of XML markup presented up to this point has been “hand coded” (i.e., typed into an editor by a document author). Using the DOM, XML documents can be created in an automated way through programming.

Figure C.11 lists a Java application that creates an XML document for a contact list. This application is compiled and executed in the same manner as the last Java application.

```
1 // Fig. C.11 : BuildXml.java
2 // Creates element node, attribute node, comment node,
3 // processing instruction and a CDATA section.
4
5 // Java core packages
6 import java.io.*;
7
8 // Java extension packages
9 import javax.xml.parsers.*;
10 import javax.xml.parsers.*;
11 import javax.xml.transform.*;
12 import javax.xml.transform.stream.*;
13 import javax.xml.transform.dom.*;
14
15 // third-party libraries
16 import org.xml.sax.*;
17 import org.w3c.dom.*;
18
19 public class BuildXml {
20     private Document document;
21
22     public BuildXml()
23     {
24
25         DocumentBuilderFactory factory =
26             DocumentBuilderFactory.newInstance();
27
28         // create new DOM tree
29         try {
30
31             // get DocumentBuilder
32             DocumentBuilder builder =
33                 factory.newDocumentBuilder();
34
35             // create root node
36             document = builder.newDocument();
37         }
38
39         // handle exception thrown by DocumentBuilder
40         catch ( ParserConfigurationException parserException ) {
41             parserException.printStackTrace();
42         }
43
44         Element root = document.createElement( "root" );
```

Fig. C.11 Building an XML document with the DOM (part 1 of 3).

```
45     document.appendChild( root );
46
47     // add comment to XML document
48     Comment simpleComment = document.createComment(
49         "This is a simple contact list" );
50     root.appendChild( simpleComment );
51
52     // add child element
53     Node contactNode = createContactNode( document );
54     root.appendChild( contactNode );
55
56     // add processing instruction
57     ProcessingInstruction pi =
58         document.createProcessingInstruction(
59             "myInstruction", "action silent" );
60     root.appendChild( pi );
61
62     // add CDATA section
63     CDATASection cdata = document.createCDATASection(
64         "I can add <, >, and ?" );
65     root.appendChild( cdata );
66
67     // write the XML document to disk
68     try {
69
70         // create DOMSource for source XML document
71         Source xmlSource = new DOMSource( document );
72
73         // create StreamResult for transformation result
74         Result result = new StreamResult(
75             new FileOutputStream( "myDocument.xml" ) );
76
77         // create TransformerFactory
78         TransformerFactory transformerFactory =
79             TransformerFactory.newInstance();
80
81         // create Transformer for transformation
82         Transformer transformer =
83             transformerFactory.newTransformer();
84
85         transformer.setOutputProperty( "indent", "yes" );
86
87         // transform and deliver content to client
88         transformer.transform( xmlSource, result );
89     }
90
91     // handle exception creating TransformerFactory
92     catch ( TransformerFactoryConfigurationError factoryError ) {
93         System.err.println( "Error creating " +
94             "TransformerFactory" );
95         factoryError.printStackTrace();
96     }
97 }
```

Fig. C.11 Building an XML document with the DOM (part 2 of 3).

```
98      // handle exception transforming document
99      catch ( TransformerException transformerError ) {
100          System.err.println( "Error transforming document" );
101          transformerError.printStackTrace();
102      }
103
104
105      // handle exception writing data to file
106      catch ( IOException ioException ) {
107          ioException.printStackTrace();
108      }
109  }
110
111  public Node createContactNode( Document document )
112  {
113
114      // create FirstName and LastName elements
115      Element firstName = document.createElement( "FirstName" );
116      Element lastName = document.createElement( "LastName" );
117
118      firstName.appendChild( document.createTextNode( "Sue" ) );
119      lastName.appendChild( document.createTextNode( "Green" ) );
120
121      // create contact element
122      Element contact = document.createElement( "contact" );
123
124      // create attribute
125      Attr genderAttribute = document.createAttribute( "gender" );
126      genderAttribute.setValue( "F" );
127
128      // append attribute to contact element
129      contact.setAttributeNode( genderAttribute );
130      contact.appendChild( firstName );
131      contact.appendChild( lastName );
132
133      return contact;
134  }
135
136  public static void main( String args[] )
137  {
138      BuildXml buildXml = new BuildXml();
139  }
140 }
```

Fig. C.11 Building an XML document with the DOM (part 3 of 3).

Lines 25–26 create and assign a **DocumentBuilderFactory** object to reference **factory**. Lines 32–33 create a new **DocumentBuilder** object and assign it to reference **builder**. Line 36 calls method **newDocument** to create a new **Document** object. We will use the **Document** object returned by **newDocument** to build an XML document in memory.

Lines 44–45 create an element named **root** and append it to the document root. This is the first element appended, so it is the root element of the document. Lines 48–50 create

a comment node using method `createComment` and append the node as a child of element `root`. Line 53 calls programmer-defined method `createContactNode` (line 111) to create the `contact` element. We will discuss this method momentarily. Lines 57–58 create a processing instruction node. The first argument passed to `createProcessingInstruction` is the target `myInstruction`, and the second argument passed is the value `action silent`. Line 60 appends the processing instruction to the root element. Lines 63–64 create a `CDATA` section, which is appended to element `root` in line 65.

Line 111 defines method `createContactNode` that returns a `Node` object. This method creates a `contact` element node and returns it. The returned `Node` is appended to the `root` element in line 53. Lines 115–116 create elements `FirstName` and `LastName`, which have their text values set on lines 118–119. Lines 125–126 create attribute `gender` using method `createAttribute` and assign it a value using `Attr` method `setValue`. Line 129 assigns the attribute to the `contact` element node using method `setAttributeNode`.

The XML document is written to disk in lines 68–89. Figure C.12 lists the XML document (`myDocument.xml`) created by `BuildXml.java` (Fig. C.11).

## C.6 Traversing the DOM

In this section, we demonstrate how to use the DOM to traverse an XML document. In Fig. C.13, we present a Java application that outputs element nodes, attribute nodes and text nodes. This application takes the name of an XML document (e.g., `simpleContact.xml` in Fig. C.14) as an argument.

```

1 <?xml version = "1.0" encoding = "UTF-8"?>
2
3 <root>
4   <!--This is a simple contact list-->
5   <contact gender = "F">
6     <FirstName>Sue</FirstName>
7     <LastName>Green</LastName>
8   </contact>
9   <?myInstruction action silent?>
10  <! [CDATA[I can add <, >, and ?]]>
11 </root>
```

Fig. C.12 Output for `buildXml.java`.

```

1 // Fig. C.13 : TraverseDOM.java
2 // Traverses DOM and prints various nodes.
3
4 // Java core packages
5 import java.io.*;
6
7 // Java extension packages
8 import javax.xml.parsers.*;
9
10 // third-party libraries
```

Fig. C.13 Traversing the DOM (part 1 of 3).

```
11 import org.w3c.dom.*;
12 import org.xml.sax.*;
13
14 public class TraverseDOM {
15     private Document document;
16
17     public TraverseDOM( String file )
18     {
19         // parse XML, create DOM tree, call method processNode
20         try {
21
22             // obtain default parser
23             DocumentBuilderFactory factory =
24                 DocumentBuilderFactory.newInstance();
25             factory.setValidating( true );
26             DocumentBuilder builder = factory.newDocumentBuilder();
27
28             // set error handler for validation errors
29             builder.setErrorHandler( new MyErrorHandler() );
30
31             // obtain document object from XML document
32             document = builder.parse( new File( file ) );
33             processNode( document );
34         }
35
36         // handle exception thrown by DocumentBuilder
37         catch ( ParserConfigurationException parserException ) {
38             parserException.printStackTrace();
39         }
40
41         // handle exception thrown by Parser
42         catch ( SAXException saxException ) {
43             saxException.printStackTrace();
44         }
45
46         // handle exception thrown when reading data from file
47         catch ( IOException ioException ) {
48             ioException.printStackTrace();
49             System.exit( 1 );
50         }
51     }
52
53     public void processNode( Node currentNode )
54     {
55         switch ( currentNode.getNodeType() ) {
56
57             // process Document root
58             case Node.DOCUMENT_NODE:
59                 Document doc = ( Document ) currentNode;
60
61                 System.out.println(
62                     "Document node: " + doc.getNodeName() +
63                     "\nRoot element: " +
```

Fig. C.13 Traversing the DOM (part 2 of 3).

```
64         doc.getDocumentElement().getnodeName() );
65     processChildNodes( doc.getChildNodes() );
66     break;
67
68     // process Element node
69     case Node.ELEMENT_NODE:
70         System.out.println( "\nElement node: " +
71                             currentNode.getNodeName() );
72         NamedNodeMap attributeNodes =
73             currentNode.getAttributes();
74
75         for ( int i = 0; i < attributeNodes.getLength(); i++ ) {
76             Attr attribute = ( Attr ) attributeNodes.item( i );
77
78             System.out.println( "\tAttribute: " +
79                                 attribute.getNodeName() + " ; Value = " +
80                                 attribute.getNodeValue() );
81         }
82
83         processChildNodes( currentNode.getChildNodes() );
84         break;
85
86     // process text node and CDATA section
87     case Node.CDATA_SECTION_NODE:
88     case Node.TEXT_NODE:
89         Text text = ( Text ) currentNode;
90
91         if ( !text.getNodeValue().trim().equals( "" ) )
92             System.out.println( "\tText: " +
93                                 text.getNodeValue() );
94         break;
95     }
96 }
97
98 public void processChildNodes( NodeList children )
99 {
100     if ( children.getLength() != 0 )
101
102         for ( int i = 0; i < children.getLength(); i++ )
103             processNode( children.item( i ) );
104
105
106     public static void main( String args[] )
107     {
108         if ( args.length < 1 )
109             System.err.println(
110                 "Usage: java TraverseDOM <filename>" );
111             System.exit( 1 );
112     }
113
114     TraverserDOM traverseDOM = new TraverserDOM( args[ 0 ] );
115 }
116 }
```

Fig. C.13 Traversing the DOM (part 3 of 3).

Lines 17–51 define the class constructor for **TraverseDOM**, which takes the name of the file (i.e., **simpleContact.xml**) specified at the command line, loads and parses the XML document before passing it to programmer-defined method **processNode**.

Lines 53–96 define method **processNode**, which takes one **Node** argument and outputs information about the **Node** and its child elements. Line 55 begins a **switch** structure that determines the **Node** type.

Line 58 matches the document node. This **case** outputs the document node (represented as **#document**) and processes its child nodes by calling method **processChildNodes** (lines 98–104). We will discuss method **processChildNodes** momentarily. Line 69 matches an element node. This **case** outputs the element's attributes and then processes its child nodes in **processChildNodes**.

Lines 87–88 match **CDATA** section nodes and text nodes. These **cases** output the node's text content (lines 91–93).

Lines 98–104 define method **processChildNodes**, which takes one **NodeList** argument and calls **processNode** on a node's child nodes. Each child node is retrieved by calling **NodeList** method **item** (line 103).

Figure C.14 lists the contents of **simpleContact.xml**, the XML document used by **TraverseDOM.java**.

## C.7 Internet and World Wide Web Resources

[www.w3.org/DOM](http://www.w3.org/DOM)

W3C DOM home page.

[www.w3schools.com/dom/default.asp](http://www.w3schools.com/dom/default.asp)

The W3Schools DOM introduction, tutorial and links site.

[www.oasis-open.org/cover/dom.html](http://www.oasis-open.org/cover/dom.html)

The Oasis-Open DOM page contains a comprehensive overview of the Document Object Model with references and links.

[dmoz.org/Computers/Programming/Internet/W3C\\_DOM](http://dmoz.org/Computers/Programming/Internet/W3C_DOM)

This is a useful set of DOM links to different locations and instructional matter.

[www.w3.org/DOM/faq.html](http://www.w3.org/DOM/faq.html)

Answers to DOM Frequently Asked Questions (FAQs).

[www.jdom.org](http://www.jdom.org)

Home page for the JDOM XML API in Java.

```
1 <?xml version = "1.0"?>
2
3 <!-- Fig C.14 : simpleContact.xml      -->
4 <!-- Input file for traverseDOM.java -->
5
6 <!DOCTYPE contacts [
7   <!ELEMENT contacts ( contact+ )>
8   <!ELEMENT contact ( FirstName, LastName )>
9   <!ATTLIST contact gender ( M | F ) "M">
10  <!ELEMENT FirstName ( #PCDATA )>
11  <!ELEMENT LastName ( #PCDATA )>
12 ]>
```

Fig. C.14 Sample execution of **TraverseDOM.java** (part 1 of 2).

```
13 <contacts>
14   <contact gender = "M">
15     <FirstName>John</FirstName>
16     <LastName>Black</LastName>
17   </contact>
18 </contacts>
```

```
javac TraverseDOM.java
java TraverseDOM simpleContact.xml

Document node: #document
Root element: contacts

Element node: contacts

Element node: contact
  Attribute: gender ; Value = M

Element node: FirstName
  Text: John

Element node: LastName
  Text: Black
```

Fig. C.14 Sample execution of **TraverseDOM.java** (part 2 of 2).

## SUMMARY

- XML documents, when parsed, are represented as a hierachal tree structure in memory. This tree structure contains the document's elements, attributes, text, etc. XML was designed to be a live, dynamic technology—the contents of the tree structure can be modified by a programmer. This essentially allows the programmer to add data, remove data, query for data, etc., in a manner similar to manipulating a database.
- The W3C provides a recommendation for building a tree structure in memory for XML documents called the XML Document Object Model (DOM). Any parser that adheres to this recommendation is called a DOM-based parser.
- A DOM-based parser exposes (i.e., makes available) a programmatic library—called the DOM Application Programming Interface (API)—that allows data in an XML document to be accessed and manipulated. This API is available for many different programming languages.
- Property **documentElement** returns a document's root element node. The root element node is a reference point for retrieving child elements, text, etc.
- Property **nodeName** returns the name of an attribute, element, etc., which are collectively called nodes.
- Property **childNodes** contains a node's child nodes. Property **length** returns the number of child nodes.
- Individual child nodes are accessed using the **item** method. Each node is given an integer value (starting at zero) based on the order in which the nodes occur in the XML document.
- Property **firstChild** retrieves the root node's first child node.

- Nodes at the same level in a document (i.e., that have the same parent node) are called siblings. Property **nextSibling** returns a node's next sibling.
- A text node's value is its text, an element node's value is **null** (which indicates the absence of a value) and an attribute node's value is the attribute's value.
- Property **parentNode** returns a node's parent node.
- The **Document** object represents the top-level node of an XML document in memory and provides a means of creating nodes and retrieving nodes.
- Interface **Node** represents an XML document node.
- **Element** represents an element node.
- Sun Microsystems provides several packages related to XML. Package **org.w3c.dom** provides the DOM-API programmatic interface (i.e., classes, methods, etc.). Package **javax.xml.parsers** provides classes related to parsing an XML document. Classes in **javax.xml.transform.\*** are necessary to transform and output XML documents.
- A DOM-based parser may use an event-based implementation (i.e., as the document is parsed, events are raised when starting tags, attributes, etc., are encountered) to help create the tree structure in memory. A popular event-based implementation is called the Simple API for XML (SAX). Package **org.xml.sax** provides the SAX programmatic interface.
- Class **DocumentBuilderFactory** (package **javax.xml.parsers**) obtains an instance of a parser.
- Method **setValidating** specifies whether a parser is validating or nonvalidating.
- Method **parse** loads and parses XML documents. If parsing is successful, a **Document** object is returned. Otherwise, a **SAXException** is thrown.
- Method **getDocumentElement** returns the **Document**'s root node. The **Document**'s root node represents the entire document—not the root element node.
- Method **getNodeType** retrieves the node's type.
- Elements in the XML document are retrieved by calling method **getElementsByTagName**. Each element is stored as an item (i.e., a **Node**) in a **NodeList**. The first item added is stored at index 0, the next at index 1, and so forth. This index is used to access an individual item in the **NodeList**.
- Interface **Text** represents an element's or attribute's character data.
- Method **replaceChild** replaces a **Node**.
- **SAXParseException** and **SAXException** contain information about errors and warnings thrown by the parser. Class **SAXParseException** is a subclass of **SAXException** and includes methods for locating the error.
- By default, JAXP does not throw any exceptions when a document fails to conform to a DTD. Programmers must provide their own implementation, which is registered using method **setErrorHandler**.
- Interface **ErrorHandler** provides methods **fatalError**, **error** and **warning** for fatal errors (i.e., errors that violate the XML 1.0 syntax; parsing is halted), errors (e.g., such as validity constraints that do not stop the parsing process) and warnings (i.e., not classified as fatal errors or errors and that do not stop the parsing process), respectively.
- Method **newDocument** creates a new **Document** object, which can be used to build an XML document in memory.
- Method **createComment** creates a comment node.
- Method **createProcessingInstruction** creates a processing instruction, and method **createCDATASection** creates a **CDATA** section node.

## TERMINOLOGY

API	<code>getTagName</code>
<code>appendChild</code>	<code>hasChildNodes</code>
<code>Attr</code>	<code>item</code> method
<code>CDATA</code> section	Java API for XML Parsing (JAXP)
<code>childNodes</code>	<code>length</code>
<code>cloneNode</code>	<code>nextSibling</code>
<code>Comment</code>	<code>Node</code>
comment node	<code>Node.ATTRIBUTE_NODE</code>
<code>createAttribute</code>	<code>Node.CDATA_SECTION_NODE</code>
<code>createCDATASection</code>	<code>Node.COMMENT_NODE</code>
<code>createComment</code>	<code>Node.ELEMENT_NODE</code>
<code>createElement</code>	<code>Node.PROCESSING_INSTRUCTION_NODE</code>
<code>createProcessingInstruction</code>	<code>Node.TEXT_NODE</code>
<code>createTextNode</code>	<code>NodeList</code>
<code>createXmlDocument</code>	<code>nodeName</code>
<code>Document</code>	<code>nodeValue</code>
document root	<code>parentNode</code>
<code>DocumentBuilder</code>	processing instruction node
<code>DocumentBuilderFactory</code>	<code>ProcessingInstruction</code>
<code>documentElement</code>	<code>removeAttribute</code>
DOM	<code>removeChild</code>
<code>Element</code>	<code>replaceChild</code>
<code>encoding</code> declaration	root element node
<code>firstChild</code>	<code>setAttribute</code>
<code>getAttribute</code>	<code>setNodeValue</code>
<code>getChildNodes</code>	<code>setOutputProperty</code>
<code>getDocumentElement</code>	<code>setValue</code> method of <code>Attr</code>
<code>getNodeName</code>	<code>Text</code>
<code>getNodeType</code>	<code>Transformer</code>
<code>getNodeValue</code>	<code>TransformerFactory</code>
<code>getParentNode</code>	<code>write</code>

## SELF-REVIEW EXERCISES

- C.1** State whether each of the following are *true* or *false*. If *false*, explain why.
- Class `Transformer` is a class in the JAXP API.
  - Text in XML document is not represented as a node.
  - A `NodeList` contains a list of `Nodes`.
  - Interface `CDATASEction` extends interface `CharacterData`.
  - Interface `Attr` extends interface `Element`.
  - Method `parse` loads and parses an XML document.
  - Interface `ErrorHandler` defines methods `fatalError`, `error` and `warning`.
  - Method `getElementByTagName` of class `Element` returns the first element in the XML document that matches the specified name.
  - The `replaceChild` method of `Node` can be used to replace child node with another node.
  - An element's node value is text (i.e., character data).
- C.2** Fill in the blanks in each of the following statements:
- DOM is an acronym for \_\_\_\_\_.

- b) DOM-based parsers represent an XML document's data as a \_\_\_\_\_ structure.
- c) The number of **Nodes** in a **NodeList** is determined by calling method \_\_\_\_\_.
- d) Method \_\_\_\_\_ replaces one child node with another.
- e) Method \_\_\_\_\_ creates a text node.
- f) Method \_\_\_\_\_ returns a **NodeList** containing every occurrence of a particular element.
- g) \_\_\_\_\_ represents the root of an XML document.
- h) \_\_\_\_\_ is a **static Node** constant that represents an element.

### ANSWERS TO SELF-REVIEW EXERCISES

**C.1** a) True. b) False. Text is represented as a node. c) True. d) True. e) False. Interface **Attr** is derived from interface **Node**. f) True. g) True. h) False. Method **getElementsByTagName** returns a **NodeList** containing all the element nodes that match the specified name. i) True. j) False. An element's node value is **null**.

**C.2** a) Document Object Model. b) tree. c) **getLength**. d) **replaceChild**. e) **createTextNode**. f) **getElementsByTagName**. g) **Document**. h) **NODE\_ELEMENT\_NODE**.



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# XSL: Extensible Stylesheet Language Transformations (XSLT)

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## Objectives

- To understand what the Extensible Stylesheet Language is and how it relates to XML.
- To understand what an Extensible Stylesheet Language Transformation (XSLT) is.
- To be able to write XSLT documents.
- To be able to write templates.
- To be able to iterate through a node set.
- To be able to sort.
- To be able to perform conditional processing.
- To be able to declare variables.

*Guess if you can, choose if you dare.*

Pierre Corneille

*A Mighty Maze! but not without a plan.*

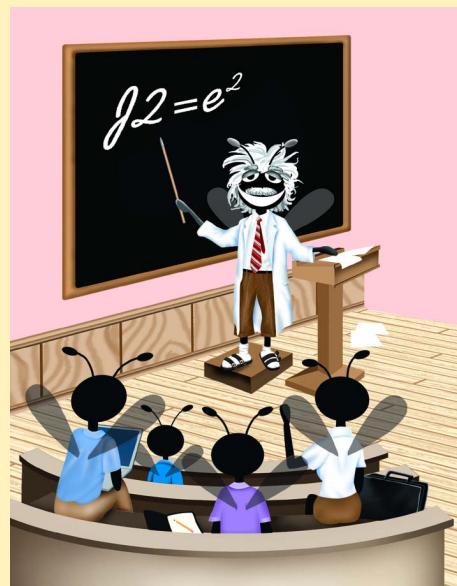
Alexander Pope

*Behind the outside pattern*

*the dim shapes get clearer every day.*

*It is always the same shape, only very numerous.*

Charlotte Perkins Gilman



## Outline

- D.1 Introduction
- D.2 Applying XSLTs with Java
- D.3 Templates
- D.4 Creating Elements and Attributes
- D.5 Iteration and Sorting
- D.6 Conditional Processing
- D.7 Combining Style Sheets
- D.8 Variables
- D.9 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises*

## D.1 Introduction

The *Extensible Stylesheet Language (XSL)* provides rules for formatting XML documents. In this appendix, we present the *XSL Transformation Language (XSLT)*. XSLT transforms an XML document to another text-based form, such as XHTML. We present many XSLT examples and show the results of the transformations.

## D.2 Applying XSLTs with Java

To process XSLT documents, you will need an *XSLT processor*. We have created a Java program that uses the XSLT processor in the JAXP library to perform XSL transformations. Our program, **Transform.java** (Fig. D.1), takes as command-line arguments the name of the XML document to be transformed, the name of the XSLT document and the name of the document that will be created by the transformation.

```
1 // Fig. D.1 : Transform.java
2 // Performs XSL Transformations.
3
4 // Java core libraries
5 import java.io.*;
6 import java.util.*;
7
8 // Java standard extensions
9 import javax.xml.parsers.*;
10 import javax.xml.transform.*;
11 import javax.xml.transform.dom.*;
12 import javax.xml.transform.stream.*;
13
14 // third-party libraries
15 import org.w3c.dom.*;
16 import org.xml.sax.SAXException;
17
```

Fig. D.1 Java application that performs XSL transformations (part 1 of 2).

```

18 public class Transform {
19
20     // execute application
21     public static void main( String args[] ) throws Exception
22     {
23         if ( args.length != 3 ) {
24             System.err.println( "Usage: java Transform input.xml"
25                     + "input.xsl output.xml" );
26             System.exit( 1 );
27         }
28
29         // factory for creating DocumentBuilders
30         DocumentBuilderFactory builderFactory =
31             DocumentBuilderFactory.newInstance();
32
33         // factory for creating Transformers
34         TransformerFactory transformerFactory =
35             TransformerFactory.newInstance();
36
37         DocumentBuilder builder =
38             builderFactory.newDocumentBuilder();
39
40         Document document = builder.parse( new File( args[ 0 ] ) );
41
42         // create DOMSource for source XML document
43         Source xmlSource = new DOMSource( document );
44
45         // create StreamSource for XSLT document
46         Source xslSource = new StreamSource( new File( args[ 1 ] ) );
47
48         // create StreamResult for transformation result
49         Result result = new StreamResult( new File( args[ 2 ] ) );
50
51         // create Transformer for XSL transformation
52         Transformer transformer =
53             transformerFactory.newTransformer( xslSource );
54
55         // transform and deliver content to client
56         transformer.transform( xmlSource, result );
57     }
58 }

```

Fig. D.1 Java application that performs XSL transformations (part 2 of 2).

Lines 1–38 import the necessary classes and create a **DocumentBuilderFactory**, a **DocumentBuilder** and a **TransformerFactory**. Line 40 creates a **Document** object, passing it the XML file to be transformed. Line 43 creates a new **DOMSource** object from which the **Transformer** reads the XML **Document**. Line 46 creates a **StreamSource** object from which the **Transformer** reads the XSL **File**. **DOMSource** and **StreamSource** both implement the **Source** interface. Line 49 creates a **StreamResult** object to which the **Transformer** writes a **File** containing the result of the transformation. Lines 52–53 call method **newTransformer**, passing it the **Source** object of the XSL file as an argument. Constructing a **Transformer** with an

XSL file allows the **Transformer** to apply the rules in that file when transforming XML documents. Line 56 applies the XSL transformation to the XML file to produce the result **File**. In this appendix, you will use this Java application to apply XSL transformations to XML files.

[Note: In this example we use a **DOMSource** to provide the XML document to the **Transformer**, although we could have used a **StreamSource** to read from the XML file directly. We chose this method, because in other examples in the book, we build the DOM tree in memory and do not have a file from which to create a **StreamSource** object.]

### D.3 Templates

An XSLT document is an XML document with a root element **stylesheet**. The namespace for an XSLT document is <http://www.w3.org/1999/XSL/Transform>. The XSLT document shown in Fig. D.2 transforms **intro.xml** (Fig. D.3) into a simple XHTML document (Fig. D.4).

XSLT uses *XPath* expressions to locate nodes in an XML document. [Note: A structured complete explanation of the *XPath* language is beyond the scope of this book. We explain each *XPath* expression as we encounter it in the examples.] In an XSL transformation, there are two trees of nodes. The first node tree is the *source tree*. The nodes in this tree correspond to the original XML document to which the transformation is applied. The second node tree is the *result tree*. The result tree contains all of the nodes produced by the XSL transformation. This result tree represents the document produced by the transformation. The document used as the source tree is not modified by an XSL transformation.

Lines 6–7 contain the XSLT document's root element (i.e., **xsl:stylesheet**). Attribute **version** indicates the XSLT specification used. Namespace prefix **xsl** is defined and assigned the URI "<http://www.w3.org/1999/XSL/Transform>".

Line 9 contains a **template** element. This element matches specific XML document nodes by using an *XPath* expression in attribute **match**. In this case, we **match** any **myMessage** element nodes.

```

1 <?xml version = "1.0"?>
2
3 <!-- Fig. D.2 : intro.xsl -->
4 <!-- Simple XSLT document for intro.xml -->
5
6 <xsl:stylesheet version = "1.0"
7   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9   <xsl:template match = "myMessage">
10    <html>
11      <body><xsl:value-of select = "message"/></body>
12    </html>
13  </xsl:template>
14
15 </xsl:stylesheet>
```

Fig. D.2 Simple template.

Lines 10–12 are the contents of the **template** element. When a **myMessage** element node is matched in the source tree (i.e., the document being transformed), the contents of the **template** element are placed in the result tree (i.e., the document created by the transformation). By using element **value-of** and an XPath expression in attribute **select**, the text contents of the node(s) returned by the XPath expression are placed in the result tree.

Figure D.3 lists the input XML document. Figure D.4 lists the results of the transformation.

## D.4 Creating Elements and Attributes

In the previous section, we demonstrated the use of XSLT for simple element matching. This section discusses the creation of new elements and attributes within an XSLT document. Figure D.5 lists an XML document that marks up various sports.

Figure D.6 lists the XSLT document that transforms the XML document in Fig. D.5 into another XML document.

```

1 <?xml version = "1.0"?>
2
3 <!-- Fig. D.3 : intro.xml -->
4 <!-- Simple introduction to XML markup -->
5
6 <myMessage>
7   <message>Welcome to XSLT!</message>
8 </myMessage>
```

Fig. D.3 Sample input XML document **intro.xml**.

```

1 <html>
2 <body>Welcome to XSLT!</body>
3 </html>
```

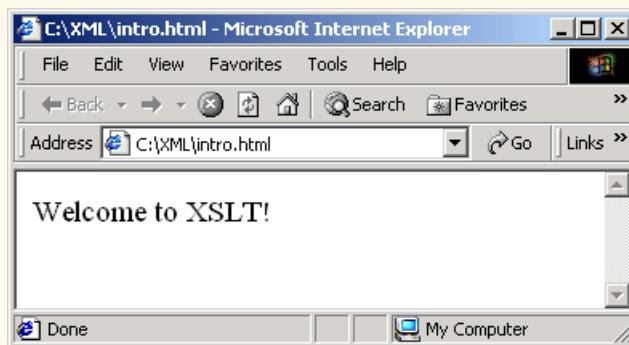


Fig. D.4 Results of XSL transformation.

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.5 : games.xml -->
4  <!-- Sports Database -->
5
6  <sports>
7
8      <game title = "cricket">
9          <id>243</id>
10
11         <para>
12             More popular among commonwealth nations.
13         </para>
14     </game>
15
16     <game title = "baseball">
17         <id>431</id>
18
19         <para>
20             More popular in America.
21         </para>
22     </game>
23
24     <game title = "soccer">
25         <id>123</id>
26
27         <para>
28             Most popular sport in the world.
29         </para>
30     </game>
31
32 </sports>

```

Fig. D.5 XML document containing a list of sports.

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.6 : elements.xsl -->
4  <!-- Using xsl:element and xsl:attribute -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "/">
10         <xsl:apply-templates/>
11     </xsl:template>
12
13     <xsl:template match = "sports">
14         <sports>
15             <xsl:apply-templates/>
16         </sports>
17     </xsl:template>

```

Fig. D.6 Using XSLT to create elements and attributes (part 1 of 2).

```

18      <xsl:template match = "game">
19          <xsl:element name = "@title">
20              <xsl:attribute name = "id">
21                  <xsl:value-of select = "id"/>
22              </xsl:attribute>
23
24          <comment>
25              <xsl:value-of select = "para"/>
26          </comment>
27
28      </xsl:element>
29  </xsl:template>
30
31 </xsl:stylesheet>
32
33

```

**Fig. D.6** Using XSLT to create elements and attributes (part 2 of 2).

Lines 9–11 use the **match** attribute to select the *document root* (i.e., the parent of the root element) of the XML document. The **/** character represents the document root. Element **apply-templates** applies the **templates** to specific nodes. In this case, we have not specified any particular nodes. By default, element **apply-templates** matches all the child nodes of an element. In Fig. D.5, the child nodes of the document root are two comment nodes and the **sports** element node.

The XSLT recommendation defines *default templates* for the nodes of an XML document. If a programmer does not specify a **template** that matches a particular element, the default XSLT template is applied. Default templates are described in Fig. D.7.

Lines 13–17 match element **sports**. We output the **sports** element and apply templates to the child nodes of the **sports** element. Line 19 matches element **game**. In the input XML document, element **game** contains the name of a sport, its unique identifier and a description.

#### Template / Description

```

<xsl:template match = "/ | *">
    <xsl:apply-templates/>
</xsl:template>

```

This template matches and applies templates to the child nodes of the document root (**/**) and any element nodes (**\***).

```

<xsl:template match = "text() | @* ">
    <xsl:value-of select = ".\"/>
</xsl:template>

```

This template matches and outputs the values of text nodes (**text()**) and attribute nodes (**@\***).

**Fig. D.7** Default XSLT templates (part 1 of 2).

**Template / Description**

```
<xsl:template match = "processing-instruction() | comment()" />
```

This template matches processing-instruction nodes (**processing-instruction()**) and comment nodes (**comment()**), but does not perform any actions with them.

**Fig. D.7** Default XSLT templates (part 2 of 2).

Line 20 shows the element **element**, which creates an element, with the element name specified in attribute **name**. Therefore, the name of this XML element will be the name of the sport contained in attribute **title** of element **game**. [Note: In XPath, the symbol **@** specifies an attribute.]

Lines 22–24 show element **attribute**, which creates an attribute for an element. Attribute **name** provides the name of the attribute. The text in element **attribute** specifies the attribute's value in the result tree. Here, the attribute statement will create attribute **id** for the new element, which contains the text in element **id** of element **game**. Lines 26–28 create element **comment** with the contents of element **para**.

Figure D.8 lists the output of the transformation. Your output may not look exactly like that in the figure, because we have modified the output in the figure for presentation. The original XML document has been transformed into a new XML document with sport names as elements (instead of attributes, as in the original document).

## D.5 Iteration and Sorting

XSLT allows for iteration through a node set (i.e., all nodes an XPath expression matches). Node sets can also be sorted in XSLT. Figure D.9 shows an XML document containing information about a book.

```

1  <?xml version = "1.0" encoding = "UTF-8"?>
2  <sports>
3
4      <cricket id = "243">
5          <comment>
6              More popular among commonwealth nations.
7          </comment>
8      </cricket>
9
10     <baseball id = "431">
11         <comment>
12             More popular in America.
13         </comment>
14     </baseball>
15
16     <soccer id = "123">
17         <comment>
18             Most popular sport in the world.
19         </comment>

```

**Fig. D.8** Output of transformation (part 1 of 2).

```

20    </soccer>
21
22  </sports>
```

Fig. D.8 Output of transformation (part 2 of 2).

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.9 : usage.xml -->
4  <!-- Book information      -->
5
6  <book isbn = "999-99999-9-X">
7      <title>Deitel&apos;s XML Primer</title>
8
9      <author>
10         <firstName>Paul</firstName>
11         <lastName>Deitel</lastName>
12     </author>
13
14     <chapters>
15         <preface num = "1" pages = "2">Welcome</preface>
16         <chapter num = "2" pages = "2">XML Elements?</chapter>
17         <chapter num = "1" pages = "4">Easy XML</chapter>
18         <appendix num = "1" pages = "9">Entities</appendix>
19     </chapters>
20
21     <media type = "CD"/>
22 </book>
```

Fig. D.9 Book table of contents as XML.

Figure D.10 shows the XSLT style sheet that transforms the document in Fig. D.9.

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.10 : usage.xsl                                     -->
4  <!-- Transformation of book information into XHTML -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "/">
10         <html>
11             <xsl:apply-templates/>
12         </html>
13     </xsl:template>
14
15     <xsl:template match = "book">
16         <head>
17             <title>ISBN <xsl:value-of select = "@isbn"/> -
18                 <xsl:value-of select = "title"/></title>
19         </head>
```

Fig. D.10 Transforming XML data into XHTML (part 1 of 2).

```
20      <body>
21          <h1><xsl:value-of select = "title"/></h1>
22
23          <h2>by <xsl:value-of select = "author/lastName"/>,
24              <xsl:value-of select = "author/firstName"/></h2>
25
26          <table border = "1">
27              <xsl:for-each select = "chapters/preface">
28                  <xsl:sort select = "@num" order = "ascending"/>
29                  <tr>
30                      <td align = "right">
31                          Preface <xsl:value-of select = "@num"/>
32                      </td>
33
34                      <td>
35                          <xsl:value-of select = "."/> (
36                              <xsl:value-of select = "@pages"/> pages )
37                          </td>
38                      </tr>
39                  </xsl:for-each>
40
41                  <xsl:for-each select = "chapters/chapter">
42                      <xsl:sort select = "@num" order = "ascending"/>
43                      <tr>
44                          <td align = "right">
45                              Chapter <xsl:value-of select = "@num"/>
46                          </td>
47
48                          <td>
49                              <xsl:value-of select = "."/> (
50                                  <xsl:value-of select = "@pages"/> pages )
51                              </td>
52                          </tr>
53                  </xsl:for-each>
54
55                  <xsl:for-each select = "chapters/appendix">
56                      <xsl:sort select = "@num" order = "ascending"/>
57                      <tr>
58                          <td align = "right">
59                              Appendix <xsl:value-of select = "@num"/>
60                          </td>
61
62                          <td>
63                              <xsl:value-of select = "."/> (
64                                  <xsl:value-of select = "@pages"/> pages )
65                              </td>
66                          </tr>
67                  </xsl:for-each>
68              </table>
69          </body>
70      </xsl:template>
71
72  </xsl:stylesheet>
```

Fig. D.10 Transforming XML data into XHTML (part 2 of 2).

Line 15 is an XSLT template that matches the **book** element. In this template, we construct the body of the XHTML document. Lines 17–18 create the title for the XHTML document. We use the ISBN of the book from attribute **isbn** and also the contents of element **title** to create the title string, resulting in **ISBN 999-99999-9-X - Deitel's XML Primer**. Line 22 creates a header element with the title of the book, selected from element **title**. Lines 24–25 create another header element, displaying the name of the book's author. The XPath expression **author/lastName** selects the author's last name, and the expression **author/firstName** selects the author's first name.

Line 28 shows XSLT element **for-each**, which applies the contents of the element to each of the nodes selected by attribute **select**. In this case, we select all **preface** elements of the **chapters** element. XSLT element **sort** (line 29) sorts the nodes selected by the **for-each** element by the field in attribute **select**. Attribute **order** specifies how these nodes should be ordered. Attribute **order** has possible values such as "**ascending**" (i.e., A–Z) and "**descending**" (i.e., Z–A). In this **for-each** element, we sort the nodes by attribute **num**, in ascending order.

Lines 30–39 output a table row displaying the preface number, the title of the preface and the number of pages in that preface for each **preface** element. Similarly, lines 42–54 output the **chapter** elements, and lines 56–68 output the **appendix** elements.

Figure D.11 shows the results of the transformation. Your output may look different, because we have modified ours for presentation. Notice that the chapters have appeared in the correct order, even though the XML document contained the elements in a different order.

```

1  <html>
2    <head>
3      <title>ISBN 999-99999-9-X - Deitel's XML Primer</title>
4    </head>
5
6    <body>
7      <h1>Deitel's XML Primer</h1>
8      <h2>by Deitel, Paul</h2>
9
10     <table border = "1">
11       <tr>
12         <td align = "right">Preface 1</td>
13         <td>Welcome ( 2 pages )</td>
14       </tr>
15
16       <tr>
17         <td align = "right">Chapter 1</td>
18         <td>Easy XML ( 4 pages )</td>
19       </tr>
20
21       <tr>
22         <td align = "right">Chapter 2</td>
23         <td>XML Elements? ( 2 pages )</td>
24       </tr>
25
26       <tr>
27         <td align = "right">Appendix 1</td>

```

Fig. D.11 Output of the transformation (part 1 of 2).

```
28             <td>Entities ( 9 pages )</td>
29         </tr>
30     </table>
31 </body>
32
33 </html>
```

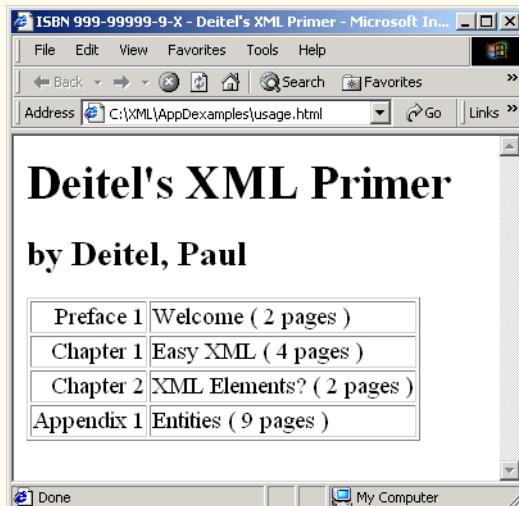


Fig. D.11 Output of the transformation (part 2 of 2).

## D.6 Conditional Processing

In the previous section, we discussed the iteration of a node set. XSLT also provides elements to perform conditional processing, such as **if** elements. Figure D.12 is an XML document that a day planner application might use.

```
1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.12 : planner.xml    -->
4  <!-- Day Planner XML document -->
5
6  <planner>
7
8      <year value = "2001">
9
10     <date month = "7" day = "15">
11         <note time = "1430">Doctor's appointment</note>
12         <note time = "1620">Physics class at BH291C</note>
13     </date>
14
15     <date month = "7" day = "4">
16         <note>Independence Day</note>
17     </date>
```

Fig. D.12 Day planner XML document (part 1 of 2).

```

18      <date month = "7" day = "20">
19          <note time = "0900">General Meeting in room 32-A</note>
20      </date>
21
22      <date month = "7" day = "20">
23          <note time = "1900">Party at Joe's</note>
24      </date>
25
26      <date month = "7" day = "20">
27          <note time = "1300">Financial Meeting in room 14-C</note>
28      </date>
29
30
31  </year>
32
33  </planner>

```

Fig. D.12 Day planner XML document (part 2 of 2).

Figure D.13 is an XSLT document for transforming the day planner XML document into an XHTML document.

XSLT provides the **choose** element (lines 34–60) to allow alternative conditional statements, similar to a nested **if/else** structure in Java. Element **when** corresponds to an **if** statement. The **test** attribute of the **when** element specifies the expression that is being tested. If the expression is true, the XSLT processor evaluates the code inside the **when** element. Line 37, for instance, is an expression that will be true when the **time** is between "0500" and "1200". The element **choose** serves to group all the **when** elements, thereby making them exclusive of one another (i.e., the first **when** element whose conditional is satisfied will be executed). The element **otherwise** (lines 56–58) corresponds to the final **else** statement in a nested **if/else** structure and is likewise optional.

Lines 64–66 show the **if** conditional statement. This **if** determines whether the current node (represented as **.**) is empty. If so, **n/a** is inserted into the result tree. Unlike element **choose**, element **if** provides a single conditional test.

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.13 : conditional.xsl           -->
4  <!-- xsl:choose, xsl:when and xsl:otherwise -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "/">
10         <html>
11
12         <body>
13             Appointments
14             <br />

```

Fig. D.13 Using conditional elements (part 1 of 3).

```

15          <xsl:apply-templates select = "planner/year"/>
16      </body>
17
18      </html>
19  </xsl:template>
20
21  <xsl:template match = "year">
22      <strong>Year: </strong>
23      <xsl:value-of select = "@value"/>
24      <br/>
25      <xsl:for-each select = "date/note">
26          <xsl:sort select = ".../@day" order = "ascending"
27              data-type = "number"/>
28          <strong>
29              Day:
30              <xsl:value-of select = ".../@day"/>/
31              <xsl:value-of select = ".../@month"/>
32          </strong>
33
34      <xsl:choose>
35
36          <xsl:when test =
37              "@time &gt; '0500' and @time &lt; '1200'">
38              Morning (<xsl:value-of select = "@time"/>):
39          </xsl:when>
40
41          <xsl:when test =
42              "@time &gt; '1200' and @time &lt; '1700'">
43              Afternoon (<xsl:value-of select = "@time"/>):
44          </xsl:when>
45
46          <xsl:when test =
47              "@time &gt; '1700' and @time &lt; '2000'">
48              Evening (<xsl:value-of select = "@time"/>):
49          </xsl:when>
50
51          <xsl:when test =
52              "@time &gt; '2000' and @time &lt; '2400'">
53              Night (<xsl:value-of select = "@time"/>):
54          </xsl:when>
55
56          <xsl:otherwise>
57              Entire day:
58          </xsl:otherwise>
59
60      </xsl:choose>
61
62      <xsl:value-of select = ".,"/>
63
64      <xsl:if test = ". = ''">
65          n/a
66      </xsl:if>
67

```

Fig. D.13 Using conditional elements (part 2 of 3).

```

68      <br/>
69      </xsl:for-each>
70
71  </xsl:template>
72
73 </xsl:stylesheet>
```

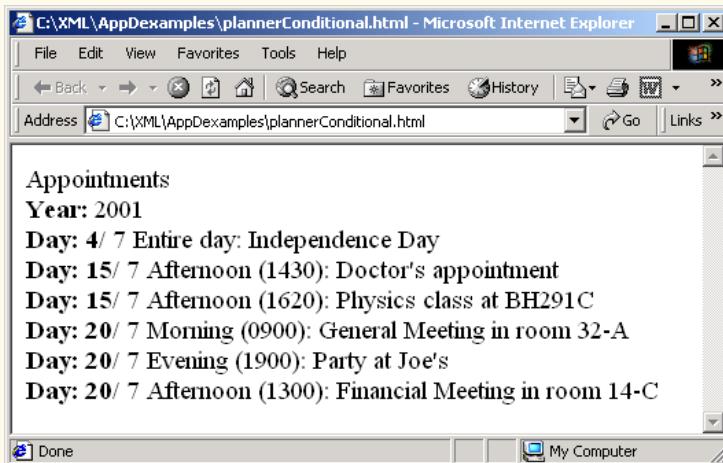


Fig. D.13 Using conditional elements (part 3 of 3).

## D.7 Combining Style Sheets

XSLT allows for modularity in style sheets. This feature enables XSLT documents to import other XSLT documents. Figure D.14 lists an XSLT document that is imported into the XSLT document in Fig. D.15 using element ***import***.

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.14 : usage2.xsl      -->
4  <!-- xsl:import example       -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "book">
10         <html>
11
12             <body>
13                 <xsl:apply-templates/>
14             </body>
15         </html>
16
17     </xsl:template>
18
```

Fig. D.14 XSLT document being imported (part 1 of 2).

```
19      <xsl:template match = "title">
20          <xsl:value-of select = "."/>
21      </xsl:template>
22
23      <xsl:template match = "author">
24          <br/>
25
26          <p>Author:
27              <xsl:value-of select = "lastName"/>,
28              <xsl:value-of select = "firstName"/>
29          </p>
30
31      </xsl:template>
32
33      <xsl:template match = "*|text()" />
34
35  </xsl:stylesheet>
```

Fig. D.14 XSLT document being imported (part 2 of 2).

The XSLT document in Fig. D.14 is similar to the ones presented earlier. One notable difference is line 33, which provides a **template** to match any element or text nodes. When these nodes are matched, this **template** indicates that no data will be written to the result tree. If the **template** is not provided, default **templates** will output the other nodes.

Line 9 in Fig. D.15 uses element **import** to use the **templates** defined in the XSLT document (Fig. D.14) referenced by attribute **href**.

Line 13 provides a **template** for element **title**, which already has been defined in the XSLT document being **imported**. This *local template* has higher precedence than the imported template, so it is used instead of the **imported** template. Figure D.16 shows the result of transforming **usage.xml** (Fig. D.9).

```
1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.15 : usage1.xsl           -->
4  <!-- xsl:import example using usage.xml -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:import href = "usage2.xsl"/>
10
11     <!-- this template has higher precedence over
12         templates being imported  -->
13     <xsl:template match = "title">
14
15         <h2>
16             <xsl:value-of select = "."/>
17         </h2>
18
19     </xsl:template>
```

Fig. D.15 Importing another XSLT document (part 1 of 2).

---

```

20 </xsl:stylesheet>
21 
```

---

Fig. D.15 Importing another XSLT document (part 2 of 2).

```

1 <html>
2   <body>
3     <h2>Deitel's XML Primer</h2>
4     <br>
5     <p>
6       Author: Deitel, Paul
7     </p>
8   </body>
9 </html>

```

---

Fig. D.16 Transformation results.

Figure D.17 shows an example of the XSLT element ***include***, which includes other XSLT documents in the current XSLT document. Lines 28–29 contain element ***include***, which includes the files referenced by attribute ***href***. The difference between element ***include*** and element ***import*** is that ***templates*** that are ***included*** have the same precedence as the local templates. Therefore, if any templates are duplicated, the ***template*** that occurs last is used.

---

```

1 <?xml version = "1.0"?>
2
3 <!-- Fig. D.17 : book.xsl          -->
4 <!-- xsl:include example using usage.xml -->
5
6 <xsl:stylesheet version = "1.0"
7   xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9   <xsl:template match = "/>
10
11   <html>
12     <body>
13       <xsl:apply-templates select = "book"/>
14     </body>
15   </html>
16
17 </xsl:template>
18
19 <xsl:template match = "book">
20
21   <h2>
22     <xsl:value-of select = "title"/>
23   </h2>
24 
```

---

Fig. D.17 Combining style sheets using **xsl:include** (part 1 of 2).

---

```

25      <xsl:apply-templates/>
26  </xsl:template>
27
28  <xsl:include href = "author.xsl"/>
29  <xsl:include href = "chapters.xsl"/>
30
31  <xsl:template match = "*|text()" />
32
33 </xsl:stylesheet>

```

---

Fig. D.17 Combining style sheets using **xsl:include** (part 2 of 2).

Figure D.18 and Figure D.19 list the XSLT documents being included by Figure D.17.

---

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.18 : author.xsl          -->
4  <!-- xsl:include example using usage.xml -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "author">
10
11         <p>Author:
12             <xsl:value-of select = "lastName"/>,
13             <xsl:value-of select = "firstName"/>
14         </p>
15
16     </xsl:template>
17
18 </xsl:stylesheet>

```

---

Fig. D.18 XSLT document for rendering the author's name.

---

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.19 : chapters.xsl          -->
4  <!-- xsl:include example using usage.xml -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "chapters">
10         Chapters:
11
12         <ul>
13             <xsl:apply-templates select = "chapter"/>
14         </ul>
15     </xsl:template>

```

---

Fig. D.19 XSLT document for rendering chapter names (part 1 of 2).

```

16      <xsl:template match = "author">
17          <p><strong>Author is: </strong>
18              <xsl:value-of select = "lastName"/>,
19              <xsl:value-of select = "firstName"/>
20          </p>
21      </xsl:template>
22
23      <xsl:template match = "chapter">
24          <li>
25              <xsl:value-of select = "."/>
26          </li>
27      </xsl:template>
28
29  </xsl:stylesheet>
30
31
32
33
34

```

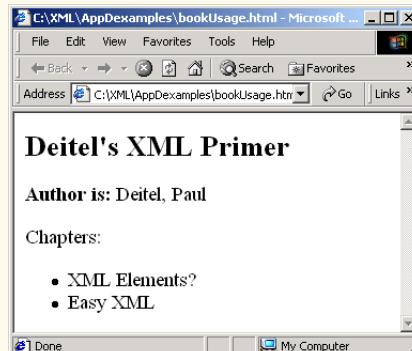
**Fig. D.19** XSLT document for rendering chapter names (part 2 of 2).

Figure D.20 shows the result of the XSLT document (Fig. D.17) applied to the XML document describing a book (Fig. D.9).

```

1  <html>
2      <body>
3          <h2>Deitel's XML Primer</h2>
4          <strong>Author is: </strong>Deitel,
5              Paul</p>
6
7          Chapters:
8          <ul>
9              <li>XML Elements?</li>
10             <li>Easy XML</li>
11         </ul>
12     </body>
13 </html>

```



**Fig. D.20** Output of an XSLT document using element **include**.

## D.8 Variables

XSLT provides variables for storing information. These variables are not like Java variables, but rather more like Java constants. Figure D.21 provides an example of an XSLT document using element **variable**.

Lines 13–14 use element **variable** to create a variable named **pageCount**, which stores the total number of pages in the book. Attribute **select** has the value "**sum(book/chapters/\*/@pages)**", which is an XPath expression for summing the number of **pages**. This XPath expression uses function **sum** to iterate over a set of nodes and sum their values. The set of nodes includes any element (\*) containing an attribute **pages** that is a child of **book/chapters**.

Line 15 uses element **value-of** to output the variable **pageCount**'s value. The *dollar sign* (\$) references the variable's content.

Figure D.22 shows the output of the XSLT document (Fig. D.21) when it is applied to **usage.xml** (Fig. D.9). The total number of pages is 17.

## D.9 Internet and World Wide Web Resources

[www.w3.org/Style/XSL](http://www.w3.org/Style/XSL)

The W3C Extensible Stylesheet Language Web site.

```

1  <?xml version = "1.0"?>
2
3  <!-- Fig. D.21 : variables.xsl -->
4  <!-- using xsl:variables -->
5
6  <xsl:stylesheet version = "1.0"
7      xmlns:xsl = "http://www.w3.org/1999/XSL/Transform">
8
9      <xsl:template match = "/">
10
11         <total>
12             Number of pages =
13                 <xsl:variable name = "pageCount"
14                     select = "sum(book/chapters/*/@pages)"/>
15                 <xsl:value-of select = "$pageCount"/>
16         </total>
17
18     </xsl:template>
19
20 </xsl:stylesheet>
```

Fig. D.21 Demonstrating **xsl:variable**.

```

1  <?xml version="1.0" encoding="UTF-8"?>
2  <total>
3      Number of pages =
4      17</total>
```

Fig. D.22 Result of **variables.xsl** transformation.

**[www.w3.org/TR/xsl](http://www.w3.org/TR/xsl)**

The most current W3C XSL recommendation.

**[www.w3schools.com/xsl](http://www.w3schools.com/xsl)**

This site features an XSL tutorial, along with a list of links and resources.

**[www.dpawson.co.uk/xsl/xsldfaq.html](http://www.dpawson.co.uk/xsl/xsldfaq.html)**

A comprehensive collection of XSL FAQs.

**[www.bayes.co.uk/xml/index.xml](http://www.bayes.co.uk/xml/index.xml)**

A portal site that heavily uses XML and XSL.

**[msdn.microsoft.com/xml](http://msdn.microsoft.com/xml)**

Microsoft Developer Network XML home page, which provides information on XML and XML-related technologies, such as XSL/XSLT.

**[xml.apache.org/xalan-j/index.html](http://xml.apache.org/xalan-j/index.html)**

Home page for Apache's XSLT processor Xalan.

**[java.sun.com/xml/xml\\_jaxp.html](http://java.sun.com/xml/xml_jaxp.html)**

Home page for JAXP, an implementation of XSLT in Java.

## SUMMARY

- XSL Transformation Language (XSLT) transforms XML documents into other text-based documents using XSL format instructions. XSLT uses XPath to match nodes when transforming an XML document into a different document. The resulting document may be XML, XHTML, plain text or any other text-based document.
- To process XSLT documents, you will need an XSLT processor such as the **Transformer**-related classes in JAXP.
- An XSLT document is an XML document with a root element **xsl:stylesheet**. Attribute **version** indicates the XSLT specification used.
- An XSLT document's namespace URI is **http://www.w3.org/1999/XSL/Transform**.
- A **template** element matches specific XML document nodes by using an XPath expression in attribute **match**.
- Element **apply-templates** applies an XSLT document's templates to specific element nodes. By default, element **apply-templates** matches all element child nodes.
- The XSLT specification defines default templates for an XML document's nodes. The template

```
<xsl:template match = "/ | *">
    <xsl:apply-templates/>
</xsl:template>
```

matches the document root node and any element nodes of an XML document and applies templates to their child nodes. The template

```
<xsl:template match = "text() | @*">
    <xsl:value-of select = "./">
</xsl:template>
```

matches text nodes and attribute nodes and outputs their values. The template

```
<xsl:template match ="processing-instruction() | comment()" />
```

matches processing-instruction nodes and comment nodes, but does not perform any actions with them.

- Element **element** creates an element with the name specified in attribute **name**.
- Element **attribute** creates an attribute for an element and can be contained only within an **element** element. Attribute **name** provides the name of the attribute.
- XSLT provides the capability to iterate through a node set returned by an XPath expression. XSLT also provides the capability to sort a node set.
- XSLT element **for-each** applies the element's contents to each of the nodes specified by attribute **select**.
- Element **sort** sorts (in the order specified by attribute **order**) the nodes specified in attribute **select**. Attribute **order** has values **ascending** (i.e., A–Z) and **descending** (i.e., Z–A).
- XSLT provides elements to perform conditional processing.
- Element **choose** allows alternative conditional statements to be processed.
- XSLT allows for modularity in style sheets. This feature allows XSLT documents to import other XSLT documents by using element **import**. Other XSLT document are referenced using attribute **href**.
- Local templates have higher precedence than imported templates. XSLT element **include** includes other XSLT documents in the current XSLT document.
- The difference between element **include** and element **import** is that templates included using element **include** have the same precedence as the local templates. Therefore, if any templates are duplicated, the template that occurs last is used.
- XSLT provides variables for storing values.

## TERMINOLOGY

\$	element <b>include</b>
<b>ascending</b>	element <b>otherwise</b>
attribute <b>href</b>	element <b>sort</b>
attribute <b>match</b>	element <b>value-of</b>
attribute <b>name</b>	element <b>variable</b>
attribute <b>order</b>	element <b>when</b>
attribute <b>select</b>	Extensible Stylesheet Language (XSL)
attribute <b>test</b>	<a href="http://www.w3.org/1999/XSL/Transform">http://www.w3.org/1999/XSL/Transform</a>
attribute <b>type</b>	form URI
attribute <b>version</b>	<b>if</b> conditional statement
<b>choose</b> element	<b>otherwise</b> conditional
conditional processing	root element <b>stylesheet</b>
<b>descending</b>	<b>StreamSource</b>
<b>DOMSource</b>	<b>template</b> element
element <b>apply-templates</b>	text-based document
element <b>attribute</b>	<b>when</b> conditional
element <b>element</b>	XPath
element <b>for-each</b>	XPath expression
element <b>if</b>	XSLT (XSL Transformation Language)
element <b>import</b>	XSLT processor

## SELF-REVIEW EXERCISES

- D.1 State whether the following are *true* or *false*. If *false*, explain why.

- a) XSLT uses XHTML to match nodes for transforming an XML document into a different document.
- b) In its most current specification, XSLT does not allow for iteration through a node set returned by an XPath expression.
- c) By using XSLT, XML documents can easily be converted between formats.
- d) Like element **choose**, element **if** provides a single conditional test.
- e) XSLT allows for modularity in stylesheets, which enables XSLT documents to import other XSLT documents.
- f) The document resulting from an XSLT transformation may be in the format of an XML document, XHTML/plain text or any other text-based document.
- g) XSLT does not provide default templates; all templates must be custom built by the programmer.
- h) XSLT provides elements to perform conditional processing, such as **if** elements.
- i) XSLT does not provide variables.

**D.2** Fill in the blanks in each of the following statements.

- a) Attribute \_\_\_\_\_ defines the XSLT specification used in an XSLT document.
- b) An XSLT document is an XML document with a root element \_\_\_\_\_.
- c) XSLT provides the \_\_\_\_\_ element to allow alternative conditional statements.
- d) The letter T in XSLT stands for \_\_\_\_\_.
- e) Templates of an XSLT document can be applied to specific nodes of an element by using element \_\_\_\_\_.
- f) The **template** element matches specific \_\_\_\_\_ of an XML document.
- g) Attribute \_\_\_\_\_ has values **ascending** and **descending**.
- h) Element \_\_\_\_\_ includes other XSLT documents in the current XSLT document.

### ANSWERS TO SELF-REVIEW EXERCISES

**D.1** a) False. XSLT uses XPath to match nodes when transforming an XML document into a different document. b) False. XSLT allows for iteration through a node set returned by an XPath expression. c) True. d) False. Unlike element **choose**, element **if** provides a single conditional test. e) True. f) True. g) False. XSLT provides several default templates for the nodes of an XML document. h) True. i) False. XSLT provides variables.

**D.2** a) **version**. b) **stylesheet**. c) **choose**. d) Transformation. e) **apply-templates**. f) nodes. g) **order**. h) **include**.



---

# Downloading and Installing J2EE 1.2.1

---

## E.1 Introduction

In this appendix, we provide instructions for downloading, installing and configuring Sun Microsystem's Java 2 Enterprise Edition SDK (J2EE SDK), which is a reference implementation of the J2EE 1.2.1 specification. The J2EE SDK is not intended for use in production environments, because it lacks the advanced features and stability of commercial application servers. Instead, it serves as a tool that developers can use to test applications, and as a guide for application-server vendors when building their own J2EE implementations.

## E.2 Installation

The J2EE SDK version 1.2.1 is available for download from [java.sun.com/j2ee/j2sdkee](http://java.sun.com/j2ee/j2sdkee). Download the appropriate version for your platform and follow the installation instructions at [java.sun.com/j2ee/j2sdkee/install.html](http://java.sun.com/j2ee/j2sdkee/install.html). The J2EE SDK requires two environment variables—**J2EE\_HOME** and **JAVA\_HOME**. The variables should be set to your J2EE SDK installation directory (e.g., `c:\j2sdkee1.2.1`) and J2SE SDK installation directory (e.g., `c:\jdk1.3.1`), respectively. In Windows 2000, specify these environment variables in the **System** control panel on the **Advanced** tab. For most UNIX systems, use the following commands to set the environment variables

```
J2EE_HOME=/usr/local/j2sdkee.1.2.1; export J2EE_HOME  
JAVA_HOME=/usr/local/jdk1.3.1; export JAVA_HOME
```

Be sure to replace `/usr/local/` with the name of the directory in which you installed each SDK. If you require database drivers or other packages that are not part of the J2EE

or J2SE SDKs, you also must set the **J2EE\_CLASSPATH** environment variable to include those packages.

Throughout this book we use the Cloudscape 3.6 database. The J2EE SDK includes an older version of Cloudscape. To upgrade Cloudscape to the current version, you must replace the JAR files in the **j2sdkee1.2.1\lib\cloudscape** subdirectory with current versions. Copy **client.jar**, **tools.jar** and **cloudscape.jar** from the **Cloudscape\_3.6\lib\** directory to **j2sdkee1.2.1\lib\cloudscape**. Also, copy **RmiJdbc.jar** from **Cloudscape\_3.6\frameworks\RmiJdbc\classes** to **j2sdkee1.2.1\lib\cloudscape**.

## E.3 Configuration

After installing the J2EE SDK, you must configure several options in the SDK's configuration files. The following subsections provide instructions for configuring data sources and the HTTP server in the J2EE SDK.

### E.3.1 JDBC Drivers and Data Sources

The configuration file **j2sdkee1.2.1\config\default.properties** contains configuration information for data sources, including URLs, JNDI names, properties and JDBC driver classes. Property **jdbc.drivers** is a colon separated list of JDBC driver class names. For example:

```
jdbc.drivers=COM.cloudscape.core.JDBCDataSource:  
oracle.jdbc.driver.OracleDriver
```

Note that there should be no spaces in the value of the **jdbc.drivers** property, and all values must appear on a single line. Property **jdbc.datasources** assigns JNDI names, URLs and properties for data sources. The pipe character separates JNDI names and URLs, it also separates each data source entry. For example, the following line includes the JNDI name and URL for the Deitel Bookstore database (Chapters 17–20) and for the **authors** database of Chapter 8. Note that all entries must appear on the same line, and without spaces between entries.

```
jdbc.datasources=jdbc/books|jdbc:cloudscape:rmi:books;create=true|jdbc/Bookstore|jdbc:cloudscape:rmi:Bookstore;create=true
```

### E.3.2 HTTP properties

HTTP and Web properties are configured in file **web.properties**. Property **http.port** specifies the port number for the HTTP server. The default port is 8000. If you have other services that use port 8000 running on your computer, you may need to change the port value. Property **documentroot** configures the base location from the Web server serves documents. The default directory is **j2eesdk1.2.1\public\_html**.



---

# Java Community Process<sup>SM</sup> (JCP)

---

## F.1 Introduction

The Java Community Process (JCP)<sup>1</sup>, which started in 1998, is a community-built organization designed to improve the progress and efficiency of Java technologies. Through a multistage process of testing and revision, the JCP creates and updates Java specifications. Along with each specification, the JCP includes a reference implementation and a compatibility test suite. The JCP enables everyone to participate in the development and ratification of the Java Platform. After reading this appendix, you may wish to visit the JCP Web site at [www.jcp.org](http://www.jcp.org) for further details on the JCP and to learn about the various specifications currently under development.

## F.2 Participants

The JCP consists of five participants who contribute to the improvement and evolution of each Java specification—the *Program Management Office (PMO)*, the *Executive Committees (ECs)*, *Experts*, *members* and the *public*.

### F.2.1 Program Management Office

The Program Management Office (PMO) is the branch of Sun Microsystems that governs and directs JCP. The PMO does not work directly on the specifications, but instead it oversees the work and decisions of the Executive Committee.

### F.2.2 Executive Committee

JCP members are elected or ratified to serve three years on an Executive Committee (EC). The primary function of the ECs is to vote on each Java Specification Request (JSR) and the subsequent drafts of the specification. There are two ECs, each covering different Java

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1. The **jcp.org** Web site was our primary resource for information presented in this appendix.

Platforms. One EC is responsible for desktop/server specifications, corresponding to the Java 2 Standard Edition (J2SE) and Java 2 Enterprise Edition (J2EE); this EC currently contains representatives from fifteen organizations and companies including IBM, Apple, and BEA Systems, and one individual. The other EC is responsible for consumer/embedded specifications, corresponding to the Java 2 Micro Edition (J2ME); this EC also consists of sixteen represented companies including Sony, Palm, Motorola, and IBM.

### F.2.3 Experts

Every *Java Specification Request (JSR)* has an *Expert Group* associated with it. Experts are nominated representatives from JCP member organizations, or individuals who have completed an Individual Expert Participation Agreement (IEPA). Experts have an advanced knowledge in the material covered by the particular JSR. Individuals may nominate themselves to join an Expert Group or other members may suggest them. Through a series of public and community-restricted drafts, the Expert Group creates the specification proposed in the JSR. Each JSR also has a *Specification Lead (Spec Lead)* associated with it; an Expert from the Expert Group may accept the position and head the formation of the specification. The submitter of the JSR proposal typically becomes the Spec Lead.

### F.2.4 Members

JCP Members are companies or individuals who sign a Java Specification Participation Agreement (JSPA) and pay a \$5000 yearly fee for commercial businesses or a \$2000 yearly fee for government, education or non-profit organizations. Membership allows individuals to submit JSRs, review all drafts of the specifications, vote for members of the Executive Committees, and attend Java events. Currently, there are over 400 businesses, including IBM, Bank of America, Motorola, and Xerox, holding a JCP membership.

### F.2.5 Public Participation

The public (anyone with Internet access) also has the chance to be part of the development process. Current JSRs and public drafts up for review are available for the public to download, read and comment on via the Internet.

## F.3 Java Community Process

The JCP follows a detailed procedure to ensure the practicality and assurance of each specification. Each proposed specification must pass a series of critiques, revisions, and ballots before meeting the corresponding EC's approval.

### F.3.1 Initiation Phase

The introduction of a new specification or the revision of an old one begins with the JCP members. A single member or group of members may produce and submit a JSR to the PMO. Included in the JSR are the names of the members making the request, a proposed Spec Lead and a list of preferred members for the Expert Group. The JSR states the grounds for the proposal, goals for the outcome of the specification and helpful guides to beginning the project.

Upon receiving a JSR, the PMO assigns the JSR to the appropriate EC. By creating a Web page for the JSR, the PMO makes the JSR public. This begins the fourteen day *JSR Review* process; current JSRs are available at [jcp.org/jsr/all](http://jcp.org/jsr/all). After reading the proposal, the public can submit comments and ideas. The EC then reviews these remarks and posts them on the JSR's Web Page. During the JSR Review, members have the opportunity to submit applications to the PMO, requesting to join the Expert Group (should the EC approve the JSR).

While the public, Experts and members review the JSR, the EC reads the JSR, considers received comments and votes on the *JSR Approval Ballot*. After the fourteen day period of the JSR Review, all votes are submitted, and the JSR passes or fails.

If the JSR fails, a new revision period of fourteen days begins. During this time, the PMO sends all of the EC's comments to the creators of the JSR. The creators may then review the suggestions and criticisms and revise the JSR. When the PMO receives a redrafted edition of the JSR, the PMO posts the fresh copy and the review period begins again. If the revised document fails to receive approval in the JSR Reconsideration Ballot, the failure status is permanent. If the JSR meets approval, the JSR is ready to be developed.

### F.3.2 Community Draft Phase

After the JSR passes either the Approval Ballot or the Reconsideration Ballot, the Expert Group forms. The Spec Lead position is usually filled by the Expert suggested in the JSR. The Expert Group contains members requested in the JSR as well as members who applied after viewing the JSR. Note that there is not a specified size for the Expert Group. The Spec Lead, in accordance with the existing Expert Group, may accept new members, allowing the Expert Group to diversify and gain a broad range of opinions.

The Spec Lead and the Expert Group work with software developers, computer industry workers, educators and other members to form a draft of the specification suitable for the community to review. During the *Community Review* (a thirty to ninety day period), members and Experts review and comment on the Community Draft.

Throughout the Community Review, the Spec Lead is required to report all changes on the draft to the PMO. The PMO then announces the alterations to the community and posts the latest version of the draft on the JCP Web page.

In addition to the actual specification, JCP provides a *Reference Implementation (RI)* and a *Technology Compatibility Kit (TCK)*. The RI is an implementation of the specification, confirming that the specification can in fact be implemented. The RI also will act as a guide for others who implement the specification. The TCK is a set of trials, tools and records that implementors of the specification use as a test suite. The Spec Lead is responsible for both producing and licensing the RI and TCK. When the Community Draft released, the Spec Lead provides information on the production and licensing of the RI and TCK to the PMO.

In the final seven days of the Community Review, the EC votes on the *Draft Specification Approval Ballot*. If the draft fails the vote, the Expert Group has thirty days to read the comments provided by the EC and alter the draft. After a new edition is submitted, the EC votes in the *Draft Specification Reconsideration Ballot*. If the draft meets the EC's approval, the Expert Group addresses appropriate feedback from the community review, then makes the draft available for public review.

### F.3.3 Public Draft Phase

During the Public Review (a thirty to ninety day period), the draft of the approved specification is posted for both members and the public to view and comment on. The Expert Group considers the received commentary and makes appropriate changes to the draft, posting the latest version of the specification on the corresponding JSR Web page.

### F.3.4 Final Phase

The Expert Group has the opportunity to update the draft after the public reviews it. Both JCP members and the public may view the Proposed Final Draft on the JCP Web site.

The Spec Lead must test that it is possible to implement the specification. By providing the RI, the Spec Lead ensures that an implementation of the specification is possible. The Expert Group must confirm that the RI implements the specification adequately, that the TCK provides sufficient test coverage and that the RI passes the tests in the TCK. Any changes to the specification are posted on the JCP Web site and are open to comments. In addition, the PMO requires the Spec Lead to record challenges faced with the tests in the TCK; this information is also posted on the JCP Web site.

The PMO sends the *Final Draft* to the Executive Committee and announces where to find the RI and TCK. In the *Final Approval Ballot*, the EC votes on the Final Draft. If the draft fails, the Spec Lead and Expert Group have thirty days to modify the specification, RI and TCK. If a modified specification is submitted, the EC votes on a *Final Reconsideration Ballot*. If the Final Draft is approved, the Final Draft is posted on the JCP Web site, along with all alterations. The JSR is complete, and the Expert Group is dismissed.

### F.3.5 Maintenance Phase

After the specification, RI and TCK are finished and implemented, a *Maintenance Period* begins. The *Maintenance Lead (ML)*, usually the same person as the Spec Lead, answers questions, clarifies discrepancies and decides if the specification should be updated. The ML considers requests for alterations to the specification and enters them into a Change Log as “proposed” changes. For the following thirty days, anyone can comment on the suggested changes by visiting the JCP Web site.

After the thirty day Maintenance Period the ML categorizes a suggested change as “accepted,” meaning the minor revision will be made, “deferred,” meaning the revision will possibly become a JSR, or “proposed,” meaning the revision will remain as a suggested idea. If the ML terms the revision as “deferred,” the ML may decide to submit the proposed change as a JSR.

During the Maintenance Period a member of the EC may request to change the status of a minor change to a JSR. For this request the PMO will hold an Item Exception Ballot in the last seven days of the Maintenance Period. If the ballot passes the revision will change status to a JSR, otherwise the change remains in the “proposed” category.

Along with the upkeep of the specification, the ML also accordingly updates the TCK and RI. The ML must record challenges of the tests contained in the TCK. If the original TCK implementor is dissatisfied with the change, the implementor may appeal it by sending a written document to the PMO. The EC votes on the complaint in an *Appeal Ballot*.



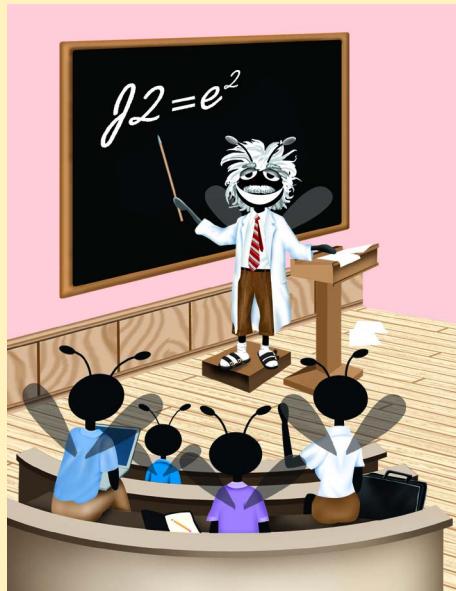
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# Java Native Interface (JNI)

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## Objectives

- To become familiar with basic JNI concepts.
- To create simple JNI applications.
- To convert C++ and JNI types.
- To learn how to interact with Java objects natively.
- To learn native exception handling.



## Outline

- G.1 Introduction
- G.2 Getting Started with Java Native Interface
- G.3 Accessing Java Methods and Objects from Native Code
- G.4 JNI and Arrays
- G.5 Handling Exceptions with JNI
- G.6 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### G.1 Introduction

The *Java Native Interface (JNI)* allows programmers to access existing *libraries* written in other languages such as C and C++. JNI allows programmers to use Java without requiring that existing libraries be entirely rebuilt. JNI makes it possible for large companies to migrate to Java without sacrificing the resources required to port existing libraries to Java. JNI also provides the developer with access to system libraries—at the cost of portability. JNI can be useful in time-critical applications—programmers may write a piece of the application in assembly code and link this program with Java to provide better performance. In this appendix, we explain how to integrate Java with C++ libraries. We show how to call *native functions* stored in compiled libraries from Java, and how to access Java objects, methods and member variables from C++. This appendix assumes a familiarity with C or C++. Although the examples are written in C++, they can be converted to C with little effort. Throughout this appendix we refer to *native functions* as the routines written in C++ and *native methods* as the native declarations contained in Java. Native code can be defined as code which can be compiled down to a processor specific binary format.



#### Performance Tip G.1

Communication between Java and native code is slow, too many JNI calls will actually degrade performance.

### G.2 Getting Started with Java Native Interface

Enabling a Java program to call a native function requires several steps. A Java *wrapper class* is a class that either aggregates methods from disparate sources into a single class or encapsulates a complex API into simple method calls. In the wrapper classes presented in this appendix, we will define native methods that correspond to functions implemented in a C++ library. The **javah** utility generates header files that enable the Java program to invoke native methods. This utility is part of the J2SE SDK 1.3.1.

Class **JNIPrintWrapper** (Fig. G.1) is a wrapper class for a native method that prints a simple message to the standard output. It contains an example of the code required to load a *library*—the compiled code that will be accessed by the Java program (line 8). **System.loadLibrary** will search your library paths for a library with the given name. Generally, the library should be loaded in a **static** block. This ensures that the library is loaded before any native methods are called. If the library is not loaded before a native call, the program will exit with a **UnsatisfiedLinkError**. Line 12 declares method

**printMessage** with the keyword **native**, which indicates that the method is implemented in a native library, not in Java. Similar to an **abstract** method, **native** method definition is never provided in Java.

JNI needs specific header files to interact with native code. The JDK includes the tool **javah** to produce ANSI C header files for use with native C and C++ code. The command line indicates that **javah** should create *JNI header files*. You must run **javah** on each compiled Java class that contains a **native** method. Do not edit these headers—if you make a change to the wrapper class, run **javah** again on the compiled class to generate appropriate header files. The following command:

```
javah -jni JNIPrintWrapper
```

creates the **JNIPrintWrapper.h** header file. If **JNIPrintWrapper** were in a package named **utilities.native** the resulting file would be named **utilities\_native\_JNIPrintWrapper.h**. Note that the **-jni** option specifies that headers are produced for JNI.<sup>1</sup>

Header **JNIPrintWrapper** (Fig. G.2) is the header that **javah** creates for Java class **JNIPrintWrapper**. Line 2 includes **jni.h**, the header that contains *JNI helper functions* required for the C++ library to interact with the Java. JNI requires the use of C-style function identifiers, thus, the preprocessor commands on lines 7–9 ensure the native functions are compiled correctly. The comments on lines 10–14 represent information needed by JNI to use the methods. The signature (line 13) indicates the argument and the return types of the function. Lines 15–16 contain two platform specific **#defines**—**JNIEEXPORT** and **JNICALL**, each help handle JNI interactions with the C++ code for your system. The function name consists of **Java\_calling\_class\_methodname**. Function **printMessage** takes three arguments. The first argument, of type **JNIEnv** is a pointer to a table of functions that assist the native code's interaction with Java. **JNIEnv** is always passed as the first argument to a JNI function. In this appendix, **JNIEnv** variables are accessed using C++. In C++ a **JNIEnv\*** pointer would be accessed like an object:

```
env->functionName(args)

1 // Fig. G.1 JNIPrintWrapper.java
2 // Allows access to native methods
3
4 public class JNIPrintWrapper {
5
6     // load library JNIPrintLibrary into JVM
7     static {
8         System.loadLibrary( "JNIPrintLibrary" );
9     }
10
11     // native C++ method
12     public native void printMessage( String message );
13 }
```

Fig. G.1 **JNIPrintWrapper** loads a library and declares a **native** method.

1. JNI was introduced in JDK 1.1—before that developers used a more cumbersome native interface, the headers for this older style may be generated with the **-stubs** option.

```

1  /* DO NOT EDIT THIS FILE - it is machine generated */
2  #include <jni.h>
3  /* Header for class JNIPrintWrapper */
4
5  #ifndef _Included_JNIPrintWrapper
6  #define _Included_JNIPrintWrapper
7  #ifdef __cplusplus
8  extern "C" {
9  #endif
10 /* 
11  * Class:     JNIPrintWrapper
12  * Method:    printMessage
13  * Signature: (Ljava/lang/String;)V
14  */
15 JNIEXPORT void JNICALL Java_JNIPrintWrapper_printMessage
16   (JNIEnv *, jobject, jstring);
17
18 #ifdef __cplusplus
19 }
20 #endif
21 #endif

```

Fig. G.2 `JNIPrintWrapper.h` header file generated by `javah`.

In C, it would be accessed using the syntax:

```
(*env) ->functionName(env, args)
```

The second argument sent to `printMessage` is a reference to the Java object that called this native function. Any arguments that follow are the values passed to the function from the Java code.

Before using this header you must make sure that your compiler or IDE knows where to look for `jni.h` and the `#defines`. They are located in the following directories:

```
JDK directory\include\
JDK directory\include\your platform\
```

Java primitive types and object types do not map directly to those used in C/C++. To pass these types between languages, JNI includes a predefined set of types. All Java objects are passed as `jobjects`, all `Strings` are passed as `jstrings`, and primitives are passed as `jtype` (e.g., `jint` and `jdouble`). Conversion between C/C++ and JNI primitive types is handled transparently. However, working with `jobjects`, including arrays is more complicated.

The implementation of the `javah` header (Fig. G.3) `JNIPrintWrapper-Impl.cpp` converts a `jstring` into a `char *` and uses C++ to output the string. Java uses *Unicode* (see Appendix I) to represent its characters, however C++ uses an *ANSI* format (Latin-1). Consequently, a direct assignment is not possible. Unicode may be converted into an ANSI comparable format called *UTF-8*, which C++ supports. JNI performs conversion with the function `GetStringUTFChars`, which returns a pointer to the string in UTF-8 format. JNI sets `jboolean` variable `copied` to `JNI_TRUE` if the string passed

```

1 // Fig. G.3 JNIPrintWrapperImpl.cpp
2 // Implements the header created by Java
3 // to integrate with JNI.
4
5 // C++ core header
6 #include <iostream.h>
7
8 // header produced by javah
9 #include "JNIPrintWrapper.h"
10
11 // prints string provided by Java application
12 JNIEXPORT void JNICALL Java_JNIPrintWrapper_printMessage
13     ( JNIEnv * env, jobject thisObject, jstring message )
14 {
15     // boolean to determine if string is copied
16     jboolean copied;
17
18     // call JNI method to convert jstring to cstring
19     const char* charMessage =
20         env->GetStringUTFChars( message, &copied );
21
22     // print message
23     cout << charMessage;
24
25     // release string to prevent memory leak
26     env->ReleaseStringUTFChars( message, charMessage );
27 }
```

**Fig. G.3** `JNIPrintWrapperImpl.cpp` implements the `javah` header to print a message.

is a copy of the Java string and `JNI_FALSE` if it is a pointer to the original string. We discuss the differences between a values vs. a reference to a string or array in Section G.4. In either case the returned string should be assigned to a `char *`. After displaying the string release the memory used by the UTF-8 string. If the string is not released it will result in a memory leak. Releasing the string requires a call to `ReleaseStringUTFChars`, with the `jstring` and `char *` as arguments.

After creating the library and the wrapper class the native code must be loaded into the the Java JVM. On Win32 platforms, libraries have the extension `.dll`. To avoid a Java `UnsatisfiedLinkError` the path to the library must be set with this command:

```
set PATH=%PATH%;library path
```

On Solaris, with `csh`, the library must be named `liblibraryname.so` and the library path is set with:

```
setenv LD_LIBRARY_PATH $LD_LIBRARY_PATH:library path
```

Class `JNIPrintMain` (Fig. G.4) demonstrates the main class of the JNI application. The body of the `main` method (lines 14–17) demonstrates the benefit of the wrapper class. Within the main Java application, native calls written in the same manner as other method calls.

```

1 // Fig. G.4 JNIPrintMain.java
2 // Creates a new instance of the Java wrapper class,
3 // and calls the native methods.
4
5 public class JNIPrintMain{
6
7     // uses JNI to print a message
8     public static void main( String args[] )
9     {
10         JNIPrintWrapper wrapper = new JNIPrintWrapper();
11
12         // call to native methods through JNIWrapper
13         wrapper.printMessage( "Welcome to JNI!\n" );
14     }
15 }
```

Welcome to JNI!

Fig. G.4 **JNIPrintMain** calls the **native** method via the wrapper class.

### G.3 Accessing Java Methods and Objects from Native Code

JNI can do far more with native code than just sending and receiving arguments. You may access Java methods directly from the native library, create new Java objects and even create a new instance of the JVM. This section includes demonstrations of method calling, object creation and array handling, directly from native code.

Class **JNIMethodWrapper** (Fig. G.5) behaves similarly to the previous wrapper class, except that it contains two methods. In the first native function we will call a method on the **PIContainer** class passed to the function (line 12). In the second method, we do not pass an instance of **PIContainer**, it is created in native code (line 13).

```

1 // Fig. G.5 JNIPILWrapper.java
2 // Allows for access to native function.
3
4 public class JNIPILWrapper {
5
6     // load JNIPILibrary into JVM
7     static {
8         System.loadLibrary( "JNIPILibrary" );
9     }
10
11    // native c++ methods
12    public native double getPI( PIContainer container );
13    public native double getPI();
14 }
```

Fig. G.5 **JNIPILWrapper** encapsulates the **native** methods and loads the library.

Class **PIContainer** (Fig. G.6) contains method **getPI** that returns the value of the constant **PI**. The native code uses **PIContainer** to demonstrate the construction of Java objects and the invocation of methods.

**JNIPIMethodWrapper.h** (Fig. G.7) is the **javah**-generated header for our library, which includes the return type **jdouble** (line 15).

```
1 // Fig. G.6 PIContainer.java
2 // Contains one method, retrieves Math.PI.
3
4 public class PIContainer {
5
6     // return java.lang.Math PI member variable
7     public double getPI()
8     {
9         return Math.PI;
10    }
11 }
```

Fig. G.6 **PIContainer** returns the **PI** member of **java.lang.Math**.

```
1 /* DO NOT EDIT THIS FILE - it is machine generated */
2 #include <jni.h>
3 /* Header for class JNIPIMethodWrapper */
4
5 #ifndef _Included_JNIPIMethodWrapper
6 #define _Included_JNIPIMethodWrapper
7 #ifdef __cplusplus
8 extern "C" {
9 #endif
10 /*
11  * Class:      JNIPIMethodWrapper
12  * Method:    getPI
13  * Signature: ()D
14  */
15 JNIEXPORT jdouble JNICALL Java_JNIPIMethodWrapper_getPI_
16     (JNIEnv *, jobject);
17
18 /*
19  * Class:      JNIPIMethodWrapper
20  * Method:    getPI
21  * Signature: (LPIContainer;)D
22  */
23 JNIEXPORT jdouble JNICALL Java_JNIPIMethodWrapper_getPI__LPIContainer_2
24     (JNIEnv *, jobject, jobject);
25
26 #ifdef __cplusplus
27 }
28 #endif
29 #endif
```

Fig. G.7 **JNIPIMethodWrapper.h** is the **javah** generated header file for the **native** functions.

C++ file **JNIPILoggerImpl.cpp** (Fig. G.8) uses JNI to create and invoke **native** methods and objects. Lines 16–22 demonstrate invoking a method on an object that has already been created. **GetObjectClass** in line 16 takes an argument of type **jobject** and returns the **jclass** to which it belongs. The argument in this case is the **jobject** passed by the calling method.

```
1 // Fig. G.8 JNIPILoggerImpl.cpp
2 // Calls methods on the PIContainer object sent to it.
3 // Creates new Java objects.
4
5 // standard c header
6 #include <iostream.h>
7
8 // header produced by javah
9 #include "JNIPILogger.h"
10
11 // retrieves value of PI based on passed PIContainer
12 JNIEXPORT jdouble JNICALL Java_JNIPILogger_getPI__LPIContainer_2
13 (JNIEnv * env, jobject thisObject, jobject containerObject)
14 {
15     // retrieve PIContainer class
16     jclass PIClass = env->GetObjectClass( containerObject );
17
18     // retrieve method ID of getPI
19     jmethodID mid = env->GetMethodID( PIClass, "getPI", "()D" );
20
21     // call method getPI of class PIContainer with no arguments
22     jdouble PI = env->CallDoubleMethod( containerObject, mid, NULL );
23
24     return PI;
25 }
26
27 // retrieves value of PI by creating new PIContainer
28 JNIEXPORT jdouble JNICALL Java_JNIPILogger_getPI__
29 ( JNIEnv * env, jobject thisObject ) {
30
31     // finds Class PIContainer
32     jclass PIClass = env->FindClass( "PIContainer" );
33
34     // retrieves ID of constructor
35     jmethodID constructorID =
36         env->GetMethodID( PIClass, "<init>", "()V" );
37
38     // creates new PIContainer
39     jobject newContainer =
40         env->NewObject( PIClass, constructorID, NULL );
41
42     // retrieves method ID of getPI
43     jmethodID mid = env->GetMethodID( PIClass, "getPI", "()D" );
44 }
```

Fig. G.8 **JNIPILoggerImpl.cpp** demonstrates method calls and object construction (part 1 of 2).

```

45     // call method getPI of class PIContainer with no arguments
46     jdouble PI = env->CallDoubleMethod( newContainer, mid, NULL );
47
48     return PI;
49 }

```

Fig. G.8 `JNIPIDWrapperImpl.cpp` demonstrates method calls and object construction (part 2 of 2).

Function `GetMethodID` (line 19) requires a `jclass` object to determine the method's `jmethodID`. A *method ID* is a unique ID created and associated with each class method. Function `GetMethodID` also requires the name of a method within the `jclass` object and a signature string specifying the arguments and return type of that method. If the specified method cannot be found, the method ID returned is zero. The signature must be in the format:

```
( <argument types> ) <return type>
```

Primitive types are usually specified by their uppercase first letter (e.g., `D` for `double`, `I` for `int` and `V` for `void`). Exceptions to this rule are `J` for `long` and `Z` for `boolean`. Object types must be prefixed by `L` followed by the class, including packages and terminated by a semicolon. For example, `Ljava/lang/String;` specifies the `String` type. Including an open bracket (`[`) before a signature indicates an array, `( [D] V` represents a method that requires an array of `double`s and returns `void`. The full listing of type mappings is shown in Fig. G.9.

Line 22 calls the function `CallDoubleMethod` to invoke the Java method `getPI`. Methods can be called with `CalltypeMethod`, where *type* represents the return type. `CallObjectMethod` can be called for any Java object. The first argument is a reference to the object containing the method, the second contains the method ID and any additional arguments are parameters to send to the method.

Type	Signature
<code>byte</code>	<code>B</code>
<code>char</code>	<code>C</code>
<code>double</code>	<code>D</code>
<code>float</code>	<code>F</code>
<code>int</code>	<code>I</code>
<code>long</code>	<code>J</code>
<code>short</code>	<code>S</code>
<code>void</code>	<code>V</code>
<code>boolean</code>	<code>Z</code>
<code>class</code>	<code>Lfull/class/name;</code>
<code>array of type</code>	<code>[type</code>

Fig. G.9 Signature type mappings.

The second function, lines 28–49 creates a new **PIContainer**, then retrieves its value of **PI**. Line 32 demonstrates the use of JNI function **FindClass**, which returns a reference to any fully qualified class name. If you do not have an object instance, call function **FindClass** from native code to retrieve the **jclass** object. After obtaining the class, a new instance must be created. The first step is to obtain the method ID of **<init>**, the method name used in JNI to signify a constructor. The method ID, along with the class, and any constructor arguments must be used in the **NewObject** function to create a new object of that class (line 40).

Class **JNIPIMain** (Fig. G.10) uses the wrapper class to retrieve **PI**. It creates a new instance of **PIContainer** (line 12) for native use. The class displays the retrieved **PI** value to demonstrate correct return value. Method **getPI** is then called again without passing any arguments.

Next, we will demonstrate how to call **static** methods. An instance of a **static** member cannot be obtained—thus the **jobject** which refers to an instance of an object cannot be used. The **static** JNI functions require the **jclass** of the object, which simply represents the class and contains any **static** members.

Class **JNISStaticWrapper** (Fig. G.11) is the wrapper class for gaining access to **static** methods and variables. The **native** method in this class will receive **static** variables from class **MathConstants**.

Class **MathConstants** (Fig. G.12) is a container class for the member variables of class **Math**. **MathConstants** methods and variables will be accessed from native code.

**JNISStaticWrapper.h** (Fig. G.13) is the **javah** generated header file. The signature on line 12 specifies that the method must take an argument of type **MathConstants**.

```

1 // Fig. G.10 JNIPIMain.java
2 // Loads the native library, creates a new instance of the
3 // Java wrapper class and uses native code to call getPI.
4
5 public class JNIPIMain {
6
7     public static void main( String args[] )
8     {
9         JNIPIMWrapper wrapper = new JNIPIMWrapper();
10
11         // native code retrieves PI from instance of PIContainer
12         double pi = wrapper.getPI( new PIContainer() );
13         System.out.println( "PI is " + pi );
14
15         // native code retrieves PI, creates its own PIContainer
16         double pi2 = wrapper.getPI();
17         System.out.println( "PI2 is " + pi2 );
18     }
19 }
```

```

PI is 3.141592653589793
PI2 is 3.141592653589793
```

Fig. G.10 **JNIPIMain** calls each **native** method via the wrapper class.

---

```

1 // Fig. G.11 JNIStaticWrapper.java
2 // Allows access to native printStaticMembers function.
3
4 public class JNIStaticWrapper {
5
6     // load library JNIMathLibrary into JVM
7     static {
8         System.loadLibrary( "JNIMathLibrary" );
9     }
10
11     // native C++ method
12     public native void printStaticMembers( MathConstants constants );
13
14 }
```

---

Fig. G.11 `JNIStaticWrapper` loads `JNIMathLibrary` and declares native method `printStaticMembers`.

---

```

1 // Fig. G.12 MathConstants.java
2 // Contains static member variables
3 // and methods for native retrieval.
4
5 // container class containing static math constants
6 public class MathConstants {
7
8     public static final double PI = Math.PI;
9     public final double E = Math.E;
10
11    public static double getPI()
12    {
13        return PI;
14    }
15 }
```

---

Fig. G.12 `MathConstants` contains common math constants from `Math`.

---

```

1 /* DO NOT EDIT THIS FILE - it is machine generated */
2 #include <jni.h>
3 /* Header for class JNIStaticWrapper */
4 #ifndef _Included_JNIStaticWrapper
5 #define _Included_JNIStaticWrapper
6 #ifdef __cplusplus
7 extern "C" {
8 #endif
9 /*
10  * Class:      JNIStaticWrapper
11  * Method:    printStaticMembers
12  * Signature: (LMathConstants;)V
13  */
14 JNIEXPORT void JNICALL Java_JNIStaticWrapper_printStaticMembers
15 (JNIEnv *, jobject, jobject);
```

---

Fig. G.13 `JNIStaticWrapper.h` `javah` generated header file (part 1 of 2).

```

16
17 #ifdef __cplusplus
18 }
19 #endif
20 #endif

```

Fig. G.13 `JNIStraticWrapper.h` `javah` generated header file (part 2 of 2).

`JNIStraticWrapperImpl.cpp` (Fig. G.14) demonstrates native calls to `static` and non-static members from native code. Accessing member variables follows the JNI format—obtain the `jclass`, get the member ID and access the member. Lines 19–25 show these steps to access a `static` variable. `GetFieldID` obtains the `jfieldID` of the variable you wish to access. A `jfieldID` is the unique ID of a variable field within an object. The `jfieldID` can be used to locate a member variable the same way a `jmethodID` can locate a method. You must specify the class, the variable name and the *field signature*. Field signatures correspond to method signatures—however, only a single type must be specified. `GettypeField` returns the non-static member contained within the given object instance that matches the given `jfieldID`. To obtain the `jfieldID` of a `static` member requires a call to `GetStaticFieldID` and requires the same arguments as a call to a non-static field (line 30). Retrieving the field requires a call to `GetStatictypeField`, and passes `jclass` as the first argument (line 31–32). To set member fields call `SettypeField`, with a `jobject` instance, the `fieldID` and a value of `type` as arguments. Setting `static` fields requires a call to `SetStatictypeField` with the `jclass` as the first argument. Invoking `static` methods uses the same technique: specify `GetStaticMethodID`, and call `CallStatictypeMethod` with the `jclass` as an argument.

```

1 // Fig. G.14 JNIStraticWrapperImpl.cpp
2 // Integrates with JNI to retrieve the static
3 // members of the given MathConstant object.
4
5 // C++ header
6 #include <iostream.h>
7
8 // header produced by javah
9 #include "JNIStraticWrapper.h"
10
11 JNIEXPORT void JNICALL Java_JNIStraticWrapper_printStaticMembers
12     ( JNIEnv * env, jobject thisObject, jobject MathObject )
13 {
14     jclass constantClass;
15     jfieldID fieldID;
16     jmethodID methodID;
17
18     // get class MathObject
19     constantClass = env->GetObjectClass( MathObject );
20

```

Fig. G.14 `JNIStraticWrapperImpl` accesses and prints `static` members of the given `MathConstants` class (part 1 of 2).

```

21 // retrieve FieldID of static member variable E
22 fieldID = env->GetFieldID( constantClass, "E", "D" );
23
24 // retrieves double at given fieldID
25 const jdouble E = env->GetDoubleField( MathObject, fieldID );
26
27 // output to show proper retrieval
28 cout << "Value of E in MathConstants is " << E << endl;
29
30 fieldID = env->GetStaticFieldID( constantClass, "PI", "D" );
31 const jdouble PI = env->GetStaticDoubleField( constantClass,
32 fieldID );
33
34 cout << "Value of PI in MathConstants is " << PI << endl;
35
36 // retrieve static method id
37 methodID = env->GetStaticMethodID(
38     constantClass, "getPI", "()D" );
39
40 // invoke static method getPI
41 env->CallStaticDoubleMethod( constantClass, methodID );
42 }

```

**Fig. G.14** `JNIStaticWrapperImpl` accesses and prints `static` members of the given `MathConstants` class (part 2 of 2).

Class `JNIStaticMain` (Fig. G.15) is the main class for this example, it loads the library, creates the wrapper and calls the `native` method.

```

1 // Fig. G.15 JNIStaticMain.java
2 // creates a new instance of the Java wrapper class and calls to
3 // print the static members of the MathConstants class.
4
5 public class JNIStaticMain {
6
7     public static void main( String args[] )
8     {
9         JNIStaticWrapper wrapper = new JNIStaticWrapper();
10
11         // access static members from MathConstants
12         wrapper.printStaticMembers( new MathConstants() );
13     }
14 }

```

```

Value of E in MathConstants is 2.71828
Value of PI in MathConstants is 3.14159

```

**Fig. G.15** `JNIStaticMain` prints `static` math constants via the wrapper class.

## G.4 JNI and Arrays

Converting arrays from Java to native code is complex because, as opposed to native languages, elements in Java arrays are not always placed together in contiguous memory. Thus, when a native function requires access to an array created in Java, JNI must organize the array correctly, then it must ensure the array is returned back to Java when the **native** function completes.

**JNIArraWapper** (Fig. G.16) contains functionality to print the array returned by a native function. Method **newRandomArray** creates an array of random integers of length **size**.

**JNIArraWapper.h** (Fig. G.17) declares the function with a return type of **jin-tarray**, which is an array of integers. The *suffix Array* is added to any JNI type to specify a Java array.

```

1 // Fig. G.16 JNIArraWapper.java
2 // Allows access to native methods.
3
4 public class JNIArraWapper {
5
6     // load library JNIArraLibrary into JVM
7     static {
8         System.loadLibrary( "JNIArraLibrary" );
9     }
10
11    // native C++ method
12    public native int[] newRandomArray( int size );
13
14    // Java method that calls native method
15    public void outputRandomNumbers( int amount )
16    {
17        int randomNumbers[] = newRandomArray( amount );
18
19        for ( int i = 0 ; i < amount ; i++ )
20            System.out.println( randomNumbers[ i ] +
21                " random number " + i );
22    }
23 }
```

Fig. G.16 **JNIArraWapper** loads **JNIArraLibrary** and displays the numbers in the returned array.

```

1 /* DO NOT EDIT THIS FILE - it is machine generated */
2 #include <jni.h>
3 /* Header for class JNIArraWapper */
4
5 #ifndef _Included_JNIArraWapper
6 #define _Included_JNIArraWapper
7 #ifdef __cplusplus
8 extern "C" {
9 #endif
```

Fig. G.17 **JNIArraWapper.h** **javah** generated header file (part 1 of 2).

```

10  /*
11   * Class:      JNIArrayWrapper
12   * Method:    newRandomArray
13   * Signature: (I)[I
14   */
15 JNIEXPORT jintArray JNICALL Java_JNIArrayWrapper_newRandomArray
16  (JNIEnv *, jobject, jint);
17
18 #ifdef __cplusplus
19 }
20#endif
21#endif

```

Fig. G.17 `JNIArrayWrapper.h` `javah` generated header file (part 2 of 2).

C++ file `JNIArrayWrapperImpl.cpp` (Fig. G.18) creates two arrays, one of primitive type `jintArray`, and the other a `jobject` array containing `Integer` objects. Lines 29–30 create a new instance of class `Integer`. Line 33 invokes JNI function `NewObjectArray` to create the `Integer` array. Function `NewObjectArray` takes as arguments the array size, the array type and the initial value for each array element. Creating a primitive integer array works similarly; however, function `NewIntArray` requires one argument, the size, which is the size of the array. Each of these functions builds a Java array. Accordingly, the elements may or may not be created contiguously in memory. To obtain access to individual elements of a primitive array within native code requires a call to `GetPrimitiveArrayElements`, with the `jtypeArray` and a `jboolean` as arguments. The `jboolean` `isCopy` is passed by reference (line 40), and is set by the function to either `JNI_TRUE` or `JNI_FALSE`. If the array is laid out in contiguous memory the resulting `jboolean` has the value `JNI_FALSE` which indicates that the native code has direct access to the array. However, `JNI_TRUE` indicates that a copy of the array was created. If we have received a copy, we must be careful to release the memory, and be sure the array is updated in Java. Lines 61–63 determine how the array was received, if it is a copy it is released with the call `ReleasePrimitiveArrayElements`. Releasing an array requires passing the array, our pointer to the array, and the way it is to be released. We set the final argument to `0` in line 62—this tells JNI to release the memory and update the original array in Java. Other options include `JNI_ABORT` which frees the memory but not update Java and `JNI_COMMIT` which will update Java but does not release the memory. Currently there is no documentation on how to release the memory manually, thus `JNI_COMMIT` is not recommended.

```

1 // Fig. G.18 JNIArrayWrapperImpl.cpp
2 // Implements the header created by java
3 // to integrate with JNI. Creates a new array
4 // of random integers and returns it to java.
5
6 // C++ core header
7 #include <stdlib.h>
8 #include <time.h>

```

Fig. G.18 `JNIArrayWrapperImpl.cpp` demonstrates primitive and `Object` array creation and control (part 1 of 3).

```
9
10 // header produced by javah
11 #include "JNIArrayWrapper.h"
12
13 // creates and fills two arrays
14 JNIEXPORT jintArray JNICALL Java_JNIArrayWrapper_newRandomArray
15     ( JNIEnv * env, jobject thisObject, jint size )
16 {
17     // boolean to determine if elements are copied
18     jboolean isCopy;
19     jclass integerClass;
20     jobjectArray objectArray;
21     jobject randomIntegerObject;
22     jmethodID mid;
23     int randomInt;
24
25     // seed rand function with time
26     srand( time( NULL ) );
27
28     // locate object and constructor
29     integerClass = env->FindClass( "java/lang/Integer" );
30     mid = env->GetMethodID( integerClass, "<init>", "(I)V" );
31
32     // build new Integer array of length size
33     objectArray = env->NewObjectArray( size, integerClass, NULL );
34
35     // create new primitive int array
36     jintArray intArray = env->NewIntArray( size );
37
38     // return pointer to array of elements
39     jint * intArrayPointer =
40         env->GetIntArrayElements( intArray, &isCopy );
41
42     // fill arrays with random numbers
43     for ( int i = 0 ; i < size ; i++ ) {
44
45         // create random int
46         randomInt = rand() % 100;
47
48         // create Integer containing random int
49         randomIntegerObject =
50             env->NewObject( integerClass, mid, randomInt );
51
52         // add element to Integer array
53         env->SetObjectArrayElement(
54             objectArray, i, randomIntegerObject );
55
56         // assign random int to primitive array
57         intArrayPointer[ i ] = randomInt;
58     }
59 }
```

Fig. G.18 **JNIArrayWrapperImpl.cpp** demonstrates primitive and **Object** array creation and control (part 2 of 3).

```

60     // if JNI made a copy, release it and update Java
61     if ( isCopy == JNI_TRUE )
62         env->ReleaseIntArrayElements( intArray, intArrayPointer, 0 );
63
64     return intArray;
65 }

```

Fig. G.18 **JNIArrayWrapperImpl.cpp** demonstrates primitive and **Object** array creation and control (part 3 of 3).

Lines 39–54 populate both arrays with a set of random numbers. Function **NewObject** creates a new **Integer** object. However, unlike a primitive type, we do not have a handle to the array in a format that C++ can use. We cannot directly convert a Java object into a C++ object, thus we must access it in the Java memory space through JNI. JNI includes the functions **SetObjectArrayElement** (line 49) and **GetObjectArrayElement** to provide access to an object array. The first argument is the array of objects, the third is the object to add to the array, and the second is the index at which to place the object in the array. There is no need to release object arrays, they are never copied from the JVM’s memory space, thus Java’s built-in garbage collector will manage the object memory allocation.

**JNIArrayMain** (Fig. G.19) is similar to the other main classes, it instantiates a wrapper object and calls the **native** method (line 19).

```

1 // JNIArrayMain.java
2 // Loads the native library, creates a new instance of the
3 // Java wrapper class, and calls for it to print 10 random
4 // numbers.
5
6 public class JNIArrayMain {
7
8     // instantiate JNIArrayWrapper and call outputRandomNumbers
9     public static void main( String args[] )
10    {
11        JNIArrayWrapper wrapper = new JNIArrayWrapper();
12
13        // outputs ten random numbers
14        wrapper.outputRandomNumbers( 10 );
15    }
16 }

41 random number 0
67 random number 1
34 random number 2
0 random number 3
69 random number 4
24 random number 5
78 random number 6

```

(continued on next page)

Fig. G.19 **JNIArray** loads library and calls **JNIArrayWrapper** to print 10 numbers (part 1 of 2).

(continued from previous page)

```

58 random number 7
62 random number 8
64 random number 9

```

Fig. G.19 **JNIArra** loads library and calls **JNIArra** to print 10 numbers (part 2 of 2).

## G.5 Handling Exceptions with JNI

Handling exceptions natively can be essential when integrating native code with Java. JNI allows **native** functions to catch exceptions themselves, or to throw exceptions back to Java. The example in this section uses JNI to do image processing. A resource intensive task such as image processing might gain performance via JNI. However, in our demonstration on exception handling we use of several JNI calls, which significantly reduces performance.

The application calls method **ImageSizeException** (Fig. G.20) if there is an attempt to process an image that is too large.

The application calls exception **PixelTintException** (Fig. G.21) if the parameters entered for color tinting would increase the color value over an allowable value—255.

```

1 // Fig. G.20 ImageSizeException.java
2 // thrown when the image to be processed is too large.
3
4 public class ImageSizeException extends Exception {
5
6     // calls parent constructor
7     public ImageSizeException( String message )
8     {
9         super( message );
10    }
11 }

```

Fig. G.20 **ImageSizeException** used when image is too large.

```

1 // Fig. G.21 PixelTintException.java
2 // extends exception, called when a pixel cannot be fully tinted.
3
4 public class PixelTintException extends Exception {
5
6     // calls parent constructor
7     public PixelTintException( String message )
8     {
9         super( message );
10    }
11 }

```

Fig. G.21 **PixelTintException** is used for invalid pixel tint values.

Class **JNITintWrapper** (Fig. G.22) calls the **loadLibrary** method to load the native library **JNITint** (line 8). It also declares the **native** method **tintImage**. This method takes an array of RGB color values and tint the color based on **rTint**, **gTint** and **bTint** (lines 12–14). This method throws an **ImageSizeException**, which ensures that the exception declared in the native code is handled by Java.



### Good Programming Practice G.1

*Specify the exceptions a native call throws in the wrapper class, this ensures that all calls catch these exceptions.*

Header file **JNITintWrapper.h** (Fig. G.23) contains the JNI function declaration for **tintImage**. The arguments passed are the JNI environment pointer, a reference to the calling object, the RGB color array, the length of the array, the red tint, green tint and blue tint.

```

1 // Fig. G.22 JNITintWrapper.java
2 // loads library JNITint and wraps the native tintImage function.
3
4 public class JNITintWrapper {
5
6     // load library JNITint into JVM
7     static {
8         System.loadLibrary( "JNITint" );
9     }
10
11    // tints image based on tint values
12    public native int[] tintImage(
13        int[] image, int length, int rTint, int gTint, int bTint )
14        throws ImageSizeException;
15 }
```

Fig. G.22 **JNITintWrapper** loads the native library and wraps the **native** function.

```

1 /* DO NOT EDIT THIS FILE - it is machine generated */
2 #include <jni.h>
3 /* Header for class JNITintWrapper */
4
5 #ifndef _Included_JNITintWrapper
6 #define _Included_JNITintWrapper
7 #ifdef __cplusplus
8 extern "C" {
9 #endif
10 /*
11  * Class:      JNITintWrapper
12  * Method:     tintImage
13  * Signature:  ([IIIII) [I
14  */
15 JNIEXPORT jintArray JNICALL Java_JNITintWrapper_tintImage
16     (JNIEnv *, jobject, jintArray, jint, jint, jint, jint);
17
```

Fig. G.23 **JNITintWrapper.h** javah generated JNI header file (part 1 of 2).

```

18 #ifdef __cplusplus
19 }
20 #endif
21 #endif

```

Fig. G.23 `JNITintWrapper.h` `javah` generated JNI header file (part 2 of 2).

`JNITintImage.cpp` contains function `tintImage`, which separates the color values from the `int` array and increases each by the tint amount to provide a tinting effect (Fig. G.24). This is not the only, or most accurate method of tinting, but it is simple. Line 7 defines `MAX_IMAGE_SIZE` as `65536`, the value of a  $256 \times 256$  pixel image. Lines 18–28 check the size of the image, and throw an exception if it is too large. Line 21 assigns the `jclass` of `ImageSizeException` to `sizeException` with the `FindClass` function. Function `ThrowNew` throws an exception of the provided `jclass` type, with the given message. After throwing an exception, `tintImage` exits (line 27), any thrown exception declared in native code will be handled in Java if it is not cleared. Lines 52–106 contain the color tinting code. The ARGB integers passed to this function are in sRGB format. This 32 bit format allocates 8 bits for each element, Alpha (transparency), red, green then blue, in that order. We use bit masking to separate the colors from the combined integer (line 54–61). Then, we shift the bits of the tint values to match the color location. The colors are incremented by the tint values to produce a tinting effect. (lines 63–65).



### Common Programming Error G.1

*When an exception has been thrown, do not make any JNI function calls, except those that deal with exceptions, until the flag has been cleared. Further calls may lead to unpredictable results, including crashing the JVM. Check for any exception that can be fixed natively, clear the exception, then fix it.*

```

1 // Fig. G.24 JNITintImage.cpp
2 // tints an array of RGB values by given colors. Throws
3 // exception if image is larger than 256x256, also returns an
4 // int array of indexes of pixels that could not be fully tinted.
5
6 // max image size is 256x256
7 #define MAX_IMAGE_SIZE 65536
8
9 // include JNI header
10 #include "JNITintWrapper.h"
11
12 JNIEXPORT jintArray JNICALL Java_JNITintWrapper_tintImage
13     ( JNIEnv * env, jobject thisObject, jintArray imagerGB,
14       jint length, jint rTint, jint gTint, jint bTint ) {
15
16     jclass sizeException, pixelTintException;
17
18     if ( length > MAX_IMAGE_SIZE ) {
19

```

Fig. G.24 `JNITintImages.cpp` tints an array of sRGB color values to demonstrate exception handling (part 1 of 4).

```
20     // obtain jclass ImageSizeException
21     sizeException = env->FindClass( "ImageSizeException" );
22
23     // throw exception
24     env->ThrowNew( sizeException, "Image is too large" );
25
26     // return and allow Java to handle the exception
27     return NULL;
28 }
29
30 // obtain jclass of PixelTintException for use later
31 pixelTintException = env->FindClass( "PixelTintException" );
32
33 jthrowable exception;
34 int warningCount = 0;
35 jboolean isCopy, isCopy1;
36 unsigned int red, blue, green;
37
38 // create new array of size length
39 jintArray warningArray = env->NewIntArray( length );
40
41 // obtain pointer to the array object
42 jint * warningArrayPointer =
43     env->GetIntArrayElements( warningArray, &isCopy );
44
45 // storage location for RGB array elements
46 long* elements;
47
48 // points elements to the integer array
49 elements = env->GetIntArrayElements( imageRGB, &isCopy1 );
50
51
52 for ( int i = 0; i < length; i++ ) {
53
54     // determine red element by masking
55     red = elements[ i ] & 0xFF0000;
56
57     // determine green element by masking
58     green = elements[ i ] & 0xFF00;
59
60     // determine blue element by masking
61     blue = elements[ i ] & 0xFF;
62
63     red += rTint << 16;
64     green += gTint << 8;
65     blue += bTint;
66
67     // throw exception if red value is too large
68     if ( red > 0xFFFF0000 ) {
69         env->ThrowNew(
70             pixelTintException, "red value reduced to 255" );
```

Fig. G.24 **JNITintImages.cpp** tints an array of sRGB color values to demonstrate exception handling (part 2 of 4).

```
71             red = 0xFF0000;
72         }
73         // throw exception if green value is too large
74         if ( green > 0xFF00 ) {
75             env->ThrowNew(
76                 pixelTintException, "green value reduced to 255");
77             green = 0xFF00;
78         }
79         // throw exception if blue value is too large
80         if ( blue > 0xFF ) {
81             env->ThrowNew(
82                 pixelTintException, "blue value reduced to 255" );
83             blue = 0xFF;
84         }
85
86         // if an exception occurs store it in exception
87         if ( ( exception = env->ExceptionOccurred() ) != NULL ) {
88
89             // if exception was of type pixelTintException record
90             // the index in an array and clear the exception
91             if ( env->IsInstanceOf(
92                 exception, pixelTintException ) == JNI_TRUE ) {
93                 warningArrayPointer[ warningCount ] = i;
94                 warningCount++;
95                 env->ExceptionClear();
96             }
97
98             // else we do not know the exception type, return.
99             else
100                 return warningArray;
101         }
102
103         // shift bits to recreate pixel
104         elements[ i ] =
105             0xFF000000 | red | green | blue;
106     }
107
108     // if first array is copy, release it
109     if ( isCopy )
110         env->ReleaseIntArrayElements( warningArray,
111             warningArrayPointer, 0 );
112
113     // if second array is copy, release it
114     if ( isCopy1 )
115         env->ReleaseIntArrayElements( imageRGB, elements, 0 );
116
117     if ( warningCount != 0 )
118
119         // return any warnings
120         return warningArray;
```

Fig. G.24 **JNITintImages.cpp** tints an array of sRGB color values to demonstrate exception handling (part 3 of 4).

```
121     else
122         // no warnings
123         return NULL;
124     }
125 }
```

Fig. G.24 **JNITintImages.cpp** tints an array of sRGB color values to demonstrate exception handling (part 4 of 4).

After tinting the values it is possible for a color value to be larger than 255. In this example, we wish to record all pixels that could not be fully tinted. Thus for each value over 255 we throw an exception, and reset the value to 255 (lines 68–84). These exceptions are used as warnings. We do not want the program to terminate when it returns to Java code, to avoid this we clear the exception. To determine if an exception has been thrown, we call JNI function **ExceptionOccurred**. This function returns a **jthrowable** instance of the exception or **JNI\_NULL** if an exception was not thrown. We check for the exception (line 87) and then determine the type of the exception using JNI function **IsInstanceOf**, which returns **JNI\_TRUE** if the first argument is an instance of the second argument. After determining the type of exception (lines 91–92), we store the current index and make a call to JNI function **ExceptionClear** which clears any thrown exceptions. If possible, you should clear the exception before making JNI calls. Many JNI function calls will crash the JVM if an exception has been thrown.

If the exception does not match our defined exception types, the native function is exited and control returns to Java, where the exception will be handled (lines 99–100). After setting the colors we rebuild the color value by using the **or** operator (lines 104–105). Then, we determine if any of arrays that we have been manipulating are copies, if so we release them back to the Java memory space (lines 109–115). Finally, we return the warning array if it is not empty (lines 117–124).

Class **JNIPanel** extends **JPanel** to provide a display surface for our images (Fig. G.25). The constructor initializes the panels, buttons and sliders in lines 26–91. It loads the image with the **Toolkit** method **getImage**, then uses a **MediaTracker** object to ensure the image is completely loaded before continuing (lines 93–106). We then create a **BufferedImage** with the same dimensions as the loaded image, and assign it a ARGB color format (lines 110–112). We then obtain the graphics context of the **BufferedImage** and write the image's contents onto it (lines 115–118). Lines 124–126 obtain the array of pixels in the sRGB format and store them in **imageRGB**. Lines 129–131 create a new **BufferedImage** that contains the tinted color values. Finally, the constructor calls method **updateTint**—to processes the image. Method **updateTint** (lines 148–181) retrieves the values of the slider and calls the **native** tinting method. First, a copy is made of the array of colors, this copy allows us to maintain an unmodified copy of the original color values. It calls the **native** method, then prints a warning if any pixels could not be fully tinted, and catches the **ImageSizeException** (lines 154–171). Method **actionPerformed** simply calls **updateTint** when the button is pressed (lines 183–189). Finally, we override the **paintComponent** method of **JPanel** to display our images (lines 138–145).

```
1 // Fig. I.25 JNIPanel.java
2 // Loads an image, creates a copy and uses JNI to tint the image.
3
4 // Java headers
5 import javax.swing.*;
6 import java.awt.*;
7 import java.awt.image.*;
8 import java.awt.event.*;
9
10 public class JNIPanel extends JPanel implements ActionListener {
11     BufferedImage loadedImage;
12     BufferedImage tintedImage;
13     int[] imageRGB;
14     int[] tintedRGB;
15     JSlider tintRed, tintGreen, tintBlue;
16     JButton tintButton;
17     JNITintWrapper imageProcess;
18
19     // obtains image, processes it and displays warnings
20     public JNIPanel( String file, LayoutManager layout )
21     {
22         super( layout );
23         setPreferredSize( new Dimension( 640, 425 ) );
24
25         // create image manipulation components
26         tintRed = new JSlider( 0, 255, 0 );
27         tintBlue = new JSlider( 0, 255, 0 );
28         tintGreen = new JSlider( 0, 255, 0 );
29         tintButton = new JButton( "Tint Image" );
30
31         JLabel redLabel = new JLabel( "Red" );
32         JLabel greenLabel = new JLabel( "Green" );
33         JLabel blueLabel = new JLabel( "Blue" );
34
35         // set properties for red slider
36         tintRed.setMajorTickSpacing( 50 );
37         tintRed.setMinorTickSpacing( 10 );
38         tintRed.setPaintTicks( true );
39         tintRed.setPaintLabels( true );
40
41         // set properties for green slider
42         tintGreen.setMajorTickSpacing( 50 );
43         tintGreen.setMinorTickSpacing( 10 );
44         tintGreen.setPaintTicks( true );
45         tintGreen.setPaintLabels( true );
46
47         // set properties for blue slider
48         tintBlue.setMajorTickSpacing( 50 );
49         tintBlue.setMinorTickSpacing( 10 );
50         tintBlue.setPaintTicks( true );
51         tintBlue.setPaintLabels( true );
52 }
```

Fig. G.25 **JNIPanel** creates the application GUI and calls the **native** method (part 1 of 4).

```
53     tintButton.setActionCommand( "tint" );
54
55     // use this class to process action
56     tintButton.addActionListener( this );
57
58     // create new panels
59     JPanel sliderPanel =
60         new JPanel( new FlowLayout( FlowLayout.LEFT ) );
61
62     JPanel redPanel = new JPanel( new FlowLayout() );
63     redPanel.setPreferredSize( new Dimension( 200, 250 ) );
64
65     JPanel greenPanel = new JPanel( new FlowLayout() );
66     greenPanel.setPreferredSize( new Dimension( 200, 250 ) );
67
68     JPanel bluePanel = new JPanel( new FlowLayout() );
69     bluePanel.setPreferredSize( new Dimension( 200, 250 ) );
70
71     // add the components
72     redPanel.add( tintRed );
73     redPanel.add( redLabel );
74
75     greenPanel.add( tintGreen );
76     greenPanel.add( greenLabel );
77
78     bluePanel.add( tintBlue );
79     bluePanel.add( blueLabel );
80
81     sliderPanel.add( redPanel );
82     sliderPanel.add( greenPanel );
83     sliderPanel.add( bluePanel );
84
85     // set panel size
86     sliderPanel.setPreferredSize( new Dimension( 650, 75 ) );
87
88     add( sliderPanel );
89
90     // add components to JNIPanel
91     add( tintButton );
92
93     MediaTracker tracker = new MediaTracker( this );
94
95     // load image
96     Image image = Toolkit.getDefaultToolkit().getImage( file );
97
98     // add image to tracker
99     tracker.addImage( image, 0 );
100
101    try{
102
103        // wait until image is loaded
104        tracker.waitForID( 0 );
```

Fig. G.25 **JNIPanel** creates the application GUI and calls the **native** method (part 2 of 4).

```
105     } catch ( InterruptedException e ) {
106         e.printStackTrace();
107     }
108
109     // create new buffered image
110     loadedImage = new BufferedImage(
111         image.getWidth( this ), image.getHeight( this ),
112         BufferedImage.TYPE_INT_ARGB );
113
114     // get graphics context of BufferedImage
115     Graphics2D graphics = ( Graphics2D )loadedImage.getGraphics();
116
117     // draw Image on BufferedImage
118     graphics.drawImage( image , 0 , 0 , this );
119
120     // create new native wrapper
121     imageProcess = new JNITintWrapper();
122
123     // obtains array of RGB integer values
124     imageRGB = loadedImage.getRGB( 0 , 0 , loadedImage.getWidth(),
125         loadedImage.getHeight() , imageRGB ,
126         0 , loadedImage.getWidth() );
127
128     // create new buffered image for new RGB values
129     tintedImage = new BufferedImage(
130         loadedImage.getWidth() , loadedImage.getHeight(),
131         BufferedImage.TYPE_INT_ARGB );
132
133     // process image and print any warnings
134     updateTint();
135 }
136
137 // draw our two BufferedImages
138 public void paintComponent( Graphics g )
139 {
140     super.paintComponent( g );
141     Graphics2D graphics = ( Graphics2D )g;
142     graphics.drawImage( loadedImage, null , 150 , 150 );
143     graphics.drawImage(
144         tintedImage, null , loadedImage.getWidth() + 160 , 150 );
145 }
146
147 // tints image and displays warnings
148 public void updateTint()
149 {
150     // get copy of original RGB values
151     tintedRGB = ( int[] )imageRGB.clone();
152
153     // try to tint image
154     try {
155
```

Fig. G.25 **JNIPanel** creates the application GUI and calls the **native** method (part 3 of 4).

```

156         // call to native code for image processing tint 20 green
157         int[] warnings =
158             imageProcess.tintImage(
159                 tintedRGB, tintedRGB.length, tintRed.getValue(),
160                 tintGreen.getValue(), tintBlue.getValue() );
161
162         if ( warnings != null )
163             System.out.println(
164                 "Not all pixels could be fully tinted" );
165
166         // if image is too large catch exception and end program
167     } catch ( ImageSizeException sizeException ) {
168         System.out.println(
169             "Image is too large, error was:" );
170         sizeException.printStackTrace();
171     }
172
173         // set RGB values
174         tintedImage.setRGB( 0, 0, tintedImage.getWidth(),
175             tintedImage.getHeight(), tintedRGB, 0,
176             tintedImage.getWidth() );
177
178         // repaint image
179         repaint();
180     }
181
182     // handles button events
183     public void actionPerformed( ActionEvent e )
184     {
185         // if button pressed then update image
186         if ( e.getActionCommand().equals( "tint" ) )
187             updateTint();
188     }
189 }
190 }
```

**Fig. G.25** **JNIPanel** creates the application GUI and calls the **native** method (part 4 of 4).

Class **JNIImageFrame** extends **JFrame** to allow us to add **JNIPanel** object and serves as an entry point for the application (Fig. G.26). The constructor creates a new **JNIPanel** and adds it to the frame inside a **JScrollPane**.

```

1 // Fig. G.26 JNIImageFrame.java
2 // extends JFrame, adds a scroll pane and
3 // serves as an entry point for the application.
4
5 // Java headers
6 import javax.swing.*;
7 import java.awt.*;
8 import java.awt.event.*;
```

**Fig. G.26** **JNIImageFrame** serves as an entry point for the application (part 1 of 2).

```
9
10 public class JNIIImageFrame extends JFrame
11 {
12     // serves as entry point, creates new JNIIImageFrame
13     public static void main( String[] args )
14     {
15         JNIIImageFrame imageFrame = new JNIIImageFrame();
16     }
17
18     // constructs new JNIIImageFrame containing JNIPanel
19     public JNIIImageFrame()
20     {
21         super( "Deitel Image Processing" );
22
23         getContentPane().setLayout( new FlowLayout() );
24
25         // adds new JNIPanel and defines image to process
26         getContentPane().add(
27             new JScrollPane( new JNIPanel(
28                 "advjhtp1_small.jpg" , new BorderLayout() ) ) );
29
30         addWindowListener( new WindowAdapter() {
31             public void windowClosing( WindowEvent event ) {
32                 dispose();
33                 System.exit( 0 );
34             }
35         });
36         setSize( 670, 500 );
37         setVisible( true );
38     }
39 }
40 }
```

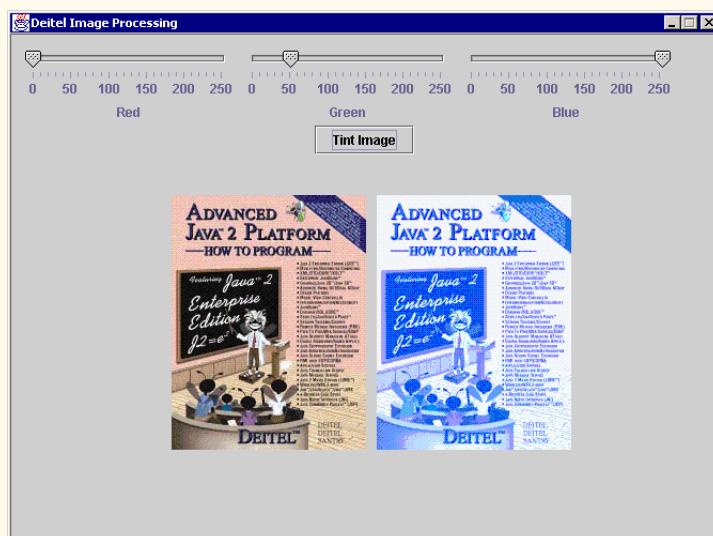


Fig. G.26 **JNIIImageFrame** serves as an entry point for the application (part 2 of 2).

In this appendix, we presented the most common JNI techniques and functions. We have covered the fundamentals of interaction between Java and C++, including objects, arrays and exceptions. For additional JNI resources consult Section G.6.

## G.6 Internet and World Wide Web Resources

[www.java.sun.com/docs/books/tutorial/native1.1/index.html](http://www.java.sun.com/docs/books/tutorial/native1.1/index.html)

This tutorial covers the fundamentals of JNI.

[www.jguru.com/faq/subtopic.jsp?topicID=472](http://www.jguru.com/faq/subtopic.jsp?topicID=472)

This site contains well over 100 frequently asked questions (FAQs) and answers.

[www.acm.org/crossroads/xrds4-2/jni.html](http://www.acm.org/crossroads/xrds4-2/jni.html)

This site is a JNI reference.

[www.symbolstone.org/technology/java/index.html](http://www.symbolstone.org/technology/java/index.html)

A JNI book available for download. It includes detailed JNI information and tips on using JNI with applets.

## SUMMARY

- The Java Native Interface (JNI) allows programmers to access existing applications written in other languages.
- JNI can be useful in time-critical applications—programmers can write a piece of the application in native code for performance reasons.
- Communication between Java and native code is slow, large amounts of communication will significantly degrade performance.
- Enabling a Java program to access native code requires a compiled wrapper class, a **javah** generated header and a library.
- The **native** keyword indicates that the method is implemented in a native library, not in Java.
- You must run **javah** on each Java class that contains a **native** method. Do not edit these headers—if you make a change to the wrapper class, run **javah** to generate appropriate header files again.
- **jni.h** is the header that contains all the JNI helper functions required for C++ to interact with Java.
- A signature is the argument and the return types of the function.
- **#defines** **JNIEXPORT** and **JNICALL** each help handle system specific JNI interactions with C++.
- **JNIEnv** is a pointer to a table of functions that assist the native code's interaction with Java; it is always passed as the first argument to a JNI function.
- A **JNIEnv\*** pointer named **env** would be accessed as **env->functionName(args)** in C++. In C, it would be accessed as **(\*env)->functionName(env, args)**.
- The second argument sent to a native function is a reference to the Java object that called it.
- The third through the final arguments sent to a native function are the arguments as they would be sent from Java code.
- Java Primitives and objects do not directly map to those used in C/C++.
- Java objects are passed as **jobjects**.
- Strings are passed as **jstring**.

- Primitives are passed as **jtype**.
- Conversion between C/C++ and JNI primitive types is transparent to the programmer and may be done with simple assignment.
- Java uses Unicode to represent its characters, however C++ can only read the subset UTF-8 format.
- **GetStringUTFChars** converts a Unicode string to UTF-8 string.
- Releasing the string requires a call to **ReleaseStringUTFChars**, and must be done to avoid memory leaks.
- **System.loadLibrary** searches your library paths for a library with the given name and loads it into the Java JVM.
- Generally the library should be loaded in a **static** block. This ensures that the library is loaded before any **native** methods are called.
- If a native call is made before the library is loaded, the program will exit with an **UnsatisfiedLinkError**.
- **GetObjectClass** returns the **jclass** of the given object.
- A method ID is a unique ID associated with each method of a class, it may be obtained through the **GetMethodID** JNI function.
- Method signatures must be in the format: *(argument types) return type*.
- Primitive signatures are usually specified by their uppercase first letter e.g., **D** for **double**, **I** for **int** and **V** for **void**. Exceptions to this rule are **J** for **long** and **Z** for **boolean**.
- Object signatures must be prefixed by **L** followed by the class, including packages, and terminated by a semicolon, e.g., **Ljava/lang/String;** specifies the **String** type.
- Including an open bracket (**[**) before a signature indicates an array, (**[D**) **V** represents a method that requires an array of **doubles** and returns **void**.
- Methods can be called with **CalltypeMethod**, where *type* represents the return type.
- JNI method **FindClass** returns a **jclass** reference to any fully qualified class name. If you have no instance of an object, **FindClass** must be called to retrieve the **jclass**.
- **<init>** is the method name used in JNI to signify a constructor.
- JNI function **NewObject** creates a new object of the given class.
- The standard JNI procedure to get a method or field is to obtain the **jclass**, get an ID for the member and access the member.
- **GetFieldID** obtains the field ID of the variable you wish to access.
- **GettypeField** returns the member contained within the given object at the **jfieldID** as type **jtype**.
- **GetStaticFieldID** obtains the **jfieldID** of a **static** member variable.
- Retrieving the field uses **GetStatictypeField**, and uses a **jclass** as the first argument, not the **jobject** used for non-static members.
- Converting arrays from Java to native code is complex because, as opposed to native languages, elements in a Java array are not always placed together in contiguous memory.
- The JNI function **NewObjectArray** creates a new array of the given object. **NewtypeArray** creates a new array of the specified primitive type.
- To obtain access to individual elements of a primitive array within native code requires a call to **GetPrimitiveTypeArrayElements**.
- **ReleasetypeArrayElements** causes JNI to release the memory and update the original array. The argument **JNI\_ABORT** frees the memory, but will not update the changes for Java, and argument **JNI\_COMMIT** will update Java, but not free the array.

- **SetObjectArrayElements** and **GetObjectArrayElements** each provide simple access to an object array.
- There is no need to release object arrays. They are never copied from Java, thus Java's built-in garbage collector will destroy them if they are unused.
- Handling exceptions natively can be essential to integrating native code with Java. JNI allows **native** methods to catch exceptions themselves, or to throw exceptions back to Java.
- JNI function **ThrowNew** signals Java to create a new exception of that type, with the given string as a message.
- Function **ExceptionOccurred** returns **JNI\_NULL** if an exception was not thrown.
- JNI function **IsInstanceOf** takes an object and a class and returns **JNI\_TRUE** if the object is an instance of the class. Accordingly, you may use **IsSameObject** to determine if two references are actually the same object.
- Call JNI function **Clear** to remove the error flag from JNI.

## TERMINOLOGY

ANSI	JNI helper function
C	<b>jni.h</b>
C++	<b>JNI_ABORT</b>
C++ library	<b>JNI_COMMIT</b>
<b>CallStaticTypeMethod</b> JNI function	<b>JNI_FALSE</b>
<b>CallTypeMethod</b> JNI function	<b>JNI_TRUE</b>
<b>char *</b>	<b>JNICALL</b>
<b>ExceptionOccurred</b> JNI function	<b>JNIEnv</b> variable
<b>FatalError</b> JNI function	<b>JNIEEXPORT</b>
field ID	JNI-style header file
<b>FindClass</b> JNI function	<b>jobject</b>
<b>GetPrimitiveTypeArrayElement</b>	<b>jstring</b>
<b>GetFieldID</b> JNI function	<b>jthrowable</b>
<b>GetMethodID</b> JNI function	library
<b>GetObjectArrayElements</b> JNI function	method ID
<b>GetStaticFieldID</b> JNI function	native
<b>GetStaticMethodID</b> JNI function	<b>native</b> keyword
<b>GetStaticTypeField</b> JNI function	native library
<b>GetStaticTypeMethod</b> JNI function	<b>NewObject</b> JNI function
<b>GetStringUTFChars</b> JNI function	<b>NewObjectArray</b> JNI function
<b>GetTypeMethod</b> JNI function	<b>NewTypeArray</b> JNI function
<b>IsInstanceOf</b> JNI function	<b>OutOfMemoryError</b>
<b>IsSameObject</b> JNI function	<b>ReleaseStringUTFChars</b> JNI function
Java Native Interface	<b>SetObjectArrayElement</b> JNI function
<b>javah</b>	signature
<b>jboolean</b>	<b>System.loadLibrary</b>
<b>jclass</b>	<b>ThrowNew</b> JNI function
<b>jdouble</b>	Unicode
<b>jint</b>	<b>UnsatisfiedLinkError</b>
<b>jIntArray</b>	UTF-8
JNI	wrapper class

## SELF-REVIEW EXERCISES

**G.1** Fill in the blanks for each of the following:

- a) Code that can be compiled to a binary format is also known as \_\_\_\_\_ code.
- b) \_\_\_\_\_ is the tool used to create C headers for JNI.
- c) To convert Unicode strings to UTF-8 strings the \_\_\_\_\_ function of the **JNIEnv** pointer may be used.
- d) Accessing a non-static method from native code requires three steps: \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
- e) The **CallStaticTypeMethod** differs from the **CallTypeMethod** because it requires an argument of type \_\_\_\_\_ while **CallTypeMethod** uses an argument of type \_\_\_\_\_.

**G.2** State whether each of the following is *true* or *false*. If *false* explain your answers.

- a) Java is a native language.
- b) Type **JNIEnv** does not refer to an object.
- c) Java primitives can be converted to C++ primitives through assignment.
- d) JNI always increases program performance.
- e) Java objects may only be created from a Java program and passed to the native function.

## ANSWERS TO SELF-REVIEW EXERCISES

**G.1** a) native. b) **javah**. c) **GetStringUTFChars**. d) obtain **jclass**, obtain method ID, call the method. e) **jclass**, **jobject**.

**G.2** a) False, Java is not compiled to a binary format. b) True. c) True. d) False, JNI often reduces performance due to the overhead associated with JNI calls. e) False, native code can create new Java objects.

## EXERCISES

**G.3** Explain why Java arrays do not directly map to C++ arrays. Explain how JNI deals with this complication, and contrast between primitive and object arrays.

**G.4** Define the term “method signatures” and explain why JNI needs them.

**G.5** What should you be careful with after throwing an exception in native code? Why?

**G.6** Write native code to obtain the method ID of the constructor for class **Integer** that takes an **int** as an argument. Assume you already have the class stored in **jclass integerClass**.

**G.7** Write the native code required to call the Java method **isEmpty** of class **Vector**. Assume you have an instance of a **Vector** assigned to **jobject myVector**.

**G.8** Create a wrapper class **MathWrapper** that contains three native functions **cSin**, **cCos**, and **cLn**, each taking a **double** for an argument and returning a **double**. The wrapper class should explicitly declare that the **cLn** function throws an **Exception**. Create library **MathLibrary**. It should implement the header created from running **javah** on **MathWrapper** and contain three JNI-style functions that encapsulate the use of **sin**, **cos**, and **ln** of C++ header **math.h**. If the argument to **ln** is less than or equal to zero, throw an exception, and have Java handle the exception. Finally, write a Java class **MathMain** that calls **native** methods for the math operations in class **MathWrapper**. It should load the native library, **MathLibrary**, and test each function with arguments entered by the user. **cLn** must catch an **Exception** and print its message.

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3. Stearns, B. "Trail: Java Native Interface," <[www.java.sun.com/docs/books/tutorial/native1.1/index.html](http://www.java.sun.com/docs/books/tutorial/native1.1/index.html)>



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# Career Opportunities

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## Objectives

- To explore the various online career services.
- To examine the advantages and disadvantages of posting and finding jobs online.
- To review the major online career services Web sites available to job seekers.
- To explore the various online services available to employers seeking to build their workforces.

*What is the city but the people?*

William Shakespeare

*A great city is that which has the greatest men and women,  
If it be a few ragged huts it is still the greatest city in the  
whole world.*

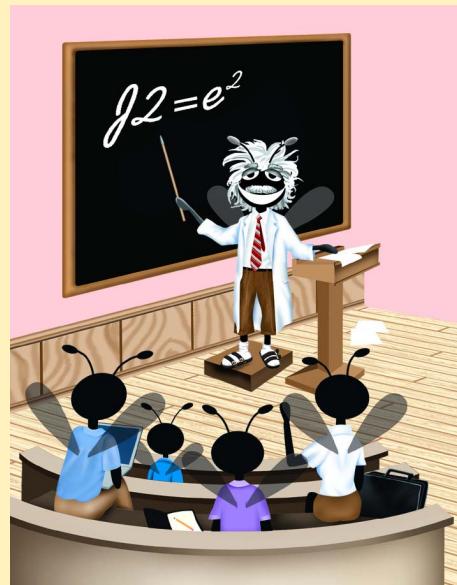
Walt Whitman

*To understand the true quality of people, you must look into  
their minds, and examine their pursuits and aversions.*

Marcus Aurelius

*The soul is made for action, and cannot rest till it be  
employed. Idleness is its rust. Unless it will up and think and  
taste and see, all is in vain.*

Thomas Traherne



## Outline

- H.1 Introduction
- H.2 Resources for the Job Seeker
- H.3 Online Opportunities for Employers
  - H.3.1 Posting Jobs Online
  - H.3.2 Problems with Recruiting on the Web
  - H.3.3 Diversity in the Workplace
- H.4 Recruiting Services
  - H.4.1 Testing Potential Employees Online
- H.5 Career Sites
  - H.5.1 Comprehensive Career Sites
  - H.5.2 Technical Positions
  - H.5.3 Wireless Positions
  - H.5.4 Contracting Online
  - H.5.5 Executive Positions
  - H.5.6 Students and Young Professionals
  - H.5.7 Other Online Career Services
- H.6 Internet and World Wide Web Resources

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises • Works Cited*

### H.1 Introduction

There are approximately 40,000 career-advancement services on the Internet today.<sup>1</sup> These services include large, comprehensive job sites, such as **Monster.com** (see the upcoming **Monster.com** feature), as well as interest-specific job sites such as **JustJava-Jobs.com**. Companies can reduce the amount of time spent searching for qualified employees by building a recruiting feature on their sites or establishing an account with a career site. This results in a larger pool of qualified applicants, as online services can automatically select and reject resumes based on user-designated criteria. Online interviews, testing services and other resources also expedite the recruiting process.

Applying for a position online is a relatively new method of exploring career opportunities. Online recruiting services streamline the process and allow job seekers to concentrate their energies in careers that are of interest to them. Job seekers can explore opportunities according to geographic location, position, salary or benefits packages.

Job seekers can learn how to write a resume and cover letter, post them online and search through job listings to find the jobs that best suit their needs. *Entry-level positions*, or positions commonly sought by individuals who are entering a specific field or the job market for the first time; contracting positions; executive-level positions and middle-management-level positions are all available on the Web.

Job seekers will find a number of time-saving features when searching for a job online. These include storing and distributing resumes digitally, e-mail notification of possible positions, salary and relocation calculators, job coaches, self-assessment tools and information on continuing education.

In this appendix, we explore online career services from the employer and employee's perspective. We suggest sites on which applications can be submitted, jobs can be searched for and applicants can be reviewed. We also review services that build recruiting pages directly into an e-business.

## H.2 Resources for the Job Seeker

Finding a job online can greatly reduce the amount of time spent applying for a position. Instead of searching through newspapers and mailing resumes, job seekers can request a specific position in a specific industry through a search engine. Some sites allow job seekers to setup intelligent agents to find jobs that meet their requirements. Intelligent agents are programs that search and arrange large amounts of data, and report answers based on that data. When the agent finds a potential match, it sends it to the job seeker's inbox. Resumes can be stored digitally, customized quickly to meet job requirements and e-mailed instantaneously. Potential candidates can also learn more about a company by visiting its Web site. Most employment sites are free to job seekers. These sites typically generate their revenues by charging employers for posting job opportunities and by selling advertising space on their Web pages (see the **Monster.com** feature).

Career services, such as **FlipDog.com**, search a list of employer job sites to find positions. By searching links to employer Web sites, **FlipDog.com** is able to identify positions from companies of all sizes. This feature enables job seekers to find jobs that employers may not have posted outside the corporation's Web site.

### **Monster.com**

Super Bowl ads and effective marketing have made **Monster.com** one of the most recognizable online brands (see Fig. B.1). In fact, in the 24 hours following Super Bowl XXXIV, 5 million job searches occurred on **Monster.com**.<sup>2</sup> The site allows people looking for jobs to post their resumes, search job listings, read advice and information about the job-search process and take proactive steps to improve their careers. These services are free to job seekers. Employers can post job listings, search resume databases and become featured employers.

Posting a resume at **Monster.com** is simple and free. **Monster.com** has a resume builder that allows users to post a resume to its site in 15–30 minutes. Each user can store up to 5 resumes and cover letters on the **Monster.com** server. Some companies offer their employment applications directly through the **Monster.com** site. **Monster.com** has job postings in every state and all major categories. Users can limit access to their personal identification information. As one of the leading recruiting sites on the Web, **Monster.com** is a good place to begin a job search or to find out more about the search process.

**Monster.com (Cont.)**

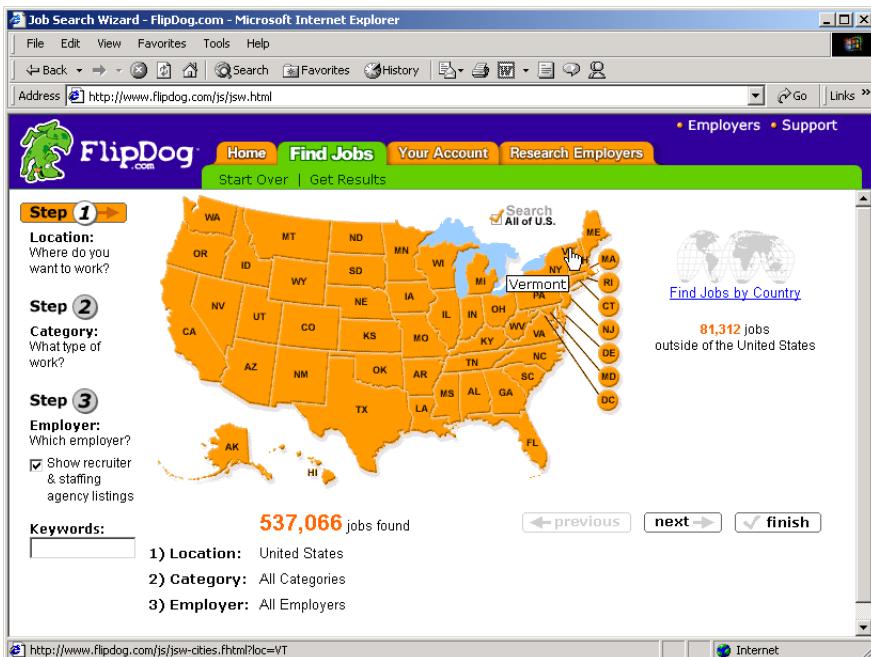
Fig. H.1 The **Monster.com** home page. (Courtesy of **Monster.com**.)

Job seekers can visit **FlipDog.com** and choose, by state, the area in which they are looking for a position. Applicants can also conduct worldwide searches. After a user selects a region, **FlipDog.com** requests the user to specify a job category containing several specific positions. The user's choice causes a list of local employers to appear. The user can choose a specific employer or request that **FlipDog.com** search the employment databases for jobs offered by all employers (see Fig. B.2).

Other services, such as employment networks, also help job seekers in their search. Sites such as **Vault.com** (see the **Vault.com** feature) and **WetFeet.com** allow job seekers to post questions about employers and positions in designated chat rooms and on bulletin boards.

### H.3 Online Opportunities for Employers

Recruiting on the Internet provides several benefits over traditional recruiting. For example, Web recruiting reaches a much larger audience than posting an advertisement in a local newspaper. Given the breadth of the services provided by most online career services Web sites, the cost of posting online can be considerably less expensive than posting positions through traditional means. Even newspapers, which depend greatly on career opportunity advertising, are starting online career sites.<sup>3</sup>



**Fig. H.2** [flipDog.com](http://www.flipdog.com/jsw.html) job search. (Courtesy of [flipdog.com](http://www.flipdog.com).)

### Vault.com: Finding the Right Job on the Web<sup>4</sup>

**Vault.com** allows potential employees to seek out additional, third-party information for over 3000 companies. By visiting the *Insider Research* page, Web users have access to a profile on the company of their choice, as long as it exists in **Vault.com**'s database. In addition to **Vault.com**'s profile, there is a link to additional commentary by company employees. Most often anonymous, these messages can provide prospective employees with potentially valuable decision-making information. However, users must consider the integrity of the source. For example, a disgruntled employee may leave a posting that is not an accurate representation of the corporate culture of his or her company.

The **Vault.com** *Electronic Watercooler*™ is a message board that allows visitors to post stories, questions and concerns and to advise employees and job seekers. In addition, the site provides e-newsletters and feature stories designed to help job seekers in their search. Individuals seeking information on business, law and graduate schools can also find information on **Vault.com**.

Job-posting and career-advancement services for the job seeker are featured on **Vault.com**. These services include *VaultMatch*, a career service that e-mails job postings as requested, and *Salary Wizard*™, which helps job seekers determine the salary they are worth. Online guides with advice for fulfilling career ambitions are also available.

### Vault.com: Finding the Right Job on the Web<sup>4</sup> (Cont.)

Employers can also use the site. *HR Vault*, a feature of **vault.com**, provides employers with a free job-posting site. It offers career-management advice, employer-to-employee relationship management and recruiting resources.



#### e-Fact H.1

According to Forrester Research, 33 percent of today's average company's hiring budget goes toward online career services, while the remaining 66 percent is used toward traditional recruiting mechanisms. Online use is expected to increase to 42 percent by 2004, while traditional mechanisms may be reduced to 10 percent.<sup>5</sup>

Generally, jobs posted online are viewed by a larger number of job seekers than jobs posted through traditional means. However, it is important not to overlook the benefits of combining online efforts with human-to-human interaction. There are many job seekers who are not yet comfortable with the process of finding a job online. Often, online recruiting is used as a means of freeing up a recruiter's time for the interviewing process and final selection.



#### e-Fact H.2

Cisco Systems cites a 39 percent reduction in cost-per-hire expenses, and a 60 percent reduction in the time spent hiring.<sup>6</sup>

### H.3.1 Posting Jobs Online

When searching for job candidates online, there are many things employers need to consider. The Internet is a valuable tool for recruiting, but one that takes careful planning to acquire the best results. It provides a good supplementary tool, but should not be considered the complete solution for filling positions. Web sites, such as WebHire ([www.webhire.com](http://www.webhire.com)), enhance a company's online employment search (see the WebHire feature).

There are a variety of sites that allow employers to post jobs online. Some of these sites require a fee, which generally runs between \$100–200. Postings typically remain on the Web site for 30–60 days. Employers should be careful to post to sites that are most likely to be visited by eligible candidates. As we discovered in the previous section, there are a variety of online career services focused on specific industries, and many of the larger, more comprehensive sites have categorized their databases by job category.

When designing a posting, the recruiter should consider the vast number of postings already on the Web. Defining what makes the job position unique, including information such as benefits and salary, might convince a qualified candidate to further investigate the position (see Fig. B.3).<sup>7</sup>

**HotJobs.com** career postings are cross-listed on a variety of other sites, thus increasing the number of potential employees who see the job listings. Like **Monster.com** and **jobfind.com**, **hotjobs.com** requires a fee per listing. Employers also have the option of becoming **HotJob.com** members. Employers can gain access to HotJob's *Private Label Job Boards* (private corporate employment sites), online recruiting technology and online career fairs.

### WebHire™<sup>8</sup>

Designed specifically for recruiters and employers, WebHire is a multifaceted service that provides employers with *end-to-end recruiting solutions*. The service offers job-posting services as well as candidate searches. The most comprehensive of the services, *WebHire™ Enterprise*, locates and ranks candidates found through resume-scanning mechanisms. Clients will also receive a report indicating the best resources for their search. Other services available through the *WebHire™ Employment Services Network* include preemployment screening, tools for assessing employees' skill levels and information on compensation packages. An employment law advisor helps organizations design interview questions.

*WebHire™ Agent* is an intelligent agent that searches for qualified applicants based on job specifications. When WebHire Agent identifies a potential candidate, an e-mail is automatically sent to the candidate to generate interest. WebHire Agent then ranks applicants according to the skills information it gains from the Web search; the information is stored so that new applicants are distinguished from those who have already received an e-mail from the site.

*Yahoo!® Resumes*, a feature of WebHire, allows recruiters to find potential employees by typing in keywords on the Yahoo! Resumes search engine. Employers can purchase a year's membership to the recruiting solution for a flat fee; there are no per-use charges.

### Job Seeker's Criteria

- Position (responsibilities)
- Salary
- Location
- Benefits (health, dental, stock options)
- Advancement
- Time Commitment
- Training Opportunities
- Tuition Reimbursement
- Corporate Culture

Fig. H.3 List of a job seeker's criteria.

Boston Herald *Job Find* ([www.jobfind.com](http://www.jobfind.com)) also charges employers to post on its site. The initial fee entitles the employer to post up to three listings. Employers have no limitations on the length of their postings.

Other Web sites providing employers with employee recruitment services include **CareerPath.com**, America's Job Bank ([www.ajb.dni.us/employer](http://www.ajb.dni.us/employer)), **CareerWeb** ([www.cweb.com](http://www.cweb.com)), **Jobs.com** and **Career.com**.

### H.3.2 Problems with Recruiting on the Web

The large number of applicants presents a challenge to both job seekers and employers. On many recruitment sites, matching resumes to positions is conducted by *resume-filtering software*. The software scans a pool of resumes for keywords that match the job description. While this software increases the number of resumes that receive attention, it is not a fool-proof system. For example, the resume-filtering software might overlook someone with similar skills to those listed in the job description, or someone whose abilities would enable them to learn the skills required for the position. Digital transmissions can also create problems because certain software platforms are not always acceptable by the recruiting software. This sometimes results in an unformatted transmission, or a failed transmission.

A lack of confidentiality is another disadvantage of online career services. In many cases, a job candidate will want to search for job opportunities anonymously. This reduces the possibility of offending the candidate's current employer. Posting a resume on the Web increases the likelihood that the candidate's employer might come across it when recruiting new employees. The traditional method of mailing resumes and cover letters to potential employers does not impose the same risk.

According to recent studies, the number of individuals researching employment positions through traditional means, such as referrals, newspapers and temporary agencies, far outweighs the number of job seekers researching positions through the Internet.<sup>9</sup> Optimists feel, however, that this disparity is largely due to the early stages of e-business development. Given time, online career services will become more refined in their posting and searching capabilities, decreasing the amount of time it takes for a job seeker to find jobs and employers to fill positions.

### H.3.3 Diversity in the Workplace

Every workplace inevitably develops its own culture. Responsibilities, schedules, deadlines and projects all contribute to a working environment. Perhaps the most defining elements of a *corporate culture* are the employees. For example, if all employees were to have the same skills and the same ideas, the workplace would lack diversity. It might also lack creativity and enthusiasm. One way to increase the dynamics of an organization is to employ people of all backgrounds and cultures.

The Internet hosts demographic-specific sites for employers seeking to increase diversity in the workplace. By recruiting people from different backgrounds, new ideas and perspectives are brought forth, helping businesses meet the needs of a larger, more diverse target audience.<sup>10</sup>

**Blackvoices.com** and **hirediversity.com** are demographic-specific Web sites. BlackVoices™, which functions primarily as a portal (a site offering news, sports and weather information, as well as the ability to search the Web), features job searching capabilities and the ability for prospective employees to post resumes. HireDiversity is divided into several categories, including opportunities for African Americans, Hispanics and women. Other online recruiting services place banner advertisements on ethnic Web sites for companies seeking diverse workforces.

The Diversity Directory ([www.mindexchange.com](http://www.mindexchange.com)) offers international career-searching capabilities. Users selecting the **Diversity** site can find job opportunities, information and additional resources to help them in their career search. The site can be searched

according to demographics (African American, Hispanic, alternative lifestyle, etc.) or by subject (employer, position, etc.) via hundreds of links. Featured sites include **BilingualJobs.com**, *Latin World* and *American Society for Female Entrepreneurs*.

Many sites have sections dedicated to job seekers with disabilities. In addition to providing job-searching capabilities, these sites include additional resources, such as equal opportunity documents and message boards. The *National Business and Disability Council (NBDC)* provides employers with integration and accessibility information for employing people with disabilities, and the site also lists opportunities for job seekers.

## H.4 Recruiting Services

There are many services on the Internet that help employers match individuals to positions. The time saved by conducting preliminary searches on the Internet can be dedicated to interviewing qualified candidates and making the best matches possible.

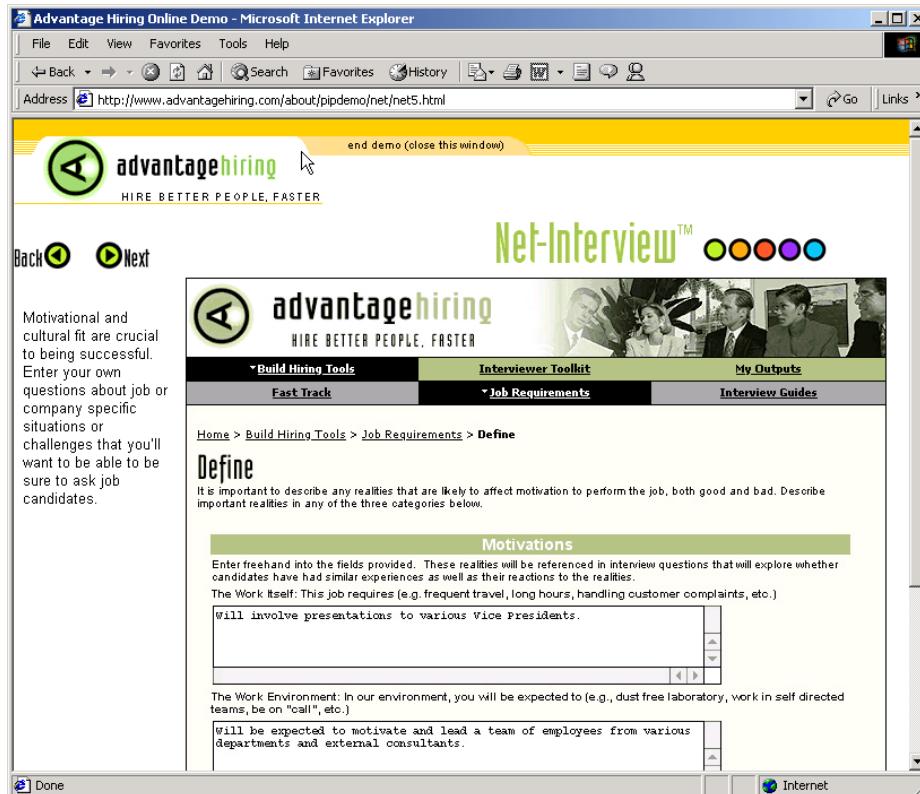
Advantage Hiring, Inc. ([www.advantagehiring.com](http://www.advantagehiring.com)) provides employers with a resume-screening service. When a prospective employee submits a resume for a particular position, Advantage Hiring, Inc. presents *Net-Interview™*, a small questionnaire to supplement the information presented on the resume. The site also offers *SiteBuilder*, a service that helps employers build an employee recruitment site. An online demonstration can be found at [www.advantagehiring.com](http://www.advantagehiring.com). The demonstration walks the user through the Net-Interview software, as well as a number of other services offered by Advantage Hiring (see Fig. B.4).

**Recruitsoft.com** is an application service provider (ASP) that offers companies recruiting software on a *pay-per-hire* basis (Recruitsoft receives a commission on hires made via its service). *Recruiter WebTop™* is the company's online recruiting software. It includes features such as Web-site hosting, an employee-referral program, skill-based resume screening, applicant-tracking capabilities and job-board posting capabilities. A demonstration of Recruiter WebTop's *Corporate Recruiting Solutions* can be found at [www.recruitsoft.com/process](http://www.recruitsoft.com/process). The demonstration shows how recruiting solutions find and rank potential candidates. More information about Recruitsoft's solution can be viewed in a *QuickTime* media player demonstration, found at [www.recruitsoft.com/corpovideo](http://www.recruitsoft.com/corpovideo).

**Peoplescape.com** is an online service that helps employers recruit employees and maintain a positive work environment once the employee has been hired. In addition to searches for potential candidates, Peoplescape offers *PayCheck™*, *LegalCheck™* and *PeopleCheck™*. These services help to ensure that compensation offers are adequate, legal guidelines are met and candidates have provided accurate information on their resumes and during the hiring process. For job seekers, Peoplescape offers searching capabilities, insights to career transitions, a job compensation calculator that takes benefits and bonuses into consideration when exploring a new job possibility and a series of regularly posted articles relevant to the job search.<sup>11</sup>

To further assist companies in their recruiting process, Web sites such as **Refer.com** reward visitors for successful job referrals. Highly sought-after positions can earn thousands of dollars. If a user refers a friend or a family member and he or she is hired, the user receives a commission.

Other online recruiting services include **SkillsVillage.com**, **Hire.com**, **MorganWorks.com** and **Futurestep.com™**.



**Fig. H.4** Advantage Hiring, Inc.'s Net-Interview™ service. (Courtesy of Advantage Hiring, Inc.)

#### H.4.1 Testing Potential Employees Online

The Internet also provides employers with a cost-effective means of testing their prospective employees in such categories as decision making, problem solving and personality. Services such *eTest* help to reduce the cost of in-house testing and to make the interview process more effective. Test results, given in paragraph form, present employers with the interested individual's strengths and weaknesses. Based on these results, the report suggests interview methods, such as asking *open-ended questions*, which are questions that require more than a "yes" or "no" response. Sample reports and a free-trial test can be found at [www.etest.net](http://www.etest.net).

Employers and job seekers can also find career placement exercises at [www.advisorteam.net/AT/User/kcs.asp](http://www.advisorteam.net/AT/User/kcs.asp). Some of these services require a fee. The tests ask several questions regarding the individual's interests and working style. Results help candidates determine the best career for their skills and interests.

## H.5 Career Sites

Online career sites can be comprehensive or industry specific. In this section, we explore a variety of sites on the Web that accommodate the needs of both the job seeker and the employer. We review sites offering technical positions, free-lancing opportunities and contracting positions.

### H.5.1 Comprehensive Career Sites

As mentioned previously, there are many sites on the Web that provide job seekers with career opportunities in multiple fields. **Monster.com** is the largest of these sites, attracting the greatest number of unique visitors per month. Other popular online recruiting sites include **JobsOnline.com**, **HotJobs.com**, **www.jobtrak.com** and **Headhunter.net**.

Searching for a job online can be conducted in a few steps. For example, during an initial visit to **JobsOnline.com**, a user is required to fill out a registration form. The form requests basic information, such as name, address and area of interest. After registering, members can search through job postings according to such criteria as job category, location and the number of days the job has been posted. Contact information is provided for additional communication. Registered members are offered access to XDrive™ (**www.xdrive.com**), which provides 25 MB of storage space for resumes, cover letters and additional communication. Stored files can be shared through any Web browser or Wireless Application Protocol (WAP)-enabled device. **Driveway.com** offers a similar service, allowing individuals to store, share and organize job search files online. An online demonstration of the service can be found at **www.driveway.com**. The animated demo walks the user through the features offered by the service. **Driveway.com** offers 100 MB of space, and the service is free.<sup>12</sup> Other sites, such as Cruel World (see the Cruel World feature), allow users to store and send their resumes directly to employers.

#### Cruel World<sup>13</sup>

Cruel World is a free, online career advancement service for job seekers. After becoming a registered member, your information is matched with available positions in the Cruel World database. When an available job matches your criteria, *JobCast®*, a feature of Cruel World, sends an e-mail alerting you of the available position. If you are interested, you can send your resume to the employer that posted the position, customized to the job's requirements. If you do not wish to continue your search, you can simply send a negative response via e-mail.

The client list, or the list of companies seeking new employees through Cruel World, can be viewed at **www.cruelworld.com/corporate/aboutus.asp** (Fig. B.5). Additional features on the site include hints for salary negotiation; a self-assessment link to **CareerLeader.com**, where, for a small fee, members can reassess their career goals under the advisement of career counselors and a relocation calculator for job seekers who are considering changing location.

Employers seeking to hire new talent can post opportunities through Cruel World. posting positions requires a fee. A demonstration of the service can be viewed at **www.cruelworld.com/clients/quicktour1.asp**. The demonstration is a three-step slide of JobCast.

### Cruel World<sup>13</sup> (Cont.)



Fig. H.5 Cruel World online career services. (Courtesy of Cruel World.)

## H.5.2 Technical Positions

Technical positions are becoming widely available as the Internet grows more pervasive. Limited job loyalty and high turnover rates in technical positions allow job seekers to find jobs that best suit their needs and skills. Employers are required to rehire continuously to keep positions filled and productivity levels high. The amount of time for an employer to fill a technical position can be greatly reduced by using an industry-specific site. Career sites designed for individuals seeking technical positions are among the most popular online career sites. In this section, we review several sites that offer recruiting and hiring opportunities for technical positions.



### e-Fact H.3

*It costs a company 25 percent more to hire a new technical employee than it does to pay an already employed individual's salary.<sup>14</sup>*

**Dice.com** ([www.dice.com](http://www.dice.com)) is a recruiting Web site that focuses on technical fields. Company fees are based on the number of jobs the company posts and the frequency

with which the postings are updated. Job seekers can post their resumes and search the job database for free. **JustComputerJobs.com** directs job seekers toward 39 specific computer technologies for their job search. Language-specific sites include **JustJava-Jobs.com**, **JustCJobs.com** and **JustPerlJobs.com**. Hardware, software and communications technology sites are also available. Other technology recruiting sites include **HireAbility.com**, **Bid4Geeks.com**, **HotDispatch.com** and [www.cmpnet.com/careerdirect](http://www.cmpnet.com/careerdirect).

### H.5.3 Wireless Positions

The wireless industry is developing rapidly. According to **WirelessResumes.com**, the number of wireless professionals is 328,000. This number is expected to increase 40 percent each year for the next five years. To accommodate this growth, and the parallel demand for professionals, **WirelessResumes.com** has created an online career site specifically for the purpose of filling wireless jobs (see the **WirelessResumes.com** feature).

*The Caradyne Group ([www.pcsjobs.com](http://www.pcsjobs.com))*, an executive search firm, connects job seekers to employers in the wireless technology field. Interested job seekers must first fill out a “Profile Questionnaire.” This information is then entered into The Caradyne Group’s database and is automatically matched to an open position in the job seeker’s field of expertise. If there are no open positions, a qualified consultant from The Caradyne Group will contact the job seeker for further interview and discussion. **Jobs4wireless.com** also provides job seekers with employment opportunities in the wireless industry.

### H.5.4 Contracting Online

The Internet also serves as a forum for job seekers to find employment on a project-by-project basis. *Online contracting services* allow businesses to post positions for which they wish to hire outside resources, and individuals can identify projects that best suit their interests, schedules and skills.



#### e-Fact H.4

Approximately six percent of America’s workforce falls into the category of independent contractor.<sup>15</sup>

#### WirelessResumes.com: Filling Wireless Positions

**WirelessResumes.com** is an online career site focused specifically on matching wireless professionals with careers in the industry. This narrow focus enables businesses to locate new employees quickly—reducing the time and expense attached to traditional recruiting methods. Similarly, candidates can limit their searches to precisely the job category of interest. Wireless carriers, device manufacturers, WAP and Bluetooth developers, e-commerce companies and application service providers (ASPs) are among those represented on the site.

In addition to searching for jobs and posting a resume, **WirelessResumes.com** provides job seekers with resume writing tips, interviewing techniques, relocation tools and assistance in obtaining a Visa or the completion of other necessary paperwork. Employers can use the site to search candidates and post job opportunities.

**Guru.com** ([www.guru.com](http://www.guru.com)) is a recruiting site for contract employees. Independent contractors, private consultants and trainers use **guru.com** to find short-term and long-term contract assignments. Tips, articles and advice are available for contractors who wish to learn more about their industry. Other sections of the site teach users how to manage their businesses, buy the best equipment and deal with legal issues. **Guru.com** includes an online store where contractors can buy products associated with small-business management, such as printing services and office supplies. Companies wishing to hire contractors must register with **guru.com**, but individuals seeking contract assignments do not.

**Monster.com**'s Talent Market™ offers online auction-style career services to free agents. Interested users design a profile, listing their qualifications. After establishing a profile, free agents "Go Live" to start the bidding on their services. The bidding lasts for five days during which users can view the incoming bids. At the close of five days, the user can choose the job of his or her choice. The service is free for users, and bidding employers pay a commission on completed transactions.

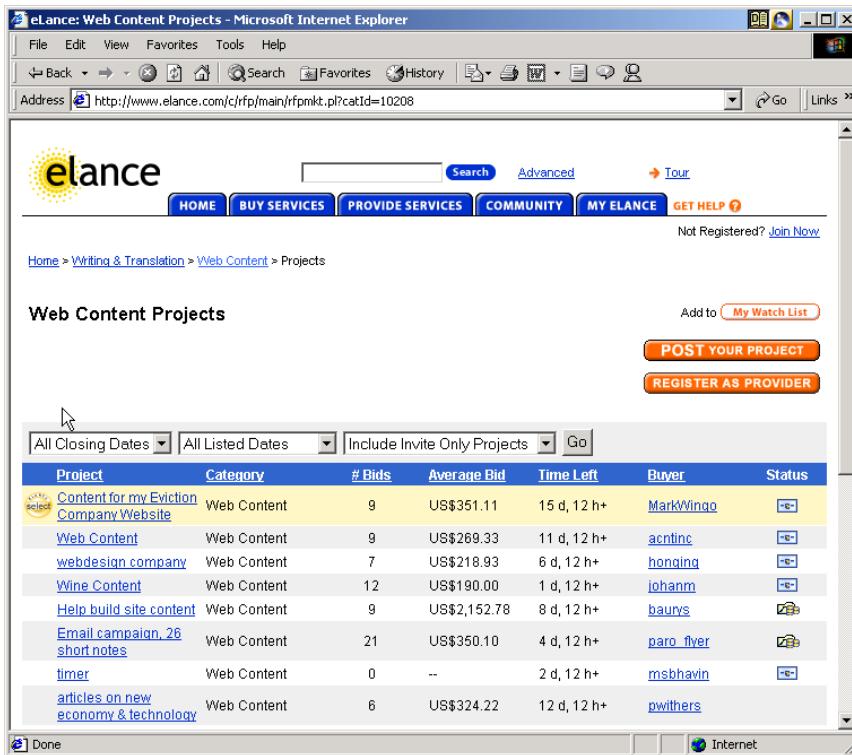
**eLance.com** is another site where individuals can find contracting work. Interested applicants can search eLance's database by category, including business, finance and marketing (see Fig. B.6). These projects, or *requests for proposals* (RFPs), are posted by companies worldwide. When users find projects for which they feel qualified, they submit bids on the projects. Bids must contain a user's required payment, a statement detailing the user's skills and a feedback rating drawn from other projects on which the user has worked. If a user's bid is accepted, the user is given the project, and the work is conducted over eLance's file-sharing system, enabling both the contractor and the employer to contact one another quickly and easily. For an online demonstration, visit [www.elance.com](http://www.elance.com) and click on the **demonstration** icon.

FreeAgent ([www.freeagent.com](http://www.freeagent.com)) is another site designed for contracting projects. Candidates create an *e.portfolio* that provides an introductory "snapshot" of their skills, a biography, a list of their experience and references. The interview section of the portfolio lists questions and the applicant's answers. Examples of *e.portfolios* can be found at [www.freeagent.com/splash/models.asp](http://www.freeagent.com/splash/models.asp). Free Agent's *e.office* offers a benefits package to outside contractors, including health insurance, a retirement plan and reimbursement for business-related expenses.

Other Web sites that provide contractors with projects and information include eWork® Exchange ([www.ework.com](http://www.ework.com)), **MBAFreeAgent.com**, **Aquent.com** and **WorkingSolo.com**.

## H.5.5 Executive Positions

Next, we discuss the advantages and disadvantages of finding an executive position online. Executive career advancement sites usually include many of the features found on comprehensive job-search sites. Searching for an executive position online differs from finding an entry-level position online. The Internet allows individuals to continually survey the job market. However, candidates for executive-level positions must exercise a higher level of caution when determining who is able to view their resume. Applying for an executive position online is an extensive process. As a result of the high level of scrutiny passed on a candidate during the hiring process, the initial criteria presented by an executive level candidate often are more specific than the criteria presented by the first-time job seeker. Executive positions often are difficult to fill, due to the high demands and large amount of experience required for the jobs.



**Fig. H.6** [eLance.com](#) request for proposal (RFP) example. (Courtesy of eLance, Inc.)

SixFigureJobs ([www.sixfigurejobs.com](#)) is a recruitment site designed for experienced executives. Resume posting and job searching is free to job seekers. Other sites, including [www.execunet.com](#), [Monster.com's ChiefMonster™](#) ([www.chiefmonster.com](#)) and [www.nationjob.com](#) are designed for helping executives find positions.

## H.5.6 Students and Young Professionals

The Internet provides students and young professionals with tools to get them started in the job market. Individuals still in school and seeking internships, individuals who are just graduating and individuals who have been in the workforce for a few years make up the target market. Additional tools specifically designed for this *demographic* (a population defined by a specific characteristic) are available. For example, journals kept by previous interns provide prospective interns with information regarding what to look for in an internship, what to expect and what to avoid. Many sites will provide information to lead young professionals in the right direction, such as matching positions to their college or university major.

**Experience.com** is a career services Web site geared toward the younger population. Members can search for positions according to specific criteria, such as geo-

graphic location, job category, keywords, commitment (i.e. full time, part time, internship), amount of vacation and amount of travel time. After applicants register, they can send their resumes directly to the companies posted on the site. In addition to the resume, candidates provide a personal statement, a list of applicable skills and their language proficiency. Registered members also receive access to the site's *Job Agent*. Up to three Job Agents can be used by each member. The agents search for available positions, based on the criteria posted by the member. If a match is made, the site contacts the candidate via e-mail.<sup>16,17</sup>

**internshipprograms.com** helps students find internships. In addition to posting a resume and searching for an internship, students can use the relocation calculator to compare the cost of living in different regions. Tips on building resumes and writing essays are provided. The *City Intern* program provides travel, housing and entertainment guides to interns interviewing or accepting a position in an unfamiliar city, making them feel more at home in a new location.

In addition to its internship locators, undergraduate, graduate, law school, medical school and business school services, the Princeton Review's Web site ([www.review.com](http://www.review.com)) offers career services to graduating students. While searching for a job, students and young professionals can also read through the site's news reports or even increase their vocabulary by visiting the "word for the day." Other career sites geared toward the younger population include **campuscareercenter.com**, **brassring-campus.com** and **collegegrads.com**.

## H.5.7 Other Online Career Services

In addition to Web sites that help users find and post jobs online, there are a number of Web sites that offer features that will enhance searches, prepare users to search online, help applicants design resumes or help users calculate the cost of relocating.

**Salary.com** helps job seekers gauge their expected income, based on position, level of responsibility and years of experience. The search requires job category, ZIP code and specific job title. Based on this information, the site will return an estimated salary for an individual living in the specified area and employed in the position described. Estimates are returned based on the average level of income for the position.

In addition to helping applicants find employment, **www.careerpower.com** provides individuals with tests that will help them realize their strengths, weaknesses, values, skills and personality traits. Based on the results, which can be up to 10–12 pages per test, users can best decide what job categories they are qualified for and what career choice will be best suited to their personal ambitions. The service is available for a fee.

InterviewSmart™ is another service offered through CareerPower that prepares job seekers of all levels for the interviewing process. The service can be downloaded for a minimal fee or can be used on the Web for free. Both versions are available at [www.career-power.com/CareerPerfect/interviewing.htm#is.start.anchor](http://www.career-power.com/CareerPerfect/interviewing.htm#is.start.anchor).

Additional services will help applicants find positions that meet their unique needs, or design their resumes to attract the attention of specific employers. **Dogfriendly.com**, organized by geographic location, helps job seekers find opportunities that allow them to bring their pets to work, and **cooljobs.com** is a searchable database of unique job opportunities.

## H.6 Internet and World Wide Web Resources

### *Information Technology (IT) Career Sites*

#### **www.dice.com**

This is a recruiting Web site that focuses on the computer industry.

#### **www.guru.com**

This is a recruiting site for contract employees. Independent contractors, private consultants and trainers can use **guru.com** to find short-term and long-term work.

#### **www.hallkinion.com**

This is a Web recruiting service for individuals seeking IT positions.

#### **www.techrepublic.com**

This site provides employers and job seekers with recruiting capabilities and information regarding developing technology.

#### **www.justcomputerjobs.com**

This site serves as a portal with access to language-specific sites, including Java, Perl, C and C++.

#### **www.bid4geeks.com**

This career services site is geared toward the technical professional.

#### **www.hotdispatch.com**

This forum provides software developers with the opportunity to share projects, discuss code and ask questions.

#### **www.techjobs.bizhosting.com/jobs.htm**

This site directs job seekers to links of numerous technological careers listed by location, internet, type of field, etc.

### *Career Sites*

#### **www.careerbuilder.com**

A network of career sites, including IT Careers, *USA Today* and MSN, CareerBuilder attracts 3 million unique job seekers per month. The site provides resume-builder and job-searching agents.

#### **www.recruitek.com**

This free site caters to jobs seekers, employers and contractors.

#### **www.monster.com**

This site, the largest of the online career sites, allows people looking for jobs to post their resumes, search job listings and read advice and information about the job-search process. It also provides a variety of recruitment services for employers.

#### **www.jobsonline.com**

Similar to **Monster.com**, this site provides opportunities for job seekers and employers.

#### **www.hotjobs.com**

This online recruiting site offers cross-listing possibilities on additional sites.

#### **www.jobfind.com**

This job site is an example of locally targeted job-search resources. **JobFind.com** targets the Boston area.

#### **www.flipdog.com**

This site allows online job candidates to search for career opportunities. It employs intelligent agents to scour the Web and return jobs matching the candidate's request.

**[www.cooljobs.com](http://www.cooljobs.com)**

This site highlights unique job opportunities.

**[www.careerhighway.com](http://www.careerhighway.com)**

This site presents an opportunity for job seekers and employers to match up and register the career-specific information for which they are searching.

**[www.inetsupermall.com](http://www.inetsupermall.com)**

This site aids job searchers in creating professional resumes and connecting with employers.

**[www.wirelessnetworksonline.com](http://www.wirelessnetworksonline.com)**

This site helps connect job searchers to careers for which they are qualified.

**[www.careerweb.com](http://www.careerweb.com)**

This site highlights featured employers and jobs and allows job seekers and employers to post and view resumes, respectively.

***Executive Positions*****[www.sixfigurejobs.com](http://www.sixfigurejobs.com)**

This is a recruitment site designed for experienced executives.

**[www.leadersonline.com](http://www.leadersonline.com)**

This career services Web site offers confidential job searches for mid-level professionals. Potential job matches are e-mailed to job candidates.

**[www.ecrutinginc.com](http://www.ecrutinginc.com)**

This site is designed to search for employees for executive positions.

***Diversity*****[www.latpro.com](http://www.latpro.com)**

This site is designed for Spanish-speaking and Portuguese-speaking job seekers. In addition to providing resume-posting services, the site enables job seekers to receive matching positions via e-mail. Advice and information services are available.

**[www.blackvoices.com](http://www.blackvoices.com)**

This portal site hosts a career center designed to match African American job seekers with job opportunities.

**[www.hirediversity.com](http://www.hirediversity.com)**

In addition to services for searching for and posting positions, resume-building and updating services are also available on this site. The site targets a variety of demographics including African Americans, Asian Americans, people with disabilities, women and Latin Americans.

***People with Disabilities*****[www.halftheplanet.com](http://www.halftheplanet.com)**

This site represents people with disabilities. The site is large and includes many different resources and information services. A special section is dedicated to job seekers and employers.

**[www.wemedia.com](http://www.wemedia.com)**

This site is designed to meet the needs of people with disabilities. It includes a section for job seekers and employers.

**[www.disabilities.com](http://www.disabilities.com)**

This site provides users with a host of links to information resources on career opportunities.

**[www.rileygude.com](http://www.rileygude.com)**

This site includes a section with opportunities for people with disabilities, which can be viewed at [www.dbm.com/jobguide/vets.html#abled](http://www.dbm.com/jobguide/vets.html#abled).

**[www.mindexchange.com](http://www.mindexchange.com)**

The diversity section of this site provides users with several links to additional resources regarding people with disabilities and employment.

**[www.usdoj.gov/crt/ada/adahom1.htm](http://www.usdoj.gov/crt/ada/adahom1.htm)**

This is the Americans with Disabilities Act home page.

**[www.abanet.org/disability/home.html](http://www.abanet.org/disability/home.html)**

This is the Web site for The Commission on Mental and Physical Disability Law.

**[janweb.icdi.wvu.edu](http://janweb.icdi.wvu.edu)**

The Job Accommodation Web site offers consulting services to employers regarding integration of people with disabilities into the workplace.

***General Resources*****[www.vault.com](http://www.vault.com)**

This site provides potential employees with “insider information” on over 3000 companies. In addition, job seekers can search through available positions and post and answer questions on the message board.

**[www.wetfeet.com](http://www.wetfeet.com)**

Similar to [vault.com](http://www.vault.com), this site allows visitors to ask questions and receive “insider information” on companies that are hiring.

***Free Services*****[www.sleuth.com](http://www.sleuth.com)**

On this site job seekers can fill out a form that indicates their desired field of employment. Job Sleuth™ searches the Internet and returns potential matches to the user’s inbox. The service is free.

**[www.ajb.org](http://www.ajb.org)**

America’s Job Bank is an online recruiting service provided through the Department of Labor and the state employment service. Searching for and posting positions on the site are free.

**[www.xdrive.com](http://www.xdrive.com)**

This free site provides members with 25 MB of storage space for housing documents related to a user’s job search. XDrive is able to communicate with all browser types and has wireless capabilities.

**[www.driveway.com](http://www.driveway.com)**

Similar to [XDrive.com](http://www.xdrive.com), this Web site provides users with 100 MB of storage space. Users can back up, share and organize information about various job searches. [Driveway.com](http://www.driveway.com) works on all platforms.

***Special Interest*****[www.eharvest.com/careers/index.cfm](http://www.eharvest.com/careers/index.cfm)**

This Web site provides job seekers interested in agricultural positions with online career services.

**[www.opportunitynocs.org](http://www.opportunitynocs.org)**

This career services site is for both employers and job seekers interested in non-profit opportunities.

**[www.experience.com](http://www.experience.com)**

This Web site is designed specifically for young professionals and students seeking full-time, part-time and internship positions.

**www.internshipprograms.com**

Students seeking internships can search job listings on this site. It also features City Intern, to help interns become acquainted with a new location.

**www.brassringcampus.com**

This site provides college grads and young professionals with less than five years of experience with job opportunities. Additional features help users buy cars or find apartments.

***Online Contracting*****www.ework.com**

This online recruiting site matches outside contractors with companies needing project specialists. Other services provided through eWork include links to online training sites, benefits packages and payment services and online meeting and management resources.

**www.elance.com**

Similar to **eWork.com**, eLance matches outside contractors with projects.

**www.freeagent.com**

FreeAgent matches contractors with projects.

**www.MBAFreeAgent.com**

This site is designed to match MBAs with contracting opportunities.

**www.aquent.com**

This site provides access to technical contracting positions.

**www.WorkingSolo.com**

This site helps contractors begin their own projects.

***Recruiting Services*****www.advantagehiring.com**

This site helps employers screen resumes.

**www.etest.net**

This site provides employers with testing services to assess the strengths and weaknesses of prospective employees. This information can be used for better hiring strategies.

**www.hire.com**

**Hire.com**'s eRecruiter is an application service provider that helps organizations streamline their Web-recruiting process.

**www.futurestep.com**

Executives can register confidentially at **Futurestep.com** to be considered for senior executive positions. The site connects registered individuals to positions. It also offers career management services.

**www.webhire.com**

This site provides employers with end-to-end recruiting solutions.

***Wireless Career Resources*****www.wirelessresumes.com**

This site connects employers and job seekers with resumes that focus on jobs revolving around wireless technology.

**www.msua.org/job.htm**

This site contains links to numerous wireless job-seeking Web sites.

**www.jobs4wireless.com**

This site searches for jobs in the wireless telecommunications field.

**www.staffing.net**

This site allows job seekers to discover openings in the world of wireless technology and communications.

**www.wiwc.org**

This site's focus is wireless communication job searching for women.

**www.firstsearch.com**

At this site a job seeker is able to discover part-time, full-time and salary-based opportunities in the wireless industry.

**www.pcsjobs.com**

This is the site for The Caradyne Group, which is an executive search firm that focuses on finding job seekers wireless job positions.

**www.cnijoblink.com**

CNI Career Networks offers confidential, no-charge job placement in the wireless and telecommunications industries.

## SUMMARY

- The Internet can improve an employer's ability to recruit employees and help users find career opportunities worldwide.
- Job seekers can learn how to write a resume and cover letter, post them online and search through job listings to find the jobs that best suit their needs.
- Employers can post jobs that can be searched by an enormous pool of applicants.
- Job seekers can store and distribute resumes digitally, receive e-mail notification of possible positions, use salary and relocation calculators, consult job coaches and use self-assessment tools when searching for a job on the Web.
- There are approximately 40,000 career-advancement services on the Internet today.
- Finding a job online can greatly reduce the amount of time spent applying for a position. Potential candidates can also learn more about a company by visiting its Web site.
- Most sites are free to job seekers. These sites typically generate their revenues by charging employers who post their job opportunities, and by selling advertising space on their Web pages.
- Sites such as **Vault.com** and **WetFeet.com** allow job seekers to post questions about employers and positions in chat rooms and on bulletin boards.
- On many recruitment sites, the match of a resume to a position is conducted with resume-filtering software.
- A lack of confidentiality is a disadvantage of online career services.
- According to recent studies, the number of individuals researching employment positions through means other than the Internet, such as referrals, newspapers and temporary agencies, far outweighs the number of Internet job seekers.
- Career sites designed for individuals seeking technical positions are among the most popular online career sites.
- Online contracting services allow businesses to post positions for which they wish to hire outside resources, and allow individuals to identify projects that best suit their interests, schedules and skills.
- The Internet provides students and young professionals with some of the necessary tools to get them started in the job market. The target market is made up of individuals still in school and seek-

ing internships, individuals who are just graduating and individuals who have been in the work-force for a few years.

- There are a number of Web sites that offer features that enhance job searches, prepare users to search online, help design applicants' resumes or help users calculate the cost of relocating.
- Web recruiting reaches a much larger audience than posting an advertisement in the local newspaper.
- There are a variety of sites that allow employers to post jobs online. Some of these sites require a fee, which generally runs between \$100–200. Postings remain on the Web site for approximately 30–60 days.
- Employers should try to post to sites that are most likely to be visited by eligible candidates.
- When designing a job posting, defining what makes a job position unique and including information such as benefits and salary might convince a qualified candidate to further investigate the position.
- The Internet hosts demographic-specific sites for employers seeking to increase diversity in the workplace.
- The Internet has provided employers with a cost-effective means of testing their prospective employees in such categories as decision making, problem solving and personality.

## TERMINOLOGY

corporate culture	open-ended question
demographic	pay-per-hire
end-to-end recruiting solutions	
entry-level position	request for proposal (RFP)
online contracting service	resume-filtering software

## SELF-REVIEW EXERCISES

- H.1** State whether each of the following is *true* or *false*. If *false*, explain why.
- Online contracting services allow businesses to post job listings for specific projects that can be viewed by job seekers over the Web.
  - Employment networks are Web sites designed to provide information on a selected company to better inform job seekers of the corporate environment.
  - The large number of applications received over the Internet is considered an advantage by most online recruiters.
  - There is a greater number of individuals searching for work on the Web than through all other mediums combined.
  - Sixteen percent of America's workforce is categorized as independent contractors.
- H.2** Fill in the blanks in each of the following statements:
- There are approximately \_\_\_\_\_ online career services Web sites on the Internet today.
  - The Internet hosts demographic-specific sites for employers seeking to increase \_\_\_\_\_ in the workplace.
  - In the 24 hours following the Super Bowl, \_\_\_\_\_ job searches occurred on **Monster.com**.
  - Many recruitment sites use \_\_\_\_\_ to filter through received resumes.
  - Employers should try to post to sites that are most likely to be visited by \_\_\_\_\_ candidates.

## ANSWERS TO SELF-REVIEW EXERCISES

**H.1** a) True. b) True. c) False. The large number of applicants reduces the amount of time a recruiter can spend interviewing and making decisions. Despite screening processes, many highly qualified applicants can be overlooked. d) False. The number of individuals researching employment positions through other means, such as referrals, newspapers and temporary agencies, far outweighs the number of Internet job seekers. e) False. Six percent of America's workforce is categorized as independent consultants.

**H.2** a) 40,000. b) diversity. c) 5 million. d) resume-filtering software. e) eligible.

## EXERCISES

**H.3** State whether each of the following is *true* or *false*. If *false*, explain why.

- a) RFP is the acronym for request for proposal.
- b) The Internet has provided employers with a cost-effective means of testing their prospective employees in such categories as decision making, problem solving and personality.
- c) Online job recruiting can completely replace other means of hiring employees.
- d) Posting a job online is less expensive than placing ads in more traditional media.
- e) A lack of confidentiality is a disadvantage of online career services.

**H.4** Fill in the blanks in each of the following statements:

- a) Finding a job online can greatly \_\_\_\_\_ the amount of time spent applying for a position.
- b) \_\_\_\_\_ is an example of a Web site in which contractors can bid on projects.
- c) When designing a job posting, defining what makes the position unique and including information such as \_\_\_\_\_ and \_\_\_\_\_ might convince a qualified candidate to further investigate the position.
- d) The Internet hosts \_\_\_\_\_ for employers seeking to increase diversity in the workplace.
- e) The Internet provides employers with a cost-effective means of testing their prospective employees in such categories as \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.

**H.5** Define the following

- a) corporate culture
- b) pay-per-hire
- c) request for proposal (RFP)
- d) resume-filtering software

**H.6** (*Class discussion*). In this appendix, we discuss the shortcomings and advantages of recruiting on the Internet. Using the text, additional reading material and personal accounts answer the following questions. Be prepared to discuss your answers.

- a) Do you think finding a job is easier on the Web? Why or why not?
- b) What disadvantages can you identify?
- c) What are some of the advantages?
- d) Which online recruiting services do you think will be most successful? Why?

**H.7** Many of the career services Web sites we have discussed in this appendix offer resume-building capabilities. Begin building your resume, choosing an objective that is of interest to you. Think of your primary concerns. Are you searching for a paid internship or a volunteer opportunity? Do you have a specific location in mind? Do you have an opportunity for future employment? Are stock options important to you? Find several entry-level jobs that meet your requirements. Write a short summary of your results. Include any obstacles and opportunities.

**H.8** In this appendix, we have discussed online contracting opportunities. Visit FreeAgent ([www.freeagent.com](http://www.freeagent.com)) and create your own e.portfolio, or visit eLance ([www.elance.com](http://www.elance.com)) and search the requests for proposals for contracting opportunities that interest you.

**H.9** In this appendix, we have discussed many career services Web sites. Choose three sites. Explore the opportunities and resources offered by the sites. Visit any demonstrations, conduct a job search, build your resume and calculate your salary or relocation expenses. Answer the following questions.

- a) Which site provides the best service? Why?
- b) What did you like? Dislike?
- c) Write a brief summary of your findings, including descriptions of any features that you would add.

## WORKS CITED

The notation <[www.domain-name.com](#)> indicates that the citation is for information found at the Web site.

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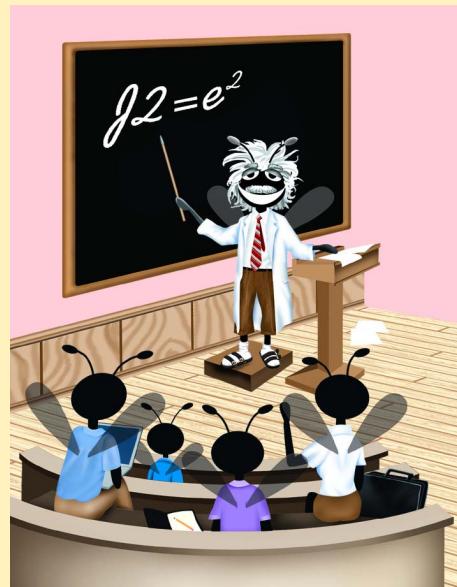
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# Unicode®

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## Objectives

- To become familiar with Unicode.
- To discuss the mission of the Unicode Consortium.
- To discuss the design basis of Unicode.
- To understand the three Unicode encoding forms: UTF-8, UTF-16 and UTF-32.
- To introduce characters and glyphs.
- To discuss the advantages and disadvantages of using Unicode.
- To provide a brief tour of the Unicode Consortium's Web site.



## Outline

- I.1 **Introduction**
- I.2 **Unicode Transformation Formats**
- I.3 **Characters and Glyphs**
- I.4 **Advantages/Disadvantages of Unicode**
- I.5 **Unicode Consortium's Web Site**
- I.6 **Using Unicode**
- I.7 **Character Ranges**

*Summary • Terminology • Self-Review Exercises • Answers to Self-Review Exercises • Exercises*

### I.1 Introduction

The use of inconsistent character *encodings* (i.e., numeric values associated with characters) when developing global software products causes serious problems because computers process information using numbers. For instance, the character “a” is converted to a numeric value so that a computer can manipulate that piece of data. Many countries and corporations have developed their own encoding systems that are incompatible with the encoding systems of other countries and corporations. For example, the Microsoft Windows operating system assigns the value 0xC0 to the character “A with a grave accent” while the Apple Macintosh operating system assigns that same value to an upside-down question mark. This results in the misrepresentation and possible corruption of data because data is not processed as intended.

In the absence of a widely-implemented universal character encoding standard, global software developers had to *localize* their products extensively before distribution. Localization includes the language translation and cultural adaptation of content. The process of localization usually includes significant modifications to the source code (such as the conversion of numeric values and the underlying assumptions made by programmers), which results in increased costs and delays releasing the software. For example, some English-speaking programmers might design global software products assuming that a single character can be represented by one byte. However, when those products are localized in Asian markets, the programmer’s assumptions are no longer valid, thus the majority, if not the entirety, of the code needs to be rewritten. Localization is necessary with each release of a version. By the time a software product is localized for a particular market, a newer version, which needs to be localized as well, is ready for distribution. As a result, it is cumbersome and costly to produce and distribute global software products in a market where there is no universal character encoding standard.

In response to this situation, the *Unicode Standard*, an encoding standard that facilitates the production and distribution of software, was created. The Unicode Standard outlines a specification to produce consistent encoding of the world’s characters and *symbols*. Software products which handle text encoded in the Unicode Standard need to be localized, but the localization process is simpler and more efficient because the numeric values need not be converted and the assumptions made by programmers about the character encoding are universal. The Unicode Standard is maintained by a non-profit organization called the

*Unicode Consortium*, whose members include Apple, IBM, Microsoft, Oracle, Sun Microsystems, Sybase and many others.

When the Consortium envisioned and developed the Unicode Standard, they wanted an encoding system that was *universal, efficient, uniform* and *unambiguous*. A universal encoding system encompasses all commonly used characters. An efficient encoding system allows text files to be parsed easily. A uniform encoding system assigns fixed values to all characters. An unambiguous encoding system represents a given character in a consistent manner. These four terms are referred to as the Unicode Standard design basis.

## I.2 Unicode Transformation Formats

Although Unicode incorporates the limited ASCII *character set* (i.e., a collection of characters), it encompasses a more comprehensive character set. In ASCII each character is represented by a byte containing 0s and 1s. One byte is capable of storing the binary numbers from 0 to 255. Each character is assigned a number between 0 and 255, thus ASCII-based systems can support only 256 characters, a tiny fraction of world's characters. Unicode extends the ASCII character set by encoding the vast majority of the world's characters. The Unicode Standard encodes all of those characters in a uniform numerical space from 0 to 10FFFF hexadecimal. An implementation will express these numbers in one of several transformation formats, choosing the one that best fits the particular application at hand.

Three such formats are in use, called *UTF-8*, *UTF-16* and *UTF-32*, depending on the size of the units—in *bits*—being used. UTF-8, a variable width encoding form, requires one to four bytes to express each Unicode character. UTF-8 data consists of 8-bit bytes (sequences of one, two, three or four bytes depending on the character being encoded) and is well suited for ASCII-based systems when there is a predominance of one-byte characters (ASCII represents characters as one-byte). Currently, UTF-8 is widely implemented in UNIX systems and in databases.

The variable width UTF-16 encoding form expresses Unicode characters in units of 16-bits (i.e., as two adjacent bytes, or a short integer in many machines). Most characters of Unicode are expressed in a single 16-bit unit. However, characters with values above FFFF hexadecimal are expressed with an ordered pair of 16-bit units called *surrogates*. Surrogates are 16-bit integers in the range D800 through DFFF, which are used solely for the purpose of “escaping” into higher numbered characters. Approximately one million characters can be expressed in this manner. Although a surrogate pair requires 32-bits to represent characters, it is space-efficient to use these 16-bit units. Surrogates are rare characters in current implementations. Many string-handling implementations are written in terms of UTF-16. [Note: Details and sample-code for UTF-16 handling are available on the Unicode Consortium Web site at [www.unicode.org](http://www.unicode.org).]

Implementations that require significant use of rare characters or entire scripts encoded above FFFF hexadecimal, should use UTF-32, a 32-bit fixed-width encoding form that usually requires twice as much memory as UTF-16 encoded characters. The major advantage of the fixed-width UTF-32 encoding form is that it uniformly expresses all characters, so it is easy to handle in arrays.

There are few guidelines that state when to use a particular encoding form. The best encoding form to use depends on computer systems and business protocols, not on the data itself. Typically, the UTF-8 encoding form should be used where computer systems and business protocols require data to be handled in 8-bit units, particularly in legacy systems

being upgraded because it often simplifies changes to existing programs. For this reason, UTF-8 has become the encoding form of choice on the Internet. Likewise, UTF-16 is the encoding form of choice on Microsoft Windows applications. UTF-32 is likely to become more widely used in the future as more characters are encoded with values above FFFF hexadecimal. Also, UTF-32 requires less sophisticated handling than UTF-16 in the presence of surrogate pairs.

Figure K.1 shows the different ways in which the three encoding forms handle character encoding.

### I.3 Characters and Glyphs

The Unicode Standard consists of *characters*, written components (i.e., alphabets, numbers, punctuation marks, accent marks, etc.) that can be represented by numeric values. Examples of characters include: U+0041 LATIN CAPITAL LETTER A. In the first character representation, U+yyyy is a *code value*, in which U+ refers to Unicode code values, as opposed to other hexadecimal values. The yyyy represents a four-digit hexadecimal number of an encoded character. Code values are bit combinations that represent encoded characters. Characters are represented using *glyphs*, various shapes, fonts and sizes for displaying characters. There are no code values for glyphs in the Unicode Standard. Examples of glyphs are shown in Fig. K.2.

The Unicode Standard encompasses the alphabets, ideographs, syllabaries, punctuation marks, *diacritics*, mathematical operators, etc. that comprise the written languages and scripts of the world. A diacritic is a special mark added to a character to distinguish it from another letter or to indicate an accent (e.g., in Spanish, the tilde “~” above the character “n”). Currently, Unicode provides code values for 94,140 character representations, with more than 880,000 code values reserved for future expansion.

Character	UTF-8	UTF-16	UTF-32
LATIN CAPITAL LETTER A	0x41	0x0041	0x00000041
GREEK CAPITAL LETTER ALPHA	0xCD 0x91	0x0391	0x00000391
CJK UNIFIED IDEOGRAPH-4E95	0xE4 0xBA 0x95	0x4E95	0x00004E95
OLD ITALIC LETTER A	0xF0 0x80 0x83 0x80	0xDC00 0xDF00	0x00010300

Fig. I.1 Correlation between the three encoding forms.



Fig. I.2 Various glyphs of the character A.

## I.4 Advantages/Disadvantages of Unicode

The Unicode Standard has several significant advantages that promote its use. One is the impact it has on the performance of the international economy. Unicode standardizes the characters for the world's writing systems to a uniform model that promotes transferring and sharing data. Programs developed using such a schema maintain their accuracy because each character has a single definition (i.e., *a* is always U+0061, % is always U+0025). This enables corporations to manage the high demands of international markets by processing different writing systems at the same time. Also, all characters can be managed in an identical manner, thus avoiding any confusion caused by different character code architectures. Moreover, managing data in a consistent manner eliminates data corruption, because data can be sorted, searched and manipulated using a consistent process.

Another advantage of the Unicode Standard is *portability* (i.e., software that can execute on disparate computers or with disparate operating systems). Most operating systems, databases, programming languages and Web browsers currently support, or are planning to support, Unicode.

A disadvantage of the Unicode Standard is the amount of memory required by UTF-16 and UTF-32. ASCII character sets are 8-bits in length, so they require less storage than the default 16-bit Unicode character set. However, the *double-byte character set (DBCS)* and the *multi-byte character set (MBCS)* that encode Asian characters (ideographs) require two to four bytes, respectively. In such instances, the UTF-16 or the UTF-32 encoding forms may be used with little hindrance on memory and performance.

Another disadvantage of Unicode is that although it includes more characters than any other character set in common use, it does not yet encode all of the world's written characters.

Another disadvantage of the Unicode Standard is that UTF-8 and UTF-16 are variable width encoding forms, so characters occupy different amounts of memory.

## I.5 Unicode Consortium's Web Site

If you would like to learn more about the Unicode Standard, visit [www.unicode.org](http://www.unicode.org). This site provides a wealth of information about the Unicode Standard that is insightful to those new to Unicode. Currently, the home page is organized into various sections—*New to Unicode*, *General Information*, *The Consortium*, *The Unicode Standard*, *Work in Progress* and *For Members*.

The *New to Unicode* section consists of two subsections: **What is Unicode** and **How to Use this Site**. The first subsection provides a technical introduction to Unicode by describing design principles, character interpretations and assignments, text processing and Unicode conformance. This subsection is recommended reading for anyone new to Unicode. Also, this subsection provides a list of related links that provide the reader with additional information about Unicode. The **How to Use this Site** subsection contains information about using and navigating the site as well hyperlinks to additional resources.

The *General Information* section contains six subsections: **Where is my Character**, **Display Problems**, **Useful Resources**, **Enabled Products**, **Mail Lists** and **Conferences**. The main areas covered in this section include a link to the Unicode code charts (a complete listing of code values) assembled by the Unicode Consortium as well as a detailed outline on how to locate an encoded character in the code chart. Also, the section contains advice on how to configure different operating systems and Web browsers so that

the Unicode characters can be viewed properly. Moreover, from this section, the user can navigate to other sites that provide information on various topics such as, fonts, linguistics and other standards such as the *Armenian Standards Page* and the *Chinese GB 18030 Encoding Standard*.

The *Consortium* section consists of five subsections: **Who we are, Our Members, How to Join, Press Info** and **Contact Us**. This section provides a list of the current Unicode Consortium members as well as information on how to become a member. Privileges for each member type—*full, associate, specialist* and *individual*—and the fees assessed to each member are listed here.

The *Unicode Standard* section consists of nine subsections: **Start Here, Latest Version, Technical Reports, Code Charts, Unicode Data, Update & Errata, Unicode Policies, Glossary** and **Technical FAQ**. This section describes the updates applied to the latest version of the Unicode Standard as well as categorizing all defined encoding. The user can learn how the latest version has been modified to encompass more features and capabilities. For instance, one enhancement of Version 3.1 is that it contains additional encoded characters. Also, if users are unfamiliar with vocabulary terms used by the Unicode Consortium, then they can navigate to the **Glossary** subsection.

The *Work in Progress* section consists of three subsections: **Calendar of Meetings, Proposed Characters** and **Submitting Proposals**. This section presents the user with a catalog of the recent characters included into the Unicode Standard scheme as well as those characters being considered for inclusion. If users determine that a character has been overlooked, then they can submit a written proposal for the inclusion of that character. The **Submitting Proposals** subsection contains strict guidelines that must be adhered to when submitting written proposals.

The *For Members* section consists of two subsections: **Member Resources** and **Working Documents**. These subsections are password protected; only consortium members can access these links.

## I.6 Using Unicode

Numerous programming languages (e.g., C, Java, JavaScript, Perl, Visual Basic, etc.) provide some level of support for the Unicode Standard. Figure K.3 shows a Java program that prints the text “Welcome to Unicode!” in eight different languages: English, Russian, French, German, Japanese, Portuguese, Spanish and Traditional Chinese. [Note: The Unicode Consortium’s Web site contains a link to code charts that lists the 16-bit Unicode code values.]

```
1 // Fig. K.3: Unicode.java
2 // Demonstrating how to use Unicode in Java programs.
3
4 // Java core packages
5 import java.awt.*;
6
7 // Java extension packages
8 import javax.swing.*;
9
```

Fig. I.3 Java program that uses Unicode encoding (part 1 of 3).

```
10 public class Unicode extends JFrame {
11     private JLabel english, chinese, cyrillic, french, german,
12         japanese, portuguese, spanish;
13
14     // Unicode constructor
15     public Unicode()
16     {
17         super( "Demonstrating Unicode" );
18
19         // get content pane and set its layout
20         Container container = getContentPane();
21         container.setLayout( new GridLayout( 8, 1 ) );
22
23         // JLabel constructor with a string argument
24         english = new JLabel( "\u0057\u0065\u006C\u0063\u006F" +
25             "\u006D\u0065\u0020\u0074\u006F\u0020Unicode\u0021" );
26         english.setToolTipText( "This is English" );
27         container.add( english );
28
29         chinese = new JLabel( "\u6B22\u8FCE\u4F7F\u7528\u0020" +
30             "\u0020Unicode\u0021" );
31         chinese.setToolTipText( "This is Traditional Chinese" );
32         container.add( chinese );
33
34         cyrillic = new JLabel( "\u0414\u043E\u0431\u0440\u043E" +
35             "\u0020\u043F\u043E\u0436\u0430\u043B\u043E\u0432" +
36             "\u0430\u0422\u044A\u0020\u0432\u0020Unicode\u0021" );
37         cyrillic.setToolTipText( "This is Russian" );
38         container.add( cyrillic );
39
40         french = new JLabel( "\u0042\u0069\u0065\u006E\u0076" +
41             "\u0065\u006E\u0075\u0065\u0020\u0061\u0075\u0020" +
42             "Unicode\u0021" );
43         french.setToolTipText( "This is French" );
44         container.add( french );
45
46         german = new JLabel( "\u0057\u0069\u006C\u006B\u006F" +
47             "\u006D\u0065\u006E\u0020\u007A\u0075\u0020" +
48             "Unicode\u0021" );
49         german.setToolTipText( "This is German" );
50         container.add( german );
51
52         japanese = new JLabel( "Unicode\u3078\u3087\u3045\u3053" +
53             "\u305D\u0021" );
54         japanese.setToolTipText( "This is Japanese" );
55         container.add( hiragana );
56
57         portuguese = new JLabel( "\u0053\u00E9\u006A\u0061\u0020" +
58             "\u0042\u0065\u006D\u0076\u0069\u006E\u0064" +
59             "\u006F\u0020Unicode\u0021" );
60         portuguese.setToolTipText( "This is Portuguese" );
61         container.add( portuguese );
62 }
```

Fig. I.3 Java program that uses Unicode encoding (part 2 of 3).

```
63     spanish = new JLabel( "\u0042\u0069\u0065\u006E\u0076" +
64         "\u0065\u006E\u0069\u0064\u0061\u0020\u0061\u0020" +
65         "Unicode\u0021" );
66     spanish.setToolTipText( "This is Spanish" );
67     container.add( spanish );
68
69 } // end Unicode constructor
70
71 // execute application
72 public static void main( String args[] )
73 {
74     Unicode application = new Unicode();
75     application.setDefaultCloseOperation(
76         JFrame.EXIT_ON_CLOSE );
77     application.pack();
78     application.setVisible( true );
79
80 } // end method main
81
82 } // end class Unicode
```



Fig. I.3 Java program that uses Unicode encoding (part 3 of 3).

The **Unicode.java** program uses *escape sequences* to represent characters. An escape sequence is in the form \uyyyy, where yyyy represents the four-digit hexadecimal code value. Lines 24 and 25 contain the series of escape sequences necessary to print “Welcome to Unicode!” in English. The first escape sequence (\u0057) equates to the character “W,” the second escape sequence (\u0065) equates to the character “e,” and so on. The \u0020 escape sequence (line 25) is the encoding for the *space* character. The \u0074 and \u006F escape sequences equate to the word “to.” Note that “Unicode” is not encoded because it is a registered trademark and has no equivalent translation in most languages. Line 25 also contains the \u0021 escape sequence for the exclamation mark (!).

Lines 29–65 contain the escape sequences for the other seven languages. The English, French, German, Portuguese and Spanish characters are located in the **Basic Latin** block, the Japanese characters are located in the **Hiragana** block, the Russian characters are located in the **Cyrillic** block and the Traditional Chinese characters are located in the **CJK Unified Ideographs** block.

[Note: To display the output of **Unicode.java** properly, copy the **font.properties.zh** file to the **font.properties** files (located in the **C:\Program Files\JavaSoft\JRE1.3.1\lib** and in the **C:\jdk1.3.1\jre\lib** directories). Save the contents of **font.properties** prior to overwriting them with the contents from **font.properties.zh**.

## I.7 Character Ranges

The Unicode Standard assigns code values, which range from **0000 (Basic Latin)** to **E007F (Tags)**, to the written characters of the world. Currently, there are code values for 94,140 characters. To simplify the search for a character and its associated code value, the Unicode Standard generally groups code values by *script* and function (i.e., Latin characters are grouped in a block, mathematical operators are grouped in another block, etc.). As a rule, a script is a single writing system that is used for multiple languages (e.g., the Latin script is used for English, French, Spanish, etc.). The **Code Charts** page on the Unicode Consortium Web site lists all the defined blocks and their respective code values. Figure I.4 lists some blocks (scripts) from the Web site and their range of code values.

### SUMMARY

- Before Unicode, software developers were plagued by the use of inconsistent character encoding (i.e., numeric values for characters). Most countries and organizations had their own encoding systems, which were incompatible. A good example is the individual encoding systems on the Windows and Macintosh platforms.

Script	Range of Code Values
<b>Arabic</b>	<b>U+0600–U+06FF</b>
<b>Basic Latin</b>	<b>U+0000–U+007F</b>
<b>Bengali</b> (India)	<b>U+0980–U+09FF</b>
<b>Cherokee</b> (Native America)	<b>U+13A0–U+13FF</b>
<b>CJK Unified Ideographs</b> (East Asia)	<b>U+4E00–U+9FAF</b>
<b>Cyrillic</b> (Russia and Eastern Europe)	<b>U+0400–U+04FF</b>
<b>Ethiopic</b>	<b>U+1200–U+137F</b>
<b>Greek</b>	<b>U+0370–U+03FF</b>
<b>Hangul Jamo</b> (Korea)	<b>U+1100–U+11FF</b>
<b>Hebrew</b>	<b>U+0590–U+05FF</b>
<b>Hiragana</b> (Japan)	<b>U+3040–U+309F</b>
<b>Khmer</b> (Cambodia)	<b>U+1780–U+17FF</b>
<b>Lao</b> (Laos)	<b>U+0E80–U+0EFF</b>
<b>Mongolian</b>	<b>U+1800–U+18AF</b>
<b>Myanmar</b>	<b>U+1000–U+109F</b>
<b>Ogham</b> (Ireland)	<b>U+1680–U+169F</b>
<b>Runic</b> (Germany and Scandinavia)	<b>U+16A0–U+16FF</b>
<b>Sinhala</b> (Sri Lanka)	<b>U+0D80–U+0DFF</b>
<b>Telugu</b> (India)	<b>U+0C00–U+0C7F</b>
<b>Thai</b>	<b>U+0E00–U+0E7F</b>

Fig. I.4 Some character ranges.

- Computers process data by converting characters to numeric values. For instance, the character “a” is converted to a numeric value so that a computer can manipulate that piece of data.
- Localization of global software requires significant modifications to the source code, which results in the increased cost and delays releasing the product.
- Localization is necessary with each release of a version. By the time a software product is localized for a particular market, a newer version, which needs to be localized as well, is ready for distribution. As a result, it is cumbersome and costly to produce and distribute global software products in a market where there is no universal character encoding standard.
- The Unicode Consortium developed the Unicode Standard in response to the serious problems created by multiple character encodings and the use of those encodings.
- The Unicode Standard facilitates the production and distribution of localized software. It outlines a specification for the consistent encoding of the world’s characters and symbols.
- Software products which handle text encoded in the Unicode Standard need to be localized, but the localization process is simpler and more efficient because the numeric values need not be converted.
- The Unicode Standard is designed to be universal, efficient, uniform and unambiguous.
- A universal encoding system encompasses all commonly used characters; an efficient encoding system parses text files easily; a uniform encoding system assigns fixed values to all characters; and a unambiguous encoding system represents the same character for any given value.
- Unicode extends the limited ASCII character set to include all the major characters of the world.
- Unicode makes use of three Unicode Transformation Formats (UTF): UTF-8, UTF-16 and UTF-32, each of which may be appropriate for use in different contexts.
- UTF-8 data consists of 8-bit bytes (sequences of one, two, three or four bytes depending on the character being encoded) and is well suited for ASCII-based systems when there is a predominance of one-byte characters (ASCII represents characters as one-byte).
- UTF-8 is a variable width encoding form that is more compact for text involving mostly Latin characters and ASCII punctuation.
- UTF-16 is the default encoding form of the Unicode Standard. It is a variable width encoding form that uses 16-bit code units instead of bytes. Most characters are represented by a single 16-bit unit, but some characters require surrogate pairs.
- Without surrogate pairs, the UTF-16 encoding form can only encompass 65,000 characters, but with the surrogate pairs, this is expanded to include over a million characters.
- UTF-32 is a 32-bit encoding form. The major advantage of the fixed-width encoding form is that it uniformly expresses all characters, so that they are easy to handle in arrays and so forth.
- The Unicode Standard consists of characters. A character is any written component that can be represented by a numeric value.
- Characters are represented using glyphs, which are various shapes, fonts and sizes for displaying characters.
- Code values are bit combinations that represent encoded characters. The Unicode notation for a code value is U+yyyy in which U+ refers to the Unicode code values, as opposed to other hexadecimal values. The yyyy represents a four-digit hexadecimal number.
- Currently, the Unicode Standard provides code values for 94,140 character representations.
- An advantage of the Unicode Standard is its impact on the overall performance of the international economy. Applications that conform to an encoding standard can be processed easily by computers.
- Another advantage of the Unicode Standard is its portability. Applications written in Unicode can be easily transferred to different operating systems, databases, Web browsers, etc. Most companies currently support, or are planning to support Unicode.

- To obtain more information about the Unicode Standard and the Unicode Consortium, visit [www.unicode.org](http://www.unicode.org). It contains a link to the code charts, which contain the 16-bit code values for the currently encoded characters.
- Numerous programming languages provide some level of support for the Unicode Standard.
- In Java programs, the `\uyyyy` escape sequence represents a character, where `yyyy` is the four-digit hexadecimal code value. The `\u0020` escape sequence is the universal encoding for the *space* character.

## TERMINOLOGY

\uyyyy escape sequence	portability
ASCII	script
block	surrogate
character	symbol
character set	unambiguous (Unicode design basis)
code value	Unicode Consortium
diacritic	Unicode design basis
double-byte character set (DBCS)	Unicode Standard
efficient (Unicode design basis)	Unicode Transformation Format (UTF)
encode	uniform (Unicode design basis)
escape sequence	universal (Unicode design basis)
glyph	UTF-8
hexadecimal notation	UTF-16
localization	UTF-32
multi-byte character set (MBCS)	

## SELF-REVIEW EXERCISES

- I.1** Fill in the blanks in each of the following.
- Global software developers had to \_\_\_\_\_ their products to a specific market before distribution.
  - The Unicode Standard is an \_\_\_\_\_ standard that facilitates the uniform production and distribution of software products.
  - The four design basis that constitute the Unicode Standard are: \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
  - A \_\_\_\_\_ is the smallest written component that can be represented with a numeric value.
  - Software that can execute on different operating systems is said to be \_\_\_\_\_.
- I.2** State whether each of the following is *true* or *false*. If *false*, explain why.
- The Unicode Standard encompasses all the world's characters.
  - A Unicode code value is represented as U+yyyy, where yyyy represents a number in binary notation.
  - A diacritic is a character with a special mark that emphasizes an accent.
  - Unicode is portable.
  - When designing Java programs, the escape sequence is denoted by /uyyyy.

## SELF-REVIEW ANSWERS

- I.1** a) localize. b) encoding. c) universal, efficient, uniform, unambiguous. d) character. e) portable.

**I.2** a) False. It encompasses the majority of the world's characters. b) False. The yyyy represents a hexadecimal number. c) False. A diacritic is a special mark added to a character to distinguish it from another letter or to indicate an accent. d) True. e) False. The escape sequence is denoted by \u<sub>4</sub>yyyy.

## EXERCISES

**I.3** Navigate to the Unicode Consortium Web site ([www.unicode.org](http://www.unicode.org)) and write the hexa-decimal code values for the following characters. In which block were they located?

- a) Latin letter 'Z.'
- b) Latin letter 'n' with the 'tilde (~).'
- c) Greek letter 'delta.'
- d) Mathematical operator 'less than or equal to.'
- e) Punctuation symbol 'open quote ("').'

**I.4** Describe the Unicode Standard design basis.

**I.5** Define the following terms:

- a) code value.
- b) surrogates.
- c) Unicode Standard.

**I.6** Define the following terms:

- a) UTF-8.
- b) UTF-16.
- c) UTF-32.

**I.7** Describe a scenario where it is optimal to store your data in UTF-16 format.

**I.8** Using the Unicode Standard code values, write a Java program that prints your first and last name. The program should print your name in all uppercase letters and in all lowercase letters. If you know other languages, print your first and last name in those languages as well.

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