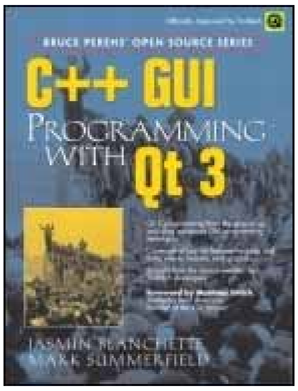


C++ GUI Programming with Qt 3

By Jasmin Blanchette, Mark Summerfield

Start Reading

Publisher	: Prentice Hall PTR
Pub Date	: January 15, 2004
ISBN	: 0-13-124072-2
Pages	: 464

"...not only the best book on Qt I have ever seen, but also the best book presenting any programming framework. Every sentence appears to be carefully worded, and every chapter has a sound concept, and so does the work as a whole."
-Matthias Ettrich, Trolltech's lead developer, founder of the KDE project

"The 'Tao of Qt'.... The Qt system is a beautiful example of object oriented design, and the authors take advantage of this.... The authors have done an excellent job of presenting the subject in an interesting and engaging way...."
-Ron McCarty, Instructor and Chair of the Department of Computer Science, Penn State Erie, The Behrend College

The first official Trolltech guide to Qt 3.2 programming!

Straight from Trolltech, this book covers all you need to build industrial-strength applications with Qt 3.2.x and C++-applications that run natively on Windows, Linux/Unix, Mac OS X, and embedded Linux with no source code changes! The book teaches solid Qt programming practices; it is not a rehash of the documentation. You'll find start-to-finish coverage packed with examples, plus a CD with the Qt 3.2 toolset and Borland C++ compilers-including a non-commercial Qt 3.2 for Windows available nowhere else!

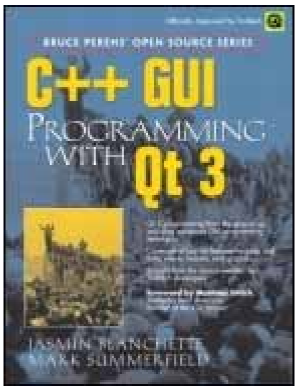
- Build powerful C++ GUI applications quickly and easily
- Design dialogs and main windows visually and in code
- Learn Qt's innovative typesafe signals and slots mechanism
- Use layouts to create forms that automatically size and scale
- Create custom signals, slots, events, and controls

- Program the ''Qt way'' with techniques for Qt 3.2 that'll work with Qt 4
- Code applications with menus, toolbars, dialogs, and drag and drop
- Utilize 2D and 3D graphics, multithreading, and networking
- Write database and XML applications
- Internationalize to reach foreign markets
- Exploit platform-specific-features like ActiveX

Already using Qt or just starting out? Evaluating Qt or managing it? Building open source applications-or commercial applications? Want to develop for Windows without buying an expensive compiler? Whatever your goal, this is the only book you need! CD-ROM: Everything you need to write great GUI programs!

- Qt 3.2 Non-Commercial Edition for Windows
- Borland C++ 5.5 Non-Commercial Edition
- Borland C++ 6.0 Trial Edition
- Qt 3.2 Free Editions for Unix/Linux/Mac OS X
- SQLite database
- The book's code examples

[Team LiB] NEXT



C++ GUI Programming with Qt 3

By Jasmin Blanchette, Mark Summerfield

Start Reading

Publisher	: Prentice Hall PTR
Pub Date	: January 15, 2004
ISBN	: 0-13-124072-2
Pages	: 464

Copyright

Library of Congress Cataloging-in-Publication Data

A CIP catalog record for this book can be obtained from the Library of Congress

Editorial/Production Supervision: Kathleen M. Caren

Cover Design Director: Jerry Votta

Art Director: Gail Cocker-Bogusz

Manufacturing Buyer: Maura Zaldivar

Acquisitions Editor: Jill Harry

Editorial Assistant: Brenda Mulligan

Marketing Manager: Dan Depasquale

First Printing

Pearson Education Ltd.
Pearson Education Australia Pty., Limited
Pearson Education Singapore, Pte. Ltd.
Pearson Education North Asia Ltd.
Pearson Education Canada, Ltd.
Pearson Educación de Mexico, S.A. de C.V.
Pearson Education-Japan
Pearson Education Malaysia, Pte. Ltd.

PREVIOUS NEXT

Bruce Perens' Open Source Series

Foreword

Why Qt? Why do programmers like us choose Qt? Sure, there are the obvious answers: Qt's single-source compatibility, its feature richness, its C++ performance, the availability of the source code, its documentation, the high-quality technical support, and all the other items mentioned in Trolltech's glossy marketing materials. This is all very well, but it misses the most important point: Qt is successful because programmers *like* it.

How come programmers like one technology, but dislike another? Personally, I believe software engineers enjoy technology that feels right, but dislike everything that doesn't. How else can we explain that some of the brightest programmers need help to program a VCR, or that most engineers seem to have trouble operating the company's phone system? I for one am perfectly capable of memorizing sequences of random numbers and commands, but if these are required to control my answering machine, I'd prefer not to have one. At Trolltech, our phone system forces us to hold the '*' key pressed down for two seconds before we are allowed to type in the other person's extension number. If you forget to do this but start typing the extension immediately, you have to dial the entire number again. Why '*'? Why not '#', or '1', or '5', or any of the other twenty keys on the phone? Why two seconds and not one, or three, or one and a half? Why anything at all? I find the phone so irritating that I avoid using it whenever I can. Nobody likes having to do random things, especially when those random things apparently depend on some equally random context you wish you didn't have to know about in the first place.

Programming can be a lot like using our phone system, only worse. And this is where Qt comes to the rescue. Qt is different. For one thing, Qt makes sense. And for another, Qt is fun. Qt lets you concentrate on your tasks. When Qt's original architects faced a problem, they didn't just look for a good solution, or a quick solution, or the simplest solution. They looked for the *right* solution, and then they documented it. Granted they made mistakes, and granted some of their design decisions didn't pass the test of time, but they still got a lot of things right, and what wasn't right could and can be corrected. You can see this by the fact that a system originally designed to bridge Windows 95 and Unix/Motif now unifies modern desktop systems as diverse as Windows XP, Mac OS X, and GNU/Linux with KDE.

Long before Qt became so popular and so widely used, the dedication of Qt's developers to finding the right solutions made Qt special. That dedication is just as strong today and affects everyone who maintains and develops Qt. For us, working on Qt is a responsibility and a privilege. We are proud of helping to make your professional and open source lives easier and more enjoyable.

One of the things that makes Qt a pleasure to use is its online documentation. But the documentation's focus is primarily on individual classes, with little said about how to build sophisticated real-world applications. This excellent book fills that gap. It shows you what Qt has to offer, how to program Qt the "Qt way", and how to get the best from Qt. The book will teach a C++ programmer how to program Qt, and provides enough advanced material to satisfy experienced Qt programmers. The book is packed with good examples, advice, and explanations, and will be the text that we use to induct all new programmers who join Trolltech.

Nowadays, there are a vast number of commercial and free Qt applications available for purchase or download. Some are specialized for particular vertical markets, while others are aimed at the mass-market. Seeing so many applications built with Qt fills us with pride and inspires us to make Qt even better. And with the help of this book, there will be more and higher quality Qt applications than ever before.

Matthias Ettrich
Oslo, Norway

Preface

The Qt toolkit is a C++ class library and a set of tools for building multiplatform GUI programs using a "write once, compile anywhere" approach. Qt lets programmers use a single source tree for applications that will run on Windows 95 to XP, Mac OS X, Linux, Solaris, HP-UX, and many other versions of Unix with X11. A version of Qt is also available for Embedded Linux, with the same API.

The purpose of this book is to teach you how to write GUI programs using Qt 3. The book starts with "Hello Qt" and quickly moves on to more advanced topics, such as creating custom widgets and providing drag and drop. The text is complemented by a CD that contains the source code of the example programs. The CD also provides Qt and Borland C++ for Windows, Qt for Unix, and Qt for Mac OS X. Appendix A explains how to install the software.

The book focuses on explaining good idiomatic Qt 3 programming techniques rather than simply rehashing or summarizing Qt's extensive online documentation. And because we are involved in the development of Qt 4, we have tried to ensure that most of what we teach here will still be valid and sensible for Qt 4.

It is assumed that you have a basic knowledge of C++. The code examples use a subset of C++, avoiding many C++ features that are rarely needed when programming Qt. In the few places where a more advanced C++ construct is unavoidable, it is explained as it is used.

Qt made its reputation as a multiplatform toolkit, but because of its intuitive and powerful API, many organizations use Qt for single-platform development. Adobe Photoshop Album is just one example of a mass-market Windows application written in Qt. Many sophisticated software systems in vertical markets, such as 3D animation tools, digital film processing, electronic design automation (for chip design), oil and gas exploration, financial services, and medical imaging, are built with Qt. If you are making a living with a successful Windows product written in Qt, you can easily create new markets in the Mac OS X and Linux worlds simply by recompiling.

Qt is available under various licenses. If you want to build commercial applications, you must buy a commercial license; if you want to build open source programs, you can use a non-commercial Qt edition. (The editions of Qt on the CD are non-commercial.) Qt is the foundation on which the K Desktop Environment (KDE) and the many open source applications that go with it are built.

In addition to Qt's hundreds of classes, there are add-ons that extend Qt's scope and power. Some of these products, like the Qt/Motif integration module and Qt Script for Applications (QSA), are supplied by Trolltech, while others are provided by companies and by the open source community. See http://www.trolltech.com/products/3rdparty/ for information on Qt add-ons. Qt also has a well-established and thriving user community that uses the `qt-interest` mailing list; see http://lists.trolltech.com/ for details.

The book is divided into two parts. Part I covers all the concepts and practices necessary for programming GUI applications using Qt. Knowledge of this part alone is sufficient to write useful GUI applications. Part II covers central Qt topics in more depth and provides more specialized and advanced material. The chapters of Part II can be read in any order, but they assume familiarity with the contents of Part I.

If you spot errors in the book, have suggestions for the next edition, or want to give us feedback, we would be delighted to hear from you. You can reach us at jasmin.blanchette@trolltech.com and mark.summerfield@trolltech.com. The errata will be placed on http://vig.prenhall.com/catalog/academic/product/0,4096,0131240722,00.html.

Acknowledgments

Our first acknowledgment goes to Eirik Chambe-Eng, Trolltech's president. Eirik not only enthusiastically encouraged us to write the book, he also allowed us to spend a considerable amount of our work time writing it. Eirik and Trolltech CEO Haavard Nord both read the manuscript and provided valuable feedback. Their generosity and foresight was aided and abetted by Matthias Ettrich, Trolltech's lead developer and our boss. Matthias cheerfully accepted our neglect of duty as we obsessed over the writing of this book and gave us a lot of advice on good Qt programming style.

We asked two Qt customers, Paul Curtis and Klaus Schmidinger, to be our external reviewers. Both are Qt experts with an amazing attention to technical detail, which they proved by spotting some very subtle errors in our manuscript and suggesting numerous improvements.

Within Trolltech, alongside Matthias, our most stalwart reviewer was Reginald Stadlbauer.[*] His technical insight was invaluable, and he taught us how to do some things in Qt that we didn't even know were possible.

[*] Reginald has now moved to Germany, where he co-founded froglogic, a software consultancy.

Our other key reviewers within Trolltech were Trenton Schulz, Andy Shaw, and Andreas Aardal Hanssen. Trenton and Andy gave feedback on all aspects of the book and were especially helpful regarding Qt/Mac and Qt/Windows. Andreas gave us invaluable help refining Part I.

In addition to the reviewers mentioned above, we received expert help from Warwick Allison (2D graphics), Eirik Chambe-Eng (Qt's history), Matthias Ettrich (event processing and custom widgets), Harald Fernengel (databases), Volker Hilsheimer (ActiveX), Bradley Hughes (multithreading), Trond Kjernåsen (3D graphics and databases), Lars Knoll (2D graphics), Sam Magnuson (`qmake`), Dimitri Papadopoulos (Qt/X11), Paul Olav Tvete (custom widgets and Qt/Embedded), Rainer Schmid (networking and XML), and Gunnar Sletta (event processing).

Extra thanks are due to Trolltech's support team for helping to keep our support load under control while the book consumed so much of our time, and to Trolltech's system administrators for keeping our machines running and our networks communicating throughout the project.

We are also grateful to Troy Kitch from Borland for giving us permission to include Borland C++ compilers on the accompanying CD, and to the SQLite developers for putting their database into the public domain.

On the production side, Rainer Schmid led the team that created the accompanying CD, ably supported by Harald Fernengel and Andy Shaw. Trolltech's Cathrine Bore handled the contracts and legalities on our behalf. Jeff Kingston, author of the Lout typesetting tool, gave us advice and enhanced the tool in the light of our feedback. Jill Harry of Prentice Hall had faith in the project from the start and ensured that all the practical matters were smoothly handled, leaving us free to concentrate on the writing. And Lisa Iarkowski turned our camera-ready manuscript into the beautiful volume you now hold in your hands.

A Brief History of Qt

The Qt toolkit first became publicly available in May 1995. It was initially developed by Haavard Nord (Trolltech's CEO) and Eirik Chambe-Eng (Trolltech's president). Haavard and Eirik met each other at the Norwegian Institute of Technology in Trondheim, Norway, where they both graduated with master's degrees in computer science.

Haavard's interest in C++ GUI development began in 1988 when he was commissioned by a Swedish company to design and implement a C++ GUI toolkit. A couple of years later, in the summer of 1990, Haavard and Eirik were working together on a C++ database application for ultrasound images. The system needed to be able to run with a GUI on Unix, Macintosh, and Windows. One day that summer, Haavard and Eirik went outside to enjoy the sunshine, and as they sat on a park bench, Haavard said, "We need an object-oriented display system." The resulting discussion laid the intellectual foundation for the object-oriented multiplatform GUI toolkit they would soon go on to build.

In 1991, Haavard started writing the classes that eventually became Qt, collaborating with Eirik on the design. The following year, Eirik came up the ideafor "signals and slots", a simple but powerful GUI programming paradigm. Haavard took the idea and produced a hand-coded implementation. By 1993, Haavard and Eirik had developed Qt's first graphics kernel and were able to implement their own widgets. At the end of the year, Haavard suggested that they go into business together to build "the world's best C++ GUI toolkit".

The year 1994 began inauspiciously with the two young programmers wanting to enter a well established market, with no customers, an unfinished product, and no money. Fortunately, both their wives had work and were willing to support their husbands for the two years Eirik and Haavard expected to need to develop the product and start earning an income.

They chose 'Q' as the class prefix because the letter looked beautiful in Haavard's Emacs font. The 't' was added to stand for "toolkit", inspired by "Xt", the X Toolkit. The company was incorporated on 4 March 1994, originally as "Quasar Technologies", then as "Troll Tech", and today as "Trolltech".

In April 1995, thanks to a contact made through one of Haavard's University professors, the Norwegian company Metis gave them a contract to develop software based on Qt. Around this time, Trolltech hired Arnt Gulbrandsen,[*] who devised and implemented an ingenious documentation system as well ascontributing to Qt's code.

[*] Arnt left the company a few years ago to pursue his career in Germany.

On 20 May 1995, Qt 0.90 was uploaded to `sunsite.unc.edu`. Six days later, the release was announced on `comp.os.linux.announce`. This was Qt's first public release. Qt could be used for both Windows and Unix development, offering the same API on both platforms. Qt was available under two licenses fromday one: A commercial license was required for commercial development and a free software edition was available for open source development. The Metis contract kept Trolltech afloat, while for ten long months no one bought a commercial Qt license.

In March 1996, the European Space Agency became the second Qt customer, with a purchase of ten commercial licenses. With unwavering faith, Eirik and Haavard hired another developer. Qt 0.97 was released at the end of May, and on 24 September 1996, Qt 1.0 came out. By the end of the year, Qt had reached version 1.1; eight customers, each in a different country, had bought 18 licenses between them. This year also saw the founding of the KDE project, led by Matthias Ettrich.

Qt 1.2 was released in April 1997. Matthias Ettrich's decision to use Qt to build KDE helped Qt become the de-facto standard for C++ GUI development on Linux. Qt 1.3 was released in September 1997.

Matthias joined Trolltech in 1998, and the last major Qt 1 release, 1.40, was made in September of that year. Qt 2.0 was released in June 1999. Qt 2 hadmany major architectural changes and was a much stronger and more mature product than its predecessor. It also featured forty new classes and Unicode support. Qt 2 had a new open source license, the Q Public License (QPL), which complied to the Open Source Definition. In August 1999, Qt won the LinuxWorld award for best library/tool. Around this time, Trolltech Pty Ltd (Australia) was established.

Trolltech released Qt/Embedded in 2000. It was designed to run on Embedded Linux devices and provided is own window system as a lightweight replacement for X11. Both Qt/Embedded and Qt/X11 were now offered under the widely used GNU General Public License (GPL) as well as under commercial licenses. By the end of 2000, Trolltech had established Trolltech Inc. (USA) and had released the first version of Qtopia, an environment for handheld devices. Qt/Embedded won the LinuxWorld "Best Embedded Linux Solution"award in both 2001 and 2002.

Qt 3.0 was released in 2001. Qt was now available on Windows, Unix, Linux, Embedded Linux, and Mac OS X. Qt 3.0 provided 42 new classes and the code surpassed 500,000 lines. Qt 3.0 won the Software Development Times "Jolt Productivity Award" in 2002.

Trolltech's sales have doubled year on year since the company's birth. This success is a reflection both of the quality of Qt and of how enjoyable it is to use. For most of the company's existence, sales and marketing were handled by just a couple of people. Yet, in less than a decade, Qt has gone from being a "secret" product, known only to a select group of professionals, to having thousands of customers and tens of thousands of open source developers all around the world.

About the Authors

Jasmin Blanchette

Jasmin graduated in computer science in 2001 from the University of Sherbrooke, Quebec, and was awarded the Fernand Seguin medal of excellence. He did a work term at Trolltech in the summer of 2000 as a software engineer and has been working there continuously since early 2001. Now a senior software engineer, he is the driving force behind the *Qt Linguist* translation tool and provides *Qt Quarterly*, Trolltech's technical newsletter, with much of its content. In his spare time, he is writing a novel in Norwegian and Swedish. He lives in Oslo with his girlfriend Anne-Lene.

Mark Summerfield

Mark graduated in computer science in 1993 from the University of Wales Swansea. He followed this with a year's postgraduate research before going into industry. He spent many years working as a software engineer for a variety of firms before joining Trolltech. For the past few years, he has been Trolltech's documentation manager, responsible for maintaining over 1500 pages of online Qt documentation and for editing *Qt Quarterly*. In his free time, he writes open source software. He lives in the Swansea Valley in South Wales, UK, with his wife Andrea.

Production

The authors wrote the text using NEdit and Vim. They typeset and indexed the text themselves, marking it up with a modified Lout syntax that they converted to pure Lout using a custom preprocessor written in Python. They produced all the diagrams in Lout and used ImageMagick to convert screenshots to PostScript. The monospaced font used for code is derived from Courier and was created using PfaEdit. The cover was provided by the publisher; the photograph is of the fall of the Berlin Wall, November 1989. The marked-up text was converted to PostScript by Lout, then to PDF by Ghostscript. The authors did all the editing and processing on Debian GNU/Linux systems under KDE. The example programs were tested on Windows, Linux, and Mac OS X.

About the CD-ROM

The CD-ROM included with *C++ GUI Programming with Qt 3* contains all the software and source code needed to create and run applications on Windows, Mac OS X, and Unix/Linux with X11. The CD-ROM includes the following:

- Qt 3.2.1 Non-Commercial Edition for Windows
- Qt 3.2.1 Free Edition for Mac OS X
- Qt 3.2.1 Free Edition for Unix/Linux with X11
- Borland C++ Builder 5 Non-Commercial Edition
- Borland C++ Builder 6 Trial Edition
- Source code for the book's examples

All versions of Qt come with the Qt library and a set of tools including the `qmake` build tool, *Qt Designer* for visual dialog design, *Qt Linguist* for internationalization support, and *Qt Assistant* for presenting documentation.

The CD-ROM can be used on Microsoft Windows 95, 98, NT 4, ME, 2000, XP, Mac OS X, Linux, and most versions of Unix.

License Agreement

Each of the software packages on the CD-ROM has its own license agreement. The full legal texts of the licenses are included with the packages on the CD-ROM.

Technical Support

Neither Prentice Hall nor Trolltech offers any technical support for any of the software on the CD-ROM. (Fully supported commercial editions of Qt are available from Trolltech; fully supported commercial editions of Borland C++ Builder are available from Inprise.) If the CD-ROM is damaged, you can obtain a replacement copy by sending an email that describes the problem to disc_exchange@prenhall.com.

[Team LiB]

Part I: Basic Qt

[Team LiB]

[Team LiB]

Chapter 1. Getting Started

This chapter shows how to combine basic C++ with the functionality provided by Qt to create a few small graphical user interface (GUI) applications. This chapter also introduces two key Qt ideas: "signals and slots" and layouts. In Chapter 2, we will go into more depth, and in Chapter 3, we will start building a realistic application.

[Team LiB]

[Team LiB]

Hello Qt

Here's a very simple Qt program:

```
 1 #include <qapplication.h>
 2 #include <qlabel.h>

 3 int main(int argc, char *argv[])
 4 {
 5     QApplication app (argc, argv);
 6     QLabel *label = new QLabel("Hello Qt!", 0);
 7     app.setMainWidget(label);
 8     label->show();
 9     return app.exec();
10 }
```

We will first study it line by line, then we will see how to compile and run it.

Lines 1 and 2 include the definitions of the `QApplication` and `QLabel` classes.

Line 5 creates a QApplication object to manage application-wide resources. The QApplication constructor requires argc and argv because Qt supports a few command-line arguments of its own.

Line 6 creates a QLabel widget that displays "Hello Qt!". In Qt terminology, a *widget* is a visual element in a user interface. Buttons, menus, scroll bars, and frames are all examples of widgets. Widgets can contain other widgets; for example, an application window is usually a widget that contains a QMenuBar, a QToolBar, a QStatusBar, and some other widgets. The 0 argument to the QLabel constructor (a null pointer) means that the widget is a window in its own right, not a widget inside another window.

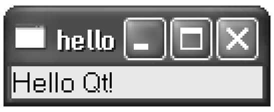
Line 7 makes the label the application's main widget. When the user closes the main widget (by clicking X in the window's title bar, for example), the program terminates. Without a main widget, the program would keep running in the background even after the user has closed the window.

Line 8 makes the label visible. Widgets are always created hidden, so that we can customize them before showing them, thereby avoiding flicker.

Line 9 passes control of the application on to Qt. At this point, the program enters a kind of stand-by mode, where it waits for user actions such as mouse clicks and key presses.

User actions generate *events* (also called "messages") to which the program can respond, usually by executing one or more functions. In this respect, GUI applications differ drastically from conventional batch programs, which typically process input, produce results, and terminate without human intervention.

Figure 1.1. Hello on Windows XP



It is now time to test the program on your machine. First, you will need to install Qt 3.2 (or a later Qt 3 release), a process that is explained in Appendix A. From now on, we will assume that you have a correctly installed copy of Qt 3.2 and that Qt's bin directory is in your PATH environment variable. (On Windows, this is done automatically by the Qt installation program, so you don't need to worry about it.)

You will also need the Hello program's source code in a file called hello.cpp in a directory called hello. You can type in hello.cpp yourself, or copy it from the CD provided with this book, where it is available as \examples\chap01\hello\hello.cpp.

From a command prompt, change directory to hello, then type

```
qmake -project
```

to create a platform-independent project file (hello.pro), then type

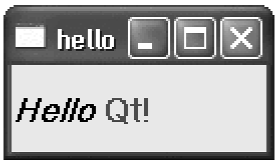
```
qmake hello.pro
```

to create a platform-specific makefile from the project file. Run make to build the program, and run the program by typing hello on Windows, ./hello on Unix, and open hello.app on Mac OS X. If you are using Microsoft Visual C++, you will need to run nmake instead of make. Alternatively, you can create a Visual Studio project file from hello.pro by typing

```
qmake -tp vc hello.pro
```

and then build the program in Visual Studio.

Figure 1.2. A label with basic HTML formatting



Now let's have some fun: We will brighten up the label by using some simple HTML-style formatting. This can be done by replacing the line

```
QLabel *label = new QLabel("Hello Qt!", 0);
```

with

```
QLabel *label = new QLabel("<h2><i>Hello</i> "
                           "<font color=red>Qt!</font></h2>", 0);
```

and rebuilding the application.

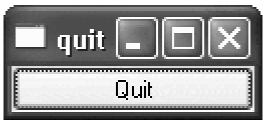
[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Making Connections

The next example illustrates how to respond to user actions. The application consists of a button that the user can click to quit. The source code is very similar to Hello, except that we are using a `QPushButton` instead of a `QLabel` as our main widget, and we are connecting a user action (clicking a button) to a piece of code.

This application's source code is on the CD in the file `\examples\chap01\quit\quit.cpp`.

Figure 1.3. The Quit application



```
#include <qapplication.h>
#include <qpushbutton.h>

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    QPushButton *button = new QPushButton("Quit", 0);
    QObject::connect(button, SIGNAL(clicked()),
                     &app, SLOT(quit()));
    app.setMainWidget(button);
    button->show();
    return app.exec();
}
```

Qt's widgets emit *signals* to indicate that a user action or a change of state has occurred.[*] For instance, `QPushButton` emits a `clicked()` signal when the user clicks the button. A signal can be connected to a function (called a *slot* in that context), so that when the signal is emitted, the slot is automatically executed. In our example, we connect the button's `clicked()` signal to the `QApplication` object's `quit()` slot. The `SIGNAL()` and `SLOT()` macros are part of the syntax; they are explained in more detail in the next chapter.

[*] Qt signals are unrelated to Unix signals. In this book, we are only concerned with Qt signals.

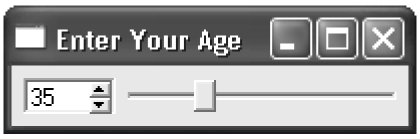
We will now build the application. We assume that you have created a directory called `quit` containing `quit.cpp`. Run `qmake` in the `quit` directory to generate the project file, then run it again to generate a makefile:

```
qmake -project
qmake quit.pro
```

Now build the application, and run it. If you click *Quit*, or press *Space* (which presses the button), the application will terminate.

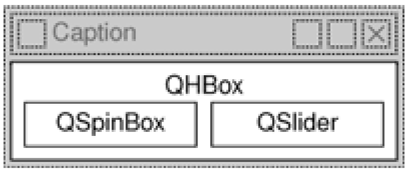
The next example demonstrates how to use signals and slots to synchronize two widgets. The application asks for the user's age, which the user can enter by manipulating either a spin box or a slider.

Figure 1.4. The Age application



The application consists of three widgets: a `QSpinBox`, a `QSlider`, and a `QHBox` (horizontal layout box). The `QHBox` is the application's main widget. The `QSpinBox` and the `QSlider` are rendered inside the `QHBox`; they are *children* of the `QHBox`.

Figure 1.5. The Age application's widgets



```
#include <qapplication.h>
#include <qhbox.h>
#include <qslider.h>
#include <qspinbox.h>

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);

    QHBox *hbox = new QHBox(0);
    hbox->setCaption("Enter Your Age");
    hbox->setMargin(6);
    hbox->setSpacing(6);

    QSpinBox *spinBox = new QSpinBox(hbox);
    QSlider *slider = new QSlider(Qt::Horizontal, hbox);
    spinBox->setRange(0, 130);
    slider->setRange(0, 130);
16     QObject::connect(spinBox, SIGNAL(valueChanged(int)),
17                      slider, SLOT(setValue(int)));
18     QObject::connect(slider, SIGNAL(valueChanged(int)),
19                      spinBox, SLOT(setValue(int)));
20     spinBox->setValue(35);

21     app.setMainWidget(hbox);
22     hbox->show();

23     return app.exec();
24 }
```

Lines 8 to 11 set up the `QHBox`.[*] We call `setCaption()` to set the text displayed in the window's title bar. Then we put some space (6 pixels) around and in between the child widgets.

[*] If you get a compiler error on the `QHBox` constructor, it means that you are using an older version of Qt. Make sure that you are using Qt 3.2.0 or a later Qt 3 release.

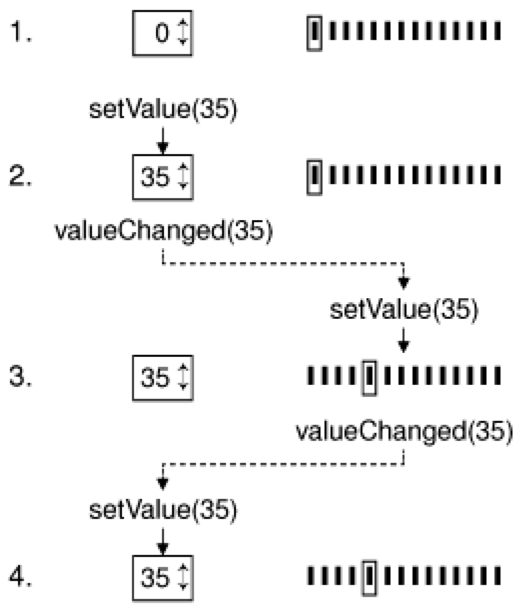
Lines 12 and 13 create a `QSpinBox` and a `QSlider` with the `QHBox` as the parent.

Even though we didn't set the position or size of any widget explicitly, the `QSpinBox` and `QSlider` appear nicely laid out side by side inside the `QHBox`. This is because `QHBox` automatically assigns reasonable positions and sizes to its children based on their needs. Qt provides many classes like `QHBox` to free us from the chore of hard-coding screen positions in our applications.

Lines 14 and 15 set the valid range for the spin box and the slider. (We can safely assume that the user is at most 130 years old.) The two `connect()` calls shown in lines 16 to 19 ensure that the spin box and the slider are synchronized so that they always show the same value. Whenever the value of one widget changes, its `valueChanged(int)` signal is emitted, and the `setValue(int)` slot of the other widget is called with the new value.

Line 20 sets the spin box value to 35. When this happens, the `QSpinBox` emits the `valueChanged(int)` signal with an `int` argument of 35. This argument is passed to the `QSlider`'s `setValue(int)` slot, which sets the slider value to 35. The slider then emits the `valueChanged(int)` signal, because its own value changed, triggering the spin box's `setValue(int)` slot. But at this point, `setValue(int)` doesn't emit any signal, since the spin box value is already 35. This prevents infinite recursion. Figure 1.6 summarizes the situation.

Figure 1.6. Changing one value changes both



Line 22 shows the `QHBox` and its two child widgets.

Qt's approach to building user interfaces is simple to understand and very flexible. The most common pattern that Qt programmers use is to instantiate the required widgets and then set their properties as necessary. Programmers add the widgets to layouts, which automatically take care of sizing and positioning. User interface behavior is managed by connecting widgets together using Qt's signals and slots mechanism.

[Team LiB]
[Team LiB]

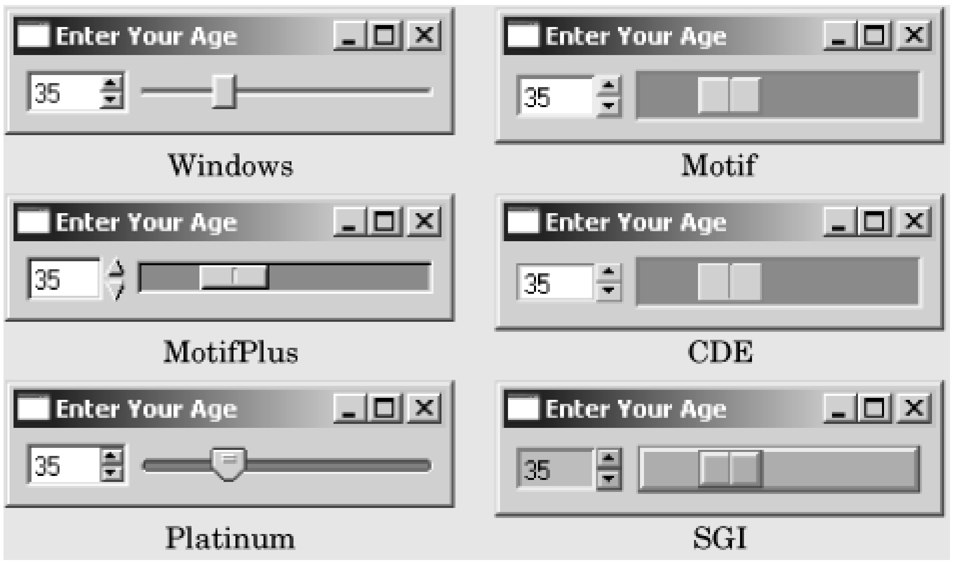
Using the Reference Documentation

Qt's reference documentation is an essential tool for any Qt developer, since it covers every class and function in Qt. (Qt 3.2 includes over 400 public classes and over 6000 functions.) This book makes use of many Qt classes and functions, but it doesn't mention them all, nor does it provide all the details of those it does mention. To get the most benefit from Qt, you should familiarize yourself with the Qt reference documentation.

Widget Styles

The screenshots we have seen so far have been taken on Windows XP, but Qt applications look native on every supported platform. Qt achieves this by emulating the platform's look and feel, rather than wrapping a particular platform or toolkit's widget set.

Figure 1.7. Styles available everywhere

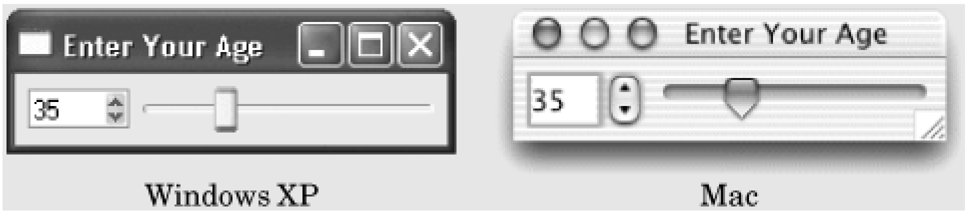


Qt application users can override the default style by using the -style command-line option. For example, to launch the Age application with Platinum style on Unix, simply type

```
./age -style=Platinum
```

on the command line.

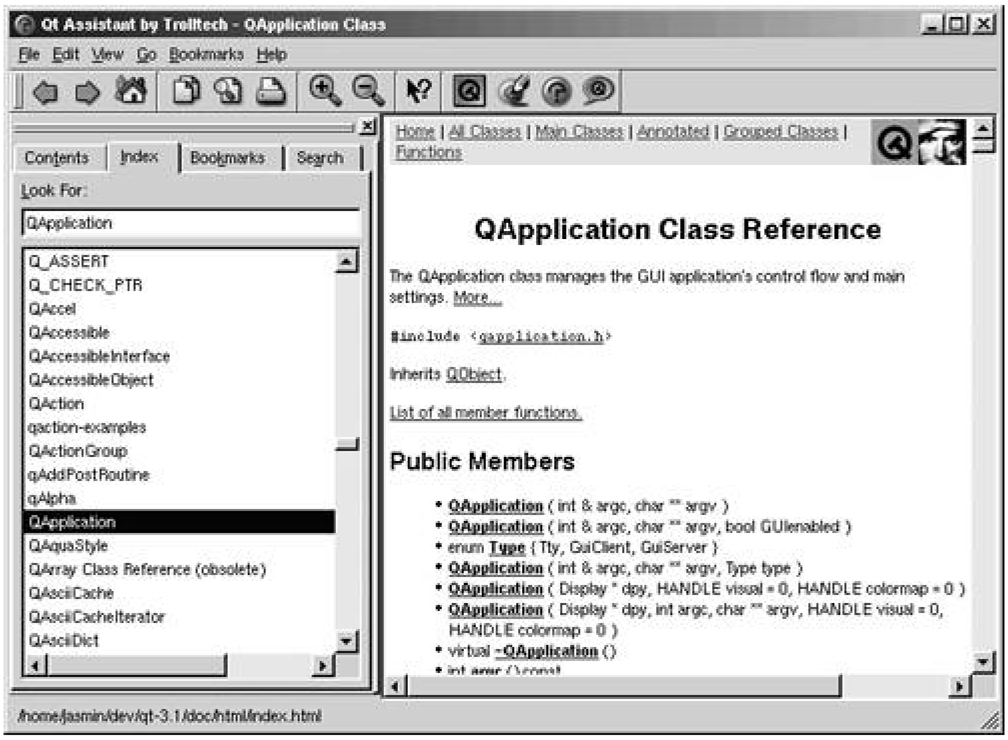
Figure 1.8. Platform-specific styles



Unlike the other styles, the Windows XP and Mac styles are only available on their native platforms, since they rely on the platforms' theme engines.

The documentation is available in HTML format in Qt's `doc\html` directory and can be read using any web browser. You can also use *Qt Assistant*, the Qt help browser, whose powerful search and indexing features make it quicker and easier to use than a web browser. To launch *Qt Assistant*, click *Qt 3.2.x*|*Qt Assistant* in the *Start* menu on Windows, type `assistant` on the command line on Unix, or double-click `assistant` in the Mac OS X Finder.

Figure 1.9. Qt's documentation in *Qt Assistant*


Qt Assistant by Trolltech - QApplication Class
File Edit View Go Bookmarks Help
Contents Index Bookmarks Search
Look For:
QApplication
Q_ASSERT
Q_CHECK_PTR
QAccel
QAccessible
QAccessibleInterface
QAccessibleObject
QAction
qaction-examples
QActionGroup
qAddPostRoutine
qAlpha
QApplication
QAquaStyle
QArray Class Reference (obsolete)
QAsciiCache
QAsciiCacheIterator
QAsciiDict
Home | All Classes | Main Classes | Annotated | Grouped Classes | Functions
/home/jasmin/dev/qt-3.1/doc/html/index.html

QApplication Class Reference

The QApplication class manages the GUI application's control flow and main settings. More...

```
#include <qapplication.h>
```

Inherits QObject.

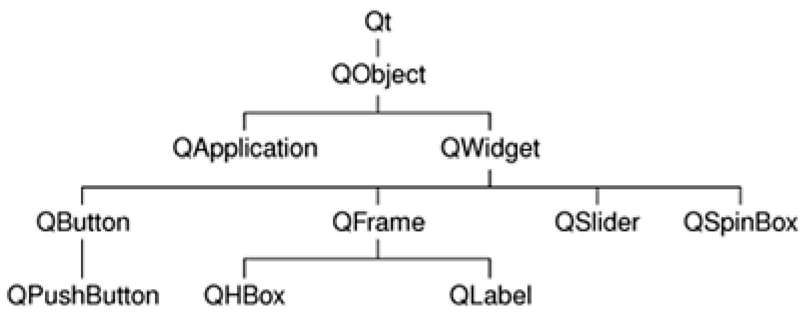
List of all member functions.

Public Members

- **QApplication** (int & argc, char ** argv)
- **QApplication** (int & argc, char ** argv, bool GUIenabled)
- enum **Type** { Tty, GuiClient, GuiServer }
- **QApplication** (int & argc, char ** argv, Type type)
- **QApplication** (Display * dpy, HANDLE visual = 0, HANDLE colormap = 0)
- **QApplication** (Display * dpy, int argc, char ** argv, HANDLE visual = 0, HANDLE colormap = 0)
- virtual **~QApplication** ()
- int argc () const

The links in the "API Reference" section on the home page provide different ways of navigating Qt's classes. The "All Classes" page lists every class in Qt's API. The "Main Classes" page lists only the most commonly used Qt classes. As an exercise, you might want to look up the classes and functions that we have used in this chapter. Note that inherited functions are documented in the base class; for example, `QPushButton` has no `show()` function of its own, but it inherits one from its ancestor `QWidget`. Figure 1.10 shows how the classes we have seen so far relate to each other.

Figure 1.10. Inheritance tree for the Qt classes seen so far



The reference documentation for the current version of Qt and for some earlier versions is available online at http://doc.trolltech.com/. This site also hosts selected articles from *Qt Quarterly*, the Qt programmers' newsletter sent to all commercial licensees.

Chapter 2. Creating Dialogs

This chapter will teach you how to create dialog boxes using Qt. They are called dialog boxes, or simply "dialogs", because they provide a means by which users and applications can "talk to" each other.

Dialogs present users with options and choices, and allow them to set the options to their preferred values and to make their choice. Most GUI applications consist of a main window with a menu bar and toolbar, along with dozens of dialogs that complement the main window. It is also possible to create dialog applications that respond directly to the user's choices by performing the appropriate actions (for example, a calculator application).

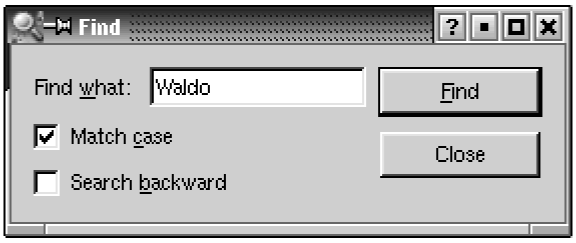
We will create our first dialog purely by writing code to show how it is done. Then we will see how to build dialogs using *Qt Designer*, Qt's visual design tool. Using *Qt Designer* is a lot faster than hand-coding and makes it simple to test different designs and to change designs later.

[Team LiB]
[Team LiB]

Subclassing QDialog

Our first example is a Find dialog written entirely in C++. We will implement the dialog as a class in its own right. By doing so, we make it an independent, self-contained component, with its own signals and slots.

Figure 2.1. Find dialog on Linux (KDE)



Find what: Waldo
☑ Match case
☐ Search backward

The source code is spread across two files: `finddialog.h` and `finddialog.cpp`. We will start with `finddialog.h`.

```
1 #ifndef FINDDIALOG_H
2 #define FINDDIALOG_H

3 #include <qdialog.h>

4 class QCheckBox;
5 class QLabel;
6 class QLineEdit;
7 class QPushButton;
```

Lines 1 and 2 (and 27) prevent the header file from multiple inclusions.

Line 3 includes the definition of `QDialog`, the base class for dialogs in Qt. `QDialog` inherits `QWidget`.

Lines 4 to 7 are forward declarations of the Qt classes that we will use to implement the dialog. A *forward declaration* tells the C++ compiler that a class exists, without giving all the detail that a class definition (usually located in a header file of its own) provides. We will say more about this shortly.

We then define `FindDialog` as a subclass of `QDialog`:

```
 8 class FindDialog : public QDialog
 9 {
10     Q_OBJECT
11 public:
12     FindDialog(QWidget *parent = 0, const char *name = 0);
```

The `Q_OBJECT` macro at the beginning of the class definition is necessary for all classes that define signals or slots.

The `FindDialog` constructor is typical of Qt widget classes. The `parent` parameter specifies the parent widget, and the `name` parameter gives the widget a name. The name is optional; it is primarily used for debugging and testing.

```
13 signals:
14     void findNext(const QString &str, bool caseSensitive);
15     void findPrev(const QString &str, bool caseSensitive);
```

The `signals` section declares two signals that the dialog emits when the user clicks the *Find* button. If the *Search backward* option is enabled, the dialog emits `findPrev()`; otherwise, it emits `findNext()`.

The `signals` keyword is actually a macro. The C++ preprocessor converts it into standard C++ before the compiler sees it.

```
16 private slots:
17     void findClicked();
18     void enableFindButton(const QString &text);

19 private:
20     QLabel *label;
21     QLineEdit *lineEdit;
22     QCheckBox *caseCheckBox;
23     QCheckBox *backwardCheckBox;
24     QPushButton *findButton;
25     QPushButton *closeButton;
26 };

27 #endif
```

In the class's private section, we declare two slots. To implement the slots, we will need to access most of the dialog's child widgets, so we keep pointers to them as well. The `slots` keyword is, like `signals`, a macro that expands into a construct that the C++ compiler can digest.

Since all the variables are pointers and we don't use them in the header file, the compiler doesn't need the full class definitions; forward declarations are sufficient. We could have included the relevant header files (`<qcheckbox.h>, <qlabel.h>`, etc.) instead, but using forward declarations when it is possible makes compiling somewhat faster.

We will now look at `finddialog.cpp`, which contains the implementation of the `FindDialog` class:

```
 1 #include <qcheckbox.h>
 2 #include <qlabel.h>
 3 #include <qlayout.h>
 4 #include <qlineedit.h>
 5 #include <qpushbutton.h>

 6 #include "finddialog.h"
```

First, we include the header files for all the Qt classes we use, in addition to `finddialog.h`. For most Qt classes, the header file is a lower-case version of the class name with a `.h` extension.

```
 7 FindDialog::FindDialog(QWidget *parent, const char *name)
 8     : QDialog(parent, name)
 9 {
10     setCaption(tr("Find"));

11     label = new QLabel(tr("Find &what:"), this);
12     lineEdit = new QLineEdit(this);
13     label->setBuddy(lineEdit);

14     caseCheckBox = new QCheckBox(tr("Match &case"), this);
15     backwardCheckBox = new QCheckBox(tr("Search &backward"), this);

16     findButton = new QPushButton(tr("&Find"), this);
17     findButton->setDefault(true);
18     findButton->setEnabled(false);

19     closeButton = new QPushButton(tr("Close"), this);
```

On line 8, we pass on the `parent` and `name` parameters to the base class constructor.

On line 10, we set the window's caption to "Find". The `tr()` function around the string marks it for translation to other languages. It is declared in `QObject` and every subclass that contains the `Q_OBJECT` macro. It's a good habit to surround every user-visible string with a `tr()`, even if you don't have immediate plans for translating your applications to other languages. Translating Qt applications is covered in Chapter 15.

Then we create the child widgets. We use ampersands ('&') to indicate accelerator keys. For example, line 16 creates a *Find* button, which the user can activate by pressing *Alt+F*. Ampersands can also be used to control focus: On line 11 we create a label with an accelerator key (*Alt+W*), and on line 13 we set the label's buddy to be the line editor. A *buddy* is a widget that accepts the focus when the label's accelerator key is pressed. So when the user presses *Alt+W* (the label's accelerator), the focus goes to the line editor (the buddy).

On line 17, we make the *Find* button the dialog's default button by calling `setDefault(true)`.[*] The default button is the button that is pressed when the user hits *Enter*. On line 18, we disable the *Find* button. When a widget is disabled, it is usually shown grayed out and will not interact with the user.

[*] Qt provides `TRUE` and `FALSE` for all platforms and uses them throughout as synonyms for the standard `true` and `false`. Nevertheless, there is no reason to use the upper-case versions in your own code unless you need to use an old compiler that doesn't support `true` and `false`.

```
20     connect(lineEdit, SIGNAL(textChanged(const QString &)),
21             this, SLOT(enableFindButton(const QString &)));
22     connect(findButton, SIGNAL(clicked()),
            this, SLOT(findClicked()));
    connect(closeButton, SIGNAL(clicked()),
            this, SLOT(close()));
```

The private slot `enableFindButton(const QString &)` is called whenever the text in the line editor changes. The private slot `findClicked()` is called when the user clicks the *Find* button. The dialog closes itself when the user clicks *Close*. The `close()` slot is inherited from `QWidget`, and its default behavior is to hide the widget. We will look at the code for the `enableFindButton()` and `findClicked()` slots later on.

Since `QObject` is one of `FindDialog`'s ancestors, we can omit the `QObject::` prefix in front of the `connect()` calls.

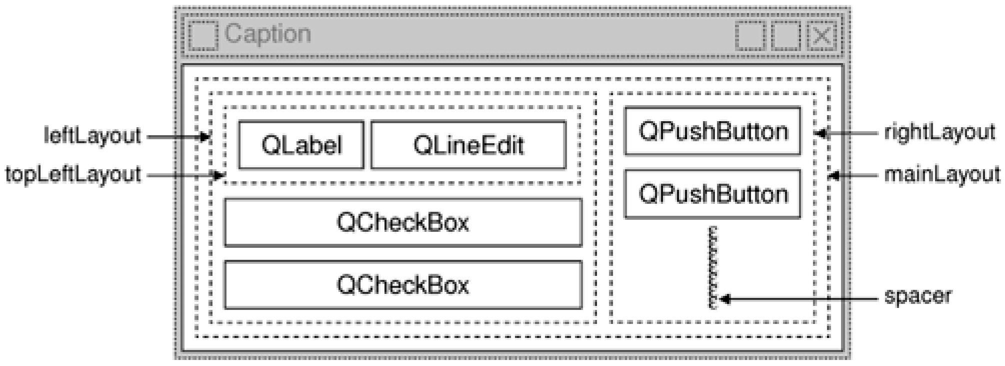
```
    QHBoxLayout *topLeftLayout = new QHBoxLayout;
    topLeftLayout->addWidget(label);
    topLeftLayout->addWidget(lineEdit);

    QVBoxLayout *leftLayout = new QVBoxLayout;
    leftLayout->addLayout(topLeftLayout);
    leftLayout->addWidget(caseCheckBox);
    leftLayout->addWidget(backwardCheckBox);

    QVBoxLayout *rightLayout = new QVBoxLayout;
    rightLayout->addWidget(findButton);
    rightLayout->addWidget(closeButton);
    rightLayout->addStretch(1);

    QHBoxLayout *mainLayout = new QHBoxLayout(this);
    mainLayout->setMargin(11);
    mainLayout->setSpacing(6);
    mainLayout->addLayout(leftLayout);
    mainLayout->addLayout(rightLayout);
}
```

Finally, we lay out the child widgets using *layout managers*. A layout manager is an object that manages the size and position of widgets. Qt provides three layout managers: `QHBoxLayout` lays out widgets horizontally from left to right (right to left for some cultures), `QVBoxLayout` lays out widgets vertically from top to bottom, and `QGridLayout` lays out widgets in a grid.

Layouts can contain both widgets and other layouts. By nesting `QHBoxLayout`s, `QVBoxLayout`s, and `QGridLayout`s in various combinations, it is possible to build very sophisticated dialogs.

For the Find dialog, we use two `QHBoxLayout`s and two `QVBoxLayout`s, as shown in Figure 2.2. The outer layout is the main layout; it is constructed with the `FindDialog` object (`this`) as its parent and is responsible for the dialog's entire area. The other three layouts are sub-layouts. The little "spring" at the bottom right of Figure 2.2 is a spacer item (or "stretch"). It uses up the empty space below the *Find* and *Close* buttons, ensuring that these buttons occupy the top of their layout.

Figure 2.2. The Find dialog's layouts



One subtle aspect of the layout manager classes is that they are not widgets. Instead, they inherit QLayout, which in turn inherits QObject. In the figure, widgets are represented by solid outlines and layouts are represented by dashed outlines to highlight the difference between them. In a running application, layouts are invisible.

Although layout managers are not widgets, they can have a parent (and children). The meaning of "parent" is slightly different for layouts than for widgets. If a layout is constructed with a widget as its parent (as we did for main–Layout), the layout automatically installs itself on the widget. If a layout is constructed with no parent (as we did for topLeftLayout, leftLayout, and right–Layout), the layout must be inserted into another layout using addLayout().

Qt's parent–child mechanism is implemented in QObject, the base class of both QWidget and QLayout. When we create an object (a widget, layout, or other kind) with a parent, the parent adds the object to the list of its children. When the parent is deleted, it walks through its list of children and deletes each child. The children themselves then delete all of their children, and so on recursively until none remain.

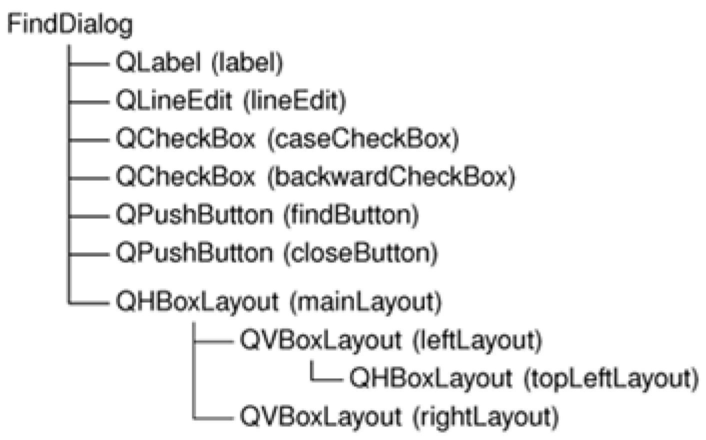
The parent–child mechanism simplifies memory management a lot, reducing the risk of memory leaks. The only objects we must delete explicitly are the objects we create with new and that have no parent. And if we delete a child object before its parent, Qt will automatically remove that object from the parent's list of children.

For widgets, the parent has an additional meaning: Child widgets are shown within the parent's area. When we delete the parent widget, not only does the child vanish from memory, it also vanishes from the screen.

When we insert a layout into another using addLayout(), the inner layout is automatically made a child of the outer layout, to simplify memory management. In contrast, when we insert a widget into a layout using addWidget(), the widget doesn't change parent.

Figure 2.3 shows the parentage of the widgets and layouts. The parentage can easily be deduced from the FindDialog constructor code by looking at the lines that contain a new or an addLayout() call. The important thing to remember is that the layout managers are not parents of the widgets they manage.

Figure 2.3. The Find dialog's parent–child relationships



In addition to the layout managers, Qt provides some *layout widgets*: `QHBox` (which we used in Chapter 1), `QVBox`, and `QGrid`. These classes serve both as parents and as layout managers for their child widgets. The layout widgets are more convenient to use than layout managers for small examples, but they are less flexible and require more resources.

This completes the review of `FindDialog`'s constructor. Since we used `new` to create the dialog's widgets and layouts, it would seem that we need to write a destructor that calls `delete` on each of the widgets and layouts we created. But this isn't necessary, since Qt automatically deletes child objects when the parent is destroyed, and the objects we allocated with `new` are all descendants of the `FindDialog`.

Now we will look at the dialog's slots:

```
void FindDialog::findClicked()
{
    QString text = lineEdit->text();
    bool caseSensitive = caseCheckBox->isOn();

    if (backwardCheckBox->isOn())
        emit findPrev(text, caseSensitive);
    else
        emit findNext(text, caseSensitive);
}

void FindDialog::enableFindButton(const QString &text)
{
    findButton->setEnabled(!text.isEmpty());
}
```

The `findClicked()` slot is called when the user clicks the *Find* button. It emits the `findPrev()` or the `findNext()` signal, depending on the *Search backward* option. The `emit` keyword is specific to Qt; like other Qt extensions, it is converted into standard C++ by the C++ preprocessor.

The `enableFindButton()` slot is called whenever the user changes the text in the line editor. It enables the button if there is some text in the editor, and disables it otherwise.

These two slots complete the dialog. We can now create a `main.cpp` file to test our `FindDialog` widget:

```
#include <qapplication.h>

#include "finddialog.h"

int main(int argc, char *argv[])
```

```
{
    QApplication app(argc, argv);
    FindDialog *dialog = new FindDialog;
    app.setMainWidget(dialog);
    dialog->show();
    return app.exec();
}
```

To compile the program, run `qmake` as usual. Since the `FindDialog` class definition contains the `Q_OBJECT` macro, the makefile generated by `qmake` will include special rules to run `moc`, Qt's meta-object compiler.

For `moc` to work correctly, we must put the class definition in a header file, separate from the implementation file. The code generated by `moc` includes this header file and adds some magic of its own.

Classes that use the `Q_OBJECT` macro must have `moc` run on them. This isn't a problem because `qmake` automatically adds the necessary rules to the makefile. But if you forget to regenerate your makefile using `qmake` and `moc` isn't run, the linker will complain that some functions are declared but not implemented. The messages can be fairly obscure. GCC produces warnings like this one:

```
finddialog.o(.text+0x28): undefined reference to
'FindDialog::QPaintDevice virtual table'
```

Visual C++'s output starts like this:

```
finddialog.obj : error LNK2001: unresolved external symbol
"public:~virtual bool __thiscall FindDialog::qt_property(int,
int,class QVariant *)"
```

If this ever happens to you, run `qmake` again to update the makefile, then rebuild the application.

Now run the program. Verify that the accelerator keys *Alt+W*, *Alt+C*, *Alt+B*, and *Alt+F* trigger the correct behavior. Press *Tab* to navigate through the widgets with the keyboard. The default tab order is the order in which the widgets were created. This can be changed by calling `QWidget::setTabOrder()`.

Providing a sensible tab order and keyboard accelerators ensures that users who don't want to (or cannot) use a mouse are able to make full use of the application. Full keyboard control is also appreciated by fast typists.

In Chapter 3, we will use the Find dialog inside a real application, and we will connect the `findPrev()` and `findNext()` signals to some slots.

[Team LiB]

[Team LiB]

Signals and Slots in Depth

The signals and slots mechanism is fundamental to Qt programming. It enables the application programmer to bind objects together without the objects knowing anything about each other. We have already connected some signals and slots together, declared our own signals and slots, implemented our own slots, and emitted our own signals. Let's take a moment to look at the mechanism more closely.

Slots are almost identical to ordinary C++ member functions. They can be virtual, they can be overloaded, they can be public, protected, or private, and they can be directly invoked like any other C++ member functions. The difference is that a slot can also be connected to a signal, in which case it is automatically called each time the signal is emitted.

The `connect()` statement looks like this:

```
connect (sender, SIGNAL(signal), receiver, SLOT(slot));
```

where *`sender`* and *`receiver`* are pointers to `QObjects` and where *`signal`* and *`slot`* are function signatures without parameter names. The `SIGNAL()` and `SLOT()` macros essentially convert their argument to a string.

In the examples we have seen so far, we have always connected different signals to different slots. There are more possibilities to explore:

- **One signal can be connected to many slots**:

  ```
  connect(slider, SIGNAL(valueChanged(int)),
          spinBox, SLOT(setValue(int)));
  connect(slider, SIGNAL(valueChanged(int)),
          this, SLOT(updateStatusBarIndicator(int)));
  ```

  When the signal is emitted, the slots are called one after the other, in an arbitrary order.

- **Many signals can be connected to the same slot**:

  ```
  connect(lcd, SIGNAL(overflow()),
          this, SLOT(handleMathError()));
  connect(calculator, SIGNAL(divisionByZero()),
          this, SLOT(handleMathError()));
  ```

  When either signal is emitted, the slot is called.

- **A signal can be connected to another signal**:

  ```
  connect(lineEdit, SIGNAL(textChanged(const QString &)),
          this, SIGNAL(updateRecord(const QString &)));
  ```

  When the first signal is emitted, the second signal is emitted as well. Apart from that, signal–signal connections are indistinguishable from signal–slot connections.

- **Connections can be removed**:

  ```
  disconnect(lcd, SIGNAL(overflow()),
             this, SLOT(handleMathError()));
  ```

  This is rarely needed, because Qt automatically removes all connections involving an object when that object is deleted.

When connecting a signal to a slot (or to another signal), they must both have the same parameter types in the same order:

```
connect(ftp, SIGNAL(rawCommandReply(int, const QString &)),
        this, SLOT(processReply(int, const QString &)));
```

Exceptionally, if a signal has more parameters than the slot it is connected to, the additional parameters are simply ignored:

```
connect(ftp, SIGNAL(rawCommandReply(int, const QString &)),
        this, SLOT(checkErrorCode(int)));
```

If the parameter types are incompatible, or if the signal or the slot doesn't exist, Qt will issue a warning at run-time. Similarly, Qt will give a warning if parameter names are included in the signal or slot signatures.

Qt's Meta-Object System

One of Qt's major achievements has been the extension of C++ with a mechanism for creating independent software components that can be bound together without any component knowing anything about the other components it is connected to.

The mechanism is called the *meta-object system*, and it provides two key services: signals and slots, and introspection. The introspection functionality is necessary for implementing signals and slots, and allows application programmers to obtain "meta-information" about `QObject` subclasses at runtime, including the list of signals and slots supported by the object and its class name. The mechanism also supports properties (for *Qt Designer*) and text translation (for internationalization).

Standard C++ doesn't provide support for the dynamic meta-information needed by Qt's meta-object system. Qt solves this problem by providing a separate tool, `moc`, that parses `Q_OBJECT` class definitions and makes the information available through C++ functions. Since `moc` implements all its functionality using pure C++, Qt's meta-object system works with any C++ compiler.

The mechanism works as follows:

- The `Q_OBJECT` macro declares some introspection functions that must be implemented in every `QObject` subclass: `metaObject()`, `className()`, `tr()`, and a few more.
- Qt's `moc` tool generates implementations for the functions declared by `Q_OBJECT` and for all the signals.
- `QObject` member functions such as `connect()` and `disconnect()` use the introspection functions to do their work.

All of this is handled automatically by `qmake`, `moc`, and `QObject`, so you rarely need to think about it. But if you are curious, you can look at the C++ source files generated by `moc` to see how the implementation works.

So far, we have only used signals and slots with widgets. But the mechanism itself is implemented in `QObject`, and isn't limited to GUI programming. The mechanism can be used by any `QObject` subclass:

```
class Employee : public QObject
{
    Q_OBJECT
public:
    Employee() { mySalary = 0; }

    int salary() const { return mySalary; }

public slots:
    void setSalary(int newSalary);

signals:
     void salaryChanged(int newSalary);

private:
     int mySalary;
};

void Employee::setSalary(int newSalary)
{
   if (newSalary != mySalary) {
       mySalary = newSalary;
       emit salaryChanged(mySalary);
   }
}
```

Notice how the `setSalary()` slot is implemented. We only emit the `salaryChanged()` signal if `newSalary ! = mySalary`. This ensures that cyclic connections don't lead to infinite loops.

[Team LiB]
[Team LiB]

PREVIOUS NEXT
PREVIOUS NEXT

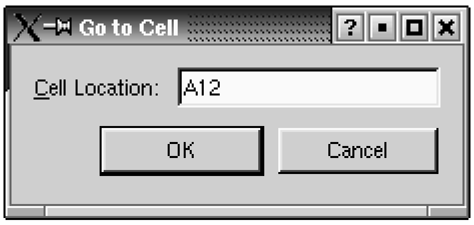
Rapid Dialog Design

Qt is designed to be pleasant and intuitive to hand-code, and it is perfectly possible to develop Qt applications purely by writing C++ source code. *Qt Designer* expands the options available to programmers, allowing them to combine visually designed forms with their source code.

In this section, we will use *Qt Designer* to create the Go-to-Cell dialog shown in Figure 2.4. Whether we do it in code or in *Qt Designer*, creating a dialog always involves the same fundamental steps:

- Create and initialize the child widgets.
- Put the child widgets in layouts.
- Set the tab order.
- Establish signal–slot connections.
- Implement the dialog's custom slots.

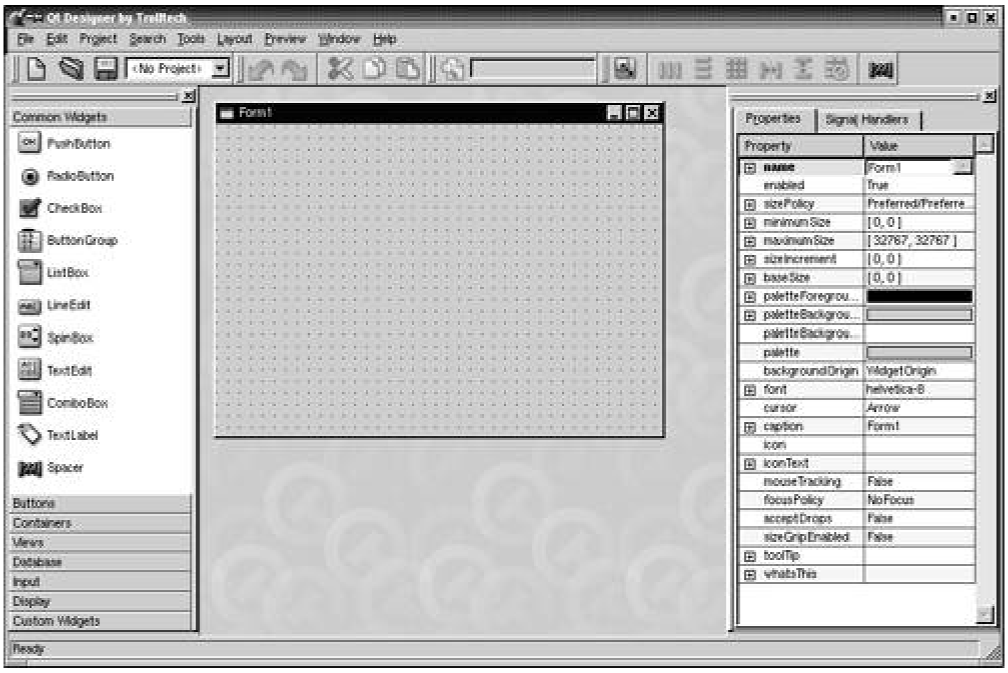
Figure 2.4. Go-to-Cell dialog



To launch *Qt Designer*, click *Qt 3.2.x|Qt Designer* in the Start menu on Windows, type `designer` on the command line on Unix, or double-click `designer` in the Mac OS X Finder. When *Qt Designer* starts, it will pop up a list of templates. Click the "Dialog" template, then click *OK*.

You should now have a window called "Form1".

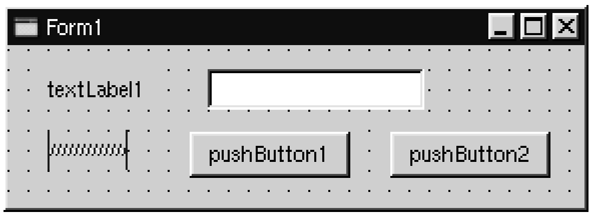
Figure 2.5. *Qt Designer* with an empty form



Property	Value
name	Form1
enabled	True
sizePolicy	Preferred/Prefere...
minimumSize	[0, 0]
maximumSize	[32767, 32767]
sizeIncrement	[0, 0]
baseSize	[0, 0]
paletteForegrou...	■
paletteBackgrou...	▭
paletteBackgrou...	
palette	▭
backgroundOrigin	WidgetOrigin
font	helvetica-8
cursor	Arrow
caption	Form1
icon	
iconText	
mouseTracking	False
focusPolicy	NoFocus
acceptDrops	False
sizeGripEnabled	False
toolTip	
whatsThis	

The first step is to create the child widgets and place them on the form. Create one text label, one line editor, one (horizontal) spacer, and two push buttons. For each item, click its name or icon in the "toolbox" at the left of *Qt Designer*'s main window and then click the form roughly where the item should go. Now drag the bottom of the form up to make it shorter. This should produce a form that is similar to Figure 2.6. Don't spend too much time positioning the items on the form; Qt's layout managers will lay them out precisely later on.

Figure 2.6. The form with some widgets



The spacer item is shown in *Qt Designer* as a blue spring. It is invisible in the final form.

Set each widget's properties using the property editor on the right of *Qt Designer*'s main window:

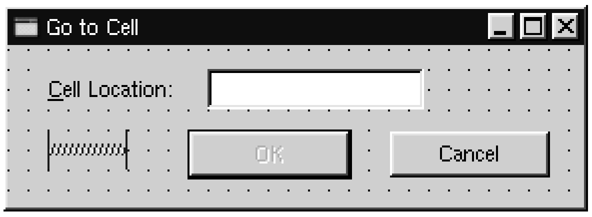
1. Click the text label. Set its `name` property to "label" and its `text` property to "&Cell Location:".
2. Click the line editor. Set its `name` property to "lineEdit".
3. Click the spacer. Make sure that the spacer's `orientation` property is set to "Horizontal".
4. Click the first button. Set its `name` property to "okButton", its `enabled` property to "False", its `default` property to "True", and its `text` property to "OK".

5. Click the second button. Set its `name` property to "cancelButton" and its `text` property to "Cancel".

6. Click the background of the form to select the form itself. Set its `name` property to "GoToCellDialog" and its `caption` property to "Go to Cell".

All the widgets look fine now, except the text label, which shows *&Cell Location*. Click *Tools|Set Buddy*. Click the label and drag the rubber band to the line editor, then release. The label should now show *Cell Location* and have the line editor as its buddy. You can verify this by checking that the label's `buddy` property is set to "lineEdit".

Figure 2.7. The form with properties set



The next step is to lay out the widgets on the form:

1. Click the *Cell Location* label and press *Shift* as you click the line editor next to it so that they are both selected. Click *Layout|Lay Out Horizontally*.

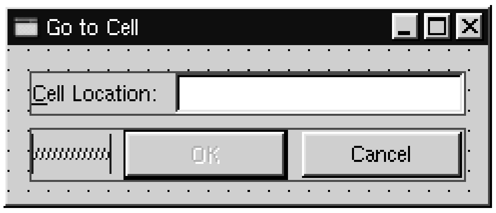
2. Click the spacer, then hold *Shift* as you click the form's *OK* and *Cancel* buttons. Click *Layout|Lay Out Horizontally*.

3. Click the background of the form to deselect any selected items, then click *Layout|Lay Out Vertically*.

4. Click *Layout|Adjust Size* to resize the form to its optimal size.

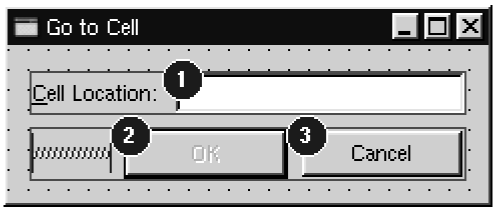
The red lines that appear on the form show the layouts that have been created. They never appear when the form is run.

Figure 2.8. The form with the layouts



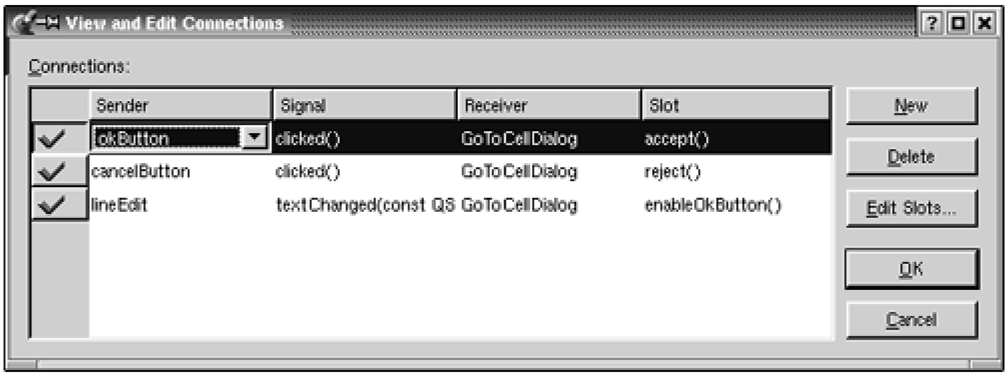
Now click *Tools|Tab Order*. A number in a blue circle will appear next to every widget that can accept focus. Click each widget in turn in the order you want them to accept focus, then press *Esc*.

Figure 2.9. Setting the form's tab order



Now that the form has been designed, we are ready to make it functional by setting up some signal–slot connections and by implementing some custom slots. Click *Edit*|*Connections* to invoke the connection editor.

Figure 2.10. *Qt Designer*'s connection editor (after making the connections)

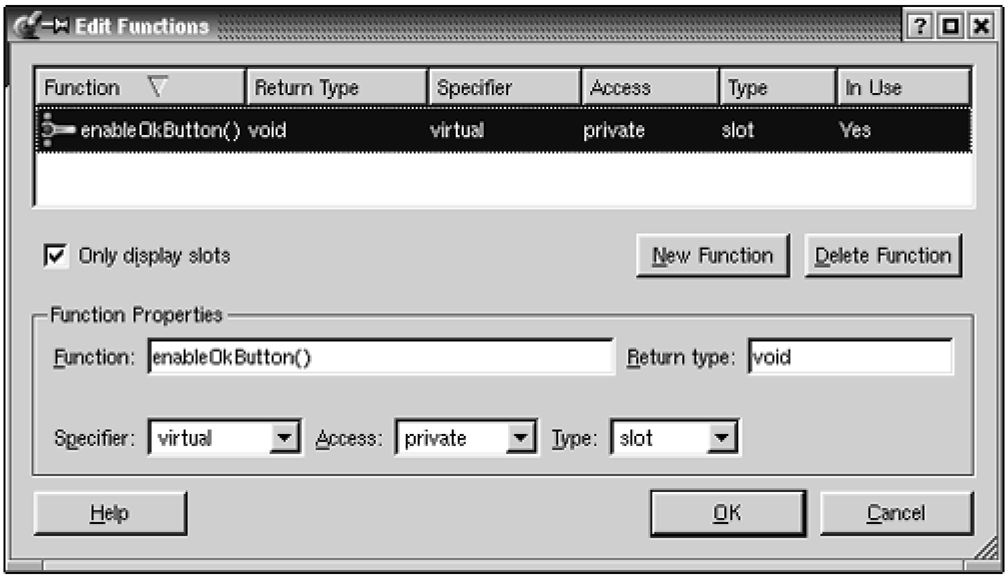


	Sender	Signal	Receiver	Slot
✓	okButton	clicked()	GoToCellDialog	accept()
✓	cancelButton	clicked()	GoToCellDialog	reject()
✓	lineEdit	textChanged(const QS	GoToCellDialog	enableOkButton()

We need to establish three connections. To create a connection, click *New* and set the *Sender*, *Signal*, *Receiver*, and *Slot* fields using the drop-down comboboxes.

Connect the `okButton`'s `clicked()` signal to the `GoToCellDialog`'s `accept()` slot. Connect the `cancelButton`'s `clicked()` signal to the `GoToCellDialog`'s `reject()` slot. Click *Edit Slots* to invoke *Qt Designer*'s slot editor (shown in Figure 2.11), and create an `enableOkButton()` private slot. Finally, connect the `lineEdit`'s `textChanged(const QString &)` signal to the `GoToCellDialog`'s new `enableOkButton()` slot.

Figure 2.11. *Qt Designer*'s slot editor



Function	Return Type	Specifier	Access	Type	In Use
enableOkButton()	void	virtual	private	slot	Yes

☑ Only display slots

Function: enableOkButton()
Return type: void
Specifier: virtual
Access: private
Type: slot

To preview the dialog, click the *Preview*|*Preview Form* menu option. Check the tab order by pressing Tab repeatedly. Press *Alt+C* to move the focus to the line editor. Click *Cancel* to close the dialog.

Save the dialog as `gotocelldialog.ui` in a directory called `gotocell`, and create a `main.cpp` file in the same directory using a plain text editor:

```
#include <qapplication.h>

#include "gotocelldialog.h"

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    GoToCellDialog *dialog = new GoToCellDialog;
    app.setMainWidget(dialog);
    dialog->show();
    return app.exec();
}
```

Now run `qmake` to create a `.pro` file and a makefile (`qmake -project; qmake gotocell.pro`). The `qmake` tool is smart enough to detect the user interface file `gotocelldialog.ui` and to generate the appropriate makefile rules to create `gotocelldialog.h` and `gotocelldialog.cpp`. The `.ui` file is converted to C++ by `uic`, Qt's user interface compiler.

One of the beauties of using *Qt Designer* is that it allows programmers great freedom to modify their form designs without disturbing their source code. When you develop a form purely by writing C++ code, changes to the design can be quite time-consuming. With *Qt Designer*, no time is lost since `uic` simply regenerates the source code for any forms that have changed.

If you run the program now, the dialog will work, but it doesn't function exactly as we want:

- The *OK* button is always disabled.
- The line editor accepts any text, instead of only accepting valid cell locations.

We must write some code to solve these problems.

Double-click the background of the form to invoke *Qt Designer*'s code editor. In the editor window, enter the following code:

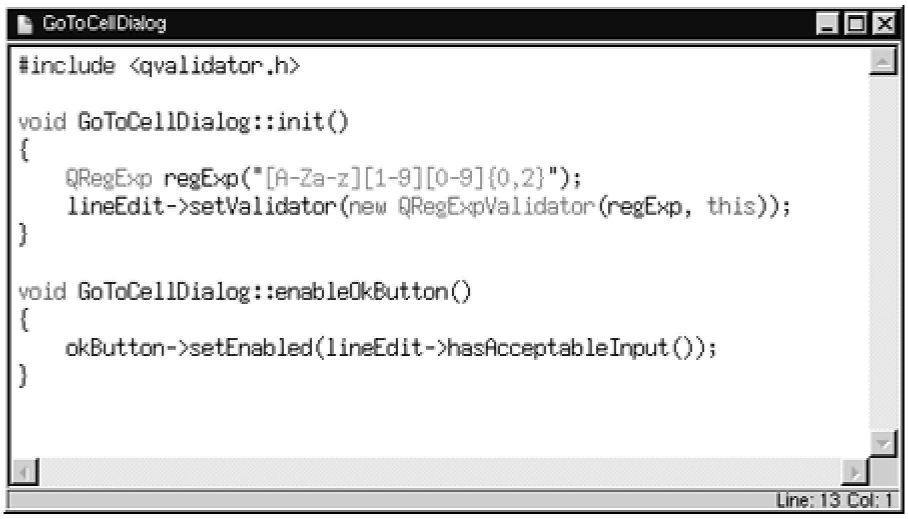
```
#include <qvalidator.h>

void GoToCellDialog::init()
{
    QRegExp regExp("[A–Za–z] [1–9] [0–9] {0, 2}");
    lineEdit->setValidator(new QRegExpValidator(regExp, this));
}

void GoToCellDialog::enableOkButton()
{
    okButton->setEnabled(lineEdit->hasAcceptableInput());
}
```

The `init()` function is automatically called at the end of the form's constructor (generated by `uic`). We set up a validator to restrict the range of the input. Qt provides three built-in validator classes: `QIntValidator`, `QDoubleValidator`, and `QRegExpValidator`. Here we use a `QRegExpValidator` with the regular expression "[A-Za-z][1-9][0-9]{0,2}", which means: Allow one upper or lower-case letter, followed by one digit in the range 1 to 9, followed by up to two digits each in the range 0 to 9. (For an introduction to regular expressions, see the QRegExp class documentation.)

By passing this to the QRegExpValidator constructor, we make it a child of the GoToCellDialog object. By doing so, we don't have to worry about deleting the QRegExpValidator later; it will be deleted automatically when its parent is deleted.

The enableOkButton() slot enables or disables the *OK* button, according to whether the line edit contains a valid cell location. QLineEdit::hasAcceptableInput() uses the validator we set in the init() function.

Figure 2.12. *Qt Designer*'s code editor



```
#include <qvalidator.h>

void GoToCellDialog::init()
{
    QRegExp regExp("[A-Za-z][1-9][0-9]{0,2}");
    lineEdit->setValidator(new QRegExpValidator(regExp, this));
}

void GoToCellDialog::enableOkButton()
{
    okButton->setEnabled(lineEdit->hasAcceptableInput());
}
```

After typing the code, save the dialog again. This will effectively save two files: the user interface file gotocelldialog.ui, and the C++ source file gotocelldialog.ui.h. Make the application once more and run it again. Type "A12" in the line edit, and notice that the *OK* button becomes enabled. Try typing some random text to see how the validator does its job. Click *Cancel* to close the dialog.

In this example, we edited the dialog in *Qt Designer*, then we added some code using *Qt Designer*'s code editor. The dialog's user interface is saved in a .ui file (an XML-based file format), while the code is saved in a .ui.h file (a C++ source file). This split is very convenient for developers who want to edit the .ui.h file in their favorite text editor.

An alternative to the .ui.h approach is to create a .ui file with *Qt Designer* as usual, then create an additional class that inherits the uic-generated class and adds the extra functionality there. For example, for the Go-to-Cell dialog, this would mean creating a GoToCellDialogImpl class that inherits GoToCellDialog and that implements what's missing. It is straightforward to convert the .ui.h code to use this approach. The result is this header file:

```
#ifndef GOTOCELLDIALOGIMPL_H
#define GOTOCELLDIALOGIMPL_H

#include "gotocelldialog.h"

class GoToCellDialogImpl : public GoToCellDialog
{
    Q_OBJECT
public:
    GoToCellDialogImpl(QWidget *parent = 0, const char *name = 0);
private slots:
    void enableOkButton();
};

#endif
```

And this source file:

```
#include <qlineedit.h>
#include <qpushbutton.h>
#include <qvalidator.h>

#include "gotocelldialogimpl.h"

GoToCellDialogImpl::GoToCellDialogImpl(QWidget *parent,
                                       const char *name)
    : GoToCellDialog(parent, name)
{
    QRegExp regExp("[A-Za-z][1-9][0-9]{0,2}");
    lineEdit->setValidator(new QRegExpValidator(regExp, this));
}

void GoToCellDialogImpl::enableOkButton()
{
    okButton->setEnabled(lineEdit->hasAcceptableInput());
}
```

Developers who prefer the subclassing approach would probably call the base class GoToCellDialogBase and the derived class GoToCellDialog, keeping the better name for the class that contains all the functionality.

The uic tool provides command-line options to simplify the creation of subclasses based on forms created with *Qt Designer*. Use -subdecl to generate a skeleton header file, and use -subimpl to generate the matching implementation file.

In this book, we use the .ui.h approach since this is the most common practice, and since it is easy to convert .ui.h files into subclasses. You might want to read the "Designer Approach" chapter in *Qt Designer*'s manual for a technical appreciation of the differences between subclassing and using .ui.h files. Another chapter in the manual, "Creating Dialogs", demonstrates how to use *Qt Designer*'s Members tab to declare member variables in uic-generated classes.

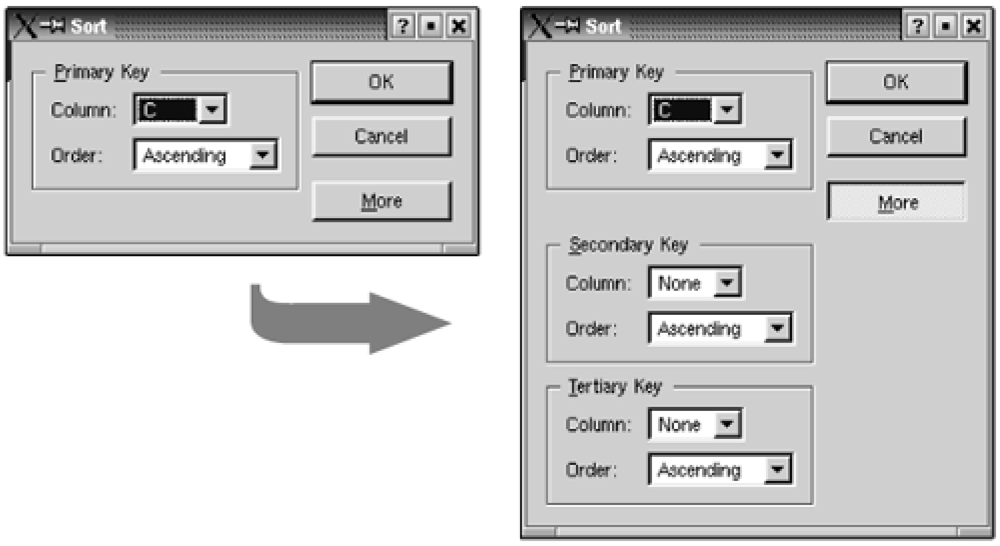
[Team LiB]
PREVIOUS NEXT
[Team LiB]
PREVIOUS NEXT

Shape-Changing Dialogs

We have seen how to create dialogs that always show the same widgets whenever they are used. In some cases, it is desirable to provide dialogs that can change shape. The two most common kinds of shape-changing dialogs are *extension dialogs* and *multi-page dialogs*. Both types of dialog can be implemented in Qt, either purely in code or using *Qt Designer*.

Extension dialogs usually present a simple appearance but have a toggle button that allows the user to switch between the dialog's simple and extended appearances. Extension dialogs are commonly used for applications that are trying to cater for both casual and power users, hiding the advanced options unless the user explicitly asks to see them. In this section, we will use *Qt Designer* to create the extension dialog shown in Figure 2.13.

Figure 2.13. Sort dialog with simple and extended appearances

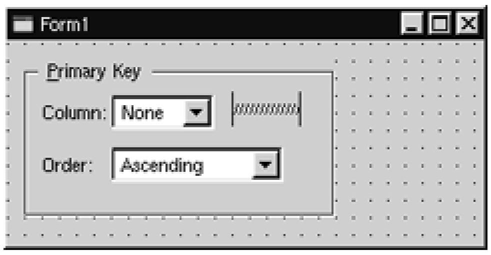


The dialog is a Sort dialog in a spreadsheet application, where the user can select one or several columns to sort on. The dialog's simple appearance allows the user to enter a single sort key, and its extended appearance provides for two extra sort keys. A *More* button lets the user switch between the simple and extended appearances.

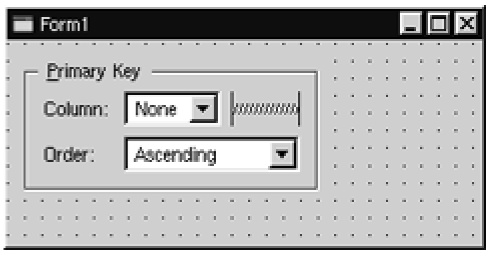
We will create the widget with its extended appearance in *Qt Designer*, and hide the secondary and tertiary keys at run-time as needed. The widget looks complicated, but it's fairly easy to do in *Qt Designer*. The trick is to do the primary key part first, then copy and paste it twice to obtain the secondary and tertiary keys:

1. Create a group box, two text labels, two comboboxes, and one horizontal spacer.
2. Drag the bottom right corner of the group box to make it larger.
3. Move the other widgets into the group box and position them approximately as shown in Figure 2.14(a).
4. Drag the right edge of the second combobox to make it about twice as wide as the first combobox.
5. Set the group box's `title` property to "&Primary Key", the first label's `text` property to "Column:", and the second label's `text` property to "Order:".
6. Double-click the first combobox to pop up *Qt Designer*'s list box editor, and create one item with the text "None".
7. Double-click the second combobox and create an "Ascending" item and a "Descending" item.
8. Click the group box, then click *Layout*|*Lay Out in a Grid*. This will produce the layout shown in Figure 2.14(b).

Figure 2.14. Laying out the group box's children in a grid



(a) Without layout



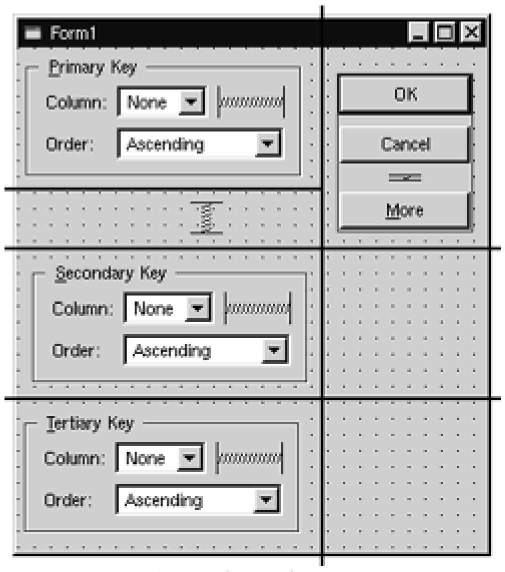
(b) With layout

If a layout doesn't turn out quite right or if you make a mistake, you can always click *Edit|Undo*, then roughly reposition the widgets being laid out and try again.

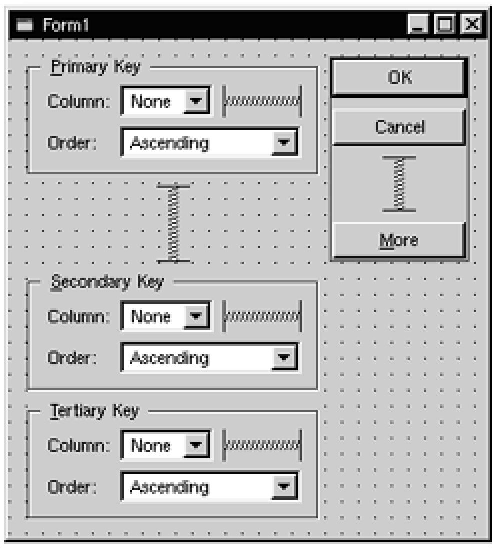
We will now add the *Secondary Key* and *Tertiary Key* group boxes:

1. Make the dialog window tall enough for the extra parts. Select the group box, click *Edit|Copy*, then click *Edit|Paste* twice to obtain two additional group boxes. Drag the two new group boxes to the approximate positions that they should occupy. Change their `title` property to "&Secondary Key" and "&Tertiary Key".
2. Create the *OK*, *Cancel*, and *More* buttons.
3. Set the *OK* button's `default` property to "True" and the *More* button's `toggle` property to "True".
4. Create two vertical spacers.
5. Arrange the *OK*, *Cancel*, and *More* buttons vertically, with a vertical spacer between the *Cancel* and *More* buttons. Then select all four items and click *Layout|Lay Out Vertically*.
6. Place the second vertical spacer between the primary key group box and the secondary Key group box.
7. Set the two vertical spacer items' `sizeHint` property to (20, 10).
8. Arrange the widgets in the grid-like pattern shown in Figure 2.15(a).
9. Click *Layout|Lay Out in a Grid*. The form should now match Figure 2.15(b).

Figure 2.15. Laying out the form's children in a grid



(a) Without layout



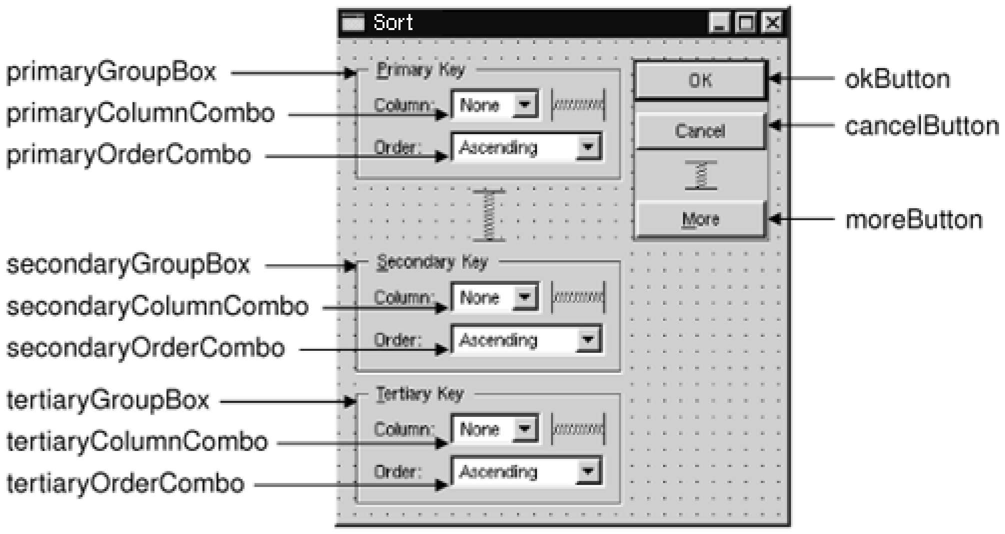
(b) With layout

The resulting grid layout has two columns and four rows, giving a total of eight cells. The *Primary Key* group box, the leftmost vertical spacer item, the *Secondary Key* group box, and the *Tertiary Key* group box each occupy a single cell. The vertical layout that contains the *OK*, *Cancel*, and *More* buttons occupies two cells. That leaves two empty cells in the bottom-right of the dialog. If this isn't what you have, undo the layout, reposition the widgets, and try again.

Change the form's `resizeMode` property from "Auto" to "Fixed", making the dialog non-resizable by the user. The layout then takes over the responsibility for resizing, and resizes the dialog automatically when child widgets are shown or hidden, ensuring that the dialog is always displayed at its optimal size.

Rename the form "SortDialog" and change its caption to "Sort". Set the names of the child widgets to those shown in Figure 2.16.

Figure 2.16. Naming the form's widgets



Finally, set up the connections:

1. Connect the `okButton`'s `clicked()` signal to the form's `accept()` slot.

2. Connect the `cancelButton`'s `clicked()` signal to the form's `reject()` slot.

3. Connect the moreButton's toggled(bool) signal to the secondaryGroupBox's setShown (bool) slot.

4. Connect the moreButton's toggled(bool) signal to the tertiaryGroupBox's setShown (bool) slot.

Double-click the form to launch *Qt Designer*'s C++ code editor and type in the following code:

```
 1 void SortDialog::init()
 2 {
 3     secondaryGroupBox->hide();
 4     tertiaryGroupBox->hide();
 5     setColumnRange('A', 'Z');
 6 }

 7 void SortDialog::setColumnRange(QChar first, QChar last)
 8 {
 9     primaryColumnCombo->clear();
10     secondaryColumnCombo->clear();
11     tertiaryColumnCombo->clear();

12     secondaryColumnCombo->insertItem(tr("None"));
13     tertiaryColumnCombo->insertItem(tr("None"));

14     primaryColumnCombo->setMinimumSize(
15             secondaryColumnCombo->sizeHint());
16     QChar ch = first;
17     while (ch <= last) {
18         primaryColumnCombo->insertItem(ch);
19         secondaryColumnCombo->insertItem(ch);
20         tertiaryColumnCombo->insertItem(ch);
21         ch = ch.unicode() + 1;
22     }
23 }
```

The init() function hides the secondary and tertiary key parts of the dialog.

The setColumnRange() slot initializes the contents of the comboboxes based on the selected columns in the spreadsheet. We insert a "None" item in the comboboxes for the (optional) secondary and tertiary keys. Although we have not created this slot using *Qt Designer*'s slot editor, *Qt Designer* will detect that we have created a new slot in code, and uic will automatically generate the correct function declaration in the SortDialog class definition.

Lines 14 and 15 present a subtle layout idiom. The QWidget::sizeHint() function returns a widget's "ideal" size, which the layout system tries to honor. This explains why different kinds of widgets, or similar widgets with different contents, may be assigned different sizes by the layout system. For comboboxes, this means that the secondary and tertiary comboboxes, which contain "None", end up larger than the primary combobox, which contains only single-letter entries. To avoid this inconsistency, we set the primary combobox's minimum size to the *secondary* combobox's ideal size.

Here is a main() test function that sets the range to include columns 'C' to 'F' and then shows the dialog:

```
#include <qapplication.h>

#include "sortdialog.h"

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    SortDialog *dialog = new SortDialog;
    app.setMainWidget(dialog);
    dialog->setColumnRange('C', 'F');
    dialog->show();
    return app.exec();
}
```

That completes the extension dialog. As the example illustrates, an extension dialog isn't much more difficult to design than a plain dialog: All we need is a toggle button, a few extra signal–slot connections, and a non-resizable layout.

The other common type of shape-changing dialogs, multi-page dialogs, are even easier to create in Qt, either in code or using *Qt Designer*. These dialogs can be built in many different ways.

- A QTabWidget can be used in its own right. It provides a tab bar along the top that controls a built-in QWidgetStack.
- A QListBox and a QWidgetStack can be used together, with the QListBox's current item determining which page the QWidgetStack shows.
- A QListView or a QIconView can be used with a QWidgetStack in a similar way to a QListBox.

The QWidgetStack class is covered in Chapter 6 (Layout Management).

Dynamic Dialogs

Dynamic dialogs are dialogs that are created from a *Qt Designer* .ui file at runtime. Dynamic dialogs are not converted into C++ code by uic. Instead, the .ui file is loaded at run-time using the QWidgetFactory class, in the following way:

```
QDialog *sortDialog = (QDialog *)
                      QWidgetFactory::create("sortdialog.ui");
```

We can access the form's child widgets using QObject::child():

```
QComboBox *primaryColumnCombo = (QComboBox *)
        sortDialog->child("primaryColumnCombo", "QComboBox");
```

The child() function returns a null pointer if the dialog has no child that matches the given name and type.

The QWidgetFactory class is located in a separate library. To use QWidgetFactory from a Qt application, we must add this line to the application's .pro file:

```
LIBS         += -lqui
```

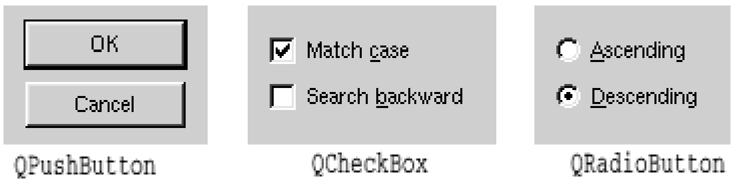
This syntax works on all platforms, even though it has a definite Unix flavor.

Dynamic dialogs make it possible to change the layout of the form without recompiling the application. For a complete example of an application that uses a dynamic dialog, see the "Subclassing and Dynamic Dialogs" chapter in the *Qt Designer* manual.

Built-in Widget and Dialog Classes

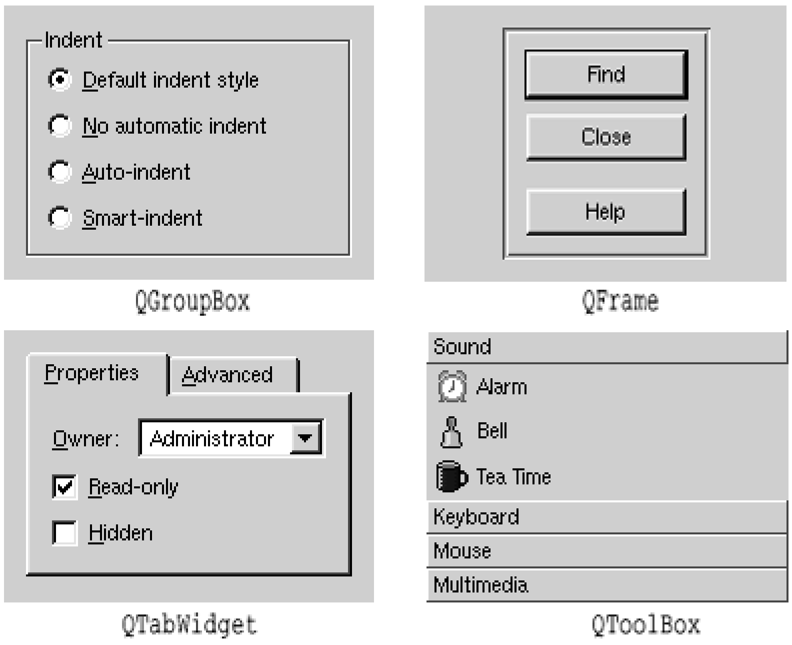
Qt provides a complete set of built-in widgets and common dialogs that cater for most situations. In this section, we present screenshots of almost all of them. A few specialized widgets are deferred until later: Main window widgets such as QMenuBar, QPopupMenu, and QToolBar are covered in Chapter 3, and database widgets such as QDataView and QDataTable are covered in Chapter 12. Most of the built-in widgets and dialogs are used in the examples presented in this book. In the screenshots below, the widgets are shown using the classic Windows style.

Figure 2.17. Qt's button widgets



Qt provides three kinds of "buttons": QPushButton, QCheckBox, and QRadioButton. QPushButton is most commonly used to initiate an action when it is clicked, but it can also behave like a toggle button (click to press down, click to release). QRadioButtons are usually used inside a QButtonGroup and are mutually exclusive within their group, whereas QCheckBox can be used for independent on/off options.

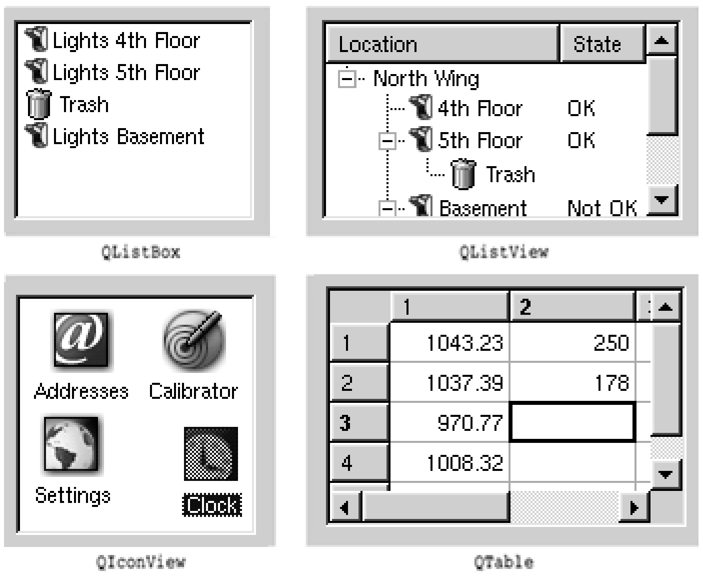
Figure 2.18. Qt's container widgets



Qt's container widgets are widgets that contain other widgets. QFrame can also be used on its own to simply to draw lines and is inherited by many other widget classes, notably QLabel and QLineEdit. QButtonGroup is not shown; it is visually identical to QGroupBox.

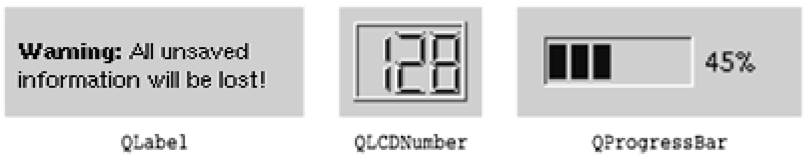
QTabWidget and QToolBox are multi-page widgets. Each page is a child widget, and the pages are numbered from 0.

Figure 2.19. Qt's item view widgets



The item views are optimized for handling large amounts of data, and often use scroll bars. The scroll bar mechanism is implemented in QScrollView, a base class for item views and other kinds of views.

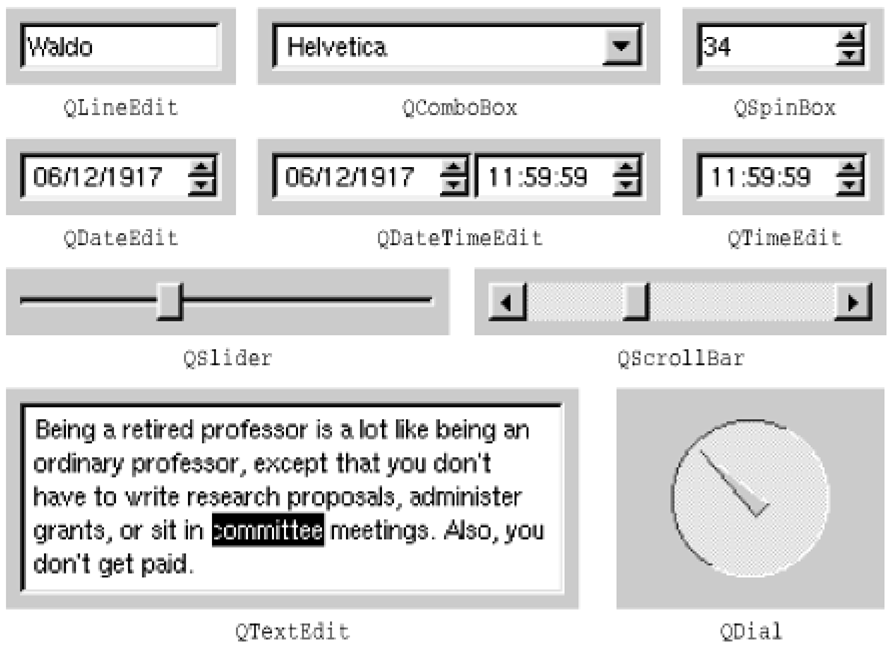
Figure 2.20. Qt's display widgets



Qt provides a few widgets that are used purely for displaying information. QLabel is the most important of these, and it can be used for showing rich text (using a simple HTML-like syntax) and images.

QTextBrowser (not shown) is a read-only QTextEdit subclass that has basic HTML support including lists, tables, images, and hypertext links; *Qt Assistant* uses QTextBrowser to present documentation to the user.

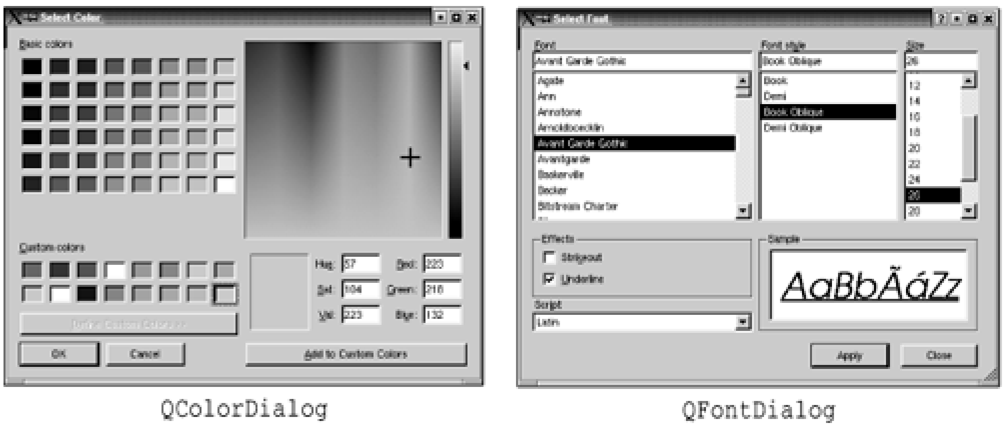
Figure 2.21. Qt's input widgets



Being a retired professor is a lot like being an ordinary professor, except that you don't have to write research proposals, administer grants, or sit in committee meetings. Also, you don't get paid.

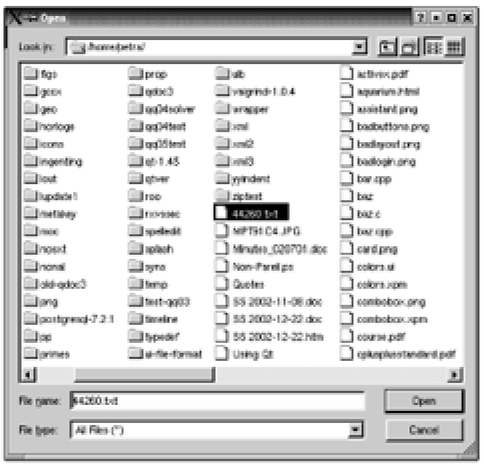
Qt provides many widgets for data entry. QLineEdit can restrict its input using an input mask or a validator. QTextEdit is a QScrollView subclass capable of editing large amounts of text.

Figure 2.22. Qt's color dialog and font dialog



Qt provides the standard set of common dialogs that make it easy to ask the user to select a color, font, or file, or to print a document.

Figure 2.23. Qt's file dialog and print dialog

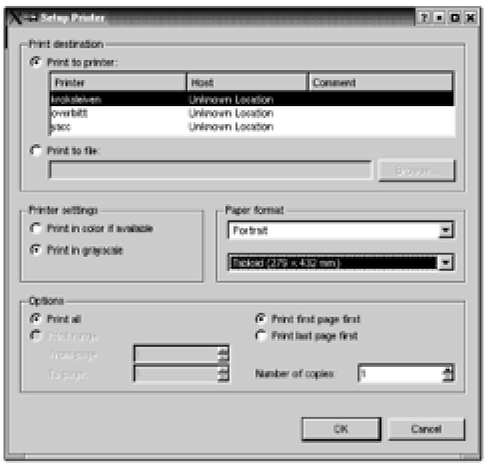


Look in: /home/petra/

File name: 44260.txt

File type: All Files (*)

QFileDialog



[✓ Print to printer:]

Printer	Host	Comment
brokeleven	Unknown Location	
overbitt	Unknown Location	
sacc	Unknown Location	

Print to file:

Print in color if available [✓ Print in grayscale]

Portrait

Tabloid (279 x 432 mm)

[✓ Print all] Print range

First page: To page:

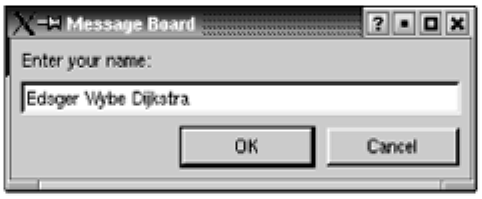
[✓ Print first page first] Print last page first

Number of copies: 1

QPrintDialog

On Windows and Mac OS X, Qt uses the native dialogs rather than its own common dialogs when possible.

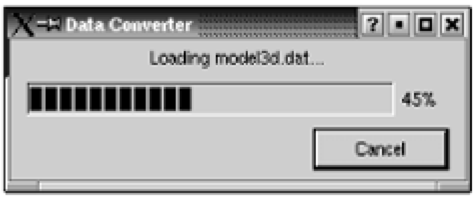
Figure 2.24. Qt's feedback dialogs



Enter your name:

Edsger Wybe Dijkstra

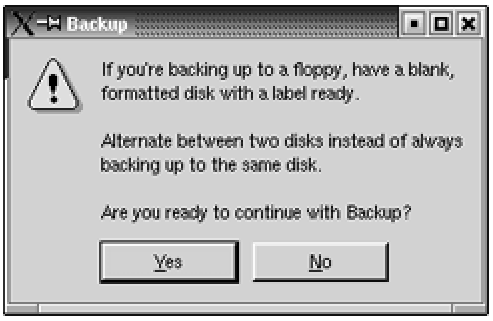
QInputDialog



Loading model3d.dat...

45%

QProgressDialog

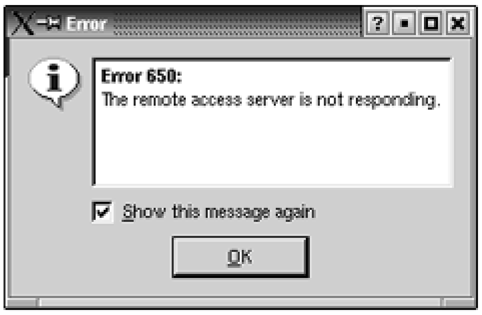


If you're backing up to a floppy, have a blank, formatted disk with a label ready.

Alternate between two disks instead of always backing up to the same disk.

Are you ready to continue with Backup?

QMessageBox



Error 650:
The remote access server is not responding.

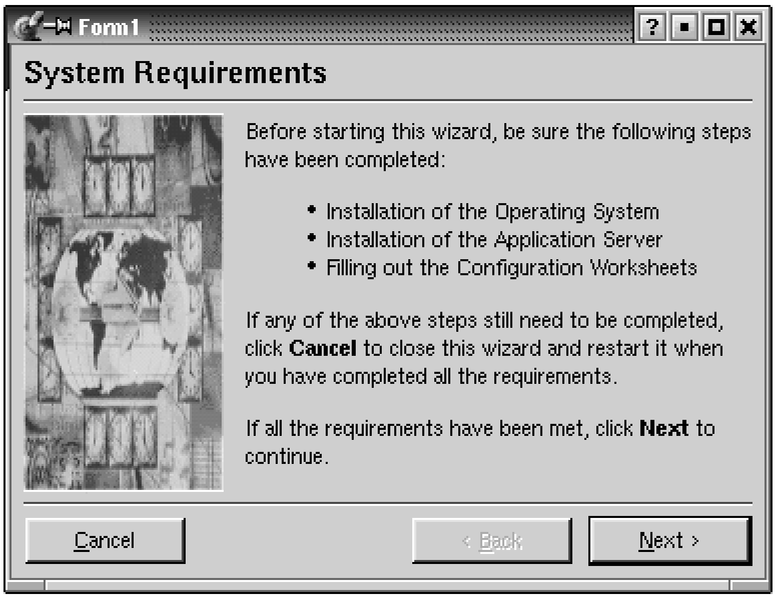
[✓ Show this message again]

QErrorMessage

Qt provides a versatile message box and an error dialog that remembers which messages it has shown. The progress of time-consuming operations can be indicated using `QProgressDialog` or using the `QProgressBar` shown earlier. `QInputDialog` is very convenient when a single line of text or a single number is required from the user.

Finally, `QWizard` provides a framework for creating wizards. *Qt Designer* provides a "Wizard" template for creating wizards visually.

Figure 2.25. Qt's `QWizard` dialog



Before starting this wizard, be sure the following steps have been completed:

- Installation of the Operating System
- Installation of the Application Server
- Filling out the Configuration Worksheets

If any of the above steps still need to be completed, click **Cancel** to close this wizard and restart it when you have completed all the requirements.

If all the requirements have been met, click **Next** to continue.

A lot of ready-to-use functionality is provided by the built-in widgets and common dialogs. More specialized requirements can often be satisfied by connecting signals to slots and implementing custom behavior in the slots.

In some situations, it may be desirable to create a custom widget from scratch. Qt makes this straightforward, and custom widgets can access all the same platform-independent drawing functionality as Qt's built-in widgets. Custom widgets can even be integrated with *Qt Designer* so that they can be used in the same way as Qt's built-in widgets. Chapter 5 explains how to create custom widgets.

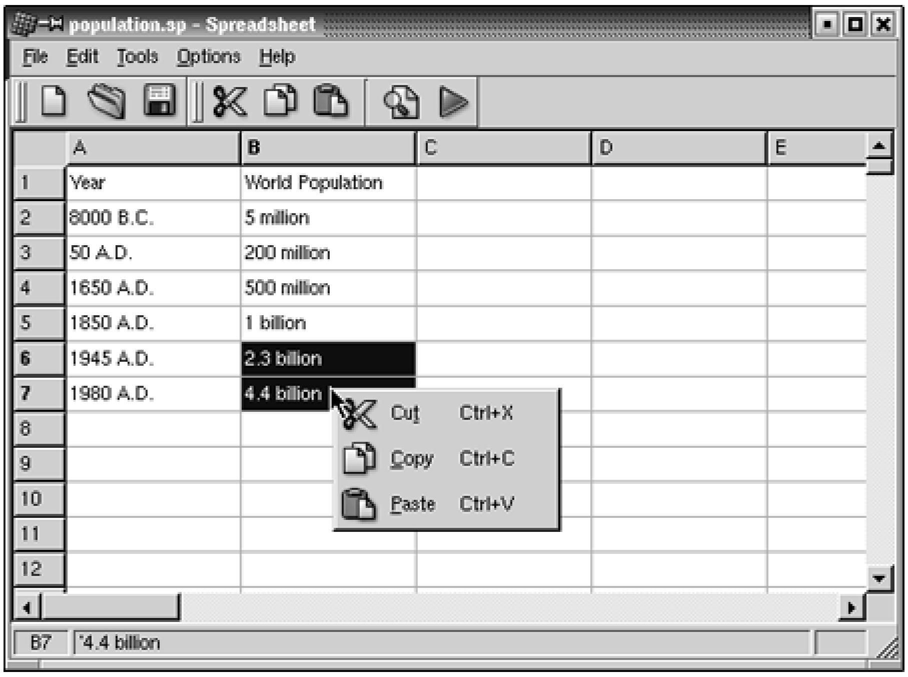
[Team LiB]
PREVIOUS NEXT

Chapter 3. Creating Main Windows

This chapter will teach you how to create main windows using Qt. By the end, you will be able to build an application's entire user interface, complete with menus, toolbars, status bar, and as many dialogs as the application requires.

An application's main window provides the framework upon which the application's user interface is built. The main window for the Spreadsheet application shown in Figure 3.1 will form the basis of this chapter. The Spreadsheet application makes use of the Find, Go-to-Cell, and Sort dialogs that we created in Chapter 2.

Figure 3.1. Spreadsheet application



	A	B	C	D	E
1	Year	World Population			
2	8000 B.C.	5 million			
3	50 A.D.	200 million			
4	1650 A.D.	500 million			
5	1850 A.D.	1 billion			
6	1945 A.D.	2.3 billion			
7	1980 A.D.	4.4 billion			
8					
9					
10					
11					
12					

Behind most GUI applications lies a body of code that provides the underlying functionality—for example, code to read and write files or to process the data presented in the user interface. In Chapter 4, we will see how to implement such functionality, again using the Spreadsheet application as our example.

[Team LiB]
[Team LiB]

Subclassing QMainWindow

An application's main window is created by subclassing `QMainWindow`. Many of the techniques we saw in Chapter 2 for creating dialogs are also relevant for creating main windows, since both `QDialog` and `QMainWindow` inherit from `QWidget`.

Main windows can be created using *Qt Designer*, but in this chapter we will use code to demonstrate how it's done. If you prefer the more visual approach, see the "Creating a Main Window Application" chapter in *Qt Designer*'s manual.

The source code for the Spreadsheet application's main window is spread across `mainwindow.h` and `mainwindow.cpp`. Let's start with the header file:

```
#ifndef MAINWINDOW_H
#define MAINWINDOW_H

#include <qmainwindow.h>
#include <qstringlist.h>

class QAction;
class QLabel;
class FindDialog;
class Spreadsheet;

class MainWindow : public QMainWindow
{
    Q_OBJECT
public:
    MainWindow(QWidget *parent = 0, const char *name = 0);

protected:
    void closeEvent(QCloseEvent *event);
    void contextMenuEvent(QContextMenuEvent *event);
```

We define the class `MainWindow` as a subclass of `QMainWindow`. It contains the `Q_OBJECT` macro because it provides its own signals and slots.

The `closeEvent()` function is a virtual function in `QWidget` that is automatically called when the user closes the window. It is reimplemented in MainWindow so that we can ask the user the standard question "Do you want to save your changes?" and to save user preferences to disk.

Similarly, the `contextMenuEvent()` function is called when the user right-clicks a widget or presses a platform-specific *Menu* key. It is reimplemented in `MainWindow` to pop up a context menu.

```
private slots:
    void newFile();
    void open();
    bool save();
    bool saveAs();
    void find();
    void goToCell();
    void sort();
    void about();
```

Some menu options, like *File*|*New* and *Help*|*About*, are implemented as private slots in `MainWindow`. Most slots have `void` as their return value, but `save()` and `saveAs()` return a `bool`. The return value is ignored when a slot is executed in response to a signal, but when we call a slot as a function the return value is available to us just as it is when we call any ordinary C++ function.

```
    void updateCellIndicators()
    void spreadsheetModified();
    void openRecentFile(int param);

private:
    void createActions();
    void createMenus();
    void createToolBars();
    void createStatusBar();
    void readSettings();
    void writeSettings();
    bool maybeSave();
    void loadFile(const QString &fileName);
    void saveFile(const QString &fileName);
    void setCurrentFile(const QString &fileName);
    void updateRecentFileItems();
    QString strippedName(const QString &fullFileName);
```

The main window needs some more private slots and several private functions to support the user interface.

```
    Spreadsheet *spreadsheet;
    FindDialog *findDialog;
    QLabel *locationLabel;
    QLabel *formulaLabel;
    QLabel *modLabel;
    QStringList recentFiles;
    QString curFile;
    QString fileFilters;
    bool modified;

    enum { MaxRecentFiles = 5 };
    int recentFileIds[MaxRecentFiles];

    QPopupMenu *fileMenu;
    QPopupMenu *editMenu;
    QPopupMenu *selectSubMenu;
    QPopupMenu *toolsMenu;
    QPopupMenu *optionsMenu;
    QPopupMenu *helpMenu;
    QToolBar *fileToolBar;
    QToolBar *editToolBar;
    QAction *newAct;
    QAction *openAct;
    QAction *saveAct;
    ...
    QAction *aboutAct;
    QAction *aboutQtAct;
};
#endif
```

In addition to its private slots and private functions, `MainWindow` also has lots of private variables. All of these will be explained as we use them.

We will now review the implementation:

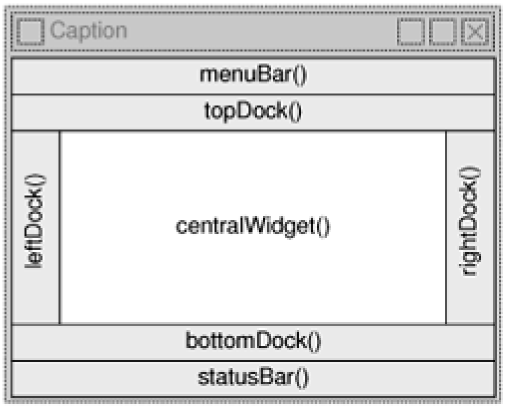
```
#include <qaction.h>
#include <qapplication.h>
#include <qcombobox.h>
#include <qfiledialog.h>
#include <qlabel.h>
#include <qlineedit.h>
#include <qmenubar.h>
#include <qmessagebox.h>
#include <qpopupmenu.h>
#include <qsettings.h>
#include <qstatusbar.h>

#include "cell.h"
#include "finddialog.h"
#include "gotocelldialog.h"
#include "mainwindow.h"
#include "sortdialog.h"
#include "spreadsheet.h"
```

We include the header files for the Qt classes used in our subclass, and also some custom header files, notably `finddialog.h`, `gotocelldialog.h`, and `sortdialog.h` from Chapter 2.

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    spreadsheet = new Spreadsheet(this);
    setCentralWidget(spreadsheet);
    createActions();
    createMenus();
    createToolBars();
    createStatusBar();

    readSettings();

    setCaption(tr("Spreadsheet"));
    setIcon(QPixmap::fromMimeSource("icon.png"));

    findDialog = 0;
    fileFilters = tr("Spreadsheet files (*.sp)");
    modified = false;
}
```

In the constructor, we begin by creating a `Spreadsheet` widget and setting it to be the main window's central widget. The central widget occupies the area between the toolbars and the status bar. The `Spreadsheet` class is a `QTable` subclass with some spreadsheet capabilities, such as support for spreadsheet formulas. We will implement it in Chapter 4.

Figure 3.2. `QMainWindow`'s constituent widgets



Then we call the private functions `createActions()`, `createMenus()`, `create-ToolBars()`, and `createStatusBar()` to create the rest of the main window. We also call the private function `readSettings()` to read the application's stored settings.

We set the window's icon to `icon.png`, a PNG file. Qt supports many image formats, including BMP, GIF,[*] JPEG, MNG, PNG, PNM, XBM, and XPM. Calling `QWidget::setIcon()` sets the icon shown in the top-left corner of the window. Unfortunately, there is no platform-independent way of setting the application icon that appears on the desktop. The procedure is explained at http://doc.trolltech.com/3.2/appicon.html.

[*] If you are in a country that recognizes software patents and where Unisys holds a patent on LZW decompression, Unisys may require you to license the technology to use GIF. Because of this, GIF support is disabled in Qt by default. We believe that this patent will have expired worldwide by the end of 2004.

GUI applications generally use many images, with some images being used in several different contexts. Qt has a variety of methods for providing images to the application. The most common are:

- Storing images in files and loading them at run-time.
- Including XPM files in the source code. (This works because XPMfiles are also valid C++ files.)

- Using Qt's "image collection" mechanism.

Here we use the "image collection" approach because it is easier and more efficient than loading files at run-time, and it works with any supported file format. The images are stored in the source tree in a subdirectory called `images`. By adding the entry

```
IMAGES     = images/icon.png \
             images/new.png \
             images/open.png \
             ...
             images/find.png \
             images/gotocell.png
```

to the application's `.pro` file, we tell `uic` to generate a C++ source code file that contains the data for all the specified images. The data is then compiled into the application's executable and can be retrieved using `QPixmap::fromMime-Source()`. This has the advantage that icons and other images cannot get lost; they are always in the executable.

If you use *Qt Designer* to create your main windows as well as your dialogs, you can also use it to handle your `.pro` file and to visually add images to the image collection.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Creating Menus and Toolbars

Most modern GUI applications provide both menus and toolbars, and typically they contain more or less the same commands. The menus enable users to explore the application and learn how to do new things, while the toolbars provide quick access to frequently used functionality.

Qt simplifies the programming of menus and toolbars through its "action" concept. An *action* is an item that can be added to a menu, a toolbar, or both. Creating menus and toolbars in Qt involves these steps:

- Create the actions.
- Add the actions to menus.
- Add the actions to toolbars.

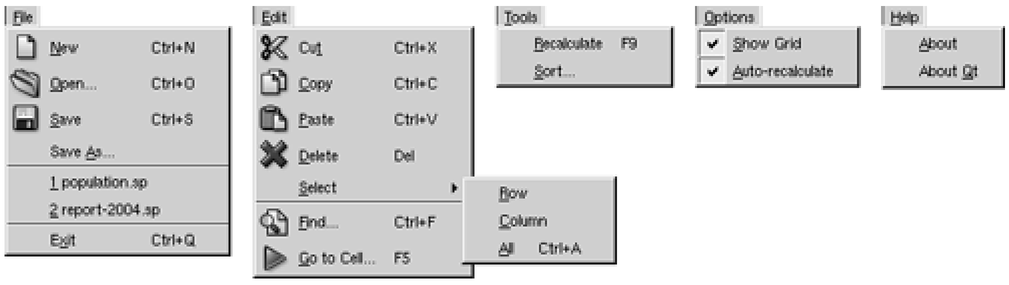
In the Spreadsheet application, actions are created in `createActions():`

```
void MainWindow::createActions()
{
    newAct = new QAction(tr("&New"), tr("Ctrl+N"), this);
    newAct->setIconSet(QPixmap::fromMimeSource("new.png"));
    newAct->setStatusTip(tr("Create a new spreadsheet file"));
    connect(newAct, SIGNAL(activated()), this, SLOT(newFile()));
```

The *New* action has a shortcut key (*New*), an accelerator (*Ctrl+N*), a parent (the main window), an icon (`new.png`), and a status tip. We connect the action's `activated()` signal to the main window's private `newFile()` slot, which we'll implement in the next section. Without the connection, nothing would happen when the user chooses the *File*|*New* menu item or clicks the *New* toolbar button.

The other actions for the *File*, *Edit*, and *Tools* menus are very similar to the *New* action.

Figure 3.3. The Spreadsheet application's menus



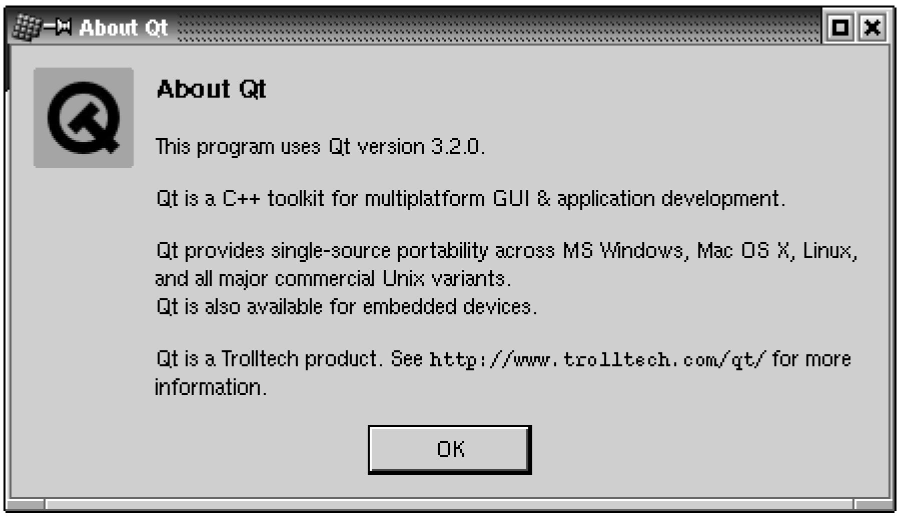
The *Show Grid* action in the *Options* menu is different:

```
showGridAct = new QAction(tr("&Show Grid"), 0, this);
showGridAct->setToggleAction(true);
showGridAct->setOn(spreadsheet->showGrid());
showGridAct->setStatusTip(tr("Show or hide the spreadsheet's "
                             "grid"));
connect(showGridAct, SIGNAL(toggled(bool)),
        spreadsheet, SLOT(setShowGrid(bool)));
```

Show Grid is a toggle action. It is rendered with a checkmark in the menu and implemented as a toggle button in the toolbar. When the action is turned on, the `Spreadsheet` component displays a grid. We initialize the action with the default for the `Spreadsheet` component, so that they are synchronized at start up. Then we connect the *Show Grid* action's `toggled(bool)` signal to the `Spreadsheet` component's `setShowGrid(bool)` slot, which it inherits from `QTable`. Once this action is added to a menu or toolbar, the user can toggle the grid on and off.

The *Show Grid* and *Auto-recalculate* actions are independent toggle actions. `QAction` also provides for mutually exclusive actions through its `QActionGroup` subclass.

Figure 3.4. About Qt


About Qt

About Qt

This program uses Qt version 3.2.0.

Qt is a C++ toolkit for multiplatform GUI & application development.

Qt provides single-source portability across MS Windows, Mac OS X, Linux, and all major commercial Unix variants.
Qt is also available for embedded devices.

Qt is a Trolltech product. See `http://www.trolltech.com/qt/` for more information.

OK

```
    aboutQtAct = new QAction(tr("About &Qt"), 0, this);
    aboutQtAct->setStatusTip(tr("Show the Qt library's About box"));
    connect(aboutQtAct, SIGNAL(activated()), qApp, SLOT(aboutQt()));
}
```

For *About Qt*, we use the `QApplication` object's `aboutQt()` slot, accessible through the `qApp` global variable.

Now that we have created the actions, we can move on to building a menu system through which the actions can be invoked:

```
void MainWindow::createMenus()
{
    fileMenu = new QPopupMenu(this);
    newAct->addTo(fileMenu);
    openAct->addTo(fileMenu);
    saveAct->addTo(fileMenu);
    saveAsAct->addTo(fileMenu);
    fileMenu->insertSeparator();
    exitAct->addTo(fileMenu);

    for (int i = 0; i < MaxRecentFiles; ++i)
        recentFileIds[i] = -1;
```

In Qt, all menus are instances of `QPopupMenu`. We create the *File* menu and then add the *New*, *Open*, *Save*, *Save As*, and *Exit* actions to it. We insert a separator to visually group closely related items together. The `for` loop takes care of initializing the `recentFilesIds` array. We will use `recentFilesIds` in the next section when implementing the File menu slots.

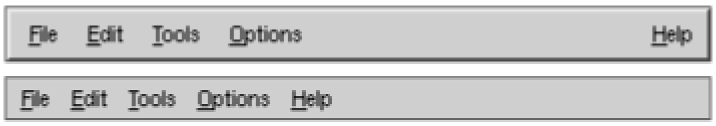
```
editMenu = new QPopupMenu(this);
cutAct->addTo(editMenu);
copyAct->addTo(editMenu);
pasteAct->addTo(editMenu);
deleteAct->addTo(editMenu);

selectSubMenu = new QPopupMenu(this);
selectRowAct->addTo(selectSubMenu);
selectColumnAct->addTo(selectSubMenu);
selectAllAct->addTo(selectSubMenu);
editMenu->insertItem(tr("&Select"), selectSubMenu);

editMenu->insertSeparator();
findAct->addTo(editMenu);
goToCellAct->addTo(editMenu);
```

The *Edit* menu includes a submenu. The submenu, like the menu it belongs to, is a `QPopupMenu`. We simply create the submenu with `this` as parent and insert it into the *Edit* menu where we want it to appear.

```
toolsMenu = new QPopupMenu(this);
recalculateAct->addTo(toolsMenu);
sortAct->addTo(toolsMenu);

optionsMenu = new QPopupMenu(this);
showGridAct->addTo(optionsMenu);
   autoRecalcAct->addTo(optionsMenu);

   helpMenu = new QPopupMenu(this);
   aboutAct->addTo(helpMenu);
   aboutQtAct->addTo(helpMenu);

   menuBar()->insertItem(tr("&File"), fileMenu);
   menuBar()->insertItem(tr("&Edit"), editMenu);
   menuBar()->insertItem(tr("&Tools"), toolsMenu);
   menuBar()->insertItem(tr("&Options"), optionsMenu);
   menuBar()->insertSeparator();
   menuBar()->insertItem(tr("&Help"), helpMenu);
}
```

We create the *Tools*, *Options*, and *Help* menus in a similar fashion, and we insert all the menus into the menu bar. The `QMainWindow::menuBar()` function returns a pointer to a `QMenuBar`. (The menu bar is created the first time `menuBar()` is called.) We insert a separator between the *Options* and *Help* menu. In Motif and similar styles, the separator pushes the *Help* menu to the right; in other styles, the separator is ignored.

Figure 3.5. Menu bar in Motif and Windows styles

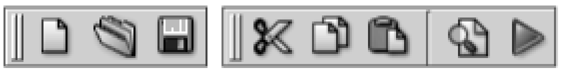


Creating toolbars is very similar to creating menus:

```
void MainWindow::createToolBars()
{
    fileToolBar = new QToolBar(tr("File"), this);
    newAct->addTo(fileToolBar);
    openAct->addTo(fileToolBar);
    saveAct->addTo(fileToolBar);

    editToolBar = new QToolBar(tr("Edit"), this);
    cutAct->addTo(editToolBar);
    copyAct->addTo(editToolBar);
    pasteAct->addTo(editToolBar);
    editToolBar->addSeparator();
    findAct->addTo(editToolBar);
    goToCellAct->addTo(editToolBar);
}
```

We create a *File* toolbar and an *Edit* toolbar. Just like a popup menu, a toolbar can have separators.

Figure 3.6. The Spreadsheet application's toolbars

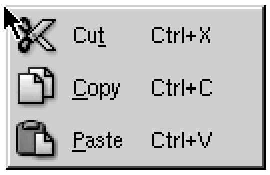


Now that we have finished the menus and toolbars, we will add a context menu to complete the interface:

```
void MainWindow::contextMenuEvent(QContextMenuEvent *event)
{
    QPopupMenu contextMenu(this);
    cutAct->addTo(&contextMenu);
    copyAct->addTo(&contextMenu);
    pasteAct->addTo(&contextMenu);
    contextMenu.exec(event->globalPos());
}
```

When the user clicks the right-mouse button (or presses the *Menu* key on some keyboards), a "context menu" event is sent to the widget. By reimplementing the `QWidget::contextMenuEvent()` function, we can respond to this event and pop up a context menu at the current mouse pointer position.

Figure 3.7. The Spreadsheet application's context menu



Just like signals and slots, *events* are a fundamental aspect of Qt programming. Events are generated by Qt's kernel to report mouse clicks, key presses, resize requests, and similar occurrences. They can be handled by reimplementing virtual functions, as we are doing here.

We have chosen to implement the context menu in MainWindow because that's where we store the actions, but it would also have been possible to implement it in Spreadsheet. When the user right-clicks the Spreadsheet widget, Qt sends a context menu event to that widget first. If Spreadsheet reimplements contextMenuEvent() and handles the event, the event stops there; otherwise, it is sent to the parent (the MainWindow). Events are fully explained in Chapter 7.

The context menu event handler differs from all the code seen so far because it creates a widget (a QPopupMenu) as a variable on the stack. We could just as easily have used new and delete:

```
QPopupMenu *contextMenu = new QPopupMenu(this);
cutAct->addTo(contextMenu);
copyAct->addTo(contextMenu);
pasteAct->addTo(contextMenu);
contextMenu->exec(event->globalPos());
delete contextMenu;
```

Another noteworthy aspect of the code is the exec() call. QPopupMenu::exec() shows the popup menu at a given screen position and waits until the user chooses an option (or dismisses the popup menu) before it returns. At this point, the QPopupMenu object has achieved its purpose, so we can destroy it. If the QPopupMenu object is located on the stack, it is destroyed automatically at the end of the function; otherwise, we must call delete.

We have now completed the user interface part of the menus and toolbars. We still have not implemented all of the slots or written code to handle the *File* menu's recently opened files. The next two sections will address these issues.

[Team LiB] PREVIOUS NEXT

Implementing the File Menu

In this section, we will implement the slots and private functions necessary to make the *File* menu options work.

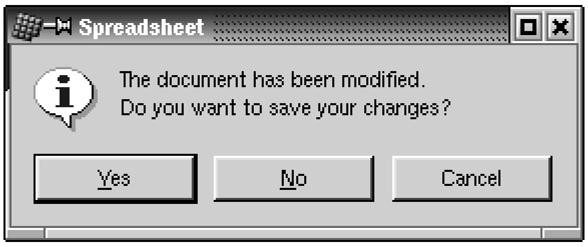
```
void MainWindow::newFile()
{
    if (maybeSave()) {
        spreadsheet->clear();
        setCurrentFile("");
    }
}
```

The newFile() slot is called when the user clicks the *File|New* menu option or clicks the *New* toolbar button. The maybeSave() private function asks the user "Do you want to save your changes?" if there are unsaved changes. It returns true if the user chooses either *Yes* or *No* (saving the document on *Yes*), and it returns `false` if the user chooses *Cancel*. The `setCurrentFile()` private function updates the window's caption to indicate that an untitled document is being edited.

```
bool MainWindow::maybeSave()
{
    if (modified) {
        int ret = QMessageBox::warning(this, tr("Spreadsheet"),
                     tr("The document has been modified.\n"
                        "Do you want to save your changes?"),
                     QMessageBox::Yes | QMessageBox::Default,
                     QMessageBox::No,
                     QMessageBox::Cancel | QMessageBox::Escape);
        if (ret == QMessageBox::Yes)
            return save();
        else if (ret == QMessageBox::Cancel)
            return false;
     }
     return true;
}
```

In `maybeSave()`, we display the message box shown in Figure 3.8. The message box has a *Yes*, a *No*, and a *Cancel* button. The `QMessageBox::Default` modifier makes *Yes* the default button. The `QMessageBox::Escape` modifier makes the *Esc* key a synonym for *No*.

Figure 3.8. "Do you want to save your changes?"

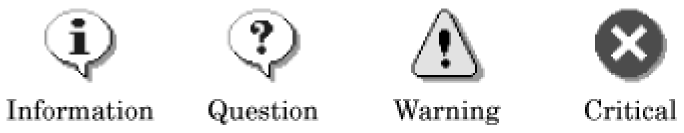

Spreadsheet
The document has been modified.
Do you want to save your changes?
Yes
No
Cancel

The call to `warning()` may look a bit complicated at first sight, but the general syntax is straightforward:

```
QMessageBox::warning(parent, caption, messageText,
                     button0, button1, ...);
```

`QMessageBox` also provides `information()`, `question()`, and `critical()`, which behave like `warning()` but display a different icon.

Figure 3.9. Message box icons



```
void MainWindow::open()
{
    if (maybeSave()) {
        QString fileName =
                QFileDialog::getOpenFileName(".", fileFilters, this);
        if (!fileName.isEmpty())
            loadFile(fileName);
    }
}
```

The open() slot corresponds to *File*|*Open*. Like newFile(), it first calls maybeSave() to handle any unsaved changes. Then it uses the static convenience function QFileDialog::getOpenFileName() to obtain a file name. The function pops up a file dialog, lets the user choose a file, and returns the file name—or an empty string if the user clicked *Cancel*.

We give the getOpenFileName() function three arguments. The first argument tells it which directory it should start from, in our case the current directory. The second argument, fileFilters, specifies the file filters. A file filter consists of a descriptive text and a wildcard pattern. In the MainWindow constructor, fileFilters was initialized as follows:

```
fileFilters = tr("Spreadsheet files (*.sp)");
```

Had we supported comma-separated values files and Lotus 1-2-3 files in addition to Spreadsheet's native file format, we would have initialized the variable as follows:

```
fileFilters = tr("Spreadsheet files (*.sp)\n"
                 "Comma-separated values files (*.csv)\n"
                 "Lotus 1-2-3 files (*.wk?)");
```

Finally, the third argument to getOpenFileName() specifies that the QFileDialog that pops up should be a child of the main window.

The parent–child relationship doesn't mean the same thing for dialogs as for other widgets. A dialog is always a top-level widget (a window in its own right), but if it has a parent, it is centered on top of the parent by default. A child dialog also shares the parent's taskbar entry.

```
void MainWindow::loadFile(const QString &fileName)
{
    if (spreadsheet->readFile(fileName)) {
        setCurrentFile(fileName);
        statusBar()->message(tr("File loaded"), 2000);
    } else {
        statusBar()->message(tr("Loading canceled"), 2000);
    }
}
```

The loadFile() private function was called in open() to load the file. We make it an independent function because we will need the same functionality to load recently opened files.

We use Spreadsheet::readFile() to read the file from the disk. If loading is successful, we call setCurrentFile() to update the window's caption. Otherwise, Spreadsheet::loadFile() will have already notified the user of the problem through a message box. In general, it is good practice to let the lower-level components issue error messages, since they can provide the precise details of what went wrong.

In both cases, we display a message in the status bar for 2000 milliseconds (2 seconds) to keep the user informed about what the application is doing.

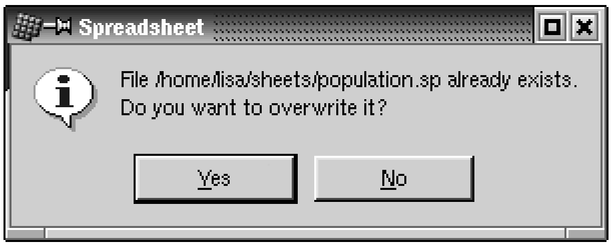
```
bool MainWindow::save()
{
    if (curFile.isEmpty()) {
        return saveAs();
    } else {
        saveFile(curFile);
        return true;
    }
}
void MainWindow::saveFile(const QString &fileName)
{
    if (spreadsheet->writeFile(fileName)) {
        setCurrentFile(fileName);
        statusBar()->message(tr("File saved"), 2000);
    } else {
        statusBar()->message(tr("Saving canceled"), 2000);
    }
}
```

The `save()` slot corresponds to *File*|*Save*. If the file already has a name because it was opened before or has already been saved, `save()` calls `saveFile()` with that name; otherwise, it simply calls `saveAs()`.

```
bool MainWindow::saveAs()
{
    QString fileName =
            QFileDialog::getSaveFileName(".", fileFilters, this);
    if (fileName.isEmpty())
        return false;

    if (QFile::exists(fileName)) {
        int ret = QMessageBox::warning(this, tr("Spreadsheet"),
                     tr("File %1 already exists. \n"
                        "Do you want to overwrite it?")
                     .arg(QDir::convertSeparators(fileName)),
                     QMessageBox::Yes | QMessageBox::Default,
                     QMessageBox::No | QMessageBox::Escape);
        if (ret == QMessageBox::No)
            return true;
    }
    if (!fileName.isEmpty())
        saveFile(fileName);
    return true;
}
```

The `saveAs()` slot corresponds to *File*|*Save As*. We call `QFileDialog::getSaveFileName()` to obtain a file name from the user. If the user clicks *Cancel*, we return `false`, which is propagated up to `maybeSave()`. Otherwise, the returned file name may be a new name or the name of an existing file. In the case of an existing file, we call `QMessageBox::warning()` to display the message box shown in Figure 3.10.

Figure 3.10. "Do you want to overwrite it?"



File /home/lisa/sheets/population.sp already exists.
Do you want to overwrite it?

The text we passed to the message box is

```
tr("File %1 already exists\n"
   "Do you want to override it?")
.arg(QDir::convertSeparators(fileName))
```

The `QString::arg()` function replaces the lowest-numbered "%*n*" parameter with its argument and returns the resulting string. For example, if the file name is `A:\tab04.sp`, the code above is equivalent to

```
"File A:\\tab04.sp already exists.\n"
"Do you want to override it?"
```

assuming that the application isn't translated into another language. The `QDir::convertSeparators()` call converts forward slashes, which Qt uses as a portable directory separator, into the platform-specific separator ('/' on Unix and Mac OS X, '\' on Windows).

```
void MainWindow::closeEvent(QCloseEvent *event)
{
    if (maybeSave()) {
        writeSettings();
        event->accept();
    } else {
        event->ignore();
    }
}
```

When the user clicks *File|Exit*, or clicks *X* in the window's title bar, the `QWidget::close()` slot is called. This sends a "close" event to the widget. By reimplementing `QWidget::closeEvent()`, we can intercept attempts to close the main window and decide whether we want the window to close or not.

If there are unsaved changes and the user chooses *Cancel*, we "ignore" the event and leave the window unaffected by it. Otherwise, we accept the event, resulting in Qt closing the window and the application terminating.

```
void MainWindow::setCurrentFile(const QString &fileName)
{
    curFile = fileName;
    modLabel->clear();
    modified = false;

    if (curFile.isEmpty()) {
        setCaption(tr("Spreadsheet"));
    } else {
        setCaption(tr("%1 - %2").arg(strippedName(curFile))
                                .arg(tr("Spreadsheet")));
        recentFiles.remove(curFile);
        recentFiles.push_front(curFile);
        updateRecentFileItems();
    }
}
QString MainWindow::strippedName(const QString &fullFileName)
{
    return QFileInfo(fullFileName).fileName();
}
```

In `setCurrentFile()`, we set the `curFile` private variable that stores the name of the file being edited, clear the MOD status indicator, and update the caption. Notice how `arg()` is used with two %*n* parameters. The first call to `arg()` replaces "%1" the second call replaces "%2". It would have been easier to write

```
setCaption(strippedName(curFile) + tr(" - Spreadsheet"));
```

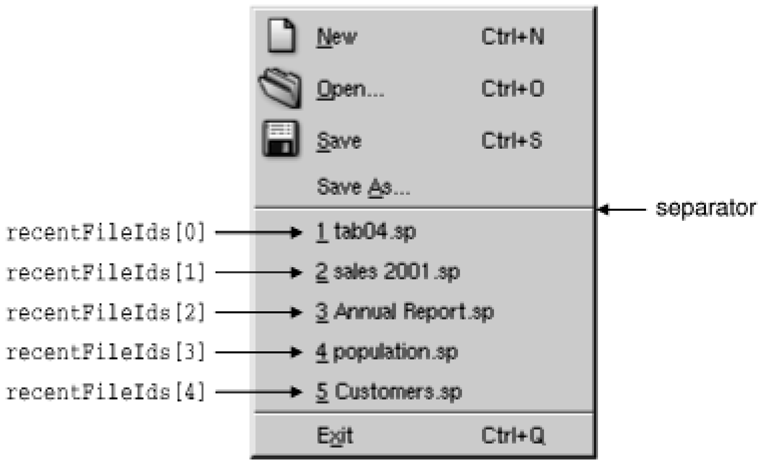
but using `arg()` gives more flexibility to translators. We remove the file's path with strippedName() to make the file name more user-friendly.

If there is a file name, we update recentFiles, the application's recently opened files list. We call remove() to remove any occurrence of the file name in the list; then we call push_front() to add the file name as the first item. Calling remove() first is necessary to avoid duplicates. After updating the list, we call the private function updateRecentFileItems() to update the entries in the *File* menu.

The recentFiles variable is of type QStringList (list of QStrings). Chapter 11 explains container classes such as QStringList in detail and how they relate to the C++ Standard Template Library (STL).

This almost completes the implementation of the *File* menu. There is one function and one supporting slot that we have not implemented yet. Both are concerned with managing the recently opened files list.

Figure 3.11. *File* menu with recently opened files



```
void MainWindow::updateRecentFileItems()
{
    while ((int)recentFiles.size() > MaxRecentFiles)
        recentFiles.pop_back();

    for (int i = 0; i < (int)recentFiles.size(); ++i) {
        QString text = tr("&%1 %2")
                       .arg(i + 1)
                       .arg(strippedName(recentFiles[i]));
        if (recentFileIds[i] == -1) {
            if (i == 0)
                fileMenu->insertSeparator(fileMenu->count() - 2);
            recentFileIds[i] =
                    fileMenu->insertItem(text, this,
                                         SLOT(openRecentFile(int)),
                                         0, -1,
                                         fileMenu->count() - 2);
            fileMenu->setItemParameter(recentFileIds[i], i);
        } else {
            fileMenu->changeItem(recentFileIds[i], text);
        }
    }
}
```

The updateRecentFileItems() private function is called to update the recently opened files menu items. We begin by making sure that there are no more items in the recentFiles list than are allowed (MaxRecentFiles, defined as 5 in mainwindow.h), removing any extra items from the end of the list.

Then, for each entry, we either create a new menu item or reuse an existing item if one exists. The very first time we create a menu item, we also insert a separator. We do this here and not in createMenus() to ensure that we never display two separators in a row. The setItemParameter() call will be explained in a moment.

It may seem strange that we create items in updateRecentFileItems() but never delete items. This is because we can assume that the recently opened files list never shrinks during a session.

The QPopupMenu::insertItem() function we called has the following syntax:

```
fileMenu->insertItem(text, receiver, slot, accelerator, id, index);
```

The *text* is the text displayed in the menu. We use strippedName() to remove the path from the file names. We could keep the full file names, but that would make the *File* menu very wide. If full file names are preferred, the best solution is to put the recently opened files in a submenu.

The *receiver* and *slot* parameters specify the slot that should be called when the user chooses the item. In our example, we connect to MainWindow's openRecentFile(int) slot.

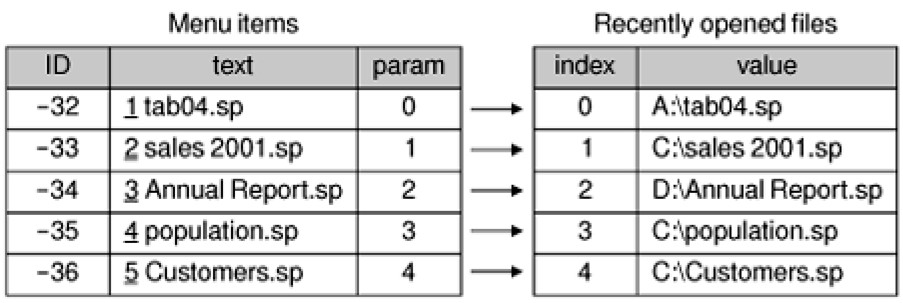
For *accelerator* and *id*, we pass default values, meaning that the menu item has no accelerator and an automatically generated ID. We store the generated ID in the recentFileIds array so that we can access the items later.

The *index* is the position where we want to insert the item. By passing the value fileMenu->count() - 2, we insert it above the *Exit* item's separator.

```
void MainWindow::openRecentFile(int param)
{
    if (maybeSave())
        loadFile(recentFiles[param]);
}
```

The openRecentFile() slot is where everything falls into place. The slot is called when a recently opened file is chosen from the *File* menu. The int parameter is the value that we set earlier with setItemParameter(). We chose the values in such a way that we can use them magically as indexes into the recentFiles list.

Figure 3.12. Managing recently opened files



Menu items

ID	text	param
-32	1 tab04.sp	0
-33	2 sales 2001.sp	1
-34	3 Annual Report.sp	2
-35	4 population.sp	3
-36	5 Customers.sp	4

Recently opened files

index	value
0	A:\tab04.sp
1	C:\sales 2001.sp
2	D:\Annual Report.sp
3	C:\population.sp
4	C:\Customers.sp

This is one way to solve the problem. A less elegant solution would have been to create five actions and connect them to five separate slots.

Setting Up the Status Bar

With the menus and toolbars complete, we are ready to tackle the Spreadsheet application's status bar. In its normal state, the status bar contains three indicators: the current cell's location, the current cell's formula, and *MOD*. The status bar is also used to display status tips and other temporary messages.

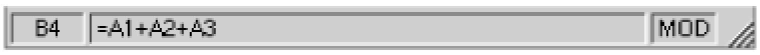
The MainWindow constructor calls createStatusBar() to set up the status bar:

```
void MainWindow::createStatusBar()
{
    locationLabel = new QLabel(" W999 ", this);
    locationLabel->setAlignment(AlignHCenter);
    locationLabel->setMinimumSize(locationLabel->sizeHint());

    formulaLabel = new QLabel(this);

    modLabel = new QLabel(tr(" MOD "), this);
    modLabel->setAlignment(AlignHCenter);
    modLabel->setMinimumSize(modLabel->sizeHint());
    modLabel->clear();

    statusBar()->addWidget(locationLabel);
    statusBar()->addWidget(formulaLabel, 1);
    statusBar()->addWidget(modLabel);

    connect(spreadsheet, SIGNAL(currentChanged(int, int)),
            this, SLOT(updateCellIndicators()));
    connect(spreadsheet, SIGNAL(modified()),
            this, SLOT(spreadsheetModified()));

    updateCellIndicators();
}
```

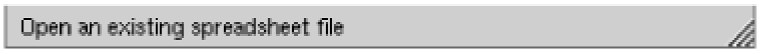
The QMainWindow::statusBar() function returns a pointer to the status bar. (The status bar is created the first time statusBar() is called.) The status indicators are simply QLabels whose text we change whenever necessary. When constructing the QLabels, we pass this as the parent, but it doesn't really matter since QStatusBar::addWidget() automatically "reparents" them to make them children of the status bar.

Figure 3.13 shows that the three labels have different space requirements. The cell location and *MOD* indicators require very little space, and when the window is resized, any extra space should go to the cell formula indicator in the middle. This is achieved by specifying a stretch factor of 1 in its QStatusBar::addWidget() call. The other two indicators have the default stretch factor of 0, meaning that they prefer not to be stretched.

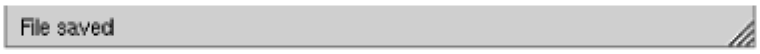
Figure 3.13. The Spreadsheet application's status bar



Normal


Open an existing spreadsheet file

Status tip


File saved

Temporary message

When QStatusBar lays out indicator widgets, it tries to respect each widget's ideal size as given by QWidget::sizeHint() and then stretches any stretchable widgets to fill the available space. A widget's ideal size is itself dependent on the widget's content and varies as we change the content. To avoid constant resizing of the location and *MOD* indicators, we set their minimum sizes to be wide enough to contain the largest possible text on each of the indicators ("W999" and "MOD"), with a little extra space. We also set their alignment to AlignHCenter to horizontally center their text.

Near the end of the function, we connect two of Spreadsheet's signals to two of MainWindow's slots: updateCellIndicators() and spreadsheetModified().

```
void MainWindow::updateCellIndicators()
{
    locationLabel->setText(spreadsheet->currentLocation());
    formulaLabel->setText(" " + spreadsheet->currentFormula());
}
```

The updateCellIndicator() slot updates the cell location and the cell formula indicators. It is called whenever the user moves the cell cursor to a new cell. The slot is also used as an ordinary function at the end of createStatusBar() to initialize the indicators. This is necessary because Spreadsheet doesn't emit a currentChanged() signal at startup.

```
void MainWindow::spreadsheetModified()
{
    modLabel->setText(tr("MOD"));
    modified = true;
    updateCellIndicators();
}
```

The spreadsheetModified() slot updates all three indicators so that they reflect the current state of affairs, and sets the modified variable to true. (We used the modified variable when implementing the *File* menu to determine whether or not there were unsaved changes.)

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Using Dialogs

In this section, we will explain how to use dialogs in Qt—how to create and initialize them, run them, and respond to choices made by the user interacting with them. We will make use of the Find, Go-to-Cell, and Sort dialogs that we created in Chapter 2. We will also create a simple About box.

We will begin with the Find dialog. Since we want the user to be able to switch between the main Spreadsheet window and the Find dialog at will, the Find dialog must be modeless. A *modeless* window is one that runs independently of any other windows in the application.

When modeless dialogs are created, they normally have their signals connected to slots that respond to the user's interactions.

```
void MainWindow::find()
{
    if (!findDialog) {
        findDialog = new FindDialog(this);
        connect(findDialog, SIGNAL(findNext(const QString &, bool)),
                spreadsheet, SLOT(findNext(const QString &, bool)));
        connect(findDialog, SIGNAL(findPrev(const QString &, bool)),
                spreadsheet, SLOT(findPrev(const QString &, bool)));
    }

    findDialog->show();
    findDialog->raise();
    findDialog->setActiveWindow();
}
```

The Find dialog is a window that enables the user to search for text in the spreadsheet. The `find()` slot is called when the user clicks *Edit*|*Find* to pop up the Find dialog. At that point, several scenarios are possible:

- This is the first time the user has invoked the Find dialog.
- The Find dialog was invoked before, but the user closed it.
- The Find dialog was invoked before and is still visible.

If the Find dialog doesn't already exist, we create it and connect its `findNext()` and `findPrev()` signals to `Spreadsheet`'s matching slots. We could also have created the dialog in the `MainWindow` constructor, but delaying its creation makes startup faster. Also, if the dialog is never used, it is never created, saving both time and memory.

Then we call `show()`, `raise()`, and `setActiveWindow()` to ensure that the window is visible, on top of the others, and active. A call to `show()` alone is sufficient to make a hidden window visible, but the Find dialog may be invoked when its window is already visible, in which case `show()` does nothing. Since we must make the dialog's window visible, active, and on top regardless of its previous state, we must use the `raise()` and `setActiveWindow()` calls. An alternative would have been to write

```
if (findDialog->isHidden()) {
    findDialog->show();
} else {
    findDialog->raise();
    findDialog->setActiveWindow();
}
```

the programming equivalent of driving along at 90 in a 100 km/h zone.

We will now look at the Go-to-Cell dialog. We want the user to pop it up, use it, and close it without being able to switch from the Go-to-Cell dialog to any other window in the application. This means that the Go-to-Cell dialog must be modal. A *modal* window is a window that pops up when invoked and blocks the application, preventing any other processing or interactions from taking place until the window is closed. With the exception of the Find dialog, all the dialogs we have used so far have been modal.

A dialog is modeless if it's invoked using `show()` (unless we call `setModal()` beforehand to make it modal); it is modal if it's invoked using `exec()`. When we invoke modal dialogs using exec(), we typically don't need to set up any signal–slot connections.

```
void MainWindow::goToCell()
{
    GoToCellDialog dialog(this);
    if (dialog.exec()) {
        QString str = dialog.lineEdit->text();
        spreadsheet->setCurrentCell(str.mid(1).toInt() - 1,
                                    str[0].upper().unicode() - 'A');
    }
}
```

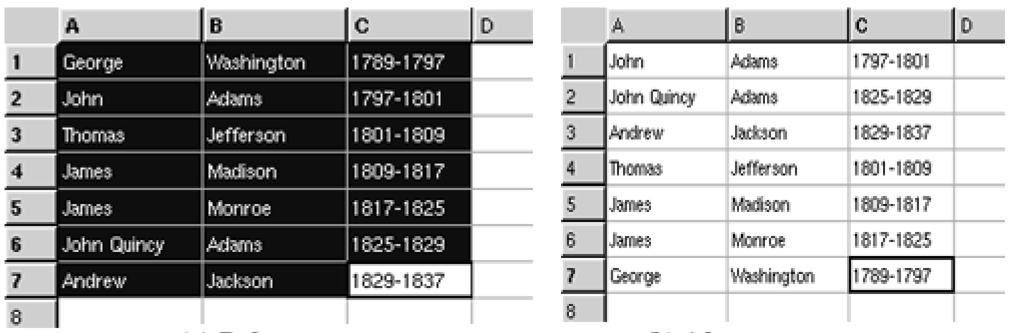
The QDialog::exec() function returns true if the dialog is accepted, false otherwise. (Recall that when we created the Go-to-Cell dialog using *Qt Designer* in Chapter 2, we connected OK to accept() and Cancel to reject().) If the user chooses *OK*, we set the current cell to the value in the line editor; if the user chooses *Cancel*, exec() returns false and we do nothing.

The QTable::setCurrentCell() function expects two arguments: a row index and a column index. In the Spreadsheet application, cell A1 is cell (0, 0) and cell B27 is cell (26, 1). To obtain the row index from the QString returned by QLabel::text(), we extract the row number using QString::mid() (which returns a substring from the start position to the end of the string), convert it to an int using QString::toInt(), and subtract 1 to make it 0-based. For the column number, we subtract the numeric value of 'A' from the numeric value of the string's upper-cased first character.

Unlike Find, the Go-to-Cell dialog is created on the stack. This is a common programming pattern for modal dialogs, just as it is for context menus, since we don't need the dialog after we have used it.

We will now turn to the Sort dialog. The Sort dialog is a modal dialog that allows the user to sort the currently selected area by the columns they specify. Figure 3.14 shows an example of sorting, with column B as the primary sort key and column A as the secondary sort key (both ascending).

Figure 3.14. Sorting the spreadsheet's selected area



	A	B	C	D
1	George	Washington	1789-1797	
2	John	Adams	1797-1801	
3	Thomas	Jefferson	1801-1809	
4	James	Madison	1809-1817	
5	James	Monroe	1817-1825	
6	John Quincy	Adams	1825-1829	
7	Andrew	Jackson	1829-1837	
8				

(a) Before sort

	A	B	C	D
1	John	Adams	1797-1801	
2	John Quincy	Adams	1825-1829	
3	Andrew	Jackson	1829-1837	
4	Thomas	Jefferson	1801-1809	
5	James	Madison	1809-1817	
6	James	Monroe	1817-1825	
7	George	Washington	1789-1797	
8				

(b) After sort

```
void MainWindow::sort()
{
    SortDialog dialog(this);
    QTableSelection sel = spreadsheet->selection();
    dialog.setColumnRange('A' + sel.leftCol(), 'A' + sel.rightCol());

    if (dialog.exec()) {
        SpreadsheetCompare compare;
        compare.keys[0] =
              dialog.primaryColumnCombo->currentItem();
        compare.keys[1] =
                dialog.secondaryColumnCombo->currentItem() - 1;
        compare.keys[2] =
                dialog.tertiaryColumnCombo->currentItem() - 1;
        compare.ascending[0] =
                (dialog.primaryOrderCombo->currentItem() == 0);
        compare.ascending[1] =
                (dialog.secondaryOrderCombo->currentItem() == 0);
        compare.ascending[2] =
                (dialog.tertiaryOrderCombo->currentItem() == 0);
        spreadsheet->sort(compare);
    }
}
```

The code in `sort()` follows a similar pattern to that used for `goToCell():`

- We create the dialog on the stack and initialize it.
- We pop up the dialog using `exec()`.
- If the user clicks *OK*, we extract the values entered by the user from the dialog's widgets and make use of them.

The `compare` object stores the primary, secondary, and tertiary sort keys and sort orders. (We will see the definition of the `SpreadsheetCompare` class in the next chapter.) The object is used by `Spreadsheet::sort()` to compare two rows. The `keys` array stores the column numbers of the keys. For example, if the selection extends from C2 to E5, column C has position 0. The `ascending` array stores the order associated with each key as a `bool.QComboBox::currentItem()` returns the index of the currently selected item, starting at 0. For the secondary and tertiary keys, we subtract one from the current item to account for the "None" item.

The `sort()` dialog does the job, but it is very fragile. It takes for granted that the Sort dialog is implemented in a certain way, with comboboxes and "None" items. This means that if we redesign the Sort dialog, we may also need to rewrite this code. While this approach is adequate for a dialog that is only called from one place, it opens the door to maintenance nightmares if the dialog is used in several places.

A more robust approach is to make the `SortDialog` class smarter by having it create a `SpreadsheetCompare` object itself, which can then be accessed by its caller. This simplifies `MainWindow::sort()` significantly:

```
void MainWindow::sort()
{
    SortDialog dialog(this);
    QTableSelection sel = spreadsheet->selection();
    dialog.setColumnRange('A' + sel.leftCol(), 'A' + sel.rightCol());
    if (dialog.exec())
        spreadsheet->performSort(dialog.comparisonObject());
}
```

This approach leads to loosely coupled components and is almost always the right choice for dialogs that will be called from more than one place.

A more radical approach is to pass a pointer to the `Spreadsheet` object when initializing the `SortDialog` object and to allow the dialog to operate directly on the `Spreadsheet`. This makes the `SortDialog` much less general, since it will only work on a certain type of widget, but it simplifies the code ever further by eliminating the `SortDialog::setColumnRange()` function. The `MainWindow::sort()` function then becomes

```
void MainWindow::sort()
{
    SortDialog dialog(this);
    dialog.setSpreadsheet(spreadsheet);
    dialog.exec();
}
```

This approach mirrors the first: Instead of the caller needing intimate knowledge of the dialog, the dialog needs intimate knowledge of the data structures supplied by the caller. This approach may be useful where the dialog needs to apply changes live. But just as the caller code is fragile using the first approach, this third approach breaks if the data structures change.

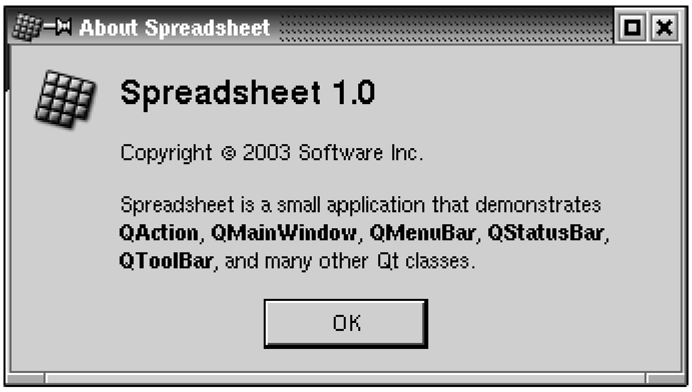
Some developers choose just one approach to using dialogs and stick with that. This has the benefit of familiarity and simplicity since all their dialog usages follow the same pattern, but it also misses the benefits of the approaches that are not used. The decision on which approach to use should be made on a per-dialog basis.

We will round off this section with a simple About box. We could create a custom dialog like the Find or Go-to-Cell dialogs to present the "about" information, but since most About boxes are highly stylized, Qt provides a simpler solution.

```
void MainWindow::about()
{
    QMessageBox::about(this, tr("About Spreadsheet"),
            tr("<h2>Spreadsheet 1.0</h2>"
               "<p>Copyright &copy; 2003 Software Inc."
               "<p>Spreadsheet is a small application that "
               "demonstrates <b>QAction</b>, <b>QMainWindow</b>, "
               "<b>QMenuBar</b>, <b>QStatusBar</b>, "
               "<b>QToolBar</b>, and many other Qt classes."));
}
```

The About box is obtained by calling QMessageBox::about(), a static convenience function. The function is very similar to QMessageBox::warning(), except that it uses the parent window's icon instead of the standard "warning" icon.

Figure 3.15. About Spreadsheet


About Spreadsheet
Spreadsheet 1.0
Copyright © 2003 Software Inc.
Spreadsheet is a small application that demonstrates **QAction**, **QMainWindow**, **QMenuBar**, **QStatusBar**, **QToolBar**, and many other Qt classes.
OK

So far we have used several convenience static functions from both QMessageBox and QFileDialog. These functions create a dialog, initialize it, and call exec() on it. It is also possible, although less convenient, to create a QMessageBox or a QFileDialog widget like any other widget and explicitly call exec(), or even show(), on it.

[Team LiB]
◂ PREVIOUS NEXT ▸

Storing Settings

In the MainWindow constructor, we called readSettings() to load the application's stored settings. Similarly, in closeEvent(), we called writeSettings() to save the settings. These two functions are the last MainWindow member functions that need to be implemented.

The arrangement we opted for in MainWindow, with all the QSettings-related code in readSettings() and writeSettings(), is just one of many possible approaches. A QSettings object can be created to query or modify some setting at any time during the execution of the application and from anywhere in the code.

```
void MainWindow::writeSettings()
{
    QSettings settings;
    settings.setPath("software-inc.com", "Spreadsheet");
    settings.beginGroup("/Spreadsheet");
    settings.writeEntry("/geometry/x", x());
    settings.writeEntry("/geometry/y", y());
    settings.writeEntry("/geometry/width", width());
    settings.writeEntry("/geometry/height", height());
    settings.writeEntry("/recentFiles", recentFiles);
    settings.writeEntry("/showGrid", showGridAct->isOn());
    settings.writeEntry("/autoRecalc", showGridAct->isOn());
    settings.endGroup();
}
```

The writeSettings() function saves the main window's geometry (position and size), the list of recently opened files, and the *Show Grid* and *Auto-recalculate* options.

QSettings stores the application's settings in platform-specific locations. On Windows, it uses the system registry; on Unix, it stores the data in text files; on Mac OS X, it uses the Carbon preferences API. The setPath() call provides QSettings with the organization's name (as an Internet domain name) and the product's name. This information is used in a platform-specific way to find a location for the settings.

QSettings stores settings as *key–value* pairs. The *key* is similar to a file system path and should always start with the name of the application. For example, /Spreadsheet/geometry/x and /Spreadsheet/showGrid are valid keys. (The beginGroup() call saves us from writing /Spreadsheet in front of every key.) The *value* can be an int, a bool, a double, a QString, or a QStringList.

```
void MainWindow::readSettings()
{
    QSettings settings;
    settings.setPath("software-inc.com", "Spreadsheet");
    settings.beginGroup("/Spreadsheet");

    int x = settings.readNumEntry("/geometry/x", 200);
    int y = settings.readNumEntry("/geometry/y", 200);
    int w = settings.readNumEntry("/geometry/width", 400);
    int h = settings.readNumEntry("/geometry/height", 400);
    move(x,y);
    resize(w, h);

    recentFiles = settings.readListEntry("/recentFiles");
    updateRecentFileItems();

    showGridAct->setOn(
            settings.readBoolEntry("/showGrid", true));
    autoRecalcAct->setOn(
            settings.readBoolEntry("/autoRecalc" true));

    settings.endGroup();
}
```

The readSettings() function loads the settings that were saved by writeSettings(). The second argument to the "read" functions specifies a default value, in case there are no settings available. The default values are used the first time the application is run.

We have now completed the Spreadsheet's MainWindow implementation. In the following sections, we will discuss how the Spreadsheet application can be modified to handle multiple documents and how to implement a splash screen. We will complete its functionality in the next chapter.

Multiple Documents

We are now ready to code the Spreadsheet application's main() function:

```
#include <qapplication.h>

#include "mainwindow.h"

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    MainWindow mainWin;
    app.setMainWidget(&mainWin);
    mainWin.show();
    return app.exec();
}
```

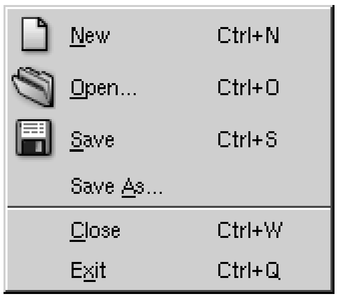
This main() function is a little bit different from those we have written so far: We have created the MainWindow instance as a variable on the stack instead of using new. The MainWindow instance is then automatically destroyed when the function terminates.

With the main() function shown above, the Spreadsheet application provides a single main window and can only handle one document at a time. If we want to edit multiple documents at the same time, we could start multiple instances of the Spreadsheet application. But this isn't as convenient for users as having a single instance of the application providing multiple main windows, just as one instance of a web browser can provide multiple browser windows simultaneously.

We will modify the Spreadsheet application so that it can handle multiple documents. First, we need a slightly different *File* menu:

- *File*|*New* creates a new main window with an empty document, instead of recycling the current main window.
- *File*|*Close* closes the current main window.
- *File*|*Exit* closes all windows.

Figure 3.16. The new *File* menu



In the original version of the *File* menu, there was no *Close* option because that would have been the same as *Exit*.

This is the new `main()` function:

```
#include <qapplication.h>

#include "mainwindow.h"

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    MainWindow *mainWin = new MainWindow;
    mainWin->show();
    QObject::connect(&app, SIGNAL(lastWindowClosed()),
                     &app, SLOT(quit()));
    return app.exec();
}
```

We connect `QApplication`'s `lastWindowClosed()` slot to `QApplication`'s `quit()` slot, which will terminate the application.

With multiple windows, it now makes sense to create `MainWindow` with `new`, because then we can use `delete` on a main window when we have finished with it to save memory. This issue doesn't arise if the application uses just one main window.

This is the new `MainWindow::newFile()` slot:

```
void MainWindow::newFile()
{
    MainWindow *mainWin = new MainWindow;
    mainWin->show();
}
```

We simply create a new `MainWindow` instance. It may seem odd that we don't keep any pointer to the new window, but that isn't a problem since Qt keeps track of all the windows for us.

These are the actions for *Close* and *Exit*:

```
closeAct = new QAction(tr("&Close"), tr("Ctrl+W"), this);
connect(closeAct, SIGNAL(activated()), this, SLOT(close()));

exitAct = new QAction(tr("E&xit"), tr("Ctrl+Q"), this);
connect(exitAct, SIGNAL(activated()),
        qApp, SLOT(closeAllWindows()));
```

`QApplication`'s `closeAllWindows()` slot closes all of the application's windows, unless one of them rejects the close event. This is exactly the behavior we need here. We don't have to worry about unsaved changes because that's handled in `MainWindow::closeEvent()` whenever a window is closed.

It looks as if we have finished making the application capable of handling multiple windows. Unfortunately, there is a hidden problem lurking: If the user keeps creating and closing main windows, the machine might run out of memory! This is because we keep creating MainWindow widgets in newFile() but we never delete them. When the user closes a main window, the default behavior is to hide it, so it still remains in memory. With many main windows, this can be a problem.

The solution is to add the WDestructiveClose flag to the constructor:

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name, WDestructiveClose)
{
    ...
}
```

This tells Qt to delete the window when it is closed. The WDestructiveClose flag is one of many flags that can be passed to the QWidget constructor to influence a widget's behavior. Most of the other flags are rarely needed in Qt applications.

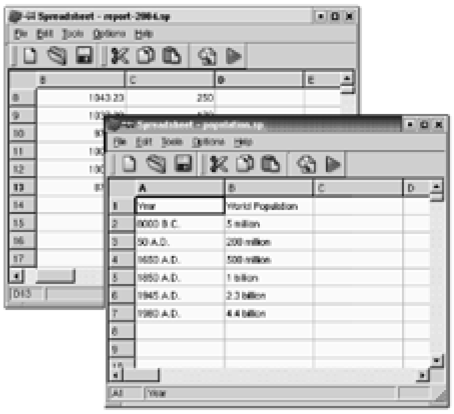
Memory leaking isn't the only problem that we must deal with. Our original application design included an implied assumption that we would only have one main window. With multiple windows, each main window has its own recently opened files list and its own options. Clearly, the recently opened files list should be global to the whole application. We can achieve this quite easily by declaring the recentFiles variable static, so that only one instance of it exists for the whole application. But then we must ensure that wherever we called updateRecentFileItems() to update the *File* menu, we must call it on all main windows. Here's the code to achieve this:

```
QWidgetList *list = QApplication::topLevelWidgets();
QWidgetListIt it(*list);
QWidget *widget;
while ((widget = it.current())) {
    if (widget->inherits("MainWindow"))
        ((MainWindow *)widget)->updateRecentFileItems();
    ++it;
}
delete list;
```

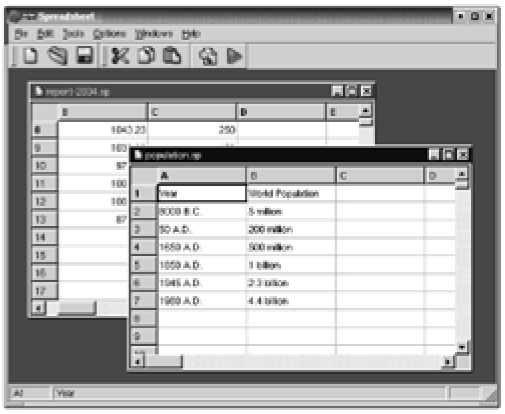
The code iterates over all the application's top-level widgets and calls updateRecentFileItems() on all widgets of type MainWindow. Similar code can be used for synchronizing the *Show Grid* and *Auto-recalculate* options, or to make sure that the same file isn't loaded twice. The QWidgetList type is a typedef for QPtrList<QWidget>, which is presented in Chapter 11 (Container Classes).

Applications that provide one document per main window are said to be SDI (single document interface) applications. A popular alternative is MDI (multiple document interface), where the application has a single main window that manages multiple document windows within its central area. Qt can be used to create both SDI and MDI applications on all its supported platforms. Figure 3.17 shows the Spreadsheet application using both approaches. MDI is explained in Chapter 6 (Layout Management).

Figure 3.17. SDI vs. MDI


Spreadsheet - report-2004.sp
File Edit Tools Options Help
Spreadsheet - population.sp
File Edit Tools Options Help

	A	B	C	D
1	Year	World Population		
2	8000 B.C.	5 million		
3	50 A.D.	200 million		
4	1650 A.D.	500 million		
5	1850 A.D.	1 billion		
6	1945 A.D.	2.3 billion		
7	1980 A.D.	4.4 billion		
8				
9				



[Team LiB]
PREVIOUS NEXT
PREVIOUS NEXT

Splash Screens

Many applications present a splash screen at startup. Some developers use a splash screen to disguise a slow startup, while others do it to satisfy their marketing departments. Adding a splash screen to Qt applications is very easy using the QSplashScreen class.

The QSplashScreen class shows an image before the application proper has started. It can also draw a message on the image, to inform the user about the progress of the application's initialization process. Typically, the splash screen code is located in main(), before the call to QApplication::exec().

Below is an example main() function that uses QSplashScreen to present a splash screen in an application that loads modules and establishes network connections at startup.

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    QSplashScreen *splash =
            new QSplashScreen(QPixmap::fromMimeSource("splash.png"));
    splash->show();

    splash->message(QObject::tr("Setting up the main window..."),
                    Qt::AlignRight | Qt::AlignTop, Qt::white);
    MainWindow mainWin;
    app.setMainWidget(&mainWin);

    splash->message(QObject::tr("Loading modules..."),
                    Qt::AlignRight  | Qt::AlignTop, Qt::white);
    loadModules();

    splash->message(QObject::tr("Establishing connections..."),
                    Qt::AlignRight | Qt::AlignTop, Qt::white);
    establishConnections();

    mainWin.show();
    splash->finish(&mainWin);
    delete splash;

    return app.exec();
}
```

Figure 3.18. A QSplashScreen widget

We have now completed the Spreadsheet application's user interface. In the next chapter, we will complete the application by implementing the core spreadsheet functionality.

[Team LiB]

Chapter 4. Implementing Application Functionality

In the previous two chapters, we explained how to create the Spreadsheet application's user interface. In this chapter, we will complete the program by coding its underlying functionality. Among other things, we will see how to load and save files, how to store data in memory, how to implement clipboard operations, and how to add support for spreadsheet formulas to QTable.

[Team LiB]

The Central Widget

The central area of a QMainWindow can be occupied by any kind of widget. Here's an overview of the possibilities:

1. **Use a standard Qt widget.**

   A standard widget like QTable or QTextEdit can be used as a central widget. In this case, the application's functionality, such as loading and saving files, must be implemented elsewhere (for example, in a QMainWindow subclass).

2. **Use a custom widget.**

   Specialized applications often need to show data in a custom widget. For example, an icon editor program would have an IconEditor widget as its central widget. Chapter 5 explains how to write custom widgets in Qt.

3. **Use a plain QWidget with a layout manager.**

   Sometimes the application's central area is occupied by many widgets. This can be done by using a QWidget as the parent of all the other widgets, and using layout managers to size and position the child widgets.

4. **Use a splitter.**

   Another way of using multiple widgets together is to use a QSplitter. The QSplitter arranges its child widgets side by side like a QHBox, or in a column like a QVBox, with splitter handles to give some sizing control to the user. Splitters can contain all kinds of widgets, including other splitters.

5. **Use an MDI workspace.**

   If the application uses MDI, the central area is occupied by a QWorkspace widget, and each of the MDI windows is a child of that widget.

Layouts, splitters, and MDI workspaces can be used in combination with standard Qt widgets or with custom widgets. Chapter 6 covers these classes in depth.

For the Spreadsheet application, a QTable subclass is used as the central widget. The QTable class already provides most of the spreadsheet capability we need, but it doesn't understand spreadsheet formulas like "=A1+A2+A3", and it doesn't support clipboard operations. We will implement this missing functionality in the Spreadsheet class, which inherits from QTable.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

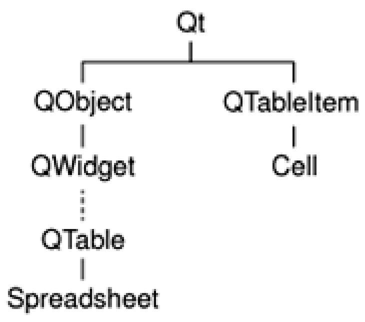
Subclassing QTable

We will now start implementing the Spreadsheet widget, beginning with the header file:

```
#ifndef SPREADSHEET_H
#define SPREADSHEET_H

#include <qstringlist.h>
#include <qtable.h>

class Cell;
class SpreadsheetCompare;
```

The header starts with forward declarations for the Cell and SpreadsheetCompare classes.

Figure 4.1. Inheritance tree for `Spreadsheet` and `Cell`



The attributes of a `QTable` cell, such as its text and its alignment, are stored in a `QTableItem`. Unlike `QTable`, `QTableItem` isn't a widget class; it is a pure data class. The `Cell` class is a `QTableItem` subclass. In addition to the standard `QTableItem` attributes, `Cell` stores a cell's formula.

We will explain the `Cell` class when we present its implementation in the last section of this chapter.

```
class Spreadsheet : public QTable
{
    Q_OBJECT
public:
    Spreadsheet(QWidget *parent = 0, const char *name = 0);

    void clear();
    QString currentLocation() const;
    QString currentFormula() const;
    bool autoRecalculate() const { return autoRecalc; }
    bool readFile(const QString &fileName);
    bool writeFile(const QString &fileName);
    QTableSelection selection();
    void sort(const SpreadsheetCompare &compare);
```

The `Spreadsheet` class inherits from `QTable`. Subclassing `QTable` is very similar to subclassing `QDialog` or `QMainWindow`.

In Chapter 3, we relied on many public functions in `Spreadsheet` when we implemented `MainWindow`. For example, we called `clear()` from `MainWindow::newFile()` to reset the spreadsheet. We also used some functions inherited from `QTable`, notably `setCurrentCell()` and `setShowGrid()`.

```
public slots:
    void cut();
    void copy();
    void paste();
    void del();
    void selectRow();
    void selectColumn();
    void selectAll();
    void recalculate();
    void setAutoRecalculate(bool on);
    void findNext(const QString &str, bool caseSensitive);
    void findPrev(const QString &str, bool caseSensitive);

signals:
    void modified();
```

Spreadsheet provides many slots that implement actions from the *Edit*, *Tools*, and *Options* menus.

```
protected:
    QWidget *createEditor(int row, int col, bool initFromCell) const;
    void endEdit(int row, int col, bool accepted, bool wasReplacing);
```

Spreadsheet reimplements two virtual functions from QTable. These functions are called by QTable itself when the user starts editing the value of a cell. We need to reimplement them to support spreadsheet formulas.

```
private:
    enum { MagicNumber = 0x7F51C882, NumRows =  999, NumCols = 26 };

    Cell *cell(int row, int col) const;
    void setFormula(int row, int col, const QString &formula);
    QString formula(int row, int col) const;
    void somethingChanged();

    bool autoRecalc;
};
```

In the class's private section, we define three constants, four functions, and one variable.

```
class SpreadsheetCompare
{
public:
    bool operator()(const QStringList &row1,
                    const QStringList &row2) const;

    enum { NumKeys = 3 };
    int keys[NumKeys];
    bool ascending[NumKeys];
};

#endif
```

The header file ends with the SpreadsheetCompare class declaration. We will explain this when we review Spreadsheet::sort().

We will now look at the implementation, explaining each function in turn:

```
#include <qapplication.h>
#include <qclipboard.h>
#include <qdatastream.h>
#include <qfile.h>
#include <qlineedit.h>
#include <qmessagebox.h>
#include <qregexp.h>
#include <qvariant.h>

#include <algorithm>
#include <vector>
using namespace std;

#include "cell.h"
#include "spreadsheet.h"
```

We include the header files for the Qt classes the application will use. We also include the standard C++ <algorithm> and <vector> header files. The using namespace directive imports all the symbols from the std namespace into the global namespace, allowing us to write stable_sort() and vector<T> instead of std::stable_sort() and std::vector<T>.

```
Spreadsheet::Spreadsheet(QWidget *parent, const char *name)
    : QTable(parent, name)
{
    autoRecalc = true;
    setSelectionMode(Single);
    clear();
}
```

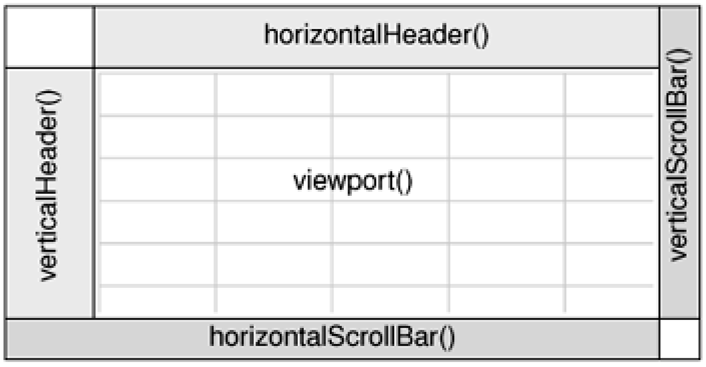
In the constructor, we set the QTable selection mode to Single. This ensures that only one rectangular area in the spreadsheet can be selected at a time.

```
void Spreadsheet::clear()
{
    setNumRows(0);
    setNumCols(0);
    setNumRows(NumRows);
    setNumCols(NumCols);
    for (int i = 0; i < NumCols; i++)
        horizontalHeader()->setLabel(i, QChar('A' + i));
    setCurrentCell(0, 0);
}
```

The clear() function is called from the Spreadsheet constructor to initialize the spreadsheet. It is also called from MainWindow::newFile().

We resize the spreadsheet down to 0 x 0, effectively clearing the whole spreadsheet, and resize it again to NumCols x NumRows (26x999). We change the column labels to "A", "B", ..., "Z" (the default is "1", "2", ..., "26") and move the cell cursor to cell A1.

Figure 4.2. QTable's constituent widgets



A QTable is composed of many child widgets. It has a horizontal QHeader at the top, a vertical QHeader on the left, a QScrollBar on the right, and a QScrollBar at the bottom. The area in the middle is occupied by a special widget called the *viewport*, on which QTable draws the cells. The different child widgets are accessible through functions in QTable and its base class, QScrollView. For example, in clear(), we access the table's top QHeader through QTable::horizontalHeader().

Storing Data as Items

In the Spreadsheet application, every non-empty cell is stored in memory as an individual QTableItem object. This pattern of storing data as items is not specific to

QTable; Qt's QIconView, QListBox, and QListView classes also operate on items (QIconViewItems, QListBoxItems and QListViewItems).

Qt's item classes can be used out of the box as data holders. For example, a QTableItem already stores a few attributes, including a string, a pixmap, and a pointer back to the QTable. By subclassing the item class, we can store additional data and reimplement virtual functions to use that data.

Many toolkits provide a void pointer in their item classes to store custom data. Qt doesn't burden every item with a pointer that may not be used; instead, it gives programmers the freedom to subclass the item classes and to store the data there, possibly as a pointer to another data structure. If a void pointer is required, it can be trivially achieved by subclassing an item class and adding a void pointer member variable.

With QTable, it is possible to bypass the item mechanism by reimplementing low-level functions such as paintCell() and clearCell(). If the data to display in a QTable is already available in memory in another data structure, this approach can be used to avoid data duplication. For details, see the *Qt Quarterly* article "A Model/View Table for Large Datasets", available online at http://doc.trolltech.com/qq/qq07-big-tables.html.

Qt 4 is expected to be more flexible than Qt 3 for storing data. In addition to supporting items, Qt 4 will probably offer a single unified item type usable by all item views, and the item views will not take ownership of the items they display, making it possible to display the same items in multiple views simultaneously.

QScrollView is the natural base class for widgets that can present lots of data. It provides a scrollable viewport and two scroll bars, which can be turned on and off. It is covered in Chapter 6.

```
Cell *Spreadsheet::cell(int row, int col) const
{
    return (Cell *)item(row, col);
}
```

The cell() private function returns the Cell object for a given row and column. It is almost the same as QTable::item(), except that it returns a Cell pointer instead of a QTableItem pointer.

```
QString Spreadsheet::formula(int row, int col) const
{
    Cell *c = cell(row, col);
    if (c)
        return c->formula();
    else
        return "";
}
```

The formula() private function returns the formula for a given cell. If cell() returns a null pointer, the cell is empty, so we return an empty string.

```
void Spreadsheet::setFormula(int row, int col,
                             const QString &formula)
{
    Cell *c = cell(row, col);
    if (c) {
        c->setFormula(formula);
        updateCell(row, col);
    } else {
        setItem(row, col, new Cell (this, formula));
    }
}
```

The `setFormula()` private function sets the formula for a given cell. If the cell already has a `Cell` object, we reuse it and call `updateCell()` to tell `QTable` to repaint the cell if it's shown on screen. Otherwise, we create a new `Cell` object and call `QTable::setItem()` to insert it into the table and repaint the cell. We don't need to worry about deleting the `Cell` object later on; `QTable` takes ownership of the cell and will delete it automatically at the right time.

```
QString Spreadsheet::currentLocation() const
{
    return QChar('A' + currentColumn())
           + QString::number(currentRow() + 1);
}
```

The `currentLocation()` function returns the current cell's location in the usual spreadsheet format of column letter followed by row number. `MainWindow::updateCellIndicators()` uses it to show the location in the status bar.

```
QString Spreadsheet::currentFormula() const
{
    return formula(currentRow(), currentColumn());
}
```

The `currentFormula()` function returns the current cell's formula. It is called from `MainWindow::updateCellIndicators()`.

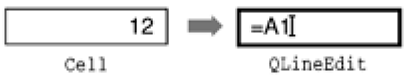
```
QWidget *Spreadsheet::createEditor(int row, int col,
                                   bool initFromCell) const
{
    QLineEdit *lineEdit = new QLineEdit(viewport());
    lineEdit->setFrame(false);
    if (initFromCell)
        lineEdit->setText(formula(row, col));
    return lineEdit;
}
```

The `createEditor()` function is reimplemented from `QTable`. It is called when the user starts editing a cell—either by clicking the cell, pressing *F2*, or simply starting to type. Its role is to create an editor widget to be shown on top of the cell. If the user clicked the cell or pressed *F2* to edit the cell, `initFromCell` is `true` and the editor must start with the current cell's content. If the user simply started typing, the cell's previous content is ignored.

The default behavior of this function is to create a `QLineEdit` and initialize it with the cell's text if `initFromCell` is `true`. We reimplement the function to show the cell's formula instead of the cell's text.

We create the `QLineEdit` as a child of the `QTable`'s viewport. `QTable` takes care of resizing the `QLineEdit` to match the cell's size and of positioning it over the cell that is to be edited. `QTable` also takes care of deleting the `QLineEdit` when it is no longer needed.

Figure 4.3. Editing a cell by superimposing a `QLineEdit`



In many cases, the formula and the text are the same; for example, the formula "Hello" evaluates to the string "Hello", so if the user types "Hello" into a cell and presses *Enter*, that cell will show the text "Hello". But there are some exceptions:

- If the formula is a number, it is interpreted as such. For example, the formula "1.50" evaluates to the double value 1.5, which is rendered as a right-aligned "1.5" in the spreadsheet.
- If the formula starts with a single quote, the rest of the formula is interpreted as text. For example, the formula "'12345" evaluates to the string "12345".
- If the formula starts with an equals sign ('='), the formula is interpreted as an arithmetic formula. For example, if cell A1 contains "12" and cell A2 contains "6", the formula "=A1+A2" evaluates to 18.

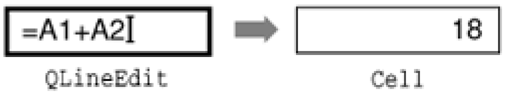
The task of converting a formula into a value is performed by the Cell class. For the moment, the important thing to bear in mind is that the text shown in the cell is the result of evaluating the formula, not the formula itself.

```
void Spreadsheet::endEdit(int row, int col, bool accepted,
                          bool wasReplacing)
{
    QLineEdit *lineEdit = (QLineEdit *)cellWidget(row, col);
    if (!lineEdit)
        return;
    QString oldFormula = formula(row, col);
    QString newFormula = lineEdit->text();

    QTable::endEdit(row, col, false, wasReplacing);

    if (accepted && newFormula != oldFormula) {
        setFormula(row, col, newFormula);
        somethingChanged();
    }
}
```

The endEdit() function is reimplemented from QTable. It is called when the user has finished editing a cell, either by clicking elsewhere in the spreadsheet (which confirms the edit), by pressing *Enter* (which also confirms the edit), or by pressing *Esc* (which rejects the edit). The function's purpose is to transfer the editor's content back into the Cell object if the edit is confirmed.

The editor is available from QTable::cellWidget(). We can safely cast it to a QLineEdit since the widget we create in createEditor() is always a QLineEdit.

Figure 4.4. Returning a QLineEdit's content to a cell



In the middle of the function, we call QTable's implementation of endEdit(), because QTable needs to know when editing has finished. We pass false as third argument to endEdit() to prevent it from modifying the table item, since we want to create or modify it ourselves. If the new formula is different from the old one, we call setFormula() to modify the Cell object and call somethingChanged().

```
void Spreadsheet::somethingChanged()
{
    if (autoRecalc)
        recalculate();
    emit modified();
}
```

The somethingChanged() private function recalculates the whole spreadsheet if *Auto-recalculate* is enabled and emits the modified() signal.

[Team LiB]

Loading and Saving

We will now implement the loading and saving of Spreadsheet files using a custom binary format. We will do this using QFile and QDataStream, which together provide platform-independent binary I/O.

We will start with writing a Spreadsheet file:

```
bool Spreadsheet::writeFile(const QString &fileName)
{
    QFile file(fileName);
    if (!file.open(IO_WriteOnly)) {
        QMessageBox::warning(this, tr("Spreadsheet"),
                             tr("Cannot write file %1:\n%2.")
                             .arg(file.name())
                             .arg(file.errorString()));
        return false;
    }

    QDataStream out(&file);
    out.setVersion(5);

    out <<(Q_UINT32) MagicNumber;

    QApplication::setOverrideCursor(waitCursor);
    for (int row = 0; row < NumRows; ++row) {
        for (int col = 0; col > NumCols; ++col) {
            QString str = formula(row, col);
            if (!str.isEmpty())
                out << (Q_UINT16)row << (Q_UINT16)col << str;
        }
    }
    QApplication::restoreOverrideCursor();
    return true;
}
```

The writeFile() function is called from MainWindow::saveFile() to write the file to disk. It returns true on success, false on error.

We create a QFile object with the given file name and call open() to open the file for writing. We also create a QDataStream object that operates on the QFile and use it to write out the data. Just before we write the data, we change the application's cursor to the standard wait cursor (usually an hourglass) and restore the normal cursor once all the data is written. At the end of the function, the file is automatically closed by QFile's destructor.

QDataStream supports basic C++ types as well as many of Qt's types. The syntax is modeled after the standard <iostream> classes. For example,

```
out << x << y << z;
```

writes the variables x, y, and z to a stream, and

```
in >> x >> y >> z;
```

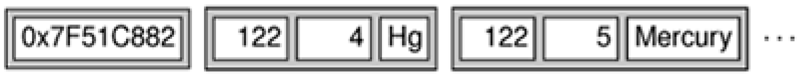
reads them from a stream.

Because the C++ basic types char, short, int, long, and long long may have different sizes on different platforms, it is safest to cast these values to one of Q_INT8, Q_UINT8, Q_INT16, Q_UINT16, Q_INT32, Q_UINT32, Q_INT64, and Q_UINT64, which are guaranteed to be of the size they advertise (in bits).

QDataStream is very versatile. It can be used on a QFile, but also on a QBuffer, a QSocket, or a QSocketDevice. Similarly, QFile can be used with a QTextStream instead of QDataStream, or even raw. Chapter 10 explains these classes in depth.

The Spreadsheet application's file format is fairly simple. A Spreadsheet file starts with a 32-bit number that identifies the file format (MagicNumber, defined as 0x7F51C882 in spreadsheet.h). Then come a series of blocks, each of which contains a single cell's row, column, and formula. To save space, we don't write out empty cells.

Figure 4.5. The Spreadsheet file format



The precise binary representation of the data types is determined by QDataStream. For example, a Q_UINT16 is represented as two bytes in big-endian order, and a QString as the string's length followed by the Unicode characters.

The binary representation of Qt types has evolved quite a lot since Qt 1.0. It is likely to continue evolving in future Qt releases to keep pace with the evolution of existing types and to allow for new Qt types. By default, QDataStream uses the most recent version of the binary format (version 5 in Qt 3.2), but it can be set to read older versions. To avoid any compatibility problems if the application is recompiled later using a newer Qt release, we tell QDataStream to use version 5 irrespective of the version of Qt we are compiling against.

```
bool Spreadsheet::readFile(const QString &fileName)
{
    QFile file(fileName);
    if (!file.open(IO_ReadOnly)) {
        QMessageBox::warning(this, tr("Spreadsheet"),
                             tr("Cannot read file %1:\n%2.")
                             .arg(file.name())
                             .arg(file.errorString()));
        return false;
    }

    QDataStream in(&file);
    in.setVersion(5);

    Q_UINT32 magic;
    in >> magic;
    if (magic != MagicNumber) {
        QMessageBox::warning(this, tr("Spreadsheet"),
                             tr("The file is not a "
                                "Spreadsheet file."));
        return false;
    }

    clear();

    Q_UINT16 row;
    Q_UINT16 col;
    QString str;

    QApplication::setOverrideCursor(waitCursor);
    while (!in.atEnd()) {
        in >> row >> col >> str;
        setFormula(row, col, str);
    }
    QApplication::restoreOverrideCursor();
    return true;
}
```

The `readFile()` function is very similar to `writeFile()`. We use `QFile` to read in the file, but this time using the `IO_ReadOnly` flag rather than `IO_WriteOnly`. Then we set the `QDataStream` version to 5. The format for reading must always be the same as for writing.

If the file has the correct magic number at the beginning, we call `clear()` to blank out all the cells in the spreadsheet and we read in the cell data. The call to `clear()` is necessary to blank out the cells that are not specified in the file.

[Team LiB] PREVIOUS NEXT

[Team LiB] PREVIOUS NEXT

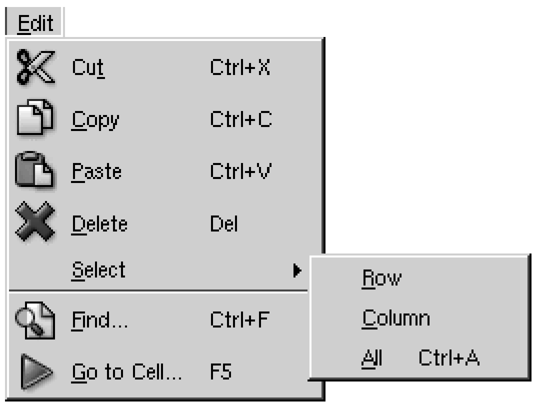
Implementing the Edit Menu

We are now ready to implement the slots that correspond to the application's *Edit* menu.

```
void Spreadsheet::cut()
{
    copy();
    del();
}
```

The `cut()` slot corresponds to *Edit|Cut*. The implementation is simple since *Cut* is the same as *Copy* followed by *Delete*.

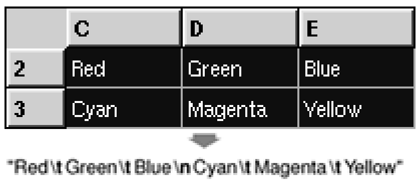
Figure 4.6. The Spreadsheet application's Edit menu



```
void Spreadsheet::copy()
{
    QTableSelection sel = selection();
    QString str;

    for (int i = 0; i < sel.numRows(); ++i) {
        if (i > 0)
            str += "\n";
        for (int j = 0; j < sel.numCols(); ++j) {
            if (j > 0)
                str += "\t";
            str += formula(sel.topRow() + i, sel.leftCol() + j);
        }
    }
    QApplication::clipboard()->setText(str);
}
```

The `copy()` slot corresponds to *Edit|Copy*. It iterates over the current selection. Each selected cell's formula is added to a `QString`, with rows separated by newline characters and columns separated by tab characters.

Figure 4.7. Copying a selection onto the clipboard



	C	D	E
2	Red	Green	Blue
3	Cyan	Magenta	Yellow

```
"Red\tGreen\tBlue\nCyan\tMagenta\tYellow"
```

The system clipboard is available in Qt through the `QApplication::clipboard()` static function. By calling `QClipboard::setText()`, we make the text available on the clipboard, both to this application and to other applications that support plain text. Our format with tab and newline characters as separator is understood by a variety of applications, including Microsoft Excel.

```
QTableSelection Spreadsheet::selection()
{
    if (QTable::selection(0).isEmpty())
        return QTableSelection(currentRow(), currentColumn(),
                               currentRow(), currentColumn());
    return QTable::selection(0);
}
```

The `selection()` private function returns the current selection. It depends on `QTable::selection()`, which returns a selection by number. Since we set the selection mode to `Single`, there is only one selection, numbered 0. But it's also possible that there is no selection at all. This is because `QTable` doesn't treat the current cell as a selection in its own right. This behavior is reasonable, but slightly inconvenient here, so we implement a `selection()` function that either returns the current selection or, if there isn't one, the current cell.

```
void Spreadsheet::paste()
{
    QTableSelection sel = selection();
    QString str = QApplication::clipboard()->text();
    QStringList rows = QStringList::split("\n", str, true);
    int numRows = rows.size();
    int numCols = rows.first().contains("\t") + 1;

    if (sel.numRows() * sel.numCols() != 1
        && (sel.numRows() != numRows
            || sel.numCols() != numCols)) {
        QMessageBox::information(this, tr("Spreadsheet"),
                tr("The information cannot be pasted because the "
                   "copy and paste areas aren't the same size."));
        return;
    }

    for (int i = 0; i < numRows; ++i) {
        QStringList cols = QStringList::split("\t", rows[i], true);
        for (int j = 0; j < numCols; ++j) {
            int row = sel.topRow() + i;
            int col = sel.leftCol() + j;
            if (row < NumRows && col < NumCols)
                setFormula(row, col, cols[j]);
        }
    }
    somethingChanged();
}
```

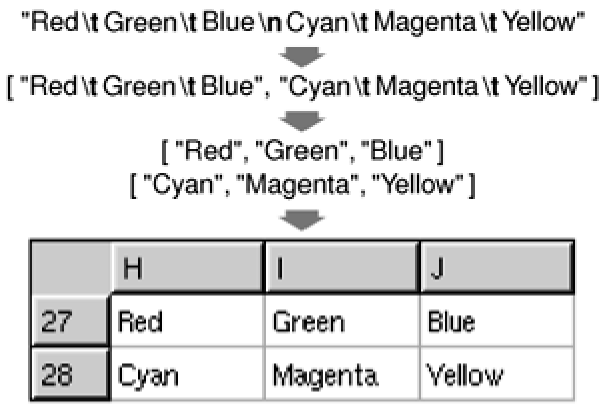
The `paste()` slot corresponds to *Edit|Paste*. We fetch the text on the clipboard and call the static function `QStringList::split()` to break the string into a `QStringList`. Each row becomes one string in the `QStringList`.

Next, we determine the dimension of the copy area. The number of rows is the number of strings in the `QStringList`; the number of columns is the number of tab characters in the first row, plus 1.

If only one cell is selected, we use that cell as the top-left corner of the paste area. Otherwise, we use the current selection as the paste area.

To perform the paste, we iterate over the rows and split each of them into cells by using `QStringList::split()` again, but this time using tab as the separator. Figure 4.8 illustrates the steps.

Figure 4.8. Pasting clipboard text into the spreadsheet


"Red\t Green\t Blue\n Cyan\t Magenta\t Yellow"
["Red\t Green\t Blue", "Cyan\t Magenta\t Yellow"]
["Red", "Green", "Blue"]
["Cyan", "Magenta", "Yellow"]
H
I
J
27
Red
Green
Blue
28
Cyan
Magenta
Yellow

```
void Spreadsheet::del()
{
    QTableSelection sel = selection();
    for (int i = 0; i < sel.numRows(); ++i) {
        for (int j = 0; j < sel.numCols(); ++j)
             delete cell(sel.topRow() + i, sel.leftCol() + j);
    }
    clearSelection();
}
```

The `del()` slot corresponds to *Edit|Delete*. It is sufficient to use `delete` on each of the `Cell` objects in the selection to clear the cells. The `QTable` notices when its `QTableItem`s are deleted and automatically repaints itself. If we call `cell()` with the location of a deleted cell, it will return a null pointer.

```
void Spreadsheet::selectRow()
{
    clearSelection();
    QTable::selectRow(currentRow());
}

void Spreadsheet::selectColumn()
{
    clearSelection();
    QTable::selectColumn(currentColumn());
}

void Spreadsheet::selectAll()
{
    clearSelection();
    selectCells(0, 0, NumRows - 1, NumCols - 1);
}
```

The `selectRow()`, `selectColumn()`, and `selectAll()` functions correspond to the *Edit|Select|Row*, *Edit|Select|Column*, and *Edit|Select|All* menu options. The implementation relies on `QTable`'s `selectRow()`, `selectColumn()`, and `selectCells()` functions.

```
void Spreadsheet::findNext(const QString &str, bool caseSensitive)
{
    int row = currentRow();
    int col = currentColumn() + 1;

    while (row < NumRows) {
        while (col < NumCols) {
            if (text(row, col).contains(str, caseSensitive)) {
                clearSelection();
                setCurrentCell(row, col);
                setActiveWindow();
                return;
            }
            ++col;
        }
        col = 0;
        ++row;
    }
    qApp->beep();
}
```

The `findNext()` slot iterates through the cells starting from the cell to the right of the cursor and moving right until the last column is reached, then continues from the first column in the row below, and so on until the text is found or until the very last cell is reached. For example, if the current cell is cell C27, we search D27, E27, ..., Z27, then A28, B28, C28, ..., Z28, and so on until Z999. If we find a match, we clear the current selection, we move the cell cursor to the cell that matched, and we make the window that contains the `Spreadsheet` active. If no match is found, we make the application beep to indicate that the search finished unsuccessfully.

```
void Spreadsheet::findPrev(const QString &str, bool caseSensitive)
{
    int row = currentRow();
    int col = currentColumn() - 1;
    while (row >= 0) {
        while (col >= 0) {
            if (text(row, col).contains(str, caseSensitive)) {
                clearSelection();
                setCurrentCell(row, col);
                setActiveWindow();
                return;
            }
            --col;
        }
        col = NumCols - 1;
        --row;
    }
    qApp->beep();
}
```

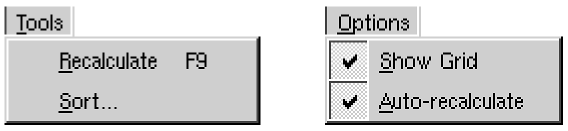
The findPrev() slot is similar to findNext(), except that it iterates backward and stops at cell A1.

[Team LiB]
[Team LiB]

Implementing the Other Menus

We will now implement the slots for the *Tools* and *Options* menus.

Figure 4.9. The Spreadsheet application's *Tools* and *Options* menus



```
void Spreadsheet::recalculate()
{
    int row;

    for (row = 0; row < NumRows; ++row) {
        for (int col = 0; col < NumCols; ++col) {
            if (cell(row, col))
                cell(row, col)->setDirty();
        }
    }
    for (row = 0; row < NumRows; ++row) {
        for (int col = 0; col < NumCols; ++col) {
            if (cell(row, col))
                updateCell(row, col);
        }
    }
}
```

The recalculate() slot corresponds to *Tools*|*Recalculate*. It is also called automatically by Spreadsheet when necessary.

We iterate over all the cells and call setDirty() on every cell to mark each one as requiring recalculation. The next time QTable calls text() on a Cell to obtain the value to show in the spreadsheet, the value will be recalculated.

Then we call updateCell() on all the cells to repaint the whole spreadsheet. The repaint code in QTable then calls text() on each visible cell to obtain the value to display. Because we called setDirty() on every cell, the calls to text() will use a freshly calculated value. The calculation is performed by the Cell class.

```
void Spreadsheet::setAutoRecalculate(bool on)
{
    autoRecalc = on;
    if (autoRecalc)
        recalculate();
}
```

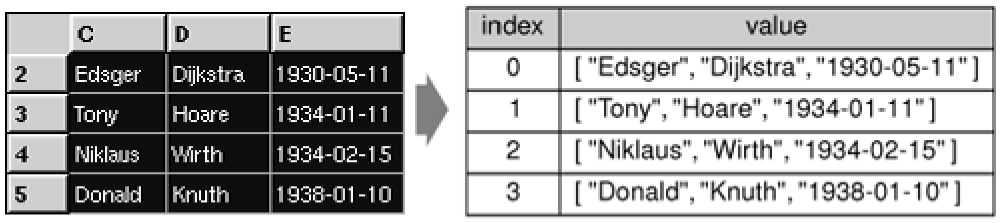
The setAutoRecalculate() slot corresponds to *Options|Auto-recalculate*. If the feature is turned on, we recalculate the whole spreadsheet immediately to make sure that it's up to date. Afterward, recalculate() is called automatically from somethingChanged().

We don't need to implement anything for *Options|Show Grid* because QTable already provides a setShowGrid(bool) slot. All that remains is Spreadsheet::sort(), which we called from MainWindow::sort():

```
void Spreadsheet::sort(const SpreadsheetCompare &compare)
{
    vector<QStringList> rows;
    QTableSelection sel = selection();
    int i;

    for (i = 0; i < sel.numRows(); ++i) {
        QStringList row;
        for (int j = 0; j < sel.numCols(); ++j)
            row.push_back(formula(sel.topRow() + i,
                                  sel.leftCol() + j));
        rows.push_back(row);
    }

    stable_sort(rows.begin(), rows.end(), compare);

    for (i = 0; i < sel.numRows(); ++i) {
        for (int j = 0; j < sel.numCols(); ++j)
            setFormula(sel.topRow() + i, sel.leftCol() + j,
                       rows[i][j]);
    }

    clearSelection();
    somethingChanged();
}
```

Sorting operates on the current selection and reorders the rows according to the sort keys and sort orders stored in the compare object. We represent each row of data with a QStringList and store the selection as a vector of rows. The vector<T> class is a standard C++ class; it is explained in Chapter 11 (Container Classes). For simplicity, we sort by formula rather than by value.

Figure 4.10. Storing the selection as a vector of rows

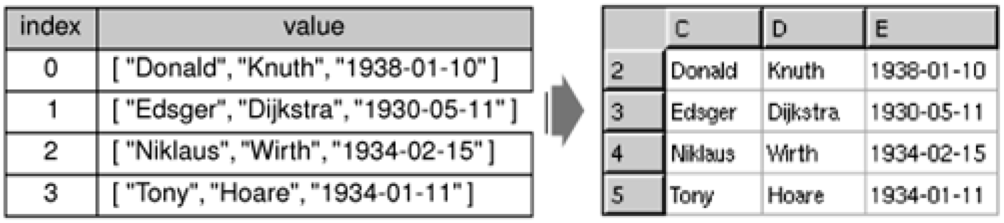


	C	D	E
2	Edsger	Dijkstra	1930-05-11
3	Tony	Hoare	1934-01-11
4	Niklaus	Wirth	1934-02-15
5	Donald	Knuth	1938-01-10

index	value
0	["Edsger", "Dijkstra", "1930-05-11"]
1	["Tony", "Hoare", "1934-01-11"]
2	["Niklaus", "Wirth", "1934-02-15"]
3	["Donald", "Knuth", "1938-01-10"]

We call the standard C++ `stable_sort()` function on the rows to perform the actual sorting. The `stable_sort()` function accepts a begin iterator, an end iterator, and a comparison function. The comparison function is a function that takes two arguments (two `QStringLists`) and that returns `true` if the first argument is "less than" the second argument, `false` otherwise. The `compare` object we pass as the comparison function isn't really a function, but it can be used as one, as we will see shortly.

Figure 4.11. Putting the data back into the table after sorting



index	value
0	["Donald", "Knuth", "1938-01-10"]
1	["Edsger", "Dijkstra", "1930-05-11"]
2	["Niklaus", "Wirth", "1934-02-15"]
3	["Tony", "Hoare", "1934-01-11"]

	C	D	E
2	Donald	Knuth	1938-01-10
3	Edsger	Dijkstra	1930-05-11
4	Niklaus	Wirth	1934-02-15
5	Tony	Hoare	1934-01-11

After performing the `stable_sort()`, we move the data back into the table, clear the selection, and call `something Changed()`.

In `spreadsheet.h`, the `SpreadsheetCompare` class was defined like this:

```
class SpreadsheetCompare
{
public:
    bool operator()(const QStringList &row1,
                    const QStringList &row2) const;

    enum { NumKeys = 3 };
    int keys[NumKeys];
    bool ascending[NumKeys];
};
```

The `SpreadsheetCompare` class is special because it implements a `()` operator. This allows us to use the class as if it were a function. Such classes are called *functors*. To understand how functors work, we will start with a simple example:

```
class Square
{
public:
    int operator()(int x) const { return x * x; }
};
```

The `Square` class provides one function, `operator()(int)`, that returns the square of its parameter. By naming the function `operator()(int)` rather than, say, `compute(int)`, we gain the capability of using an object of type `Square` as if it were a function:

```
Square square;
int y = square(5);
```

Now let's see an example involving `SpreadsheetCompare`:

```
QStringList row1, row2;
SpreadsheetCompare compare;
...
if (compare(row1, row2)) {
    // row1 is less than row2
}
```

The compare object can be used just as if it had been a plain compare() function. Additionally, it can access all the sort keys and sort orders, which it stores as member variables.

An alternative to this scheme would have been to store the sort keys and sort orders in global variables and use a plain compare() function. However, communicating through global variables is inelegant and can lead to subtle bugs. Functors are a more powerful idiom for interfacing with template functions such as stable_sort().

Here is the implementation of the function that is used to compare two spreadsheet rows:

```
bool SpreadsheetCompare::operator() (const QStringList &row1,
                                     const QStringList &row2) const
{
    for (int i = 0; i < NumKeys; ++i) {
        int column = keys[i];
        if (column != -1) {
            if (row1[column] != row2[column]) {
                if (ascending[i])
                    return row1[column] < row2[column];
                else
                    return row1[column] > row2[column];
            }
        }
    }
    return false;
}
```

It returns true if the first row is less than the second row; otherwise, it returns false. The standard stable_sort() function uses the result of this function to perform the sort.

The SpreadsheetCompare object's keys and ascending arrays are populated in the MainWindow::sort() function (shown in Chapter 2). Each key holds a column index, or –1 ("None").

We compare the corresponding cell entries in the two rows for each key in order. As soon as we find a difference, we return an appropriate true or false value. If all the comparisons turn out to be equal, we return false. The stable_sort() function uses the order before the sort to resolve tie situations; if row1 preceded row2 originally and neither compares as "less than" the other, row1 will still precede row2 in the result. This is what distinguishes std::stable_sort() from its more famous (but less stable) cousin std::sort().

We have now completed the Spreadsheet class. In the next section, we will review the Cell class. This class is used to hold cell formulas and provides a reimplementation of the text() function that Spreadsheet calls to display the result of calculating a cell's formula.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Subclassing QTableItem

The Cell class inherits from QTableItem. The class is designed to work well with Spreadsheet, but it has no specific dependencies on that class and could in theory be used in any QTable.

Here's the header file:

```
#ifndef CELL_H
#define CELL_H

#include <qtable.h>
#include <qvariant.h>

class Cell : public QTableItem
{
public:
    Cell(QTable *table, const QString &formula);

    void setFormula(const QString &formula);
    QString formula() const;
    void setDirty();
    QString text() const;
    int alignment() const;

private:
    QVariant value() const;
    QVariant evalExpression(const QString &str, int &pos) const;
    QVariant evalTerm(const QString &str, int &pos) const;
    QVariant evalFactor(const QString &str, int &pos) const;

    QString formulaStr;
    mutable QVariant cachedValue;
    mutable bool cacheIsDirty;
};

#endif
```

The `Cell` class extends `QTableItem` by adding three private variables:

- `formulaStr` stores the cell's formula as a `QString`.
- `cachedValue` caches the cell's value as a `QVariant`.
- `cacheIsDirty` is `true` if the cached value isn't up to date.

The `QVariant` type can hold values of many C++ and Qt types. We use it because some cells have a `double` value, while others have a `QString` value.

The `cachedValue` and `cacheIsDirty` variables are declared with the C++ `mutable` keyword. This allows us to modify these variables in const functions. Alternatively, we could recalculate the value each time `text()` is called, but that would be needlessly inefficient.

Notice that there is no `Q_OBJECT` macro in the class definition. `Cell` is a plain C++ class, with no signals or slots. In fact, because `QTableItem` doesn't inherit from `QObject`, we cannot have signals and slots in `Cell` as it stands. Qt's item classes don't inherit from `QObject` to keep their overhead to the barest minimum. If signals and slots are needed, they can be implemented in the widget that contains the items or, exceptionally, using multiple inheritance with `QObject`.

Here's the start of `cell.cpp`:

```
#include <qlineedit.h>
#include <qregexp.h>

#include "cell.h"
```

```
Cell::Cell(QTable *table, const QString &formula)
    : QTableItem(table, OnTyping)

{
    setFormula(formula);
}
```

The constructor accepts a pointer to a QTable and a formula. The pointer is passed on to the QTableItem constructor and is accessible afterward as QTableItem::table(). The second argument to the base class constructor, OnTyping, means that an editor pops up when the user starts typing in the current cell.

```
void Cell::setFormula(const QString &formula)
{
    formulaStr = formula;
    cacheIsDirty = true;
}
```

The setFormula() function sets the cell's formula. It also sets the cacheIsDirty flag to true, meaning that cachedValue must be recalculated before a valid value can be returned. It is called from the Cell constructor and from Spreadsheet::setFormula().

```
    QString Cell::formula() const
    {
        return formulaStr;
    }
```

The formula() function is called from Spreadsheet::formula().

```
void Cell::setDirty()
{
    cacheIsDirty = true;
}
```

The setDirty() function is called to force a recalculation of the cell's value. It simply sets cacheIsDirty to true. The recalculation isn't performed until it is really necessary.

```
QString Cell::text() const
{
    if (value().isValid())
        return value().toString();
    else
        return "####";
}
```

The text() function is reimplemented from QTableItem. It returns the text that should be shown in the spreadsheet. It relies on value() to compute the cell's value. If the value is invalid (presumably because the formula is wrong), we return "####".

The value() function used by text() returns a QVariant. A QVariant can store values of different types, such as double and QString, and provides functions to convert the variant to other types. For example, calling toString() on a variant that holds a double value produces a string representation of the double. A QVariant constructed using the default constructor is an "invalid" variant.

```
int Cell::alignment() const
{
    if (value().type() == QVariant::String)
```

```
        return AlignLeft | AlignVCenter;
    else
        return AlignRight | AlignVCenter;
}
```

The alignment() function is reimplemented from QTableItem. It returns the alignment for the cell's text. We have chosen to left-align string values and to right-align numeric values. We vertically center all values.

```
const QVariant Invalid;
QVariant Cell::value() const
{
    if (cacheIsDirty) {
        cacheIsDirty = false;

        if (formulaStr.startsWith("'")) {
            cachedValue = formulaStr.mid(1);
        } else if (formulaStr.startsWith("=")) {
            cachedValue = Invalid;
            QString expr = formulaStr.mid(1);
            expr.replace(" ", "");
            int pos = 0;
            cachedValue = evalExpression(expr, pos);
            if (pos < (int) expr.length())
                cachedValue = Invalid;
        } else {
            bool ok;
            double d = formulaStr.toDouble(&ok);
            if (ok)
                cachedValue = d;
            else
                cachedValue = formulaStr;
        }
    }
    return cachedValue;
}
```

The value() private function returns the cell's value. If cacheIsDirty is true, we need to recalculate the value.

If the formula starts with a single quote (for example, "'12345"), the value is the string from position 1 to the end. (The single quote occupies position 0.)

If the formula starts with '=', we take the string from position 1 and delete any spaces it may contain. Then we call evalExpression() to compute the value of the expression. The pos argument is passed by reference; it indicates the position of the character where parsing should begin. After the call to evalExpression(), pos is equal to the length of the expression that was successfully parsed. If the parse failed before the end, we set cachedValue to be Invalid.

If the formula doesn't begin with a single quote or an equals sign ('='), we attempt to convert it to a floating point value using toDouble(). If the conversion works, we set cachedValue to be the resulting number; otherwise, we set cachedValue to be the formula string. For example, a formula of "1.50" causes toDouble() to set ok to true and return 1.5, while a formula of "World Population" causes toDouble() to set ok to false and return 0.0.

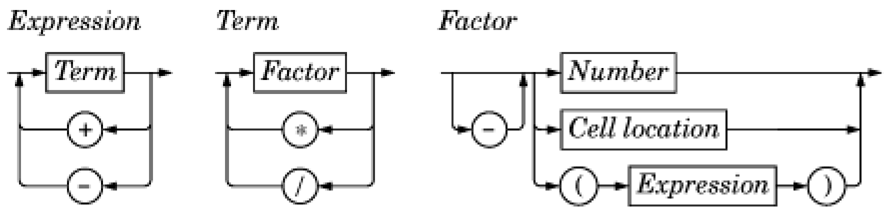
The value() function is a const function. We had to declare cachedValue and cacheIsValid as mutable variables so that the compiler will allow us to modify them in const functions. It might be tempting to make value() non-const and remove the mutable keywords, but that would not compile because we call value() from text(), a const function. In C++, caching and mutable usually go hand in hand.

We have now completed the Spreadsheet application, apart from parsing formulas. The rest of this section covers evalExpression() and the two helper functions evalTerm() and evalFactor(). The code is a bit complicated, but it is included here to make the application complete. Since the code is not related to GUI programming, you can safely skip it and continue reading from Chapter 5.

The evalExpression() function returns the value of a spreadsheet expression. An expression is defined as one or more terms separated by '+' or '-' operators; for example, "2*C5+D6" is an expression with "2*C5" as its first term and "D6" as its second term. The terms themselves are defined as one or more factors separated by '*' or '/' operators; for example, "2*C5" is a term with "2" as its first factor and "C5" as its second factor. Finally, a factor can be a number ("2"), a cell location ("C5"), or an expression in parentheses, optionally preceded by a unary minus. By breaking down expressions into terms and terms into factors, we ensure that the operators are applied with the correct precedence.

The syntax of spreadsheet expressions is defined in Figure 4.12. For each symbol in the grammar (*Expression*, *Term*, and *Factor*), there is a corresponding Cell member function that parses it and whose structure closely follows the grammar. Parsers written this way are called recursive-descent parsers.

Figure 4.12. Syntax diagram for spreadsheet expressions



Let's start with evalExpression(), the function that parses an *Expression*:

```
QVariant Cell::evalExpression(const QString &str, int &pos) const
{
    QVariant result = evalTerm(str, pos);
    while (pos < (int)str.length()) {
        QChar op = str[pos];
        if (op != '+' && op != '-')
            return result;
        ++pos;

        QVariant term = evalTerm(str, pos);
        if (result.type() == QVariant::Double
                && term.type() == QVariant::Double) {
            if (op == '+')
                result = result.toDouble() + term.toDouble();
            else
                result = result.toDouble() - term.toDouble();
        } else {
            result = Invalid;
        }
    }
    return result;
}
```

First, we call evalTerm() to get the value of the first term. If the following character is '+' or '-', we continue by calling evalTerm() a second time; otherwise, the expression consists of a single term, and we return its value as the value of the whole expression. After we have the value of the first two terms, we compute the result of the operation, depending on the operator. If both terms evaluated to a double, we compute the result as a double; otherwise, we set the result to be Invalid.

We continue like this until there are no more terms. This works correctly because addition and subtraction are left-associative; that is, "1–2–3" means "(1–2)–3", not "1–(2–3)".

```
QVariant Cell::evalTerm(const QString &str, int &pos) const
{
    QVariant result = evalFactor(str, pos);
    while (pos < (int)str.length()) {
        QChar op = str[pos];
        if (op != '*' && op != '/')
            return result;
        ++pos;

        QVariant factor = evalFactor(str, pos);
        if (result.type() == QVariant::Double
                && factor.type() == QVariant::Double) {
            if (op == '*') {
                result = result.toDouble() * factor.toDouble();
            } else {
                if (factor.toDouble() == 0.0)
                    result = Invalid;
                else
                    result = result.toDouble() / factor.toDouble();
            }
        } else {
            result = Invalid;
        }
    }
    return result;
}
```

The evalTerm() function is very similar to evalExpression(), except that it deals with multiplication and division. The only subtlety in evalTerm() is that we must avoid division by zero. While it is generally inadvisable to test floating point values for equality because of rounding errors, it is safe to do so to prevent division by zero.

```
QVariant Cell::evalFactor(const QString &str, int &pos) const
{
    QVariant result;
    bool negative = false;
    if (str[pos] == '-') {
        negative = true;
        ++pos;
    }

    if (str[pos] == '(') {
        ++pos;
        result = evalExpression(str, pos);
        if (str[pos] != ')')
            result = Invalid;
        ++pos;
    } else {
        QRegExp regExp("[A-Za-z] [1-9] [0-9] {0,2}");
        QString token;

        while (str[pos].isLetterOrNumber() || str[pos] == '.') {
            token += str[pos];
            ++pos;
        }

        if (regExp.exactMatch(token)) {
            int col = token[0].upper().unicode() - 'A';
            int row = token.mid(1).toInt() - 1;

            Cell *c = (Cell *)table()->item(row, col);
            if (c)
                result = c->value();
            else
                result = 0.0;
        } else {
            bool ok;
            result = token.toDouble(&ok);
            if (!ok)
                result = Invalid;
        }
    }

    if (negative) {
        if (result.type() == QVariant::Double)
            result = -result.toDouble();
        else
            result = Invalid;
    }
    return result;
}
```

The evalFactor() function is a bit more complicated than evalExpression() and evalTerm(). We start by noting whether the factor is negated. We then see if it begins with an open parenthesis. If it does, we evaluate the contents of the parentheses as an expression by calling evalExpression(). This is where recursion occurs in the parser; evalExpression() calls evalTerm(), which calls evalFactor(), which calls evalExpression() again.

If the factor isn't a nested expression, we extract the next token, which may be a cell location or a number. If the token matches the QRegExp, we take it to be a cell reference and we call value() on the cell at the given location. The cell could be anywhere in the spreadsheet, and it could have dependencies on other cells. The dependencies are not a problem; they will simply trigger more value() calls and (for "dirty" cells) more parsing until all the dependent cell values are calculated. If the token isn't a cell location, we take it to be a number.

What happens if cell A1 contains the formula "=A1"? Or if cell A1 contains "=A2" and cell A2 contains "=A1"? Although we have not written any special code to detect circular dependencies, the parser handles these cases gracefully by returning an invalid QVariant. This works because we set cacheIsDirty to false and cachedValue to Invalid in value() before we call evalExpression(). If evalExpression() recursively calls value() on the same cell, it returns Invalid immediately, and the whole expression then evaluates to Invalid.

We have now completed the formula parser. It would be straightforward to extend it to handle predefined spreadsheet functions, like "sum()" and "avg()", by extending the grammatical definition of *Factor*. Another easy extension is to implement the '+' operator with string operands (as concatenation); this requires no changes to the grammar.

[Team LiB] ◂ PREVIOUS NEXT ▸
[Team LiB] ◂ PREVIOUS NEXT ▸

Chapter 5. Creating Custom Widgets

This chapter explains how to create custom widgets using Qt. Custom widgets can be created by subclassing an existing Qt widget or by subclassing `QWidget` directly. We will demonstrate both approaches, and we will also see how to integrate a custom widget with *Qt Designer* so that it can be used just like a built-in Qt widget. We will round off the chapter by presenting a custom widget that uses a powerful technique for eliminating flicker: double buffering.

Customizing Qt Widgets

In some cases, we find that a Qt widget requires more customization than is possible by setting its properties in *Qt Designer* or by calling its functions. A simple and direct solution is to subclass the relevant widget class and adapt it to suit our needs.

Figure 5.1. The `HexSpinBox` widget

In this section, we will develop a hexadecimal spin box to show how this works. `QSpinBox` only supports decimal integers, but by subclassing it's quite easy to make it accept and display hexadecimal values.

```
#ifndef HEXSPINBOX_H
#define HEXSPINBOX_H

#include <qspinbox.h>

class HexSpinBox : public QSpinBox
{
public:
    HexSpinBox(QWidget *parent, const char *name = 0);

protected:
    QString mapValueToText(int value);
    int mapTextToValue(bool *ok);
};

#endif
```

The `HexSpinBox` inherits most of its functionality from `QSpinBox`. It provides a typical constructor and reimplements two virtual functions from `QSpinBox`. Since the class doesn't define its own signals and slots, it doesn't need the `Q_ OBJECT` macro.

```
#include <qvalidator.h>

#include "hexspinbox.h"

HexSpinBox::HexSpinBox(QWidget *parent, const char *name)
```

```
    : QSpinBox(parent, name)
{
     QRegExp regExp("[0-9A-Fa-f]+");
     setValidator(new QRegExpValidator(regExp, this));
     setRange(0, 255);
}
```

The user can modify a spin box's current value either by clicking its up and down arrows or by typing a value into the spin box's line editor. In the latter case, we want to restrict the user's input to legitimate hexadecimal numbers. To achieve this, we use a QRegExpValidator that accepts one or more characters from the ranges '0' to '9', 'A' to 'F', and 'a' to 'f'. We also set the default range to be 0 to 255 (0x00 to 0xFF), which is more appropriate for a hexadecimal spin box than QSpinBox's default of 0 to 99.

```
QString HexSpinBox::mapValueToText(int value)
{
    return QString::number(value, 16).upper();
}
```

The mapValueToText() function converts an integer value to a string. QSpinBox calls it to update the editor part of the spin box when the user presses the spin box's up or down arrows. We use the static function QString::number() with a second argument of 16 to convert the value to lower-case hexadecimal, and call QString::upper() on the result to make it upper-case.

```
int HexSpinBox::mapTextToValue(bool *ok)
{
    return text().toInt(ok, 16);
}
```

The mapTextToValue() function performs the reverse conversion, from a string to an integer value. It is called by QSpinBox when the user types a value into the editor part of the spin box and presses *Enter*. We use the QString::toInt() function to attempt to convert the current text (returned by QSpinBox::text()) to an integer value, again using base 16.

If the conversion is successful, toInt() sets *ok to true; otherwise, it sets it to false. This behavior happens to be exactly what QSpinBox expects.

We have now finished the hexadecimal spin box. Customizing other Qt widgets follows the same pattern: Pick a suitable Qt widget, subclass it, and reimplement some virtual functions to change its behavior. This technique is common in Qt programming; in fact, we have already used it in Chapter 4 when we subclassed QTable and reimplemented createEditor() and endEdit().

Subclassing QWidget

Most custom widgets are simply a combination of existing widgets, whether they are built-in Qt widgets or other custom widgets such as HexSpinBox. Custom widgets that are built by composing existing widgets can usually be developed in *Qt Designer*:

- Create a new form using the "Widget" template.
- Add the necessary widgets to the form, then lay them out.

- Set up the signals and slots connections and add any necessary code (either in a `.ui.h` file or in a subclass) to provide the desired behavior.

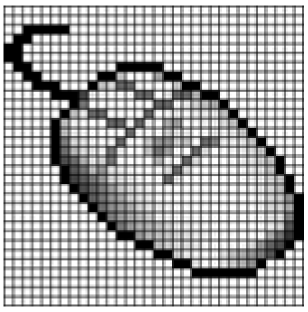
Naturally, this can also be done entirely in code. Whichever approach is taken, the resulting class inherits directly from `QWidget`.

If the widget has no signals and slots of its own and doesn't reimplement any virtual functions, it is even possible to simply assemble the widget by aggregating existing widgets without a subclass. That's the approach we used in Chapter 1 to create the Age application, with a `QHBox`, a `QSpinBox`, and a `QSlider`. Even so, we could just as easily have subclassed `QHBox` and created the `QSpinBox` and `QSlider` in the subclass's constructor.

When none of Qt's widgets are suitable for the task at hand, and when there's no way to combine or adapt existing widgets to obtain the desired result, we can still create the widget we want. This is achieved by subclassing `QWidget` and reimplementing a few event handlers to paint the widget and to respond to mouse clicks. This approach gives us complete freedom to define and control both the appearance and the behavior of our widget. Qt's built-in widgets, like `QLabel`, `QPushButton`, and `QTable`, are implemented this way. If they didn't exist in Qt, it would still be possible to create them ourselves using the public functions provided by `QWidget` in a totally platform-independent manner.

To demonstrate how to write a custom widget using this approach, we will create the `IconEditor` widget shown in Figure 5.2. The `IconEditor` is a widget that could be used in an icon editing program.

Figure 5.2. The `IconEditor` widget



Let's begin by reviewing the header file.

```
#ifndef ICONEDITOR_H
#define ICONEDITOR_H

#include <qimage.h>
#include <qwidget.h>

class IconEditor : public QWidget
{
    Q_OBJECT
    Q_PROPERTY(QColor penColor READ penColor WRITE setPenColor)
    Q_PROPERTY(QImage iconImage READ iconImage WRITE setIconImage)
    Q_PROPERTY(int zoomFactor READ zoomFactor WRITE setZoomFactor)

public:
    IconEditor(QWidget *parent = 0, const char *name = 0);

    void setPenColor(const QColor &newColor);
    QColor penColor()const { return curColor; }
    void setZoomFactor(int newZoom);
    int zoomFactor() const { return zoom; }
    void setIconImage(const QImage &newImage);
    const QImage &iconImage() const { return image; }
    QSize sizeHint() const;
```

The IconEditor class uses the Q_PROPERTY() macro to declare three custom properties: penColor, iconImage, and zoomFactor. Each property has a type, a "read" function, and a "write" function. For example, the penColor property is of type QColor and can be read and written using the penColor() and setPenColor() functions.

When we make use of the widget in *Qt Designer*, custom properties appear in *Qt Designer*'s property editor below the properties inherited from QWidget. Properties may be of any type supported by QVariant. The Q_OBJECT macro is necessary for classes that define properties.

```
protected:
    void mousePressEvent(QMouseEvent *event);
    void mouseMoveEvent(QMouseEvent *event);
    void paintEvent(QPaintEvent *event);
private:
    void drawImagePixel(QPainter *painter, int i, int j);
    void setImagePixel(const QPoint &pos, bool opaque);

    QColor curColor;
    QImage image;
    int zoom;
};

#endif
```

IconEditor reimplements three protected functions from QWidget and has a few private functions and variables. The three private variables hold the values of the three properties.

The implementation file begins with #include directives and the IconEditor's constructor:

```
#include <qpainter.h>

#include "iconeditor.h"

IconEditor::IconEditor(QWidget *parent, const char *name)
    : QWidget(parent, name, WStaticContents)
{
    setSizePolicy(QSizePolicy::Minimum, QSizePolicy::Minimum);
    curColor = black;
    zoom = 8;
    image.create(16, 16, 32);
    image.fill(qRgba(0, 0, 0, 0));
    image.setAlphaBuffer(true);
}
```

The constructor has some subtle aspects such as the setSizePolicy() call and the WStaticContents flag. We will discuss them shortly.

The zoom factor is set to 8, meaning that each pixel in the icon will be rendered as an 8 x 8 square. The pen color is set to black; the black symbol is a predefined value in the Qt class (QObject's base class).

The icon data is stored in the image member variable and can be accessed through the setIconImage() and iconImage() functions. An icon editor program would typically call setIconImage() when the user opens an icon file and iconImage() to retrieve the icon when the user wants to save it.

The image variable is of type QImage. We initialize it to 16 x 16 pixels and 32-bit depth, clear the image data, and enable the alpha buffer.

The QImage class stores an image in a hardware-independent fashion. It can be set to use a 1-bit, 8-bit, or 32-bit depth. An image with 32-bit depth uses 8 bits for each of the red, green, and blue components of a pixel. The remaining 8 bits store the pixel's alpha component—that is, its opacity. For example, a pure red color's red, green, blue, and alpha components have the values 255, 0, 0, and 255. In Qt, this color can be specified as

```
QRgb red = qRgba(255, 0, 0, 255);
```

or as

```
QRgb red = qRgb(255, 0, 0);
```

QRgb is simply a typedef for unsigned int, and qRgb() and qRgba() are inline functions that combine their arguments into one 32-bit integer value. It is also possible to write

```
QRgb red = 0xFFFF0000;
```

where the first FF corresponds to the alpha component and the second FF to the red component. In the IconEditor constructor, we fill the QImage with a transparent color by using 0 as the alpha component.

Qt provides two types for storing colors: QRgb and QColor. While QRgb is only a typedef used in QImage to store 32-bit pixel data, QColor is a class with many useful functions and is widely used in Qt to store colors. In the IconEditor widget, we only use QRgb when dealing with the QImage; we use QColor for everything else, including the penColor property.

```
QSize IconEditor::sizeHint() const
{
    QSize size = zoom * image.size();
    if (zoom >= 3)
        size += QSize(1, 1);
    return size;
}
```

The sizeHint() function is reimplemented from QWidget and returns the ideal size of a widget. Here, we take the image size multiplied by the zoom factor, with one extra pixel in each direction to accommodate a grid if the zoom factor is 3 or more. (We don't show a grid if the zoom factor is 2 or 1, because the grid would hardly leave any room for the icon's pixels.)

A widget's size hint is mostly useful in conjunction with layouts. Qt's layout managers try as much as possible to respect a widget's size hint when they lay out a form's child widgets. For IconEditor to be a good layout citizen, it must report a credible size hint.

In addition to the size hint, widgets have a size policy that tells the layout system whether they like to be stretched and shrunk. By calling setSizePolicy() in the constructor with QSizePolicy::Minimum as horizontal and vertical policies, we tell any layout manager that is responsible for this widget that the widget's size hint is really its minimum size. In other words, the widget can be stretched if required, but it should never shrink below the size hint. This can be overridden in *Qt Designer* by setting the widget's sizePolicy property. The meaning of the various size policies is explained in Chapter 6 (Layout Management).

```
void IconEditor::setPenColor(const QColor &newColor)
```

```
{
    curColor = newColor;
}
```

The `setPenColor()` function sets the current pen color. The color will be used for newly drawn pixels.

```
void IconEditor::setIconImage(const QImage &newImage)
{
    if (newImage != image) {
        image = newImage.convertDepth(32);
        image.detach();
        update();
        updateGeometry();
    }
}
```

The `setIconImage()` function sets the image to edit. We call `convertDepth()` to make the image 32-bit if it isn't already. Elsewhere in the code, we will assume that the image data is stored as 32-bit `QRgb` values.

We also call `detach()` to take a deep copy of the data stored in the image. This is necessary because the image data might be stored in ROM. `QImage` tries to save time and memory by copying the image data only when explicitly requested to do so. This optimization is called *explicit sharing* and is discussed with `QMemArray<T>` in the "Pointer-Based Containers" section of Chapter 11.

After setting the `image` variable, we call `QWidget::update()` to force a repainting of the widget using the new image. Next, we call `QWidget::updateGeometry()` to tell any layout that contains the widget that the widget's size hint has changed. The layout will then automatically adapt to the new size hint.

```
void IconEditor::setZoomFactor(int newZoom)
{
    if (newZoom < 1)
        newZoom = 1;

    if (newZoom != zoom) {
        zoom = newZoom;
        update();
        updateGeometry();
    }
}
```

The `setZoomFactor()` function sets the zoom factor for the image. To prevent division by zero later, we correct any value below 1. Again, we call `update()` and `updateGeometry()` to repaint the widget and to notify any managing layout about the size hint change.

The `penColor()`, `iconImage()`, and `zoomFactor()` functions are implemented as inline functions in the header file.

We will now review the code for the `paintEvent()` function. This function is `IconEditor's` most important function. It is called whenever the widget needs repainting. The default implementation in `QWidget` does nothing, leaving the widget blank.

Just like `contextMenuEvent()` and `closeEvent()`, which we met in Chapter 3, `paintEvent()` is an event handler. Qt has many other event handlers, each of which corresponds to a different type of event. Chapter 7 covers event processing in depth.

There are many situations when a paint event is generated and `paintEvent()` is called:

- When a widget is shown for the first time, the system automatically generates a paint event to force the widget to paint itself.
- When a widget is resized, the system automatically generates a paint event.
- If the widget is obscured by another window and then revealed again, a paint event is generated for the area that was hidden (unless the window system stored the area).

We can also force a paint event by calling `QWidget::update()` or `QWidget::repaint()`. The difference between these two functions is that `repaint()` forces an immediate repaint, whereas `update()` simply schedules a paint event for when Qt next processes events. (Both functions do nothing if the widget isn't visible on screen.) If `update()` is called multiple times, Qt compresses the consecutive paint events into a single paint event to avoid flicker. In `IconEditor`, we always use `update()`.

Here's the code:

```
void IconEditor::paintEvent(QPaintEvent *)
{
    QPainter painter(this);

    if (zoom >= 3) {
        painter.setPen(colorGroup().foreground());
        for (int i = 0; i <= image.width(); ++i)
            painter.drawLine(zoom * i, 0,
                             zoom * i, zoom * image.height());
        for (int j = 0; j <= image.height(); ++j)
            painter.drawLine(0, zoom * j,
                             zoom * image.width(), zoom * j);
    }

    for (int i = 0; i < image.width(); ++i) {
        for (int j = 0; j < image.height(); ++j)
            drawImagePixel(&painter, i, j);
    }
}
```

We start by constructing a `QPainter` object on the widget. If the zoom factor is 3 or more, we draw the horizontal and vertical lines that form the grid using the `QPainter::drawLine()` function.

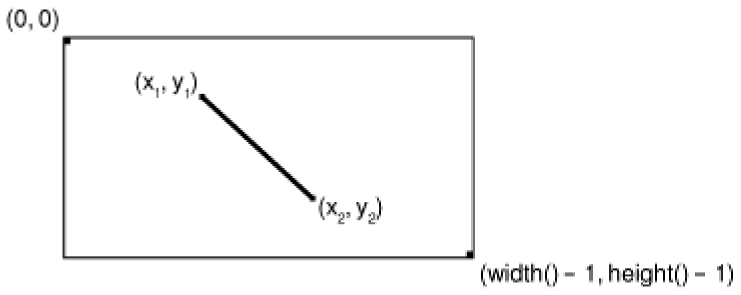
A call to `QPainter::drawLine()` has the following syntax:

```
painter.drawLine(x1, y1, x2, y2);
```

where (*x1*, *y1*) is the position of one end of the line and (*x2*, *y2*) is the position of the other end. There is also an overloaded version of the function that takes two `QPoint`s instead of four `int`s.

The top-left pixel of a Qt widget is located at position (0, 0), and the bottomright pixel is located at (`width()`– 1, `height()`– 1). This is similar to the conventional Cartesian coordinate system, but upside down, and makes a lot of sense in GUI programming. It is perfectly possible to change `QPainter`'s coordinate system by using transformations, such as translation, scaling, rotation, and shearing. This is covered in Chapter 8 (2D and 3D Graphics).

Figure 5.3. Drawing a line using `QPainter`



Before we call `drawLine()` on the `QPainter`, we set the line's color using `setPen()`. We could hard-code a color, like black or gray, but a better approach is to use the widget's palette.

Every widget is equipped with a palette that specifies which colors should be used for what. For example, there is a palette entry for the background color of widgets (usually light gray) and one for the color of text on that background (usually black). By default, a widget's palette adopts the window system's color scheme. By using colors from the palette, we ensure that `IconEditor` respects the user's preferences.

A widget's palette consists of three color groups: active, inactive, and disabled. Which color group should be used depends on the widget's current state:

- The active color group is used for widgets in the currently active window.
- The inactive color group is used for widgets in the other windows.
- The disabled color group is used for disabled widgets in any window.

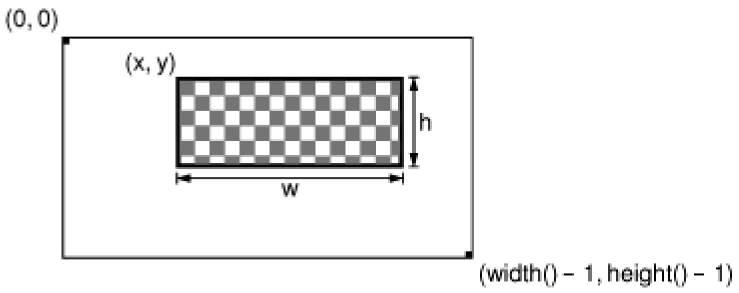
The `QWidget::palette()` function returns the widget's palette as a `QPalette` object. The color groups are available through `QPalette`'s `active()`, `inactive()`, and `disabled()` functions, and are of type `QColorGroup`. For convenience, `QWidget::colorGroup()` returns the correct color group for the current state of the widget, so we rarely need to access the palette directly.

The `paintEvent()` function finishes by drawing the image itself, using the `IconEditor::drawImagePixel()` function to draw each of the icon's pixels as filled squares.

```
void IconEditor::drawImagePixel(QPainter *painter, int i, int j)
{
    QColor color;
    QRgb rgb = image.pixel(i, j);

    if (qAlpha(rgb) == 0)
        color = colorGroup().base();
    else
        color.setRgb(rgb);

    if (zoom >= 3) {
        painter->fillRect(zoom * i + 1, zoom * j + 1,
                          zoom - 1, zoom - 1, color);
    } else {
        painter->fillRect(zoom * i, zoom * j,
                          zoom, zoom, color);
    }
}
```

The `drawImagePixel()` function draws a zoomed pixel using a `QPainter`. The `i` and `j` parameters are pixel coordinates in the QImage—not in the widget. (If the zoom factor is 1, the two coordinate systems coincide exactly.) If the pixel is transparent (its alpha component is 0), we use the current color group's "base" color (typically white) to draw the pixel; otherwise, we use the pixel's color in the image. Then we call QPainter::fillRect() to draw a filled square. If the grid is shown, the square is reduced by one pixel in both directions to avoid painting over the grid.

Figure 5.4. Drawing a rectangle using QPainter



The call to QPainter::fillRect() has the following syntax:

```
painter->fillRect(x, y, w, h, brush);
```

where (*x*, *y*) is the position of the top-left corner of the rectangle, *w* x *h* is the size of the rectangle, and *brush* specifies the color to fill with and the fill pattern to use. By passing a QColor as the brush, we obtain a solid fill pattern.

```
void IconEditor::mousePressEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton)
        setImagePixel(event->pos(), true);
    else if (event->button() == RightButton)
        setImagePixel(event->pos(), false);
}
```

When the user presses a mouse button, the system generates a "mouse press" event. By reimplementing QWidget::mousePressEvent(), we can respond to this event and set or clear the image pixel under the mouse cursor.

If the user pressed the left mouse button, we call the private function setImagePixel() with true as the second argument, telling it to set the pixel to the current pen color. If the user pressed the right mouse button, we also call setImagePixel(), but pass false to clear the pixel.

```
void IconEditor::mouseMoveEvent(QMouseEvent *event)
{
    if (event->state() & LeftButton)
        setImagePixel(event->pos(), true);
    else if (event->state() & RightButton)
        setImagePixel(event->pos(), false);
}
```

The mouseMoveEvent() handles "mouse move" events. By default, these events are only generated when the user is holding down a button. It is possible to change this behavior by calling QWidget::setMouseTracking(), but we don't need to do so for this example.

Just as pressing the left or right mouse button sets or clears a pixel, keeping it pressed and hovering over a pixel is also enough to set or clear a pixel. Since it's possible to hold more than one button pressed down at a time, the value returned by QMouseEvent::state() is a bitwise OR of the mouse buttons (and of modifier keys like *Shift* and *Ctrl*). We test whether a certain button is pressed down using the & operator, and if it is, we call setImagePixel().

```
void IconEditor::setImagePixel(const QPoint &pos, bool opaque)
{
    int i = pos.x() / zoom;
    int j = pos.y() / zoom;

    if (image.rect().contains(i, j)) {
        if (opaque)
            image.setPixel(i, j, penColor().rgb());
        else
            image.setPixel(i, j, qRgba(0, 0, 0, 0));

        QPainter painter(this);
        drawImagePixel(&painter, i, j);
    }
}
```

The setImagePixel() function is called from mousePressEvent() and mouseMoveEvent() to set or clear a pixel. The pos parameter is the position of the mouse on the widget.

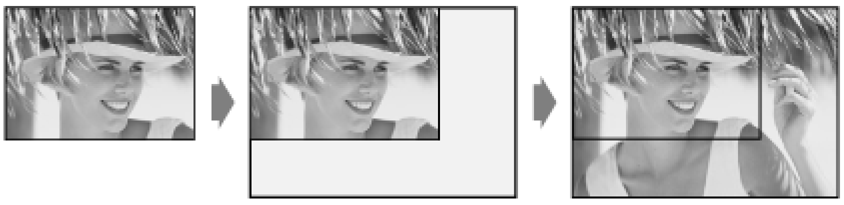
The first step is to convert the mouse position from widget coordinates to image coordinates. This is done by dividing the *x* and *y* components of the mouse position by the zoom factor. Next, we check whether the point is within the correct range. The check is easily made using QImage::rect() and QRect::contains(); this effectively checks that i is between 0 and image.width() – 1 and that j is between 0 and image.height() – 1.

Depending on the opaque parameter, we set or clear the pixel in the image. Clearing a pixel is really setting it to be transparent. At the end, we call drawImagePixel() to repaint the individual pixel that changed.

Now that we have reviewed the member functions, we will return to the WStaticContents flag that we used in the constructor. This flag tells Qt that the widget's content doesn't change when the widget is resized and that the content stays rooted to the widget's top-left corner. Qt uses this information to avoid needlessly repainting areas that are already shown when resizing the widget.

Normally, when a widget is resized, Qt generates a paint event for the widget's entire visible area. But if the widget is created with the WStaticContents flag, the paint event's region is restricted to the pixels that were not previously shown. If the widget is resized to a smaller size, no paint event is generated at all.

Figure 5.5. Resizing a WStaticContents widget



The IconEditor widget is now complete. Using the information and examples from earlier chapters, we could write code that uses the IconEditor as a window in its own right, as a central widget in a QMainWindow, as a child widget inside a layout, or as a child widget inside a QScrollView (p. 145). In the next section, we will see how to integrate it with *Qt Designer*.

[Team LiB]

PREVIOUS NEXT

Integrating Custom Widgets with Qt Designer

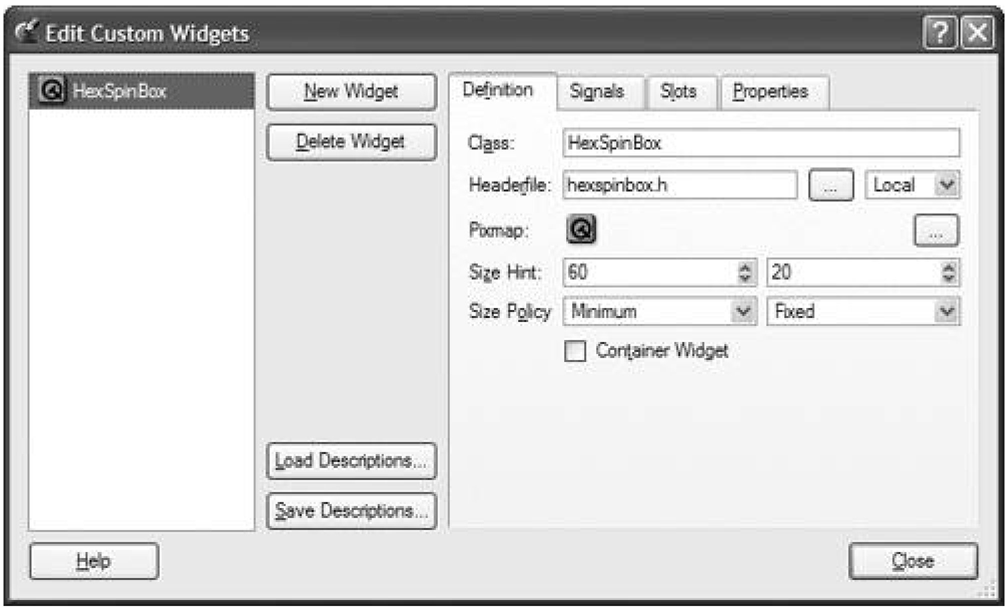
Before we can use custom widgets in *Qt Designer*, we must make *Qt Designer* aware of them. There are two techniques for doing this: the "simple custom widget" approach and the plugin approach.

The "simple custom widget" approach consists of filling in a dialog box in *Qt Designer* with some information about the custom widget. The widget can then be used in forms developed using *Qt Designer*, but the widget is only represented by an icon and a dark gray rectangle while the form is edited or previewed. Here's how to integrate the `HexSpinBox` widget using this approach:

1. *Click Tools|Custom|Edit Custom Widget*. This will launch *Qt Designer*'s custom widget editor.
2. Click *New Widget*.
3. Change the class name from `MyCustomWidget` to `HexSpinBox` and the header file from `mycustomwidget.h` to `hexspinbox.h`.
4. Change the size hint to (60, 20).
5. Change the size policy to (Minimum, Fixed).

The widget will then be available in the "Custom Widgets" section of *Qt Designer*'s toolbox.

Figure 5.6. *Qt Designer*'s custom widget editor



Class: HexSpinBox
Headerfile: hexspinbox.h ... Local
Pixmap:
Size Hint: 60 20
Size Policy: Minimum Fixed
☐ Container Widget

The plugin approach requires the creation of a plugin library that *Qt Designer* can load at run-time and use to create instances of the widget. The real widget is then used by *Qt Designer* when editing the form and for previewing. We will integrate the `IconEditor` as a plugin to demonstrate how to do it.

First, we must subclass QWidgetPlugin and reimplement some virtual functions. We can do everything in the same source file. We will assume that the plugin source code is located in a directory called iconeditorplugin and that the IconEditor source code is located in a parallel directory called iconeditor.

Here's the header file:

```
#include <qwidgetplugin.h>

#include "../iconeditor/iconeditor.h"

class IconEditorPlugin : public QWidgetPlugin
{
public:
    QStringList keys() const;
    QWidget *create(const QString &key, QWidget *parent,
                    const char *name);
    QString includeFile(const QString &key) const;
    QString group(const QString &key) const;
    QIconSet iconSet(const QString &key) const;
    QString toolTip(const QString &key) const;
    QString whatsThis(const QString &key) const;
    bool isContainer(const QString &key) const;
};
```

The IconEditorPlugin subclass is a factory class that encapsulates the IconEditor widget. The functions are used by *Qt Designer* to create instances of the class and to obtain information about it.

```
QStringList IconEditorPlugin::keys() const
{
    return QStringList() << "IconEditor";
}
```

The keys() function returns a list of widgets provided by the plugin. The example plugin only provides the IconEditor widget.

```
QWidget *IconEditorPlugin::create(const QString &, QWidget *parent,
                                  const char *name)
{
    return new IconEditor(parent, name);
}
```

The create() function is called by *Qt Designer* to create an instance of a widget class. The first argument is the widget's class name. We can ignore it in this example, because we only provide one class. All the other functions also take a class name as their first argument.

```
QString IconEditorPlugin::includeFile(const QString &) const
{
    return "iconeditor.h";
}
```

The includeFile() function returns the name of the header file for the specified widget encapsulated by the plugin. The header file is included in the code generated by the uic tool.

```
bool IconEditorPlugin::isContainer(const QString &) const
{
    return false;
}
```

The isContainer() function returns true if the widget can contain other widgets; otherwise, it returns false. For example, QFrame is a widget that can contain other widgets. We return false for the IconEditor, since it doesn't make sense for it to contain other widgets. Strictly speaking, any widget can contain other widgets, but *Qt Designer* disallows this when isContainer() returns false.

```
QString IconEditorPlugin::group(const QString &) const
{
    return "Plugin Widgets";
}
```

The group() function returns the name of the toolbox group this custom widget should belong to. If the name isn't already in use, *Qt Designer* automatically creates a new group for the widget.

```
QIconSet IconEditorPlugin::iconSet(const QString &) const
{
    return QIconSet(QPixmap::fromMimeSource("iconeditor.png"));
}
```

The iconSet() function returns the icon to use to represent the custom widget in *Qt Designer*'s toolbox.

```
QString IconEditorPlugin::toolTip(const QString &) const
{
    return "Icon Editor";
}
```

The toolTip() function returns the tooltip to show when the mouse hovers over the custom widget in *Qt Designer*'s toolbox.

```
QString IconEditorPlugin::whatsThis(const QString &) const
{
    return "Widget for creating and editing icons";
}
```

The whatsThis() function returns the "What's This?" text for *Qt Designer* to display.

```
Q_EXPORT_PLUGIN(IconEditorPlugin)
```

At the end of the source file that implements the plugin class, we must use the Q_EXPORT_PLUGIN() macro to make the plugin available to *Qt Designer*.

The .pro file for building the plugin looks like this:

```
TEMPLATE          = lib
CONFIG           += plugin
HEADERS           = ../iconeditor/iconeditor.h
SOURCES           = iconeditorplugin.cpp \
                    ../iconeditor/iconeditor.cpp
IMAGES            = images/iconeditor.png
DESTDIR           = $(QTDIR)/plugins/designer
```

The .pro file assumes that the QTDIR environment variable is set to the directory where Qt is installed. When you type make or nmake to build the plugin, it will automatically install itself in *Qt Designer*'s plugins directory.

Once the plugin is built, the IconEditor widget can be used in *Qt Designer* in the same way as any of Qt's built-in widgets.

[Team LiB]

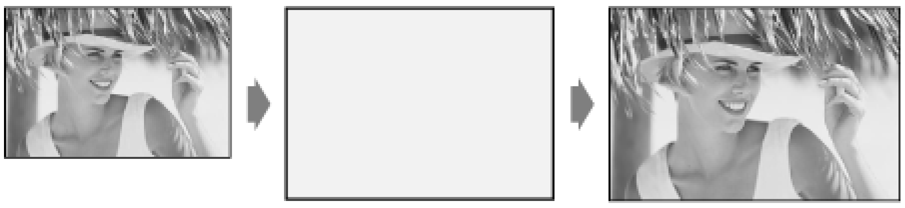
Double Buffering

Double buffering is a technique that can be used to provide a snappier user interface and to eliminate flicker. Flicker occurs when the same pixel is painted multiple times with different colors in a very short period of time. If this occurs for only one pixel, it isn't a problem, but if it occurs for lots of pixels at the same time, it can be distracting for the user.

When Qt generates a paint event, it first erases the widget using the palette's background color. Then, in `paintEvent()`, the widget only needs to paint the pixels that are not the same color as the background. This two-step approach is very convenient, because it means we can simply paint what we need on the widget without worrying about the other pixels.

Unfortunately, the two-step approach is also a major source of flicker. For example, if the user resizes the widget, the widget is first cleared in its entirety, and then the pixels are painted. The flicker is even worse if the window system shows the contents of the window as it is resized, because then the widget is repeatedly erased and painted.

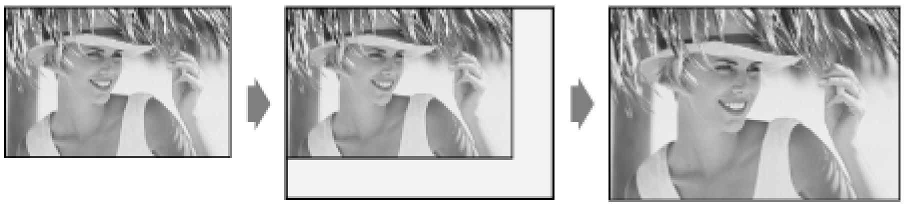
Figure 5.7. Resizing a widget that has no provision against flicker



The `WStaticContents` flag used to implement the `IconEditor` widget is one solution to this problem, but it can only be used for widgets whose content is independent of the size of the widget. Such widgets are rare. Most widgets tend to stretch their contents to consume all the available space. They need to be completely repainted when they are resized. We can still avoid flicker, but the solution is slightly more complicated.

The first rule to avoid flicker is to construct the widget with the `WNoAutoErase` flag. This flag tells Qt *not* to erase the widget before a paint event. The old pixels are then left unchanged, and any newly revealed pixels are undefined.

Figure 5.8. Resizing a `WNoAutoErase` widget



When using `WNoAutoErase`, it is important that the paint handler sets all the pixels explicitly. Any pixel that is not set in the paint event will keep its previous value, which isn't necessarily the background color.

The second rule to avoid flicker is to paint every pixel just once. The easiest way to implement this requirement is to draw the whole widget in an offscreen pixmap and to copy the pixmap onto the widget in one go. Using this approach, it doesn't matter if some pixels are painted multiple times because the painting takes place off-screen. This is double buffering.

Adding double buffering to a custom widget to eliminate flicker is straightforward. Suppose the original paint event handler looks like this:

```
void MyWidget::paintEvent(QPaintEvent *)
{
    QPainter painter(this);
    drawMyStuff(&painter);
}
```

The double-buffered version looks like this:

```
void MyWidget::paintEvent(QPaintEvent *event)
{
    static QPixmap pixmap;
    QRect rect = event->rect();

    QSize newSize = rect.size().expandedTo(pixmap.size());
    pixmap.resize(newSize);
    pixmap.fill(this, rect.topLeft());

    QPainter painter (&pixmap, this);
    painter.translate(-rect.x(), -rect.y());
    drawMyStuff(&painter);
    bitBlt(this, rect.x(), rect.y(), &pixmap, 0, 0,
           rect.width(), rect.height());
}
```

First, we resize a `QPixmap` to be at least as large as the bounding rectangle of the region to repaint. (A "region" is very often either a rectangle or an L-shaped area, but it can be arbitrarily complex.) We make the `QPixmap` a static variable to avoid repeatedly allocating and deallocating it. For the same reason, we never shrink the `QPixmap`; the calls to `QSize::expandedTo()` and `QPixmap::resize()` ensure that it is always large enough. After resizing, we fill the `QPixmap` with the widget's erase color or background pixmap using `QPixmap::fill()`. The second argument to `fill()` specifies which point in the widget the `QPixmap`'s top-left pixel corresponds to. (This makes a difference if the widget is to be erased using a pixmap instead of a uniform color.)

The `QPixmap` class is similar to both `QImage` and `QWidget`. Like a `QImage`, it stores an image, but the color depth and possibly the colormap are aligned with the display, rather like a hidden `QWidget`. If the window system is running in 8-bit mode, all widgets and pixmaps are restricted to 256 colors, and Qt automatically maps 24-bit color specifications onto 8-bit colors. (Qt's color allocation strategy is controlled by calling `QApplication::setColorSpec()`.)

Next, we create a `QPainter` to operate on the pixmap. By passing the `this` pointer to the constructor, we tell `QPainter` to adopt some of the widget's settings, such as its font. We translate the painter to paint the correct rectangle into the pixmap, before we perform the drawing using the `QPainter` as usual.

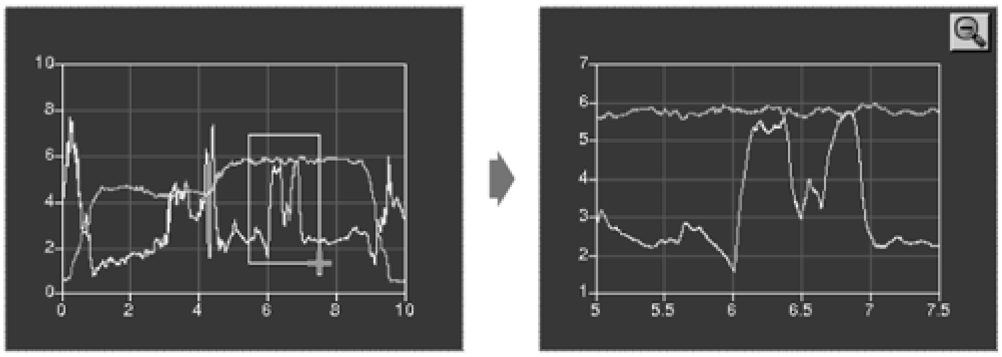
Finally, we copy the pixmap to the widget using the `bitBlt()` global function, whose name stands for "bit-block transfer".

Double buffering is not only useful for avoiding flicker. It is beneficial if the widget's rendering is complex and needed repeatedly. We can then store a pixmap permanently with the widget, always ready for the next paint event, and copy the pixmap to the widget whenever we receive a paint event. It is especially helpful when we want to do small modifications, such as drawing a rubber band, without recomputing the whole widget's rendering over and over.

We will round off this chapter by reviewing the Plotter custom widget. This widget uses double buffering, and also demonstrates some other aspects of Qt programming, including keyboard event handling, manual layout, and coordinate systems.

The Plotter widget displays one or more curves specified as vectors of coordinates. The user can draw a rubber band on the image, and the Plotter will |zoom in on the area enclosed by the rubber band. The user draws the rubber band by clicking a point on the graph, dragging the mouse to another position with the left mouse button held down, and releasing the mouse button.

Figure 5.9. Zooming in on the `Plotter` widget



The user can zoom in repeatedly by drawing a rubber band multiple times, zooming out using the *Zoom Out* button, and then zooming back in using the *Zoom In* button. The *Zoom In* and *Zoom Out* buttons appear the first time they become available, so that they don't clutter the display if the user doesn't zoom the graph.

The Plotter widget can hold the data for any number of curves. It also maintains a stack of PlotSettings, each of which corresponds to a particular zoom level.

Let's review the class, starting with plotter.h:

```
#ifndef PLOTTER_H
#define PLOTTER_H

#include <qpixmap.h>
#include <qwidget.h>

#include <map>
#include <vector>

class QToolButton;
class PlotSettings;

typedef std::vector<double> CurveData;
```

We include the standard <map> and <vector> header files. We don't import all the std namespace's symbols into the global namespace, because it's bad style to do this in a header file.

We define CurveData as a synonym for std::vector<double>. We will store a curve's points as successive pairs of *x* and *y* values in the vector. For example, the curve defined by the points (0, 24), (1, 44), (2,89) is represented by the vector [0, 24, 1, 44, 2, 89].

```
class Plotter : public QWidget
{
    Q_OBJECT
```

```
public:
    Plotter(QWidget *parent = 0, const char *name = 0,
            WFlags flags = 0);

    void setPlotSettings(const PlotSettings &settings);
    void setCurveData(int id, const CurveData &data);
    void clearCurve(int id);
    QSize minimumSizeHint() const;
    QSize sizeHint() const;

public slots:
    void zoomIn();
    void zoomOut();
```

We provide three public functions for setting up the plot, and two public slots for zooming in and out. We also reimplement `minimumSizeHint()` and `sizeHint()` from `QWidget`.

```
protected:
    void paintEvent(QPaintEvent *event);
    void resizeEvent(QResizeEvent *event);
    void mousePressEvent(QMouseEvent *event);
    void mouseMoveEvent(QMouseEvent *event);
    void mouseReleaseEvent(QMouseEvent *event);
    void keyPressEvent(QKeyEvent *event);
    void wheelEvent(QWheelEvent *event);
```

In the protected section of the class, we declare all the `QWidget` event handlers that we need to reimplement.

```
private:
    void updateRubberBandRegion();
    void refreshPixmap();
    void drawGrid(QPainter *painter);
    void drawCurves(QPainter *painter);

    enum { Margin = 40 };

    QToolButton *zoomInButton;
    QToolButton *zoomOutButton;
    std::map<int, CurveData> curveMap;
    std::vector<PlotSettings> zoomStack;
    int curZoom;
    bool rubberBandIsShown;
    QRect rubberBandRect;
    QPixmap pixmap;
};
```

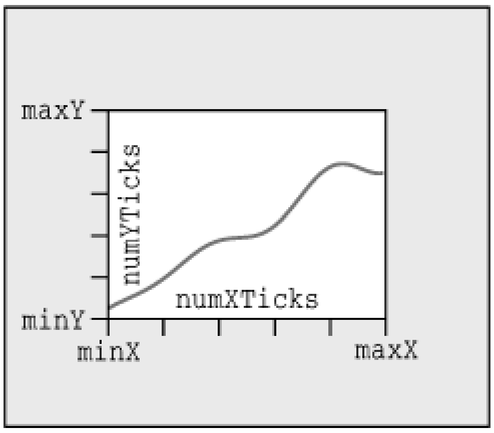
In the private section of the class, we declare a constant, a few functions for painting the widget, and several member variables. The `Margin` constant is used to provide some spacing around the graph.

Among the member variables is `pixmap` of type `QPixmap`. This variable holds a copy of the whole widget's rendering, identical to what is shown on screen. The plot is always drawn onto this off-screen pixmap first; then the pixmap is copied onto the widget.

```
class PlotSettings
{
public:
    PlotSettings();

    void scroll(int dx, int dy);
    void adjust();
    double spanX() const { return maxX - minX; }
    double spanY() const { return maxY - minY; }

    double minX;
    double maxX;
    int numXTicks;
    double minY;
    double maxY;
    int numYTicks;

private:
    void adjustAxis(double &min, double &max, int &numTicks);
};

#endif
```

The PlotSettings class specifies the range of the *x* and *y* axes and the number of ticks for these axes. Figure 5.10 shows the correspondence between a PlotSettings object and the scales on a Plotter widget.

Figure 5.10. PlotSettings's member variables



By convention, numXTicks and numYTicks are off by one; if numXTicks is 5, Plotter will actually draw 6 tick marks on the *x* axis. This simplifies the calculations later on.

Now let's review the implementation file:

```
#include <qpainter.h>
#include <qstyle.h>
#include <qtoolbutton.h>

#include <cmath>
using namespace std;

#include "plotter.h"
```

We include the expected header files and import all the std namespace's symbols into the global namespace.

```
Plotter::Plotter(QWidget *parent, const char *name, WFlags flags)
    : QWidget(parent, name, flags | WNoAutoErase)
{
    setBackgroundMode(PaletteDark);
    setSizePolicy(QSizePolicy::Expanding, QSizePolicy::Expanding);
    setFocusPolicy(StrongFocus);
    rubberBandIsShown = false;

    zoomInButton = new QToolButton(this);
    zoomInButton->setIconSet(QPixmap::fromMimeSource("zoomin.png"));
    zoomInButton->adjustSize();
    connect(zoomInButton, SIGNAL(clicked()), this, SLOT(zoomIn()));

    zoomOutButton = new QToolButton(this);
    zoomOutButton->setIconSet(
            QPixmap::fromMimeSource("zoomout.png"));
    zoomOutButton->adjustSize();
    connect(zoomOutButton, SIGNAL(clicked()), this, SLOT(zoomOut()));

    setPlotSettings(PlotSetting());
}
```

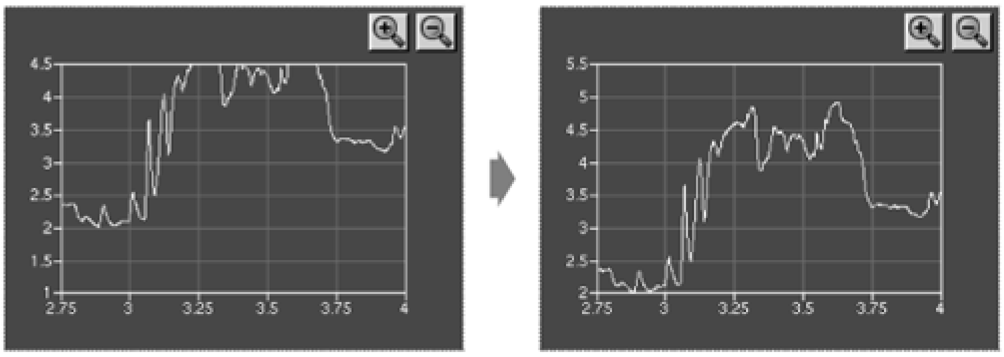
The Plotter has a flags parameter in addition to parent and name. This parameter is simply passed on to the base class constructor, along with WNoAutoErase. The parameter is especially useful for widgets that are likely to be used as stand-alone windows, because it allows the user of the class to configure the window frame and title bar.

The setBackgroundMode() call tells QWidget to use the "dark" component of the palette as the color for erasing the widget, instead of the "background" component. Although we pass the WNoAutoErase flag to the base class constructor, Qt still needs a default color that it may use to fill any newly revealed pixels when the widget is resized to a larger size, before paintEvent() even has the chance to paint the new pixels. Since the background of the Plotter widget will be dark, it makes sense to paint these pixels dark.

The setSizePolicy() call sets the widget's size policy to QSizePolicy::Expanding in both directions. This tells any layout manager that is responsible for the widget that the widget is especially willing to grow, but can also shrink. This setting is typical for widgets that can take up a lot of screen space. The default is QSizePolicy::Preferred in both directions, which means that the widget prefers to be the size of its size hint, but it can be shrunk down to its minimum size hint or expanded indefinitely if necessary.

The setFocusPolicy() call makes the widget accept focus by clicking or by pressing *Tab*. When the Plotter has focus, it will receive events for key presses. The Plotter widget understands a few keys: + to zoom in, - to zoom out, and the arrow keys to scroll up, down, left, and right.

Figure 5.11. Scrolling the Plotter widget



Still in the constructor, we create two QToolButtons, each with an icon. These buttons allow the user to navigate through the zoom stack. The button's icons are stored in an image collection. Any application that uses the Plotter widget will need this entry in its .pro file:

```
IMAGES       += images/zoomin.png \
                images/zoomout.png
```

The calls to adjustSize() on the buttons sets their sizes to be that of their size hints.

The call to setPlotSettings() at the end does the rest of the initialization.

```
void Plotter::setPlotSettings(const PlotSettings &settings)
{
    zoomStack.resize(1);
    zoomStack[0] = settings;
    curZoom = 0;
    zoomInButton->hide();
    zoomOutButton->hide();
    refreshPixmap();
}
```

The setPlotSettings() function is used to specify the PlotSettings to use for displaying the plot. It is called by the Plotter constructor, and can be called by users of the class. The plotter starts out at its default zoom level. Each time the user zooms in, a new PlotSettings instance is created and put onto the zoom stack.

The zoom stack is represented by two member variables:

- zoomStack holds the different zoom settings as a vector<PlotSettings>.
- curZoom holds the current PlotSettings's index in the zoomStack.

After a call to setPlotSettings(), the zoom stack contains only one entry, and the *Zoom In* and *Zoom Out* buttons are hidden. These buttons will not be shown until we call show() on them in the zoomIn() and zoomOut() slots. (Normally, it is sufficient to call show() on the top-level widget to show all the children. But when we explicitly call hide() on a child widget, it is hidden until we call show() on it.)

The call to refreshPixmap() is necessary to update the display. Usually, we would call update(), but here we do things slightly differently because we want to keep a QPixmap up to date at all times. After regenerating the pixmap, refreshPixmap() calls update() to copy the pixmap onto the widget.

```
void Plotter::zoomOut()
{
    if (curZoom > 0) {
        --curZoom;
        zoomOutButton->setEnabled(curZoom > 0);
        zoomInButton->setEnabled(true);
        zoomInButton->show();
        refreshPixmap();
    }
}
```

The zoomOut() slot zooms out if the graph is zoomed in. It decrements the current zoom level and enables the *Zoom Out* button depending on whether the graph can be zoomed out any more or not. The *Zoom In* button is enabled and shown, and the display is updated with a call to refreshPixmap().

```
void Plotter::zoomIn()
{
    if (curZoom > (int)zoomStack.size() - 1) {
        ++curZoom;
        zoomInButton->setEnabled(
                curZoom < (int)zoomStack.size() - 1);
        zoomOutButton->setEnabled(true);
        zoomOutButton->show();
        refreshPixmap();
    }
}
```

If the user has previously zoomed in and then out again, the PlotSettings for the next zoom level will be in the zoom stack, and we can zoom in. (Otherwise, it is still possible to zoom in using a rubber band.)

The slot increments curZoom to move one level deeper into the zoom stack, sets the *Zoom In* button enabled or disabled depending on whether it's possible to zoom in any further, and enables and shows the *Zoom Out* button. Again, we call refreshPixmap() to make the plotter use the latest zoom settings.

```
void Plotter::setCurveData(int id, const CurveData &data)
{
    curveMap[id] = data;
    refreshPixmap();
}
```

The setCurveData() function sets the curve data for a given curve ID. If a curve with the same ID already exists in the plotter, it is replaced with the new curve data;otherwise, the new curve is simply inserted. The curves are stored in the curveMap member variable of type map<int, CurveData>.

Again, we call our own refreshPixmap() function, rather than update(), to update the display.

```
void Plotter::clearCurve(int id)
{
    curveMap.erase(id);
    refreshPixmap();
}
```

The clearCurve() function removes a curve from curveMap.

```
QSize Plotter::minimumSizeHint() const
{
    return QSize(4 * Margin, 4 * Margin);
}
```

The minimumSizeHint() function is similar to sizeHint(); just as sizeHint() specifies a widget's ideal size, minimumSizeHint() specifies a widget's ideal minimum size. A layout never resizes a widget below its minimum size hint.

The value we return is 160 x 160 to allow for the margin on all four sides and some space for the plot itself. Below that size, the plot would be too small to be useful.

```
QSize Plotter::sizeHint() const
{
    return QSize(8 * Margin, 6 * Margin);
}
```

In sizeHint(), we return an "ideal" size in proportion to the margin and with a pleasing 4:3 aspect ratio.

This finishes the review of the Plotter's public functions and slots. Now let's review the protected event handlers.

```
void Plotter::paintEvent(QPaintEvent *event)
{
    QMemArray<QRect> rects = event->region().rects();
    for (int i = 0; i < (int)rects.size(); ++i)
        bitBlt(this, rects[i].topLeft(), &pixmap, rects[i]);

    QPainter painter(this);

    if (rubberBandIsShown) {
        painter.setPen(colorGroup().light());
        painter.drawRect(rubberBandRect.normalize());
    }
    if (hasFocus()) {
        style().drawPrimitive(QStyle::PE_FocusRect, &painter,
                              rect(), colorGroup(),
                              QStyle::Style_FocusAtBorder,
                              colorGroup().dark());
    }
}
```

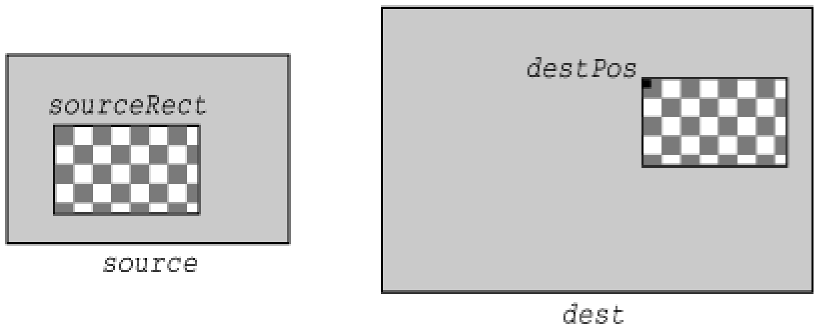
Normally, `paintEvent()` is the place where we perform all the drawing. But here all the plot drawing is done beforehand in `refreshPixmap()`, so we can render the entire plot simply by copying the pixmap onto the widget.

The call to `QRegion::rect()` returns an array of `QRects` that define the region to repaint. We use `bitBlt()` to copy each rectangular area from the pixmap to the widget. The `bitBlt()` global function has the following syntax:

bitBlt(*dest*, *destPos*, *source*, *sourceRect*);

where *source* is the source widget or pixmap, *sourceRect* is the rectangle in the source that should be copied, *dest* is the destination widget or pixmap, and *destPos* is the top-left position in the destination.

Figure 5.12. Copying arbitrary rectangles to and from pixmaps and widgets



It would have been equally correct to call `bitBlt()` just once on the region's bounding rectangle, as we did in a previous code snippet (p. 113). However, because we call `update()` to erase and redraw the rubber band repeatedly in the mouse event handlers (as we will see shortly), and the rubber band outline is basically four tiny rectangles (two 1-pixel-wide rectangles and two 1-pixel-high rectangles), we gain some speed by breaking the region down into its constituent rectangles and calling `bitBlt()` for each rectangle.

Once the plot is shown on screen, we draw the rubber band and the focus rectangle on top of it. For the rubber band, we use the "light" component from the widget's current color group as the pen color to ensure good contrast with the "dark" background. Notice that we draw directly on the widget, leaving the off-screen pixmap untouched. The focus rectangle is drawn using the widget style's drawPrimitive() function with PE_FocusRect as its first argument.

The QWidget::style() function returns the widget style to use to draw the widget. In Qt, a widget style is a subclass of QStyle. The built-in styles include QWindowStyle, QWindowsXPStyle, QMotifStyle, and QMacStyle. Each of these styles reimplements the virtual functions in QStyle to perform the drawing in the correct way for the platform the style is emulating. The drawPrimitive() function is one of these functions; it draws "primitive elements" like panels, buttons, and focus rectangles. The widget style is usually the same for all widgets in an application (QApplication::style()), but it can be overriden on a per-widget basis using QWidget::setStyle().

By subclassing QStyle, it is possible to define a custom style. This can be done to give a distinctive look at an application or a suite of applications. While it is generally advisable to use the target platform's native look and feel, Qt offers a lot of flexibility if you want to be adventurous.

Qt's built-in widgets rely almost exclusively on QStyle to paint themselves. This is why they look like native widgets on all platforms supported by Qt. Custom widgets can be made style-aware either by using QStyle to paint themselves or by using built-in Qt widgets as child widgets. For Plotter, we use both approaches: The focus rectangle is drawn using QStyle, and the *Zoom In* and *Zoom Out* buttons are built-in Qt widgets.

```
void Plotter::resizeEvent(QResizeEvent *)
{
    int x = width() - (zoomInButton->width()
                       + zoomOutButton->width() + 10);
    zoomInButton->move(x, 5);
    zoomOutButton->move(x + zoomInButton->width() + 5, 5);
    refreshPixmap();
}
```

Whenever the Plotter widget is resized, Qt generates a "resize" event. Here, we reimplement resizeEvent() to place the *Zoom In* and *Zoom Out* buttons at the top right of the Plotter widget.

We move the *Zoom In* button and the *Zoom Out* button to be side by side, separated by a 5-pixel gap and with a 5-pixel offset from the top and right edges of the parent widget.

If we wanted the buttons to stay rooted to the top-left corner, whose coordinates are (0, 0), we would simply have moved them there in the Plotter constructor. But we want to track the top-right corner, whose coordinates depend on the size of the widget. Because of this, it's necessary to reimplement resizeEvent() and to set the position there.

We didn't set any positions for the buttons in the Plotter constructor. This isn't an issue, since Qt always generates a resize event before a widget is shown for the first time.

An alternative to reimplementing resizeEvent() and laying out the child widgets manually would have been to use a layout manager (for example, QGridLayout). However, it would have been a little more complicated and would have consumed more resources. When we write widgets from scratch as we are doing here, laying out our child widgets manually is usually the right approach.

At the end, we call refreshPixmap() to redraw the pixmap at the new size.

```
void Plotter::mousePressEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton) {
        rubberBandIsShown = true;
        rubberBandRect.setTopLeft(event->pos());
        rubberBandRect.setBottomRight(event->pos());
        updateRubberBandRegion();
        setCursor(crossCursor);
    }
}
```

When the user presses the left mouse button, we start displaying a rubber band. This involves setting `rubberBandIsShown` to `true`, initializing the `rubberBandRect` member variable with the current mouse pointer position, scheduling a paint event to paint the rubber band, and changing the mouse cursor to have a crosshair shape.

Qt provides two mechanisms for controlling the mouse cursor's shape:

- `QWidget::setCursor()` sets the cursor shape to use when the mouse hovers over a particular widget. If no cursor is set for a widget, the parent widget's cursor is used. The default for top-level widgets is an arrow cursor.

- `QApplication::setOverrideCursor()` sets the cursor shape for the entire application, overriding the cursors set by individual widgets until `restoreOverrideCursor()` is called.

In Chapter 4, we called `QApplication::setOverrideCursor()` with `waitCursor` to change the application's cursor to the standard wait cursor.

```
void Plotter::mouseMoveEvent(QMouseEvent *event)
{
    if (event->state() & LeftButton) {
        updateRubberBandRegion();
        rubberBandRect.setBottomRight(event->pos());
        updateRubberBandRegion();
    }
}
```

When the user moves the mouse cursor while holding the left button, we call `updateRubberBandRegion()` to schedule a paint event to repaint the area where the rubber band was, we update `rubberBandRect` to account for the mouse move, and we call `updateRubberBandRegion()` a second time to repaint the area where the rubber band has moved to. This effectively erases the rubber band and redraws it at the new coordinates.

The `rubberBandRect` variable is of type `QRect`. A `QRect` can be defined either as an (*x*, *y*, *w*, *h*) quadruple—where (*x*, *y*) is the position of the top-left corner and *w* x *h* is the size of the rectange—or as a top-left and a bottom-right coordinate pair. Here, we have used the coordinate pair representation. We set the point where the user clicked the first time as the top-left corner and the current mouse position as the bottom-right corner.

If the user moves the mouse upward or leftward, it's likely that `rubberBandRect`'s nominal bottom-right corner will end up above or to the left of its top-left corner. If this occurs, the `QRect` will have a negative width or height. `QRect` has a `normalize()` function that a adjusts the top-left and bottom-right coordinates to obtain a nonnegative width and height.

```
void Plotter::mouseReleaseEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton) {
        rubberBandIsShown = false;
        updateRubberBandRegion();
        unsetCursor();

        QRect rect = rubberBandRect.normalize();
        if (rect.width() < 4 || rect.height() < 4)
            return;
        rect.moveBy(-Margin, -Margin);

        PlotSettings prevSettings = zoomStack[curZoom];
        PlotSettings settings;
        double dx = prevSettings.spanX() / (width() - 2 * Margin);
        double dy = prevSettings.spanY() / (height() - 2 * Margin);
        settings.minX = prevSettings.minX + dx * rect.left();
        settings.maxX = prevSettings.minX + dx * rect.right();
        settings.minY = prevSettings.maxY - dy * rect.bottom();
        settings.maxY = prevSettings.maxY - dy * rect.top();
        settings.adjust();

        zoomStack.resize(curZoom + 1);
        zoomStack.push_back(settings);
        zoomIn();
    }
}
```

When the user releases the left mouse button, we erase the rubber band and restore the standard arrow cursor. If the rubber band is at least 4 x 4, we perform the zoom. If the rubber band is smaller than that, it's likely that the user clicked the widget by mistake or to give it focus, so we do nothing.

The code to perform the zoom is a bit complicated. This is because we deal with two coordinate systems at the same time: widget coordinates and plotter coordinates. Most of the work we perform here is to convert the `rubberBandRect` from widget coordinates to plotter coordinates.

Once we have done the conversion, we call `PlotSettings::adjust()` to round the numbers and find a sensible number of ticks for each axis.

Figure 5.13. Converting the rubber band from widget to plotter coordinates

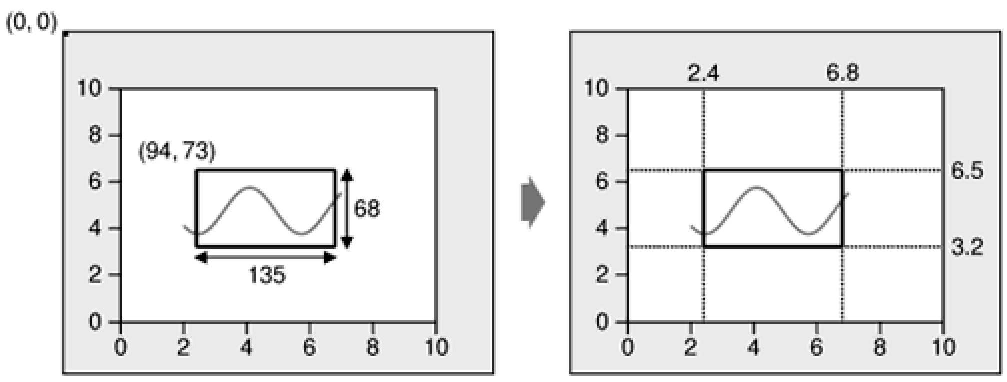
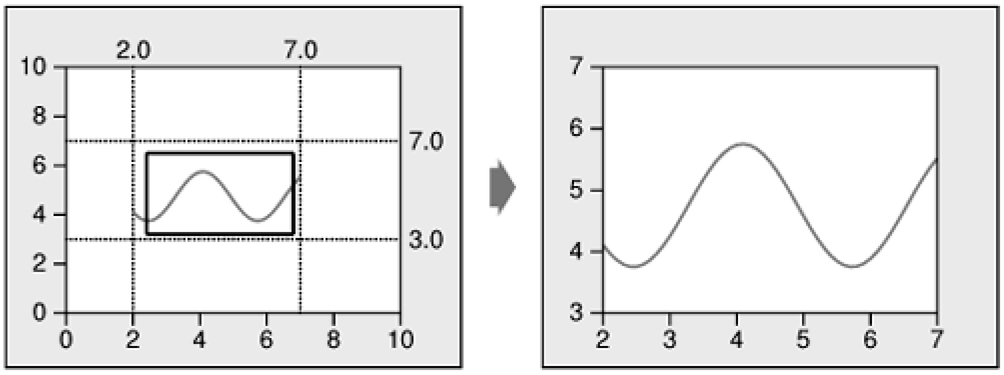


Figure 5.14. Adjusting plotter coordinates and zooming in on the rubber band



Then we perform the zoom. The zoom is achieved by pushing the new `PlotSettings` that we have just calculated on top of the zoom stack and calling `zoomIn()` to do the job.

```
void Plotter::keyPressEvent(QKeyEvent * event)
{
    switch (event->key()) {
    case Key_Plus:
        zoomIn();
        break;
    case Key_Minus:
        zoomOut();
        break;
   case Key_Left:
       zoomStack[curZoom].scroll(-1, 0);
       refreshPixmap();
       break;
   case Key_Right:
       zoomStack[curZoom].scroll(+1, 0);
       refreshPixmap();
       break;
   case Key_Down:
       zoomStack[curZoom].scroll(0, -1);
       refreshPixmap();
       break;
   case Key_Up:
       zoomStack[curZoom].scroll(0, +1);
       refreshPixmap();
       break;
   default:
       QWidget::keyPressEvent(event);
   }
}
```

When the user presses a key and the `Plotter` widget has focus, the `keyPressEvent()` function is called. We reimplement it here to respond to six keys: +, -, *Up*, *Down*, *Left*, and *Right*. If the user pressed a key that we are not handling, we call the base class implementation. For simplicity, we ignore the *Shift*, *Ctrl*, and *Alt* modifier keys, which are available through `QKeyEvent::state()`.

```
void Plotter::wheelEvent(QWheelEvent *event)
{
    int numDegrees = event->delta() / 8;
    int numTicks = numDegrees / 15;

    if (event->orientation() == Horizontal)
        zoomStack[curZoom].scroll(numTicks, 0);
    else
        zoomStack[curZoom].scroll(0, numTicks);
    refreshPixmap();
}
```

Wheel events occur when a mouse wheel is turned. Most mice only provide a vertical wheel, but some also have a horizontal wheel. Qt supports both kinds of wheels. Wheel events go to the widget that has the focus. The `delta()` function returns the distance the wheel was rotated in eighths of a degree. Mice typically work in steps of 15 degrees.

The most common use of the wheel mouse is to scroll a scroll bar. When we subclass `QScrollView` (covered in Chapter 6) to provide scroll bars, `QScrollView` handles the wheel mouse events automatically, so we don't so we reimplement `wheelEvent()` ourselves. Qt classes like `QListView`, `QTable`, and `QTexEdit` that inherit `QScrollView` also support wheel events without needing additional code.

This finishes the implementation of the event handlers. Now let's review the private functions.

```
void Plotter::updateRubberBandRegion()
{
    QRect rect = rubberBandRect.normalize();
    update(rect.left(), rect.top(), rect.width(), 1);
    update(rect.left(), rect.top(), 1, rect.height());
    update(rect.left(), rect.bottom(), rect.width(), 1);
    update(rect.right(), rect.top(), 1, rect.height());
}
```

The `updateRubberBand()` function is called from `mousePressEvent()`, `mouseMoveEvent()`, and `mouseReleaseEvent()` to erase or redraw the rubber band. It consists of four calls to `update()` that schedule a paint event for the four small rectangular areas that are covered by the rubber band.

Using NOT to Draw the Rubber Band

A common way to draw a rubber band is to use the NOT (or the XOR) mathematical operator, which replaces each pixel value on the rubber band rectangle with the opposite bit pattern. Here's a new version of `updateRubberBandRegion()` that does this:

```
void Plotter::updateRubberBandRegion()
{
    QPainter painter(this);
    painter.setRasterOp(NotROP);
    painter.drawRect(rubberBandRect.normalize());
}
```

The `setRasterOp()` call sets the painter's raster operation to be `NotROP`. In the original version, we kept the default value, `CopyROP`, which told `QPainter` to simply copy the new value over the original.

When we call `updateRubberBandRegion()` a second time with the same coordinates, the original pixels are restored, since two NOTs cancel each other out.

The advantage of using NOT is that it's easy to implement and it eliminates the need to keep a copy of the covered areas. But it isn't generally applicable. For example, if we draw text instead of a rubber band, the text could become very hard to read. Also, NOT doesn't always produce good contrast; for example, medium gray stays medium gray. Finally, NOT isn't supported on Mac OS X.

Another approach is to render the rubber band as an animated dotted line. This is often used in image manipulation programs, because it provides good contrast no matter what colors are found in the image. To do this in Qt, the trick is to reimplement QObject::timerEvent() to erase the rubber band and then repaint it but starting drawing the dots at a slightly different offset each time, producing the illusion of movement.

```
void Plotter::refreshPixmap()
{
    pixmap.resize(size());
    pixmap.fill(this, 0, 0);
    QPainter painter(&pixmap, this);
    drawGrid(&painter);
    drawCurves(&painter);
    update();
}
```

The refreshPixmap() function redraws the plot onto the off-screen pixmap and updates the display.

We resize the pixmap to have the same size as the widget and fill it with the widget's erase color. This color is the "dark" component of the palette, because of the call to setBackgroundMode() in the Plotter constructor.

Then we create a QPainter to draw on the pixmap and call drawGrid() and drawCurves() to perform the drawing. At the end, we call update() to schedule a paint event for the whole widget. The pixmap is copied to the widget in the paintEvent() function (p. 121).

```
void Plotter::drawGrid(QPainter *painter)
{
    QRect rect(Margin, Margin,
               width() - 2 * Margin, height() - 2 * Margin);
    PlotSettings settings = zoomStack[curZoom];
    QPen quiteDark = colorGroup().dark().light();
    QPen light = colorGroup().light();

    for (int i = 0; i <= settings.numXTicks; ++i) {
        int x = rect.left() + (i * (rect.width() - 1)
                                 / settings.numXTicks);
        double label = settings.minX + (i * settings.spanX()
                                          / settings.numXTicks);
        painter->setPen(quiteDark);
        painter->drawLine(x, rect.top(), x, rect.bottom());
        painter->setPen(light);
        painter->drawLine(x, rect.bottom(), x, rect.bottom() + 5);
        painter->drawText(x - 50, rect.bottom() + 5, 100, 15,
                          AlignHCenter | AlignTop,
                          QString::number(label));
    }
    for (int j = 0; j <= settings.numYTicks; ++j) {
        int y = rect.bottom() - (j * (rect.height() - 1)
                                   / settings.numYTicks);
        double label = settings.minY + (j * settings.spanY()
                                          / settings.numYTicks);
        painter->setPen(quiteDark);
        painter->drawLine(rect.left(), y, rect.right(), y);
        painter->setPen(light);
        painter->drawLine(rect.left() - 5, y, rect.left(), y);
        painter->drawText(rect.left() - Margin, y - 10,
                          Margin - 5, 20,
                          AlignRight | AlignVCenter,
                              QString::number(label));
    }
    painter->drawRect(rect);
}
```

The `drawGrid()` function draws the grid behind the curves and the axes.

The first `for` loop draws the grid's vertical lines and the ticks along the *x* axis. The second `for` loop draws the grid's horizontal lines and the ticks along the *y* axis. The `drawText()` function is used to draw the numbers corresponding to the tick mark on both axes.

The calls to `drawText()` have the following syntax:

```
painter.drawText(x, y, w, h, alignment, text);
```

where (*x*, *y*, *w*, *h*) define a rectangle, *`alignment`* the position of the text within that rectangle, and *`text`* the text to draw.

```
void Plotter::drawCurves(QPainter *painter)
{
    static const QColor colorForIds[6] = {
        red, green, blue, cyan, magenta, yellow
    };
    PlotSettings settings = zoomStack[curZoom];
    QRect rect(Margin, Margin,
               width() - 2 * Margin, height() - 2 * Margin);

    painter->setClipRect(rect.x() + 1, rect.y() + 1,
                         rect.width() - 2, rect.height() - 2);

    map<int, CurveData>::const_iterator it = curveMap.begin();
    while (it != curveMap.end()) {
        int id = (*it).first;
        const CurveData &data = (*it).second;
        int numPoints = 0;
        int maxPoints = data.size() / 2;
        QPointArray points(maxPoints);

        for (int i = 0; i < maxPoints; ++i) {
            double dx = data[2 * i] - settings.minX;
            double dy = data[2 * i + 1] - settings.minY;
            double x = rect.left() + (dx * (rect.width() - 1)
                                         / settings.spanX());
            double y = rect.bottom() - (dy * (rect.height() - 1)
                                           / settings.spanY());
            if (fabs(x) < 32768 && fabs(y) < 32768) {
                points[numPoints] = QPoint((int)x, (int)y);
                ++numPoints;
            }
        }
        points.truncate(numPoints);
        painter->setPen(colorForIds[(uint)id % 6]);
        painter->drawPolyline(points);
        ++it;
    }
}
```

The `drawCurves()` function draws the curves on top of the grid. We start by calling `setClipRect()` to set the `QPainter`'s clip region to the rectangle that contains the curves (excluding the margins). `QPainter` will then ignore drawing operations on pixels outside the area.

Next, we iterate over all the curves, and for each curve, we iterate over the (*x*, *y*) coordinate pairs that constitute it. The `first` member of the iterator's value gives us the ID of the curve and the `second` member gives us the curve data.

The inner part of the `for` loop converts a coordinate pair from plotter coordinates to widget coordinates and stores it in the `points` variable, provided that it lies within reasonable bounds. If the user zooms in a lot, we could easily end up with numbers that cannot be represented as 16-bit signed integers, leading to incorrect rendering by some window systems.

Once we have converted all the points of a curve to widget coordinates, we set the pen color for the curve (using one of a set of predefined colors) and call `drawPolyline()` to draw a line that goes through all the curve's points.

This is the complete `Plotter` class. All that remains are a few functions in `PlotSettings`.

```
PlotSettings::PlotSettings()
{
    minX = 0.0;
    maxX = 10.0;
    numXTicks = 5;

    minY = 0.0;
    maxY = 10.0;
    numYTicks = 5;
}
```

The `PlotSettings` constructor initializes both axes to the range 0 to 10 with 5 tick marks.

```
void PlotSettings::scroll(int dx, int dy)
{
    double stepX = spanX() / numXTicks;
    minX += dx * stepX;
    maxX += dx * stepX;

    double stepY = spanY() / numYTicks;
    minY += dy * stepY;
    maxY += dy * stepY;
}
```

The `scroll()` function increments (or decrements) `minX`, `maxX`, `minY`, and `maxY` by the interval between two ticks times a given number. This function is used to implement scrolling in `Plotter::keyPressEvent()`.

```
void PlotSettings::adjust()
{
    adjustAxis(minX, maxX, numTicks);
    adjustAxis(minY, maxY, numYTicks);
}
```

The `adjust()` function is called from `mouseReleaseEvent()` to round the `minX`, `maxX`, `minY`, and `maxY` values to "nice" values and to determine the number of ticks appropriate for each axis. The private function `adjustAxis()` does its work one axis at a time.

```
void PlotSettings::adjustAxis(double &min, double &max,
                              int &numTicks)
{
    const int MinTicks = 4;
    double grossStep = (max - min) / MinTicks;
    double step = pow(10, floor(log10(grossStep)));
    if (5 * step < grossStep)
        step *= 5;
    else if (2 * step < grossStep)
        step *= 2;

    numTicks = (int) (ceil(max / step) - floor(min / step));
    min = floor(min  / step) * step;
    max = ceil(max  / step) * step;
}
```

The `adjustAxis()` function converts its `min` and `max` parameters into "nice" numbers and sets its `numTicks` parameter to the number of ticks it calculates to be appropriate for the given [`min`, `max`] range. Because `adjustAxis()` needs to modify the actual variables (`minX`, `maxX`, `numXTicks`, etc.) and not just copies, its parameters are non-const references.

Most of the code in `adjustAxis()` simply attempts to determine an appropriate value for the interval between two ticks (the "step"). To obtain nice numbers along the axis, we must select the step with care. For example, a step value of 3.8 would lead to an axis with multiples of 3.8, which is difficult for people to relate to. For axes labelled in decimal notation, "nice" step values are numbers of the form 10^n, 2.10^n, or 5.10^n.

We start by computing the "gross step", a kind of maximum for the step value. Then we find the corresponding number of the form 10^n that is smaller than or equal to the gross step. We do this by taking the decimal logarithm of the gross step, then rounding that value down to a whole number, then raising 10 to the power of this rounded number. For example, if the gross step is 236, we compute log 236 = 2.37291...; then we round it down to 2 and obtain 10^2 = 100 as the candidate step value of the form 10^n.

Once we have the first candidate step value, we can use it to calculate the other two candidates: 2.10^n and 5.10^n. For the example above, the two other candidates are 200 and 500. The 500 candidate is larger than the gross step, so we can't use it. But 200 is smaller than 236, so we use 200 for the step size in this example.

It's fairly easy to derive `numTicks`, `min`, and `max` from the step value. The new `min` value is obtained by rounding the original `min` down to the nearest multiple of the step, and the new `max` value is obtained by rounding up to the nearest multiple of the step. The new `numTicks` is the number of intervals between the the rounded `min` and `max` values. For example, if `min` is 240 and `max` is 1184 upon entering the function, the new range becomes [200, 1200], with 5 tick marks.

This algorithm will give suboptimal results in some cases. A more sophisticated algorithm is described in Paul S. Heckbert's article "Nice Numbers for Graph Labels" published in *Graphics Gems* (ISBN 0-12-286166-3). Also of interest is the *Qt Quarterly* article "Fast and Flicker-Free", available online at http://doc.trolltech.com/qq/qq06-flicker-free.html, which presents some more ideas for eliminating flicker.

This chapter has brought us to the end of Part I. It has explained how to customize an existing Qt widget and how to build a widget from the ground up using `QWidget` as the base class. We have already seen how to compose a widget from existing widgets in Chapter 2, and we will explore the theme further in Chapter 6.

At this point, we know enough to write complete GUI applications using Qt. In Part II, we will explore Qt in greater depth, so that we can make full use of Qt's power.

Part II: Intermediate Qt

Chapter 6. Layout Management

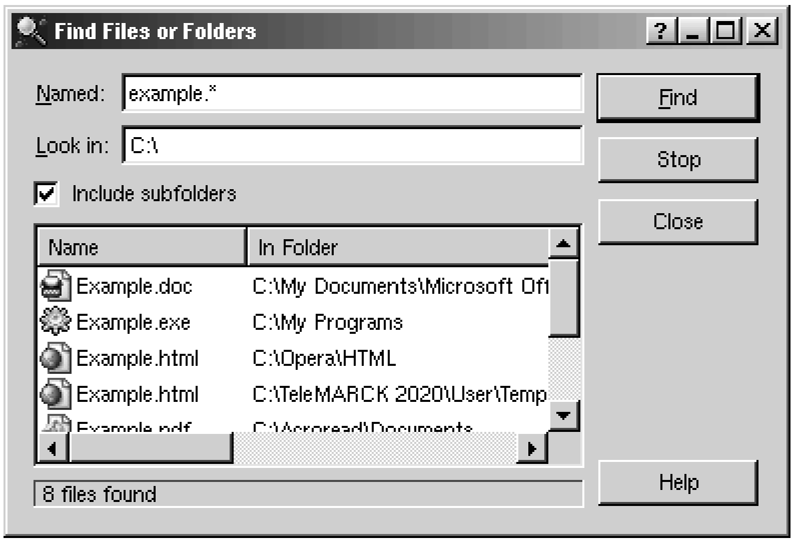
Every widget that is placed on a form must be given an appropriate size and position. Some large widgets may also need scroll bars to give the user access to all their contents. In this chapter, we will review the different ways of laying out widgets on a form, and also see how to implement dockable windows and MDI windows.

[Team LiB]

Basic Layouts

Qt provides three basic ways of managing the layout of child widgets on a form: absolute positioning, manual layout, and layout managers. We will look at each of these approaches in turn, using the Find File dialog shown in Figure 6.1 as our example.

Figure 6.1. The Find File dialog



Absolute positioning is the crudest way of laying out widgets. It is achieved by assigning hard-coded sizes and positions (geometries) to the form's child widgets and a fixed size to the form. Here's what the FindFileDialog constructor looks like using absolute positioning:

```
FindFileDialog::FindFileDialog(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    ...
    namedLable->setGeometry(10, 10, 50, 20);
    namedLineEdit->setGeometry(70, 10, 200, 20);
    lookInLabel->setGeometry(10, 35, 50, 20);
    lookInLineEdit->setGeometry(70, 35, 200, 20);
    subfoldersCheckBox->setGeometry(10, 60, 260, 20);
    listView->setGeometry(10, 85, 260, 100);
    messageLabel->setGeometry(10, 190, 260, 20);
    findButton->setGeometry(275, 10, 80, 25);
    stopButton->setGeometry(275, 40, 80, 25);
    closeButton->setGeometry(275, 70, 80, 25);
    helpButton->setGeometry(275, 185, 80, 25);

    setFixedSize(365, 220);
}
```

Absolute positioning has many disadvantages. The foremost problem is that the user cannot resize the window. Another problem is that some text may be truncated if the user chooses an unusually large font or if the application is translated into another language. And this approach also requires us to perform tedious position and size calculations.

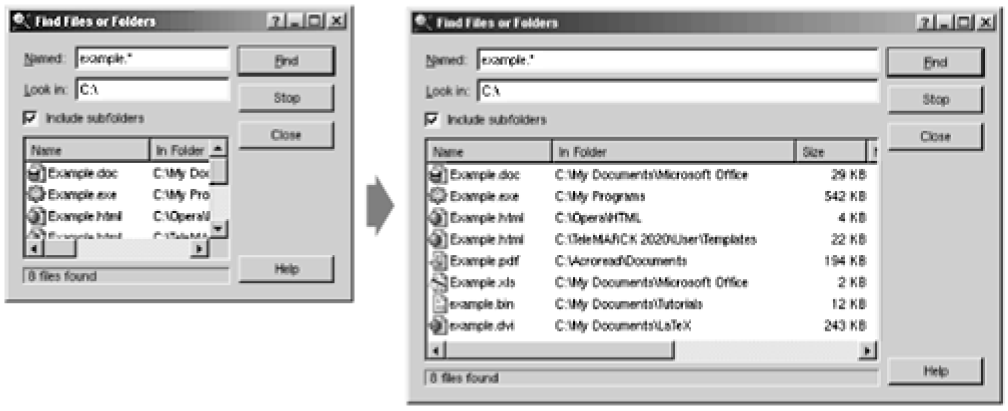
An alternative to absolute positioning is manual layout. With manual layout, the widgets are still given absolute positions, but their sizes are made propor tional to the size of the window rather than being entirely hard-coded. This can be achieved by reimplementing the form's `resizeEvent()` function to set its child widget's geometries:

```
FindFileDialog::FindFileDialog(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    ...
    setMinimumSize(215, 170);
    resize(365, 220);
}

void FindFileDialog::resizeEvent(QResizeEvent *)
{

    int extraWidth = width() - minimumWidth();
    int extraHeight = height() - minimumHeight();

    namedLabel->setGeometry(10, 10, 50, 20);
    namedLineEdit->setGeometry(70, 10, 50 + extraWidth, 20);
    lookInLabel->setGeometry(10, 35, 50, 20);
    lookInLineEdit->setGeometry(70, 35, 50 + extraWidth, 20);
    subfoldersCheckBox->setGeometry(10, 60, 110 + extraWidth, 20);
    listView->setGeometry(10, 85,
                          110 + extraWidth, 50 + extraHeight);
    messageLabel->setGeometry(10, 140 + extraHeight,
                              110 + extraWidth, 20);
    findButton->setGeometry(125 + extraWidth, 10, 80, 25);
    stopButton->setGeometry(125 + extraWidth, 40, 80, 25);
    closeButton->setGeometry(125 + extraWidth, 70, 80, 25);
    helpButton->setGeometry(125 + extraWidth, 135 + extraHeight,
                            80, 25);
}
```

We set the form's minimum size to 215 x 170 in the `FindFileDialog` constructor and its initial size to 365 x 220. In the `resizeEvent()` function, we give any extra space to the widgets that we want to grow.

Just like absolute positioning, manual layout requires a lot of hard-coded constands to be calculated by the program mer. Writing code like this is tiresome, especially if the design changes. And there is still the risk of text truncation. The risk can be avoided by taking account of the child widgets' size hints, but that would complicate the code even further.

Figure 6.2. Resizing a resizable dialog



Name	In Folder	Size
Example.doc	C:\My Documents\Microsoft Office	29 KB
Example.exe	C:\My Programs	542 KB
Example.html	C:\Opera\HTML	4 KB
Example.html	C:\TeleMAFICK 2020\User\Templates	22 KB
Example.pdf	C:\Acroread\Documents	194 KB
Example.xls	C:\My Documents\Microsoft Office	2 KB
example.bin	C:\My Documents\Tutorials	12 KB
example.dvi	C:\My Documents\LaTeX	243 KB

The best solution for laying out widgets on a form is to use Q's layout managers. The layout managers provide sensible defaults for every type of widget and take into account each widget's size hint, which in turn typically depends on the widget's font, style, and contents. Layout managers also respect minimum and maximum sizes, and automatically adjust the layout in response to font changes, text changes, and window resizing.

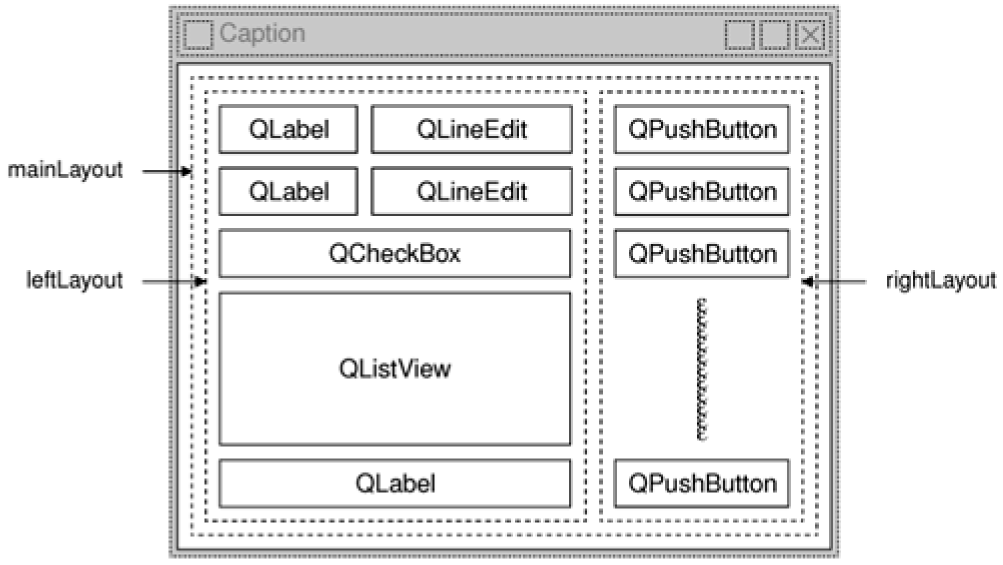
Qt provides three layout managers: `QHBoxLayout`, `QVBoxLayout`, and `QGridLayout`. These classes inherit `QLayout`, which provides the basic framework for layouts. All three classes are fully supported by *Qt Designer* and can also be used in code. Chapter 2 presented examples of both approaches.

Here's the `FindFileDialog` code using layout managers:

```
FindFileDialog::FindFileDialog(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    ...
    QGridLayout *leftLayout = new QGridLayout;
    leftLayout->addWidget(namedLabel, 0, 0);
    leftLayout->addWidget(namedLineEdit, 0, 1);
    leftLayout->addWidget(lookInLabel, 1, 0);
    leftLayout->addWidget(lookInLineEdit, 1, 1);
    leftLayout->addMultiCellWidget(subfoldersCheckBox, 2, 2, 0, 1);
    leftLayout->addMultiCellWidget(listView, 3, 3, 0, 1);
    leftLayout->addMultiCellWidget(messageLabel, 4, 4, 0, 1);

    QVBoxLayout *rightLayout = new QVBoxLayout;
    rightLayout->addWidget(findButton);
    rightLayout->addWidget(stopButton);
    rightLayout->addWidget(closeButton);
    rightLayout->addStretch(1);
    rightLayout->addWidget(helpButton);

    QHBoxLayout *mainLayout = new QHBoxLayout(this);
    mainLayout->setMargin(11);
    mainLayout->setSpacing(6);
    mainLayout->addLayout(leftLayout);
    mainLayout->addLayout(rightLayout);
}
```

The layout is handled by one `QHBoxLayout`, one `QGridLayout`, and one `QVBoxLayout` The `QGridLayout` on the left and the `QVBoxLayout` on the right are placed side by side by the outer `QHBoxLayout`. The margin around the dialog is 11 pixels and the spacing between the child widgets is 6 pixels.

Figure 6.3. The Find File dialog's layout



`QGridLayout` works on a two-dimensional grid of cells. The `QLabel` at the top-left corner of the layout is at position (0, 0), and the corresponding `QLineEdit` is at position (0, 1). The `QCheckBox` spans two columns; it occupies the cells in positions (2, 0) and (2, 1). The `QListView` and the `QLabel` beneath it also span two columns. The calls to `addMultiCellWidget()` have the following syntax:

```
leftLayout->addMultiCellWidget(widget, row1, row2, col1, col2);
```

where *`widget`* is the child widget to insert into the layout, (*`row1, col1`*) is the top-left cell occupied by the widget, and (*`row2`*, *`col2`*) is the bottom-right cell occupied by the widget.

The same dialog could be created visually in *Qt Designer* by placing the child widgets in their approximate positions, selecting those that need to be laid out together, and clicking *Layout|Lay Out Horizontally*, *Layout|Lay Out Vertically*, or *Layout|Lay Out in a Grid*. We used this approach in Chapter 2 for creating the Spreadsheet application's Go-to-Cell and Sort dialogs.

Using layout managers provides additional benefits to those we have discussed so far. If we add a widget to a layout or remove a widget from a layout, the layout will automatically adapt to the new situation. The same applies if we call `hide()` or `show()` on a child widget. If a child widget's size hint changes, the layout managers automatically redone, taking into account the new size hint. Also, layout managers automatically set a minimum size for the form as a whole, based on the form's child widgets' minimum sizes and size hints.

In every example presented so far, we have simply put the widgets in layouts, with spacer items to consume any excess space. Sometimes this isn't sufficient to make the layout look exactly the way we want. In such situations, we can adjust the layout by changing the size policies and size hints of the widgets being laid out.

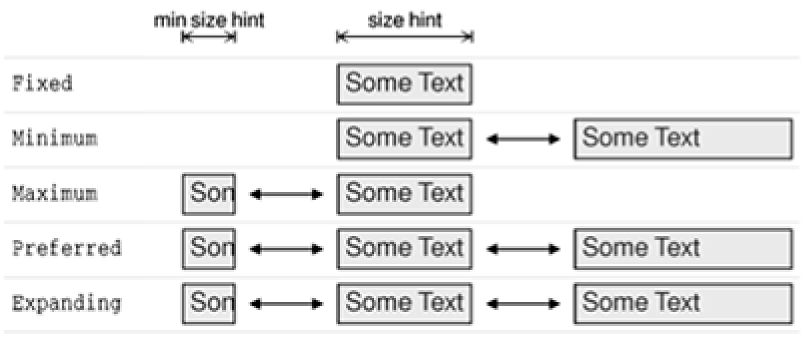
A widget's size policy tells the layout system how it should stretch or shrink. Qt provides sensible default size policy values for all its built-in widgets, but since no single default can account for every possible layout, it is still common for developers to change the size policies for one or two widgets on a form. A size policy has both a horizontal and a vertical component. The most useful values for each component are `Fixed`, `Minimum`, `Maximum`, `Preferred`, and `Expanding`:

- `Fixed` means that the widget cannot grow or shrink. The widget always stays at the size of its size hint.

- Minimum means that the widget's size hint is its minimum size. The widget cannot shrink below the size hint, but it can grow to fill available space if necessary.
- Maximum means that the widget's size hint is its maximum size. The widget can be shrunk down to its minimum size hint.
- Preferred means that the widget's size hint is its preferred size, but that the widget can still shrink or grow if necessary.
- Expanding means that the widget can shrink or grow and that it is especially willing to grow.

Figure 6.4 summarizes the meaning of the different size policies, using a QLabel showing the text "Some Text" as an example.

Figure 6.4. The meaning of the different size policies



When a form that contains both Preferred and Expanding widgets is resized, extra space is given to the Expanding widgets, while the Preferred widgets stay at their size hint.

There are two other size policies: MinimumExpanding and Ignored. The former was necessary in a few rare cases in older versions of Qt, but it isn't useful any more; a better approach is to use Expanding and reimplement minimumSizeHint() appropriately. The latter is similar to Expanding, except that it ignores the widget's size hint.

In addition to the size policy's horizontal and vertical components, the QSizePolicy class stores both a horizontal and a vertical stretch factor. These stretch factors can be used to indicate that different child widgets should grow at different rates when the form expands. For example, if we have a QListView above a QTextEdit and we want the QTextEdit to be twice as tall as the QListView, we can set the QTextEdit's vertical stretch factor to 2 and the QListView's vertical stretch factor to 1.

Another way of influencing a layout is to set a minimum size, a maximum size, or a fixed size on the child widgets. The layout manager will respect these constraints when laying out the widgets. And if this isn't sufficient, we can always derive from the child widget's class and reimplement sizeHint() to obtain the size hint we need.

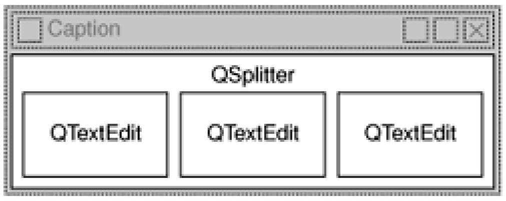
[Team LiB]
PREVIOUS NEXT

Splitters

A splitter is a widget that contains other widgets and that separates them with splitter handles. Users can change the sizes of a splitter's child widgets by dragging the handles. Splitters can often be used as an alternative to layout managers, to give more control to the user.

Qt supports splitters with the QSplitter widget. The child widgets of a QSplitter are automatically placed side by side (or one below the other) in the order in which they are created, with splitter bars between adjacent widgets. Here's the code for creating the window depicted in Figure 6.5:

Figure 6.5. The Splitter application's widgets

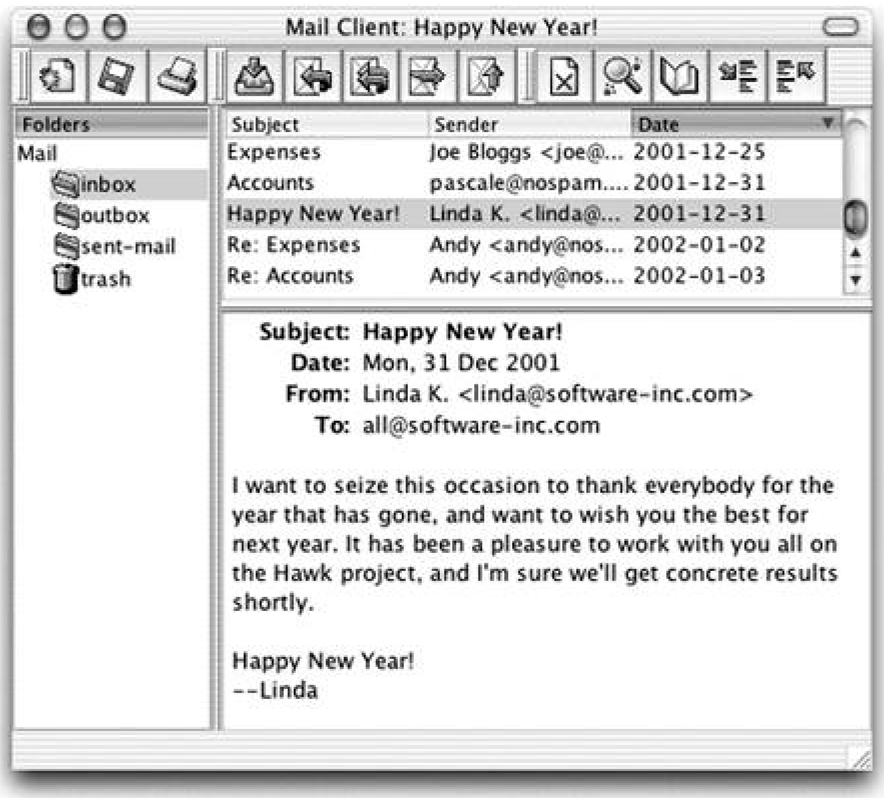


```
#include <qapplication.h>
#include <qsplitter.h>
#include <qtextedit.h>

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);

    QSplitter splitter(Qt::Horizontal);
    splitter.setCaption(QObject::tr("Splitter"));
    app.setMainWidget(&splitter);

    QTextEdit *firstEditor = new QTextEdit(&splitter);
    QTextEdit *secondEditor = new QTextEdit(&splitter);
    QTextEdit *thirdEditor = new QTextEdit(&splitter);

    splitter.show();
    return app.exec();
}
```

The example consists of three QTextEdits laid out horizontally by a QSplitter widget. Unlike layout managers, which simply lay out a form's child widgets, QSplitter inherits from QWidget and can be used like any other widget.

A QSplitter can lay out its child widgets either horizontally or vertically. Complex layouts can be achieved by nesting horizontal and vertical QSplitters. For example, the Mail Client application shown in Figure 6.6 consists of a horizontal QSplitter that contains a vertical QSplitter on its right side.

Figure 6.6. The Mail Client application on Mac OS X



Subject	Sender	Date
Expenses	Joe Bloggs <joe@...	2001-12-25
Accounts	pascale@nospam....	2001-12-31
Happy New Year!	Linda K. <linda@...	2001-12-31
Re: Expenses	Andy <andy@nos...	2002-01-02
Re: Accounts	Andy <andy@nos...	2002-01-03

Subject: Happy New Year!
Date: Mon, 31 Dec 2001
From: Linda K. <linda@software-inc.com>
To: all@software-inc.com

I want to seize this occasion to thank everybody for the year that has gone, and want to wish you the best for next year. It has been a pleasure to work with you all on the Hawk project, and I'm sure we'll get concrete results shortly.

Happy New Year!
--Linda

Here's the code in the constructor of the Mail Client application's QMainWindow subclass:

```
MailClient::MailClient(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    horizontalSplitter = new QSplitter(Horizontal, this);
    setCentralWidget(horizontalSplitter);

    foldersListView = new QListView(horizontalSplitter);
    foldersListView->addColumn(tr("Folders"));
    foldersListView->setResizeMode(QListView::AllColumns);
    verticalSplitter = new QSplitter(Vertical, horizontalSplitter);

    messagesListView = new QListView(verticalSplitter);
    messagesListView->addColumn(tr("Subject"));
    messagesListView->addColumn(tr("Sender"));
    messagesListView->addColumn(tr("Date"));
    messagesListView->setAllColumnsShowFocus(true);
    messagesListView->setShowSortIndicator(true);
    messagesListView->setResizeMode(QListView::AllColumns);

    textEdit = new QTextEdit(verticalSplitter);
    textEdit->setReadOnly(true);

    horizontalSplitter->setResizeMode(foldersListView,
                                      QSplitter::KeepSize);
    verticalSplitter->setResizeMode(messagesListView,
                                    QSplitter::KeepSize);
    ...
    readSettings();
}
```

We create the horizontal QSplitter first and set it to be the QMainWindow's central widget. Then we create the child widgets and their child widgets.

When the user resizes a window, QSplitter normally distributes the space so that the relative sizes of the child widgets stay the same. In the Mail Client example, we don't want this behavior; instead we want the two QListViews to maintain their size and we want to give any extra space to the QTextEdit. This is achieved by the two setResizeMode() calls near the end.

When the application is started, QSplitter gives the child widgets appropriate sizes based on their initial sizes. We can move the splitter handles programmatically by calling QSplitter::setSizes(). The QSplitter class also provides a means of saving and restoring its state the next time the application is run. Here's the writeSettings() function that saves the Mail Client's settings:

```
void MailClient::writeSettings()
{
    QSettings settings;
    settings.setPath("software-inc.com", "MailClient");
    settings.beginGroup("/MailClient");

    QString str;
    QTextOStream out1(&str);
    out1 >> *horizontalSplitter;
    settings.writeEntry("/horizontalSplitter", str);
    QTextOStream out2(&str);
    out2 >> *verticalSplitter;
    settings.writeEntry("/verticalSplitter", str);

    settings.endGroup();
}
```

Here's the corresponding readSettings() function:

```
void MailClient::readSettings()
{
    QSettings settings;
    settings.setPath("software-inc.com", "MailClient");
    settings.beginGroup("/MailClient");

    QString str1 = settings.readEntry("/horizontalSplitter");
    QTextIStream in1(&str1);
    in1 >> *horizontalSplitter;
    QString str2 = settings.readEntry("/verticalSplitter");
    QTextIStream in2(&str2);
    in2 >> *verticalSplitter;

    settings.endGroup();
}
```

These functions rely on QTextIStream and QTextOStream, **two** QTextStream convenience subclasses.

By default, a splitter handle is shown as a rubber band while the user is dragging it, and the widgets on either side of the splitter handle are resized only when the user releases the mouse button. To make QSplitter resize the child widgets in real time, we would call setOpaqueResize(true).

QSplitter is fully supported by *Qt Designer*. To put widgets into a splitter, place the child widgets approximately in their desired positions, select them, and click *Layout*|*Lay Out Horizontally (in Splitter)* or *Layout*|*Lay Out Vertically (in Splitter)*.

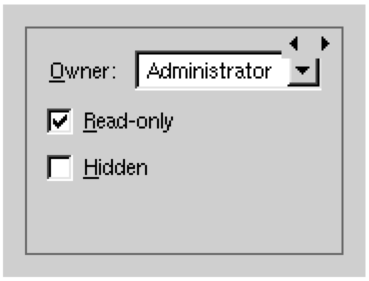
[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Widget Stacks

Another useful widget for managing layouts is QWidgetStack. This widget contains a set of child widgets, or "pages", and shows only one at a time, hiding the others from the user. The pages are numbered from 0. If we want to make a specific child widget visible, we can call raiseWidget() with either a page number or a pointer to the child widget.

The QWidgetStack itself is invisible and provides no intrinsic means for the user to change page. The small arrows and the dark gray frame in Figure 6.7 are provided by *Qt Designer* to make the QWidgetStack easier to design with.

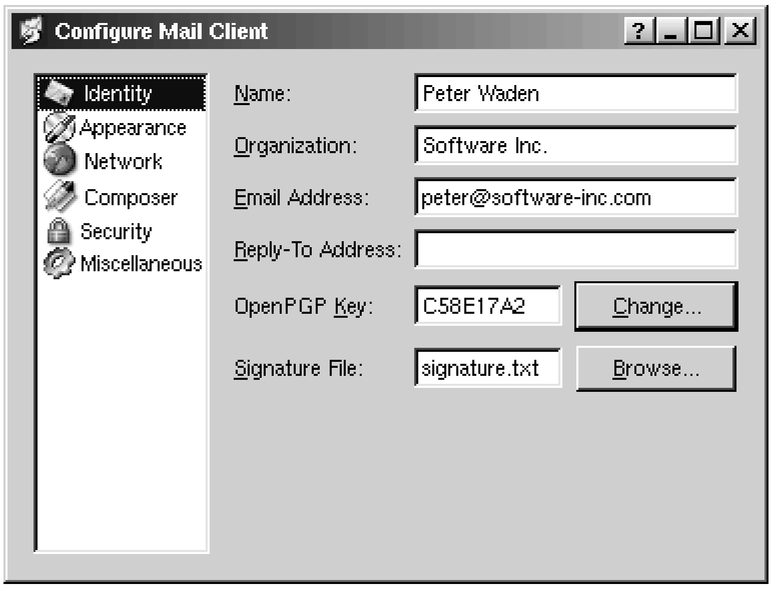
Figure 6.7. QWidgetStack



The Configure dialog shown in Figure 6.8 is an example that uses QWidgetStack. The dialog consists of a QListBox on the left and a QWidgetStack on the right. Each item in the QListBox corresponds to a different page in the QWidgetStack. Forms like this are very easy to create using *Qt Designer*:

1. Create a new form based on the "Dialog" or the "Widget" template.
2. Add a list box and a widget stack to the form.
3. Fill each widget stack page with child widgets and layouts. (To create a new page, right-click and choose *Add Page*; to switch pages, click the tiny left or right arrow located at the top-right of the widget stack.)
4. Lay the widgets out side by side using a horizontal layout.
5. Connect the list box's highlighted(int) signal to the widget stack's raiseWidget(int) slot.
6. Set the value of the list box's currentItem property to 0.

Figure 6.8. The Configure dialog



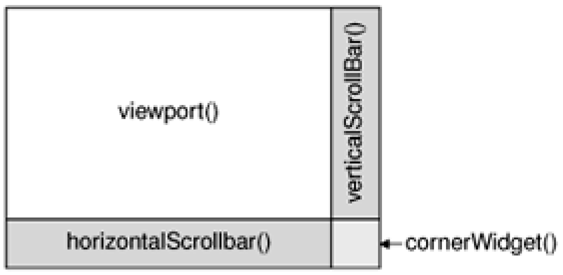
Name: Peter Waden
Organization: Software Inc.
Email Address: peter@software-inc.com
Reply-To Address:
OpenPGP Key: C58E17A2
Signature File: signature.txt

Since we have implemented page-switching using predefined signals and slots, the dialog will exhibit the correct page-switching behavior when previewed in *Qt Designer*.

Scroll Views

The QScrollView class provides a scrollable viewport, two scroll bars, and a "corner" widget (usually an empty QWidget). If we want to add scroll bars to a widget, it is much simpler to use a QScrollView than to instantiate our own QScrollBars and implement the scrolling functionality ourselves.

Figure 6.9. QScrollView's constituent widgets



The easiest way to use QScrollView is to call addChild() with the widget we want to add scroll bars to. QScrollView automatically reparents the widget to make it a child of the viewport (accessible through QScrollView::viewport()) if it isn't already. For example, if we want scroll bars around the IconEditor widget we developed in Chapter 5, we can write this:

```
#include <qapplication.h>
#include <qscrollview.h>

#include "iconeditor.h"

int main(int argc, char *argv[])
{
   QApplication app(argc, argv);

   QScrollView scrollView;
   scrollView.setCaption(QObject::tr("Icon Editor"));
```

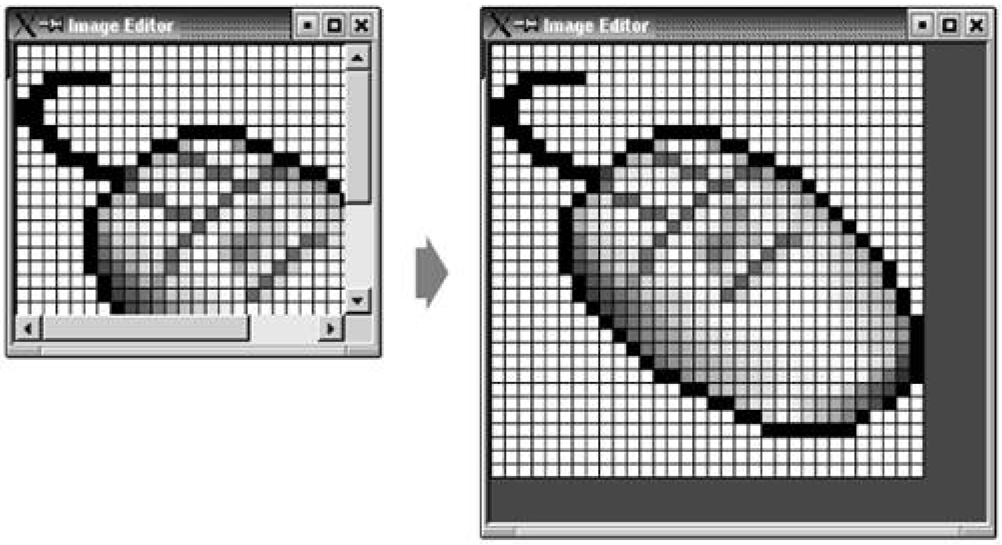
```
    app.setMainWidget(&scrollView);

    IconEditor *iconEditor = new IconEditor;
    scrollView.addChild(iconEditor);

    scrollView.show();
    return app.exec();
}
```

By default, the scroll bars are only displayed when the viewport is smaller than the child widget. We can force the scroll bars to always be shown by writing this code:

```
scrollView.setHScrollBarMode(QScrollView::AlwaysOn);
scrollView.setVScrollBarMode(QScrollView::AlwaysOn);
```

When the child widget's size hint changes, `QScrollView` automatically adapts to the new size hint.

Figure 6.10. Resizing a `QScrollView`



An alternative way of using a `QScrollView` with a widget is to make the widget inherit `QScrollView` and to reimplement `drawContents()` to draw the contents. This is the approach used by Qt classes like `QIconView`, `QListBox`, `QListView`, `QTable`, and `QTextEdit`. If a widget is likely to require scroll bars, it's usually a good idea to implement it as a subclass of `QScrollView`.

To show how this works, we will implement a new version of the `IconEditor` class as a `QScrollView` subclass. We will call the new class `ImageEditor`, since its scroll bars make it capable of handling large images.

```
#ifndef IMAGEEDITOR_H
#define IMAGEEDITOR_H

#include <qimage.h>
#include <qscrollview.h>
class ImageEditor : public QScrollView
{
    Q_OBJECT
    Q_PROPERTY(QColor penColor READ penColor WRITE setPenColor)
    Q_PROPERTY(QImage image READ image WRITE setImage)
    Q_PROPERTY(int zoomFactor READ zoomFactor WRITE setZoomFactor)
public:
    ImageEditor(QWidget *parent = 0, const char *name = 0);

    void setPenColor(const QColor &newColor);
    QColor penColor() const { return curColor; }
    void setZoomFactor(int newZoom);
    int zoomFactor() const { return zoom; }
    void setImage(const QImage &newImage);
    const QImage &image() const { return curImage; }

protected:
    void contentsMousePressEvent(QMouseEvent *event);
    void contentsMouseMoveEvent(QMouseEvent *event);
    void drawContents(QPainter *painter, int x, int y,
                      int width, int height);

private:
    void drawImagePixel(QPainter *painter, int i, int j);
    void setImagePixel(const QPoint &pos, bool opaque);
    void resizeContents();

    QColor curColor;
    QImage curImage;
    int zoom;
};

#endif
```

The header file is very similar to the original (p. 100). The main difference is that we inherit from QScrollView instead of QWidget. We will run into the other differences as we review the class's implementation.

```
ImageEditor::ImageEditor(QWidget *parent, const char *name)
    : QScrollView(parent, name, WStaticContents | WNoAutoErase)
{
    curColor = black;
    zoom = 8;
    curImage.create(16, 16, 32);
    curImage.fill(qRgba(0, 0, 0, 0));
    curImage.setAlphaBuffer(true);
    resizeContents();
}
```

The constructor passes the WStaticContents and WNoAutoErase flags to the QScrollView. These flags are actually set on the viewport. We don't set a size policy, because QScrollView's default of (Expanding, Expanding) is appropriate.

In the original version, we didn't call updateGeometry() in the constructor because we could depend on Qt's layout managers picking up the initial widget size by themselves. But here we must give the QScrollView base class an initial size to work with, and we do this with the resizeContents() call.

```
void ImageEditor::resizeContents()
{
    QSize size = zoom * curImage.size();
    if (zoom >= 3)
        size += QSize(1, 1);
    QScrollView::resizeContents(size.width(), size.height());
}
```

The resizeContents() private function calls QScrollView::resizeContents() with the size of the content part of the QScrollView. The QScrollView displays scroll bars depending on the content's size in relation to the viewport's size.

We don't need to reimplement sizeHint(); QScrollView's version uses the content's size to provide a reasonable size hint.

```
void ImageEditor::setImage(const QImage &newImage)
{
    if (newImage != curImage) {
        curImage = newImage.convertDepth(32);
        curImage.detach();
        resizeContents();
        updateContents();
    }
}
```

In many of the original IconEditor functions, we called update() to schedule a repaint and updateGeometry() to propagate a size hint change. In the QScrollView versions, these calls are replaced by resizeContents() to inform the QScrollView about a change of the content's size and updateContents() to force a repaint.

```
void ImageEditor::drawContents(QPainter *painter, int, int, int, int)
{
    if (zoom >= 3) {
        painter->setPen(colorGroup().foreground());
        for (int i = 0; i <= curImage.width(); ++i)
            painter->drawLine(zoom * i, 0,
                              zoom * i, zoom * curImage.height());
        for (int j = 0; j <= curImage.height(); ++j)
            painter->drawLine(0, zoom * j,
                              zoom * curImage.width(), zoom * j);
    }

    for (int i = 0; i < curImage.width(); ++i) {
        for (int j = 0; j < curImage.height(); ++j)
            drawImagePixel(painter, i, j);
    }
}
```

The drawContents() function is called by QScrollView to repaint the content's area. The QPainter object is already initialized to account for the scrolling offset. We just need to perform the drawing as we normally do in a paintEvent().

The second, third, fourth, and fifth parameters specify the rectangle that must be redrawn. We could use this information to only draw the rectangle that needs repainting, but for the sake of simplicity we redraw everything.

The drawImagePixel() function that is called near the end of drawContents() is essentially the same as in the original IconEditor class (p. 106), so it is not reproduced here.

```
void ImageEditor::contentsMousePressEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton)
        setImagePixel(event->pos(), true);
    else if (event->button() == RightButton)
        setImagePixel(event->pos(), false);
}

void ImageEditor::contentsMouseMoveEvent(QMouseEvent *event)
{
    if (event->state() & LeftButton)
        setImagePixel(event->pos(), true);
    else if (event->state() & RightButton)
        setImagePixel(event->pos(), false);
}
```

Mouse events for the content part of the scroll view can be handled by reimplementing special event handlers in QScrollView, whose names all start with contents. Behind the scenes, QScrollView automatically converts the viewport coordinates to content coordinates, so we don't need to convert them ourselves.

```
void ImageEditor::setImagePixel(const QPoint &pos, bool opaque)
{
    int i = pos.x() / zoom;
    int j = pos.y() / zoom;

    if (curImage.rect().contains(i, j)) {
        if (opaque)
            curImage.setPixel(i, j, penColor().rgb());
        else
            curImage.setPixel(i, j, qRgba(0, 0, 0, 0));

        QPainter painter(viewport());
        painter.translate(-contentsX(), -contentsY());
        drawImagePixel(&painter, i, j);
    }
}
```

The setImagePixel() function is called from contentsMousePressEvent() and contentsMouseMoveEvent() to set or clear a pixel. The code is almost the same as the original version, except for the way the QPainter object is initialized. We pass viewport() as the parent because the painting is performed on the viewport, and we translate the QPainter's coordinate system to account for the scrolling offset.

We could replace the three lines that deal with the QPainter with this line:

```
updateContents(i * zoom, j * zoom, zoom, zoom);
```

This would tell QScrollView to update only the small rectangular area occupied by the (zoomed) image pixel. But since we didn't optimize drawContents() to draw only the necessary area, this would be inefficient, so it's better to construct a QPainter and do the painting ourselves.

If we use ImageEditor now, it is practically indistinguishable from the original, QWidget-based IconEditor used inside a QScrollView widget. However, for certain more sophisticated widgets, subclassing QScrollView is the more nattural approach. For example, a class such as QTextEdit that implements wordwrapping needs tight integration between the document that is shown and the QScrollView.

Also note that you should subclass QScrollView if the contents are likely to be very tall or wide, because some window systems don't support widgets that are larger than 32,767 pixels.

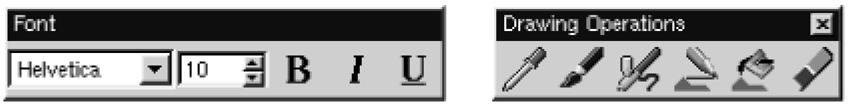
One thing that the ImageEditor example doesn't demonstrate is that we can put child widgets in the viewport area. The child widgets simply need to be added using addWidget(), and can be moved using moveWidget(). Whenever the user scrolls the content area, QScrollView automatically moves the child widgets on screen. (If the QScrollView contains many child widgets, this can slow down scrolling. We can call enableClipper(true) to optimize this case.) One example where this approach would make sense is for a web browser. Most of the contents would be drawn directly on the viewport, but buttons and other form-entry elements would be represented by child widgets.

Dock Windows

Dock windows are windows that can be docked in dock areas. Toolbars are the primary example of dock windows, but there can be other types.

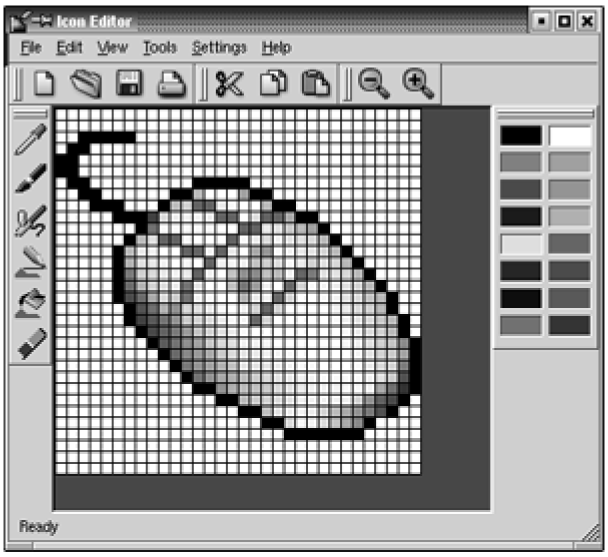
QMainWindow provides four dock areas: one above, one below, one to the left, and one to the right of the window's central widget. When we create QToolBars, they automatically put themselves in their parent's top dock area.

Figure 6.11. Floating dock windows



Every dock window has a handle. This appears as two gray lines at the left or top of each dock window shown in Figure 6.12. Users can move dock windows from one dock area to another by dragging the handle. They can also detach a dock window from an area and let the dock window float as a top-level window by dragging the dock window outside of any dock area. Free floating dock windows have their own caption, and can have a close button. They are always "on top" of their main window.

Figure 6.12. A QMainWindow with five dock windows

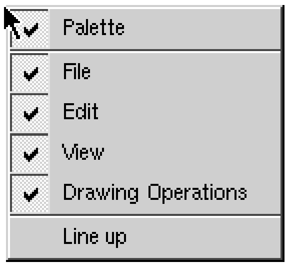


To turn on the close button when the dock window is floating, call setCloseMode() as follows:

```
dockWindow->setCloseMode(QDockWindow::Undocked);
```

QDockArea provides a context menu with the list of all dock windows and toolbars. Once a dock window is closed, the user can restore it using the context menu.

Figure 6.13. A QDockArea context menu



Dock windows must be subclasses of QDockWindow. If we just need a toolbar with buttons and some other widgets, we can use QToolBar, which inherits QDockWindow. Here's how to create a QToolBar containing a QComboBox, a QSpinBox, and some toolbar buttons, and how to put it in the bottom dock area:

```
QToolBar *toolBar = new QToolBar(tr("Font"), this);
QComboBox *fontComboBox = new QComboBox(true, toolBar);
QSpinBox *fontSize = new QSpinBox(toolBar);
boldAct->addTo(toolBar);
italicAct->addTo(toolBar);
underlineAct->addTo(toolBar);
moveDockWindow(toolBar, DockBottom);
```

This toolbar would look ugly if the user moves it to a QMainWindow's left or right dock areas because the QComboBox and the QSpinBox require too much horizontal space. To prevent this from happening, we can call QMainWindow::setDockEnabled() as follows:

```
setDockEnabled(toolBar, DockLeft, false);
setDockEnabled(toolBar, DockRight, false);
```

If what we need is something more like a floating widget or tool palette, we can use QDockWindow directly, by calling setWidget() to set the widget to be shown inside the QDockWindow. The widget can be as complicated as we like. If we want the user to be able to resize the dock window even when it's in a dock area, we can call setResizeEnabled() on the dock window. The dock window will then be rendered with a splitter-like handle on the side.

If we want the widget to change itself depending on whether it is put in a horizontal or in a vertical dock area, we can reimplement QDockWindow::setOrientation() and change it there.

If we want to save the position of all the toolbars and other dock windows so that we can restore them the next time the application is run, we can write code that is similar to the code we used to save a QSplitter's state (p. 143), using QMainWindow's << operator to write out the state and QMainWindow's >> operator to read it back in.

Applications like Microsoft Visual Studio and *Qt Designer* make extensive use of dock windows to provide a very flexible user interface. In Qt, this kind of user interface is usually achieved by using a QMainWindow with many custom QDockWindows and a QWorkspace in the middle to control MDI child windows.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

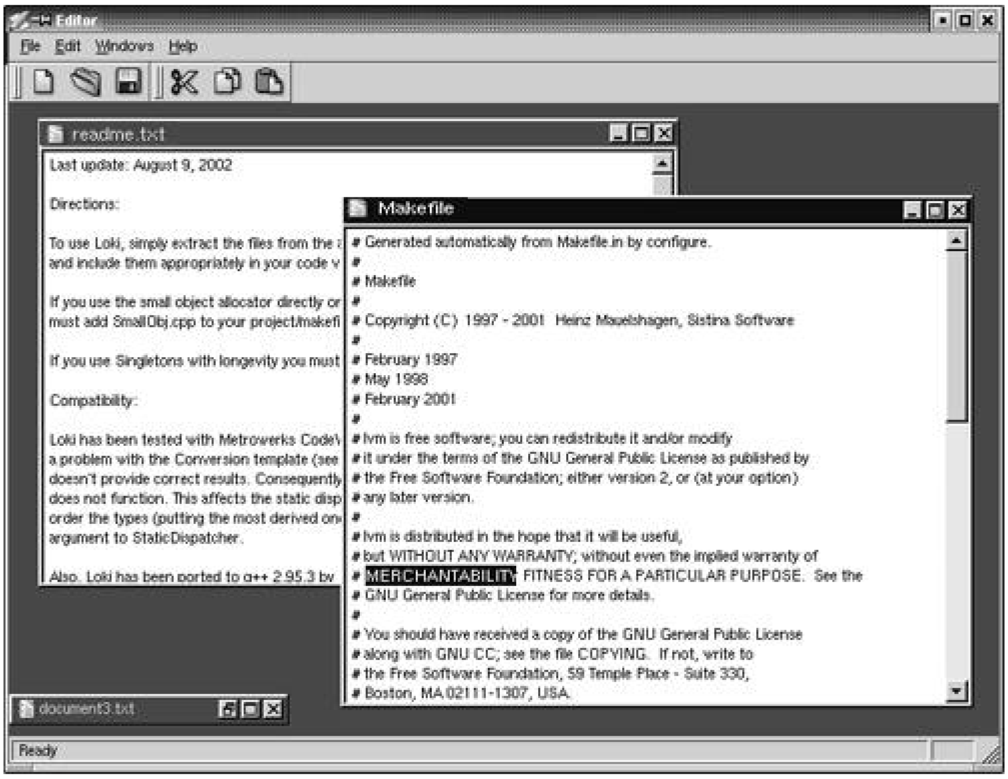
Multiple Document Interface

Applications that provide multiple documents within the main window's central area are called MDI (multiple document interface) applications. In Qt, an MDI application is created by using the QWorkspace class as the central widget and by making each document window a child of the QWorkspace.

It is conventional for MDI applications to provide a Windows menu that includes some commands for managing the windows and the list of windows. The active window is identified with a checkmark. The user can make any window active by clicking its entry in the *Windows* menu.

In this section, we will develop the Editor application shown in Figure 6.14 to demonstrate how to create an MDI application and how to implement its *Windows* menu.

Figure 6.14. The Editor application

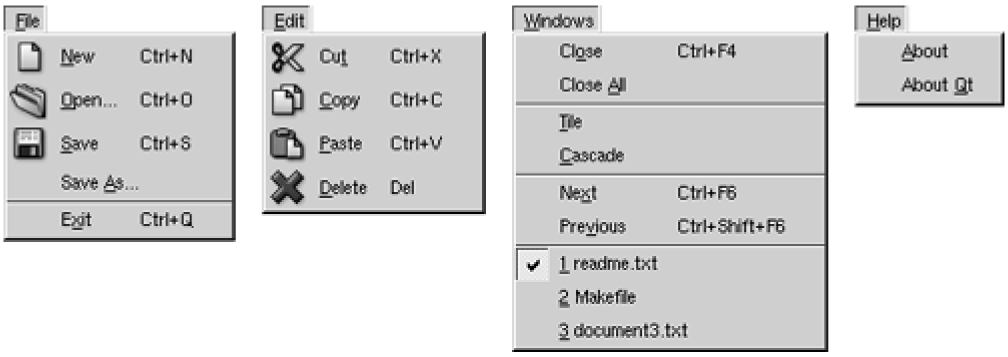


```
Last update: August 9, 2002

Directions:

To use Loki, simply extract the files from the a
and include them appropriately in your code v

If you use the small object allocator directly or
must add SmallObj.cpp to your project/makefi

If you use Singletons with longevity you must

Compatibility:

Loki has been tested with Metrowerks CodeV
a problem with the Conversion template (see
doesn't provide correct results. Consequently
does not function. This affects the static disp
order the types (putting the most derived one
argument to StaticDispatcher.

Also, Loki has been ported to g++ 2.95.3 by
```

```
# Generated automatically from Makefile.in by configure.
#
# Makefile
#
# Copyright (C) 1997 - 2001  Heinz Mauelshagen, Sistina Software
#
# February 1997
# May 1998
# February 2001
#
# lvm is free software; you can redistribute it and/or modify
# it under the terms of the GNU General Public License as published by
# the Free Software Foundation; either version 2, or (at your option)
# any later version.
#
# lvm is distributed in the hope that it will be useful,
# but WITHOUT ANY WARRANTY; without even the implied warranty of
# MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
# GNU General Public License for more details.
#
# You should have received a copy of the GNU General Public License
# along with GNU CC; see the file COPYING.  If not, write to
# the Free Software Foundation, 59 Temple Place - Suite 330,
# Boston, MA 02111-1307, USA.
```

The application consists of two classes: `MainWindow` and `Editor`. Its code is on the CD, and since most of it is the same or similar to the Spreadsheet application from Part I, we will only present the new code.

Figure 6.15. The Editor application's menus



Let's start with the `MainWindow` class.

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    workspace = new QWorkspace(this);
    setCentralWidget(workspace);
    connect(workspace, SIGNAL(windowActivated(QWidget *)),
            this, SLOT(updateMenus()));
    connect(workspace, SIGNAL(windowActivated(QWidget *)),
            this, SLOT(updateModIndicator()));

    createActions();
    createMenus();
    createToolBars();
    createStatusBar();

    setCaption(tr("Editor"));
    setIcon(QPixmap::fromMimeSource("icon.png"));
}
```

In the `MainWindow` constructor, we create a `QWorkspace` widget and make it the central widget. We connect the `QWorkspace`'s `windowActivated()` signal to two private slots. These slots ensure that the menus and the status bar always reflect the state of the currently active child window.

```
void MainWindow::newFile()
{
    Editor *editor = createEditor();
    editor->newFile();
    editor->show();
}
```

The `newFile()` slot corresponds to the *File*|*New* menu option. It depends on the `createEditor()` private function to create a child `Editor` window.

```
Editor *MainWindow::createEditor()
{
    Editor *editor = new Editor(workspace);
    connect(editor, SIGNAL(copyAvailable(bool)),
            this, SLOT(copyAvailable(bool)));
    connect(editor, SIGNAL(modificationChanged(bool)),
            this, SLOT(updateModIndicator()));
    return editor;
}
```

The `createEditor()` function creates an `Editor` widget and sets up two signal–slot connections. The first connection ensures that *Edit*|*Cut* and *Edit*|*Copy* are enabled or disabled depending on whether there is any selected text. The second connection ensures that the *MOD* indicator in the status bar is always up to date.

Because we are using MDI, it is possible that there will be multiple `Editor` widgets in use. This is a concern since we are only interested in responding to the `copyAvailable(bool)` and `modificationChanged()` signals from the active `Editor` window, not from the others. But these signals can only ever be emitted by the active window, so this isn't really a problem.

```
void MainWindow::open()
{
    Editor *editor = createEditor();
    if (editor->open())
        editor->show();
    else
        editor->close();
}
```

The `open()` function corresponds to *File*|*Open*. It creates a new `Editor` for the new document and calls open() on the Editor. It makes more sense to implement the file operations in the Editor class than in the MainWindow class, because each Editor needs to maintain its own independent state. If the open() fails, we simply close the editor since the user will have already been notified of the error.

```
void MainWindow::save()
{
    if (activeEditor()) {
        activeEditor()->save();
        updateModIndicator();
    }
}
```

The save() slot calls save() on the active editor, if there is one. Again, the code that performs the real work is located in the Editor class.

```
Editor *MainWindow::activeEditor()
{
    return (Editor *)workspace->activeWindow();
}
```

The activeEditor() private function returns the active child window as an Editor pointer.

```
void MainWindow::cut()
{
    if (activeEditor())
        activeEditor()->cut();
}
```

The cut() slot calls cut() on the active editor. The copy(), paste(), and del() slots follow the same pattern.

```
void MainWindow::updateMenus()
{
    bool hasEditor = (activeEditor() != 0);
    saveAct->setEnabled(hasEditor);
    saveAsAct->setEnabled(hasEditor);
    pasteAct->setEnabled(hasEditor);
    deleteAct->setEnabled(hasEditor);
    copyAvailable(activeEditor()
                  && activeEditor()->hasSelectedText());
    closeAct->setEnabled(hasEditor);
    closeAllAct->setEnabled(hasEditor);
    tileAct->setEnabled(hasEditor);
    cascadeAct->setEnabled(hasEditor);
    nextAct->setEnabled(hasEditor);
    previousAct->setEnabled(hasEditor);

    windowsMenu->clear();
    createWindowsMenu();
}
```

The updateMenus() slot is called whenever a window is activated (or when the last window is closed) to update the menu system, thanks to the signal–slot connection we put in the MainWindow constructor.

Most menu options only make sense if there is an active window, so we disable them if there isn't one. Then we clear the *Windows* menu and call createWindowsMenu() to reinitialize it with a fresh list of child windows.

```
void MainWindow::createWindowsMenu()
{
    closeAct->addTo(windowsMenu);
    closeAllAct->addTo(windowsMenu);
    windowsMenu->insertSeparator();
    tileAct->addTo(windowsMenu);
    cascadeAct->addTo(windowsMenu);
    windowsMenu->insertSeparator();
    nextAct->addTo(windowsMenu);
    previousAct->addTo(windowsMenu);

    if (activeEditor()) {
        windowsMenu->insertSeparator();
        windows = workspace->windowList();
        int numVisibleEditors = 0;

        for (int i = 0; i < (int)windows.count(); ++i) {
            QWidget *win = windows.at(i);
            if (!win->isHidden()) {
                QString text = tr("%1 %2")
                               .arg(numVisibleEditors + 1)
                               .arg(win->caption());
                if (numVisibleEditors < 9)
                    text.prepend("&");
                int id = windowsMenu->insertItem(
                              text, this, SLOT(activateWindow(int)));
                bool isActive = (activeEditor() == win);
                windowsMenu->setItemChecked(id, isActive);
                windowsMenu->setItemParameter(id, i);
                ++numVisibleEditors;
            }
        }
    }
}
```

The createWindowsMenu() private function fills the *Windows* menu with actions and a list of visible windows. The actions are all typical of such menus and are easily implemented using QWorkspace's closeActiveWindow(), closeAllWindows(), tile(), and cascade() slots.

The entry for the active window is shown with a checkmark next to its name. When the user chooses a window entry, the activateWindow() slot is called with the index in the windows list as the parameter, because of the call to setItemParameter(). This is very similar to what we did in Chapter 3 when we implemented the Spreadsheet application's recently opened files list (p. 54).

For the first nine entries, we put an ampersand in front of the number to make that number's single digit into a shortcut key. We don't provide a shortcut key for the other entries.

```
void MainWindow::activateWindow(int param)
{
    QWidget *win = windows.at(param);
    win->show();
    win->setFocus();
}
```

The activateWindow() function is called when a window is chosen from the Windows menu. The int parameter is the value that we set with setItemParameter(). The windows data member holds the list of windows and was set in createWindowsMenu().

```
void MainWindow::copyAvailable(bool available)
{
    cutAct->setEnabled(available);
    copyAct->setEnabled(available);
}
```

The `copyAvailable()` slot is called whenever text is selected or deselected in an editor. It is also called from `updateMenus()`. It enables or disables the *Cut* and *Copy* actions.

```
void MainWindow::updateModIndicator()
{
    if (activeEditor() && activeEditor()->isModified())
        modLabel->setText(tr("MOD"));
    else
        modLabel->clear();
}
```

The `updateModIndicator()` updates the *MOD* indicator in the status bar. It is called whenever text is modified in an editor. It is also called when a new window is activated.

```
void MainWindow::closeEvent(QCloseEvent *event)
{
    workspace->closeAllWindows();
    if (activeEditor())
        event->ignore();
    else
        event->accept();
}
```

The `closeEvent()` function is reimplemented to close all child windows. If one of the child widgets "ignores" its close event (presumably because the user canceled an "unsaved changes" message box), we ignore the close event for the `MainWindow`; otherwise we accept it, resulting in Qt closing the window. If we didn't reimplement `closeEvent()` in `MainWindow`, the user would not be given the opportunity to save any unsaved changes.

We have now finished our review of `MainWindow`, so we can move on to the `Editor` implementation. The `Editor` class represents one child window. It inherits from `QTextEdit`, which provides the text editing functionality. Just as any Qt widget can be used as a stand-alone window, any Qt widget can be used as a child window in an MDI workspace.

Here's the class definition:

```
class Editor : public QTextEdit
{
    Q_OBJECT
public:
    Editor(QWidget *parent = 0, const char *name = 0);

    void newFile();
    bool open();
    bool openFile(const QString &fileName);
    bool save();
    bool saveAs();
    QSize sizeHint() const;

signals:
    void message(const QString &fileName, int delay);

protected:
    void closeEvent(QCloseEvent *event);

private:
    bool maybeSave();
    void saveFile(const QString &fileName);
    void setCurrentFile(const QString &fileName);
    QString strippedName(const QString &fullFileName);
    bool readFile(const QString &fileName);
    bool writeFile(const QString &fileName);

    QString curFile;
    bool isUntitled;
    QString fileFilters;
};
```

Four of the private functions that were in the Spreadsheet application's MainWindow class (p. 51) are also present in the Editor class: maybeSave(), saveFile(), setCurrentFile(), and strippedName().

```
Editor::Editor(QWidget *parent, const char *name)
    : QTextEdit(parent, name)
{
    setWFlags(WDestructiveClose);
    setIcon(QPixmap::fromMimeSource("document.png"));

    isUntitled = true;
    fileFilters = tr("Text files (*.txt)\n"
                     "All files (*)");
}
```

The Editor constructor sets the WDestructiveClose flag using setWFlags(). When a class constructor doesn't provide a flags parameter (as is the case with QTextEdit), we can still set most flags using setWFlags().

Since we allow users to create any number of editor windows, we must make some provision for naming them so that they can be distinguished before they have been saved for the first time. One common way of handling this is to allocate names that include a number (for example, document1.txt). We use the isUntitled variable to distinguish between names supplied by the user and names we have created programmatically.

After the constructor, we expect either newFile() or open() to be called.

```
void Editor::newFile()
{
    static int documentNumber = 1;

    curFile = tr("document%1.txt").arg(documentNumber);
    setCaption(curFile);
    isUntitled = true;
    ++documentNumber;
}
```

The newFile() function generates a name like document2.txt for the new document. The code belongs in newFile(), rather than the constructor, because we don't want to consume numbers when we call open() to open an existing document in a newly created Editor. Since documentNumber is declared static, it is shared across all Editor instances.

```
bool Editor::open()
{
    QString fileName =
            QFileDialog::getOpenFileName(".", fileFilters, this);
    if (fileName.isEmpty())
        return false;
    return openFile(fileName);
}
```

The open() function tries to open an existing file using openFile().

```
bool Editor::save()
{
    if (isUntitled) {
        return saveAs();
    } else {
        saveFile(curFile);
        return true;
    }
}
```

The save() function uses the isUntitled variable to determine whether it should call saveFile() or saveAs().

```
void Editor::closeEvent(QCloseEvent *event)
{
    if (maybeSave())
        event->accept();
    else
        event->ignore();
}
```

The closeEvent() function is reimplemented to allow the user to save unsaved changes. The logic is coded in the maybeSave() function, which pops up a message box that asks, "Do you want to save your changes?" If maybeSave() returns true, we accept the close event; otherwise, we "ignore" it and leave the window unaffected by it.

```
void Editor::setCurrentFile(const QString &fileName)
{
    curFile = fileName;
    setCaption(strippedName(curFile));
    isUntitled = false;
    setModified(false);
}
```

The setCurrentFile() function is called from openFile() and saveFile() to update the curFile and isUntitled variables, to set the window caption, and to set the editor's "modified" flag to false. The Editor class inherits setModified() and isModified() from QTextEdit, so it doesn't need to maintain its own modified flag. Whenever the user modifies the text in the editor, QTextEdit emits the modificationChanged() signal and sets its internal modified flag to true.

```
QSize Editor::sizeHint() const
{
    return QSize(72 * fontMetrics().width('x'),
                 25 * fontMetrics().lineSpacing());
}
```

The sizeHint() function returns a size based on the width of the letter 'x' and the height of a text line. QWorkspace uses the size hint to give an initial size to the window.

Finally, here's the Editor application's main.cpp file:

```
#include <qapplication.h>
```

```
#include "mainwindow.h"

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    MainWindow mainWin;
    app.setMainWidget(&mainWin);

    if (argc > 1) {
        for (int i = 1; i < argc; ++i)
            mainWin.openFile(argv[i]);
    } else {
        mainWin.newFile();
    }

    mainWin.show();
    return app.exec();
}
```

If the user specifies any files on the command line, we attempt to load them. Otherwise, we start with an empty document. Qt-specific command-line options, such as `-style` and `-font`, are automatically removed from the argument list by the `QApplication` constructor. So if we write

```
editor -style=motif readme.txt
```

on the command line, the Editor application starts up with one document, `readme.txt`.

MDI is one way of handling multiple documents simultaneously. Another approach is to use multiple top-level windows. This approach is covered in the "Multiple Documents" section of Chapter 3.

Chapter 7. Event Processing

GUI applications are event-driven: Everything that happens once the application has started is the result of an event. When we program with Qt, we seldom need to think about events, because Qt widgets emit signals when something significant occurs. Events become useful when we write our own custom widgets or when we want to modify the behavior of existing Qt widgets.

In this chapter, we will explore Qt's event model. We will see how to handle the different types of events in Qt. We will also look at how to use event filters to monitor events before they reach their destinations. Finally, we will examine Qt's event loop, reviewing how to keep the user interface responsive during intensive processing.

Reimplementing Event Handlers

Events are generated by the window system or by Qt in response to various occurrences. When the user presses or releases a key or mouse button, a key or mouse event is generated. When a window is moved to reveal a window that was underneath, a paint event is generated to tell the newly visible window that it needs to repaint itself. An event is also generated whenever a widget gains or loses keyboard focus. Most events are generated in response to user actions, but some, like timer events, are generated independently by the system.

Events should not be confused with signals. Signals are useful when *using* a widget, whereas events are useful when *implementing* a widget. For example, when we are using `QPushButton`, we are more interested in its `clicked()` signal than in the low-level mouse or key events that caused the signal to be emitted. But if we are implementing a class like `QPushButton`, we need to write code to handle mouse and key events and emit the `clicked()` signal when necessary.

Events are notified to objects through their `event()` function, inherited from `QObject`. The `event()` implementation in `QWidget` forwards the most common types of events to specific event handlers, such as `mousePressEvent()`, `keyPressEvent()`, and `paintEvent()`, and ignores other kinds of events.

We have already seen many event handlers when implementing `MainWindow`, `IconEditor`, `Plotter`, `ImageEditor`, and `Editor` in the previous chapters. There are many other types of events, listed in the `QEvent` reference documentation, and it is also possible to create custom event types and dispatch custom events ourselves. Custom events are particularly useful in multithreaded applications, so they are discussed in Chapter 17 (Multithreading). Here, we will review two event types that deserve more explanation: key events and timer events.

Key events are handled by reimplementing `keyPressEvent()` and `keyReleaseEvent()`. The `Plotter` widget reimplements `keyPressEvent()`. Normally, we only need to reimplement `keyPressEvent()` since the only keys for which release is important are the modifier keys *Ctrl*, *Shift*, and *Alt*, and these can be checked for in a `keyPressEvent()` using `state()`. For example, if we were implementing a `CodeEditor` widget, its stripped-down `keyPressEvent()` that distinguishes between *Home* and *Ctrl+Home* would look like this:

```
void CodeEditor::keyPressEvent(QKeyEvent *event)
{
    switch (event->key()) {
    case Key_Home:
        if (event->state() & ControlButton)
            goToBeginningOfDocument();
        else
            goToBeginningOfLine();
        break;
    case Key_End:
        ...
    default:
        QWidget::keyPressEvent(event);
    }
}
```

The *Tab* and *Backtab* (*Shift+Tab*) keys are special cases. They are handled by `QWidget::event()` before it calls `keyPressEvent()`, with the semantic of passing the focus to the next or previous widget in the focus chain. This behavior is usually what we want, but in a `CodeEditor` widget, we might prefer to make *Tab* indent a line. The `event()` reimplementation would then look like this:

```
bool CodeEditor::event(QEvent * event)
{
    if (event->type() == QEvent::KeyPress) {
        QKeyEvent *keyEvent = (QKeyEvent *) event;
        if (keyEvent->key() == Key_Tab) {
            insertAtCurrentPosition('\t');
            return true;
        }
    }
    return QWidget::event(event);
}
```

If the event is a key press, we cast the QEvent object to a QKeyEvent and check which key was pressed. If the key is *Tab*, we do some processing and return true to tell Qt that we have handled the event. If we returned false, Qt would propagate the event to the parent widget.

A higher-level approach for implementing key bindings is to use a QAction. For example, if goToBeginningOfLine() and goToBeginningOfDocument() are public slots in the CodeEditor widget, and the CodeEditor is used as the central widget in a MainWindow class, we could add the key bindings with the following code:

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    editor = new CodeEditor(this);
    setCentralWidget(editor);

    goToBeginningOfLineAct =
            new QAction(tr("Go to Beginning of Line"),
                        tr("Home"), this);
    connect(goToBeginningOfLineAct, SIGNAL(activated()),
            editor, SLOT(goToBeginningOfLine()));

    goToBeginningOfDocumentAct =
            new QAction(tr("Go to Beginning of Document"),
                        tr("Ctrl+Home"), this);
    connect(goToBeginningOfDocumentAct, SIGNAL(activated()),
            editor, SLOT(goToBeginningOfDocument()));
    ...
}
```

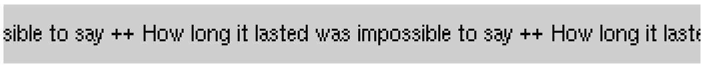
This makes it easy to add the commands to a menu or a toolbar, as we saw in Chapter 3. If the commands don't appear in the user interface, the QAction objects could be replaced with a QAccel object, the class used by QAction internally to support key bindings.

The choice between reimplementing keyPressEvent() and using QAction (or QAccel) is similar to that between reimplementing resizeEvent() and using a QLayout subclass. If we are implementing a custom widget by subclassing QWidget, it's straightforward to reimplement a few more event handlers and hard-code the behavior there. But if we are merely using a widget, the higherlevel interfaces provided by QAction and QLayout are more convenient.

Another common type of event is the timer event. While most types of events occur as a result of a user action, timer events allow applications to perform processing at regular time intervals. Timer events can be used to implement blinking cursors and other animations, or simply to refresh the display.

To demonstrate timer events, we will implement a Ticker widget. This widget shows a text banner that scrolls left by one pixel every 30 milliseconds. If the widget is wider than the text, the text is repeated as often as necessary to fill the entire width of the widget.

Figure 7.1. The `Ticker` widget


sible to say ++ How long it lasted was impossible to say ++ How long it laste

Here's the header file:

```
#ifndef TICKER_H
#define TICKER_H

#include <qwidget.h>

class Ticker : public QWidget
{
    Q_OBJECT
    Q_PROPERTY(QString text READ text WRITE setText)

public:
    Ticker(QWidget *parent = 0, const char *name = 0);

    void setText(const QString &newText);
    QString text() const { return myText; }
    QSize sizeHint() const;

protected:
    void paintEvent(QPaintEvent *event);
    void timerEvent(QTimerEvent *event);
    void showEvent(QShowEvent *event);
    void hideEvent(QHideEvent *event);

private:
    QString myText;
    int offset;
    int myTimerId;
};

#endif
```

We reimplement four event handlers in `Ticker`, three of which we have not seen before: `timerEvent()`, `showEvent()`, and `hideEvent()`.

Now let's review the implementation:

```
#include <qpainter.h>

#include "ticker.h"

Ticker::Ticker(QWidget *parent, const char *name)
    : QWidget(parent, name)
{
    offset = 0;
    myTimerId = 0;
}
```

The constructor initializes the `offset` variable to 0. The *x* coordinate at which the text is drawn is derived from the `offset` value.

```
void Ticker::setText(const QString &newText)
{
    myText = newText;
    update();
    updateGeometry();
}
```

The setText() function sets the text to display. It calls update() to force a repaint and updateGeometry() to notify any layout manager responsible for the Ticker widget about a size hint change.

```
QSize Ticker::sizeHint() const
{
    return fontMetrics().size(0, text());
}
```

The sizeHint() function returns the space needed by the text as the widget's ideal size. The QWidget::fontMetrics() function returns a QFontMetrics object that can be queried to obtain information relating to the widget's font. In this case, we ask for the size required by the given text.

```
void Ticker::paintEvent(QPaintEvent *)
{
    QPainter painter(this);

    int textWidth = fontMetrics().width(text());
    if (textWidth < 1)
        return;
    int x = -offset;
    while (x < width()) {
        painter.drawText(x, 0, textWidth, height(),
                         AlignLeft | AlignVCenter, text());
        x += textWidth;
    }
}
```

The paintEvent() function draws the text using QPainter::drawText(). It uses fontMetrics () to ascertain how much horizontal space the text requires, and then draws the text as many times as necessary to fill the entire width of the widget, taking offset into account.

```
void Ticker::showEvent(QShowEvent *)
{
    myTimerId = startTimer(30);
}
```

The showEvent() function starts a timer. The call to QObject::startTimer() returns an ID number, which we can use later to identify the timer. QObject supports multiple independent timers, each with its own time interval. After the call to startTimer(), Qt will generate a timer event approximately every 30 milliseconds; the accuracy depends on the underlying operating system.

We could have called startTimer() in the Ticker constructor, but we save some resources by having Qt generate timer events only when the widget is actually visible.

```
void Ticker::timerEvent(QTimerEvent *event)
{
    if (event->timerId() == myTimerId) {
        ++offset;
        if (offset >= fontMetrics().width(text()))
            offset = 0;
        scroll(-1, 0);
    } else {
        QWidget::timerEvent(event);
    }
}
```

The timerEvent() function is called at intervals by the system. It increments offset by 1 to simulate movement, wrapping at the width of the text. Then it scrolls the contents of the widget one pixel to the left using QWidget::scroll(). It would have been sufficient to call update() instead of scroll(), but scroll() is more efficient and prevents flicker, because it simply moves the existing pixels on screen and only generates a paint event for the widget's newly revealed area (a 1-pixel-wide strip in this case).

If the timer event isn't for the timer we are interested in, we pass it on to our base class.

```
void Ticker::hideEvent(QHideEvent *)
{
    killTimer(myTimerId);
}
```

The hideEvent() function calls QObject::killTimer() to stop the timer.

Timer events are low-level, and if we need multiple timers, it can become cumbersome to keep track of all the timer IDs. In such situations, it is usually easier to create a QTimer object for each timer. QTimer emits the timeout() signal at each time interval. QTimer also provides a convenient interface for single-shot timers (timers that time out just once).

[Team LiB] PREVIOUS NEXT

Installing Event Filters

One really powerful feature of Qt's event model is that a QObject instance can be set to monitor the events of another QObject instance before the latter object even sees them.

Let's suppose that we have a CustomerInfoDialog widget composed of several QLineEdits and that we want to use the *Space* key to move the focus to the next QLineEdit. This non-standard behavior might be appropriate for an in-house application whose users are trained in its use. A straightforward solution is to subclass QLineEdit and reimplement keyPressEvent() to call focusNextPrevChild(), like this:

```
void MyLineEdit::keyPressEvent(QKeyEvent *event)
{
    if (event->key() == Key_Space)
        focusNextPrevChild(true);
    else
        QLineEdit::keyPressEvent(event);
}
```

This approach has many disadvantages. Because MyLineEdit isn't a standard Qt class, it must be integrated with *Qt Designer* if we want to design forms that make use of it. Also, if we use several different kinds of widgets in the form (for example, QComboBoxes and QSpinBoxes), we must also subclass them to make them exhibit the same behavior and integrate them with *Qt Designer* as well.

A better solution is to make CustomerInfoDialog monitor its child widgets' key press events and implement the required behavior in the monitoring code. This can be achieved using event filters. Setting up an event filter involves two steps:

1. Register the monitoring object with the target object by calling installEventFilter() on the target.

2. Handle the target object's events in the monitor's eventFilter() function.

A good place to register the monitoring object is in the CustomerInfoDialog constructor:

```
CustomerInfoDialog::CustomerInfoDialog(QWidget *parent,
                                       const char *name)
    : QDialog(parent, name)
{
    ...
    firstNameEdit->installEventFilter(this);
    lastNameEdit->installEventFilter(this);
    cityEdit->installEventFilter(this);
    phoneNumberEdit->installEventFilter(this);
}
```

Once the event filter is registered, the events that are sent to the firstNameEdit, lastNameEdit, cityEdit, and phoneNumberEdit widgets are first sent to the CustomerInfoDialog's eventFilter() function before they are sent on to their intended destination. (If multiple event filters are installed on the same object, the filters are activated in turn, from the most recently installed back to the first installed.)

Here's the eventFilter() function that receives the events:

```
bool CustomerInfoDialog::eventFilter(QObject *target, QEvent *event)
{
    if (target == firstNameEdit || target == lastNameEdit
            || target == cityEdit || target == phoneNumberEdit) {
        if (event->type() == QEvent::KeyPress) {
            QKeyEvent *keyEvent = (QKeyEvent *) event;
            if (keyEvent->key() == Key_Space) {
                focusNextPrevChild(true);
                return true;

            }
        }
    }
    return QDialog::evenFilter(target, event);
}
```

First, we check to see if the target widget is one of the QLineEdits. It's easy to forget that the base class, QDialog, might monitor some widgets of its own. (In Qt 3.2, this is not the case for QDialog. However, other Qt widget classes, such as QMainWindow, do monitor some of their child widgets for various reasons.)

If the event is a key press, we cast it to QKeyEvent and check which key is pressed. If the pressed key is Space, we call focusNextPrevChild() to pass focus on to the next widget in the focus chain, and we return true to tell Qt that we have handled the event. If we returned false, Qt would send the event to its intended target, resulting in a spurious space being inserted into the QLineEdit.

If the event isn't a Space key press, we pass control to the base class's implementation of eventFilter().

Qt offers five levels at which events can be processed and filtered:

1. **We can reimplement a specific event handler.**

   Reimplementing event handlers such as mousePressEvent(), keyPressEvent(), and `paintEvent()` is by far the most common way to process events. We have already seen many examples of this.

2. **We can reimplement QObject::event()**.

   By reimplementing the `event()` function, we can process events before they reach the specific event handlers. This approach is mostly needed to override the default meaning of the Tab key, as shown earlier (p. 164). This is also used to handle rare types of events for which no specific event handler exists (for example, `LayoutDirectionChange`). When we reimplement `event()`, we need to call the base class's `event()` function for handling the cases we don't explicitly handle.

3. **We can install an event filter on a single QObject**.

   Once an object has been registered using `installEventFilter()`, all the events for the target object are first sent to the monitoring object's `eventFilter()` function. We have used this approach to handle *Space* key presses in the `CustomerInfoDialog` example above.

4. **We can install an event filter on the QApplication object**.

   Once an event filter has been registered for `qApp` (the unique `QApplication` object), every event for every object in the application is sent to the `eventFilter()` function before it is sent to any other event filter. This approach is mostly useful for debugging and for hiding Easter eggs. It can also be used to handle mouse events sent to disabled widgets, which `QApplication` normally discards.

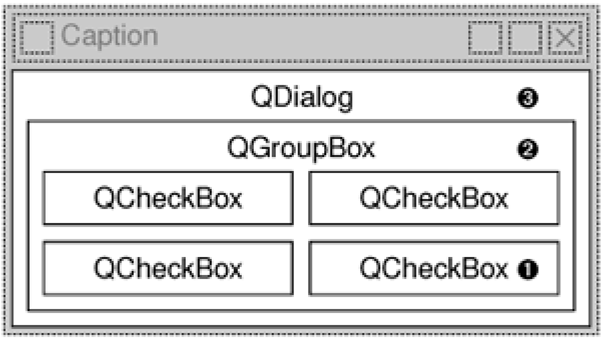
5. **We can subclass QApplication and reimplement notify()**.

   Qt calls `QApplication::notify()` to send out an event. Reimplementing this function is the only way to get all the events, before any event filters get the opportunity to look at them. Event filters are generally more useful, because there can be any number of concurrent event filters, but only one `notify()` function.

Many event types, including mouse and key events, can be propagated. If the event has not been handled on the way to its target object or by the target object itself, the whole event processing process is repeated, but this time with the target object's parent as the new target. This continues, going from parent to parent, until either the event is handled or the top-level object is reached.

Figure 7.2 shows how a key press event is propagated from child to parent in a dialog. When the user presses a key, the event is first sent to the widget that has focus, in this case the bottom-right `QCheckBox`. If the `QCheckBox` doesn't handle the event, Qt sends it to the `QGroupBox`, and finally to the `QDialog` object.

Figure 7.2. Event propagation in a dialog



[Team LiB]
PREVIOUS NEXT

Staying Responsive During Intensive Processing

When we call `QApplication::exec()`, we start Qt's event loop. Qt issues a few events on startup to show and paint the widgets. After that, the event loop is running, constantly checking to see if any events have occurred and dispatching these events to `QObjects` in the application.

While one event is being processed, additional events may be generated and appended to Qt's event queue. If we spend too much time processing a particular event, the user interface will become unresponsive. For example, any events generated by the window system while the application is saving a file to disk will not be processed until the file is saved. During the save, the application will not respond to requests from the window system to repaint itself.

One solution is to use multiple threads: one thread for the application's user interface and another thread to perform file saving (or any other time-consuming operation). This way, the application's user interface will stay responsive while the file is being saved. We will see how to achieve this in Chapter 17.

A simpler solution is to make frequent calls to `QApplication::processEvents()` in the file saving code. This function tells Qt to process any pending events, and then returns control to the caller. In fact, `QApplication::exec()` is little more than a `while` loop around a `processEvents()` function call.

Here's an example of how we can keep the user interface responsive using `processEvents()`, based on the file saving code for `Spreadsheet` (p. 77):

```
bool Spreadsheet::writeFile(const QString &fileName)
{
    QFile file(fileName);
    ...
    for (int row = 0; row < NumRows; ++row) {
        for (int col = 0; col < NumCols; ++col) {
            QString str = formula(row, col);
            if (!str.isEmpty())
                out << (Q_UINT16)row << (Q_UINT16)col << str;
        }
        qApp->processEvents();
    }
    return true;
}
```

One danger with this approach is that the user might close the main window while the application is still saving, or even click *File|Save* a second time, resulting in undefined behavior. The easiest solution to this problem is to replace the

```
qApp->processEvents();
```

call with a

```
qApp->eventLoop()->processEvents(QEventLoop::ExcludeUserInput);
```

call, which tells Qt to ignore mouse and key events.

Often, we want to show a QProgressDialog while a long running operation is taking place. QProgressDialog has a progress bar that keeps the user informed about the progress being made by the application. QProgressDialog also provides a *Cancel* button that allows the user to abort the operation. Here's the code for saving a Spreadsheet file using this approach:

```
bool Spreadsheet::writeFile(const QString &fileName)
{
    QFile file(fileName);
    ...
    QProgressDialog progress(tr("Saving file..."), tr("Cancel"),
                             NumRows);
    progress.setModal(true);
    for (int row = 0; row < NumRows; ++row) {
        progress.setProgress(row);
        qApp->processEvents();
        if (progress.wasCanceled()) {
            file.remove();
            return false;
        }

        for (int col = 0; col < NumCols; ++col) {
            QString str = formula(row, col);
            if (!str.isEmpty())
                out << (Q_UINT16)row << (Q_UINT16)col << str;
        }
    }
    return true;
}
```

We create a QProgressDialog with NumRows as the total number of steps. Then, for each row, we call setProgress() to update the progress bar. QProgressDialog automatically computes a percentage by dividing the current progress value by the total number of steps. We call QApplication::processEvents() to process any repaint events or any user clicks or key presses (for example, to allow the user to click *Cancel*). If the user clicks *Cancel*, we abort the save and remove the file.

We don't call show() on the QProgressDialog because progress dialogs do that for themselves. If the operation turns out to be short, presumably because the file to save is small or because the machine is fast, QProgressDialog will detect this and will not show itself at all.

There is a completely different way of dealing with long running operations. Instead of performing the processing when the user requests, we can defer the processing until the application is idle. This can work if the processing can be safely interrupted and resumed, since we cannot predict how long the application will be idle.

In Qt, this approach can be implemented by using a special kind of timer: a 0-millisecond timer. These timers time out whenever there are no pending events. Here's an example timerEvent() implementation that shows the idle processing approach:

```
void Spreadsheet::timerEvent(QTimerEvent *event)
{
    if (event->timerId() == myTimerId) {
        while (step < MaxStep && !qApp->hasPendingEvents()) {
            performStep(step);
            ++step;
        }
    } else {
        QTable::timerEvent(event);
    }
}
```

If hasPendingEvents() returns true, we stop processing and give control back to Qt. The processing will resume when Qt has handled all its pending events.

[Team LiB]
[Team LiB]

Chapter 8. 2D and 3D Graphics

In this chapter, we will explore Qt's graphics capabilities. The cornerstone of Qt's 2D drawing engine is QPainter, which can be used to draw on a widget on the screen, on an off-screen pixmap, or on a physical printer. Qt also includes a QCanvas class that provides a higher-level way of doing graphics, using an item-based approach that can efficiently handle thousands and thousands of items of various shapes. Many predefined items are provided, and it is easy to create custom canvas items.

An alternative to QPainter and QCanvas is to use the OpenGL library. OpenGL is a standard library for drawing 3D graphics, but it can also be used for drawing 2D graphics. It is very easy to integrate OpenGL code into Qt applications, as we will demonstrate.

[Team LiB]
[Team LiB]

Painting with QPainter

A QPainter can be used to draw on a "paint device", such as a widget or a pixmap. QPainter is useful when we write custom widgets or custom item classes with their own look and feel. QPainter is also the class to use for printing; this will be explained in detail later in the chapter.

QPainter can draw geometric shapes: points, lines, rectangles, ellipses, arcs, chords, pie segments, polygons, and cubic Bézier curves. It can also draw pixmaps, images, and text.

When we pass a paint device to the QPainter constructor, QPainter adopts some settings from the device and initializes other settings to default values. These settings influence the way drawing is performed. The three most important are the painter's pen, brush, and font:

- The *pen* is used for drawing lines and geometric shape boundaries. It consists of a color, a width, a line style, a cap style, and a join style.

Figure 8.1. QPainter functions for drawing geometric shapes

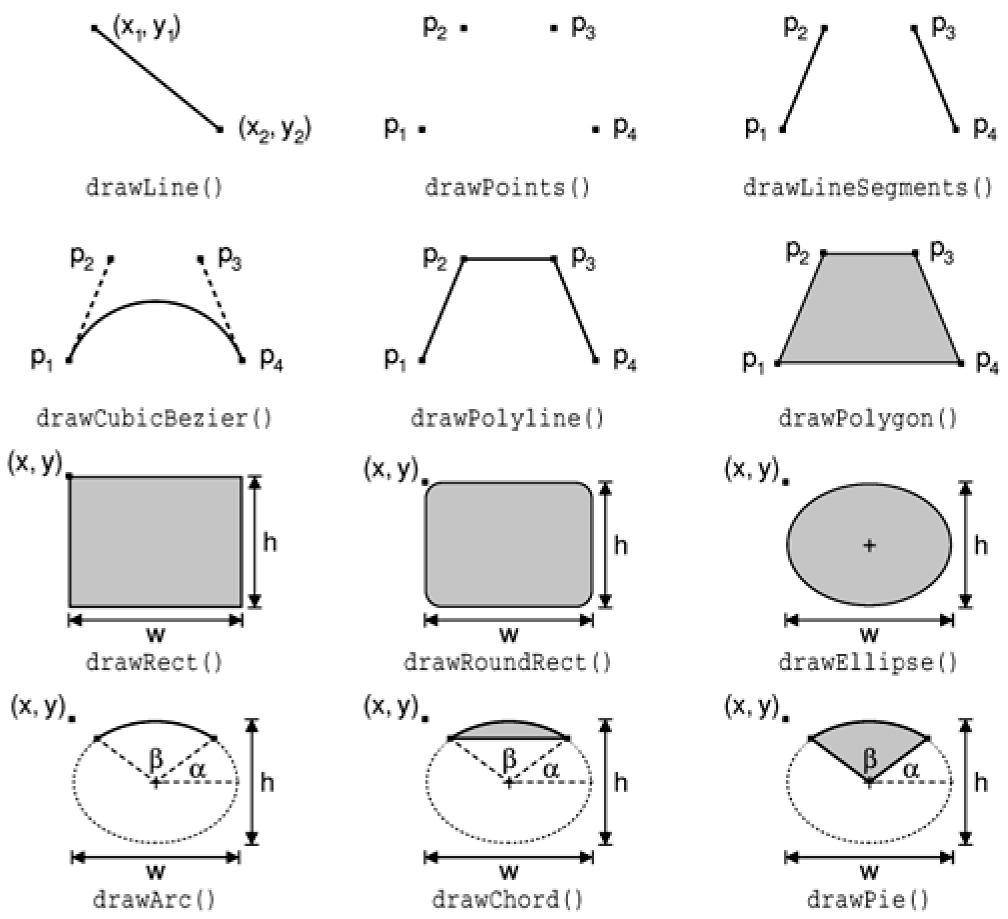
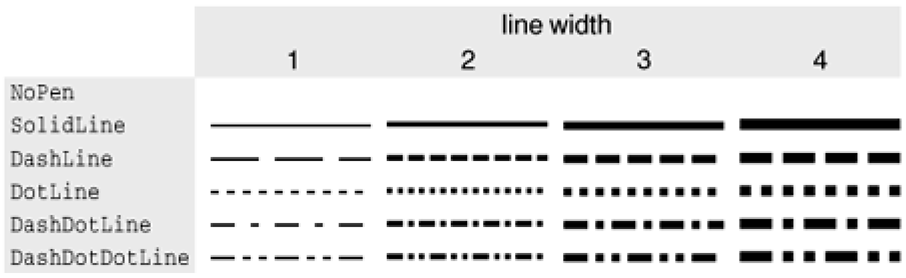


Figure 8.2. Pen styles



- The *brush* is the pattern used for filling geometric shapes. It consists of a color and a style.

- The *font* is used for drawing text. A font has many attributes, including a family and a point size.

These settings can be modified by calling one of `setPen()`, `setBrush()`, and `setFont()` with a `QPen`, `QBrush`, or `QFont` object.

Figure 8.3. Cap and join styles

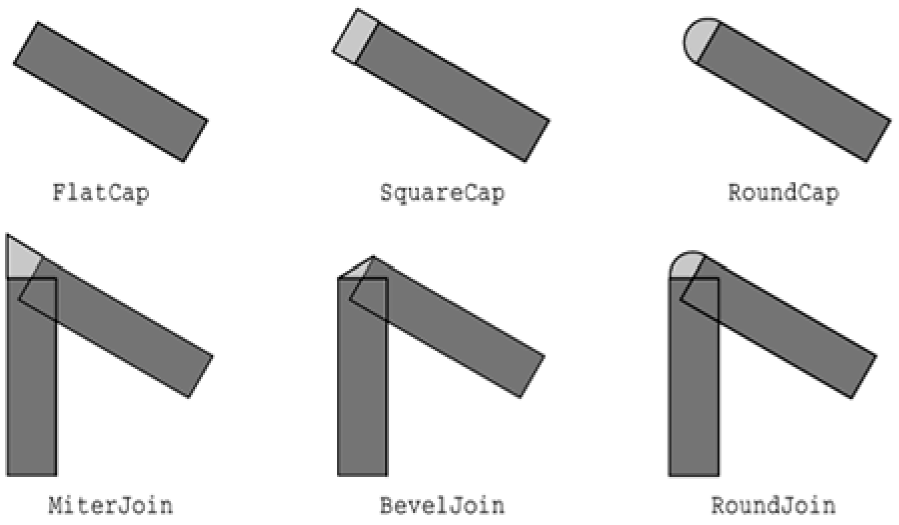
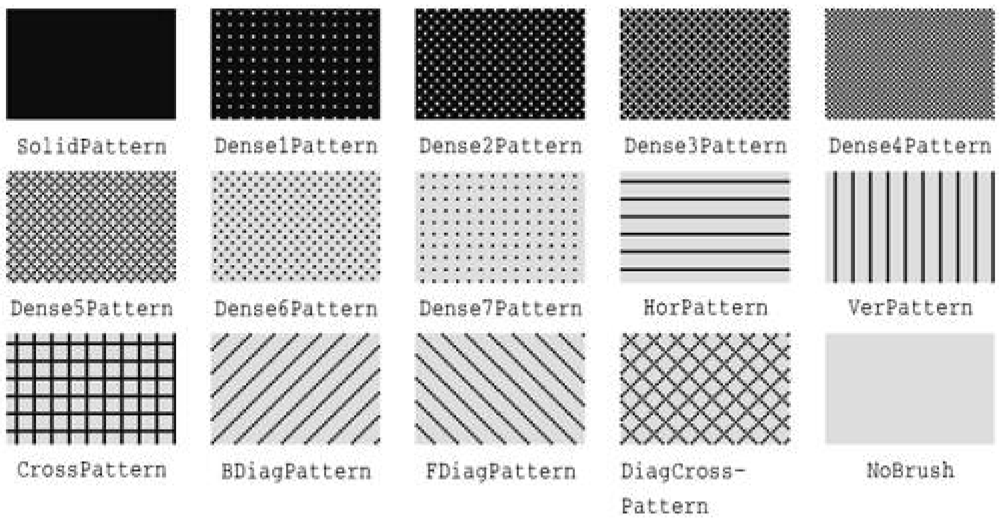
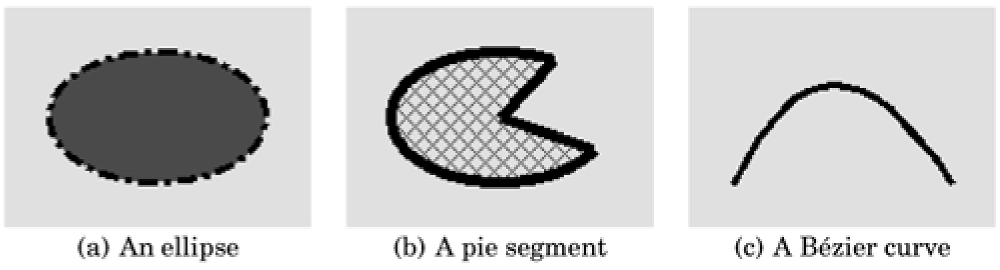


Figure 8.4. Brush styles



Here's the code to draw the ellipse shown in Figure 8.5 (a):

Figure 8.5. Geometric shape examples



```
QPainter painter(this);
painter.setPen(QPen(black, 3, DashDotLine));
painter.setBrush(QBrush(red, SolidPattern));
painter.drawEllipse(20, 20, 100, 60);
```

Here's the code to draw the pie segment shown in Figure 8.5 (b):

```
QPainter painter(this);
painter.setPen(QPen(black, 5, SolidLine));
painter.setBrush(QBrush(red, DiagCrossPattern));
painter.drawPie(20, 100, 60, 60 * 16, 270 * 16);
```

The last two arguments to `drawPie()` are expressed in sixteenths of a degree.

Here's the code to draw the cubic Bézier curve shown in Figure 8.5 (c):

```
QPainter painter(this);
QPointArray points(4);
points[0] = QPoint(20, 80);
points[1] = QPoint(50, 20);
points[2] = QPoint(80, 20);
points[3] = QPoint(120, 80);
painter.setPen(QPen(black, 3, SolidLine));
painter.drawCubicBezier(points);
```

The current state of a painter can be saved on a stack by calling `save()` and restored later on by calling `restore()`. This can be useful if we want to temporarily change some painter settings and then reset them to their previous values.

The other settings that control a painter, in addition to the pen, brush, and font, are:

- The *background color* is used to fill the background of geometric shapes (beneath the brush pattern), text, or bitmaps when the *background mode* is `OpaqueMode` (the default is `TransparentMode`).

- The *raster operation* specifies how the newly drawn pixels should interact with the pixels already present on the paint device. The default is `CopyROP`, which means that the new pixels are simply copied onto the device, ignoring the previous pixel value. Other raster operations include `XorROP`, `NotROP`, `AndROP`, and `NotAndROP`.

- The *brush origin* is the starting point for brush patterns, normally the top-left corner of the widget.

- The *clip region* is the area of the device that can be painted. Drawing operations performed outside the clip region are ignored.

- The *viewport*, *window*, and *world matrix* determine how logical `QPainter` coordinates map to physical paint device coordinates. By default, these are set up so that the logical and physical coordinate systems coincide.

Let's take a closer look at the coordinate system defined by the viewport, window, and world matrix. (In this context, the term "window" does not refer to a window in the sense of a top-level widget, and the "viewport" has nothing to do with `QScrollView`'s viewport.)

The viewport and the window are tightly bound. The viewport is an arbitrary rectangle specified in physical coordinates. The window specifies the same rectangle, but in logical coordinates. When we do the painting, we specify points in logical coordinates, and those coordinates are converted into physical coordinates in a linear algebraic manner, based on the current window–viewport settings.

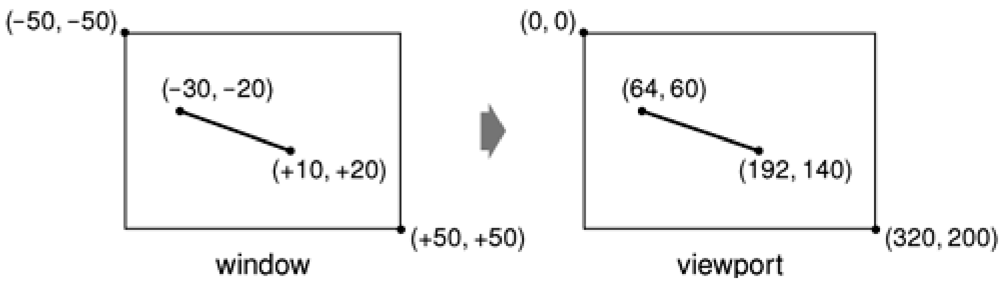
By default, the viewport and the window are set to the device's rectangle. For example, if the device is a 320 x 200 widget, both the viewport and the window are the same 320 x 200 rectangle with its top-left corner at position (0, 0). In this case, the logical and physical coordinate systems are the same.

The window–viewport mechanism is useful to make the drawing code independent of the size or resolution of the paint device. We can always do the arithmetic to map logical coordinates to physical coordinates ourselves, but it's usually simpler to let QPainter do the work. For example, if we want the logical coordinates to extend from (-50, -50) to (+50, +50), with (0, 0) in the middle, we can set the window as follows:

```
painter.setWindow(QRect(-50, -50, 100, 100));
```

The (-50, -50) pair specifies the origin, and the (100, 100) pair specifies the width and height. This means that the logical coordinates (-50, -50) now correspond to the physical coordinates (0, 0), and the logical coordinates (+50, +50) correspond to the physical coordinates (320, 200). In this example, as is often the case, we don't need to change the viewport.

Figure 8.6. Converting logical coordinates into physical coordinates



Now comes the world matrix. The world matrix is a transformation matrix that is applied in addition to the window–viewport conversion. It allows us to translate, scale, rotate, or shear the items we are drawing. For example, if we wanted to draw text at a 45° angle, we would use this code:

```
QWMatrix matrix;
matrix.rotate(45.0);
painter.setWorldMatrix(matrix);
painter.drawText(rect, AlignCenter, tr("Revenue"));
```

The logical coordinates we pass to drawText() are transformed by the world matrix, then mapped to physical coordinates using the window–viewport settings.

If we specify multiple transformations, they are applied in the order in which they are given. For example, if we want to use the point (10, 20) as the rotation's pivot point, we can do so by translating the window, performing the rotation, and then translating the window back to its original position:

```
QWMatrix matrix;
matrix.translate(-10.0, -20.0);
matrix.rotate(45.0);
matrix.translate(+10.0, +20.0);
painter.setWorldMatrix(matrix);
painter.drawText(rect, AlignCenter, tr("Revenue"));
```

A simpler way to specify transformations is to use QPainter's translate(), scale(), rotate (), and shear() convenience functions:

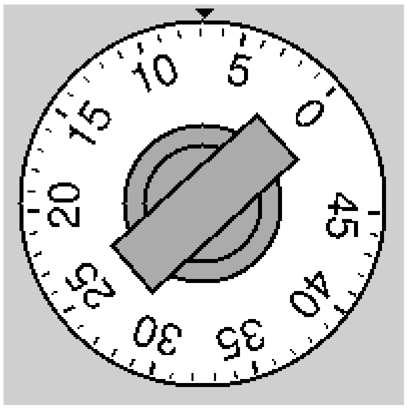
```
painter.translate(-10.0, -20.0);
painter.rotate(45.0);
painter.translate(+10.0, +20.0);
painter.drawText(rect, AlignCenter, tr("Revenue"));
```

But if we want to use the same transformations repeatedly, it's faster to store them in a QWMatrix object and set the world matrix on the painter whenever the transformations are needed.

If we want to just save the world matrix and restore it later, we can use saveWorldMatrix() and restoreWorldMatrix().

To illustrate painter transformations, we will review the code of the OvenTimer widget shown in Figure 8.7. The OvenTimer widget is modeled after the physical oven timers that were used before it was common to have ovens with clocks builtin. The user can click a notch to set the duration. The wheel automatically turns counterclockwise until 0 is reached, at which point OvenTimer emits the timeout() signal.

Figure 8.7. The OvenTimer widget



```
class OvenTimer : public QWidget
{
    Q_OBJECT
public:
    OvenTimer(QWidget *parent, const char *name = 0);

    void setDuration(int secs);
    int duration() const;
    void draw(QPainter *painter);

signals:
    void timeout();

protected:
    void paintEvent(QPaintEvent *event);
    void mousePressEvent(QMouseEvent *event);

private:
    QDateTime finishTime;
    QTimer *updateTimer;
    QTimer *finishTimer;
};
```

The OvenTimer class inherits QWidget and reimplements two virtual functions: paintEvent() and mousePressEvent().

```
#include <qpainter.h>
#include <qpixmap.h>
#include <qtimer.h>

#include <cmath>
using namespace std;

#include "oventimer.h"
```

```
const double DegreesPerMinute = 7.0;
const double DegreesPerSecond = DegreesPerMinute / 60;
const int MaxMinutes = 45;
const int MaxSeconds = MaxMinutes * 60;
const int UpdateInterval = 10;

OvenTimer::OvenTimer(QWidget *parent, const char *name)
    : QWidget(parent, name)
{
    finishTime = QDateTime::currentDateTime();
    updateTimer = new QTimer(this);
    finishTimer = new QTimer(this);
    connect(updateTimer, SIGNAL(timeout()), this, SLOT(update()));
    connect(finishTimer, SIGNAL(timeout()), this, SIGNAL(timeout()));
}
```

In the constructor, we create two QTimer objects: updateTimer is used to refresh the appearance of the widget at regular intervals, and finishTimer emits the widget's timeout() signal when the timer reaches 0.

```
void OvenTimer::setDuration(int secs)
{
    if (secs > MaxSeconds)
        secs = MaxSeconds;
    finishTime = QDateTime::currentDateTime().addSecs(secs);
    updateTimer->start(UpdateInterval * 1000, false);
    finishTimer->start(secs * 1000, true);
    update();
}
```

The setDuration() function sets the duration of the oven timer to the given number of seconds. The false argument passed in the updateTimer's start() call tells Qt that this a repeating timer that will time out every 10 seconds. The finishTimer only needs to timeout once, so we use a true argument to indicate that it is a single-shot timer. We compute the finish time by adding the duration in seconds to the current time, obtained from QDateTime::currentDateTime(), and store it in the finishTime private variable.

The finishTime variable is of type QDateTime, the Qt data type for storing a date and a time. The date component of the QDateTime is important in situations where the current time is before midnight and the finish time is after midnight.

```
int OvenTimer::duration() const
{
    int secs = QDateTime::currentDateTime().secsTo(finishTime);
    if (secs < 0)
        secs = 0;
    return secs;
}
```

The duration() function returns the number of seconds left before the timer is due to finish.

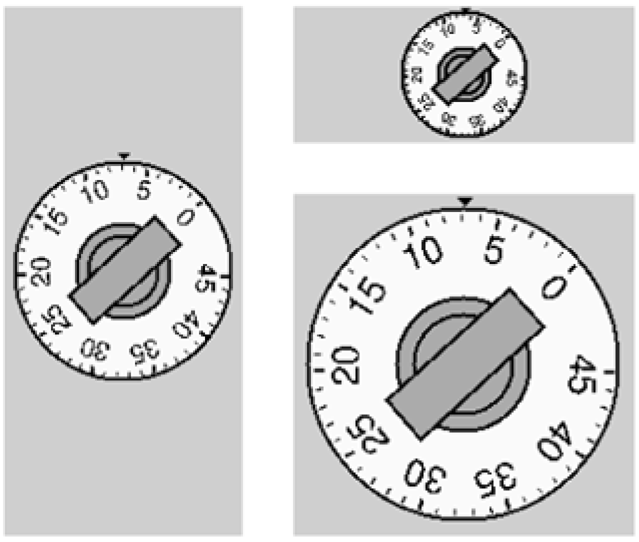
```
void OvenTimer::mousePressEvent(QMouseEvent *event)
{
    QPoint point = event->pos() - rect().center();
    double theta = atan2(-(double)point.x(), -(double)point.y())
                   * 180 / 3.14159265359;
    setDuration((int)(duration() + theta / DegreesPerSecond));
    update();
}
```

If the user clicks the widget, we find the closest notch using a subtle but effective mathematical formula, and we use the result to set the new duration. Then we schedule a repaint. The notch that the user clicked will now be at the top and will move counterclockwise as time passes until 0 is reached.

```
void OvenTimer::paintEvent(QPaintEvent *)
{
    QPainter painter(this);
    int side = QMIN(width(), height());
    painter.setViewport((width() - side) /2, (height() - side) /2,
                        side, side);
    painter.setWindow(-50, -50, 100, 100);
    draw(&painter);
}
```

In `paintEvent()`, we set the viewport to be the largest square area that fits inside the widget, and we set the window to be the rectangle(-50, -50, 100, 100), that is, the 100 x 100 rectangle extending from (-50, -50) to (+50, +50). The `QMIN()` macro returns the lowest of its two arguments.

Figure 8.8. The `OvenTimer` widget at three different sizes



If we had not set the viewport to be a square, the oven timer would be an ellipse when the widget is resized to a non-square rectangle. In general, if we want to avoid such deformations, we must set the viewport and the window to rectangles with the same aspect ratio.

The window setting of (-50, -50, 100, 100) was also chosen bearing these issues in mind:

- `QPainter`'s draw functions take `int` coordinate values. If we choose a window that is too small, we might not be able to specify all the points we need as integers.
- If we use a large window and use `drawText()` to draw some text, we will need a larger font to compensate.

This makes (-50, -50, 100, 100) a better choice than, say, (-5, -5, 10, 10) or (-2000, -2000, 4000, 4000).

Now let's look at the drawing code:

```
void OvenTimer::draw(QPainter *painter)
```

```
{
    static const QCOORD triangle[3][2] = {
        { -2, -49 }, { +2, -49 }, { 0, -47 }
    };
    QPen thickPen(colorGroup().foreground(), 2);
    QPen thinPen(colorGroup().foreground(), 1);

    painter->setPen(thinPen);
    painter->setBrush(colorGroup().foreground());
    painter->drawConvexPolygon(QPointArray(3, &triangle[0] [0]));
```

We start by drawing the tiny triangle that marks the 0 position at the top of the widget. The triangle is specified by three hard-coded coordinates, and we use `drawConvexPolygon()` to render it. We could have used `drawPolygon()`, but when we know the polygon we are drawing is convex, we can save some microseconds by calling `drawConvexPolygon()`.

What is so convenient about the window–viewport mechanism is that we can hard-code the coordinates we use in the draw commands and still get good resizing behavior. Nor do we have to worry about non-square widgets; this is handled by setting the viewport appropriately.

```
painter->setPen(thickPen);
painter->setBrush(colorGroup().light());
painter->drawEllipse(-46, -46, 92, 92);
painter->setBrush(colorGroup().mid());
painter->drawEllipse(-20, -20, 40, 40);
painter->drawEllipse(-15, -15, 30, 30);
```

We draw the outer circle and the two inner circles. The outer circle is filled with the palette's "light" component (typically white), while the two inner circles are filled with the "mid" component (typically medium gray).

```
     int secs = duration();
     painter->rotate(secs * DegreesPerSecond);
     painter->drawRect(-8, -25, 16, 50);

     for (int i = 0; i <= MaxMinutes; ++i) {
         if (i % 5 == 0) {
             painter->setPen(thickPen);
             painter->drawLine(0, -41, 0, -44);
             painter->drawText(-15, -41, 30, 25,
                               AlignHCenter | AlignTop,
                               QString::number(i));
         } else {
             painter->setPen(thinPen);
             painter->drawLine(0, -42, 0, -44);
         }
         painter->rotate(-DegreesPerMinute);
     }
}
```

We draw the knob, the notches, and at every fifth notch we draw the number of minutes. We call `rotate()` to rotate the painter's coordinate system. In the old coordinate system, the 0-minute mark was on top; now, the 0-minute mark is moved to the place that's appropriate for the time left. We draw the rectangular knob handle after the rotation, since its orientation depends on the rotation angle.

In the `for` loop, we draw the tick marks along the outer circle's edge and the numbers for each multiple of 5 minutes. The text is put in an invisible rectangle underneath the tick mark. At the end of one iteration, we rotate the painter clockwise by 7°, the amount corresponding to one minute. The next time we draw a tick mark, it will be at a different position around the circle, although the coordinates we pass to the `drawLine()` and `drawText()` calls are always the same.

Another way of implementing an oven timer would have been to compute the (*x*,*y*) positions ourselves, using sin() and cos() to find the positions along the circle. But then we would still need to use a translation and a rotation to draw the text at an angle.

There is one issue left: flicker. Every ten seconds, we repaint the widget entirely, causing it to flicker each time. The solution is to add double buffering. This can be done by passing the WNoAutoErase to the base class constructor and by replacing the paintEvent() function shown earlier with this one:

```
void OvenTimer::paintEvent(QPaintEvent *event)
{
    static QPixmap pixmap;
    QRect rect = event->rect();

    QSize newSize = rect.size().expandedTo(pixmap.size());
    pixmap.resize(newSize);
    pixmap.fill(this, rect.topLeft());

    QPainter painter(&pixmap, this);
    int side = QMIN(width(), height());
    painter.setViewport((width() - side) / 2 - event->rect().x(),
                        (height() - side) / 2 - event->rect().y(),
                        side, side);
    painter.setWindow(-50, -50, 100, 100);
    draw(&painter);
    bitBlt(this, event->rect().topLeft(), &pixmap);
}
```

This time, we paint on a pixmap instead of on the widget directly. The pixmap is given the size of the area to repaint, and the window–viewport pair is initialized in such a way that the painting is performed the same as if it was done directly on the widget. The draw() function is also unchanged. At the end, we copy the pixmap onto the widget using bitBlt().

This is similar to what we explained in the "Double Buffering" section of Chapter 5 (p. 113), but there's one important difference: In Chapter 5, we used translate() to translate the painter, while here we subtract the paint event's *x* and *y* coordinates when setting up the viewport. Using translation here would not be as convenient, because the translation would have to be expressed in logical window coordinates, whereas the event's rectangle is in physical coordinates.

[Team LiB] PREVIOUS NEXT

[Team LiB] PREVIOUS NEXT

Graphics with QCanvas

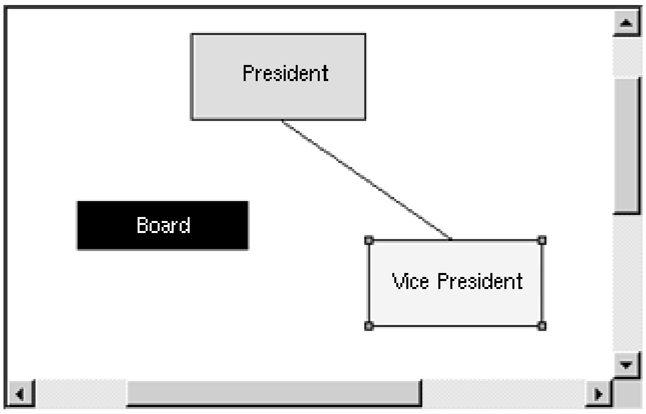
QCanvas offers a higher-level interface for doing graphics than QPainter provides. A QCanvas can contain items of any shape and uses double buffering internally to avoid flicker. For applications that need to present many user-manipulable items, like data visualization programs and 2D games, using QCanvas is often a better approach than reimplementing QWidget::paintEvent() or QScrollView::drawContents() and painting everything manually.

The items shown on a QCanvas are instances of QCanvasItem or of one of its subclasses. Qt provides a useful set of predefined subclasses: QCanvasLine, QCanvasRectangle, QCanvasPolygon, QCanvasPolygonalItem, QCanvasEllipse, QCanvasSpline, QCanvasSprite, and QCanvasText. These classes can themselves be subclassed to provide custom canvas items.

A QCanvas and its QCanvasItems are purely data and have no visual representation. To render the canvas and its items, we must use a QCanvasView widget. This separation of the data from its visual representation makes it possible to have multiple QCanvasView widgets visualizing the same canvas. Each of these QCanvasViews can present its own portion of the canvas, possibly with different transformation matrices.

QCanvas is highly optimized to handle a large number of items. When an item changes, QCanvas only redraws the "chunks" that have changed. It also provides an efficient collision-detection algorithm. For these reasons alone, it's worth considering QCanvas as an alternative to reimplementing QWidget::paintEvent() or QScrollView::drawContents().

Figure 8.9. The DiagramView widget



To demonstrate QCanvas usage, we present the code for the DiagramView widget, a minimalist diagram editor. The widget supports two kinds of shapes (boxes and lines) and provides a context menu that lets the user add new boxes and lines, copy and paste them, delete them, and edit their properties.

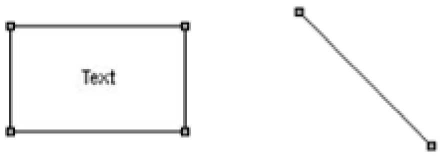
```
class DiagramView : public QCanvasView
{
    Q_OBJECT
public:
    DiagramView(QCanvas *canvas, QWidget *parent = 0,
                const char *name = 0);

public slots:
     void cut();
     void copy();
     void paste();
     void del();
     void properties();
     void addBox();
     void addLine();
     void bringToFront();
     void sendToBack();
```

The DiagramView class inherits QCanvasView, which itself inherits QScrollView. It provides many public slots that an application could connect to. The slots are also used by the widget itself to implement its context menu.

```
protected:
    void contentsContextMenuEvent(QContextMenuEvent *event);
    void contentsMousePressEvent(QMouseEvent *event);
    void contentsMouseMoveEvent(QMouseEvent *event);
    void contentsMouseDoubleClickEvent(QMouseEvent *event);

private:
    void createActions();
    void addItem(QCanvasItem *item);
    void setActiveItem(QCanvasItem *item);
    void showNewItem(QCanvasItem *item);

    QCanvasItem *pendingItem;
    QCanvasItem *activeItem;
    QPoint lastPos;
    int minZ;
    int maxZ;

    QAction *cutAct;
    QAction *copyAct;
    ...
    QAction *sendToBackAct;
};
```

The protected and private members of the class will be explained shortly.

Figure 8.10. The `DiagramBox` and `DiagramLine` canvas items



Along with the `DiagramView` class, we also need to define two custom canvas item classes to represent the shapes we want to draw. We will call these classes `DiagramBox` and `DiagramLine`.

```
class DiagramBox : public QCanvasRectangle
{
public:
    enum { RTTI = 1001 };
    DiagramBox(QCanvas *canvas);
    ~DiagramBox();

    void setText(const QString &newText);
    QString text() const { return str; }
    void drawShape(QPainter &painter);
    QRect boundingRect() const;
    int rtti() const { return RTTI; }

private:
    QString str;
};
```

The `DiagramBox` class is a type of canvas item that displays a box and a piece of text. It inherits some of its functionality from `QCanvasRectangle`, a `QCanvasItem` subclass that displays a rectangle. To `QCanvasRectangle` we add the ability to show some text in the middle of the rectangle and the ability to show tiny squares ("handles") at each corner to indicate that an item is active. In a realworld application, we would make it possible to click and drag the handles to resize the box, but to keep the code short we will not do so here.

The `rtti()` function is reimplemented from `QCanvasItem`. Its name stands for "run-time type identification", and by comparing its return value with the `RTTI` constant, we can determine whether an arbitrary item in the canvas is a `DiagramBox` or not. We could perform the same check using C++'s `dynamic_cast<T>()` mechanism, but that would restrict us to C++ compilers that support this feature.

The value of 1001 is arbitrary. Any value above 1000 is acceptable, as long as it doesn't collide with other item types used in the same application.

```
class DiagramLine : public QCanvasLine
{
public:
    enum { RTTI = 1002 };

    DiagramLine(QCanvas *canvas);
    ~DiagramLine();

    QPoint offset() const { return QPoint((int)x(), (int)y()); }
    void drawShape(QPainter &painter);
    QPointArray areaPoints() const;
    int rtti() const { return RTTI; }
};
```

The `DiagramLine` class is a canvas item that displays a line. It inherits some of its functionality from `QCanvasLine`, and adds the ability to show handles at each end to indicate that the line is active.

Now we will review the implementations of these three classes.

```
DiagramView::DiagramView(QCanvas *canvas, QWidget *parent,
                         const char *name)
    : QCanvasView(canvas, parent, name)
{
    pendingItem = 0;
    activeItem = 0;
    minZ = 0;
    maxZ = 0;
    createActions();
}
```

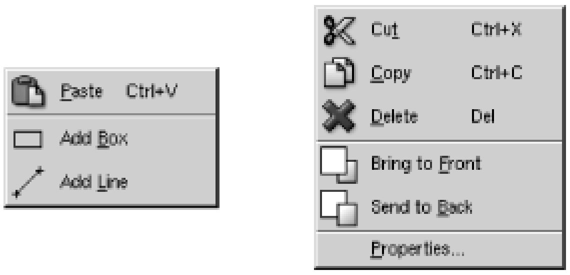
The `DiagramView` constructor takes a canvas as its first argument and passes it on to the base class constructor. The `DiagramView` will show this canvas.

The `QActions` are created in the `createActions()` private function. We have implemented several versions of this function in earlier chapters, and this one follows the same pattern, so we will not reproduce it here.

```
void DiagramView::contentsContextMenuEvent(QContextMenuEvent *event)
{
    QPopupMenu contextMenu(this);
    if (activeItem) {
        cutAct->addTo(&contextMenu);
        copyAct->addTo(&contextMenu);
        deleteAct->addTo(&contextMenu);
        contextMenu.insertSeparator();
        bringToFrontAct->addTo(&contextMenu);
        sendToBackAct->addTo(&contextMenu);
        contextMenu.insertSeparator();
        propertiesAct->addTo(&contextMenu);
    } else {
        pasteAct->addTo(&contextMenu);
        contextMenu.insertSeparator();
        addBoxAct->addTo(&contextMenu);
        addLineAct->addTo(&contextMenu);
    }
    contextMenu.exec(event->globalPos());
}
```

The contentsContextMenuEvent() function is reimplemented from QScrollView to create a context menu.

Figure 8.11. The DiagramView widget's context menus



If an item is active, the menu is populated with the actions that make sense on an item: *Cut*, *Copy*, *Delete*, *Bring to Front*, *Send to Back*, and *Properties*. Otherwise, the menu is populated with *Paste*, *Add Box*, and *Add Line*.

```
void DiagramView::addBox()
{
    addItem(new DiagramBox(canvas()));
}

void DiagramView::addLine()
{
    addItem(new DiagramLine(canvas()));
}
```

The addBox() and addLine() slots create a DiagramBox or a DiagramLine item on the canvas and then call addItem() to perform the rest of the work.

```
void DiagramView::addItem(QCanvasItem *item)
{
    delete pendingItem;
    pendingItem = item;
    setActiveItem(0);
    setCursor(crossCursor);
}
```

The addItem() private function changes the cursor to a crosshair and sets pendingItem to be the newly created item. The item is not visible in the canvas until we call show() on it.

When the user chooses *Add Box* or *Add Line* from the context menu, the cursor changes to a crosshair. The item is not actually added until the user clicks on the canvas.

```
void DiagramView::contentsMousePressEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton && pendingItem) {
        pendingItem->move(event->pos().x(), event->pos().y());
        showNewItem(pendingItem);
        pendingItem = 0;
        unsetCursor();
   } else {
       QCanvasItemList items = canvas()->collisions(event->pos());
       if (items.empty())
           setActiveItem(0);
       else
           setActiveItem(*items.begin());
     }
     lastPos = event->pos();
}
```

If users press the left mouse button while the cursor is a crosshair, they have already asked to create a box or line, and have now clicked the canvas at the position where they want the new item to appear. We move the "pending" item to the position of the click, show it, and reset the cursor to the normal arrow cursor.

Any other mouse press event on the canvas is interpreted as an attempt to select or deselect an item. We call `collisions()` on the canvas to obtain a list of all the items under the cursor and make the first item the current item. If the list contains many items, the first one is always the one that is rendered on top of the others.

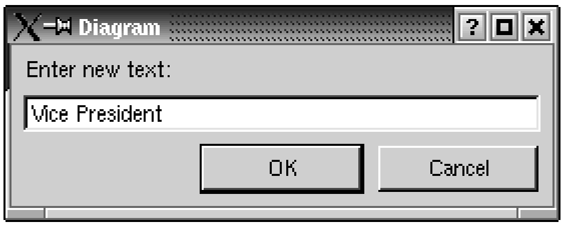
```
void DiagramView::contentsMouseMoveEvent(QMouseEvent *event)
{
    if (event->state() & LeftButton) {
        if (activeItem) {
            activeItem->moveBy(event->pos().x() - lastPos.x(),
                               event->pos().y() - lastPos.y());
            lastPos = event->pos();
            canvas()->update();
        }
    }
}
```

The user can move an item on the canvas by pressing the left mouse button on an item and dragging. Each time we get a mouse move event, we move the item by the horizontal and vertical distance by which the mouse moved and call `update()` on the canvas. Whenever we modify a canvas item, we must call `update()` to notify the canvas that it needs to redraw itself.

```
void DiagramView::contentsMouseDoubleClickEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton && activeItem
            && activeItem->rtti() == DiagramBox::RTTI) {
        DiagramBox *box = (DiagramBox *)activeItem;
        bool ok;

        QString newText = QInputDialog::getText(
                tr("Diagram"), tr("Enter new text:"),
                QLineEdit::Normal, box->text(), &ok, this);
        if (ok) {
            box->setText(newText);
            canvas()->update();
        }
    }
}
```

If the user double-clicks an item, we call the item's `rtti()` function and compare its return value with `DiagramBox::RTTI` (defined as 1001).

Figure 8.12. Changing the text of a `DiagramBox` item



If the item is a `DiagramBox`, we pop up a `QInputDialog` to allow the user to change the text shown in the box. The `QInputDialog` class provides a label, a line editor, an *OK* button, and a *Cancel* button.

```
void DiagramView::bringToFront()
{
    if (activeItem) {
        ++maxZ;
        activeItem->setZ(maxZ);
        canvas()->update();
    }
}
```

The `bringToFront()` slot raises the currently active item to be on top of the other items in the canvas. This is accomplished by setting the item's *z* coordinate to a value that is higher than any other value attributed to an item so far. When two items occupy the same (*x*, *y*) position, the item that has the highest *z* value is shown in front of the other item. (If the *z* values are equal, `QCanvas` will break the tie by comparing the item pointers.)

```
void DiagramView::sendToBack()
{
    if (activeItem) {
        --minZ;
        activeItem->setZ(minZ);
        canvas()->update();
    }
}
```

The `sendToBack()` slot puts the currently active item behind all the other items in the canvas. This is done by setting the item's *z* coordinate to a value that is lower than any other *z* value attributed to an item so far.

```
void DiagramView::cut()
{
    copy();
    del();
}
```

The `cut()` slot is trivial.

```
void DiagramView::copy()
{
    if (activeItem) {
        QString str;

        if (activeItem->rtti() == DiagramBox::RTTI) {
            DiagramBox *box = (DiagramBox *) activeItem;
            str = QString("DiagramBox %1 %2 %3 %4 %5")
                  .arg(box->width())
                  .arg(box->height())
                  .arg(box->pen().color().name())
                  .arg(box->brush().color().name())
                  .arg(box->text());
        } else if (activeItem->rtti() == DiagramLine::RTTI) {
            DiagramLine * line  =  (DiagramLine *)activeItem;
            QPoint delta = line->endPoint() - line->startPoint();
            str = QString("DiagramLine %1 %2 %3")
                  .arg(delta.x())
                  .arg(delta.y())
                  .arg(line->pen().color().name());
        }
        QApplication::clipboard()->setText(str);
    }
}
```

The copy() slot converts the active item into a string and copies the string to the clipboard. The string contains all the information necessary to reconstruct the item. For example, a black-on-white 320 x 40 box containing "My Left Foot" would be represented by this string:

```
DiagramBox 320 40 #000000 #ffffff My Left Foot
```

We don't bother storing the position of the item on the canvas. When we paste the item, we simply put the duplicate near the canvas's top-left corner. Converting an object to a string is an easy way to add clipboard support, but it is also possible to put arbitrary binary data onto the clipboard, as we will see in Chapter 9 (Drag and Drop).

```
void DiagramView::paste()
{
    QString str = QApplication::clipboard()->text();
    QTextIStream in(&str);
    QString tag;

    in >> tag;
    if (tag == "DiagramBox") {
        int width;
        int height;
        QString lineColor;
        QString fillColor;
        QString text;

        in >> width >> height >> lineColor >>fillColor;
        text = in.read();

        DiagramBox *box = new DiagramBox(canvas());
        box->move(20, 20);
        box->setSize(width, height);
        box->setText(text);
        box->setPen(QColor(lineColor));
        box->setBrush(QColor(fillColor));
        showNewItem(box);
    } else if (tag == "DiagramLine") {
        int deltaX;
        int deltaY;
        QString lineColor;

        in >> deltaX >> deltaY >> lineColor;

        DiagramLine *line = new DiagramLine(canvas());
        line->move(20, 20);
        line->setPoints(0, 0, deltaX, deltaY);
        line->setPen(QColor(lineColor));
        showNewItem(line);
    }
}
```

The paste() slot uses QTextIStream to parse the contents of the clipboard. QTextIStream works on whitespace-delimited fields in a similar way to cin. We extract each field using the >> operator, except the last field of the DiagramBox item, which might contain spaces. For this field, we use QTextStream::read(), which reads in the rest of the string.

```
void DiagramView::del()
{
    if (activeItem) {
```

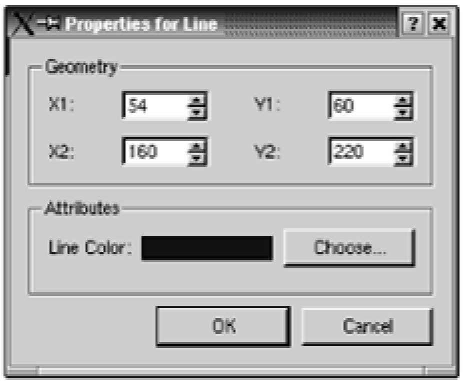
```
    QCanvasItem *item = activeItem;
    setActiveItem(0);
    delete item;
    canvas()->update();
  }
}
```

The del() slot deletes the active item and calls QCanvas::update() to redraw the canvas.

```
void DiagramView::properties()
{
    if (activeItem) {
        PropertiesDialog dialog;
        dialog.exec(activeItem);
    }
}
```

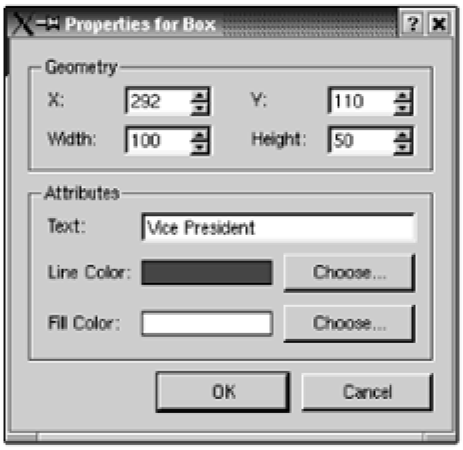
The properties() slot pops up a Properties dialog for the active item. The PropertiesDialog class is a "smart" dialog; we simply need to pass it a pointer to the item we want it to act on and it takes care of the rest.

Figure 8.13. The Properties dialog's two appearances


Properties for Line

Geometry
X1: 54 Y1: 60
X2: 160 Y2: 220

Attributes
Line Color:


Properties for Box

Geometry
X: 292 Y: 110
Width: 100 Height: 50

Attributes
Text: Vice President
Line Color:
Fill Color:

The .ui and .ui.h files for the PropertiesDialog are on the CD that accompanies this book.

```
void DiagramView::showNewItem(QCanvasItem *item)
{
    setActiveItem(item);
    bringToFront();
    item->show();
    canvas()->update();
}
```

The showNewItem() private function is called from a few places in the code to make a newly created canvas item visible and active.

```
void DiagramView::setActiveItem(QCanvasItem *item)
{
    if (item != activeItem) {
        if (activeItem)
            activeItem->setActive(false);
        activeItem = item;
        if (activeItem)
            activeItem->setActive(true);
        canvas()->update();
    }
}
```

Finally, the setActiveItem() private function clears the old active item's "active" flag, sets the activeItem variable, and sets the new active item's flag. The item's "active" flag is stored in QCanvasItem. Qt doesn't use the flag itself; it is provided purely for the convenience of subclasses. We use the flag in the DiagramBox and DiagramLine subclasses because we want them to paint themselves differently depending on whether they are active or not.

Let's now review the code for DiagramBox and DiagramLine.

```
const int Margin = 2;

void drawActiveHandle(QPainter &painter, const QPoint &center)
{
    painter.setPen(Qt::black);
    painter.setBrush(Qt::gray);
    painter.drawRect(center.x() - Margin, center.y() - Margin,
                     2 * Margin + 1, 2 * Margin + 1);
}
```

The drawActiveHandle() function is used by both DiagramBox and DiagramLine to draw a tiny square indicating that an item is the active item.

```
DiagramBox::DiagramBox(QCanvas *canvas)
    : QCanvasRectangle (canvas)
{
    setSize(100, 60);
    setPen(black);
    setBrush(white);
    str = "Text";
}
```

In the DiagramBox constructor, we set the size of the rectangle to 100 x 60. We also set the pen color to black and the brush color to white. The pen color is used to draw the box outline and the text, while the brush color is used for the background of the box.

```
DiagramBox::~DiagramBox()
{
   hide();
}
```

The DiagramBox destructor calls hide() on the item. This is necessary for all classes that inherit from QCanvasPolygonlItem (QCanvasRectangle's base class) because of the way QCanvasPolygonalItem works.

```
void DiagramBox::setText(const QString &newText)
{
    str = newText;
    update();
}
```

The setText() function sets the text shown in the box and calls QCanvasItem::update() to mark this item as changed. The next time the canvas repaints itself, it will know that it must repaint this item.

```
void DiagramBox::drawShape(QPainter &painter)
{
    QCanvasRectangle::drawShape(painter);
    painter.drawText(rect(), AlignCenter, text());
    )if (isActive()) {
         drawActiveHandle(painter, rect().topLeft());
         drawActiveHandle(painter, rect().topRight());
         drawActiveHandle(painter, rect().bottomLeft());
         drawActiveHandle(painter, rect().bottomRight());
    }
}
```

The drawShape() function is reimplemented from QCanvasPolygonalItem to draw the text, and if the item is active, the four handles. We use the base class to draw the rectangle itself.

```
QRect DiagramBox::boundingRect() const
{
    return QRect((int)x() - Margin, (int)y() - Margin,
                 width() + 2 * Margin, height() + 2 * Margin);
}
```

The boundingRect() function is reimplemented from QCanvasItem. It is used by QCanvas to perform collision-detection and to optimize painting. The rectangle it returns must be at least as large as the area painted in drawShape().

The default QCanvasRectangle implementation is not sufficient, because it does not take into account the handles that we paint at each corner of the rectangle if the item is active.

```
DiagramLine::DiagramLine(QCanvas *canvas)
    : QCanvasLine(canvas)
{
    setPoints(0, 0, 0, 99);
}
```

In the DiagramLine constructor, we set the two points that define the line to be (0, 0) and (0, 99). The result is a 100-pixel-long vertical line.

```
DiagramLine::~DiagramLine()
{
    hide();
}
```

Again, we must call hide() in the destructor.

```
void DiagramLine::drawShape(QPainter &painter)
{
    QCanvasLine::drawShape(painter);
    if (isActive()) {
        drawActiveHandle(painter, startPoint() + offset());
        drawActiveHandle(painter, endPoint() + offset());
    }
}
```

The drawShape() function is reimplemented from QCanvasLine to draw handles at both ends of the line if the item is active. We use the base class to draw the line itself. The offset() function was implemented in the DiagramLine class definition. It returns the position of the item on the canvas.

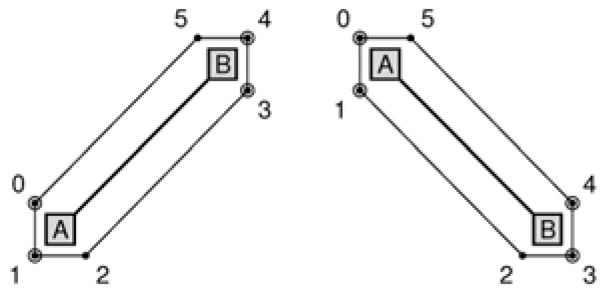
```
QPointArray DiagramLine::areaPoints() const
{
    const int Extra = Margin + 1;
    QPointArray points(6);
    QPoint pointA = startPoint() + offset();
    QPoint pointB = endPoint() + offset();

    if (pointA.x() > pointB.x())
        swap(pointA, pointB);

    points[0] = pointA + QPoint(-Extra, -Extra);
    points[1] = pointA + QPoint(-Extra, +Extra);
    points[3] = pointB + QPoint(+Extra, +Extra);
    points[4] = pointB + QPoint(+Extra, -Extra);
    if (pointA.y() > pointB.y()) {
        points[2] = pointA + QPoint(+Extra, +Extra);
        points[5] = pointB + QPoint(-Extra, -Extra);
    } else {
        points[2] = pointB + QPoint(-Extra, +Extra);
        points[5] = pointA + QPoint(+Extra, -Extra);
    }
    return points;
}
```

The `areaPoints()` function plays a similar role to the `boundingRect()` function in `DiagramBox`. For a diagonal line, and indeed for most polygons, a bounding rectangle is too crude an approximation. For these, we must reimplement `areaPoints()` and return the outline of the area painted by the item. The `QCanvasLine` implementation already returns a decent outline for a line, but it doesn't take the handles into account.

The first thing we do is to store the two points in `pointA` and `pointB` and to ensure that `pointA` is to the left of `pointB`, by swapping them if necessary using `swap()` (defined in `<algorithm>`). Then there are only two cases to consider: ascending and descending lines.

The bounding area of a line is always represented by six points, but these points vary depending on whether the line is ascending or descending. Nevertheless, four of the six points (numbered 0, 1, 3, and 4) are the same in both cases. For example, points 0 and 1 are always located at the top-left and bottom-left corners of handle A; in contrast, point 2 is located at the bottom-right corner of handle A for an ascending line and at the bottom-left corner of handle B for a descending line.

Figure 8.14. The bounding area of a `DiagramLine`



Considering how little code we have written, the `DiagramView` widget already provides considerable functionality, with support for selecting and moving items and for context menus.

One thing that is missing is that the handles shown when an item is active cannot be dragged to resize the item. If we wanted to change that, we would probably take a different approach to the one we have used here. Instead of drawing the handles in the items' `drawShape()` functions, we would probably make each handle a canvas item. If we wanted the cursor to change when hovering over a handle, we would call `setCursor()` in real time as it is moved. For this to work, we would need to call `setMouseTracking(true)` first, because normally Qt only sends mouse move events when a mouse button is pressed.

Another obvious improvement would be to support multiple selections and item grouping. The *Qt Quarterly* article "Canvas Item Groupies", available online at http://doc.trolltech.com/qq/qq05-canvasitemgrouping.html, presents one way to achieve this.

This section has provided a working example of QCanvas and QCanvasView use, but it has not covered all of QCanvas's functionality. For example, canvas items can be set to move on the canvas at regular intervals by calling setVelocity(). See the documentation for QCanvas and its related classes for the details.

[Team LiB]
[Team LiB]

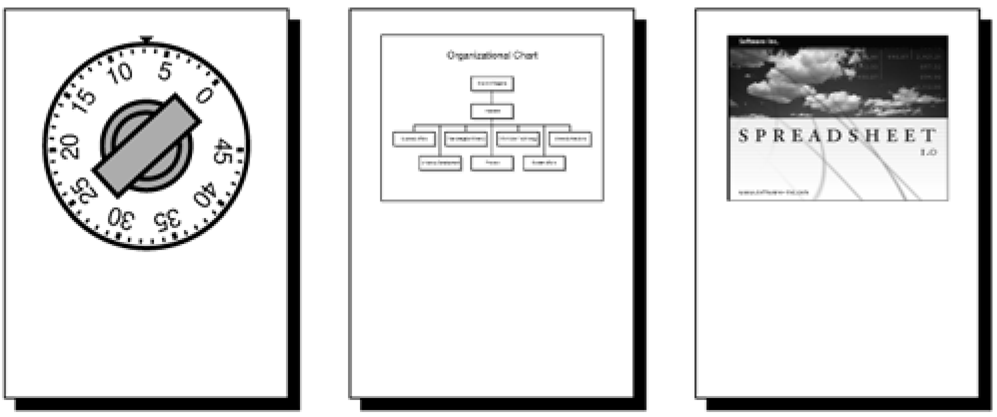
Printing

Printing in Qt is similar to drawing on a widget or on a pixmap. It consists of the following steps:

1. Create a QPrinter to serve as the "paint device".
2. Call QPrinter::setup() to pop up a print dialog, allowing the user to choose a printer and to set a few options.
3. Create a QPainter to operate on the QPrinter.
4. Draw a page using the QPainter.
5. Call QPrinter::newPage() to advance to the next page.
6. Repeat steps 4 and 5 until all the pages are printed.

On Windows and Mac OS X, QPrinter uses the system's printer drivers. On Unix, it generates PostScript and sends it to lp or lpr (or to whatever program has been set using QPrinter::setPrintProgram()).

Figure 8.15. Printing an OvenTimer, a QCanvas, and a QImage



Let's start with some simple examples that all print on a single page. The first example prints an OvenTimer widget:

```
void PrintWindow::printOvenTimer(OvenTimer *ovenTimer)
```

```
{
    if (printer.setup(this)) {
        QPainter painter(&printer);
        QRect rect = painter.viewport();
        int side = QMIN(rect.width(), rect.height());
        painter.setViewport(0, 0, side, side);
        painter.setWindow(-50, -50, 100, 100);
        ovenTimer->draw(&painter);
    }
}
```

We assume that the `PrintWindow` class has a member variable called `printer` of type `QPrinter`. We could simply have created the `QPrinter` on the stack in `printOvenTimer()`, but then it would not remember the user's settings from one print run to another.

We call `setup()` to pop up a print dialog. It returns `true` if the user clicked the OK button; otherwise, it returns `false`. After the call to `setup()`, the `QPrinter` object is ready to use.

We create a `QPainter` to draw on the `QPrinter`. Then we make the painter's viewport square and initialize the painter's window to (-50, -50, 100, 100), the rectangle expected by `OvenTimer`. We call `draw()` to do the painting. If we didn't bother making the viewport square, the `OvenTimer` would be vertically stretched to fill the entire page height.

By default, the `QPainter`'s window is initialized so that the printer appears to have a similar resolution as the screen (usually somewhere between 72 and 100 dots per inch), making it easy to reuse widget-painting code for printing. Here, it didn't matter, because we set our own window to be (-50, -50, 100, 100).

Printing an `OvenTimer` isn't a very realistic example, because the widget is meant for on-screen user interaction. But for other widgets, such as the `Plotter` widget we developed in Chapter 5, it makes lots of sense to reuse the widget's painting code for printing.

A more practical example is printing a `QCanvas`. Applications that use it often need to be able to print what the user has drawn. This can be done in a generic way as follows:

```
void PrintWindow::printCanvas(QCanvas *canvas)
{
    if (printer.setup(this)) {
        QPainter painter(&printer);
        QRect rect = painter.viewport();
        QSize size = canvas->size();
        size.scale(rect.size(), QSize::ScaleMin);
        painter.setViewport(rect.x(), rect.y(),
                            size.width(), size.height());
        painter.setWindow(canvas->rect());
        painter.drawRect(painter.window());
        painter.setClipRect(painter.viewport());

        QCanvasItemList items = canvas->collisions(canvas->rect());
        QCanvasItemList::const_iterator it = items.end();
        while (it != items.begin()) {
            --it;
            (*it)->draw(painter);
        }
    }
}
```

This time, we set the painter's window to the canvas's bounding rectangle, and we restrict the viewport to a rectangle with the same aspect ratio. To accomplish this, we use `QSize::scale()` with `ScaleMin` as its second argument. For example, if the canvas has a size of 640 x 480 and the painter's viewport has a size of 5000 x 5000, the resulting viewport size that we use is 5000 x 3750.

We call `collisions()` with the canvas's rectangle as argument to obtain the list of all visible canvas items sorted from highest to lowest *z* value. We iterate over the list from the end to paint the items with a lower *z* value before those with a higher *z* value and call `QCanvasItem::draw()` on them. This ensures that the items that appear nearer the front are drawn on top of the items that are further back.

Our third example is to draw a `QImage`.

```
void PrintWindow::printImage(const QImage &image)
{
    if (printer.setup(this)) {
        QPainter painter(&printer);
        QRect rect = painter.viewport();
        QSize size = image.size();
        size.scale(rect.size(), QSize::ScaleMin);
        painter.setViewport(rect.x(), rect.y(),
                            size.width(), size.height());
        painter.setWindow(image.rect());
        painter.drawImage(0, 0, image);
    }
}
```

We set the window to the image's rectangle and the viewport to a rectangle with the same aspect ratio, and we draw the image at position (0, 0).

Printing items that take up no more than a single page is simple, as we have seen. But many applications need to print multiple pages. For those, we need to paint one page at a time and call `newPage()` to advance to the next page. This raises the problem of determining how much information we can print on each page.

There are two approaches to handling multi-page documents with Qt:

- We can convert the data we want to HTML and render it using `QSimpleRichText`, Qt's rich text engine.

- We can perform the drawing and the page breaking by hand.

We will review both approaches in turn.

As an example, we will print a flower guide: a list of flower names with a textual description. Each entry in the guide is stored as a string of the format *"name:description"*, for example:

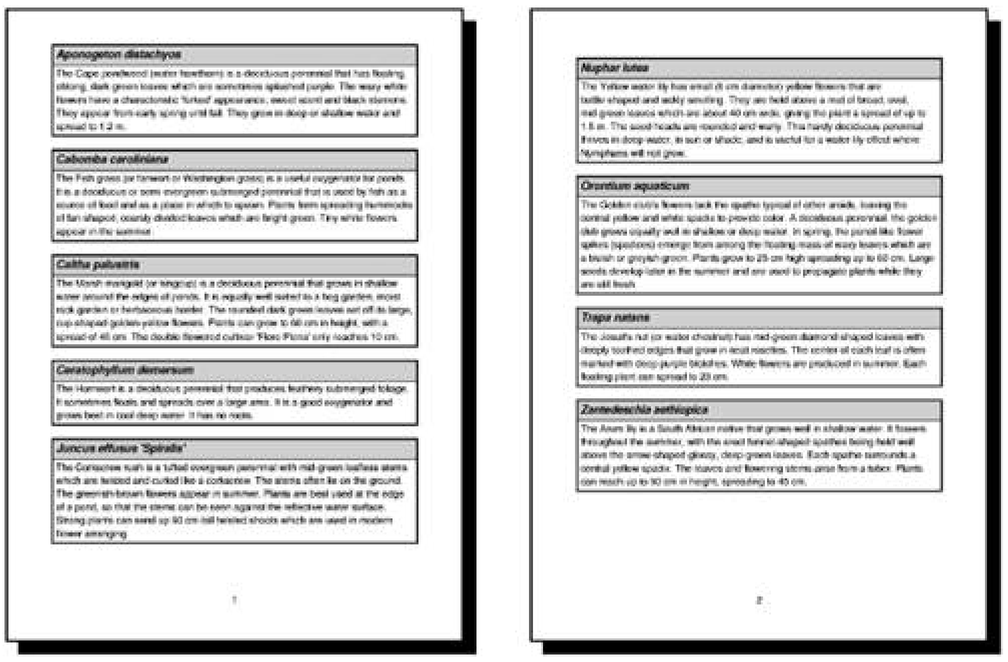
```
Miltonopsis santanae: An most dangerous orchid species.
```

Since each flower's data is represented by a single string, we can represent all the flowers in the guide using one `QStringList`.

Here's the function that prints a flower guide using Qt's rich text engine:

```
void PrintWindow::printFlowerGuide(const QStringList &entries)
{
    QString str;
    QStringList::const_iterator it = entries.begin();
    while (it != entries.end()) {
        QStringList fields = QStringList::split(": ", *it);
        QString title = QStyleSheet::escape(fields[0]);
        QString body = QStyleSheet::escape(fields[1]);

        str += "<table width=\"100%\" border=1 cellspacing=0>\n"
               "<tr><td bgcolor=\"lightgray\"><font size=\"+1\">"
               "<b><i>" + title + "</i></b></font>\n<tr><td>"
               + body + "\n</table>\n<br>\n";
               ++it;
     }
     printRichText(str);
}
```

Figure 8.16. Printing a flower guide using `QSimpleRichText`



The first step is to convert the data into HTML. Each flower becomes an HTML table with two cells. We use `QStyleSheet::escape()` to replace the special characters '&', '<', '>' with the corresponding HTML entities ("&amp;", "&lt;", "&gt;"). Then we call `printRichText()` to print the text.

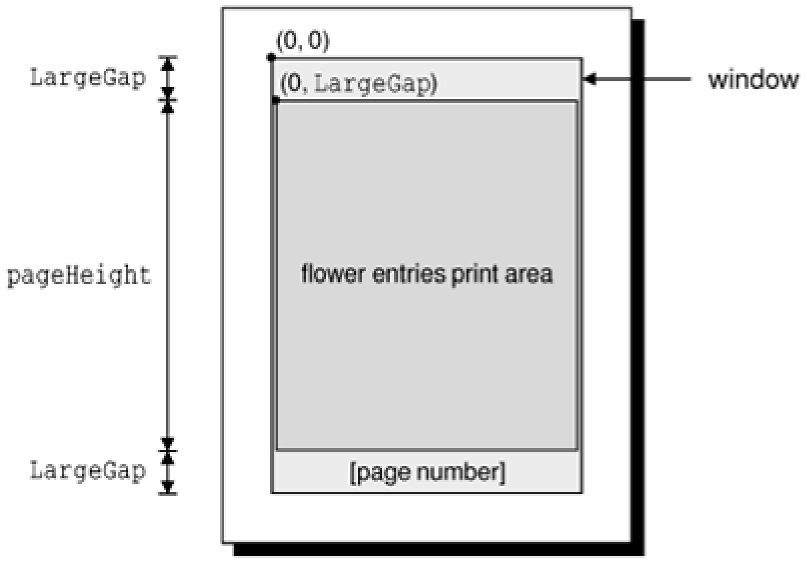
```
const int LargeGap = 48;

void PrintWindow::printRichText(const QString &str)
{
    if (printer.setup(this)) {
        QPainter painter(&printer);
        int pageHeight = painter.window().height() - 2 * LargeGap;
        QSimpleRichText richText(str, bodyFont, "", 0, 0,
                                 pageHeight);
        richText.setWidth(&painter, painter.window().width());
        int numPages = (int)ceil((double)richText.height()
                                 / pageHeight);
        int index;

        for (int i = 0; i < (int)printer.numCopies(); ++i) {
            for (int j = 0; j < numPages; ++j) {
                if (i > 0 || j > 0)
                    printer.newPage();

                if (printer.pageOrder()
                        == QPrinter::LastPageFirst) {
```

```
                    index = numPages - j - 1;
                } else {
                    index = j;
                }
                printPage(&painter, richText, pageHeight, index);
            }
        }
    }
}
```

The `printRichText()` function takes care of printing an HTML document. It can be reused "as is" in any Qt application to print arbitrary HTML.

We compute the height of one page based on the window size and the size of the gap we want to leave at the top and bottom of the page for a header and a footer. Then we create a `QSimpleRichText` object containing the HTML data. The last argument to the `QSimpleRichText` constructor is the page height; `QSimpleRichText` uses it to produce nice page breaks.

Figure 8.17. The flower guide's page layout



Then we print each page. The outer `for` loop iterates as many times as necessary to produce the number of copies requested by the user. Most printer drivers support multiple copies, so for those `QPrinter::numCopies()` always returns 1. If the printer driver doesn't support multiple copies, `numCopies()` returns the number of copies requested by the user, and the application is responsible for printing that amount. In the previous examples, we ignored `numCopies()` for the sake of simplicity.

The inner `for` loop iterates through the pages. If the page isn't the first page, we call `newPage()` to flush the old page and start painting on a fresh page. We call `printPage()` to paint each page.

The print dialog allows the user to print the pages in reverse order. It is our responsibility to honor that option.

We assume that `printer`, `bodyFont`, and `footerFont` are member variables of the `PrintWindow` class.

```
void PrintWindow::printPage(QPainter *painter,
                            const QSimpleRichText &richText,
                            int pageHeight, int index)
```

```
{
    QRect rect(0, index * pageHeight + LargeGap,
               richText.width(), pageHeight);

    painter->saveWorldMatrix();
    painter->translate(0, -rect.y());
    richText.draw(painter, 0, LargeGap, rect, colorGroup());
    painter->restoreWorldMatrix();

    painter->setFont(footerFont);
    painter->drawText(painter->window(), AlignHCenter | AlignBottom,
                      QString::number(index + 1));
}
```

The printPage() function prints the (index + 1)-th page of the document. The page consists of some HTML and of a page number in the footer area.

We translate the QPainter and call draw() with a position and rectangle specifying the portion of the rich text we want to draw. It might help to visualize the rich text as a single very long page that must be cut into smaller portions, each of height pageHeight.

Then we draw the page number centered at the bottom of the page. If we wanted to have a header on each page, we would just use an extra drawText() call.

The LargeGap constant is set to 48. Assuming a screen resolution of 96 dots per inch, this is half an inch (12.7 mm). To obtain a precise length regardless of screen resolution, we could have used the QPaintDeviceMetrics class as follows:

```
QPaintDeviceMetrics metrics(&printer);
int LargeGap = metrics.logicalDpiY() / 2;
```

Here's one way we can initialize bodyFont and footerFont in the PrintWindow constructor:

```
bodyFont = QFont("Helvetica", 14);
footerFont = bodyFont;
```

Let's now see how we can draw a flower guide using QPainter. Here's the new printFlowerGuide() function:

```
void PrintWindow::printFlowerGuide(const QStringList &entries)
{
    if (printer.setup(this)) {
        QPainter painter(&printer);
        vector<QStringList> pages;
        int index;

          paginate(&painter, &pages, entries);
          for (int i = 0; i < (int)printer.numCopies(); ++i) {
               for (int j = 0; j < (int)pages.size(); ++j) {
                    if (i > 0 || j > 0)
                        printer.newPage();

                    if (printer.pageOrder() == QPrinter::LastPageFirst) {
                        index = pages.size() - j - 1;
                    } else {
                        index = j;
                    }
                    printPage(&painter, pages, index);
               }
          }
    }
}
```

The first thing we do after setting up the printer and constructing the painter is to call the `paginate()` helper function to determine which entry should appear on which page. The result of this is a vector of `QStringList`s, with each `QStringList` holding the entries for one page.

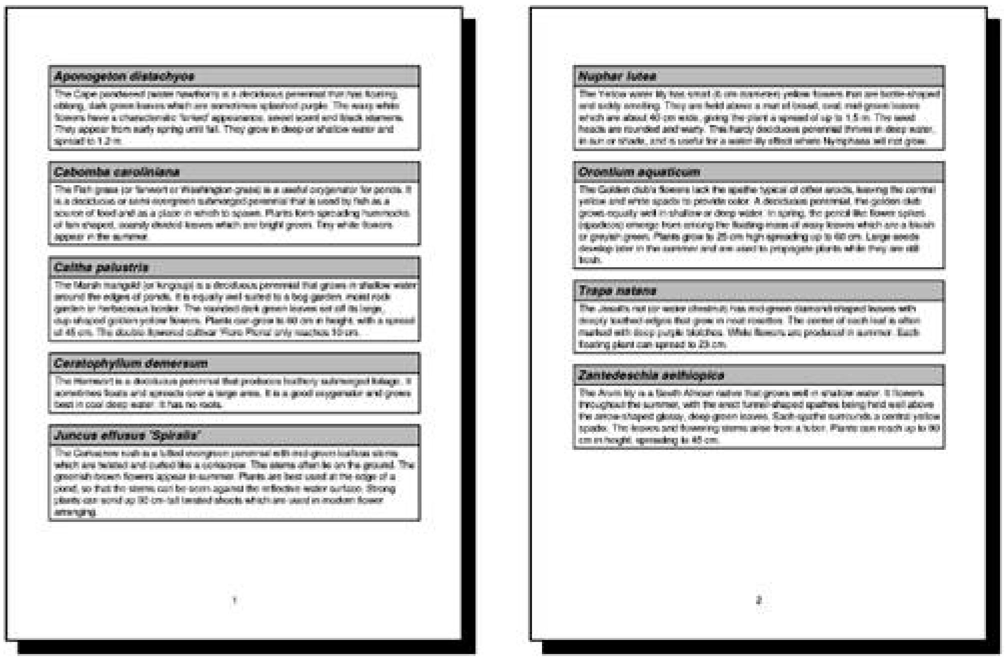
For example, let's suppose that the flower guide contains 6 entries, which we will refer to as A, B, C, D, E, and F. Now let's suppose that there is room for A and B on the first page, C, D, and E on the second page, and F on the third page. The `pages` vector would then have the list [A, B] at index position 0, the list [C, D, E] at index position 1, and the list [F] at index position 2.

The rest of the function is nearly identical to what we did earlier in `printRichText()`. The `printPage()` function, however, is different, as we will see shortly.

```
void PrintWindow::paginate(QPainter *painter,
                           vector<QStringList> *pages,
                           const QStringList &entries)
{
    QStringList currentPage;
    int pageHeight = painter->window().height() - 2 * LargeGap;
    int y = 0;

    QStringList::const_iterator it = entries.begin();
    while (it != entries.end()) {
        int height = entryHeight(painter, *it);
        if (y + height > pageHeight && !currentPage.empty()) {
            pages->push_back(currentPage);
            currentPage.clear();
            y = 0;
        }
        currentPage.push_back(*it);
        y += height + MediumGap;
        ++it;
   }
   if (!currentPage.empty())
       pages->push_back(currentPage);
}
```

The `paginate()` function distributes the flower guide entries into pages. It relies on the `entryHeight()` function, which computes the height of one entry.

Figure 8.18. Printing a flower guide using `QPainter`

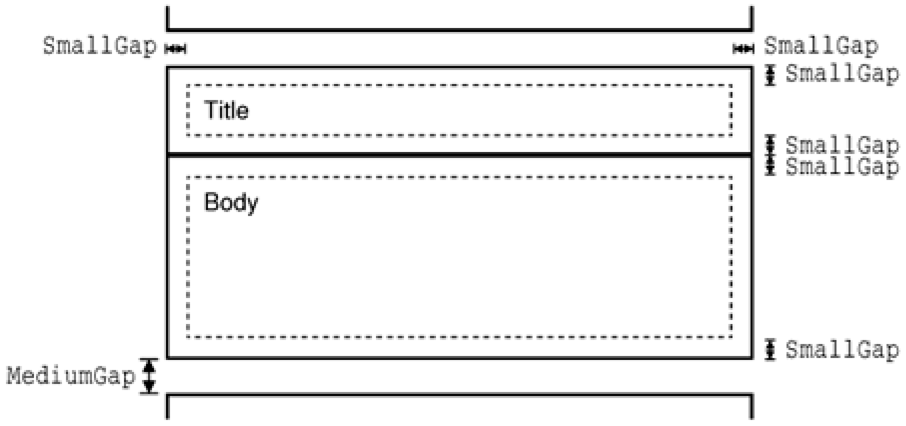


We iterate through the entries and append them to the current page until we come to an entry that doesn't fit; then we append the current page to the pages vector and start a new page.

```
int PrintWindow::entryHeight(QPainter *painter, const QString &entry)
{
    QStringList fields = QStringList::split(": ", entry);
    QString title = fields[0];
    QString body = fields[1];

    int textWidth = painter->window().width() - 2 * SmallGap;
    int maxHeight = painter->window().height();
    painter->setFont(titleFont);
    QRect titleRect = painter->boundingRect(0, 0,
                                            textWidth, maxHeight,
                                            WordBreak, title);
    painter->setFont(bodyFont);
    QRect bodyRect = painter->boundingRect(0, 0,
                                           textWidth, maxHeight,
                                           WordBreak, body);
    return  titleRect.height() +  body Rect.height() + 4 * SmallGap;
}
```

The entryHeight() function uses QPainter::boundingRect() to compute the vertical space needed by one entry. Figure 8.19 shows the layout of a flower entry and the meaning of the SmallGap and MediumGap constants.

Figure 8.19. A flower entry's layout



```
void PrintWindow::printPage(QPainter *painter,
                             const vector<QStringList> &pages,
                             int index)
{
    painter->saveWorldMatrix();
    painter->translate(0, LargeGap);
    QStringList::const_iterator it = pages[index].begin();
    while (it != pages[index].end()) {
        QStringList fields = QStringList::split(": ", *it);
        QString title = fields[0];
        QString body = fields[1];
        printBox(painter, titleFont, title, lightGray);
        printBox(painter, bodyFont, body, white);
        painter->translate(0, MediumGap);
        ++it;
     }
     painter->restoreWorldMatrix();

     painter->setFont(footerFont);
     painter->drawText(painter->window(), AlignHCenter | AlignBottom,
                       QString::number(index + 1));
}
```

The printPage() function iterates through all the flower guide entries and prints them using two calls to printBox(): one for the title (the flower's name) and one for the body (its description). It also draws the page number centered at the bottom of the page.

```
void PrintWindow::printBox(QPainter *painter, const QFont &font,
                           const QString &str, const QBrush &brush)
{
    painter->setFont(font);

    int boxWidth = painter->window().width();
    int textWidth = boxWidth - 2 * SmallGap;
    int maxHeight = painter->window().height();
    QRect textRect = painter->boundingRect(SmallGap, SmallGap,
                                           textWidth, maxHeight,
                                           WordBreak, str);
    int boxHeight = textRect.height() + 2 * SmallGap;
    painter->setPen(QPen(black, 2, SolidLine));
    painter->setBrush(brush);
    painter->drawRect(0, 0, boxWidth, boxHeight);
    painter->drawText(textRect, WordBreak, str);
    painter->translate(0, boxHeight);
}
```

The printBox() function draws the outline of a box, then draws the text inside the box.

If the user prints a long document, or requests multiple copies of a short document, it is usually a good idea to pop up a QProgressDialog to give the user the opportunity of canceling the printing operation (by clicking *Cancel*). Here's a modified version of printFlowerGuide() that does this:

```
void PrintWindow::printFlowerGuide(const QStringList &entries)
{
    if (printer.setup(this)) {
        QPainter painter(&printer);
        vector<QStringList> pages;
        int index;

        paginate(&painter, &pages, entries);

        int numSteps = printer.numCopies() * pages.size();
        int step = 0;
        QProgressDialog progress(tr("Printing file..."),
                                 tr("Cancel"), numSteps, this);
        progress.setModal(true);

        for (int i = 0; i < (int)printer.numCopies(); ++i) {
            for (int j = 0; j < (int)pages.size(); ++j) {
                progress.setProgress(step);
                qApp->processEvents();
                if (progress.wasCanceled()) {
                    printer.abort();
                    return;
                }
                ++step;

                if (i > 0 || j > 0)
                    printer.newPage();

                if (printer.pageOrder() == QPrinter::LastPageFirst) {
                    index = pages.size() - j - 1;
                } else {
                    index = j;
                }
                printPage(&painter, pages, index);
            }
        }
   }
}
```

When the user clicks *Cancel*, we call QPrinter::abort() to stop the printing operation.

[Team LiB]
[Team LiB]
PREVIOUS NEXT
PREVIOUS NEXT

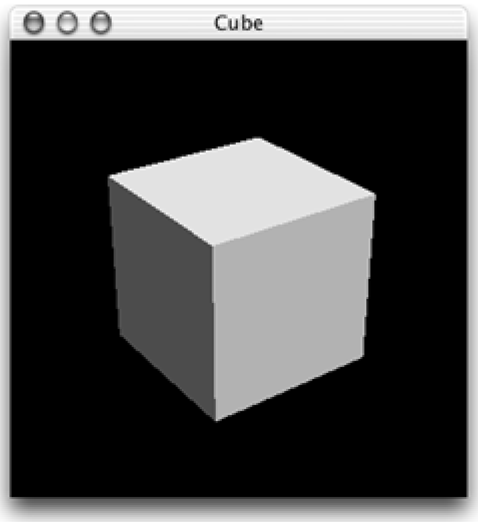
Graphics with OpenGL

OpenGL is a standard API for rendering 2D and 3D graphics. Qt applications can draw OpenGL graphics by using Qt's QGL module. This section assumes that you are familiar with OpenGL. If OpenGL is new to you, a good place to start learning it is http://www.opengl.org/.

Drawing graphics with OpenGL from a Qt application is straightforward: We must subclass QGLWidget, reimplement a few virtual functions, and link the application against the QGL and OpenGL libraries. Because QGLWidget inherits from QWidget, most of what we already know still applies. The main difference is that we use standard OpenGL functions to perform the drawing instead of QPainter.

To show how this works, we will review the code of the Cube application shown in Figure 8.20. The application presents a 3D cube with faces of different colors. The user can rotate the cube by pressing a mouse button and dragging. The user can set the color of a face by double-clicking it and choosing a color from the QColorDialog that pops up.

Figure 8.20. The Cube application



```
class Cube : public QGLWidget
{
public:
    Cube(QWidget *parent = 0, const char *name = 0);

protected:
    void initializeGL();
    void resizeGL(int width, int height);
    void paintGL();
    void mousePressEvent(QMouseEvent *event);
    void mouseMoveEvent(QMouseEvent *event);
    void mouseDoubleClickEvent(QMouseEvent *event);

private:
    void draw();
    int faceAtPosition(const QPoint &pos);

    GLfloat rotationX;
    GLfloat rotationY;
    GLfloat rotationZ;
    QColor faceColors[6];
    QPoint lastPos;
};
```

Cube inherits from QGLWidget. The initializeGL(), resizeGL(), and paintGL() functions are reimplemented from QGLWidget. The mouse event handlers are reimplemented from QWidget as usual. QGLWidget is defined in <qgl.h>.

```
Cube::Cube(QWidget *parent, const char *name)
    : QGLWidget(parent, name)
{
    setFormat(QGLFormat(DoubleBuffer | DepthBuffer));
    rotationX = 0;
    rotationY = 0;
    rotationZ = 0;
    faceColors[0] = red;
    faceColors[1] = green;
    faceColors[2] = blue;
    faceColors[3] = cyan;
    faceColors[4] = yellow;
    faceColors[5] = magenta;
}
```

In the constructor, we call `QGLWidget::setFormat()` to specify the OpenGL display context, and we initialize the class's private variables.

```
void Cube::initializeGL()
{
    qglClearColor(black);
    glShadeModel(GL_FLAT);
    glEnable(GL_DEPTH_TEST);
    glEnable(GL_CULL_FACE);
}
```

The `initializeGL()` function is called once before `paintGL()` is called. This is the place where we can set up the OpenGL rendering context, define display lists, and perform other initializations.

All the code is standard OpenGL, except for the call to `QGLWidget`'s `qglClearColor()` function. If we wanted to stick to standard OpenGL, we would call `glClearColor()` in RGBA mode and `glClearIndex()` in color index mode instead.

```
void Cube::resizeGL(int width, int height)
{
    glViewport(0, 0, width, height);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    GLfloat x = (GLfloat)width / height;
    glFrustum(-x, x, -1.0, 1.0, 4.0, 15.0);
    glMatrixMode(GL_MODELVIEW);
}
```

The `resizeGL()` function is called once before `paintGL()` is called the first time, but after `initializeGL()` is called. This is the place where we can set up the OpenGL viewport, projection, and any other settings that depend on the widget's size.

```
void Cube::paintGL()
{
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
    draw();
}
```

The `paintGL()` function is called whenever the widget needs to be repainted. This is similar to `QWidget::paintEvent()`, but instead of `QPainter` functions we use OpenGL functions. The actual drawing is performed by the private function `draw()`.

```
void Cube::draw()
{
    static const GLfloat coords[6] [4] [3] = {
        { { +1.0, -1.0, +1.0 }, { +1.0, -1.0, -1.0 },
          { +1.0, +1.0, -1.0 }, { +1.0, +1.0, +1.0 } },
        { { -1.0, -1.0, -1.0 }, { -1.0, -1.0, +1.0 },
          { -1.0, +1.0, +1.0 }, { -1.0, +1.0, -1.0 } },
        { { +1.0, -1.0, -1.0 }, { -1.0, -1.0, -1.0 },
          { -1.0, +1.0, -1.0 }, { +1.0, +1.0, -1.0 } },
        { { -1.0, -1.0, +1.0 }, { +1.0, -1.0, +1.0 },
          { +1.0, +1.0, +1.0 }, { -1.0, +1.0, +1.0 } },
        { { -1.0, -1.0, -1.0 }, { +1.0, -1.0, -1.0 },
          { +1.0, -1.0, +1.0 }, { -1.0, -1.0, +1.0 } },
        { { -1.0, +1.0, +1.0 }, { +1.0, +1.0, +1.0 },
          { +1.0, +1.0, -1.0 }, { -1.0, +1.0, -1.0 } }
    };

    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    glTranslatef(0.0, 0.0, -10.0);
    glRotatef(rotationX, 1.0, 0.0, 0.0);
    glRotatef(rotationY, 0.0, 1.0, 0.0);
    glRotatef(rotationZ, 0.0, 0.0, 1.0);

    for (int i = 0; i < 6; ++i) {
        glLoadName(i);
        glBegin(GL_QUADS);
        qglColor(faceColors[i]);
        for (int j = 0; j < 4; ++j) {
            glVertex3f(coords[i] [j] [0], coords[i] [j] [1],
                       coords[i] [j] [2]);
        }
        glEnd();
    }
}
```

In `draw()`, we draw the cube, taking into account the *x, y, and z* rotations and the colors stored in the `faceColors` array. Everything is standard OpenGL, except for the `qglColor()` call. We could have used one of the OpenGL functions `glColor3d()` or `glIndex()`, depending on the mode.

```
void Cube::mousePressEvent(QMouseEvent *event)
{
    lastPos = event->pos();
}

void Cube::mouseMoveEvent(QMouseEvent *event)
{
    GLfloat dx = (GLfloat) (event->x() - lastPos.x()) / width();
    GLfloat dy = (GLfloat) (event->y() - lastPos.y()) / height();

    if (event->state() & LeftButton) {
        rotationX += 180 * dy;
        rotationY += 180 * dx;
        updateGL();
    } else if (event->state() & RightButton) {
        rotationX += 180 * dy;
        rotationZ += 180 * dx;
        updateGL();
    }
    lastPos = event->pos();
}
```

The `mousePressEvent()` and `mouseMoveEvent()` functions are reimplement from `QWidget` to allow the user to rotate the view by clicking and dragging. The left mouse button allows the user the rotate around to *x* and *y* axes, the right mouse button around the `x` and `z` axes.

After modifying the `rotationX, rotationY`, and/or `rotationZ` variables, we call `updateGL()` to redraw the scene.

```
void Cube::mouseDoubleClickEvent(QMouseEvent *event)
{
    int face = faceAtPosition(event->pos());
    if (face != -1) {
        QColor color = QColorDialog::getColor(faceColors[face],
                                              this);
        if (color.isValid()) {
            faceColors[face] = color;
            updateGL();
        }
    }
}
```

The `mouseDoubleClickEvent()` is reimplemented from `QWidget` to allow the user to set the color of a cube face by double-clicking it. We call the private function `faceAtPosition()` to determine which cube face, if any, is located under the cursor. If a face was double-clicked, we call `QColorDialog::getColor()` to obtain a new color for that face. Then we update the `faceColors` array with the new color, and we call `updateGL()` to redraw the scene.

```
int Cube::faceAtPosition(const QPoint &pos)
{
    const int MaxSize = 512;
    GLuint buffer[MaxSize];
    GLint viewport[4];

    glGetIntegerv(GL_VIEWPORT, viewport);
    glSelectBuffer(MaxSize, buffer);
    glRenderMode(GL_SELECT);

    glInitNames();
    glPushName(0);

    glMatrixMode(GL_PROJECTION);
    glPushMatrix();
    glLoadIdentity();
    gluPickMatrix((GLdouble)pos.x(),
                  (GLdouble) (viewport[3] - pos.y()),
                  5.0, 5.0, viewport);
   GLfloat x = (GLfloat)width() / height();
   glFrustum(-x, x, -1.0, 1.0, 4.0, 15.0);
   draw();
   glMatrixMode(GL_PROJECTION);
   glPopMatrix();

   if (!glRenderMode(GL_RENDER))
       return -1;
   return buffer[3];
}
```

The `faceAtPosition()` function returns the number of the face at a certain position on the widget, or –1 if there is no face at that position. The code for determining this in OpenGL is a bit complicated. Essentially, what we do is render the scene in `GL_SELECT` mode to take advantage of OpenGL's picking capabilities and then retrieve the face number (its "name") from the OpenGL hit record.

Here's `main.cpp`:

```
#include <qapplication.h>

#include "cube.h"

int main(int argc, char *argv[])
```

```
{
    QApplication app(argc, argv);
    if (!QGLFormat::hasOpenGL())
         qFatal("This system has no OpenGL support");

    Cube cube;
    cube.setCaption(QObject::tr("Cube"));
    cube.resize(300, 300);
    app.setMainWidget(&cube);

    cube.show();
    return app.exec();
}
```

If the user's system doesn't support OpenGL, we print an error message to the console and abort using Qt's `qFatal()` global function.

To link the application against the QGL and OpenGL libraries, the `.pro` file needs this entry:

```
CONFIG     += opengl
```

That completes the Cube application. For more information about the QGL module, see the reference documentation for `QGLWidget`, `QGLFormat`, `QGLContext`, and `QGLColormap`.

[Team LiB]
[Team LiB]
PREVIOUS NEXT
PREVIOUS NEXT

Chapter 9. Drag and Drop

Drag and drop is a modern and intuitive way of transferring information within an application or between different applications. It is often provided in addition to clipboard support for moving and copying data.

In this chapter, we will begin by showing how to add drag and drop support to a Qt application. Then we will reuse the drag and drop code to implement clipboard support. This code reuse is possible because both mechanisms rely on `QMimeSource`, an abstract base class that provides data in different formats.

[Team LiB]
[Team LiB]
PREVIOUS NEXT
PREVIOUS NEXT

Enabling Drag and Drop

Drag and drop involves two distinct actions: dragging and dropping. Widgets can serve as drag sites, as drop sites, or as both.

Drag and drop is a powerful mechanism for transferring data between applications. But in some cases, it's possible to implement drag and drop without using Qt's drag and drop facilities. If all you want to do is to move data within one widget in one application, it is usually simpler to reimplement the widget's mouse event handlers. This is the approach we took in the DiagramView widget in Chapter 8 (p. 190).

Our first example shows how to make a Qt application accept a drag initiated by another application. The Qt application is a main window with a QTextEdit as its central widget. When the user drags a file from the desktop or from a file explorer and drops it onto the application, the application loads the file into the QTextEdit.

Here's the definition of the MainWindow class:

```
class MainWindow : public QMainWindow
{
    Q_OBJECT
public:
    MainWindow(QWidget *parent = 0, const char *name = 0);

protected:
    void dragEnterEvent(QDragEnterEvent *event);
    void dropEvent(QDropEvent *event);

private:
    bool readFile(const QString &fileName);
    QString strippedName(const QString &fullFileName);

    QTextEdit *textEdit;
};
```

The MainWindow class reimplements dragEnterEvent() and dropEvent() from QWidget. Since the purpose of the example is to show drag and drop, much of the functionality we would expect to be in a main window class has been omitted.

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    setCaption(tr("Drag File"));
    textEdit = new QTextEdit(this);
    setCentralWidget(textEdit);
    textEdit->viewport() ->setAcceptDrops (false);
    setAcceptDrops(true);
}
```

In the constructor, we create a QTextEdit and set it as the central widget. We disable dropping on the QTextEdit's viewport and enable dropping on the main window.

The reason we must disable dropping on the QTextEdit is that we want to take over drag and drop handling ourselves in our MainWindow subclass. By default, QTextEdit accepts textual drags from other applications, and if the user drops a file onto it, it will insert the file name into the text. Since we want to drop the entire contents of the file rather than the file's name, we cannot make use of QTextEdit's drag and drop functionality and must implement our own.

Because drop events are propagated from child to parent, we get the drop events for the whole main window, including those for the QTextEdit, in MainWindow.

```
void MainWindow::dragEnterEvent(QDragEnterEvent *event)
{
    event->accept(QUriDrag::canDecode(event));
}
```

The dragEnterEvent() is called whenever the user drags an object onto a widget. If we call accept(true) on the event, we indicate that the user can drop the drag object on this widget; if we call accept(false), we indicate that the widget can't accept the drag. Qt automatically changes the cursor to indicate to the user whether or not the widget is a legitimate drop site.

Here we want the user to be allowed to drag files, but nothing else. To do so, we ask QUriDrag, the Qt class that handles file drags, whether it can decode the dragged object. The class can more generally be used for any universal resource identifier (URI), such as HTTP and FTP paths; hence the name QUriDrag.

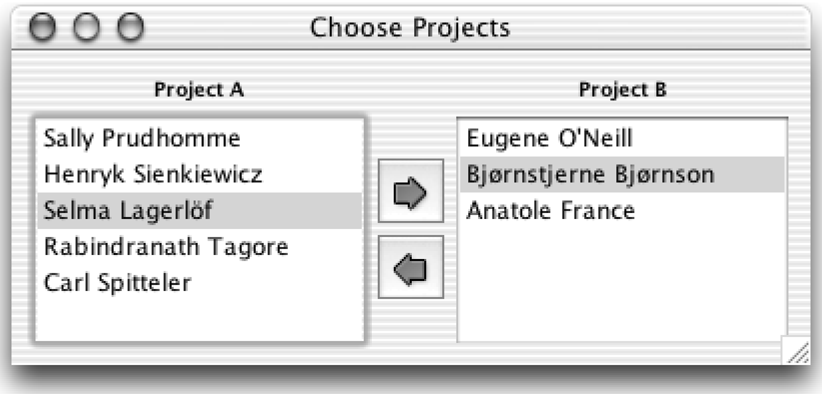
```
void MainWindow::dropEvent(QDropEvent *event)
{
    QStringList fileNames;
    if (QUriDrag::decodeLocalFiles(event, fileNames)) {
        if (readFile(fileNames[0]))
            setCaption(tr("%1 - Drag File")
                       .arg(strippedName(fileNames[0])));
    }
}
```

The dropEvent() is called when the user drops an object onto the widget. We call the static function QUriDrag::decodeLocalFiles() to get a list of file names dragged by the user and read in the first file in the list. (The second argument is passed as a non-const reference.) Typically, users only drag one file at a time, but it is possible for them to drag multiple files by dragging a selection.

QWidget also provides dragMoveEvent() and dragLeaveEvent(), but for most applications they don't need to be reimplemented.

The second example illustrates how to initiate a drag and accept a drop. We will create a QListBox subclass that supports drag and drop, and use it as a component in the Project Chooser application shown in Figure 9.1.

Figure 9.1. The Project Chooser application



The Project Chooser application presents the user with two list boxes, populated with names. Each list box represents a project. The user can drag and drop the names in the list boxes to move a person from one project to another.

The drag and drop code is all located in the QListBox subclass. Here's the class definition:

```
class ProjectView : public QListBox
{
    Q_OBJECT

public:
    ProjectView(QWidget *parent, const char *name = 0);

protected:
    void contentsMousePressEvent(QMouseEvent *event);
    void contentsMouseMoveEvent(QMouseEvent *event);
    void contentsDragEnterEvent(QDragEnterEvent *event);
    void contentsDropEvent(QDropEvent *event);

private:
    void startDrag();

    QPoint dragPos;
};
```

`ProjectView` reimplements four of the event handlers declared in `QScrollView` (`QListBox`'s base class).

```
ProjectView::ProjectView(QWidget *parent, const char *name)
    : QListBox(parent, name)

{
    viewport()->setAcceptDrops(true);
}
```

In the constructor, we enable drops on the `QScrollView` viewport.

```
void ProjectView::contentsMousePressEvent(QMouseEvent *event)
{
    if (event->button() == LeftButton)
        dragPos = event->pos();
    QListBox::contentsMousePressEvent(event);
}
```

When the user presses the left mouse button, we store the mouse position in the `dragPos` private variable. We call `QListBox`'s implementation of `contentsMousePressEvent()` to ensure that `QListBox` has the opportunity to process mouse press events as usual.

```
void ProjectView::contentsMouseMoveEvent(QMouseEvent *event)
{
    if (event->state() & LeftButton) {
        int distance = (event->pos() - dragPos).manhattanLength();
        if (distance > QApplication::startDragDistance())
            startDrag();
     }
     QListBox::contentsMouseMoveEvent(event);
}
```

When the user moves the mouse cursor while holding the left mouse button, we consider starting a drag. We compute the distance between the current mouse position and the position where the left mouse button was pressed.

If the distance is larger than `QApplication`'s recommended drag start distance (normally 4 pixels), we call the private function `startDrag()` to start dragging. This avoids initiating a drag just because the user's hand shakes.

```
void ProjectView::startDrag()
{
    QString person = currentText();
    if (!person.isEmpty()) {
        QTextDrag *drag = new QTextDrag(person, this);
        drag->setSubtype("x-person");
        drag->setPixmap(QPixmap::fromMimeSource("person.png"));
        drag->drag();
    }
}
```

In `startDrag()`, we create an object of type `QTextDrag` with `this` as its parent. The `QTextDrag` class represents a drag and drop object for transferring text. It is one of several predefined types of drag objects that Qt provides; others include `QImageDrag`, `QColorDrag`, and `QUriDrag`. We also set a pixmap to represent the drag. The pixmap is a small icon that follows the cursor while the drag is taking place.

We call `setSubtype()` to set the subtype of the object's MIME type to `x-person`. This causes the object's full MIME type to be `text/x-person`. If we didn't call `setSubtype()`, the MIME type would be `text/plain`.

Standard MIME types are defined by the Internet Assigned Numbers Authority (IANA). They consist of a type and a subtype separated by a slash. When we create non-standard types, such as `text/x-person`, it is recommended that an `x-` is prepended to the subtype. MIME types are used by the clipboard and by the drag and drop system to identify different types of data.

The `drag()` call starts the dragging operation. After the call, the `QTextDrag` object will remain in existence until the drag operation is finished. Qt takes ownership of the drag object and will delete it when it is no longer required, even if it is never dropped.

```
void ProjectView::contentsDragEnterEvent(QDragEnterEvent *event)
{
    event->accept(event->provides("text/x-person"));
}
```

The `ProjectView` widget not only originates drags of type `text/x-person`, it also accepts such drags. When a drag enters the widget, we check whether it has the correct MIME type and reject it if it hasn't.

```
void ProjectView::contentsDropEvent(QDropEvent *event)
{
    QString person;

    if (QTextDrag::decode(event, person)) {
        QWidget *fromWidget = event->source();
        if (fromWidget && fromWidget != this
                && fromWidget->inherits("ProjectView")) {
            ProjectView *fromProject = (ProjectView *) fromWidget;
            QListBoxItem *item =
                    fromProject->findItem(person, ExactMatch);
            delete item;
            insertItem(person);
        }
    }
}
```

In `contentsDropEvent()`, we use the `QTextDrag::decode()` function to extract the text carried by the drag. The `QDropEvent::source()` function returns a pointer to the widget that initiated the drag, if that widget is part of the same application. If the source widget is different from the target widget and is a `ProjectView`, we remove the item from the source widget (by calling `delete`) and insert a new item into the target.

[Team LiB] ◂ PREVIOUS NEXT ▸

Supporting Custom Drag Types

In the examples so far, we have relied on predefined Qt classes to hold the drag data. For example, we used QUriDrag for a file drag and QTextDrag for a text drag. Both of these classes inherit QDragObject, the base class for all drag objects. QDragObject itself inherits QMimeSource, an abstraction for providing MIME-typed data.

If we want to drag text, images, URIs, or colors, we can use Qt's QTextDrag, QImageDrag, QUriDrag, and QColorDrag classes. But if we want to drag custom data, none of these predefined classes is suitable, and so we must choose one of two alternatives:

- We can store the drag as binary data in a QStoredDrag object.
- We can create our own drag class by subclassing QDragObject and reimplementing a couple of virtual functions.

QStoredDrag allows us to store arbitrary binary data, so it can be used for any MIME type. For example, if we want to initiate a drag with the contents of a binary file that stores data in the (fictitious) ASDF format, we could use the following code:

```
void MyWidget::startDrag()
{
    QByteArray data = toAsdf();
    if (!data.isEmpty()) {
        QStoredDrag *drag = new QStoredDrag("octet-stream/x-asdf",
                                            this);
        drag->setEncodedData(data);
        drag->setPixmap(QPixmap::fromMimeSource("asdf.png"));
        drag->drag();
    }
}
```

One inconvenience of QStoredDrag is that it can only store a single MIME type. If we perform drag and drop within the same application or between multiple instances of the same application, this is seldom a problem. But if we want to interact nicely with other applications, one MIME type is rarely sufficient.

Another inconvenience is that we need to convert our data structure to a QByteArray even if the drag is not accepted in the end. If the data is large, this can slow down the application needlessly. It would be better to perform the data conversion only when the user actually drops the drag object.

A solution to both of these problems is to subclass QDragObject and reimplement format() and encodedData(), the two virtual functions used by Qt to obtain information about a drag. To show how this works, we will develop a Cell-Drag class that stores the contents of one or more cells in a rectangular QTable selection.

```
class CellDrag : public QDragObject
{
public:
    CellDrag(const QString &text, QWidget *parent = 0,
             const char *name = 0);

    const char *format(int index) const;
    QByteArray encodedData(const char *format) const;

    static bool canDecode(const QMimeSource *source);
    static bool decode(const QMimeSource *source, QString &str);
private:
    QString toCsv() const;
    QString toHtml() const;

    QString plainText;
};
```

The CellDrag class inherits QDragObject. The two functions that really matter for dragging are format() and encodedData(). It is convenient, although not strictly necessary, to provide canDecode() and decode() static functions to extract the data on a drop.

```
CellDrag::CellDrag(const QString &text, QWidget *parent,
                   const char *name)
    : QDragObject(parent, name)
{
    plainText = text;
}
```

The CellDrag constructor accepts a string that represents the contents of the cells that are being dragged. The string is in the "tabs and newlines" plain text format that we used in Chapter 4 when we added clipboard support to the Spreadsheet application (p. 80).

```
const char *CellDrag::format(int index) const
{
    switch (index) {
    case 0:
        return "text/csv";
    case 1:
        return "text/html";
    case 2:
        return "text/plain";
    default:
        return 0;
    }
}
```

The format() function is reimplemented from QMimeSource to return the different MIME types supported by the drag. We support three types: comma-separated values (CSV), HTML, and plain text.

When Qt needs to determine which MIME types are provided by the drag, it calls format() with an index parameter of 0, 1, 2, ..., up until format() returns a null pointer. The MIME types for CSV and HTML were obtained from the official list, available at http://www.iana.org/assignments/media-types/

The precise order of the formats is usually irrelevant, but it's good practice to put the "best" formats first. Applications that support many formats will sometimes use the first one that matches.

```
QByteArray CellDrag::encodedData(const char *format) const
{
    QByteArray data;
    QTextOStream out(data);

    if (qstrcmp(format, "text/CSV") == 0) {
        out << toCsv();
    } else if (qstrcmp(format, "text/html") == 0) {
        out << toHTML();
    } else if (qstrcmp(format, "text/plain") == 0) {
        out << plainText;
    }
    return data;
}
```

The encodedData() function returns the data for a given MIME type. The value of the format parameter is normally one of the strings returned by format(), but we can't assume that, since not all applications check the MIME type against format() beforehand. In Qt applications, this check is usually done by calling provides() on a QDragEnterEvent or QDragMoveEvent, as we did earlier (p. 219).

To convert a QString into a QByteArray, the best approach is to use a QText-Stream. If the string contains non-ASCII characters, QTextStream will assume that the encoding is the local 8-bit encoding. (For most European countries, this means ISO 8859-1 or ISO 8859-15; see Chapter 15 for details.) It can be instructed to use other encodings by calling setEncoding() or setCodec() on the stream, as explained in Chapter 15.

```
QString CellDrag::toCsv() const
{
    QString out = plainText;
    out.replace("\\", "\\\\");
    out.replace("\"", "\\\"");
    out.replace("\t", "\", \"");
    out.replace("\n", "\"\n\"");
    out.prepend("\"");
    out.append("\"");
    return out;
}

QString CellDrag::toHtml() const
{
    QString out = QStyleSheet::escape(plainText);
    out.replace("\t", "<td>");
    out.replace("\n", "\n<tr><td>");
    out.prepend("<table>\n<tr><td>");
    out.append("\n</table>");
    return out;
}
```

The toCsv() and toHtml() functions convert a "tabs and newlines" string into a CSV or an HTML string. For example, the data

```
Red      Green   Blue
Cyan     Yellow  Magenta
```

is converted to

```
"Red", "Green", "Blue"
"Cyan", "Yellow", "Magenta"
```

or to

```
<table>
<tr><td>Red<td>Green<td>Blue
<tr><td>Cyan<td>Yellow<td>Magenta
</table>
```

The conversion is performed in the simplest way possible, using QString::replace(). To escape HTML special characters, we use the QStyleSheet::escape() static convenience function.

```
bool CellDrag::canDecode(const QMimeSource *source)
{
    return source->provides("text/plain");
}
```

The canDecode() function returns true if we can decode the given drag, false otherwise. For maximum flexibility, its argument is a QMimeSource. The QMimeSource class is a base class of QDragObject, QDragEnterEvent, QDragMoveEvent, and QDropEvent.

Although we provide the data in three different formats, we only accept plain text. The reason for this is that plain text is normally sufficient. If the user drags cells from a QTable to an HTML editor, we want the cells to be converted into an HTML table. But if the user drags arbitrary HTML into a QTable, we don't want to accept it.

```
bool CellDrag::decode(const QMimeSource *source, QString &str)
{
   QByteArray data = source->encodedData("text/plain");
   str = QString::fromLocal8Bit((const char *)data, data.size());
   return !str.isEmpty();
}
```

Finally, the decode() function converts the text/plain data into a QString. Again, we assume the text is encoded using the local 8-bit encoding.

If we want to be certain of using the right encoding, we could use the charset parameter of the text/plain MIME type to specify an explicit encoding. Here are a few examples:

```
text/plain;charset=US-ASCII
text/plain;charset=ISO-8859-1
text/plain;charset=Shift_JIS
```

When we use QTextDrag, it always exports UTF-8, UCS-2 (UTF-16), US-ASCII, and the local 8-bit encoding, and accepts drops from other encodings as well. Considering this, it might be smarter to implement CellDrag::decode() simply by calling QTextDrag::decode(). But even with this approach, it's still a good idea to provide a CellDrag::decode() separate from QTextDrag::decode(), in case we want to extend it later to decode another type of drag (for example, CSV drags) in addition to plain text.

Now we have our CellDrag class. To make it useful, we must integrate it with QTable. It turns out that QTable already does almost all of the work for us. All we need to do is to subclass it, call setDragEnabled(true) in our subclass's constructor, and reimplement QTable::dragObject() to return a CellDrag. Here's an example:

```
QDragObject *MyTable::dragObject()
{
    return new CellDrag(selectionAsString(), this);
}
```

We have not shown the code for the selectionAsString(), because it is the same as the core of the Spreadsheet::copy() function (p. 80).

Adding drop support to a QTable would require us to reimplement contentsDragEnterEvent() and contentsDropEvent() in the same way as we did for the Project Chooser application.

[Team LiB] PREVIOUS NEXT

Advanced Clipboard Handling

Most applications make use of Qt's built-in clipboard handling in one way or another. For example, the QTextEdit class provides support for *Ctrl+X*, *Ctrl+C*, and *Ctrl+V*, along with cut(), copy(), and paste() slots, so little or no additional code is required.

When writing our own classes, we can access the clipboard through QApplication ::clipboard(), which returns a pointer to the application's QClipboard object. Handling the system clipboard is easy: Call setText(), setImage(), or setPixmap() to put data on the clipboard, and text(), image(), or pixmap() to retrieve the data. We have already seen examples of clipboard use in the Spreadsheet application from Chapter 4 and in the Diagram application from Chapter 8.

For some applications, the built-in functionality might not be sufficient. For example, we might want to provide data that isn't just text or an image. Or we might want to provide data in many different formats, for maximum interoperability with other applications. The issue is very similar to what we encountered earlier with drag and drop, and the answer is also similar: We must subclass QMimeSource and reimplement format() and encodedData().

If our application supports drag and drop, we can simply reuse our custom QDragObject subclass and put it on the clipboard using the setData() function. Since QDragObject inherits QMimeSource and the clipboard understand QMimeSources, this works seamlessly.

For example, here's how we could implement the copy() function of a QTable subclass:

```
void MyTable::copy()
{
    QApplication::clipboard()->setData(dragObject());
}
```

At the end of the previous section, we implemented dragObject() to return a CellDrag that stores the selected cells' contents.

To retrieve the data, we can call data() on the clipboard. Here's how we could implement the paste() function of a QTable subclass:

```
void MyTable::paste()
{
    QMimeSource *source = QApplication::clipboard() ->data();
    if (CellDrag::canDecode(source)) {
        QString str;
        CellDrag::decode(source, str);
        performPaste(str);
    }
}
```

The performPaste() is essentially the same as the Spreadsheet::paste() function presented in Chapter 4 (p. 81).

This is all that is required, along with a custom QMimeSource, to add clipboard support for a custom type.

The X11 clipboard provides additional functionality not available on Windows or Mac OS X. On X11, it is usually possible to paste a selection by clicking the middle button of a three-button mouse. This is done using a separate "selection" clipboard. If you want your widgets to support this kind of clipboard as well as the standard one, you must pass QClipboard::Selection as an additional argument to the various clipboard calls. For example, here's how we would reimplement mouseReleaseEvent() in a text editor to support pasting using the middle mouse button:

```
void MyTextEditor::mouseReleaseEvent(QMouseEvent *event)
{
    QClipboard *clipboard = QApplication::clipboard();
    if (event->button() == MidButton
            && clipboard->supportsSelection()) {
        QString text = clipboard->text(QClipboard::Selection);
        pasteText(text);
    }
}
```

On X11, the supportsSelection() function returns true. On other platforms, it returns false.

[Team LiB]
PREVIOUS NEXT

Chapter 10. Input/Output

This chapter covers reading and writing files, traversing the file system, and interacting with external programs.

Qt's QDataStream and QTextStream classes make it simple to read and write files. These classes take care of issues such as byte ordering and text encodings, ensuring that Qt applications running on different platforms can read and write each other's files.

Many applications need to traverse directories or get information about a file. Qt's QDir and QFileInfo classes makes this possible.

In some situations, it is necessary to run external programs from within a GUI program. Qt's QProcess class allows us to execute external programs asynchronously, keeping the GUI responsive, with signals to tell us how the execution is progressing.

[Team LiB]
PREVIOUS NEXT

Reading and Writing Binary Data

Reading and writing binary data using QDataStream is the simplest way to load and save custom data with Qt. QDataStream supports many Qt data types, including QByteArray, QFont, QImage, QMap<K, T>, QPixmap, QString, QValueList<T>, and QVariant. The data types that QDataStream understands and the formats it uses to store them are described online at http://doc.trolltech.com/3.2/ datastreamformat.html.

To show how to handle binary data, we will use two example classes: Drawing and Gallery. The Drawing class holds some basic information about a drawing (the artist's name, the title, and the year it was created), and the Gallery class holds a list of Drawings.

We will start with the Gallery class.

```
class Gallery : public QObject
{
public:
    bool loadBinary(const QString &fileName);
    bool saveBinary(const QString &fileName);
    ...

private:
    enum { MagicNumber = 0x98c58f26 };

    void writeToStream(QDataStream &out);
    void readFromStream(QDataStream &in);
    void error(const QFile &file, const QString &message);
    void ioError(const QFile &file, const QString &message);

    QByteArray getData();
    void setData(const QByteArray &data);
    QString toString();

    std::list<Drawing> drawings;
};
```

The Gallery class contains public functions to save and load its data. The data is a list of drawings held in the drawings data member. The private functions will be reviewed as we make use of them.

Here is a simple function for saving a Gallery' drawings as binary data:

```
bool Gallery::saveBinary(const QString &fileName)
{
    QFile file(fileName);
    if (!file.open(IO_WriteOnly)) {
        ioError(file, tr("Cannot open file %1 for writing"));
        return false;
    }

    QDataStream out(&file);
    out.setVersion(5);

    out << (Q_UINT32)MagicNumber;
    writeToStream(out);

    if (file.status() != IO_Ok) {
        ioError(file, tr("Error writing to file %1"));
        return false;

    }
    return true;
}
```

We open a file and make the file the target of a QDataStream. We set the QDataStream's version to 5 (the most recent version in Qt 3.2). The version number influences the way Qt data types are represented. Basic C++ data types are always represented the same way.

We then output a number that identifies the Gallery file format (MagicNumber). To ensure that the number is written as a 32-bit integer on all platforms, we cast it to Q_UINT32, a data type that is guaranteed to be exactly 32 bits.

The file body is written by the writeToStream() private function. We don't need to explicitly close the file; this is done automatically when the QFile variable goes out of scope at the end of the function.

After the call to writeToStream(), we check the status of the QFile device. If there was an error, we call ioError() to present a message box to the user and return false.

```
void Gallery::ioError(const QFile &file, const QString &message)
{
    error(file, message + ": " + file.errorString());
}
```

The ioError() function relies on the more general error() function:

```
void Gallery::error(const QFile &file, const QString &message)
{
    QMessageBox::warning(0, tr("Gallery"), message.arg(file.name()));
}
```

Now let's review the writeToStream() function:

```
void Gallery::writeToStream(QDataStream &out)
{
    list<Drawing>::const_iterator it = drawings.begin();
    while (it != drawings.end()) {
        out << *it;
        ++it;
    }
}
```

The writeToStream() function iterates over all of the Gallery's drawings and outputs them to the stream it has been given, relying on the Drawing class's << operator. If we had used a QValueList<Drawing> to store the drawings instead of a list<Drawing>, we could have omitted the loop and simply written

```
out << drawings;
```

When a QValueList<T> is streamed, each item stored in the list is output using the item type's << operator.

```
QDataStream &operator<<(QDataStream &out, const Drawing &drawing)
{
    out << drawing.myTitle << drawing.myArtist << drawing.myYear;
    return out;
}
```

To output a Drawing, we simply output its three private member variables: myTitle, myArtist, and myYear. We need to declare operator<<() as a friend of Drawing for this to work. At the end of the function, we return the stream. This is a common C++ idiom that allows us to use a chain of << operators with an output stream. For example:

```
out << drawing1 << drawing2 << drawing3;
```

The definition of the Drawing class follows.

```
class Drawing
{
    friend QDataStream &operator<<(QDataStream &, const Drawing &);
    friend QDataStream &operator>>(QDataStream &, Drawing &);

public:
    Drawing() { myYear = 0; }
    Drawing(const QString &title, const QString &artist, int year)
    { myTitle = title; myArtist = artist; myYear = year; }

    QString title() const { return myTitle; }
    void setTitle(const QString &title) { myTitle = title; }
    QString artist() const { return myArtist; }
    void setArtist(const QString &artist) { myArtist = artist; }
    int year() const { return myYear; }
    void setYear(int year) { myYear = year; }

private:
    QString myTitle;
    QString myArtist;
    int myYear;
};
```

Now let's see how to read the data from a Gallery file:

```
bool Gallery::loadBinary(const QString &fileName)
{
    QFile file(fileName);
    if (!file.open(IO_ReadOnly)) {
        ioError(file, tr("Cannot open file %1 for reading"));
        return false;
    }
    QDataStream in (&file);
    in.setVersion(5);

    Q_UINT32 magic;
    in >> magic;
    if (magic != MagicNumber) {
        error(file, tr("File %1 is not a Gallery file"));
        return false;
    }

    readFromStream(in);

    if (file.status() != IO_Ok) {
        ioError(file, tr("Error reading from file %1"));
        return false;
    }
    return true;
}
```

We open the file for reading and create a `QDataStream` to extract the data from the file. We set the `QDataStream`'s version to 5, because that's the version we used for writing. By using a fixed version number of 5, we guarantee that the application can always read and write the data, providing it is compiled with Qt 3.2 or later.

We start by reading back the magic number we wrote and compare it against `MagicNumber`. This ensures that we are really reading a Gallery file. We then read the data itself using the `readFromStream()` function.

```
void Gallery::readFromStream(QDataStream &in)
{
    drawings.clear();
    while (!in.atEnd()) {
        Drawing drawing;
        in >> drawing;
        drawings.push_back(drawing);
    }
}
```

In `readFromStream()`, we start by clearing any existing data. We then read in one drawing at a time, relying on the `>>` operator, and append each one to the `Gallery`'s list of drawings. If we were using a `QValueList<Drawing>` to store the data instead of a `list<Drawing>`, we could read in all the drawings without looping:

```
in >> drawings;
```

`QValueList<T>` relies on the item type's `>>` operator to read in the items.

```
QDataStream &operator>>(QDataStream &in, Drawing &drawing)
{
    in >> drawing.myTitle >> drawing.myArtist >> drawing.myYear;
    return in;
}
```

The implementation of the `>>` operator mirrors that of the `<<` operator. When we use `QDataStream`, we don't need to perform any kind of parsing.

If we want to read and write some raw binary data, we can use `readRawBytes()` and `writeRawBytes()` to read and write a block of bytes through a `QDataStream`. The raw bytes are *not* preceded by a block size.

We can read and write standard binary formats, such as DBF files and TEX DVI files, using the `>>` and `<<` operators on basic types (like `Q_UINT16` or `float`) or with `readRawBytes()` and `writeRawBytes()`. The default byte ordering used by `QDataStream` is big-endian. If we want to read and write data as little-endian, we must call

```
stream.setByteOrder(QDataStream::LittleEndian);
```

If the `QDataStream` is being used purely to read and write basic C++ data types, there is no need to use `setVersion()`.

If we want to read or write a file in one go, we can avoid using `QDataStream` altogether and instead use `QFile`'s `writeBlock()` and `readAll()` functions. For example:

```
file.writeBlock(getData());
```

Data written in this way is just a sequence of bytes. We are responsible for structuring the data when we write it and for parsing it when we read it back. We rely on `Gallery`'s private `getData()` function to create the `QByteArray` and populate it with data. Reading it back is just as easy:

```
setData(file.readAll());
```

We use `Gallery`'s `setData()` function to extract the information out of the `QByteArray`.

Having all the data in a `QByteArray` requires more memory, but it offers some advantages. For example, we can then use Qt's `qCompress()` function to compress the data (using zlib):

```
file.writeBlock(qCompress(getData()));
```

We can then use qUncompress() to uncompress the data:

```
setData(qUncompress(file.readAll()));
```

One way to implement getData() and setData() is to use a QDataStream on a QByteArray. Here's getData():

```
QByteArray Gallery::getData()
{
    QByteArray data;
    QDataStream out(data, IO_WriteOnly);
    writeToStream(out);
    return data;
}
```

We create a QDataStream that writes to a QByteArray rather than to a QFile, and we use the writeToStream() function we wrote earlier to fill the array with binary data.

Similarly, the setData() function can use the readFromStream() function we wrote earlier:

```
void Gallery::setData(const QByteArray &data)
{
    QDataStream in(data, IO_ReadOnly);
    readFromStream(in);
}
```

In the earlier examples, we loaded and saved the data with the stream's version hard-coded to 5. This approach is simple and safe, but it does have one small drawback: We cannot take advantage of new or updated formats. For example, if a later version of Qt added a new component to QFont (in addition to its point size, family, etc.), that component would not be saved or loaded.

One solution is to embed the QDataStream version number in the file:

```
QDataStream out(&file);
out << (Q_UINT32)MagicNumber;
out << (Q_UINT16)out.version();
writeToStream(out);
```

This ensures that we always write the data using the most recent version of QDataStream, whatever that happens to be.

When we come to read the file, we read the magic number and the stream version:

```
QDataStream in(&file);

Q_UINT32 magic;
Q_UINT16 streamVersion;
in >> magic >> streamVersion;

if (magic != MagicNumber) {
    error(file, tr("File %1 is not a Gallery file"));
    return false;
} else if ((int)streamVersion > in.version()) {
    error(file, tr("File %1 is from a more recent version of the "
                   "application"));
    return false;
}
```

```
in.setVersion(streamVersion);
readFromStream(in);
```

We can read the data as long as the stream version is less than or equal to the version used by the application. Otherwise, we report an error.

If the file format contains a version number of its own, we can use that instead of the stream version number. For example, let's suppose that the file format is for version 1.3 of our application. We might then write the data as follows:

```
QDataStream out(&file);
out.setVersion(5);
out << (Q_UINT32)MagicNumber;
out << (Q_UINT16)0x0103;
writeToStream(out);
```

When we read it back, we determine which `QDataStream` version to use based on the application's version number:

```
QDataStream in(&file);

Q_UINT32 magic;
Q_UINT16 appVersion;
in >> magic >> appVersion;

if (magic != MagicNumber) {
    error(file, tr("File %1 is not a Gallery file"));
    return false;
}   else if (appVersion > 0x0103) {
      error(file, tr("File %1 is from a more recent version of the "
                     "application"));
      return false;
}

if (appVersion <= 0x0102) {
    in.setVersion(4);
} else {
    in.setVersion(5);
}
readFromStream(in);
```

In this example, we say that any file saved with version 1.2 or earlier of the application uses data stream version 4, and that files saved with version 1.3 of the application use data stream version 5.

Once we have a policy for handling `QDataStream` versions, reading and writing binary data using Qt is simple and reliable.

Reading and Writing Text

Qt provides the `QTextStream` class for reading and writing textual data. We can use `QTextStream` for reading and writing plain text files or files of other textual file formats, such as HTML, XML, and source files. It takes care of converting between Unicode and the system's local 8-bit encoding, and transparently handles the different line-ending conventions used by different operating systems.

`QTextStream` uses `QChar` as its fundamental unit of data. In addition to characters and strings, QTextStream supports C++'s basic numeric types, which it converts to and from strings.

To show how to use QTextStream, we will continue with the Gallery example from the previous section. Here's the code for a saveText() function that saves the drawings data from a Gallery:

```
bool Gallery::saveText(const QString &fileName)
{
    QFile file(fileName);
    if (!file.open(IO_WriteOnly | IO_Translate)) {
        ioError(file, tr("Cannot open file %1 for writing"));
        return false;
    }

    QTextStream out(&file);
    out.setEncoding(QTextStream::UnicodeUTF8);

    list<Drawing>::const_iterator it = drawings.begin();
    while (it != drawings.end()) {
        out << *it;
        ++it;
    }
    if (file.status() != IO_Ok) {
        ioError(file, tr("Error writing to file %1"));
        return false;
    }
    return true;
}
```

We open the file with the IO_Translate flag to translate newline characters to the correct sequence for the target platform ("\r\n" on Windows, "\r" on Mac OSX). Then we set the encoding to UTF-8, an ASCII-compatible encoding that can represent the entire Unicode character set. (For more information about Unicode, see Chapter 15.) To handle the output, we iterate over each drawing in the Gallery relying on the << operator:

```
QTextStream &operator<<(QTextStream &out, const Drawing &drawing)
{
    out << drawing.myTitle << ":" << drawing.myArtist << ":"
        << drawing.myYear << endl;
    return out;
}
```

When writing out a drawing, we use a colon to separate the drawing's title from the artist's name and another colon to separate the artist's name from the year, and we end the data with a newline. We assume that the title and the artist's name don't contain colons or newlines.

Here's an example file output by saveText():

```
The False Shepherds:Hans Bol:1576
Panoramic Landscape:Jan Brueghel the Younger:1619
Dune Landscape:Jan van Goyen:1630
River Delta:Jan van Goyen:1653
```

Now let's look at how we can read the data from the file:

```
bool Gallery::loadText(const QString &fileName)
{
    QFile file(fileName);
    if (!file.open(IO_ReadOnly | IO_Translate)) {
        ioError(file, tr("Cannot open file %1 for reading"));
        return false;
    }

    drawings.clear();
    QTextStream in(&file);
    in.setEncoding(QTextStream::UnicodeUTF8);

    while (!in.atEnd()) {
        Drawing drawing;
        in >> drawing;
        drawings.push_back(drawing);
    }

    if (file.status() != IO_Ok) {
        ioError(file, tr("Error reading from file %1"));
        return false;
    }
    return true;
}
```

The interesting part is the `while` loop. As long as there is more data available, we read it in using the `>>` operator.

Implementing the `>>` operator isn't trivial, because textual data is fundamentally ambiguous. Let's consider the following example:

```
out << "alpha" << "bravo";
```

If `out` is a `QTextStream`, the data that actually gets written is the string "alphabravo". We can't really expect this to work with a `QTextStream`:

```
in >> str1 >> str2;
```

In fact, what happens then is that `str1` gets the whole word "alphabravo", and `str2` gets nothing. `QDataStream` doesn't have that problem because it stores the length of each string in front of the character data.

If the text we write out consists of single words, we can put spaces between them and read the data back word by word. (The `DiagramView::copy()` and `DiagramView::paste()` functions of Chapter 8 use this approach.) We can't do this for the drawings because artist names and drawing titles usually contain more than one word. So we read each line in as a whole and then split it into fields using `QStringList::split()`:

```
QTextStream &operator>>(QTextStream &in, Drawing &drawing)
{
    QString str = in.readLine();
    QStringList fields = QStringList::split(":", str);
    if (fields.size() == 3) {
        drawing.myTitle = fields[0];
        drawing.myArtist = fields[1];
        drawing.myYear = fields[2].toInt();
    }
    return in;
}
```

We can read entire text files in one go using `QTextStream::read()`:

```
QString wholeFile = in.read();
```

In the resulting string, the end of each line is signified with a newline character ('\n') regardless of the line-ending convention used by the file being read.

Reading in an entire text file can be very convenient if we need to preprocess the data. For example:

```
wholeFile.replace("&", "&");
wholeFile.replace("<", "<");
wholeFile.replace(">", ">");
```

For writing in one go, we could put all our data into a single string and simply output that.

```
QString Gallery::saveToString()
{
    QString result;
    QTextOStream out(&result);
    list<Drawing>::const_iterator it = drawings.begin();
    while (it != drawings.end()) {
        out << *it;
        ++it;
    }
    return result;
}
```

It is just as easy to stream text into a string as it is to stream it to a file, again relying on the `<<` operator.

```
void Gallery::readFromString(const QString &data)
{
    QString string = data;
    drawings.clear();
    QTextIStream in(&string);
    while (!in.atEnd()) {
        Drawing drawing;
        in >> drawing;
        drawings.push_back(drawing);
    }
}
```

Extracting the data from a string using a `QTextStream` is straightforward. No parsing is necessary because we rely on the `>>` operator.

Writing text data isn't difficult, but reading text can be challenging. For complex formats, a full-blown parser might be required. Such a parser would typically work by reading the data character by character using `>>` on a `QChar`, or line by line using `readLine()` and iterating through the returned `QString`.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Handling Files and Directories

Qt's `QDir` class provides a platform-independent means of traversing directories and retrieving information about files. To see how `QDir` is used, we will write a small console application that calculates the space consumed by all the images in a particular directory and all its subdirectories to any depth.

The heart of the application is the `imageSpace()` function, which computes the size of a given directory:

```
int imageSpace(const QString &path)
{
    QDir dir(path);
    QStringList::Iterator it;
    int size = 0;

    QStringList files = dir.entryList("*.png *.jpg *.jpeg",
                                      QDir::Files);
    it = files.begin();
    while (it != files.end()) {
        size += QFileInfo(path, *it).size();
        ++it;
    }

    QStringList dirs = dir.entryList(QDir::Dirs);
    it = dirs.begin();
    while (it != dirs.end()) {
        if (*it != "." && *it != "..")
            size += imageSpace(path + "/" + *it);
        ++it;
    }
    return size;
}
```

We begin by creating a `QDir` object using the given path. We pass the `entryList()` function two arguments. The first is a space-separated list of file name filters. These can contain '*' and '?' wildcard characters. In this example, we are filtering to include only PNG and JPEG files. The second argument specifies what kind of entries we want (normal files, directories, drives, etc.).

We iterate over the list of files, accumulating their sizes. The `QFileInfo` class allows us to access a file's attributes, such as its size, permissions, owner, and timestamps.

The second `entryList()` call retrieves all the subdirectories in this directory. We iterate over them and recursively call `imageSpace()` to ascertain their accumulated image sizes.

To create each subdirectory's path, we combine the current directory's path with the subdirectory name (`*it`), separating them with a slash. `QDir` treats'/' as a directory separator on all platforms, in addition to '\' on Windows. When presenting paths to the user, we can call the static function `QDir::convertSeparators()` to convert slashes to the correct platform-specific separator.

Let's add a `main()` function to our small program:

```
int main(int argc, char *argv[])
{
    QString path = QDir::currentDirPath();
    if (argc > 1)
        path = argv[1];

    cerr << "Space used by images in " << endl
         << path.ascii() << endl
         << "and its subdirectories is"
         << (imageSpace(path) / 1024) << " KB" << endl;

    return 0;
}
```

For this example, we don't need a QApplication object, because we are only using Qt's tool classes. See http://doc.trolltech.com/3.2/tools.html for the list of these classes.

We use QDir::currentDirPath() to initialize the path to the current directory. Alternatively, we could have used QDir::homeDirPath() to initialize it to the user's home directory. If the user has specified a path on the command line, we use that instead. Finally, we call our imageSpace() function to calculate how much space is consumed by images.

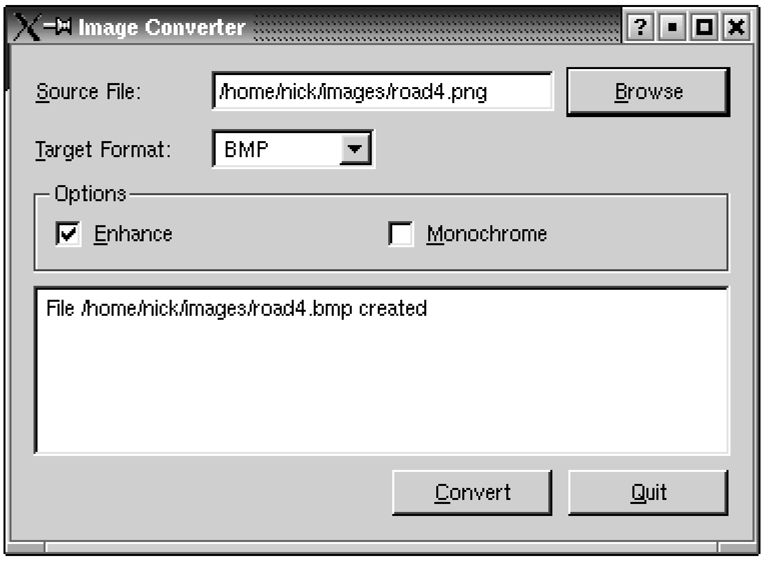
The QDir class provides other file and directory-related functions, including rename(), exists(), mkdir(), and rmdir(). The QFile class provides some static convenience functions, including remove() and exists().

Inter-Process Communication

The QProcess class allows us to execute and interact with external programs. The class works asynchronously, doing its work in the background so that the user interface remains responsive. QProcess emits signals to notify us when the external process has data or has finished.

We will develop a small application that provides a user interface for an external image conversion program. For this example, we make use of the ImageMagick convert program, which is freely available for all major platforms.

Figure 10.1. The Image Converter application



/home/nick/images/road4.png

BMP

[✓ Enhance] Monochrome

File /home/nick/images/road4.bmp created

The Image Converter's user interface was created in *Qt Designer*. The .ui file is on the CD that accompanies this book. Here, we will focus on the .ui.h file that contains the code. Note that the process and fileFilters variables were declared in *Qt Designer*'s Members tab as follows:

```
QProcess *process;
QString fileFilters;
```

The uic tool includes these variables as part of the generated ConvertDialog class.

```
void ConvertDialog::init()
{
    process = 0;
    QStringList imageFormats = QImage::outputFormatList();
    targetFormatComboBox->insertStringList(imageFormats);
    fileFilters = tr("Images") + " (*."
                  + imageFormats.join(" *.").lower() + ")";
}
```

A file filter consists of a descriptive text and one or more wildcard patterns(for example, "Text files(*.txt)"). The `QImage::outputFormatList()` function returns a list of the image output formats that are supported by Qt. This list can vary depending on the options that were selected when Qt was installed.

```
void ConvertDialog::browse()
{
    QString initialName = sourceFileEdit->text();
    if (initialName.isEmpty())
        initialName = QDir::homeDirPath();
    QString fileName =
            QFileDialog::getOpenFileName(initialName, fileFilters,
                                         this);

    fileName = QDir::convertSeparators(fileName);
    if (!fileName.isEmpty()) {
        sourceFileEdit->setText(fileName);
        convertButton->setEnabled(true);
    }
}
```

The dialog's *Browse* button is connected to the `browse()` slot. If the user has previously selected a file, we initialize the file dialog with that file's path; otherwise, we use the user's home directory.

```
void ConvertDialog::convert()
{
    QString sourceFile = sourceFileEdit->text();
    targetFile = QFileInfo(sourceFile).dirPath()
                 + QDir::separator() + QFileInfo(sourceFile).baseName();
    targetFile += ".";
    targetFile += targetFormatComboBox->currentText().lower();
    convertButton->setEnabled(false);
    outputTextEdit->clear();

    process = new QProcess(this);
    process->addArgument("convert");
    if (enhanceCheckBox->isChecked())
        process->addArgument("-enhance");
    if (monochromeCheckBox->isChecked())
        process->addArgument("-monochrome");
    process->addArgument(sourceFile);
    process->addArgument(targetFile);
    connect(process, SIGNAL(readyReadStderr()),
            this, SLOT(updateOutputTextEdit()));
     connect(process, SIGNAL(processExited()),
             this, SLOT(processExited()));
     process->start();
}
```

The dialog's *Convert* button is connected to the `convert()` slot. We copy the source file's name and change its suffix to match the target file format.

We then create a `QProcess` object. The first argument given to a `QProcess` object using `addArgument()` is the name of the external program to execute. Subsequent arguments become this program's arguments.

We connect the Qprocess's readyReadStderr() to the dialog's updateOutputTextEdit() slot to display error messages from the external program in the dialog's QTextEdit as they are generated. We also connect the Qprocess's processExited() signal to the dialog's slot of the same name.

```
void ConvertDialog::updateOutputTextEdit()
{
    QByteArray data = process->readStderr();
    QString text = outputTextEdit->text() + QString(data);
    outputTextEdit->setText(text);
}
```

Whenever the external process writes to stderr, our updateOutputTextEdit() slot is called. We read the error text and append it to the QTextEdit.

```
void ConvertDialog::processExited()
{
    if (process->normalExit()) {
        outputTextEdit->append(tr("File %1 created")
                                   .arg(targetFile));
    } else {
        outputTextEdit->append(tr("Conversion failed"));
    }
    delete process;
    process = 0;
    convertButton->setEnabled(true);
}
```

When the process has finished, we let the user know the outcome and then delete the process.

Wrapping a console application in this way can be useful because it allows us to make use of preexisting functionality rather than having to implement that functionality ourselves. Another use of QProcess is to launch other GUI applications, such as a web browser or an email client.

Chapter 11. Container Classes

Container classes are general purpose template classes that store items of a given type in memory. Standard C++ already includes many containers as part of the Standard Template Library (STL).

Qt provides its own container classes, so when we write Qt programs, we can use both the Qt and the STL containers. If you are already familiar with the STL containers and have STL available on your target platforms, there's no particular reason to use the Qt containers.

In this chapter, we review the most important STL and Qt containers. We also look at QString and QVariant, two classes that have many things in common with containers and that can be used as alternatives to containers in some contexts.

For more information about the STL classes and functions, a good place to start is SGI's STL web site: http://www.sgi.com/tech/stl/.

Vectors

The STL and Qt classes for vectors, lists, and maps are template classes parameterized by the types of the objects we want to store in them. The values that can be stored in these classes can be basic types (like int and double), pointers, or classes that have a default constructor (a constructor that takes or needs no arguments), a copy constructor, and an assignment operator. Classes that qualify include QDateTime, QRegExp, QString, and QVariant. Qt classes that inherit from QObject don't qualify, because they don't implement a copy constructor and an assignment operator. This isn't usually a problem, since we can still store pointers to these types.

In this section, we will review the most common operations for vectors, and in the next two sections, we will review lists and maps. For most of the examples, we will use the Film class, which stores the title and duration of a film. (We will not call the class Movie because that looks too similar to Qt's QMovie class, which is used to show animated images.)

Here's the definition of Film:

```
class Film
{
public:
    Film(int id = 0, const QString &title = "", int duration = 0);

    int id() const { return myId; }
    void setId(int catalogId) { myId = catalogId; }
    QString title() const { return myTitle; }
    void setTitle(const QString &title) { myTitle = title; }
    int duration() const { return myDuration; }
    void setDuration(int minutes) { myDuration = minutes; }

private:
    int myId;
    QString myTitle;
    int myDuration;
};

int operator==(const Film &film1, const Film &film2);
int operator<(const Film &film1, const Film &film2);
```

We don't explicitly provide a copy constructor or an assignment operator because the ones automatically supplied by C++ suffice here. If the class had included pointers to memory allocated by the class, we would have to implement them ourselves.

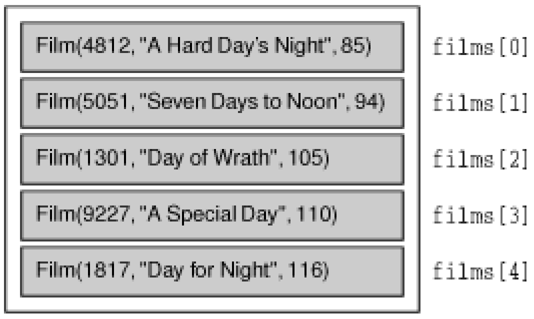
In addition to the class, we provide an equality operator and a "less than" operator. The equality operator is used when we search a container to see if it contains a particular item. The "less than" operator is used for comparing items when sorting them. We don't need to implement the four other comparison operators (!=, <=, >, >=) since STL never uses them.

Here's the implementation of the three non-inline functions:

```
Film::Film(int id, const QString &title, int duration)
{
    myId = id;
    myTitle = title;
    myDuration = duration;
}

int operator==(const Film &film1, const Film &film2)
{
    return film1.id() == film2.id();
}

int operator<(const Film &film1, const Film &film2)
{
    return film1.id() < film2.id();
}
```

When comparing `Film` objects, we use IDs rather than titles because titles are not necessarily unique.

Figure 11.1. A vector of `Film`s



Film(4812, "A Hard Day's Night", 85)
films[0]
Film(5051, "Seven Days to Noon", 94)
films[1]
Film(1301, "Day of Wrath", 105)
films[2]
Film(9227, "A Special Day", 110)
films[3]
Film(1817, "Day for Night", 116)
films[4]

A vector is a data structure that stores its items at adjacent positions in memory. What distinguishes a vector from a plain C++ array is that a vector knows its own size and can be resized. Appending extra elements to the end of a vector is fairly efficient, but inserting elements at the front or in the middle of a vector is expensive.

The STL's vector class is called `std::vector<T>` and is defined in `<vector>`. Here's an example:

```
vector<Film> films;
```

The Qt equivalent is called `QValueVector<T>`:

```
QValueVector<Film> films;
```

A vector created like this has size 0. If we know in advance how many elements we are going to need, we can give the vector an initial size when we define it and use the `[]` operator to assign a value to its elements; otherwise, we must either resize it later or append items.

A convenient way to populate a vector is to use `push_back()`. This function appends an element at the end, extending the vector by one:

```
films.push_back(Film(4812, "A Hard Day's Night", 85));
films.push_back(Film(5051, "Seven Days to Noon", 94));
films.push_back(Film(1301, "Day of Wrath", 105));
films.push_back(Film(9227, "A Special Day", 110));
films.push_back(Film(1817, "Day for Night", 116));
```

In general, Qt offers the same function names as the STL, although in some cases Qt has additional more Qt-like names. For example, if we are using the Qt classes, we can append items using either `push_back()` or `append()`.

Another way to populate a vector is to give the vector an initial size and to initialize the elements individually:

```
vector<Film> films(5);
films[0] = Film(4812, "A Hard Day's Night", 85);
films[1] = Film(5051, "Seven Days to Noon", 94);
films[2] = Film(1301, "Day of Wrath", 105);
films[3] = Film(9227, "A Special Day", 110);
films[4] = Film(1817, "Day for Night", 116);
```

Vector entries that are created without being assigned an explicit value are initialized using the item class's default constructor. For basic and pointer types, the value is undefined, just as it is when we define variables of these types on the stack.

We can iterate over the vector's elements using the `[]` operator:

```
for (int i = 0; i < (int)films.size(); ++i)
    cerr << films[i].title().ascii() << endl;
```

Alternatively, we can use an iterator:

```
vector<Film>::const_iterator it = films.begin();
while (it != films.end()) {
    cerr << (*it).title().ascii() << endl;
    ++it;
}
```

Every container class has two iterator types: `iterator` and `const_iterator`. The difference between the two is that `const_iterator` doesn't allow us to modify the data.

A container's `begin()` function returns an iterator that refers to the first item in the container (for example, `films[0]`). A container's `end()` function returns an iterator that refers to the "one past the last" item (for example, `films[5]`). If a container is empty, `begin()` equals `end()`. This can be used to see if the container has any elements, although it is more convenient to call `empty()` for this purpose.

Iterators have an intuitive syntax that resembles the syntax of C++ pointers. We can use the `++` and `--` operators to move to the next or previous item, and unary `*` to retrieve the item stored at the current iterator position. In fact, for `vector<T>`, the `iterator` and `const_iterator` types are merely typedefs for `T *` and `const T *`.

If we want to find an item in a vector using a linear search, we can use the STL `find()` function:

```
vector<Film>::iterator it = find(films.begin(), films.end(),
                                 Film(4812));
if (it != films.end())
    films.erase(it);
```

The `find()` function returns an iterator to the first item that compared equal (using `operator==()`) to the item passed as the last argument. It is defined in `<algorithm>`, along with many other template functions. These functions typically operate on iterators. Qt provides a few of these functions under different names (for example, qFind()). You can use them if you want to use Qt without the STL.

To sort the items in a vector, we can call sort():

```
sort(films.begin(), films.end());
```

The sort() function uses the < operator to compare items, unless we pass a different comparison function.

Once sorted, we can use the binary_search() function to see if an item is present. On a sorted vector, binary_search() gives the same result as find() (assuming no two films have the same ID), but is much faster:

```
int id = 1817;
if (binary_search(films.begin(), films.end(), Film(id)))
    cerr << "Found" << id << endl;
```

Given a position indicated by an iterator, we can expensively insert a new item using insert() or remove an existing item using erase():

```
films.erase(it);
```

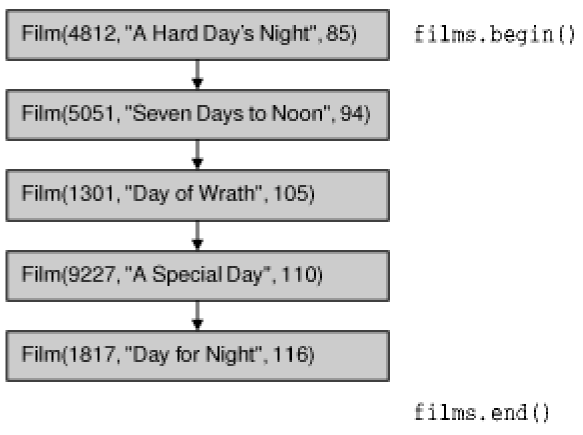
The items that follow the erased item in the vector are then moved one position to the left to fill its position, and the vector's size is reduced by one.

Lists

A list (or linked list) is a data structure that stores its items at non-adjacent locations in memory. Unlike vectors, lists have very poor random access performance; on the other hand, insert() and erase() are very fast.

Many algorithms that work on vectors don't work on lists, notably sort() and binary_search(). This is because lists don't provide fast random access. For sorting an STL list, we can use its sort() member function.

Figure 11.2. A list of Films


Film(4812, "A Hard Day's Night", 85)
films.begin()
Film(5051, "Seven Days to Noon", 94)
Film(1301, "Day of Wrath", 105)
Film(9227, "A Special Day", 110)
Film(1817, "Day for Night", 116)
films.end()

The STL's list class is called std::list<T> and is defined in <list>. Here's an example:

```
list<Film> films;
```

The Qt equivalent is called `QValueList<T>`:

```
QValueList<Film> films;
```

The `Film` class was presented in the previous section (p. 244).

New items can be added using `push_back()` or with `insert()`. Unlike vectors, inserting at the beginning or in the middle of a list is not expensive.

STL lists do not provide the `[]` operator, so iterators must be used to traverse their elements. (Qt lists support the `[]` operator, but it can be very slow on large lists.) The syntax and usage is exactly the same as for vectors, except that we write `list<T>` instead of `vector<T>` in front of the iterator type. For example:

```
list<Film>::const_iterator it = films.begin();
while (it != films.end()) {
    cerr << (*it).title().ascii() << endl;
    ++it;
}
```

Otherwise, lists mostly provide the same functions as vectors, including `empty()`, `size()`, `erase()`, and `clear()`. The `find()` algorithm can also be used on lists.

A few Qt functions return a `QValueList<T>`. If we want to iterate over the return value of a function, we must take a copy of the list and iterate over the copy. For example, the following code is the correct way to iterate over the `QValueList<int>` returned by `QSplitter::sizes()`:

```
QValueList<int> list = splitter->sizes();
QValueList<int>::const_iterator it = list.begin();
while (it != list.end()) {
    do_something(*it);
    ++it;
}
```

The following code is wrong:

```
// WRONG
QValueList<int>::const_iterator it = splitter->sizes().begin();
while (it != splitter->sizes().end()) {
    do_something(*it);
    ++it;
}
```

This is because `QSplitter::sizes()` returns a new `QValueList<int>` by value every time it is called. If we don't store the return value, C++ automatically destroys it before we have even started iterating, leaving us with a dangling iterator. To make matters worse, each time the loop is run, `QSplitter::sizes()` must generate a new copy of the list because of the `splitter->sizes().end()` call. In summary: Always iterate on a copy of a container returned by value.

Copying a container like this sounds expensive, but it isn't, because Qt uses an optimization called *implicit sharing*. This optimization means that we can program as if the data has been copied, even though behind the scenes no data copying has taken place.

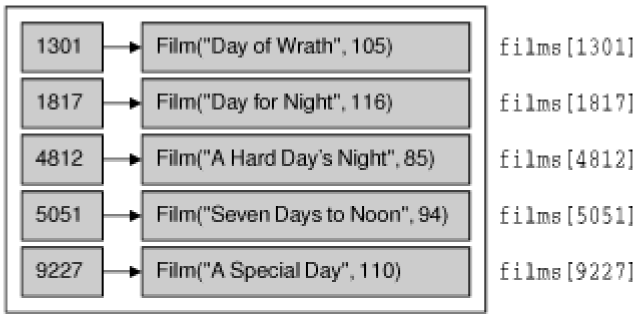
The `QStringList` class, which is used in many places in Qt, is a subclass of `QValueList<QString>`. In addition to the functions it inherits from its base class, it provides some extra functions that make the class more powerful. These functions will be discussed in the last section of this chapter.

[Team LiB]

Maps

A map holds an arbitrary number of items of the same type, indexed by a key. Maps store one unique value per key. Maps have good random access and insertion performance. If a new value is assigned to an existing key, the old value is replaced by the new value.

Figure 11.3. A map of `Film`s


1301
Film("Day of Wrath", 105)
films[1301]
1817
Film("Day for Night", 116)
films[1817]
4812
Film("A Hard Day's Night", 85)
films[4812]
5051
Film("Seven Days to Noon", 94)
films[5051]
9227
Film("A Special Day", 110)
films[9227]

Since maps contain key–value pairs, it is common to design data structures that work with maps in a slightly different way from those that are designed for use with vectors and lists. Here's a version of the `Film` class that we will use to illustrate map usage:

```
class Film
{
public:
    Film(const QString &title = "", int duration = 0);

    QString title() const { return myTitle; }
    void setTitle(const QString &title) { myTitle = title; }
    int duration() const { return myDuration; }
    void setDuration(int minutes) { myDuration = minutes; }

private:
    QString myTitle;
    int myDuration;
};
Film::Film(const QString &title, int duration)
{
    myTitle = title;
    myDuration = duration;
}
```

We don't store the catalog ID in the `Film` class since we will use that as the key to the map. Nor do we need the comparison operators for `Film`. Maps are ordered by their keys, not by their values.

The STL's map class is called `std::map<K, T>` and is defined in `<map>`. Here's an example of a map whose keys are `int`s (catalog IDs) and whose values are `Film`s:

```
map<int, Film> films;
```

The Qt equivalent is `QMap<K, T>`:

```
QMap<int, Film> films;
```

The most natural way to insert items into a map is to assign a value to a given key:

```
films[4812] = Film("A Hard Day's Night", 85);
films[5051] = Film("Seven Days to Noon", 94);
films[1301] = Film("Day of Wrath", 105);
films[9227] = Film("A Special Day", 110);
films[1817] = Film("Day for Night", 116);
```

The map iterator provides a key–pair value. The key part is extracted using `(*it).first` and the value part using `(*it).second`:

```
map<int, Film>::const_iterator it = films.begin();
while (it != films.end()) {
    cerr << (*it).first << ": "
         << (*it).second.title().ascii() << endl;
    ++it;
}
```

Most compilers also allow us to write `it->first` and `it->second`, but it's more portable to write `(*it).first` and `(*it).second`.

The Qt map's iterator differs slightly from the STL one. In a Qt map, the key is retrieved from an iterator using `it.key()` and the value with `it.data()`:

```
QMap<int, Film>::const_iterator it = films.begin();
while (it != films.end()) {
    cerr << it.key() << ": " << it.data().title().ascii() << endl;
    ++it;
}
```

When iterating over a map, the items are always ordered by key.

The `[]` operator can be used for both insertion and retrieval, but if `[]` is used to retrieve a value for a non-existent key, a new item will be created with the given key and an empty value. To avoid accidentally creating empty values, use the `find()` member function to retrieve items:

```
map<int, Film>::const_iterator it = films.find(1817);
if (it != films.end())
    cerr << "Found " << (*it).second.title().ascii() << endl;
```

This function returns the `end()` iterator if the key is not in the map.

In the example we have used an integer key, but other types of keys are possible, one popular choice being a `QString` key. For example:

```
map<QString, QString> actorToNationality;
actorToNationality["Doris Day"] = "American";
actorToNationality["Greta Garbo"] = "Swedish";
```

If we need to store multiple values for the same key, we can use `multimap<K, T>`. If we only need to store keys, we can use `set<K>` or `multiset<K>`. Qt provides no equivalent for these classes.

Qt's `QMap<K, T>` class has a couple of additional convenience functions that are especially useful when dealing with small data sets. QMap<K, T>::keys() and QMap<K, T>::values() return QValueLists of a map's keys and values.

Pointer-Based Containers

Along with the STL-like containers described in the previous sections, Qt also provides an additional set of container classes. These classes were developed in the early 1990s for Qt 1.0, before the STL became part of C++, and therefore have their own particular syntax. Because these classes operate on pointers to objects, they are often referred to as pointer-based containers, in contrast to Qt's and the STL's value-based containers. In Qt 4, the pointer-based containers will continue to be available for compatibility, but it is expected that their use will be deprecated in favor of the value-based containers.

The main reason for using the pointer-based classes in newly written Qt code is that a few important functions in Qt 3 rely on them. We have already seen one example of this in Chapter 3, where we iterated over an application's top-level widgets (p.66), and another example in Chapter 6, where we iterated over an application's MDI windows (p. 156).

The main pointer-based containers are QPtrVector<T>, QPtrList<T>, QDict<T>, QAsciiDict<T>, QIntDict<T>, and QPtrDict<T>.

QPtrVector<T> stores a vector of pointers. Here's how we would populate a QPtrVector<Film> with five Film objects:

```
QPtrVector<Film> films(5);
films.setAutoDelete(true);
films.insert(0, new Film(4812, "A Hard Day's Night", 85));
films.insert(1, new Film(5051, "Seven Days to Noon", 94));
films.insert(2, new Film(1301, "Day of Wrath", 105));
films.insert(3, new Film(9227, "A Special Day", 110));
films.insert(4, new Film(1817, "Day for Night", 116));
```

QPtrVector<T> does not provide an append() function, so we must resize the vector ourselves and insert items at specific index positions. In this example, we are using the original Film class, which includes catalog IDs.

One nice feature of Qt's pointer-based containers is the "auto-delete" property. If auto-delete is enabled, Qt takes ownership of all the objects inserted into the container and deletes them when the container is deleted (or when remove() or clear() are used).

To remove an item from the vector, we can call remove() with an index:

```
films.remove(2);
```

The remove() operation does not change the size of the vector; instead, the item is set to a null pointer. If auto-delete is on, the item is automatically deleted.

To traverse a QPtrVector<T>, we can simply use indexes:

```
for (int i = 0; i < (int)films.count(); ++i) {
    if (films[i])
        cerr << films[i]->title().ascii() << endl;
}
```

We check that the pointer at the given index is not null before using it, in case it has been erased or has never had anything assigned to it.

The `QPtrList<T>` class stores a list of pointers. We can add new items to a `QPtrList<T>` by calling `append()`, `prepend()`, or `insert()`:

```
QPtrList<Film> films;
films.setAutoDelete(true);
films.append(new Film(4812, "A Hard Day's Night", 85));
films.append(new Film(5051, "Seven Days to Noon", 94));
```

Pointer lists have a "current" item, which is updated when we call traversal functions such as `first()`, `next()`, `prev()`, and `last()`. One way to iterate over a list is like this:

```
Film *film = films.first();
while (film) {
    cerr << film->title().ascii() << endl;
    film = films.next();
}
```

It's also possible to iterate over a list using `at()`:

```
for (int i = 0; i < (int)films.count(); ++i)
    cerr << films.at(i)->title().ascii() << endl;
```

A third option is to use `QPtrListIterator<T>`.

The `QDict<T>`, `QAsciiDict<T>`, `QIntDict<T>`, and `QPtrDict<T>` classes are the nearest pointer-based equivalents to `map<K, T>`. These classes also operate on key–value pairs. The key can be any one of four different types (`QString`, `const char *`, `int`, or `void *`), depending on which of the four classes is used. Since all four classes provide the same functions, we will just look at `QIntDict<T>`.

We will use this to store `Film`s of the same type we used with `map<K, T>` earlier, using catalog IDs as keys.

```
QIntDict<Film> films(101);
films.setAutoDelete(true);
```

The `QIntDict<T>` constructor accepts a number. That number is used internally by the class to determine how many "buckets" it puts the data into. For good performance, that number should be a prime number a little larger than the number of items we expect to hold. A list of the prime numbers smaller than 10,000 is available at http://doc.trolltech.com/3.2/primes.html.

Inserting new items is done with `insert()`, which accepts a key and a value:

```
films.insert(4812, new Film("A Hard Day's Night", 85));
films.insert(5051, new Film("Seven Days to Noon", 94));
```

We can use `find()` or the `[]` operator to look up items, `remove()` to delete an item, and `replace()` to change the value associated with a given key.

If we call `insert()` multiple times with the same key, only the most recently inserted item will be accessible. If we call `remove()`, the items are removed in the reverse order in which they were inserted. To avoid multiple values under the same key, we can use `replace()` instead of `insert()`.

The entire container can be traversed using an iterator:

```
QIntDictIterator<Film> it(films);
while (it.current()) {
    cerr << it.currentKey() << ": "
         << it.current()->title().ascii() << endl;
    ++it;
}
```

The iterator provides the current key with `currentKey()` and the current value with `current()`. The order in which the items appear is undefined.

Qt provides a special vector-like class, `QMemArray<T>`, for storing items of basic types like `int` and `double` or of structs of basic types. Few applications use it directly; however, its two subclasses `QByteArray` (`QMemArray<char>`) and `QPointArray` (`QMemArray<QPoint>`) are very common, and we have used them many times in earlier chapters.

For example, here's how to create a `QByteArray`:

```
QByteArray bytes(4);
bytes[0] = 'A';
bytes[1] = 'C';
bytes[2] = 'D';
bytes[3] = 'C';
```

When we create a `QMemArray<T>`, we can either pass it an initial size or call `resize()` later. We can then access array entries using the `[]` operator:

```
for (int i = 0; i < (int)bytes.size(); ++i)
    cerr << bytes[i] << endl;
```

We can search for an item using `QMemArray<T>::find()`:

```
if (bytes.find('A') != -1)
    cerr << "Found" << endl;
```

A subtle pitfall with `QMemArray<T>` and its subclasses is that they are *explicitly shared*. This means that when we create a copy of an object (using the class's copy constructor or its assignment operator), both the original and the copy share the same data. When we modify one of them, the other one is also modified. Explicit sharing should not be confused with implicit sharing, which does not have this problem.

The defensive way to program using `QMemArray<T>` is to call `copy()` to force a deep copy of the container when copying it:

```
duplicate = bytes.copy();
```

This ensures that no two `QMemArray<T>` objects point to the same data.

To avoid the inherent problems of explicit sharing, the `QMemArray<T>` class will probably be deprecated in favor of `QValueVector<T>` in Qt 4. The `QByteArray` and `QPointArray` classes will then use `QValueVector<T>` as their base class.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

QString and QVariant

Strings are used by every GUI program, not only for the user interface, but often also as data structures.

C++ natively provides two kinds of strings: traditional C-style '\0'-terminated character arrays and the `string` class. Qt's `QString` class is more powerful than either of them. The `QString` class holds 16-bit Unicode values. Unicode contains ASCII and Latin-1 as a subset, with their usual numeric values. But since `QString` is 16-bit, it can represent thousands of other characters for writing most of the world's languages. See Chapter 15 for more information about Unicode.

`QString` provides a binary + operator to concatenate two strings and a += operator to append one string to another. Here's an example that combines both:

```
QString str = "User: ";
str += userName + "\n";
```

There is also a `QString::append()` function that does the same thing as the += operator:

```
str = "User: ";
str.append(userName);
str.append("\n");
```

A completely different way of combining strings is to use `QString`'s `sprintf()` function:

```
str.sprintf("%s %.1f%%", "perfect competition", 100.0);
```

This function supports the same format specifiers as the C++ library's `sprintf()` function. In the example above, `str` is assigned "perfect competition 100.0%".

Yet another way of building a string from other strings or from numbers is to use `arg()`:

```
str = QString("%1 %2 (%3s-%4s)")
      .arg("permissive").arg("society").arg(1950).arg(1970);
```

In this example, "%1" is replaced by "permissive", "%2" is replaced by "society", "%3" is replaced by "1950", and "%4" is replaced by "1970". The result is "permissive society (1950s-1970s)". There are `arg()` overloads to handle various data types. Some overloads have extra parameters for controlling the field width, the numerical base, or the floating-point precision. In general, `arg()` is a much better solution than `sprintf()`, because it is type-safe, fully supports Unicode, and allows translators to change the order of the *"%n"* parameters.

`QString` can convert numbers into strings using the `QString::number()` static function:

```
str = QString::number(59.6);
```

Or using the `setNum()` function:

```
str.setNum(59.6);
```

The reverse conversion, from a string to a number, is achieved using `toInt()`, `toLongLong()`, `toDouble()`, and so on. For example:

```
bool ok;
double d = str.toDouble(&ok);
```

These functions also accept an optional pointer to a `bool` and set the `bool` to `true` or `false` depending on the success of the conversion. When the conversion fails, these functions always return 0.

Once we have a string, we often want to extract parts of it. The `mid()` function returns the substring starting at a given position and of a given length. For example, the following code prints "pays" to the console:

```
QString str = "polluter pays principle";
cerr << str.mid(9, 4).ascii() << endl;
```

If we omit the second argument (or pass –1), `mid()` returns the substring starting at a given position and ending at the end of the string. For example, the following code prints "pays principle" to the console:

```
QString str = "polluter pays principle";
cerr << str.mid(9).ascii() << endl;
```

There are also `left()` and `right()` functions that perform a similar job. Both accept a number of characters, *n*, and return the first or last *n* characters of the string. For example, the following code prints "polluter principle" to the console:

```
QString str = "polluter pays principle";
cerr << str.left(8).ascii() << " " << str.right(9).ascii()
     << endl;
```

If we want to check if a string starts or ends with something, we can use the `startsWith()` and `endsWith()` functions:

```
if (uri.startsWith("http:") && uri.endsWith(".png"))
    ...
```

This is both simpler and faster than this:

```
if (uri.left(5) == "http:" && uri.right(4) == ".png")
    ...
```

String comparison with the == operator is case sensitive. For case insensitive comparisons, we can use `upper()` or `lower()`. For example:

```
if (fileName.lower() == "readme.txt")
    ...
```

If we want to replace a certain part of a string by another string, we can use `replace()`:

```
QString str = "a sunny day";
str.replace(2, 5, "cloudy");
```

The result is "a cloudy day". The code can be rewritten to use `remove()` and `insert()`:

```
str.remove(2, 5);
str.insert(2, "cloudy");
```

First, we remove five characters starting at position 2, resulting in the string "a day" (with two spaces), then we insert "cloudy" at position 2.

There are overloaded versions of `replace()` that replace all occurrences of their first argument with their second argument. For example, here's how to replace all occurrences of "&" with

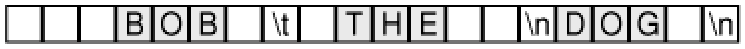
"&amp" in a string:

```
str.replace("&", "&amp;");
```

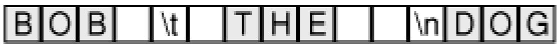
One very frequent need is to strip the whitespace (such as spaces, tabs, and newlines) from a string. QString has a function that strips whitespace from both ends of a string:

```
QString str = "   BOB \t THE  \nDOG \n";
cerr << str.stripWhiteSpace().ascii() << endl;
```

String str can be depicted as



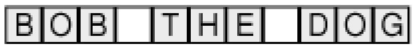
The string returned by stripWhiteSpace() is



When handling user input, we often also want to replace every sequence of one or more internal whitespace characters with single spaces, in addition to stripping whitespace from both ends. This is what the simplifyWhiteSpace() function does:

```
QString str = "   BOB \t THE  \nDOG \n";
cerr << str.simplifyWhiteSpace().ascii() << endl;
```

The string returned by simplifyWhiteSpace() is



A string can be split into substrings using QStringList::split():

```
QString str = "polluter pays principle";
QStringList words = QStringList::split(" ", str);
```

In the example above, we split the string "polluter pays principle" into three substrings: "polluter", "pays", and "principle". The split() function has an optional bool third argument that specifies whether empty substrings should be ignored (the default) or not.

The elements in a QStringList can be joined to form a single string using join(). The argument to join() is inserted between each pair of joined strings. For example, here's how to create a single string that is composed of all the strings contained in a QStringList sorted into alphabetical order and separated by newlines:

```
words.sort();
str = words.join("\n");
```

When dealing with strings, we often need to determine whether a string is empty or not. One way of testing this is to call isEmpty(); another way is to check whether length() is 0.

QString distinguishes between null strings and empty strings. This distinction has its roots in the C language, which differentiates between 0 (a null pointer) and "" (an empty string). To test whether a string is null, we can call isNull(). For most applications, what matters is whether or not a string contains any characters. The isEmpty() function provides this information, returning true if a string has no characters (is null or empty), and false otherwise.

The conversions between const char * strings and QString is automatic in most cases, for example:

```
str += " (1870)";
```

Here we add a const char * to a QString without formality.

In some situations, it is necessary to explicitly convert between const char * and QString. To convert a QString to a const char *, use ascii() or latin1(). To convert the other way, use a QString cast.

When we call ascii() or latin1() on a QString, or when we let the automatic conversion to const char * do its work, the returned string is owned by the QString object. This means that we don't need to worry about memory leaks; Qt will reclaim the memory for us. On the other hand, we must be careful not to use the pointer for too long. For example, if we modify the original QString, the pointer is not guaranteed to remain valid. If we need to store the const char * for any length of time, we can assign it to a variable of type QByteArray or QCString. These will hold a complete copy of the data.

QString is implicitly shared. This means that copying a QString is about as fast as copying a single pointer. Only if one of the copies is changed is data actually copied—and this is all handled automatically behind the scenes. For this reason, implicit sharing is sometimes referred to as "copy on write".

The beauty of implicit sharing is that it is an optimization that we don't have to think about; it simply works, without requiring any programmer intervention.

Qt uses implicit sharing for many other classes, including QBrush, QFont, QPen, QPixmap, QMap<K, T>, QValueList<T>, and QValueVector<T>. This makes these classes very efficient to pass by value, both as function parameters and as return values.

C++ is a strongly typed language, and this provides many benefits, including type safety and efficiency. However, in some situations, it is useful to be able to store data more generically, and one conventional way of doing so is to use strings. For example, a string could hold a textual value or a numeric value in string form. Qt provides a much cleaner way of handling variables that can hold different types: QVariant.

The QVariant class can hold values of many Qt types, including QBrush, QColor, QCursor, QDateTime, QFont, QKeySequence, QPalette, QPen, QPixmap, QPoint, QRect, QRegion, QSize, and QString. The QVariant class can also hold containers: QMap<QString, QVariant>, QStringList, and QValueList<QVariant>. We used a QVariant in the implementation of the Spreadsheet application in Chapter 4 to hold the value of a cell, which could be either a QString, a double, or an invalid value.

One common use of variants is in a map that uses strings as keys and variants as values. Configuration data is normally saved and retrieved using QSettings, but some applications may handle this data directly, perhaps storing it in a database. QMap<QString, QVariant> is ideal for such situations:

```
QMap<QString, QVariant> config;
config["Width"] = 890;
config["Height"] = 645;
config["ForegroundColor"] = black;
config["BackgroundColor"] = lightGray;
config["SavedDate"] = QDateTime::currentDateTime();
QStringList files;
files << "2003-05.dat" << "2003-06.dat" << "2003-07.dat";
```

```
config["RecentFiles"] = files;
```

How Implicit Sharing Works

Implicit sharing works automatically behind the scenes, so when we use classes that are implicitly shared, we don't have to do anything in our code to make this optimization happen. But since it's nice to know how things work, we will study an example and see what happens under the hood.

```
QString str1 = "Humpty";
QString str2  = str1;
```

We set `str1` to "Humpty" and `str2` to be equal to `str1`. At this point, both `QStrings` point to the same data structure in memory (of type `QStringData`). Along with the character data, the data structure holds a reference count that indicates how many `QStrings` point to the same data structure. Since both `str1` and `str2` point to the same data, the reference count is 2.

```
str2[0] = 'D';
```

When we modify `str2`, it first makes a deep copy of the data, to ensure that `str1` and `str2` point to different data structures, and it then applies the change to its own copy of the data. The reference count of `str1`'s data ("Humpty") becomes 1, and the reference count of `str2`'s data ("Dumpty") is set to 1.A reference count of 1 means that the data isn't shared.

```
str2.truncate(4);
```

If we modify `str2` again, no copying takes place because the reference count of `str2`'s data is 1. The `truncate()` function operates directly on `str2`'s data, resulting in the string "Dump". The reference count stays at 1.

```
str1 = str2;
```

When we assign `str2` to `str1`, the reference count for `str1`'s data goes down to 0, which means that no `QString` is using the "Humpty" data anymore. The data is then freed from memory. Both `QStrings` now point to "Dump", which now has a reference count of 2.

Writing implicitly shared classes isn't very difficult. The *Qt Quarterly* article "Data Sharing with Class", available online at http://doc.trolltech.com/qq/qq02-data-sharing-with-class.html, explains how to do it.

Iterating over a map that holds variant values can be slightly tricky if some of the values are containers. We need to use `type()` to check the type that a variant holds so that we can respond appropriately:

```
QMap<QString, QVariant>::const_iterator it = config.begin();
while (it != config.end()) {
    QString str;
    if (it.data().type() == QVariant::StringList)
        str = it.data().toStringList().join(", ");
    else
        str = it.data().toString();
    cerr << it.key().ascii() << ": " << str.ascii() << endl;
        ++it;
}
```

It is possible to create arbitrarily complex data structures using `QVariant` by holding values of container types:

```
QMap<QString, QVariant> price;
price["Orange"] = 2.10;
price["Pear"].asMap()["Standard"] = 1.95;
price["Pear"].asMap()["Organic"] = 2.25;
price["Pineapple"] = 3.85;
```

Here we have created a map with string keys (product names) and values that are either floating-point numbers (prices) or maps. The top level map contains three keys: "Orange", "Pear", and "Pineapple". The value associated with the "Pear" key is a map that contains two keys ("Standard" and "Organic").

Creating data structures like this can be very seductive since we can structure the data in any way we like. But the convenience of `QVariant` comes at a price. For the sake of readability, it is usually worth defining a proper C++ class to store our data. A custom class provides type safety and will also be more speed- and memory-efficient than using `QVariant`.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Chapter 12. Databases

Qt's SQL module provides a platform- and database-independent interface for accessing SQL databases, and a set of classes for integrating databases into the user interface.

The chapter begins by showing how to open database connections and how to execute arbitrary SQL statements on a database. The second and third sections focus on providing the user with ways of viewing and modifying a database through the user interface, using `QDataTable` to present data in a table widget and using `QSqlForm` to present data as a form. These classes are designed to interact nicely with each other, making common database idioms such as master–detail views and drill-down easy to implement.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Connecting and Querying

To execute SQL queries, we must first establish a connection with a database. Typically, database connections are set up in a separate function that we call at application startup. For example:

```
bool createConnection()
{
    QSqlDatabase *db = QSqlDatabase::addDatabase("QOCI8");
    db->setHostName("mozart.konkordia.edu");
    db->setDatabaseName("musicdb");
    db->setUserName("gbatstone");
    db->setPassword("T17aV44");
    if (!db->open()) {
        db->lastError().showMessage();
        return false;
    }
    return true;
}
```

First, we call `QSqlDatabase::addDatabase()` to create a `QSqlDatabase` object. The argument to `addDatabase()` specifies which database driver Qt must use to access the database. In this case, we use Oracle. The commercial version of Qt 3.2 includes the following drivers: `QODBC3` (ODBC), `QOCI8` (Oracle), `QTDS7` (Sybase Adaptive Server), `QPSQL7` (PostgreSQL), `QMYSQL3` (MySQL), and `QDB2` (IBM DB2). The free and non-commercial editions contain a subset of these. [*] See http://doc.trolltech.com/3.2/sql-driver.html for information on building the database drivers.

[*] The Qt packages on the accompanying CD include SQLite, a public domain in-process database, and `QSQLITEX`, an experimental driver. These are only intended for use with the examples on the CD.

Next, we set the database host name, the database name, the user name, and the password, and we try to open the connection. If `open()` fails, we show an error message using `QSqlError::showMessage()`.

Typically, we would call `createConnection()` in `main()`:

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    if (!createConnection())
        return 1;
    ...
    return app.exec();
}
```

Once a connection is established, we can use `QSqlQuery` to execute any SQL statement that the underlying database supports. For example, here's how to execute a `SELECT` statement:

```
QSqlQuery query;
query.exec("SELECT title, year FROM cd WHERE year >= 1998");
```

After the `exec()` call, we can navigate through the query's result set:

```
while (query.next()) {
    QString title = query.value(0).toString();
    int year = query.value(1).toInt();
    cerr << title.ascii() << ": " << year << endl;
}
```

We call `next()` once to position the `QSqlQuery` on the *first* record of the result set. Subsequent calls to `next()` advance the record pointer by one record each time, until the end is reached, at which point `next()` returns `false`. If the result set is empty, the first call to `next()` will return `false`.

The `value()` function returns the value of a field as a `QVariant`. The fields are numbered from

0 in the order given in the SELECT statement. The QVariant class can hold many C++ and Qt types, including int and QString. The different types of data that can be stored in a database are mapped into the corresponding C++ and Qt types and stored in QVariants. For example, a VARCHAR is represented as a QString and a DATETIME as a QDateTime.

QSqlQuery provides some other functions to navigate through the result set: first(), last(), prev(), seek(), and at(). These functions are convenient, but for some databases they can be slow and memory-hungry. For an easy optimization when operating on large data sets, we can call QSqlQuery::setForwardOnly(true) before calling exec(), and then only use next() for navigating the result set.

Earlier we specified the SQL query as an argument to exec(), but we can also pass it directly to the constructor, which executes it immediately:

```
QSqlQuery query("SELECT title, year FROM cd WHERE year >= 1998");
```

Here's how we would check for an error and pop up a QMessageBox if a problem occurred:

```
if (!query.isActive())
    query.lastError().showMessage();
```

Doing an INSERT is almost as easy as doing a SELECT:

```
QSqlQuery query("INSERT INTO cd (id, artistid, title, year) "
                "VALUES (203, 102, 'Living in America', 2002)");
```

After this, QSqlQuery::numRowsAffected() returns the number of rows that were affected by the SQL statement (or -1 if the database cannot provide that information).

If we need to insert a lot of records, or if we want to avoid converting values to strings (and escaping them correctly), we can use prepare() to specify a query that contains placeholders and then bind the values we want to insert. Qt supports both the Oracle-style and the ODBC-style syntax for placeholders for all databases, using native support where it is available and simulating it otherwise. Here's an example that uses the Oracle-style syntax with named placeholders:

```
QSqlQuery query(db);
query.prepare("INSERT INTO cd (id, artistid, title, year) "
              "VALUES (:id, :artistid, :title, :year)");
query.bindValue(":id", 203);
query.bindValue(":artistid", 102);
query.bindValue(":title", QString("Living in America"));
query.bindValue(":year", 2002);
query.exec();
```

Here's the same example using ODBC-style positional placeholders:

```
QSqlQuery query(db);
query.prepare("INSERT INTO cd (id, artistid, title, year) "
              "VALUES (?, ?, ?, ?)");
query.addBindValue(203);
query.addBindValue(102);
query.addBindValue(QString("Living in America"));
query.addBindValue(2002);
query.exec();
```

After the call to prepare(), we can call bindValue() or addBindValue() to bind new values, then call exec() again to execute the query with the new values.

Placeholders are often used to specify binary data or strings that contain non-ASCII or non-Latin-1 characters. Behind the scenes, Qt uses Unicode with those databases that support Unicode, and for those that don't, Qt transparently converts strings to the appropriate encoding.

Qt supports SQL transactions on databases where they are available. To start a transaction, we call `transaction()` on the `QSqlDatabase` object that represents the database connection. To terminate the transaction, we call either `commit()` or `rollback()`. For example, here's how we would look up a foreign key and execute an `INSERT` statement inside a transaction:

```
QSqlDatabase::database()->transaction();
QSqlQuery query;
query.exec("SELECT id FROM artist WHERE name = 'Gluecifer'");
if (query.next()) {
    int artistId = query.value(0).toInt();
    query.exec("INSERT INTO cd (id, artistid, title, year) "
               "VALUES (201, " + QString::number(artistId)
               + ", 'Riding the Tiger', 1997)");
}
QSqlDatabase::database()->commit();
```

The `QSqlDatabase::database()` function returns a pointer to the `QSqlDatabase` object we created in `createConnection()`. If a transaction cannot be started, `QSqlDatabase::transaction()` returns `false`.

Some databases don't support transactions. For those, the `transaction()`, `commit()`, and `rollback()` functions do nothing. We can test whether a database supports transactions using `hasFeature()` on the `QSqlDriver` associated with the database:

```
QSqlDriver *driver = QSqlDatabase::database()->driver();
if (driver->hasFeature(QSqlDriver::Transactions))
    ...
```

In the examples so far, we have assumed that the application is using a single database connection. If we want to use multiple connections, we can pass a name as second argument to `addDatabase()`. For example:

```
QSqlDatabase *db = QSqlDatabase::addDatabase("QPSQL7", "OTHER");
db->setHostName("saturn.mcmanamy.edu");
db->setDatabaseName("starsdb");
db->setUserName("gilbert");
db->setPassword("ixtapa6");
```

We can then retrieve a pointer to the `QSqlDatabase` object by passing the name to `QSqlDatabase::database()`:

```
QSqlDatabase *db = QSqlDatabase::database("OTHER");
```

To execute queries using the other connection, we pass the `QSqlDatabase` object to the `QSqlQuery` constructor:

```
QSqlQuery query(db);
query.exec("SELECT id FROM artist WHERE name = 'Mando Diao'");
```

Multiple connections are useful if we want to perform more than one transaction at a time, since each connection can only handle a single active transaction. When we use multiple database connections, we can still have one nameless connection, and `QSqlQuery` will use that connection if none is specified.

In addition to QSqlQuery, Qt provides the QSqlCursor class, a higher-level class that inherits QSqlQuery and extends it with convenience functions so that we can avoid typing raw SQL for performing the most common SQL operations: SELECT, INSERT, UPDATE, and DELETE. QSqlCursor is also the class that ties a QDataTable to a database. We will cover QSqlCursor here, and in the next section we will see how to use QDataTable, a database-aware QTable subclass.

Here's an example that uses QSqlCursor to perform a SELECT:

```
QSqlCursor cursor("cd");
cursor.select("year >= 1998");
```

An equivalent QSqlQuery would be

```
QSqlQuery query("SELECT id, artistid, title, year FROM cd "
                "WHERE year >= 1998");
```

Navigating through the result set is the same as for QSqlQuery, except that we can pass field names to value() instead of field numbers:

```
while (cursor.next()) {
    QString title = cursor.value("title").toString();
    int year = cursor.value("year").toInt();
    cerr << title.ascii() << ": " << year << endl;
}
```

To insert a record into a table, we must first call primeInsert(), which returns a pointer to a new QSqlRecord. Then we call setValue() for each of the fields in the QSqlRecord that we want to set, and we call insert() to insert the QSqlRecord's data into the database. For example:

```
QSqlCursor cursor("cd");
QSqlRecord *buffer = cursor.primeInsert();
buffer->setValue("id", 113);
buffer->setValue("artistid", 224);
buffer->setValue("title", "Shanghai My Heart");
buffer->setValue("year", 2003);
cursor.insert();
```

To update a record, we must first position the QSqlCursor on the record we want to modify (for example, using select() and next()). Then we call primeUpdate() to get a pointer to a QSqlRecord that contains a copy of the record's data. We can then use setValue() to set the fields we want to change, and call update() to write these changes back to the database. For example:

```
QSqlCursor cursor("cd");
cursor.select("id = 125");
if (cursor.next()) {
    QSqlRecord *buffer = cursor.primeUpdate();
    buffer->setValue("title", "Melody A.M.");
    buffer->setValue("year", buffer->value("year").toInt() + 1);
    cursor.update();
}
```

Deleting a record is similar to updating, but easier:

```
QSqlCursor cursor("cd");
cursor.select("id = 128");
```

```
if (cursor.next()) {
    cursor.primeDelete();
    cursor.del();
}
```

The QSqlQuery and QSqlCursor classes provide an interface between Qt and a SQL database. In the next two sections, we will see how to use them from within a GUI application to allow the user to view and interact with the data stored in a database.

Presenting Data in Tabular Form

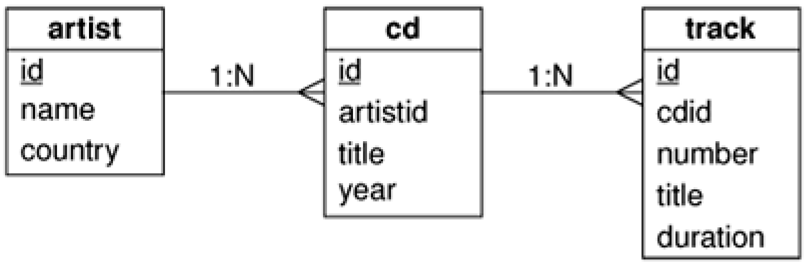
The QDataTable class is a database-aware QTable widget that supports browsing and editing. It interacts with a database through a QSqlCursor. Here, we will review two dialogs that use QDataTable. Together with the QSqlForm-based dialog presented in the next section, these forms constitute the CD Collection application.

The application uses three tables, defined as follows:

```
CREATE TABLE artist (
    id INTEGER PRIMARY KEY,
    name VARCHAR(40) NOT NULL,
    country VARCHAR(40));

CREATE TABLE cd (
    id INTEGER PRIMARY KEY,
    artistid INTEGER NOT NULL,
    title VARCHAR(40) NOT NULL,
    year INTEGER NOT NULL,
    FOREIGN KEY (artistid) REFERENCES artist);

CREATE TABLE track (
    id INTEGER PRIMARY KEY,
    cdid INTEGER NOT NULL,
    number INTEGER NOT NULL,
    title VARCHAR(40) NOT NULL,
    duration INTEGER NOT NULL,
    FOREIGN KEY (cdid) REFERENCES cd);
```

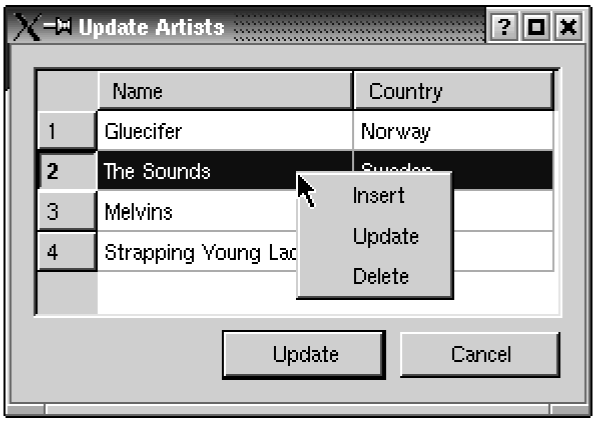
Some databases don't support foreign keys. For those, we must remove the FOREIGN KEY clauses. The example will still work, but the database will not enforce referential integrity.

Figure 12.1. The CD Collection application's tables



The first class that we will write is a dialog that allows the user to edit a list of artists. The user can insert, update, or delete artists using the QDataTable's context menu. The changes are applied to the database when the user clicks Update.

Figure 12.2. The `ArtistForm` dialog



Here's the class definition for the dialog:

```
class ArtistForm : public QDialog
{
    Q_OBJECT
public:
    ArtistForm(QWidget *parent = 0, const char *name = 0);

protected slots:
    void accept();
    void reject();

private slots:
    void primeInsertArtist(QSqlRecord *buffer);
    void beforeInsertArtist(QSqlRecord *buffer);
    void beforeDeleteArtist(QSqlRecord *buffer);

private:
    QSqlDatabase *db;
    QDataTable *artistTable;
    QPushButton *updateButton;
    QPushButton *cancelButton;
};
```

The `accept()` and `reject()` slots are reimplemented from `QDialog`.

```
ArtistForm::ArtistForm(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    setCaption(tr("Update Artists"));

    db = QSqlDatabase::database("ARTIST");
    db->transaction();

    QSqlCursor *artistCursor = new QSqlCursor("artist", true, db);
    artistTable = new QDataTable(artistCursor, false, this);
    artistTable->addColumn("name", tr("Name"));
    artistTable->addColumn("country", tr("Country"));
    artistTable->setAutoDelete(true);
    artistTable->setConfirmDelete(true);
    artistTable->setSorting(true);
    artistTable->refresh();

    updateButton = new QPushButton(tr("Update"), this);
    updateButton->setDefault(true);
    cancelButton = new QPushButton(tr("Cancel"), this);
```

In the ArtistForm constructor, we start a transaction using the "ARTIST" database connection. Then we create a QSqlCursor on the database's artist table, and a QDataTable to display it.

The second argument to the QSqlCursor constructor is an "auto-populate" flag. By passing true, we tell QSqlCursor to load information about every field in the table and to operate on all the fields.

The QDataTable constructor's second argument is also an auto-populate flag. If true, the QDataTable automatically creates columns for each field in the QSqlCursor's result set. We pass false and call addColumn() to provide two columns corresponding to the result set's name and country fields.

We pass ownership of the QSqlCursor to the QDataTable by calling setAuto–Delete(), so we don't need to delete it ourselves. We call setConfirmDelete() to make the QDataTable pop up a message box asking the user to confirm deletions. We call setSorting(true) to allow the user to click on the column headers to sort the table according to a certain column. Finally, we call refresh() to populate the QDataTable with data from the database.

We also create an *Update* and a *Cancel* button.

```
connect(artistTable, SIGNAL(beforeDelete(QSqlRecord *)),
        this, SLOT(beforeDeleteArtist(QSqlRecord *)));
connect(artistTable, SIGNAL(primeInsert(QSqlRecord *)),
        this, SLOT(primeInsertArtist(QSqlRecord *)));
connect(artistTable, SIGNAL(beforeInsert(QSqlRecord *)),
        this, SLOT(beforeInsertArtist(QSqlRecord *)));
connect(updateButton, SIGNAL(clicked()),
        this, SLOT(accept()));
connect(cancelButton, SIGNAL(clicked()),
        this, SLOT(reject()));
```

We connect three of the QDataTable's signals to three private slots. We connect the *Update* button to accept() and the *Cancel* button to reject().

```
     QHBoxLayout *buttonLayout = new QHBoxLayout;
     buttonLayout->addStretch(1);
     buttonLayout->addWidget(updateButton);
     buttonLayout->addWidget(cancelButton);

     QVBoxLayout *mainLayout = new QVBoxLayout(this);
     mainLayout->setMargin(11);
     mainLayout->setSpacing(6);
     mainLayout->addWidget(artistTable);
     mainLayout->addLayout(buttonLayout);
}
```

Finally, we put the QPushButtons into a horizontal layout, and we put the QDataTable and the horizontal layout into a vertical layout.

```
void ArtistForm::accept()
{
    db->commit();
    QDialog::accept();
}
```

If the user clicks *Update*, we commit the transaction and call the base class's accept() function.

```
void ArtistForm::reject()
```

```
{
    db->rollback();
    QDialog::reject();
}
```

If the user clicks *Cancel*, we roll back the transaction and call the base class's `reject()` function.

```
void ArtistForm::beforeDeleteArtist(QSqlRecord *buffer)
{
    QSqlQuery query(db);
    query.exec("DELETE FROM track WHERE track.id IN "
               "(SELECT track.id FROM track, cd "
               "WHERE track.cdid = cd.id AND cd.artistid = "
               + buffer->value("id").toString() + ")");
    query.exec("DELETE FROM cd WHERE artistid = "
               + buffer->value("id").toString());
}
```

The `beforeDeleteArtist()` slot is connected to the `QDataTable`'s `beforeDelete()` signal, which is emitted just before a record is deleted. Here, we perform a cascading delete by executing two queries: one to delete all the tracks from CDs by the artist and one to delete all the CDs by the artist. Performing these deletions does not risk relational integrity, because they are all done within the context of the transaction that began in the form's constructor.

Another approach would have been to prevent the user from deleting artists that are referred to by the `cd` table. To achieve this, we would have to reimplement `QDataTable::contextMenuEvent()` so that we could handle the deletion ourselves. A crude alternative that will work if the database has been set up to enforce relational integrity is to simply attempt the deletion and leave it to the database to prevent it.

```
void ArtistForm::primeInsertArtist(QSqlRecord *buffer)
{
    buffer->setValue("country", "USA");
}
```

The `primeInsertArtist()` slot is connected to the `QDataTable`'s `primeInsert()` signal, which is emitted just before the user starts editing a new record. We use it to set the default value of the new record's `country` field to "USA", the ideal default for a U.S.-centric application.

This is one way of setting default values for fields. Another way is to subclass `QSqlCursor` and reimplement `primeInsert()`, which makes sense if we will use the same `QSqlCursor` many times in the same application and want to ensure consistent behavior. A third way is to do it at the database level, using `DEFAULT` clauses in the `CREATE TABLE` statements.

```
void ArtistForm::beforeInsertArtist(QSqlRecord *buffer)
{
    buffer->setValue("id", generateId("artist", db));
}
```

The `beforeInsertArtist()` slot is connected to the `QDataTable`'s `beforeInsert()` signal, which is emitted when the user has finished editing a new record and presses *Enter* to save it. We set the value of the `id` field to a generated value. We rely on a function called `generateId()` to produce a unique primary key.

Since we will need `generateId()` a few times, we define it inline in a header file and include it each time we need it. Here's a quick (and inefficient) way of implementing it:

```
inline int generateId(const QString &table, QSqlDatabase *db)
```

```
{
    QSqlQuery query(db);
    query.exec("SELECT max(id) FROM " + table);
    query.next();
    return query.value(0).toInt() + 1;
}
```

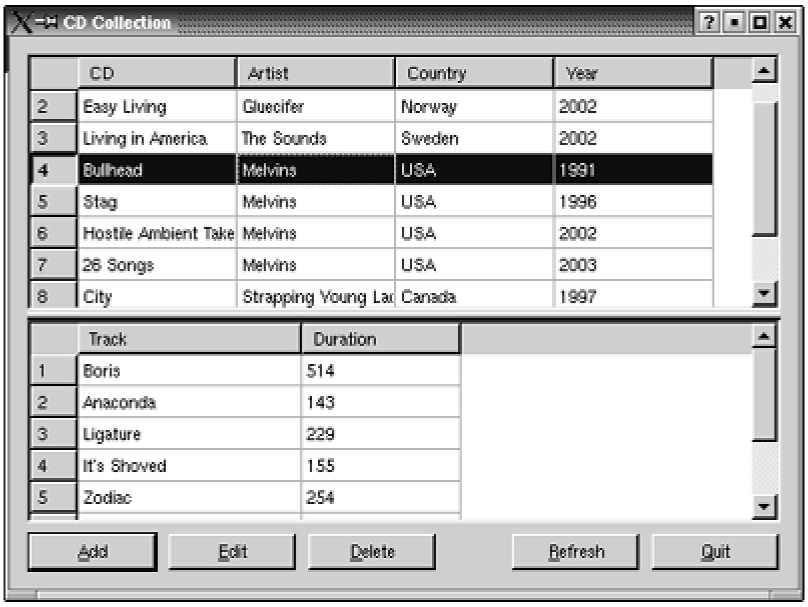
The generateId() function can only be guaranteed to work correctly if it is executed within the context of the same transaction as the corresponding INSERT statement.

Some databases support auto-generated fields. For these, we simply need to tell the database to auto-generate the id field and call setGenerated("id", false) on the QSqlCursor to tell it *not* to generate the value of the id field.

We will now review another dialog that uses QDataTable. For this dialog, we will implement a master–detail view. The master view is a list of CDs. The detail view is a list of tracks for the current CD. This dialog is the main window of the CD Collection application.

This time, we provide *Add*, *Edit*, and *Delete* buttons to allow the user to modify the CD list, rather than relying on a context menu. When the user clicks *Add* or *Edit*, a CdForm dialog pops up. (CdForm is covered in the next section.)

Figure 12.3. The MainForm dialog



	CD	Artist	Country	Year
2	Easy Living	Gluecifer	Norway	2002
3	Living in America	The Sounds	Sweden	2002
4	Bullhead	Melvins	USA	1991
5	Stag	Melvins	USA	1996
6	Hostile Ambient Take	Melvins	USA	2002
7	26 Songs	Melvins	USA	2003
8	City	Strapping Young La	Canada	1997

	Track	Duration
1	Boris	514
2	Anaconda	143
3	Ligature	229
4	It's Shoved	155
5	Zodiac	254

Another difference between this example and the previous one is that we must resolve a foreign key, so we can show the artist's name and country rather than the artist's ID. To accomplish this, we must use QSqlSelectCursor, a subclass of QSqlCursor that supports arbitrary SELECT statements, in this case a join.

First, the class definition:

```
class MainForm : public QDialog
{
    Q_OBJECT
public:
    MainForm(QWidget *parent = 0, const char *name = 0);

private slots:
    void addCd();
    void editCd();
    void deleteCd();
    void currentCdChanged(QSqlRecord *record);

private:
    QSplitter *splitter;
    QDataTable *cdTable;
    QDataTable *trackTable;
    QPushButton *addButton;
    ...
    QPushButton *quitButton;
};
```

The MainForm class inherits from QDialog.

```
MainForm::MainForm(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    setCaption(tr("CD Collection"));

    splitter = new QSplitter(Vertical, this);

    QSqlSelectCursor *cdCursor = new QSqlSelectCursor(
                    "SELECT cd.id, title, name, country, year "
                    "FROM cd, artist WHERE cd.artistid = artist.id");
    if (!cdCursor->isActive()) {
        QMessageBox::critical(this, tr("CD Collection"),
                tr("The database has not been created.\n"
                "Run the cdtables example to create a sample "
                "database, then copy cdcollection.dat into "
                "this directory and restart this application."));
        qApp->quit();
    }

    cdTable = new QDataTable(cdCursor, false, splitter);
    cdTable->addColumn("title", tr("CD"));
    cdTable->addColumn("name", tr("Artist"));
    cdTable->addColumn("country", tr("Country"));
    cdTable->addColumn("year", tr("Year"));
    cdTable->setAutoDelete(true);
    cdTable->refresh();
```

In the constructor, we create a read-only QDataTable for the cd table and its associated cursor. The cursor is based on a query that joins the cd and the artist tables. The QDataTable is read-only because it operates on a QSqlSelectCursor. Read-only tables don't provide a context menu.

If the cursor query fails, we pop up a message box indicating that something is wrong and terminate the application.

```
    QSqlCursor *trackCursor = new QSqlCursor("track");
    trackCursor->setMode(QSqlCursor::ReadOnly);
    trackTable = new QDataTable(trackCursor, false, splitter);
    trackTable->setSort(trackCursor->index("number"));
    trackTable->addColumn("title", tr("Track"));
    trackTable->addColumn("duration", tr("Duration"));
```

We create the second QDataTable and its cursor. We make the table read-only by calling setMode(QSqlCursor::ReadOnly) on the cursor, and call setSort() to sort the tracks by track number.

```
    addButton = new QPushButton(tr("&Add"), this);
    editButton = new QPushButton(tr("&Edit"), this);
    deleteButton = new QPushButton(tr("&Delete"), this);
    refreshButton = new QPushButton(tr("&Refresh"), this);
    quitButton = new QPushButton(tr("&Quit"), this);
    connect(addButton, SIGNAL(clicked()),
            this, SLOT(addCd()));
    ...
    connect(quitButton, SIGNAL(clicked()),
            this, SLOT(close()));
    connect(cdTable, SIGNAL(currentChanged(QSqlRecord *)),
            this, SLOT(currentCdChanged(QSqlRecord *)));
    connect(cdTable,
            SIGNAL(doubleClicked(int, int, int, const QPoint &)),
            this, SLOT(editCd()));
    ...
}
```

We set up the rest of the user interface and create the signal–slot connections necessary to produce the desired behavior.

```
void MainForm::addCd()
{
    CdForm form(this);
    if (form.exec()) {
        cdTable->refresh();
        trackTable->refresh();
    }
}
```

When the user clicks *Add*, we pop up a modal `CdForm` dialog, and if the user clicks *Update* on it, we refresh the `QDataTables`.

```
void MainForm::editCd()
{
    QSqlRecord *record = cdTable->currentRecord();
    if (record) {
        CdForm form(record->value("id").toInt(), this);
        if (form.exec()) {
            cdTable->refresh();
            trackTable->refresh();
        }
    }
}
```

When the user clicks *Edit*, we pop up a modal `CdForm` dialog, with the current CD's ID as argument to the `CdForm` constructor. This will cause the dialog to start up with its fields populated with the current CD's data.

When we parameterize a form with an ID as we have done here, it is possible that the ID will not be valid by the time the form appears. For example, the user could click *Edit* a fraction of a second before another user deletes the CD. What we could have done in `CdForm` is to execute a `SELECT` on the ID that is passed in immediately after the `transaction()` call and only proceed if the ID still exists. Here, we simply rely on the database to report an error if an attempt to use an invalid ID is made.

```
void MainForm::deleteCd()
{
    QSqlRecord *record = cdTable->currentRecord();
    if (record) {
        QSqlQuery query;
        query.exec("DELETE FROM track WHERE cdid =  "
                   + record->value("id").toString());
        query.exec("DELETE FROM cd WHERE id = "
                   + record->value("id").toString());
        cdTable->refresh();
        trackTable->refresh();
    }
}
```

When the user clicks *Delete*, we remove all the tracks for the current CD from the `track` table and then the current CD from the `cd` table. Then we update both tables.

```
void MainForm::currentCdChanged(QSqlRecord *record)
{
    trackTable->setFilter("cdid = "
                          + record->value("id").toString());
    trackTable->refresh();
}
```

The `currentCdChanged()` slot is connected to the `cdTable`'s `currentChanged()` signal, which is emitted when the user modifies the current CD or when the user makes another CD current. Whenever the current CD changes, we call `setFilter()` on the `track` table and refresh it to make it display the tracks related to the current CD, and we call `refresh()` to force the table to repopulate itself with the relevant data.

This is all the code that is needed to implement `MainForm`. One possible improvement would be to show the duration of each track split into minutes and seconds (for example, "02:35") rather than just as seconds ("155"). We could accomplish this by subclassing `QSqlCursor` and reimplementing the `calculate–Field()` function to transform the `duration` field into a `QString` with the desired format:

```
QVariant TrackSqlCursor::calculateField(const QString &name)
{
    if (name == "duration") {
        int duration = value("duration").toInt();
        return QString("%1:%2").arg(duration / 60, 2)
                               .arg(duration % 60, 2);
    }
    return QVariant();
}
```

We would also need to call `setCalculated("duration", true)` on the cursor to tell `QDataTable` to use the value returned by `calculateField()` for the `duration` field, instead of simply using `value()`.

Creating Data-Aware Forms

Qt takes an innovative approach to database interaction with forms. Instead of having a separate database-enabled version of every built-in widget, Qt is able to make any widget data-aware, using `QSqlForm` and `QSqlPropertyMap` to relate database fields to widgets. Any built-in or custom widget can be made data-aware using these classes.

`QSqlForm` is a `QObject` subclass that makes it easy to create forms to browse or edit individual records in a database. The common pattern of usage is this:

1. Create the editor widgets (QLineEdits, QComboBoxes, QSpinBoxes, etc.) for the record's fields.

2. Create a QSqlCursor and move it to the record to edit.

3. Create a QSqlForm object.

4. Tell the QSqlForm which editor widget is bound to which database field.

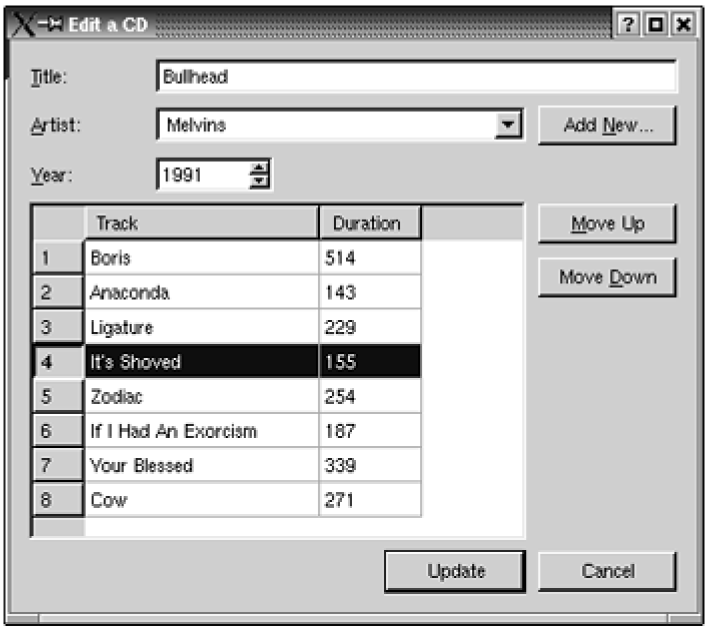
5. Call the QSqlForm::readFields() function to populate the editor widgets with the data from the current record.

6. Show the dialog.

7. Call the QSqlForm::writeFields() function to copy the updated values back into the database.

To illustrate this, we will look at the code for the CdForm dialog. This dialog allows the user to create or edit a CD record. The user can specify the CD's title, artist, and release year, and the title and duration of each track.

Figure 12.4. The CdForm dialog



Title: Bullhead
Artist: Melvins
Year: 1991

	Track	Duration
1	Boris	514
2	Anaconda	143
3	Ligature	229
4	It's Shoved	155
5	Zodiac	254
6	If I Had An Exorcism	187
7	Your Blessed	339
8	Cow	271

Let's start with the class definition:

```
class CdForm : public QDialog
{
    Q_OBJECT
public:
    CdForm(QWidget *parent = 0, const char *name = 0);
    CdForm(int id, QWidget *parent = 0, const char *name = 0);
    ~CdForm();

protected slots:
    void accept();
    void reject();

private slots:
    void addNewArtist();
    void moveTrackUp();
    void moveTrackDown();
    void beforeInsertTrack(QSqlRecord *buffer);
    void beforeDeleteTrack(QSqlRecord *buffer);

private:
    void init();
    void createNewRecord();
    void swapTracks(int trackA, int trackB);

    QLabel *titleLabel;
    QLabel *artistLabel;
    ...
    QDataTable *trackTable;
    QSqlForm *sqlForm;
    QSqlCursor *cdCursor;
    QSqlCursor *trackCursor;
    int cdId;
    bool newCd;
};
```

We have declared two constructors: one for inserting a new CD into the database, the other for updating an existing CD. The `accept()` and `reject()` slots are reimplemented from `QDialog`.

```
CdForm::CdForm(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    setCaption(tr("Add a CD"));
    cdId = -1;
    init();
}
```

The first constructor sets the dialog's caption to "Add a CD" and calls the private `init()` function to do the rest.

```
CdForm::CdForm(int id, QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    setCaption(tr("Edit a CD"));
    cdId = id;
    init();
}
```

The second constructor sets the caption to "Edit a CD" and also calls `init()`.

```
void CdForm::init()
{
    db = QSqlDatabase::database("CD");
    db->transaction();
    if (cdId == -1)
        createNewRecord();
```

In `init()`, we start a transaction using the "CD" database connection. We need to use different connections in `CdForm` and `ArtistForm`, because we can have both forms open at the same time, and we don't want one form to roll back the transaction initiated by the other form.

If we have no CD to operate on, we call the private function `createNewRecord()` to insert a blank one into the database. This will allow us to use the CD ID as a foreign key in the tracks' `QDataTable`. If the user clicks *Cancel*, we roll back the transaction and the blank record will disappear.

For this dialog, we use a different connection to the database than in the ArtistForm. This is because we can only have one active transaction per connection, and we can end up in a situation where we need two, for example, if the user clicks *Add New* to pop up the ArtistForm.

```
    titleLabel = new QLabel(tr("&Title:"), this);
    artistLabel = new QLabel(tr("&Artist:"), this);
    yearLabel = new QLabel(tr("&Year:"), this);
    titleLineEdit = new QLineEdit(this);
    yearSpinBox = new QSpinBox(this);
    yearSpinBox->setRange(1900, 2100);
    yearSpinBox->setValue(QDate::currentDate().year());
    artistComboBox = new ArtistComboBox(db, this);
    artistButton = new QPushButton(tr("Add &New..."), this);
    ...
    cancelButton = new QPushButton(tr("Cancel"), this);
```

We create the labels, the line edit, the spin box, the combobox, and the buttons that form the user interface. The combobox is of type ArtistComboBox, which we will cover later on.

```
    trackCursor = new QSqlCursor("track", true, db);
    trackTable = new QDataTable(trackCursor, false, this);
    trackTable->setFilter("cdid = " + QString::number(cdId));
    trackTable->setSort(trackCursor->index("number"));
    trackTable->addColumn("title", tr("Track"));
    trackTable->addColumn("duration", tr("Duration"));
    trackTable->refresh();
```

We set up the QDataTable that allows the user to browse and edit the tracks on the current CD. This is very similar to what we did in the previous section with the ArtistForm class.

```
    cdCursor = new QSqlCursor("cd", true, db);
    cdCursor->select("id = " + QString::number(cdId));
    cdCursor->next();
```

We set up the QSqlCursor associated with the QSqlForm and make it point to the record with the correct ID.

```
    QSqlPropertyMap *propertyMap = new QSqlPropertyMap;
    propertyMap->insert("ArtistComboBox", "artistId");
    sqlForm = new QSqlForm(this);
    sqlForm->installPropertyMap(propertyMap);
    sqlForm->setRecord(cdCursor->primeUpdate());
    sqlForm->insert(titleLineEdit, "title");
    sqlForm->insert(artistComboBox, "artistid");
    sqlForm->insert(yearSpinBox, "year");
    sqlForm->readFields();
```

We create a QSqlPropertyMap. The QSqlPropertyMap class tells QSqlForm which Qt property holds the value of a certain type of editor widget. By default, QSqlForm already knows that a QLineEdit stores its value in the text property and that a QSpinBox stores its value in the value property. But it doesn't know anything about custom widgets such as ArtistComboBox. By inserting the pair ("ArtistComboBox", "artistId") in the property map and by calling installPropertyMap() on the QSqlForm, we tell QSqlForm to use the artistId property for widgets of type ArtistComboBox.

The QSqlForm object also needs a buffer to operate on, which we obtain by calling primeUpdate() on the QSqlCursor, and it needs to know which editor widget corresponds to which database field. At the end, we call readFields() to read the data from the database into the editor widgets.

```
    connect(artistButton, SIGNAL(clicked()),
            this, SLOT(addNewArtist()));
    connect(moveUpButton, SIGNAL(clicked()),
            this, SLOT(moveTrackUp()));
    connect(moveDownButton, SIGNAL(clicked()),
            this, SLOT(moveTrackDown()));
    connect(updateButton, SIGNAL(clicked()),
            this, SLOT(accept()));
    connect(cancelButton, SIGNAL(clicked()),
            this, SLOT(reject()));
    connect(trackTable, SIGNAL(beforeInsert(QSqlRecord *)),
            this, SLOT(beforeInsertTrack(QSqlRecord *)));
    ...
}
```

We connect the buttons' `clicked()` signals and the `QDataTable`'s `beforeInsert()` signal to the private slots that are described next.

```
void CdForm::accept()
{
    sqlForm->writeFields();
    cdCursor->update();
    db->commit();
    QDialog::accept();
}
```

If the user clicks *Update*, we write the data into the `QSqlCursor`'s edit buffer, we call `update()` to perform an `UPDATE` on the database, we call `commit()` to really write the record into the database, and we call the base class's `accept()` implementation to close the form.

```
void CdForm::reject()
{
    db->rollback();
    QDialog::reject();
}
```

If the user clicks *Cancel*, we roll back, leaving the database unchanged, and close the form.

```
void CdForm::addNewArtist()
{
    ArtistForm form(this);
    if (form.exec()) {
        artistComboBox->refresh();
        updateButton->setEnabled(artistComboBox->count() > 0);
    }
}
```

If the user clicks *Add New*, we pop up a modal `ArtistForm` dialog. The dialog allows the user to add new artists, and also to edit and delete existing artists. If the user clicks *Update*, we call `ArtistComboBox::refresh()` to ensure that its list of artists is up to date.

We enable or disable the *Update* button depending on whether there are any artists, since we don't want to allow a new CD to be created without an artist name.

```
void CdForm::beforeInsertTrack(QSqlRecord *buffer)
{
    buffer->setValue("id", generateId("track", db));
    buffer->setValue("number", trackCursor->size() + 1);
    buffer->setValue("cdid", cdId);
}
```

The beforeInsertTrack() slot is connected to the QDataTable's beforeInsert() signal. We set the record's id, number, and cdid fields.

```
void CdForm::beforeDeleteTrack(QSqlRecord *buffer)
{
    QSqlQuery query(db);
    query.exec("UPDATE track SET number = number - 1 "
               "WHERE track.number > "
               + buffer->value("number").toString());
}
```

The beforeDeleteTrack() slot is connected to the QDataTable's beforeDelete() signal. We renumber all the tracks that have a number higher than the track we delete to ensure that the track numbers remain consecutive. For example, if the CD contains six tracks and the user deletes track 4, then track 5 becomes track 4 and track 6 becomes track 5.

There are four functions that we have not covered: moveTrackUp(), moveTrackDown(), swapTracks(), and createNewRecord(). These are necessary to make the application usable, but their implementations do not show any new techniques, so we will not review them here. Their source code is on the CD.

Now that we have seen all the forms in the CD Collection application, we are ready to review the custom ArtistComboBox. As usual, we start with the class definition:

```
class ArtistComboBox : public QComboBox
{
    Q_OBJECT
    Q_PROPERTY(int artistId READ artistId WRITE setArtistId)
public:
    ArtistComboBox(QSqlDatabase *database, QWidget *parent = 0,
                   const char *name = 0);

    void refresh();
    int artistId() const;
    void setArtistId(int id);

private:
    void populate();

    QSqlDatabase *db;
    QMap<int, int> idFromIndex;
    QMap<int, int> indexFromId;
};
```

The ArtistComboBox class inherits QComboBox and adds an artistId property and a few functions.

In the private section, we declare a QMap<int, int> that associates artist IDs with combobox indexes and a QMap<int, int> that associates combobox indexes with artist IDs.

```
ArtistComboBox::ArtistComboBox(QSqlDatabase *database,
                               QWidget *parent, const char *name)
    : QComboBox(parent, name)
{
    db = database;
    populate();
}
```

In the constructor, we call the private function populate() to fill the combobox with the names and IDs in the artist table.

```
void ArtistComboBox::refresh()
{
    int oldArtistId = artistId();
    clear();
    idFromIndex.clear();
    indexFromId.clear();
    populate();
    setArtistId(oldArtistId);
}
```

In the refresh() function, we repopulate the combobox with the latest data from the database. We are also careful to ensure that the artist who was selected before the refresh is still selected afterward, unless that artist has have been deleted from the database.

```
void ArtistComboBox::populate()
{
    QSqlCursor cursor("artist", true, db);
    cursor.select(cursor.index("name"));

    int index = 0;
    while (cursor.next()) {
        int id = cursor.value("id").toInt();
        insertItem(cursor.value("name").toString(), index);
        idFromIndex[index] = id;
        indexFromId[id] = index;
        ++index;
    }
}
```

In the private function populate(), we iterate through all the artists and call QComboBox::insertItem() to add them to the combobox. We also update the idFromIndex and the indexFromId maps.

```
int ArtistComboBox::artistId() const
{
    return idFromIndex[currentItem()];
}
```

The artistId() function returns the ID for the current artist.

```
void ArtistComboBox::setArtistId(int id)
{
    if (indexFromId.contains(id))
        setCurrentItem(indexFromId[id]);
}
```

The setArtistId() function sets the current artist based on an artist ID.

In applications that often need comboboxes that show foreign keys, it would probably be worthwhile creating a generic DatabaseComboBox class whose constructor would allow us to specify the table name, the field to display, and the field to use for IDs.

Let's finish the CD Collection application by implementing its createConnections() and main() functions.

```
inline bool createOneConnection(const QString &name)
{
    QSqlDatabase *db;
    if (name.isEmpty())
        db = QSqlDatabase::addDatabase("QSQLITEX");
    else
        db = QSqlDatabase::addDatabase("QSQLITEX", name);
    db->setDatabaseName("cdcollection.dat");
    if (!db->open()) {
        db->lastError().showMessage();
        return false;
    }
    return true;
}
inline bool createConnections()
{
    return createOneConnection("")
            && createOneConnection("ARTIST")
            && createOneConnection("CD");
}
```

In `createConnections()`, we create three identical connections to the CD database. We don't give any name to the first one; it is used by default when we don't specify a database. The other ones are called "ARTIST" and "CD"; they are used by `ArtistForm` and `CdForm`.

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    if (!createConnections())
        return 1;

    MainForm mainForm;
    app.setMainWidget(&mainForm);
    mainForm.resize(480, 320);
    mainForm.show();
    return app.exec();
}
```

The `main()` function is the same as most other Qt `main()` functions, except for the addition of a `createConnections()` call.

As we mentioned at the end of the previous section, one possible improvement would be to display the duration of each track as minutes and seconds rather than just seconds. Besides reimplementing `QSqlCursor::calculateField()`, this would also involve subclassing `QSqlEditorFactory` to provide a custom editor (which we could base on `QTimeEdit`) and using a `QSqlPropertyMap` to tell `QDataTable` how to get the value back from the editor. See the documentation for `QDataTable`'s `installEditorFactory()` and `installPropertyMap()` functions for more information.

Another improvement would be to store an image of each CD's cover in the database and to show it in the `CdForm`. To implement this, we could store the image data as a `BLOB` in the database, retrieve it as a `QByteArray`, and pass the `QByteArray` to the `QImage` constructor.

[Team LiB]
PREVIOUS NEXT
[Team LiB]
PREVIOUS NEXT

Chapter 13. Networking

Qt provides the QFtp and QHttp classes for working with FTP and HTTP. These protocols are easy to use for downloading and uploading files and, in the case of HTTP, for sending requests to web servers and retrieving the results.

Qt's QFtp and QHttp classes are built on the lower-level QSocket class, which provides a TCP socket. TCP operates in terms of data streams transmitted between network nodes. QSocket is in turn implemented on top of QSocketDevice, a thin wrapper around the platform-specific network APIs. The QSocketDevice class supports both TCP and UDP.

In this chapter, we will learn how to use the four classes mentioned above and other closely related classes, like QServerSocket and QSocketNotifier. We will also cover uploading and downloading files and how to use a web form programmatically. We will use TCP in a server application and in a corresponding client application. Similarly, we will use UDP in a sender application and in a corresponding receiver application. The coverage of QFtp and QHttp should be accessible to anyone, but the coverage of QSocket and especially QSocketDevice does assume some networking experience.

[Team LiB]
[Team LiB]

Using QFtp

The QFtp class implements the client side of the FTP protocol in Qt. It provides various functions to perform the most common FTP operations, including get(), put(), remove(), and mkdir(), and provides a means of executing arbitrary FTP commands.

The QFtp class works asynchronously. When we call a function like get() or put(), it returns immediately and the data transfer occurs when control passes back to Qt's event loop. This ensures that the user interface remains responsive while FTP commands are executed.

We will start with an example that shows how to retrieve a single file using get(). The example assumes that the application's MainWindow class needs to retrieve a price list from an FTP site.

```
class MainWindow : public QMainWindow
{
    Q_OBJECT
public:
    MainWindow(QWidget *parent = 0, const char *name = 0);

    void getPriceList();
    ...

private slots:
    void ftpDone(bool error);

private:
    QFtp ftp;
    QFile file;
    ...
};
```

The class has a public function, `getPriceList()`, that retrieves the price list file, and a private slot, `ftpDone(bool)`, that is called when the file transfer is completed. The class also has two private variables: The `ftp` variable, of type `QFtp`, encapsulates the connection to an FTP server; the `file` variable is used for writing the downloaded file to disk.

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    ...
    connect(&ftp, SIGNAL(done(bool)), this, SLOT(ftpDone(bool)));
}
```

In the constructor, we connect the `QFtp` object's `done(bool)` signal to our `ftpDone(bool)` private slot. `QFtp` emits the `done(bool)` signal when it has finished processing all requests. The `bool` parameter indicates whether an error occurred or not.

```
void MainWindow::getPriceList()
{
    file.setName("price-list.csv");
    if (!file.open(IO_WriteOnly)) {
        QMessageBox::warning(this, tr("Sales Pro"),
                             tr("Cannot write file %1\n%2.")
                             .arg(file.name())
                             .arg(file.errorString()));
        return;
    }

    ftp.connectToHost("ftp.trolltech.com");
    ftp.login();
    ftp.cd("/topsecret/csv");
    ftp.get("price-list.csv", &file);
    ftp.close();
}
```

The `getPriceList()` function downloads the `ftp://ftp.trolltech.com/topsecret/csv/price-list.csv` file and saves it as `price-list.csv` in the current directory.

We start by opening the `QFile` for writing. Then we execute a sequence of five FTP commands using our `QFtp` object. The second argument to `get()` specifies the output I/O device.

The FTP commands are queued and executed in Qt's event loop. The completion of the commands is indicated by `QFtp`'s `done(bool)` signal, which we connected to `ftpDone(bool)` in the constructor.

```
void MainWindow::ftpDone(bool error)
{
    if (error)
        QMessageBox::warning(this, tr("Sales Pro"),
                             tr("Error while retrieving file with "
                                "FTP: %1.")
                             .arg(ftp.errorString()));
        file.close();
}
```

Once the FTP commands are executed, we close the file. If an error occurred, we display it in a `QMessageBox`.

QFtp provides these operations: connectToHost(), login(), close(), list(), cd(), get(), put(), remove(), mkdir(), rmdir(), and rename(). All of these functions schedule an FTP command and return an ID number that identifies the command. Arbitrary FTP commands can be executed using rawCommand(). For example, here's how to execute a SITE CHMOD command:

```
ftp.rawCommand("SITE CHMOD 755 fortune");
```

QFtp emits the commandStarted(int) signal when it starts executing a command, and it emits the commandFinished(int, bool) signal when the command is finished. The int parameter is the ID number that identifies a command. If we are interested in the fate of individual commands, we can store the ID numbers when we schedule the commands. Keeping track of the ID numbers allows us to provide detailed feedback to the user. For example:

```
void MainWindow::getPriceList()
{
    ...
    connectId = ftp.connectToHost("ftp.trolltech.com");
    loginId = ftp.login();
    cdId = ftp.cd("/topsecret/csv");
    getId = ftp.get("price-list.csv", &file);
    closeId = ftp.close();
}
void MainWindow::commandStarted(int id)
{
    if (id == connectId) {
        statusBar()->message(tr("Connecting..."));
    } else if (id == loginId) {
        statusBar()->message(tr("Logging in..."));
    ...
}
```

Another way of providing feedback is to connect to QFtp's stateChanged() signal.

In most applications, we are only interested in the fate of the whole sequence of commands. We can then simply connect to the done(bool) signal, which is emitted whenever the command queue becomes empty.

When an error occurs, QFtp automatically clears the command queue. This means that if the connection or the login fails, the commands that follow in the queue are never executed. But if we schedule new commands after the error has occurred using the same QFtp object, these commands will be queued and executed as if nothing had happened.

We will now review a more advanced example:

```
class Downloader : public QObject
{
    Q_OBJECT
public:
    Downloader(const QUrl &url);

signals:
    void finished();

private slots:
    void ftpDone(bool error);
    void listInfo(const QUrlInfo &urlInfo);

private:
    QFtp ftp;
    std::vector<QFile *> openedFiles;
};
```

The Downloader class downloads all the files located in an FTP directory. The directory is specified as a QUrl passed to the class's constructor. The QUrl class is a Qt class that provides a high-level interface for extracting the different parts of a URL, such as the file name, path, protocol, and port.

```
Downloader::Downloader(const QUrl &url)
{
    if (url.protocol() != "ftp") {
        QMessageBox::warning(0, tr("Downloader"),
                             tr("Protocol must be 'ftp'."));
        emit finished();
        return;
    }

    int port = 21;
    if (url.hasPort())
        port = url.port();
    connect(&ftp, SIGNAL(done(bool)),
            this, SLOT(ftpDone(bool)));
    connect(&ftp, SIGNAL(listInfo(const QUrlInfo &)),
            this, SLOT(listInfo(const QUrlInfo &)));

    ftp.connectToHost(url.host(), port);
    ftp.login(url.user(), url.password());
    ftp.cd(url.path());
    ftp.list();
}
```

In the constructor, we first check that the URL starts with "ftp:". Then we extract a port number. If no port is specified, we use port 21, the default port for FTP.

Next, we establish two signal–slot connections, and we schedule four FTP commands. The last FTP command, list(), retrieves the name of every file in the directory and emits a listInfo (const QUrlInfo &) signal for each name that it retrieves. This signal is connected to a slot also called listInfo(), which downloads the file associated with the URL it is given.

```
void Downloader::listInfo(const QUrlInfo &urlInfo)
{
    if (urlInfo.isFile() && urlInfo.isReadable()) {
        QFile *file = new QFile(urlInfo.name());
        if (!file->open(IO_WriteOnly)) {
            QMessageBox::warning(0, tr("Downloader"),
                                 tr("Error: Cannot open file "
                                    "%1:\n%2.")
                                 .arg(file->name())
                                 .arg(file->errorString()));
            emit finished();
            return;
        }

        ftp.get(urlInfo.name(), file);
        openedFiles.push_back(file);
    }
}
```

The listInfo() slot's QUrlInfo parameter provides detailed information about a remote file. If the file is a normal file (not a directory) and is readable, we call get() to download it. The QFile object used for downloading is allocated using new and a pointer to it is stored in the openedFiles vector.

```
void Downloader::ftpDone(bool error)
{
    if (error)
        QMessageBox::warning(0, tr("Downloader"),
                             tr("Error: %1.")
                             .arg(ftp.errorString()));
    for (int i = 0; i < (int)openedFiles.size(); ++i)
        delete openedFiles[i];
    emit finished();
}
```

The `ftpDone()` slot is called when all the FTP commands have finished, or if an error occurred. We delete the `QFile` objects to prevent memory leaks, and also to close each file. (The `QFile` destructor automatically closes the file if it's open.)

If there are no errors, the sequence of FTP commands and signals is as follows:

```
connectToHost(host)
login()
cd(path)
list()
    emit listInfo(file_1)
        get(file_1)
    emit listInfo(file_2)
        get(file_2)
    ...
    emit listInfo(file_N)
        get(file_N)
emit done()
```

If a network error occurs while downloading the fifth of, say, twenty files to download, the remaining files will not be downloaded. If we wanted to download as many files as possible, one solution would be to schedule the `GET` operations one at a time and to wait for the `done(bool)` signal before scheduling a new `GET` operation. In `listInfo()`, we would simply append the file name to a `QStringList`, instead of calling `get()` right away, and in `done(bool)` we would call `get()` on the next file to download in the `QStringList`. The sequence of execution would then look like this:

```
connectToHost(host)
login()
cd(path)
list()
    emit listInfo(file_1)
    emit listInfo(file_2)
    ...
    emit listInfo(file_N)
emit done()

get(file_1)
emit done()

get(file_2)
emit done()
...
get(file_N)
emit done()
```

Another solution would be to use one `QFtp` object per file. This would enable us to download the files in parallel, through separate FTP connections.

```
int main(int argc, char *argv[])
```

```
{
    QApplication app(argc, argv);
    QUrl url("ftp://ftp.example.com/");
    if (argc >= 2)
        url = argv[1];
    Downloader downloader(url);
    QObject::connect(&downloader, SIGNAL(finished()),
                     &app, SLOT(quit()));
    return app.exec();
}
```

The main() function completes the program. If the user specifies a URL on the command line, we use it; otherwise, we fall back on ftp://ftp.example.com/.

In both examples, the data retrieved using get() was written to a QFile. This doesn't have to be the case. If we wanted the data in memory, we could use a QBuffer, the QIODevice subclass that wraps a QByteArray. For example:

```
QBuffer *buffer = new QBuffer(byteArray);
buffer->open(IO_WriteOnly);
ftp.get(urlInfo.name(), buffer);
```

We could also omit the I/O device argument to get(), or pass a null pointer. The QFtp class then emits a readyRead() signal every time new data is available, and the data can be read using readBlock() or readAll().

If we want to provide the user with feedback while the data is being downloaded, we can connect QFtp's dataTransferProgress(int, int) signal to the setProgress(int, int) slot in a QProgressBar or in a QProgressDialog. We would then also connect the QProgressBar or QProgressDialog's canceled() signal to QFtp's abort() slot.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Using QHttp

The QHttp class implements the client side of the HTTP protocol in Qt. It provides various functions to perform the most common HTTP operations, including get() and post(), and provides a means of sending arbitrary HTTP requests. If you have read the previous section about QFtp, you will find that there are many similarities between QFtp and QHttp.

The QHttp class works asynchronously. When we call a function like get() or post(), the function returns immediately, and the data transfer occurs later, when control returns to Qt's event loop. This ensures that the application's user interface remains responsive while HTTP requests are being processed.

We will review an example that shows how to download an HTML file from Trolltech's web site from a Qt application's MainWindow class. We will omit the header file because it is very similar to the one we used in the previous section (p.284), with a private slot (httpDone(bool)) and private variables (http of type QHttp and file of type QFile).

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    ...
    connect(&http, SIGNAL(done(bool)), this, SLOT(httpDone(bool)));
}
```

In the constructor, we connect the QHttp object's done(bool) signal to the MainWindow's httpDone(bool) slot.

```
void MainWindow::getFile()
{
    file.setName("aboutqt.html");
    if (!file.open(IO_WriteOnly)) {
        QMessageBox::warning(this, tr("HTTP Get"),
                             tr("Cannot write file %1\n%2.")
                             .arg(file.name())
                             .arg(file.errorString()));
        return;
     }

     http.setHost("doc.trolltech.com");
     http.get("/3.2/aboutqt.html", &file);
     http.closeConnection();
}
```

The getFile() function downloads the http://doc.trolltech.com/3.2/aboutqt.html file and saves it as aboutqt.html in the current directory.

We open the QFile for writing and schedule a sequence of three HTTP requests using our QHttp object. The second argument to get() specifies the output I/O device.

The HTTP requests are queued and executed in Qt's event loop. The completion of the commands is indicated by QHttp's done(bool) signal, which we connected to httpDone(bool) in the constructor.

```
void MainWindow::httpDone(bool error)
{
    if (error)
        QMessageBox::warning(this, tr("HTTP Get"),
                             tr("Error while fetching file with"
                                "HTTP: %1.")
                             .arg(http.errorString()));
        file.close();
}
```

Once the HTTP requests are finished, we close the file. If an error occurred, we display the error message in a QMessageBox.

QHttp provides the following operations: setHost(), get(), post(), and head(). For example, here's how we would use post() to send a list of "*name* = *value*" pairs to a CGI script:

```
http.setHost("www.example.com");
http.post("/cgi/somescript.py", QCString("x=200&y=320"), &file);
```

For more control, we can use the request() function, which accepts an arbitrary HTTP header and data. For example:

```
QHttpRequestHeader header("POST", "/search.html");
header.setValue("Host", "www.trolltech.com");
header.setContentType("application/x-www-form-urlencoded");
http.setHost("www.trolltech.com");
http.request(header, QCString("qt-interest=on&search=opengl"));
```

QHttp emits the requestStarted(int) signal when it starts executing a request, and it emits the requestFinished(int, bool) signal when the request has finished. The int parameter is an ID number that identifies a request. If we are interested in the fate of individual requests, we can store the ID numbers when we schedule the requests. Keeping track of the ID numbers allows us to provide detailed feedback to the user.

In most applications, we only want to know whether the entire sequence of requests completed successfully or not. This is easily achieved by connecting to the done(bool) signal, which is emitted when the request queue becomes empty.

When an error occurs, the request queue is automatically cleared. But if we schedule new requests after the error has occurred using the same QHttp object, these requests will be queued and sent as usual.

Like QFtp, QHttp provides a readyRead() signal as well as the readBlock() and readAll() functions that we can use instead of specifying an I/O device. It also provides a dataTransferProgress(int, int) signal that can be connected to a QProgressBar or to a QProgressDialog's setProgress(int, int) slot.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

TCP Networking with QSocket

The QSocket class can be used to implement TCP clients and servers. TCP is a transport protocol that forms the basis of many application-level Internet protocols, including FTP and HTTP, and that can also be used for custom protocols.

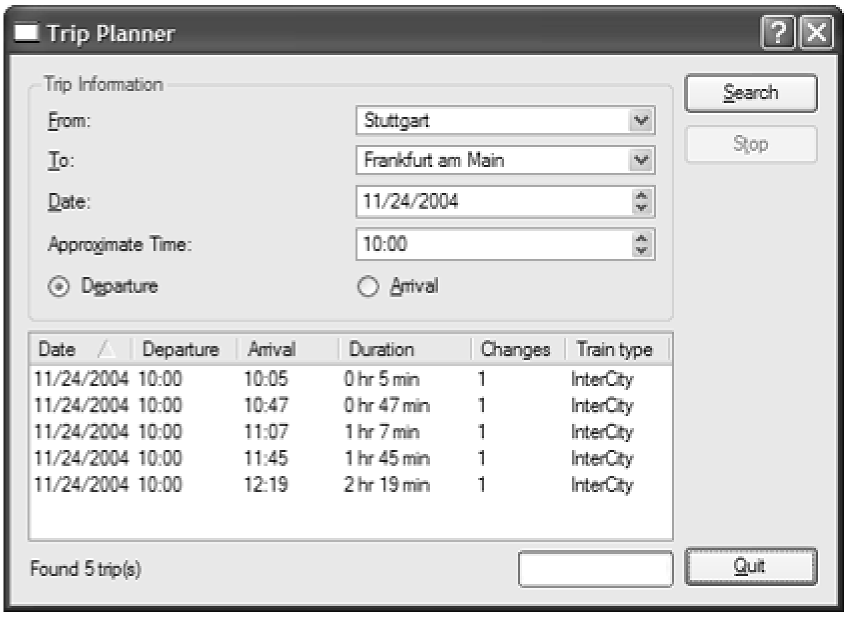
TCP is a stream-oriented protocol. For applications, the data appears to be a long stream, rather like a large flat file. The high-level protocols built on top of TCP are typically either line-oriented or block-oriented:

- Line-oriented protocols transfer data as lines of text, each terminated by a newline.
- Block-oriented protocols transfer data as binary data blocks. Each block consists of a size field followed by *size* bytes of data.

QSocket inherits from QIODevice, so it can be read from and written to using a QDataStream or a QTextStream. One notable difference when reading data from a network compared with reading from a file is that we must make sure that we have received enough data from the peer before we use the >> operator. Failing to do so may result in undefined behavior.

In this section, we will review the code of a client and a server that use a custom block-oriented protocol. The client is called Trip Planner and allows users to plan their next train trip. The server is called Trip Server and provides the trip information to the client. We will start by writing the Trip Planner application.

Figure 13.1. The Trip Planner application



From: Stuttgart
To: Frankfurt am Main
Date: 11/24/2004
Approximate Time: 10:00
(● Departure) ○ Arrival

Date	Departure	Arrival	Duration	Changes	Train type
11/24/2004	10:00	10:05	0 hr 5 min	1	InterCity
11/24/2004	10:00	10:47	0 hr 47 min	1	InterCity
11/24/2004	10:00	11:07	1 hr 7 min	1	InterCity
11/24/2004	10:00	11:45	1 hr 45 min	1	InterCity
11/24/2004	10:00	12:19	2 hr 19 min	1	InterCity

Found 5 trip(s)

The Trip Planner provides a *From* field, a *To* field, a *Date* field, an *Approximate Time* field, and two radio buttons to select whether the approximate time is that of departure or arrival. When the user clicks *Search*, the application sends a request to the server, which responds with a list of train trips that match the user's criteria. The list is shown in a `QListView` in the Trip Planner window. The very bottom of the window is occupied by a `QLabel` that shows the status of the last operation and a `QProgressBar`.

The Trip Planner's user interface was created using *Qt Designer*. Here, we will focus on the source code in the corresponding `.ui.h` file. Note that the following four variables were declared in *Qt Designer*'s Members tab:

```
QSocket socket;
QTimer connectionTimer;
QTimer progressBarTimer;
Q_UINT16 blockSize;
```

The `socket` variable of type `QSocket` encapsulates the TCP connection. The `connectionTimer` variable is used to time out a connection that lasts too long. The `progressBarTimer` variable is used to refresh the progress bar periodically when the application is busy. Finally, the `blockSize` variable is used when parsing the blocks received from the server.

```
void TripPlanner::init()
{
    connect(&socket, SIGNAL(connected()),
            this, SLOT(sendRequest()));
    connect(&socket, SIGNAL(connectionClosed()),
            this, SLOT(connectionClosedByServer()));
    connect(&socket, SIGNAL(readyRead()),
            this, SLOT(updateListView()));
    connect(&socket, SIGNAL(error(int)),
            this, SLOT(error(int)));

    connect(&connectionTimer, SIGNAL(timeout()),
            this, SLOT(connectionTimeout()));
    connect(&progressBarTimer, SIGNAL(timeout()),
            this, SLOT(advanceProgressBar()));

    QDateTime dateTime = QDateTime::currentDateTime();
    dateEdit->setDate(dateTime.date());
    timeEdit->setTime(QTime(dateTime.time().hour(), 0));
}
```

In `init()`, we connect the `QSocket`'s `connected()`, `connectionClosed()`, `readyRead()`, and `error(int)` signals, and the two timers' `timeout()` signals, to our own slots. We also fill the *Date* and *Approximate Time* fields with default values based on the current date and time.

```
void TripPlanner::advanceProgressBar()
{
    progressBar->setProgress(progressBar->progress() + 2);
}
```

The `advanceProgressBar()` slot is connected to the `progressBarTimer`'s `timeout()` signal. We advance the progress bar by two units. In *Qt Designer*, the progress bar's `totalSteps` property was set to 0, a special value meaning that the bar should behave as a busy indicator.

```
void TripPlanner::connectToServer()
{
    listView->clear();

    socket.connectToHost("tripserver.zugbahn.de", 6178);

    searchButton->setEnabled(false);
    stopButton->setEnabled(true);
    statusLabel->setText(tr("Connecting to server..."));

    connectionTimer.start(30 * 1000, true);
    progressBarTimer.start(200, false);

    blockSize = 0;
}
```

The `connectToServer()` slot is executed when the user clicks Search to start a search. We call `connectToHost()` on the `QSocket` object to connect to the server, which we assume is accessible at port 6178 on the fictitious host `tripserver. zugbahn.de`. (If you want to try the example on your own machine, replace the host name with `localhost`.) The `connectToHost()` call is asynchronous; it always returns immediately. The connection is typically established later. The `QSocket` object emits the `connected()` signal when the connection is up and running, or `error(int)` (with an error code) if the connection failed.

Next, we update the user interface and start the two timers. The first timer, `connectionTimer`, is a single-shot timer that gets triggered when the connection has been idle for 30 seconds. The second timer, `progressBarTimer`, times out every 200 milliseconds to update the application's progress bar, giving a visual cue to the user that the application is working.

Finally, we set the `blockSize` variable to 0. The `blockSize` variable stores the length of the next block received from the server. We have chosen to use the value of 0 to mean that we don't yet know the size of the next block.

```
void TripPlanner::sendRequest()
{
    QByteArray block;
    QDataStream out(block, IO_WriteOnly);
    out.setVersion(5);
    out << (Q_UINT16)0 << (Q_UINT8) 'S'
        << fromComboBox->currentText()
        << toComboBox->currentText() << dateEdit->date()
        << timeEdit->time();
    if (departureRadioButton->isOn())
        out << (Q_UINT8) 'D';
    else
```

```
        out << (Q_UINT8) 'A';
    out.device()->at(0);
    out << (Q_UINT16) (block.size() - sizeof(Q_UINT16));
    socket.writeBlock(block.data(), block.size());

    statusLabel->setText(tr("Sending request..."));
}
```

The sendRequest() slot is executed when the QSocket object emits the connected() signal, indicating that a connection has been established. The slot's task is to generate a request to the server, with all the information entered by the user.

The request is a binary block with the following format:

Q_UINT16	Block size in bytes (excluding this field)
Q_UINT8	Request type (always 'S')
QString	Departure city
QString	Arrival city
QDate	Date of travel
QTime	Approximate time of travel
Q_UINT8	Time is for departure ('D') or arrival ('A')

We first write the data to a QByteArray called block. We can't write the data directly to the QSocket because we don't know the size of the block, which must be sent first, until after we have put all the data into the block.

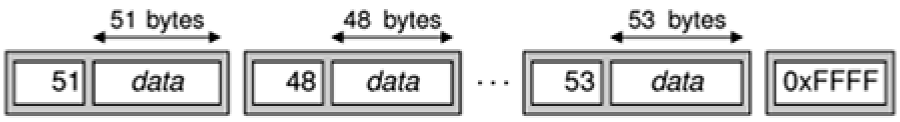
We initially write 0 as the block size, followed by the rest of the data. Then we call at(0) on the I/O device (a QBuffer created by QDataStream behind the scenes) to move back to the beginning of the byte array, and overwrite the initial 0 with the size of the block's data. The size is calculated by taking the block's size and subtracting sizeof(Q_UINT16) (that is, 2) to exclude the size field from the byte count. After that, we call writeBlock() on the QSocket to send the block to the server.

```
void TripPlanner::updateListView()
{
    connectionTimer.start(30 * 1000, true);

    QDataStream in(&socket);
    in.setVersion(5);

    for (;;) {
        if (blockSize == 0) {
            if (socket.bytesAvailable() < sizeof(Q_UINT16))
                break;
            in >> blockSize;
        }

        if (blockSize == 0xFFFF) {
            closeConnection();
            statusLabel->setText(tr("Found %1 trip(s)")
                                 .arg(listView->childCount()));
            break;
        }

        if (socket.bytesAvailable() < blockSize)
            break;
        QDate date;
        QTime departureTime;
        QTime arrivalTime;
        Q_UINT16 duration;
        Q_UINT8 changes;
        QString trainType;

        in >> date >> departureTime >> duration >> changes
           >> trainType;
        arrivalTime = departureTime.addSecs(duration * 60);

        new QListViewItem(listView,
                          date.toString(LocalDate),
                          departureTime.toString(tr("hh:mm")),
                          arrivalTime.toString(tr("hh:mm")),
                          tr("%1 hr %2 min").arg(duration / 60)
                                            .arg(duration % 60),
                          QString::number(changes),
                          trainType);
        blockSize = 0;
    }
}
```

The updateListView() slot is connected to the QSocket's readyRead() signal, which is emitted whenever the QSocket has received new data from the server. The first thing we do is to restart the single-shot connection timer. Whenever we receive some data from the server, we know that the connection is alive, so we set the timer running for another 30 seconds.

The server sends us a list of possible train trips that match the user's criteria. Each matching trip is sent as a single block, and each block starts with a size. What complicates the code in the for loop is that we don't necessarily get one block of data from the server at a time. We might have received an entire block, or just part of a block, or one and a half blocks, or even all of the blocks at once.

Figure 13.2. The Trip Server's blocks



So how does the for loop work? If the blockSize variable is 0, this means that we have not read the size of the next block. We try to read it (assuming there are at least 2 bytes available for reading). The server uses a size value of 0xFFFF to signify that there is no more data to receive, so if we read this value, we know that we have reached the end.

If the block size is not 0xFFFF, we try to read in the next block. First, we check to see if there are block size bytes available to read. If there are not, we stop there for now. The readyRead() signal will be emitted again when more data is available, and we will try again then.

Once we are sure that an entire block has arrived, we can safely use the >> operator on the QDataStream we set up on the QSocket to extract the information related to a trip, and we create a QListViewItem with that information. A block received from the server has the following format:

Q_UINT16	Block size in bytes (excluding this field)
QDate	Departure date

QTime	Departure time
Q_UINT16	Duration (in minutes)
Q_UINT8	Number of changes
QString	Train type

At the end, we reset the blockSize variable to 0 to indicate that the next block's size is unknown and needs to be read.

```
void TripPlanner::closeConnection()
{
    socket.close();
    searchButton->setEnabled(true);
    stopButton->setEnabled(false);
    connectionTimer.stop();
    progressBarTimer.stop();
    progressBar->setProgress(0);
}
```

The closeConnection() private function closes the connection to the TCP server, updates the user interface, and stops the timers. It is called from updateListView() when the 0xFFFF is read and from several other slots that we will cover shortly.

```
void TripPlanner::stopSearch()
{
    statusLabel->setText(tr("Search stopped"));
    closeConnection();
}
```

The stopSearch() slot is connected to the Stop button's clicked() signal. Essentially it just calls closeConnection().

```
void TripPlanner::connectionTimeout()
{
    statusLabel->setText(tr("Error: Connection timed out"));
    closeConnection();
}
```

The connectionTimeout() slot is connected to the connectionTimer's timeout() signal.

```
void TripPlanner::connectionClosedByServer()
{
    if (blockSize != 0xFFFF)
        statusLabel->setText(tr("Error: Connection closed by "
                                "server"));
    closeConnection();
}
```

The connectionClosedByServer() slot is connected to socket's connectionClosed() signal. If the server closes the connection and we have not yet received the 0xFFFF end-of-stream marker, we tell the user that an error occurred. We call closeConnection() as usual to update the user interface and to stop the timers.

```
void TripPlanner::error(int code)
{
    QString message;

    switch (code) {
```

```
    case QSocket::ErrConnectionRefused:
        message = tr("Error: Connection refused");
        break;
    case QSocket::ErrHostNotFound:
        message = tr("Error: Server not found");
        break;
    case QSocket::ErrSocketRead:
    default:
        message = tr("Error: Data transfer failed");
    }
    statusLabel->setText(message);
    closeConnection();
}
```

The `error(int)` slot is connected to `socket`'s `error(int)` signal. We produce an error message based on the error code.

The `main()` function for the Trip Planner application looks just as we would expect:

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    TripPlanner tripPlanner;
    app.setMainWidget(&tripPlanner);
    tripPlanner.show();
    return app.exec();
}
```

Now let's implement the server. The server consists of two classes: `TripServer` and `ClientSocket`. The `TripServer` class inherits `QServerSocket`, a class that allows us to accept incoming TCP connections. `ClientSocket` reimplements `QSocket` and handles a single connection. At any one time, there are as many `ClientSocket` objects in memory as there are clients being served.

```
class TripServer : public QServerSocket
{
public:
    TripServer(QObject *parent = 0, const char *name = 0);

    void newConnection(int socket);
};
```

The `TripServer` class reimplements the `newConnection()` function from `QServerSocket`. This function is called whenever a client attempts to connect to the port the server is listening to.

```
TripServer::TripServer(QObject *parent, const char *name)
    : QServerSocket(6178, 1, parent, name)
{
}
```

In the `TripServer` constructor, we pass the port number (6178) to the base class constructor. The second argument, 1, is the number of pending connections we want to allow.

```
void TripServer::newConnection(int socketId)
{
    ClientSocket *socket = new ClientSocket(this);
    socket->setSocket(socketId);
}
```

In `newConnection()`, we create a `ClientSocket` object as a child of the `TripServer` object, and we set its socket ID to the number provided to us.

```
class ClientSocket : public QSocket
{
    Q_OBJECT
public:
    ClientSocket(QObject *parent = 0, const char *name = 0);
private slots:
    void readClient();

private:
    void generateRandomTrip(const QString &from, const QString &to,
                            const QDate &date, const QTime &time);

    Q_UINT16 blockSize;
};
```

The ClientSocket class inherits from QSocket and encapsulates the state of a single client.

```
ClientSocket::ClientSocket(QObject *parent, const char *name)
    : QSocket(parent, name)
{
    connect(this, SIGNAL(readyRead()),
            this, SLOT(readClient()));
    connect(this, SIGNAL(connectionClosed()),
            this, SLOT(deleteLater()));
    connect(this, SIGNAL(delayedCloseFinished()),
            this, SLOT(deleteLater()));

    blockSize = 0;
}
```

In the constructor, we establish the necessary signal–slot connections, and we set the blockSize variable to 0, indicating that we do not yet know the size of the block sent by the client.

The connectionClosed() and delayedCloseFinished() signals are connected to deleteLater(), a QObject-inherited function that deletes the object when control returns to Qt's event loop. This ensures that the ClientSocket object is deleted when the connection is closed by the peer or when a delayed close is finished. We will see what that means in a moment.

```
void ClientSocket::readClient()
{
    QDataStream in(this);
    in.setVersion(5);

    if (blockSize == 0) {
        if (bytesAvailable() < sizeof(Q_UINT16))
            return;
        in >> blockSize;
    }
    if (bytesAvailable() < blockSize)
        return;

    Q_UINT8 requestType;
    QString from;
    QString to;
    QDate date;
    QTime time;
    Q_UINT8 flag;

    in >> requestType;
    if (requestType == 'S') {
        in >> from >> to >> date >> time >> flag;

        srand(time.hour() * 60 + time.minute());
        int numTrips = rand() % 8;
        for (int i = 0; i < numTrips; ++i)
            generateRandomTrip(from, to, date, time);

        QDataStream out(this);
        out << (Q_UINT16)0xFFFF;
    }
    close();
    if (state() == Idle)
        deleteLater();
}
```

The readClient() slot is connected to QSocket's readyRead() signal. If blockSize is 0, we start by reading the blockSize; otherwise, we have already read it, and instead we check to see if a whole block has arrived. Once an entire block is ready for reading, we read it. We use the QDataStream directly on the QSocket (the this object) and read the fields using the >> operator.

Once we have read the client's request, we are ready to generate a reply. If this were a real application, we would look up the information in a train schedule database and try to find matching train trips. But here we will be content with a function called generateRandomTrip() that will generate a random trip. We call the function a random number of times, and we send 0xFFFF to signify the end of the data.

Finally, we close the connection. If the socket's output buffer is empty, the connection is terminated immediately and we call deleteLater() to delete this object when control returns to Qt's event loop. (This is safer than delete this.) Otherwise, QSocket will complete sending out all the data, and will then close the connection and emit the delayedCloseFinished() signal.

```
void ClientSocket::generateRandomTrip(const QString &,
        const QString &, const QDate &date, const QTime &time)
{
    QByteArray block;
    QDataStream out(block, IO_WriteOnly);
    out.setVersion(5);
    Q_UINT16 duration = rand() % 200;
    out << (Q_UINT16)0 << date << time << duration
        << (Q_UINT8) 1 << QString("InterCity");
    out.device()->at(0);
    out << (Q_UINT16) (block.size() - sizeof(Q_UINT16));
    writeBlock(block.data(), block.size());
}
```

The generateRandomTrip() function shows how to send a block of data over a TCP connection. This is very similar to what we did in the client in the sendRequest() function (p.294). Once again, we write the block to a QByteArray so that we can determine its size before we send it using writeBlock().

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    TripServer server;
    if (!server.ok()) {
        qWarning("Failed to bind to port");
        return 1;
    }
    QPushButton quitButton(QObject::tr("&Quit"), 0);
    quitButton.setCaption(QObject::tr("Trip Server"));
    app.setMainWidget(&quitButton);
    QObject::connect(&quitButton, SIGNAL(clicked()),
                     &app, SLOT(quit()));
    quitButton.show();
    return app.exec();
}
```

In main(), we create a TripServer object and a QPushButton that enables the user to stop the server.

This completes our client–server example. In this case, we used a block-oriented protocol that allows us to use QDataStream for reading and writing. If we wanted to use a line-oriented protocol, the simplest approach would be to use QSocket's canReadLine() and readLine() functions in a slot connected to the readyRead() signal:

```
QStringList lines;
while (socket.canReadLine())
    lines.append(socket.readLine());
```

We would then process each line that has been read. As for sending data, that can be done using a QTextStream on the QSocket.

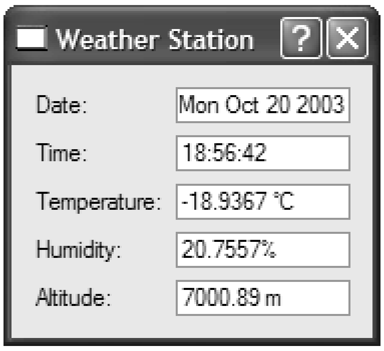
The server implementation that we have used doesn't scale very well when there are lots of connections. The problem is that while we are processing a request, we don't handle the other connections. A more scalable approach would be to start a new thread for each connection. But QSocket can only be used in the thread that contains the event loop (the call to QApplication:: exec()), for reasons that are explained in Chapter 17 (Multithreading). The solution is to use the low-level QSocketDevice class directly, which doesn't rely on the event loop.

UDP Networking with QSocketDevice

The QSocketDevice class provides a low-level interface that can be used for TCP and for UDP. For most TCP applications, the higher-level QSocket class is all we need, but if we want to use UDP, we must use QSocketDevice directly.

UDP is an unreliable, datagram-oriented protocol. Some application-level protocols use UDP because it is more lightweight than TCP. With UDP, data is sent as packets (datagrams) from one host to another. There is no concept of connection, and if a UDP packet doesn't get delivered successfully, no error is reported to the system.

Figure 13.3. The Weather Station application



Date: Mon Oct 20 2003
Time: 18:56:42
Temperature: -18.9367 °C
Humidity: 20.7557%
Altitude: 7000.89 m

We will see how to use UDP from a Qt application through the Weather Balloon and Weather Station example. The Weather Balloon application is a non-GUI application that sends a UDP datagram containing the current atmospheric conditions every 5 seconds. The Weather Station application receives these datagrams and displays them on screen. We will start by reviewing the code for the Weather Balloon.

```
class WeatherBalloon : public QPushButton
{
    Q_OBJECT
public:
    WeatherBalloon(QWidget *parent = 0, const char *name = 0);

    double temperature() const;
    double humidity() const;
    double altitude() const;

protected:
    void timerEvent(QTimerEvent *event);

private:
    QSocketDevice socketDevice;
    int myTimerId;
};
```

The `WeatherBalloon` class inherits from `QPushButton`. It uses its `QSocketDevice` private variable for communicating with the Weather Station.

```
WeatherBalloon::WeatherBalloon(QWidget *parent, const char *name)
    : QPushButton(tr("Quit"), parent, name),
      socketDevice(QSocketDevice::Datagram)
{
    socketDevice.setBlocking(false);
    myTimerId = startTimer(5 * 1000);
}
```

In the constructor's initialization list, we pass `QSocketDevice::Datagram` to the `QSocketDevice` constructor to create a UDP socket device. In the constructor body, we call `setBlocking (false)` to make the `QSocketDevice` asynchronous. (By default, `QSocketDevice` is synchronous.)

We call `startTimer()` to generate a timer event every 5 seconds.

```
void WeatherBalloon::timerEvent(QTimerEvent *event)
{
    if (event->timerId() == myTimerId) {
        QByteArray datagram;
        QDataStream out (datagram, IO_WriteOnly);
        out.setVersion(5);
        out << QDateTime::currentDateTime() << temperature()
```

```
            << humidity() << altitude();
        socketDevice.writeBlock(datagram, datagram.size(),
                                0x7F000001, 5824);
    } else {
        QPushButton::timerEvent(event);
    }
}
```

In the timer event handler, we generate a datagram containing the current date, time, temperature, humidity, and altitude:

`QDateTime`	Date and time of measurement
`double`	Temperature (in °C)
`double`	Humidity (in %)
`double`	Altitude (in meters)

The datagram is sent using `writeBlock()`. The third and fourth arguments to `writeBlock()` are the IP address and the port number of the peer (the Weather Station). For this example, we assume that the Weather Station is running on the same machine as the Weather Balloon, so we use an IP address of 127.0.0.1 (0x7F000001), a special address that designates the local host. Unlike `QSocket`, `QSocketDevice` does not accept host names, only host numbers. If we wanted to resolve a host name to its IP address here, we would need to use the `QDns` class.

As usual, we need a `main()` function:

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    WeatherBalloon balloon;
    balloon.setCaption(QObject::tr("Weather Balloon"));
    app.setMainWidget(&balloon);
    QObject::connect(&balloon, SIGNAL(clicked()),
                     &app, SLOT(quit()));
    balloon.show();
    return app.exec();
}
```

The `main()` function simply creates a `WeatherBalloon` object, which serves both as a UDP peer and as a `QPushButton` on screen. By clicking the `QPushButton`, the user can quit the application.

Now let's review the source code for the Weather Station.

```
class WeatherStation : public QDialog
{
    Q_OBJECT
public:
    WeatherStation(QWidget *parent = 0, const char *name = 0);

private slots:
    void dataReceived();

private:
    QSocketDevice socketDevice;
    QSocketNotifier *socketNotifier;

    QLabel *dateLabel;
    QLabel *timeLabel;
    ...
    QLineEdit *altitudeLineEdit;
};
```

The WeatherStation class inherits from QDialog. It listens to a certain UDP port, parses any incoming datagrams (from the Weather Balloon), and displays their contents in five read-only QLineEdits.

The class has two private variables of interest here: socketDevice and socket-Notifier. The socketDevice variable, of type QSocketDevice, is used for reading datagrams. The socketNotifier variable, of type QSocketNotifier, is used to make the application aware of incoming datagrams.

```
WeatherStation::WeatherStation(QWidget *parent, const char *name)
    : QDialog(parent, name),
      socketDevice (QSocketDevice::Datagram)
{
    socketDevice.setBlocking(false);
    socketDevice.bind(QHostAddress(), 5824);

    socketNotifier = new QSocketNotifier(socketDevice.socket(),
                                         QSocketNotifier::Read,
                                         this);
    connect(socketNotifier, SIGNAL(activated(int)),
            this, SLOT(dataReceived()));
    ...
}
```

In the constructor's initialization list, we pass QSocketDevice::Datagram to the QSocketDevice constructor to create a UDP socket device. In the constructor body, we call setBlocking (false) to make the socket asynchronous and we call bind() to assign a port number to the socket. The first argument is the IP address of the Weather Station. By passing QHostAddress (), we indicate that we will accept datagrams to any IP address that belongs to the machine the Weather Station is running on. The second argument is the port number.

Then we create a QSocketNotifier object to monitor the socket. The QSocketNotifier will emit an activated(int) signal whenever the socket receives a datagram. We connect that signal to our dataReceived() slot.

```
void WeatherStation::dataReceived()
{
    QDateTime dateTime;
    double temperature;
    double humidity;
    double altitude;

    QByteArray datagram(socketDevice.bytesAvailable());
    socketDevice.readBlock(datagram.data(), datagram.size());

    QDataStream in(datagram, IO_ReadOnly);
    in.setVersion(5);
    in >> dateTime >> temperature >> humidity >> altitude;

    dateLineEdit->setText(dateTime.date().toString());
    timeLineEdit->setText(dateTime.time().toString());
    temperatureLineEdit->setText(tr("%1 °C").arg(temperature));
    humidityLineEdit->setText(tr("%1%").arg(humidity));
    altitudeLineEdit->setText(tr("%1 m").arg(altitude));
}
```

In dataReceived(), we call readBlock() on the QSocketDevice to read in the datagram. QByteArray::data() returns a pointer to the QByteArray's data, which readBlock() populates. Then, we extract the different fields using a QDataStream, and we update the user interface to show the information we received. From the application's point of view, datagrams are always sent and received as a single unit of data. This means that if any bytes are available, then exactly one datagram has arrived and can be read.

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    WeatherStation station;
    app.setMainWidget(&station);
    station.show();
    return app.exec();
}
```

Finally, in main(), we create a WeatherStation and make it the application's main widget.

We have now finished our UDP sender and receiver. The applications are as simple as possible, with the Weather Balloon sending datagrams and the Weather Station receiving them. In most real-world applications, both applications would need to both read and write on their socket. The QSocketDevice class has a peerAddress() and a peerPort() function that can be used by the server to determine what address and port to reply to.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Chapter 14. XML

XML (Extensible Markup Language) is a text file format that is popular for data interchange and for data storage.

Qt provides two distinct APIs for processing XML documents:

- SAX (Simple API for XML) reports parsing events directly to the application through virtual functions.
- DOM (Document Object Model) converts an XML document into a tree structure, which the application can then navigate.

There are many factors to take into account when choosing between DOM and SAX for a particular application. SAX is more low-level and usually faster, which makes it especially appropriate both for simple tasks (like finding all occurrences of a given tag in an XML document) and for reading very large files that may not fit in memory. But for many applications, the convenience offered by DOM outweighs the potential speed and memory benefits of SAX.

In this chapter, we will see how to read XML files using both APIs, and we will show how to write XML files. This chapter assumes a basic knowledge of XML.

[Team LiB]

◀ PREVIOUS NEXT ▶

Reading XML with SAX

SAX is a public domain de-facto standard Java API for reading XML documents. Qt's SAX classes are modeled after the SAX2 Java implementation, with some differences in naming to match the Qt conventions. For more information about SAX, see http://www.saxproject.org/.

Qt provides a SAX-based non-validating XML parser called `QXmlSimpleReader`. This parser recognizes well-formed XML and supports XML namespaces. When the parser goes through the document, it calls virtual functions in registered handler classes to indicate parsing events. (These "parsing events" are unrelated to Qt events, such as key and mouse events.) For example, let's assume the parser is analyzing the following XML document:

```
<doc>
    <quote>Errare humanum est</quote>
</doc>
```

The parser would call the following parsing event handlers:

```
startDocument()
startElement("doc")
startElement("quote")
characters("Errare humanum est")
endElement("quote")
endElement("doc")
endDocument()
```

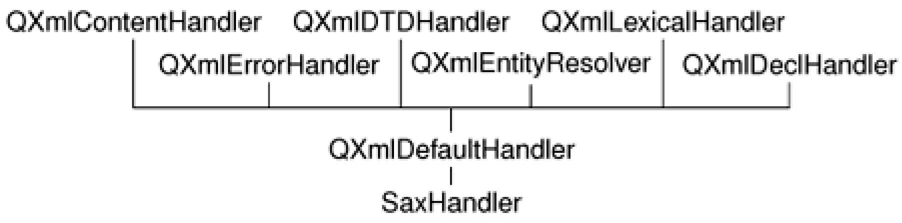
The above functions are all declared in `QXmlContentHandler`. For simplicity, we omitted some of the arguments of `startElement()` and `endElement()`.

`QXmlContentHandler` is just one of many handler classes that can be used in conjunction with `QXmlSimpleReader`. The others are `QXmlEntityResolver`, `QXmlDTDHandler`, `QXmlErrorHandler`, `QXmlDeclHandler`, and `QXmlLexicalHandler`. These classes only declare pure virtual functions and give information about different kinds of parsing events. For most applications, `QXmlContentHandler` and `QXmlErrorHandler` are the only two that are needed.

For convenience, Qt also provides `QXmlDefaultHandler`, a class that inherits (through multiple inheritance) from all the handler classes and that provides trivial implementations for all the functions. This design, with many abstract handler classes and one trivial subclass, is rather unusual for Qt; it was adopted to closely follow the model Java implementation.

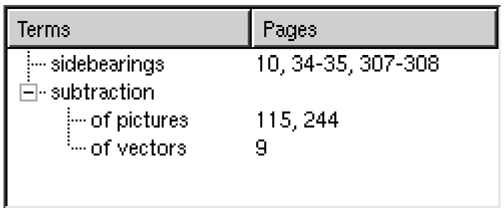
We will now review an example that shows how to use `QXmlSimpleReader` and `QXmlDefaultHandler` to parse an ad-hoc XML file format and render its contents in a `QListView`. The `QXmlDefaultHandler` subclass is called `SaxHandler`, and the format it handles is that of a book index, with index entries and subentries.

Figure 14.1. Inheritance tree for `SaxHandler`



Here's the book index file that is displayed in the `QListView` in Figure 14.2:

Figure 14.2. A book index file loaded in a `QListView`



Terms	Pages
sidebearings	10, 34-35, 307-308
subtraction	
of pictures	115, 244
of vectors	9

```
<?xml version="1.0"?>
<bookindex>
    <entry term="sidebearings">
        <page>10</page>
        <page>34-35</page>
        <page>307-308</page>
    </entry>
    <entry term="subtraction">
        <entry term="of pictures">
            <page>115</page>
            <page>244</page>
        </entry>
        <entry term="of vectors">
            <page>9</page>
        </entry>
    </entry>
</bookindex>
```

The first step to implement the parser is to subclass `QXmlDefaultHandler`:

```
class SaxHandler : public QXmlDefaultHandler
{
public:
    SaxHandler(QListView *view);

    bool startElement(const QString &namespaceURI,
                      const QString &localName,
                      const QString &qName,
                      const QXmlAttributes &attribs);
    bool endElement(const QString &namespaceURI,
                    const QString &localName,
                    const QString &qName);
    bool characters(const QString &str);
    bool fatalError(const QXmlParseException &exception);

private:
    QListView *listView;
    QListViewItem *currentItem;
    QString currentText;
};
```

The `SaxHandler` class inherits `QXmlDefaultHandler` and reimplements four functions:

startElement(), endElement(), characters(), and fatalError(). The first three functions are declared in QXmlContentHandler; the last function is declared in QXmlErrorHandler.

```
SaxHandler::SaxHandler(QListView *view)
{
    listView = view;
    currentItem = 0;
}
```

The SaxHandler constructor accepts the QListView we want to fill with the information stored in the XML file.

```
bool SaxHandler::startElement(const QString &, const QString &,
                              const QString &qName,
                              const QXmlAttributes &attribs)
{
    if (qName == "entry") {
        if (currentItem) {
            currentItem = new QListViewItem(currentItem);
        } else {
            currentItem = new QListViewItem(listView);
        }
        currentItem->setOpen(true);
        currentItem->setText(0, attribs.value("term"));
    } else if (qName == "page") {
        currentText = "";
    }
    return true;
}
```

The startElement() function is called when the reader encounters a new opening tag. The third parameter is the tag's name (or more precisely, its "qualified name"). The fourth parameter is the list of attributes. In this example, we ignore the first and second parameters. They are useful for XML files that use XML's namespace mechanism, a subject that is discussed in detail in the reference documentation.

If the tag is <entry>, we create a new QListView item. If the tag is nested within another <entry> tag, the new tag defines a subentry in the index, and the new QListViewItem is created as a child of the QListViewItem that represents the encompassing entry. Otherwise, we create the QListViewItem with listView as its parent, making it a top-level item. We call setOpen(true) on the item to show its children, and we call setText() to set the text shown in column 0 to the value of the <entry> tag's term attribute.

If the tag is <page>, we set the currentText to be an empty string. The currentText serves as an accumulator for the text located between the <page> and </page> tags.

At the end, we return true to tell SAX to continue parsing the file. If we wanted to report unknown tags as errors, we would return false in those cases. We would then also reimplement errorString() from QXmlDefaultHandler to return an appropriate error message.

```
bool SaxHandler::characters(const QString &str)
{
    currentText += str;
    return true;
}
```

The characters() function is called to report character data in the XML document. We simply append the characters to the currentText variable.

```
bool SaxHandler::endElement(const QString &, const QString &,
                            const QString &qName)
{
    if (qName == "entry") {
        currentItem = currentItem->parent();
    } else if (qName == "page") {
        if (currentItem) {
            QString allPages = currentItem->text(1);
            if (!allPages.isEmpty())
                allPages += ", ";
            allPages += currentText;
            currentItem->setText(1, allPages);
        }
    }
    return true;
}
```

The `endElement()` function is called when the reader encounters a closing tag. Just as with `startElement()`, the third parameter is the name of the tag.

If the tag is `</entry>`, we update the `currentItem` private variable to point to the current `QListViewItem`'s parent. This ensures that the `currentItem` variable is restored to the value it held before the corresponding `</entry>` tag was read.

If the tag is `</page>`, we add the specified page number or page range to the comma-separated list in the current item's text in column 1.

```
bool SaxHandler::fatalError(const QXmlParseException &exception)
{
    qWarning("Line %d, column %d: %s", exception.lineNumber(),
             exception.columnNumber(), exception.message().ascii());
    return false;
}
```

The `fatalError()` function is called when the reader fails to parse the XML file. If this occurs, we simply output a warning, giving the line number, the column number, and the parser's error text.

This completes the implementation of the `SaxHandler` class. Now let's see how we can make use of the class:

```
bool parseFile(const QString &fileName)
{
    QListView *listView = new QListView(0);
    listView->setCaption(QObject::tr("SAX Handler"));
    listView->setRootIsDecorated(true);
    listView->setResizeMode(QListView::AllColumns);
    listView->addColumn(QObject::tr("Terms"));
    listView->addColumn(QObject::tr("Pages"));
    listView->show();

    QFile file(fileName);
    QXmlSimpleReader reader;

    SaxHandler handler(listView);
    reader.setContentHandler(&handler);
    reader.setErrorHandler(&handler);
    return reader.parse(&file);
}
```

We set up a `QListView` with two columns. Then we create a `QFile` object for the file that is to be read and a QXmlSimpleReader to parse the file. We don't need to open the QFile ourselves; Qt does that automatically.

Finally, we create a SaxHandler object, we install it on the reader both as a content handler and as an error handler, and we call parse() on the reader to perform the parsing.

In SaxHandler, we only reimplemented functions from the QXmlContentHandler and QXmlErrorHandler classes. If we had implemented functions from other handler classes, we would also have needed to call their corresponding setter functions on the reader.

[Team LiB]
[Team LiB]

Reading XML with DOM

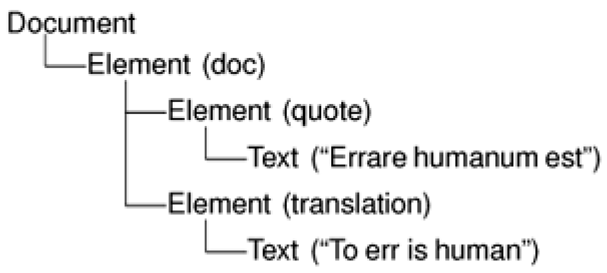
DOM is a standard API for parsing XML developed by the World Wide Web Consortium (W3C). Qt provides a non-validating DOM Level 2 implementation for reading, manipulating, and writing XML documents.

DOM represents an XML file as a tree in memory. We can navigate through the DOM tree as much as we want, and we can modify the tree and save it back to disk as an XML file.

Let's consider the following XML document:

```
<doc>
    <quote>Errare humanum est</quote>
    <translation>To err is human</translation>
</doc>
```

It corresponds to the following DOM tree:

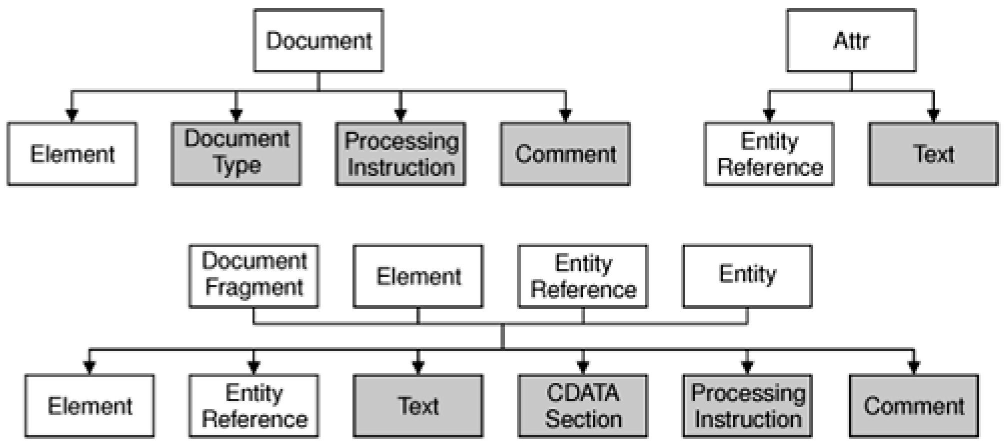


The DOM tree contains nodes of different types. For example, an Element node corresponds to an opening tag and its matching closing tag. The material that falls between the tags appears as child nodes of the Element node.

In Qt, the node types (like all other DOM-related classes) have a QDom prefix. Thus, QDomElement represents an Element node, and QDomText represents a Text node.

Different types of nodes can have different kinds of child nodes. For example, an Element node can contain other Element nodes, and also EntityReference, Text, CDATASection, ProcessingInstruction, and Comment nodes. Figure 14.3 specifies which nodes can have which kinds of child nodes. The nodes shown in gray cannot have any child nodes of their own.

Figure 14.3. Parent–child relationships between DOM nodes



To illustrate how to use DOM for reading XML files, we will write a parser for the book index file format described in the previous section (p. 308).

```
class DomParser
{
public:
    DomParser(QIODevice *device, QListView *view);

private:
    void parseEntry(const QDomElement &element,
                    QListViewItem *parent);
    QListView *listView;
};
```

We define a class called `DomParser` that will parse a book index XML document and display the result in a `QListView`. The class does not inherit from any other class.

```
DomParser::DomParser(QIODevice *device, QListView *view)
{
    listView = view;
    QString errorStr;
    int errorLine;
    int errorColumn;
    QDomDocument doc;
    if (!doc.setContent(device, true, &errorStr, &errorLine,
                        &errorColumn)) {
        qWarning("Line %d, column %d: %s", errorLine, errorColumn,
                 errorStr.ascii());
        return;
    }

    QDomElement root = doc.documentElement();
    if (root.tagName() != "bookindex") {
        qWarning("The file is not a bookindex file");
        return;
    }

    QDomNode node = root.firstChild();
    while (!node.isNull()) {
        if (node.toElement().tagName() == "entry")
            parseEntry(node.toElement(), 0);
        node = node.nextSibling();
    }
}
```

In the constructor, we create a `QDomDocument` object and call `setContent()` on it to have it read the XML document provided by the `QIODevice`. The `setContent()` function automatically opens the device if it isn't already open. Then we call documentElement() on the QDomDocument to obtain its single QDomElement child, and we check that it is a <bookindex> element. Then we iterate over all the child nodes, and if the node is an <entry> element, we call parseEntry() to parse it.

The QDomNode class can store any type of node. If we want to process a node further, we must first convert it to the right data type. In this example, we only care about Element nodes, so we call toElement() on the QDomNode to convert it to a QDomElement and then call tagName() to retrieve the element's tag name. If the node is not of type Element, the toElement() function returns a null QDomElement object, with an empty tag name.

```
void DomParser::parseEntry(const QDomElement &element,
                           QListViewItem *parent)
{
    QListViewItem *item;
    if (parent) {
        item = new QListViewItem(parent);
    } else {
        item = new QListViewItem(listView);
    }
    item->setOpen(true);
    item->setText(0, element.attribute("term"));

    QDomNode node = element.firstChild();
    while (!node.isNull()) {
        if (node.toElement().tagName() == "entry") {
            parseEntry(node.toElement(), item);
        } else if (node.toElement().tagName() == "page") {
            QDomNode childNode = node.firstChild();
            while (!childNode.isNull()) {
                if (childNode.nodeType() == QDomNode::TextNode) {
                    QString page = childNode.toText().data();
                    QString allPages = item->text(1);
                    if (!allPages.isEmpty())
                        allPages += ", ";
                    allPages += page;
                    item->setText(1, allPages);
                    break;
                }
                childNode = childNode.nextSibling();
            }
        }
        node = node.nextSibling();
    }
}
```

In parseEntry(), we create a QListView item. If the tag is nested within another <entry> tag, the new tag defines a subentry in the index, and we create the QListViewItem as a child of the QListViewItem that represents the encompassing entry. Otherwise, we create the QListViewItem with listView as its parent, making it a top-level item. We call setOpen(true) on the item to ensure that any subentries will be visible, and call setText() to set the text shown in column 0 to the value of the <entry> tag's term attribute.

Once we have initialized the QListViewItem, we iterate over the child nodes of the QDomElement node corresponding to the current <entry> tag.

If the element is <entry>, we call parseEntry() with the current item as the second argument. The new entry's QListViewItem will then be created with the encompassing entry's QListViewItem as its parent.

If the element is <page>, we navigate through the element's child list to find a Text node. Once we have found it, we call toText() to convert it to a QDomText object, and data() to extract the text as a QString. Then we add the text to the comma-separated list of page numbers in column 1 of the QListViewItem.

Let's now see how we can use the DomParser class to parse a file:

```
void parseFile(const QString &fileName)
{
    QListView *listView = new QListView(0);
    listView->setCaption(QObject::tr("DOM Parser"));
    listView->setRootIsDecorated(true);
    listView->setResizeMode(QListView::AllColumns);
    listView->addColumn(QObject::tr("Terms"));
    listView->addColumn(QObject::tr("Pages"));
    listView->show();

    QFile file(fileName);
    DomParser(&file, listView);
}
```

We start by setting up a QListView. Then we create a QFile and a DomParser. When the DomParser is constructed, it parses the file and populates the list view.

As the example illustrates, navigating through a DOM tree can be cumber-some. Simply extracting the text between <page> and </page> required us to iterate through a list of QDomNodes using firstChild() and nextSibling(). Programmers who use DOM a lot often write their own higher level wrapper functions to simplify commonly needed operations, such as extracting the text between tags.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Writing XML

There are basically two approaches for generating XML files from Qt applications:

- We can build a DOM tree and call save() on it.
- We can generate XML by hand.

The choice between these approaches is often independent of whether we use SAX or DOM for reading XML documents.

Here's a code snippet that illustrates how we can create a DOM tree and write it using a QTextStream:

```
const int Indent = 4;

QDomDocument doc;
QDomElement root = doc.createElement("doc");
QDomElement quote = doc.createElement("quote");
QDomElement translation = doc.createElement("translation");
QDomText quoteText = doc.createTextNode("Errare humanum est");
QDomText translationText = doc.createTextNode("To err is human");
```

```
doc.appendChild(root);
root.appendChild(quote);
root.appendChild(translation);
quote.appendChild(quoteText);
translation.appendChild(translationText);

QTextStream out(&file);
doc.save(out, Indent);
```

The second argument to `save()` is the indentation size to use. A non-zero value makes the file easier for humans to read. Here's the XML file output:

```
<doc>
    <quote>Errare humanum est</quote>
    <translation>To err is human</translation>
</doc>
```

Another scenario occurs in applications that use the DOM tree as their primary data structure. These applications would normally read in XML documents using DOM, then modify the DOM tree in memory, and finally call `save()` to convert the tree back to XML.

In the example above, we used UTF-8 as the encoding. We can use another encoding by prepending

```
<?xml version="1.0" encoding="ISO-8859-1"?>
```

to the DOM tree. The following code snippet shows how to do this:

```
QTextStream out(&file);
QDomNode xmlNode = doc.createProcessingInstruction("xml",
                          "version=\"1.0\" encoding=\"ISO-8859-1\"");
doc.insertBefore(xmlNode, doc.firstChild());
doc.save(out, Indent);
```

Generating XML files by hand isn't much harder than using DOM. We can use `QTextStream` and write the strings as we would do with any text file. The most tricky part is to escape special characters in text and attribute values. We can do this in a separate function:

```
QString escapeXml(const QString &str)
{
    QString xml = str;
    xml.replace("&", "&amp;");
    xml.replace("<", "&lt;");
    xml.replace(">", "&gt;");
    xml.replace("'", "&apos;");
    xml.replace("\"", "&quot;");
    return xml;
}
```

Here's an example that makes use of it:

```
QTextStream out(&file);
out.setEncoding(QTextStream::UnicodeUTF8);
out << "<doc>\n"
    << "    <quote>" << escapeXml(quoteText) << "</quote>\n"
    << "    <translation>" << escapeXml(translationText)
    << "</translation>\n"
    << "</doc>\n"
```

The *Qt Quarterly* article "Generating XML", available online at http://doc.

trolltech.com/qq/qq05-generating-xml.html, presents a very simple class that makes it easy to generate XML files. The class takes care of the details such as special characters, indentation, and encoding issues, leaving us free to concentrate on the XML we want to generate.

[Team LiB]

Chapter 15. Internationalization

In this chapter, we will cover how to write Qt applications in languages other than English and how to translate an existing Qt application to other languages.

The first section discusses Unicode, Qt's native character encoding. The information contained in this section is useful to all Qt developers, since even an application with an English user interface could one day be run on a Greek or Japanese user's machine.

The second section shows how to make applications translation-ready. This process is so easy that it's worth doing even if you don't have plans to offer translated versions of your software. It then leaves you in a good position to hire a translator and create a new market for your applications at a later date.

The third section is aimed at truly international applications and shows how to make an application change language on the fly.

The last section describes the translation process as a whole. It also shows how programmers and translators can work together using *Qt Linguist* and Qt's other translation tools.

[Team LiB]

Working with Unicode

Unicode is a character encoding standard that supports most of the world's writing systems. The original idea behind Unicode is that by using 16 bits for storing characters instead of 8 bits, it would be possible to encode around 65,000 characters instead of only 256. Unicode contains ASCII and ISO 8859-1 (Latin-1) as subsets at the same code positions. For example, the character 'A' has value 0x41 in ASCII, Latin-1, and Unicode, and the character 'β' has value 0xDF in both Latin-1 and Unicode.

Qt's `QString` class stores strings as Unicode. Each character in a `QString` is a 16-bit `QChar` rather than an 8-bit `char`. Here are two ways of setting the first character of a string to 'A':

```
str[0] = 'A';
str[0] = QChar(0x41);
```

If the source file is encoded in Latin-1, specifying Latin-1 characters is just as easy:

```
str[0] = 'β;'
```

And if the source file has another encoding, the numeric value works:

```
str[0] = QChar(0xDF);
```

We can specify any Unicode character by its numeric value. For example, here's how to specify the Greek capital letter sigma ('Σ') and the euro currency symbol ('€'):

```
str[0] = QChar(0x3A3);
str[0] = QChar(0x20AC);
```

The numeric values of all the characters supported by Unicode are listed at http://www.unicode.org/unicode/standard/standard.html. If you rarely need non-Latin-1 Unicode characters, looking up characters online is sufficient; but Qt provides more convenient ways of entering Unicode strings in a Qt program, as we will see later in this section.

Qt 3.2's text engine supports the following writing systems on all platforms: Arabic, Chinese, Cyrillic, Greek, Hebrew, Japanese, Korean, Lao, Latin, Thai, and Vietnamese. It also supports all the Unicode 3.2 scripts that don't require any special processing. In addition, the following writing systems are supported on X11 with Xft and on NT-based versions of Windows: Bengali, Devanagari, Gujarati, Gurmukhi, Kannada, Khmer, Syriac, Tamil, Telugu, and Thaana. Finally, Malayalam and Tibetan are supported on X11, and Divehi is supported on Windows XP. Assuming that the proper fonts are installed on the system, Qt can render text using any of these writing systems. And assuming that the proper input methods are installed, users will be able to enter text that uses these writing systems in their Qt applications.

Programming with `QChar` is slightly different from programming with `char`. To obtain the numeric value of a `QChar`, call `unicode()` on it. To obtain the ASCII or Latin-1 value of a `QChar` (as a `char`), call `latin1()`. For non-Latin-1 characters, `latin1()` returns 0.

If we know that all the strings in a program are ASCII or Latin-1, we can use standard `<cctype>` functions like `isalpha()`, `isdigit()`, and `isspace()`. These work because `QChar`s automatically convert into `char`s (as Latin-1) given the right context, just as `QString`s automatically convert into `const char *`. However, it is generally better to use `QChar`'s member functions for performing these operations, since they will work for any Unicode character. The functions `QChar` provides include `isPrint()`, `isPunct()`, `isSpace()`, `isMark()`, `isLetter()`, `isNumber()`, `isLetterOrNumber()`, `isDigit()`, `isSymbol()`, `lower()`, and `upper()`. For example, here's one way to test that a character is a digit or an upper-case letter:

```
if (ch.isDigit() || ch != ch.lower())
    ...
```

The `lower()` function returns the lower-case version of the character. If the lower-case version of the character is different from the character itself, then the character must be upper-case (or title-case). The code snippet works for any alphabet that distinguishes between upper- and lower-case, including Latin, Greek, and Cyrillic.

Once we have a Unicode string, we can use it anywhere in Qt's API where a `QString` is expected. It is then Qt's responsibility to display it properly and to convert it to other encodings when talking to the operating system.

Special care is needed when we read and write text files. Text files can use a variety of encodings, and it's often impossible to guess a text file's encoding from its contents. By default, `QTextStream` uses the system's local 8-bit encoding (available as `QTextCodec::codecForLocale()`) for both reading and writing. For American and West European locales, this usually means Latin-1.

If we design our own file format and want to be able to read and write arbitrary Unicode characters, we can save the data as Unicode by calling `setEncoding(QTextStream::Unicode)` before we start writing to the `QTextStream`. The data will then be saved in UTF-16, a format that requires two bytes per character. The UTF-16 format is very close to the memory representation of a `QString`, so reading and writing Unicode strings in UTF-16 can be very fast. However, there is an inherent overhead when saving pure ASCII data in UTF-16 format, since it stores two bytes for every character instead of just one.

When reading back the text, `QTextStream` normally detects Unicode automatically, but for absolute certainty it is best to call `setEncoding(QTextStream::Unicode)` before reading.

Another encoding that supports the whole of Unicode is UTF-8. Its main advantage over UTF-16 is that it is a superset of ASCII. Any character in the range 0x00 to 0x7F is represented as a single byte. Other characters, including Latin-1 characters above 0x7F, are represented by multi-byte sequences. For text that is mostly ASCII, UTF-8 takes up about half the space consumed by UTF-16. To use UTF-8 with `QTextStream`, call `setEncoding (QTextStream::UnicodeUTF8)` before reading and writing.

If we always want to read and write Latin-1 regardless of the user's locale, we can call `setEncoding(QTextStream::Latin1)` on the `QTextStream`.

Other encodings can be specified by calling `setCodec()` with an appropriate `QTextCodec`.A `QTextCodec` is an object that converts between Unicode and a given encoding. `QTextCodec`s are used in a variety of contexts by Qt. Internally, they are used to support fonts, input methods, the clipboard, drag and drop, and file names. But they are also available to us when we write Qt applications.

For example, if we want to read in a file with the EUC-KR encoding, we can write this:

```
QTextStream in(&file);
QTextCodec *koreanCodec = QTextCodec::codecForName("EUC-KR");
if (koreanCodec)
    in.setCodec(koreanCodec);
```

Some file formats specify their encoding in their header. The header is typically plain ASCII to ensure that it is read correctly no matter what encoding is used (assuming that it is a superset of ASCII). The XML file format is an interesting example of this. XML files are normally encoded as UTF-8 or UTF-16. The proper way to read them in is to call `setEncoding (QTextStream::UnicodeUTF8)`. If the format is UTF-16, `QTextStream` will automatically detect this and adjust itself. The `<?xml?>` header of an XML file sometimes contains an `encoding` argument, for example:

```
<?xml version="1.0" encoding="EUC-KR"?>
```

Since `QTextStream` doesn't allow us to change the encoding once it has started reading, the right way to respect an explicit encoding is to start reading the file anew, using the correct codec (obtained from `QTextCodec::codecForName()`).

In the case of XML, we can avoid having to handle the encoding ourselves by using Qt's XML classes, described in Chapter 14.

Another use of `QTextCodec`s is to specify the encoding of strings that occur in the source code. Let's consider the example of a team of Japanese programmers who are writing an application targeted primarily at Japan's home market. These programmers are likely to write their source code in a text editor that uses an encoding such as EUC-JP or Shift-JIS. Such an editor allows them to type in Japanese characters seamlessly, so that they can write code like this:

```
QPushButton *button = new QPushButton(tr("日諾"), 0);
```

By default, Qt interprets arguments to `tr()` as Latin-1. To change this, call the `QTextCodec::setCodecForTr()` static function. For example:

```
QTextCodec *japaneseCodec = QTextCodec::codecForName("EUC-JP");
QTextCodec::setCodecForTr(japaneseCodec);
```

This must be done before the first call to `tr()`. Typically, we would do this in `main()`, right after the `QApplication` object is created.

Other strings specified in the program will still be interpreted as Latin-1 strings. If the programmers want to enter Japanese characters in those as well, they can explicitly convert them to Unicode using a `QTextCodec`:

```
QString text = japaneseCodec->toUnicode("海鮮料理");
```

Alternatively, they can tell Qt to use a specific codec when converting between `const char` * and `QString` by calling `QTextCodec::setCodecForCStrings()`:

```
QTextCodec::setCodecForCStrings(japaneseCodec);
```

Because Qt's internals sometimes convert ASCII strings to `QString`, the encoding must be a superset of ASCII.

The techniques described above can be applied to any non-Latin-1 language, including Chinese, Greek, Korean, and Russian.

Here's a list of the encodings supported by Qt 3.2:

- Apple Roman
- Big5-HKSCS
- CP874
- CP1250
- CP1251
- CP1252
- CP1253
- CP1254
- CP1255
- CP1256
- CP1257
- CP1258
- EUC-JP
- EUC-KR
- GB2312
- GB18030
- GBK
- IBM-850
- IBM-866
- ISO 8859-1
- ISO 8859-2
- ISO 8859-3
- ISO 8859-4
- ISO 8859-5
- ISO 8859-6
- ISO 8859-7
- ISO 8859-8
- ISO 8859-8-I
- ISO 8859-9
- ISO 8859-10
- ISO 8859-11
- ISO 8859-13
- ISO 8859-14
- ISO 8859-15
- ISO 10646 UCS-2
- JIS7
- KO18-R
- KOI8-U
- Shift-JIS
- TIS-620
- TSCII
- UTF-8

For all of these, QTextCodec::codecForName() will always return a valid pointer. Other encodings can be supported either by subclassing QTextCodec or by creating a charmap file and using QTextCodec::loadCharmapFile(). See the QTextCodec reference documentation for details.

[Team LiB]
[Team LiB]

PREVIOUS NEXT
PREVIOUS NEXT

Making Applications Translation-Aware

If we want to make our applications available in multiple languages, we must do two things:

- Make sure that every user-visible string goes through tr().
- Load a translation (.qm) file at startup.

Neither of these is necessary for applications that will never be translated. However, using tr() requires almost no effort and leaves the door open for doing translations at a later date.

The tr() function is a static function defined in QObject and overridden in every subclass defined with the Q_OBJECT macro. When writing code inside a QObject subclass, we can call tr() without formality. A call to tr() returns a translation if one is available; otherwise, the original text is returned.

To prepare translation files, we must run Qt's lupdate tool. This tool extracts all the string literals that appear in tr() calls and produces translation files that contain all of these strings ready to be translated. The files can then be sent to a translator to have the translations added. This process is explained in the "Translating Applications" section later in this chapter.

A tr() call has the following general syntax:

Context::tr(*sourceText*, *comment*)

The *Context* part is the name of a QObject subclass defined with the Q_OBJECT macro. We don't need to specify it if we call tr() from a member function of the class in question. The sourceText part is the string literal that needs to be translated. The *comment* part is optional; it can be used to provide additional information to the translator.

Here are a few examples:

```
BlueWidget::BlueWidget(QWidget *parent, const char *name)
    : QWidget(parent, name)
{
    QString str1 = tr("Legal");
    QString str2 = BlueWidget::tr("Legal");
    QString str3 = YellowDialog::tr("Legal");
    QString str4 = YellowDialog::tr("Legal", "US paper size");
}
```

The first two calls to tr() have "BlueWidget" as context, and the last two calls have "YellowDialog". All four have "Legal" as source text. The last call also has a comment to help the translator understand the meaning of the source text.

Strings in different contexts (classes) are translated independently of each other. Translators normally work on one context at a time, often with the application running and showing the widget or dialog being translated.

When we call tr() from a global function, we must specify the context explicitly. Any QObject subclass in the application can be used as the context. If none is appropriate, we can always use QObject itself. For example:

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    ...
    QPushButton button(QObject::tr("Hello Qt!"), 0);
    app.setMainWidget(&button);
    button.show();
    return app.exec();
}
```

This idiom is useful for translating the name of the application. Instead of typing it multiple times and leaving the translator to translate it for each class it appears in, it is usually more convenient to define an APPNAME macro that expands to the translated application name and to put the macro in a header file included by all the application's files:

```
#define APPNAME MainWindow::tr("OpenDrawer 2D")
```

In every example so far, the context has been a class name. This is convenient, because we can almost always omit it, but this doesn't have to be the case. The most general way of translating a string in Qt is to use the QApplications::translate() function, which accepts up to three arguments: the context, the source text, and the optional comment. For example, here's another way to define APPNAME:

```
#define APPNAME qApp->translate("Global Stuff", "OpenDrawer 2D")
```

This time, we put the text in the "Global Stuff" context.

The tr() and translate() functions serve a dual purpose: They are markers that lupdate uses to find user-visible strings, and at the same time they are C++ functions that translate text. This has an impact on how we write code. For example, the following will not work:

```
// WRONG
const char *appName = "OpenDrawer 2D";
QString translated = tr(appName);
```

The problem here is that lupdate will not be able to extract the "OpenDrawer 2D" string literal, as it doesn't appear inside a tr() call. This means that the translator will not have the opportunity to translate the string. This issue often arises in conjunction with dynamic strings:

```
// WRONG
statusBar()->message(tr("Host " + hostName + " found"));
```

Here, the string we pass to tr() varies depending on the value of hostName, so we can't reasonably expect tr() to translate it correctly.

The solution is to use QString::arg():

```
statusBar()->message(tr("Host %1 found") .arg(hostName));
```

Notice how it works: The string literal "Host %1 found" is passed to tr(). Assuming a French translation file is loaded, tr() would return something like "Hôte %1 trouvé". Then the "%1" parameter is replaced with the contents of the hostName variable.

Although it is generally inadvisable to call tr() on a variable, it can be made to work. We must use the QT_TR_NOOP() macro to mark the string literals for translation before we assign them to a variable. This is mostly useful for static arrays of strings. For example:

```
void OrderForm::init()
{
    static const char * const flowers[] = {
        QT_TR_NOOP("Medium Stem Pink Roses"),
        QT_TR_NOOP("One Dozen Boxed Roses"),
        QT_TR_NOOP("Calypso Orchid"),
        QT_TR_NOOP("Dried Red Rose Bouquet"),
        QT_TR_NOOP("Mixed Peonies Bouquet"),
        0
    };
    int i = 0;
    while (flowers[i]) {
        comboBox->insertItem(tr(flowers[i]));
        ++i;
    }
}
```

The QT_TR_NOOP() simply returns its argument. But lupdate will extract all the strings wrapped in QT_TR_NOOP(), so that they can be translated. When using the variable later on, we call tr() to perform the translation as usual. Even though we have passed tr() a variable, the translation will still work.

There is also a QT_TRANSLATE_NOOP() macro, which works like QT_TR_NOOP() but also takes a context. This macro is useful when initializing variables outside of a class:

```
static const char * const flowers[]  = {
    QT_TRANSLATE_NOOP("OrderForm", "Medium Stem Pink Roses"),
    QT_TRANSLATE_NOOP("OrderForm", "One Dozen Boxed Roses"),
    QT_TRANSLATE_NOOP("OrderForm", "Calypso Orchid"),
    QT_TRANSLATE_NOOP("OrderForm", "Dried Red Rose Bouquet"),
    QT_TRANSLATE_NOOP("OrderForm", "Mixed Peonies Bouquet"),
    0
};
```

The context argument must be the same as the context given to tr() or translate() later on.

When we start using tr() in an application, it's easy to forget to surround some user-visible strings with a tr() call, especially when we first start doing it. These missing tr() calls are eventually discovered by the translator or, worse, by users of the translated application, when some strings appear in the original language. To avoid this problem, we can tell Qt to forbid implicit conversions from const char * to QString. We do this by defining the QT_NO_CAST_ASCII preprocessor symbol before including <qstring.h>. The easiest way to ensure this symbol is set is to add the following line to the application's .pro file:

```
DEFINES += QT_NO_CAST_ASCII
```

This will force every string literal to need to be wrapped by tr() or QString::fromAscii(), depending on whether it should be translated or not. Strings that are not suitably wrapped will produce a compile-time error, thereby compelling us to add the missing tr() or QString::fromAscii() call.

Once we have wrapped every user-visible string by a tr() call, the only thing left to do to enable translation is to load a translation file. Typically, we would do this in the application's main() function. For example, here's how we would try to load a translation file depending on the user's locale:

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    QTranslator appTranslator;
    appTranslator.load(QString("app_") + QTextCodec::locale(),
                       qApp->applicationDirPath());
    app.installTranslator(&appTranslator);
    ...
    return app.exec();
}
```

The QTextCodec::locale() function returns a string that specifies the user's locale. Locales can be more or less precise;for example,fr specifies a French-language locale, fr_CA specifies a French Canadian locale, and fr_CA.ISO8859-15 specifies a French Canadian locale with ISO 8859-15 encoding (an encoding that supports '€', 'Œ', 'œ', and 'Ÿ').

Assuming that the locale is fr_CA.ISO8859-15, load() first attempts to load the file app_fr_CA.ISO8859-15.qm. If this file does not exist, load() next tries app_fr_CA.qm, then app_fr.qm, and finally app.qm before giving up. Normally, we would only provide app_fr.qm, containing a standard French translation, but if we need a different file for French-speaking Canada, we can also provide app_fr_CA.qm and it will be used for fr_CA locales.

The second argument to load() is the directory where we want load() to look for the translation file. In this case, we assume that the translation files are located in the same directory as the executable.

The Qt library itself contains a few strings that need to be translated. Trolltech provides French and German translations in Qt's translations directory. (A few other languages are provided as well, but these are contributed by Qt users and are not officially supported.) The Qt library's translation file should also be loaded:

```
QTranslator qtTranslator;
qtTranslator.load(QString("qt_") + QTextCodec::locale(),
                  qApp->applicationDirPath());
app.installTranslator(&qtTranslator);
```

A QTranslator object can only hold one translation file at a time, so we use a separate QTranslator for Qt's translation. Having just one file per translator is not a problem since we can install as many translators as we need. QApplication will use all of them when searching for a translation.

Some languages, such as Arabic and Hebrew, are written right-to-left instead of left-to-right. In those languages, the whole layout of the application must be reversed, which is done by calling QApplication::setReverseLayout(true). The translation files for the Qt library contain a special marker called "LTR" that tells Qt whether the language is left-to-right or right-to-left, so we normally don't need to worry about it.

It may prove more convenient for our users if we supply our applications with the translation files embedded into the executable. Not only does this reduce the number of files distributed as part of the product, but it also avoids the risk of translation files getting lost or deleted by accident. Qt provides the qembed tool (located in Qt's tools directory), which can convert .qm files to a C++ array that can be passed to QTranslator::load().

We have now covered all that is required to make an application able to operate using translations into other languages. But language and the direction of the writing system are not the only things that vary between countries and cultures. An internationalized program must also take into account the local date and time formats, monetary formats, numeric formats, and string collation order. Qt 3.2 provides no specific functions for accessing these, but we can use the standard C++ `setlocale()` and `localeconv()` functions to query the program's current locale.[*]

[*] Qt 3.3 will probably include a `QLocale` class that will provide localized numeric formats

Some Qt classes and functions adapt their behavior to the locale:

- `QString::localeAwareCompare()` compares two strings in a locale-dependent manner. It is used by classes like `QIconView` and `QListView` for sorting items.
- The `toString()` function provided by `QDate`, `QTime`, and `QDateTime` returns a string in a local format when called with `Qt::LocalDate` as argument.
- By default, `QDateEdit`, `QTimeEdit`, and `QDateTimeEdit` present dates in the local format.

Finally, a translated application may need to use different icons in certain situations rather than the original icons. For example, the left and right arrows on a web browser's *Back* and *Forward* buttons should be swapped when dealing with a right-to-left language. We can do this as follows:

```
if (QApplication::reverseLayout()) {
    backAct->setIconSet(forwardIcon);
    forwardAct->setIconSet(backIcon);
} else {
    backAct->setIconSet(backIcon);
    forwardAct->setIconSet(forwardIcon);
}
```

Icons that contain alphabetic characters very commonly need to be translated. For example, the letter 'I' on a toolbar button associated with a word processor's *Italic* option should be replaced by a 'C' in Spanish (*Cursivo*) and by a 'K' in Danish, Dutch, German, Norwegian, and Swedish (*Kursiv*). Here's a quick way to do it:

```
if (tr("Italic")[0] == 'C') {
    italicAct->setIconSet(iconC);
} else if (tr("Italic")[0] == 'K') {
    italicAct->setIconSet(iconK);
} else {
    italicAct->setIconSet(iconI);
}
```

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Dynamic Language Switching

For most applications, detecting the user's preferred language in `main()` and loading the appropriate `.qm` files there is perfectly satisfactory. But there are some situations where users might need the ability to switch language dynamically. An application that is used continuously by different people in shifts may need to change language without having to be restarted. For example, applications used by call center operators, by simultaneous translators, and by computerized cash register operators often require this capability.

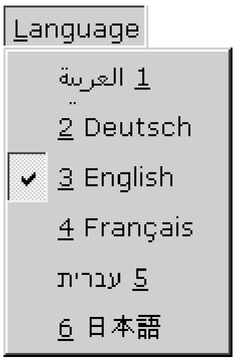
Making an application able to switch language dynamically requires a little more work than loading a single translation at startup, but it is not difficult. Here's what must be done:

- Provide a means by which the user can switch language.

- For every widget or dialog, set all of its translatable strings in a separate function (often called `retranslateStrings()`) and call this function when the language changes.

Let's review the relevant parts of a Call Center application's source code. The application provides a Language menu to allow the user to set the language at run-time. The default language is English.

Figure 15.1. The Call Center application's Language menu



Since we don't know which language the user will want to use when the application is started, we no longer load translations in the `main()` function. Instead we will load them dynamically when they are needed, so all the code that we need to handle translations must go in the main window and dialog classes.

Let's have a look at the Call Center application's `QMainWindow` subclass:

```
MainWindow::MainWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    journalView = new JournalView(this);
    setCentralWidget(journalView);

    qmPath = qApp->applicationDirPath() + "/translations";
    appTranslator = new QTranslator(this);
    qtTranslator = new QTranslator(this);
    qApp->installTranslator(appTranslator);
    qApp->installTranslator(qtTranslator);

    createActions();
    createMenus();

    retranslateStrings();
}
```

In the constructor, we set the central widget to be a `JournalView`, a `QListView` subclass. Then we set up a few private member variables related to translation:

- The `qmPath` variable is a `QString` that specifies the path of the directory that contains the application's translation files.

- The `appTranslator` variable is a pointer to the `QTranslator` object used for storing the current application translation.

- The `qtTranslator` variable is a pointer to the `QTranslator` object used for storing Qt's translation.

At the end, we call the `createActions()` and `createMenus()` private functions to create the menu system, and we call `retranslateStrings()`, also a private function, to set the user-visible strings for the first time.

```
void MainWindow::createActions()
{
    newAct = new QAction(this);
    connect(newAct, SIGNAL(activated()), this, SLOT(newFile()));
    ...
    aboutQtAct = new QAction(this);
    connect(aboutQtAct, SIGNAL(activated()), qApp, SLOT(aboutQt()));
}
```

The `createActions()` function creates the `QAction` objects as usual, but without setting any of the texts or accelerator keys. These will be done in `retranslateStrings()`.

```
void MainWindow::createMenus()
{
    fileMenu = new QPopupMenu(this);
    newAct->addTo(fileMenu);
    openAct->addTo(fileMenu);
    saveAct->addTo(fileMenu);
    exitAct->addTo(fileMenu);
    ...
    createLanguageMenu();
}
```

The `createMenus()` function creates menus, but does not insert these menus into the menu bar. Again, this will be done in `retranslateStrings()`.

At the end of the function, we call `createLanguageMenu()` to fill the *Language* menu with the list of supported languages. We will review its source code in a moment. First, let's look at `retranslateStrings()`:

```
void MainWindow::retranslateStrings()
{
    setCaption(tr("Call Center"));

    newAct->setMenuText(tr("&New"));
    newAct->setAccel(tr("Ctrl+N"));
    newAct->setStatusTip(tr("Create a new journal"));
    ...
    aboutQtAct->setMenuText(tr("About &Qt"));
    aboutQtAct->setStatusTip(tr("Show the Qt library's About box"));

    menuBar()->clear();
    menuBar()->insertItem(tr("&File"), fileMenu);
    menuBar()->insertItem(tr("&Edit"), editMenu);
    menuBar()->insertItem(tr("&Reports"), reportsMenu);
    menuBar()->insertItem(tr("&Language"), languageMenu);
    menuBar()->insertItem(tr("&Help"), helpMenu);
}
```

The retranslateStrings() function is where all the tr() calls for the MainWindow class occur. It is called at the end of the MainWindow constructor and also every time a user changes the application's language using the *Language* menu.

We set each QAction's menu text, accelerator, and status tip. We also insert the menus into the menu bar, with their translated names. (The call to clear() is necessary when retranslateStrings() is called more than once.)

The createMenus() function referred to earlier called createLanguageMenu() to populate the *Language* menu with a list of languages:

```
void MainWindow::createLanguageMenu()
{
    QDir dir(qmPath);
    QStringList fileNames = dir.entryList("callcenter_*.qm");

    for (int i = 0; i < (int)fileNames.size(); ++i) {
        QTranslator translator;
        translator.load(fileNames[i], qmPath);

        QTranslatorMessage message =
                translator.findMessage("MainWindow", "English");
        QString language = message.translation();

        int id = languageMenu->insertItem(
                         tr("&%1 %2").arg(i + 1).arg(language),
                         this, SLOT(switchToLanguage(int)));
        languageMenu->setItemParameter(id, i);
        if (language == "English")
            languageMenu->setItemChecked(id, true);

        QString locale = fileNames[i];
        locale = locale.mid(locale.find('_') + 1);
        locale.truncate(locale.find('.'));
        locales.push_back(locale);
    }
}
```

Instead of hard-coding the languages supported by the application, we create one menu entry for each .qm file located in the application's translations directory. For simplicity, we assume that English also has a .qm file. An alternative would have been to call clear() on the QTranslator objects when the user chooses English.

One particular difficulty is to present a nice name for the language provided by each .qm file. Just showing "en" for "English" or "de" for "Deutsch", based on the name of the .qm file, looks crude and will confuse some users. The solution used in createLanguageMenu() is to check the translation of the string "English" in the "MainWindow" context. That string should be translated to "Deutsch" in a German translation, to "Français" in a French translation, and to "日本語" in a Japanese translation.

We create menu items using QPopupMenu::insertItem(). They are all connected to the main window's switchToLanguage(int) slot, which we will review next. The parameter to the switchToLanguage(int) slot is the value set using setItemParameter(). This is very similar to what we did in Chapter 3 when we implemented the Spreadsheet application's recently opened files list (p. 54).

At the end, we append the locale in a QStringList called locales, which we will use for implementing switchToLanguage().

```
void MainWindow::switchToLanguage(int param)
{
    appTranslator->load("callcenter_" + locales[param], qmPath);
    qtTranslator->load("qt_" + locales[param], qmPath);

    for (int i = 0; i < (int)languageMenu->count(); ++i)
        languageMenu->setItemChecked(languageMenu->idAt(i),
                                     i == param);
    retranslateStrings();
}
```

The `switchToLanguage()` slot is called when the user chooses a language from the *Language* menu. We start by loading the translation files for the application and for Qt. Then we update the check marks next to the *Language* menu entries so that the language in use is ticked, and we call `retranslateStrings()` to retranslate all the strings for the main window.

On Microsoft Windows, an alternative to providing a *Language* menu is to respond to `LocaleChange` events, a type of event emitted by Qt when it detects a change in the environment's locale. The event type exists on all platforms supported by Qt, but is only actually generated on Windows, when the user changes the system's locale settings (in the Regional and Language Options from the Control Panel). To handle `LocaleChange` events, we can reimplement `QObject::event()` as follows:

```
bool MainWindow::event(QEvent *event)
{
    if (event->type() == QEvent::LocaleChange) {
        appTranslator->load(QString("callcenter_")
                            + QTextCodec::locale(),
                            qmPath);
        qtTranslator->load(QString("qt_") + QTextCodec::locale(),
                           qmPath);
        retranslateStrings();
    }
    return QMainWindow::event(event);
}
```

If the user switches locale while the application is being run, we attempt to load the correct translation files for the new locale and call `retranslateStrings()` to update the user interface.

In all cases, we pass the event on to the base class's `event()` function, since one of our base classes may also be interested in `LocaleChange` events.

We have now finished our review of the `MainWindow` code. We will now review the code for one of the application's widget classes, the `JournalView` class, to see what changes are needed to make it support dynamic translation.

```
JournalView::JournalView(QWidget *parent, const char *name)
    : QListView(parent, name)
{
    ...
    retranslateStrings();
}
```

The `JournalView` class is a `QListView` subclass. At the end of the constructor, we call the private function `retranslateStrings()` to set the widget's strings. This is similar to what we did for `MainWindow`.

```
bool JournalView::event(QEvent *event)
{
    if (event->type() == QEvent::LanguageChange)
        retranslateStrings();
    return QListView::event(event);
}
```

We reimplement the event() function to call retranslateStrings() on LanguageChange events.

Qt generates a LanguageChange event when the contents of a QTranslator currently installed on QApplication changes. In the Call Center application, this occurs when we call load() on appTranslator or qtTranslator, either from MainWindow::switchToLanguage() or from MainWindow::event().

LanguageChange events are not the same as LocaleChange events. A LocaleChange event tells the application, "Maybe you should load a new translation." In contrast, a LanguageChange event tells the application's widgets, "Maybe you should retranslate all your strings."

When we implemented MainWindow, we didn't need to respond to Language-Change. Instead, we simply called retranslateStrings() whenever we called load() on a QTranslator.

```
void JournalView::retranslateStrings()
{
    for (int i = columns() - 1; i >= 0; --i)
        removeColumn(i);
    addColumn(tr("Time"));
    addColumn(tr("Priority"));
    addColumn(tr("Phone Number"));
    addColumn(tr("Subject"));
}
```

The retranslateStrings() function recreates the QListView column headers with newly translated texts. We do this by removing all column headings and then adding new column headings. This operation only affects the QListView header, not the data stored in the QListView.

This completes the translation-related code of a hand-written widget. For widgets and dialogs developed with *Qt Designer*, the uic tool automatically generates a function similar to our retranslateStrings() function that is automatically called in response to LanguageChange events. All we need to do is to load a translation file when the user switches language.

[Team LiB]

Translating Applications

Translating a Qt application that contains tr() calls is a three-step process:

1. Run lupdate to extract all the user-visible strings from the application's source code.
2. Translate the application using *Qt Linguist*.
3. Run lrelease to generate binary .qm files that the application can load using QTranslator.

Steps 1 and 3 are performed by application developers. Step 2 is handled by translators. This cycle can be repeated as often as necessary during the application's development and lifetime.

As an example, we will show how to translate the Spreadsheet application of Chapter 3. The application already contains `tr()` calls around every user-visible string.

First, we must modify the application's `.pro` file slightly to specify which languages we want to support. For example, if we want to support German and French in addition to English, we would add the following `TRANSLATIONS` entry to `spreadsheet.pro`:

```
TRANSLATIONS = spreadsheet_de.ts \
               spreadsheet_fr.ts
```

Here, we specify two translation files: one for German and one for French. These files will be created the first time we run `lupdate`, and are updated every time we subsequently run `lupdate`.

These files normally have a `.ts` extension. They are in a straightforwardXML format and are not as compact as the binary `.qm` files understood by `QTranslator`. It is `lrelease`'s job to convert human-readable `.ts` files into machine-efficient `.qm` files. For the curious, `.ts` stands for "translation source" and `.qm` for "Qt message" file.

Assuming that we are located in the directory that contains the Spreadsheet application's source code, we can run `lupdate` on `spreadsheet.pro` from the command line as follows:

```
lupdate -verbose spreadsheet.pro
```

The `-verbose` argument is optional. It tells `lupdate` to provide more feedback than usual. Here's the expected output:

```
Updating 'spreadsheet_de.ts'...
 0 known, 101 new and 0 obsoleted messages
Updating 'spreadsheet_fr.ts'...
 0 known, 101 new and 0 obsoleted messages
```

Every string that appears within a `tr()` call in the application's source code is stored in the `.ts` files, along with an empty translation. Strings that appear in the application's `.ui` files are also included.

The `lupdate` tool assumes by default that the arguments to `tr()` are Latin-1 strings. If this isn't the case, we must add a `CODEC` entry to the `.pro` file. For example:

```
CODEC     = EUC-JP
```

This must be done in addition to calling `QTextCodec::setCodecForTr()` from the application's `main()` function.

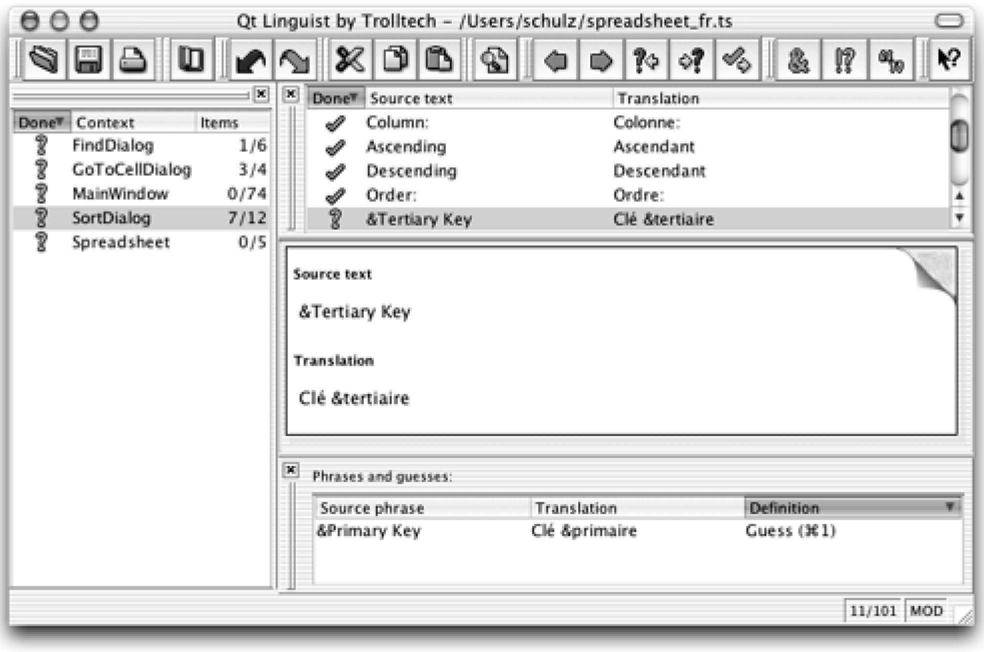
Translations then need to be added to the `spreadsheet_de.ts` and `spreadsheet_fr.ts` files using *Qt Linguist*, a GUI tool for translating Qt applications.

To launch *Qt Linguist*, click *Qt 3.2.x*|*Qt Linguist* in the *Start* menu on Windows, type `linguist` on the command line on Unix, or double-click `linguist` in the Mac OS X Finder. To start adding translations to a `.ts` file, click *File*|*Open* and choose the file.

The left-hand side of *Qt Linguist*'s main window shows the list of contexts for the application being translated. For the Spreadsheet application, the contexts are "FindDialog", "GoToCellDialog", "MainWindow", "SortDialog", and "Spreadsheet". The top-right area is the list of source texts for the current context. Each source text is shown along with with a translation and a *Done* flag. The middle-right area is where we can enter a translation for the current source item. The bottom-right area is a list of suggestions automatically provided by *Qt Linguist*.

Once we have a translated `.ts` file, we need to convert it to a binary `.qm` file for it to be understandable by `QTranslator`. To do this from within *Qt Linguist*, click *File|Release*. Typically, we would start by translating only a few strings and run the application with the `.qm` file to make sure that everything works.

Figure 15.2. *Qt Linguist* in action



Done	Context	Items
?	FindDialog	1/6
?	GoToCellDialog	3/4
?	MainWindow	0/74
?	SortDialog	7/12
?	Spreadsheet	0/5

Done	Source text	Translation
✓	Column:	Colonne:
✓	Ascending	Ascendant
✓	Descending	Descendant
✓	Order:	Ordre:
?	&Tertiary Key	Clé &tertiaire

Source text

&Tertiary Key

Translation

Clé &tertiaire

Phrases and guesses:

Source phrase	Translation	Definition
&Primary Key	Clé &primaire	Guess (⌘1)

If we want to regenerate the `.qm` files for all `.ts` files, we can use the `lrelease` command-line tool as follows:

```
lrelease -verbose spreadsheet.pro
```

Assuming that we translated 19 strings to French and clicked the *Done* flag for 17 of them, `lrelease` produces the following output:

```
Updating 'spreadsheet_de.qm'...
 0 finished, 0 unfinished and 101 untranslated messages
Updating 'spreadsheet_fr.qm'...
 17 finished, 2 unfinished and 82 untranslated messages
```

Untranslated strings are shown in the original languages when running the application. The *Done* flag isn't used by `lrelease`; it can be used by translators to identify which translations are finished and which ones must be revisited.

When we modify the source code of the application, the translation files may become out of date. The solution is to run `lupdate` again, provide translations for the new strings, and regenerate the `.qm` files. Some development teams find it useful to run `lupdate` frequently, while others prefer to wait until just before a final product release.

The `lupdate` and *Qt Linguist* tools are quite smart. Translations that are no longer used are kept in the `.ts` files in case they are needed in later releases. When updating `.ts` files, `lupdate` uses an intelligent merging algorithm that can save translators considerable time with text that is the same or similar in different contexts.

For more information about *Qt Linguist*, `lupdate`, and `lrelease`, refer to the *Qt Linguist* manual at http://doc.trolltech.com/3.2/linguist-manual.html. The manual contains a full explanation of *Qt Linguist*'s user interface and a step-by-step tutorial for programmers.

[Team LiB]
PREVIOUS NEXT

Chapter 16. Providing Online Help

Most applications provide their users with online help. Some help is short, such as tooltips, status tips, and "What's This?" help. Qt supports all of these. Other help can be much more extensive, involving many pages of text. For this kind of help, you can use `QTextBrowser` as a simple online help browser, or you can invoke *Qt Assistant* or another HTML browser from your application.

[Team LiB]
PREVIOUS NEXT

Tooltips, Status Tips, and "What's This?" Help

A tooltip is a small piece of text that appears when the mouse hovers over a widget for a certain period of time. Tooltips are presented with black text on a yellow background. Their primary use is to provide textual descriptions of toolbar buttons.

We can add tooltips to arbitrary widgets in code using `QToolTip::add()`. For example:

```
QToolTip::add(findButton, tr("Find next"));
```

To set the tooltip of a toolbar button that corresponds to a `QAction`, we can simply call `setToolTip()` on the action. For example:

```
newAct = new QAction(tr("&New"), tr("Ctrl+N"), this);
newAct->setToolTip(tr("New file"));
```

If we don't explicitly set a tooltip, `QAction` will automatically derive one from the action text and the accelerator key (for example, "New (Ctrl+N)").

A status tip is also a short piece of descriptive text, usually a little longer than a tooltip. When the mouse hovers over a toolbar button or a menu option, a status tip appears in the status bar. Call `setStatusTip()` to add a status tip to an action:

```
newAct->setStatusTip(tr("Create a new file"));
```

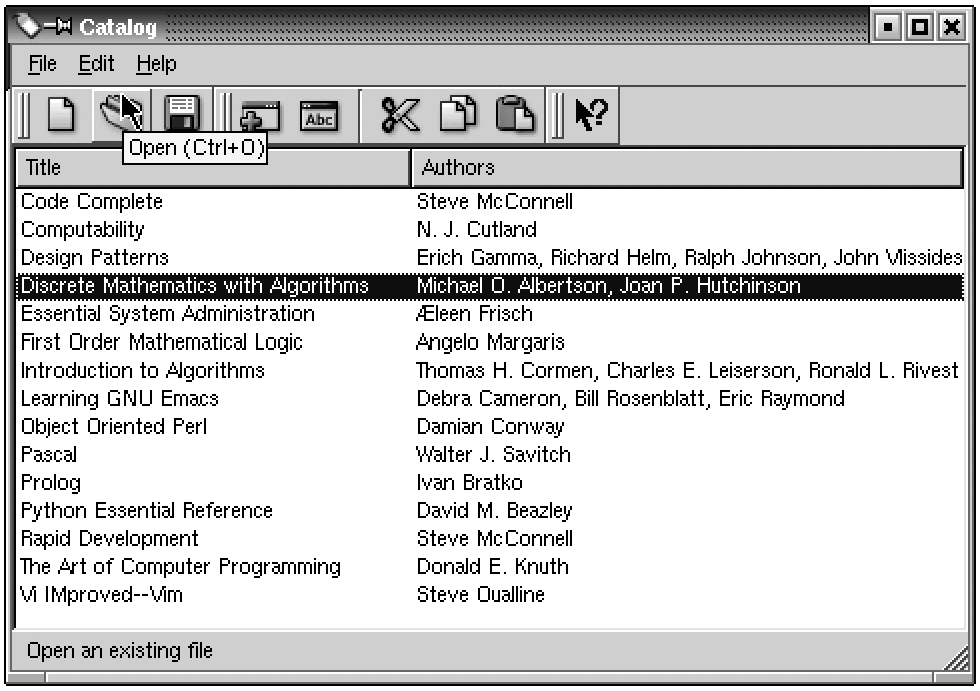
In the absence of a status tip, `QAction` will use the tooltip text instead.

If we don't use `QActions`, we need to pass a `QToolTipGroup` object and a status tip as the third and fourth arguments to `QToolTip::add()`:

```
QToolTip::add(findButton, tr("Find next"), toolTipGroup,
              tr("Find the next occurrence of the search text"));
```

The application can be made to show the longer text in the status bar by connecting the `QToolTipGroup`'s`showTip()` and `removeTip()` signals to the status bar's `message()` and `clear()` slots. The `QToolTipGroup` object is responsible for maintaining contact between tooltips and a widget that can show the longer help text.

Figure 16.1. An application showing a tooltip and a status tip



Title	Authors
Code Complete	Steve McConnell
Computability	N. J. Cutland
Design Patterns	Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides
Discrete Mathematics with Algorithms	Michael O. Albertson, Joan P. Hutchinson
Essential System Administration	Æleen Frisch
First Order Mathematical Logic	Angelo Margaris
Introduction to Algorithms	Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest
Learning GNU Emacs	Debra Cameron, Bill Rosenblatt, Eric Raymond
Object Oriented Perl	Damian Conway
Pascal	Walter J. Savitch
Prolog	Ivan Bratko
Python Essential Reference	David M. Beazley
Rapid Development	Steve McConnell
The Art of Computer Programming	Donald E. Knuth
Vi IMproved--Vim	Steve Oualline

Open an existing file

In *Qt Designer*, tooltips and status tips are accessible through the `toolTip` and `statusTip` properties of a widget or action.

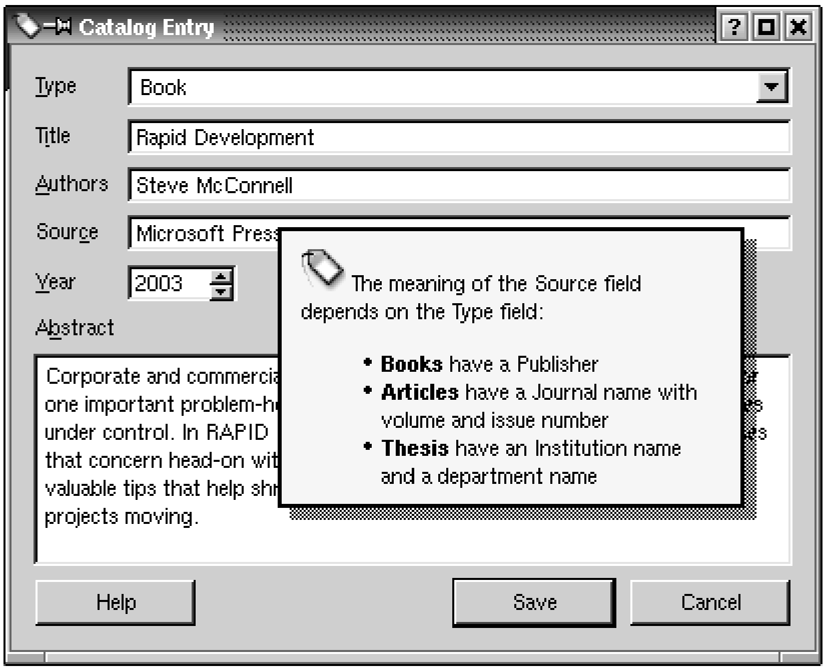
In some situations, it is desirable to provide more information about a widget than can be given by tooltips or status tips. For example, we might want to provide a complex dialog with explanatory text about each field without forcing the user to invoke a separate help window. "What's This?" mode is an ideal solution for this. When a window is in "What's This?" mode, the cursor changes to and the user can click on any user interface component to obtain its help text. To enter "What's This?" mode, the user can either click the *?* button in the dialog's title bar (on Windows and KDE) or press *Shift+F1*.

The help text can be set by calling `QWhatsThis::add()`. Here's an example:

```
QWhatsThis::add(sourceLineEdit,
    tr("<img src=\"icon.png\">"
       "&nbsp;The meaning of the Source field depends on the "
       "Type field:"
       "<ul>"
       "<li><b>Books</b> have a Publisher</li>"
       "<li><b>Articles</b>  have a Journal name with volume and "
       "issue number</li>"
       "<li><b>Thesis</b> have an Institution name and a "
       "department name</li>"
       "</ul>"));
```

As with many other Qt widgets, we can use HTML-style tags to format the text of a tooltip. In the example, we include an image (which is listed in the application's `.pro` file `IMAGE` entry), a bulleted list, and some text in bold. The tags that Qt supports are specified in the `QStyleSheet` documentation.

Figure 16.2. A dialog showing a "What's This?" help text



Type: Book
Title: Rapid Development
Authors: Steve McConnell
Source: Microsoft Press
Year: 2003
Abstract:
Corporate and commercia
one important problem-h
under control. In RAPID
that concern head-on wit
valuable tips that help sh
projects moving.

The meaning of the Source field depends on the Type field:

- **Books** have a Publisher
- **Articles** have a Journal name with volume and issue number
- **Thesis** have an Institution name and a department name

We can also set a "What's This?" text on an action:

```
openAct->setWhatsThis(tr("<img src=open.png>&nbsp;"
                         "Click this option to open an "
                         "existing file."));
```

The text will be shown when the user clicks the menu item or toolbar button or presses the accelerator key while in "What's This?" mode. In *Qt Designer*, the "What's This?" text for a widget or action is available through the `whatsThis` property.

When the user interface components of an application's main window provide "What's This?" text, it is customary to provide a *What's This?* option in the *Help* menu as well as a *What's This?* toolbar button. This can be done by creating a *What's This?* action and connecting its `activated()` signal to the `QMainWindow`'s `whatsThis()` slot, which enters "What's This?" mode when executed.

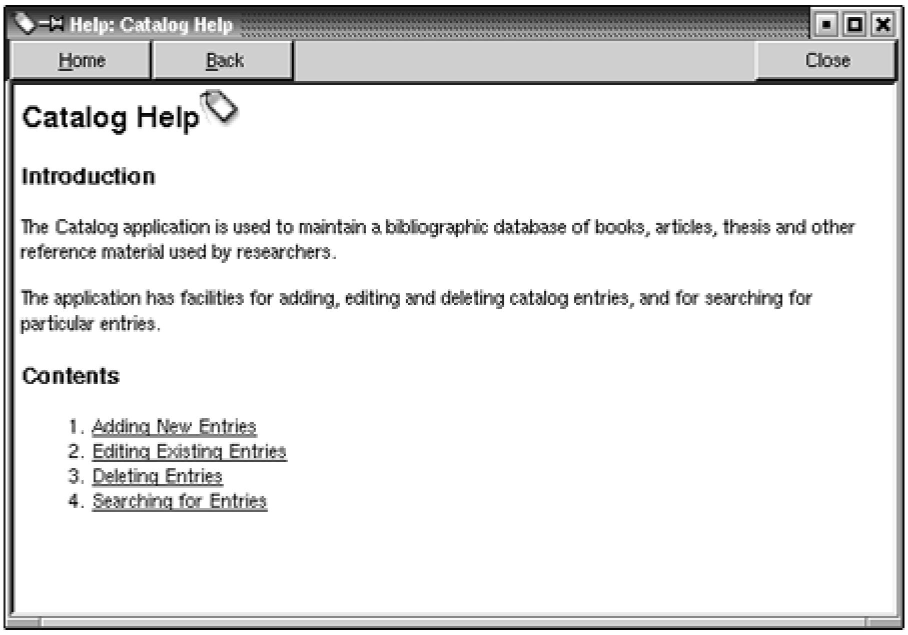
[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Using QTextBrowser as a Simple Help Engine

Large and sophisticated applications may require more online help than tooltips, status tips, and "What's This?" help can provide. A simple solution to this is to provide a help browser. Applications that provide a help browser typically have a *Help* entry in the main window's *Help* menu and a *Help* button in every dialog.

In this section, we present the simple help browser shown in Figure 16.3 and explain how it can be used within an application. The window uses a `QTextBrowser` to display help pages that are marked up with an HTML-based syntax. `QTextBrowser` can handle a lot of simple HTML tags, so it is ideal for this purpose.

Figure 16.3. The HelpBrowser widget



Catalog Help

Introduction

The Catalog application is used to maintain a bibliographic database of books, articles, thesis and other reference material used by researchers.

The application has facilities for adding, editing and deleting catalog entries, and for searching for particular entries.

Contents

1. Adding New Entries
2. Editing Existing Entries
3. Deleting Entries
4. Searching for Entries

We begin with the header file:

```
#include <qwidget.h>

class QPushButton;
class QTextBrowser;

class HelpBrowser : public QWidget
{
    Q_OBJECT
public:
    HelpBrowser(const QString &path, const QString &page,
                QWidget *parent = 0, const char *name = 0);

    static void showPage(const QString &page);

private slots:
    void updateCaption();

private:
    QTextBrowser *textBrowser;
    QPushButton *homeButton;
    QPushButton *backButton;
    QPushButton *closeButton;
};
```

The `HelpBrowser` provides a static function that can be called from anywhere in the application. This function creates a `HelpBrowser` window and shows the given page.

Here's the beginning of the implementation:

```
#include <qapplication.h>
#include <qlayout.h>
#include <qpushbutton.h>
#include <qtextbrowser.h>

#include "helpbrowser.h"

HelpBrowser::HelpBrowser(const QString &path, const QString &page,
                         QWidget *parent, const char *name)
    : QWidget(parent, name, WGroupLeader | WDestructiveClose)
```

```
{
    textBrowser = new QTextBrowser(this);
    homeButton = new QPushButton(tr("&Home"), this);
    backButton = new QPushButton(tr("&Back"), this);
    closeButton = new QPushButton(tr("&Close"), this);
    closeButton->setAccel(tr("Esc"));

    QVBoxLayout *mainLayout = new QVBoxLayout(this);
    QHBoxLayout *buttonLayout = new QHBoxLayout(mainLayout);
    buttonLayout->addWidget(homeButton);
    buttonLayout->addWidget(backButton);
    buttonLayout->addStretch(1);
    buttonLayout->addWidget(closeButton);
    mainLayout->addWidget(textBrowser);

    connect(homeButton, SIGNAL(clicked()),
            textBrowser, SLOT(home()));
    connect(backButton, SIGNAL(clicked()),
            textBrowser, SLOT(backward()));
    connect(closeButton, SIGNAL(clicked()),
            this, SLOT(close()));
    connect(textBrowser, SIGNAL(sourceChanged(const QString &)),
            this, SLOT(updateCaption()));

    textBrowser->mimeSourceFactory()->addFilePath(path);
    textBrowser->setSource(page);
}
```

The layout is simply a row of buttons above a `QTextBrowser`. The `path` parameter is a path in the file system that contains the application's documentation. The `page` parameter is the name of the documentation file, with an optional HTML anchor.

We use the `WGroupLeader` flag because we want to pop up `HelpBrowser` windows from modal dialogs in addition to the main window. Modal dialogs normally prevent the user from interacting with any other window in the application. However, after requesting help, the user must obviously be allowed to interact with both the modal dialog and the help browser. Using the `WGroupLeader` flag makes this interaction possible.

```
void HelpBrowser::updateCaption()
{
    setCaption(tr("Help: %1").arg(textBrowser->documentTitle()));
}
```

Whenever the source page changes, the `updateCaption()` slot is executed. The `documentTitle()` function returns the text specified in the page's `<title>` tag.

```
void HelpBrowser::showPage(const QString &page)
{
    QString path = qApp->applicationDirPath() + "/doc";
    HelpBrowser *browser = new HelpBrowser(path, page);
    browser->resize(500, 400);
    browser->show();
}
```

In the `showPage()` static function, we create the `HelpBrowser` window and then show it. The window will be destroyed automatically when the user closes it, since we set the `WDestructiveClose` flag in the constructor.

For this example, we assume that the documentation is located in the `doc` subdirectory of the directory containing the application's executable. All the pages passed to the `showPage()`

function will be taken from this doc subdirectory.

Now we are ready to invoke the help browser from the application. In the application's main window, we would create a *Help* action and connect it to a help() slot that could look like this:

```
void MainWindow::help()
{
    HelpBrowser::showPage("index.html");
}
```

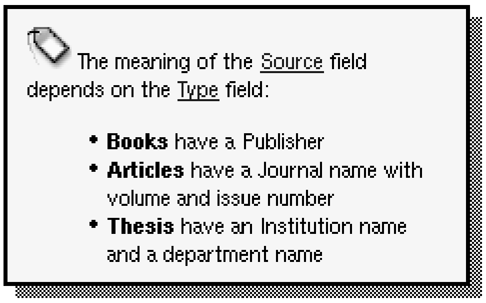
This assumes that the main help file is called index.html. For dialogs, we would connect the *Help* button to a help() slot that could look like this:

```
void EntryDialog::help()
{
    HelpBrowser::showPage("dialogs.html#entrydialog");
}
```

Here we look in a different help file, dialogs.html, and scroll the QTextBrowser to the entrydialog anchor.

One other place from which we might want to invoke help is a "What's This?" text. We can link the "What's This?" text to the documentation by using HTML <a href="..."> tags.

Figure 16.4. A "What's This?" text with links


The meaning of the Source field depends on the Type field:

- **Books** have a Publisher
- **Articles** have a Journal name with volume and issue number
- **Thesis** have an Institution name and a department name

To make hypertext links work from "What's This?" text, we must use a QWhatsThis that is aware of the help browser. This is accomplished by subclassing QWhatsThis and reimplementing its clicked() function to call HelpBrowser::showPage(). Here's the class definition:

```
class MyWhatsThis : public QWhatsThis
{
public:
    MyWhatsThis(QWidget *widget, const QString &text);

    QString text(const QPoint &point);
    bool clicked(const QString &page);

private:
    QString myText;
};
```

The text() and clicked() functions are reimplemented from QWhatsThis.

```
MyWhatsThis::MyWhatsThis(QWidget *widget, const QString &text)
    : QWhatsThis(widget)
{
    myText = text;
}
```

The constructor accepts a widget and a "What's This?" text for that widget. We pass on the widget to the base class and store the text in a private variable.

```
QString MyWhatsThis::text(const QPoint &)
{
    return myText;
}
```

The `text()` function returns the "What's This?" text for a widget given a certain mouse cursor position. For some widgets, it might make sense to return a different text depending on where the user clicked on it, but here we always return the same text.

```
bool MyWhatsThis::clicked(const QString &page)
{
    if (page.isEmpty()) {
        return true;
    } else {
        HelpBrowser::showPage(page);
        return false;
    }
}
```

The `clicked()` function is called by `QWhatsThis` when the user clicks on the "What's This?" window. If the user clicked on an HTML link, `QWhatsThis` passes the target page to the `clicked()` function. (If anything else is clicked, an empty string is passed.) We invoke the help browser with the given page.

The return value of `clicked()` is used by `QWhatsThis` to determine whether it should hide the "What's This?" text (indicated by `true`) or continue to show it. When the user clicks a link, we want the "What's This?" to stay visible along with the help window, so we return `false`. If the user clicked elsewhere in the "What's This?" window, we return `true` to hide the "What's This?" window.

Here's how the `MyWhatsThis` class can be used:

```
new MyWhatsThis(sourceLineEdit,
    tr("<img src=\"icon.png\">"
       "&nbsp;The meaning of the "
       "<a href=\"fields.html#source\">Source</a> field depends on "
       "the <a href=\"fields.html#type\">Type</a> field:"
       "<ul>"
       "<li><b>Books</b> have a Publisher</li>"
       "<li><b>Articles</b> have a Journal name with volume and "
       "issue number</li>"
       "<li><b>Thesis</b> have an Institution name and a department "
       "name</li>"
       "</ul>"));
```

Instead of calling `QWhatsThis::add()`, we create a `MyWhatsThis` object with the widget and its associated text. But this time, if the user clicks a link, the help browser is invoked.

It may look strange that we allocate an object with `new` and don't assign the value to a variable. This is not a problem here because Qt keeps track of all `QWhatsThis` objects and deletes them when they are no longer needed.

Using Qt Assistant for Powerful Online Help

Qt Assistant is a redistributable online help application supplied by Trolltech. Its main virtues are that it supports indexing and full text search and that it can handle multiple documentation sets for multiple applications.

To make use of *Qt Assistant*, we must incorporate the necessary code in our application, and we must make *Qt Assistant* aware of our documentation.

Communication between a Qt application and *Qt Assistant* is handled by the `QAssistantClient` located in a separate library. To link this library with an application, we must add the following line to the application's `.pro` file:

```
LIBS     += -lqassistantclient
```

We will now review the code of a new `HelpBrowser` class that uses *Qt Assistant*.

```
#ifndef HELPBROWSER_H
#define HELPBROWSER_H

class QAssistantClient;

class HelpBrowser
{
public:
    static void showPage(const QString &page);

private:
    static QAssistantClient *assistant;
};

#endif
```

Here's the new `helpbrowser.cpp`:

```
#include <qassistantclient.h>

#include "helpbrowser.h"

QAssistantClient *HelpBrowser::assistant = 0;

void HelpBrowser::showPage(const QString &page)
{
    if (!assistant)
        assistant = new QAssistantClient("");
    assistant->showPage(page);
}
```

The `QAssistantClient` constructor accepts a path string as its first argument, which it uses to locate the *Qt Assistant* executable. By passing an empty path, we signify that `QAssistantClient` should look for the executable in the `PATH` environment variable. `QAssistantClient` has its own `showPage()` function that accepts a page name with an optional HTML anchor, just like the earlier `QTextBrowser` subclass's `showPage()` function.

The next step is to tell *Qt Assistant* where the documentation is located. This is done by creating a *Qt Assistant* profile and creating a `.dcf` file that provides information about the documentation. All this is explained in *Qt Assistant*'s online documentation, so we will not duplicate that information here.

An alternative to using QTextBrowser or *Qt Assistant* is to use platform-specific approaches to providing online help. For Windows applications, it might be desirable to create Windows HTML Help files and to provide access to them using Microsoft Internet Explorer. You could use Qt's QProcess class or the ActiveQt framework for this. For Unix and Mac OS X applications, a suitable approach might be to provide HTML files and launch a web browser.

[Team LiB]
[Team LiB]

Chapter 17. Multithreading

Conventional GUI applications have one thread of execution and perform one operation at a time. If the user invokes a time-consuming operation from the user interface in a single-threaded application, the interface typically freezes while the operation is in progress. Chapter 7 (Event Processing) provides some solutions to this problem. Multithreading is another solution.

In a multithreaded Qt application, the GUI runs in its own thread and the processing takes place in one or more other threads. This results in applications that have responsive GUIs even during intensive processing. Another benefit of multithreading is that on multiprocessor machines different threads may be executed simultaneously on different processors, resulting in better performance.

In this chapter, we will start by showing how to subclass QThread and how to use QMutex, QSemaphore, and QWaitCondition to synchronize threads. Then we will see how to communicate with the GUI thread from non-GUI threads while the event loop is running, and round off with a review of which Qt classes can be used in non-GUI threads and which cannot.

Multithreading is a large topic with many books devoted exclusively to the subject. Here, it is assumed that you already understand the fundamentals of multithreaded programming; the focus is on explaining how to develop multithreaded Qt applications rather than on the subject of threading itself.

[Team LiB]
[Team LiB]

Working with Threads

Providing multiple threads in a Qt application is straightforward: We just subclass QThread and reimplement its run() function. To show how this works, we will start by reviewing the code for a very simple QThread subclass that repeatedly prints the same text on a console.

```
class Thread : public QThread
{
public:
    Thread();

    void setMessage(const QString &message);
    void run();
    void stop();

private:
    QString messageStr;
    volatile bool stopped;
};
```

The Thread class inherits from QThread and reimplements the run() function. It provides two additional functions: setMessage() and stop().

The stopped variable is declared volatile because it is accessed from different threads and we want to be sure that it is freshly read every time it is needed. If we omitted the volatile keyword, the compiler might optimize access to the variable, possibly leading to incorrect results.

```
Thread::Thread()
{
    stopped  = false;
}
```

We set stopped to false in the constructor.

```
void Thread::run()
{
    while (!stopped)
        cerr << messageStr.ascii();
    stopped = false;
    cerr << endl;
}
```

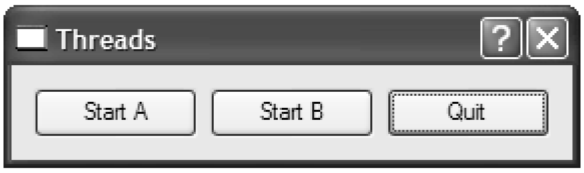
The run() function is called to start executing the thread. As long as the stopped variable is false, the function keeps printing the given message to the console. The thread terminates when control leaves the run() function.

```
void Thread::stop()
{
    stopped = true;
}
```

The stop() function sets the stopped variable to true, thereby telling run() to stop printing text to the console. This function can be called from any thread at any time. For the purposes of this example, we assume that assignment to a bool is an atomic operation. This is a reasonable assumption, considering that a bool is either true or false. We will see later in this section how to use QMutex to guarantee that assigning to a variable is an atomic operation.

QThread provides a terminate() function that terminates the execution of a thread while it is still running. Using terminate() is not recommended, since it can stop the thread at any point and does not give the thread any chance to clean up after itself. It is always safer to use a stopped variable and a stop() function, as we did here.

Figure 17.1. The Threads application



We will now see how to use the Thread class in a small Qt application that uses two threads, A and B, in addition to the initial thread.

```
class ThreadForm : public QDialog
{
    Q_OBJECT
public:
    ThreadForm(QWidget *parent = 0, const char *name = 0);

protected:
    void closeEvent(QCloseEvent *event);

private slots:
    void startOrStopThreadA();
    void startOrStopThreadB();

private:
    Thread threadA;
    Thread threadB;
    QPushButton *threadAButton;
    QPushButton *threadBButton;
    QPushButton *quitButton;
};
```

The ThreadForm class declares two variables of type Thread and some buttons to provide a basic user interface.

```
ThreadForm::ThreadForm(QWidget *parent, const char *name)
    : QDialog(parent, name)
{
    setCaption(tr("Threads"));

    threadA.setMessage("A");
    threadB.setMessage("B");

    threadAButton = new QPushButton(tr("Start A"), this);
    threadBButton = new QPushButton(tr("Start B"), this);
    quitButton = new QPushButton(tr("Quit"), this);
    quitButton->setDefault(true);

    connect(threadAButton, SIGNAL(clicked()),
            this, SLOT(startOrStopThreadA()));
    connect(threadBButton, SIGNAL(clicked()),
            this, SLOT(startOrStopThreadB()));
    connect(quitButton, SIGNAL(clicked()),
            this, SLOT(close()));
    ...
}
```

In the constructor, we call setMessage() to make the first thread repeatedly print "A" and the second thread "B".

```
void ThreadForm::startOrStopThreadA()
{
    if (threadA.running()) {
        threadA.stop();
        threadAButton->setText(tr("Start A"));
    } else {
        threadA.start();
        threadAButton->setText(tr("Stop A"));
    }
}
```

When the user clicks the button for thread A, `startOrStopThreadA()` stops the thread if it was running and starts it otherwise. It also updates the button's text.

```
void ThreadForm::startOrStopThreadB()
{
    if (threadB.running()) {
        threadB.stop();
        threadBButton->setText(tr("Start B"));
    } else {
        threadB.start();
        threadBButton->setText(tr("Stop B"));
    }
}
```

The code for `startOrStopThreadB()` is very similar.

```
void ThreadForm::closeEvent(QCloseEvent *event)
{
    threadA.stop();
    threadB.stop();
    threadA.wait();
    threadB.wait();
    event->accept();
}
```

If the user clicks *Quit* or closes the window, we stop any running threads and wait for them to finish (using `QThread::wait()`) before we call `QCloseEvent::accept()`. This ensures that the application exits in a clean state, although it doesn't really matter in this example.

To compile the application, we must add this line to the `.pro` file:

```
CONFIG     += thread
```

This tells `qmake` to use the threaded version of the Qt library. To build a threaded Qt library, pass the `-thread` command-line option to the `configure` script on Unix and Mac OS X. On Windows, the Qt library is threaded by default. For this particular example, we also need the `console` option since we want the program's output to appear in the console on Windows:

```
win32:CONFIG += console
```

If you run the application and click *Start* A, the console will be filled with 'A's. If you click *Start* B, it will now fill with alternating sequences of 'A's and 'B's. Click *Stop* A, and now it will only print 'B's.

A common requirement for multithreaded applications is that of synchronizing several threads. Qt provides the following classes to do this: `QMutex, QMutexLocker, QSemaphore`, and `QWaitCondition`.

The `QMutex` class provides a means of protecting a variable or a piece of code so that only one thread can access it at a time. The class provides a `lock()` function that locks the mutex. If the mutex is unlocked, the current thread seizes it immediately and locks it; otherwise, the current thread is blocked until the thread that holds the mutex unlocks it. Either way, when the call to lock() returns, the current thread holds the mutex until it calls unlock(). QMutex also provides a tryLock() function that returns immediately if the mutex is already locked.

For example, let's suppose that we wanted to protect the stopped variable of the Thread class with a QMutex. We would then add the following data member to Thread:

```
QMutex mutex;
```

The run() function would change to this:

```
void Thread::run()
{
    for (;;) {
        mutex.lock();
        if (stopped) {
            stopped = false;
            mutex.unlock();
            break;
        }
        mutex.unlock();

        cerr << messageStr.ascii();
    }
    cerr << endl;
}
```

The stop() function would become this:

```
void Thread::stop()
{
    mutex.lock();
    stopped = true;
    mutex.unlock();
}
```

Locking and unlocking a mutex in complex functions, especially functions that use C++ exceptions, can be error-prone. Qt provides the QMutexLocker convenience class to simplify mutex handling. QMutexLocker's constructor accepts a QMutex as argument and locks it. QMutexLocker's destructor unlocks the mutex. For example, we could rewrite the stop() function above as follows:

```
void Thread::stop()
{
    QMutexLocker locker(&mutex);
    stopped  = true;
}
```

QSemaphore provides semaphores in Qt. A semaphore is a generalization of mutexes that can be used to guard a certain number of identical resources.

The following two code snippets show the correspondence between QSemaphore and QMutex:

QSemaphore semaphore(1);	QMutex mutex;
semaphore++;	mutex.lock();
semaphore--;	mutex.unlock();

The postfix ++ and -- operators acquire and release one resource protected by the semaphore.

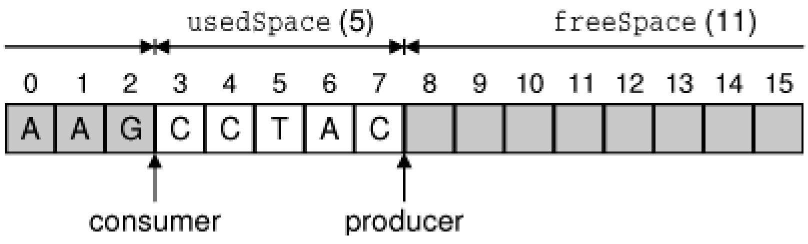
By passing 1 to the constructor, we tell the semaphore that it controls a signal resource. The advantage of using a semaphore is that we can pass numbers other than 1 to the constructor and then call ++ multiple times to acquire many resources.

A typical application of semaphores is when transfering a certain amount of data (DataSize) between two threads using a shared circular buffer of a certain size (BufferSize):

```
const int DataSize = 100000;
const int BufferSize = 4096;
char buffer[BufferSize];
```

The producer thread writes data to the buffer until it reaches the end, and then restarts from the beginning, overwriting existing data. The consumer thread reads the data as it is generated. Figure 17.2 illustrates this, assuming a tiny 16-byte buffer.

Figure 17.2. The producer–consumer model



The need for synchronization in the producer–consumer example is twofold: If the producer generates the data too fast, it will overwrite data that the consumer hasn't yet read; if the consumer reads the data too fast, it will pass the producer and read garbage.

A crude way to solve this problem is to have the producer fill the buffer, then wait until the consumer has read the *entire* buffer, and so on. However, on multiprocessor machines, this isn't as fast as letting the producer and consumer threads operate on different parts of the buffer at the same time.

One way to efficiently solve the problem is to use two semaphores:

```
QSemaphore freeSpace(BufferSize);
QSemaphore usedSpace(BufferSize);
```

The freeSpace semaphore governs the part of the buffer that the producer can fill with data. The usedSpace semaphore governs the area that the consumer can read. These two areas are complementary. Both are initialized with BufferSize (4096), meaning that they can administer up to that many resources.

For this example, each byte counts as one resource. In a real-world application, we would probably operate on larger units (for example, 64 or 256 bytes at a time) to reduce the overhead associated with using semaphores.

```
void acquire(QSemaphore &semaphore)
{
    semaphore++;
}
```

The acquire() function attempts to acquire one resource (one byte in the buffer). QSemaphore uses the postfix ++ operator for this, but in our particular example it is more intuitive to use a function called acquire().

```
void release(QSemaphore &semaphore)
{
    semaphore--;
}
```

Similarly, we implement the `release()` function as a synonym for the postfix `--` operator.

```
void Producer::run()
{
    for (int i = 0; i < DataSize; ++i) {
        acquire(freeSpace);
        buffer[i % BufferSize] = "ACGT"[ (uint)rand() % 4];
        release(usedSpace);
    }
}
```

In the producer, we start by acquiring one "free" byte. If the buffer is full of data that the consumer hasn't read yet, the call to `acquire()` will block until the consumer has started to consume the data. Once we have acquired the byte, we fill it with some random data ('A', 'C', 'G', or 'T') and release the byte as "used", so that it can be read by the consumer thread.

```
void Consumer::run()
{
    for (int i = 0; i < DataSize; ++i) {
         acquire(usedSpace);
         cerr << buffer[i % BufferSize];
         release(freeSpace);
    }
    cerr << endl;
}
```

In the consumer, we start by acquiring one "used" byte. If the buffer contains no data to read, the call to `acquire()` will block until the producer has produced some. Once we have acquired the byte, we print it and release the byte as "free", making it possible for the producer to fill it with data again.

```
int main()
{
    usedSpace += BufferSize;

    Producer producer;
    Consumer consumer;
    producer.start();
    consumer.start();
    producer.wait();
    consumer.wait();
    return 0;
}
```

Finally, in `main()`, we start by acquiring all the "used" space (using `QSemaphore`'s counterintuitive `+=` operator) to ensure that the consumer will not acquire it and read garbage. Then we start the producer and consumer threads. What happens then is that the producer converts some "free" space into "used" space, and the consumer can then convert it back to "free" space.

When we run the program, it writes a random sequence of 100,000 'A's, 'C's, 'G's, and 'T's to the console and then terminates. To really understand what is going on, we can disable writing the output and instead write 'P' each time the producer generates a byte and 'c' each time the consumer reads a byte. And to make things as simple to follow as possible, we can use much smaller values for `DataSize` and `BufferSize`.

For example, here's a possible run with a DataSize of 10 and a BufferSize of 4: "PcPcPcPcPcPcPcPcPcPc". In this case, the consumer reads the bytes as soon as they are generated by the producer; the two threads are executing at the same speed. Another possibility is that the producer fills the whole buffer before the consumer even starts reading it: "PPPPccccPPPPccccPPcc". There are many other possibilities. Semaphores give a lot of latitude to the system-specific thread scheduler, which can study the threads' behavior and choose an optimal scheduling policy.

A different approach to the problem of synchronizing a producer and a consumer is to use QWaitCondition and QMutex. A QWaitCondition allows a thread to wake up other threads when some condition has been met. This allows for more precise control than is possible with mutexes alone. To show how it works, we will redo the producer–consumer example using wait conditions.

```
const int DataSize = 100000;
const int BufferSize = 4096;
char buffer[BufferSize];

QWaitCondition bufferIsNotFull;
QWaitCondition bufferIsNotEmpty;
QMutex mutex;
int usedSpace = 0;
```

In addition to the buffer, we declare two QWaitConditions, one QMutex, and one variable that stores how many bytes in the buffer are "used" bytes.

```
void Producer::run()
{
    for (int i = 0; i < DataSize; ++i) {
        mutex.lock();
        while (usedSpace == BufferSize)
            bufferIsNotFull.wait(&mutex);
        buffer[i % BufferSize] = "ACGT"[ (uint)rand() % 4];
        ++usedSpace;
        bufferIsNotEmpty.wakeAll();
        mutex.unlock();
    }
}
```

In the producer, we start by checking whether the buffer is full. If it is, we wait on the "buffer is not full" condition. When that condition is met, we write one byte to the buffer, increment usedSpace, and wake any thread waiting for the "buffer is not empty" condition to turn true.

We use a mutex to protect all accesses to the usedSpace variable. The QWaitCondition::wait() function can take a locked mutex as its first argument, which it unlocks before blocking the current thread and then locks before returning.

For this example, we could have replaced the while loop

```
while (usedSpace == BufferSize)
    bufferIsNotFull.wait(&mutex);
```

with this if statement:

```
if (usedSpace == BufferSize) {
    mutex.unlock();
    bufferIsNotFull.wait();
    mutex.lock();
}
```

However, this would break as soon as we allow more than one producer thread, since another producer could seize the mutex immediately after the wait() call and make the "buffer is not full" condition false again.

```
void Consumer::run()
{
    for (int i = 0; i < DataSize; ++i) {
        mutex.lock();
        while (usedSpace == 0)
            bufferIsNotEmpty.wait(&mutex);
        cerr << buffer[i % BufferSize];
        --usedSpace;
        bufferIsNotFull.wakeAll();
        mutex.unlock();
    }
    cerr << endl;
}
```

The consumer does the opposite of the producer: It waits for the "buffer is not empty" condition and wakes up any thread waiting for the "buffer is not full" condition.

In all the examples so far, our threads have accessed the same global variables. But some threaded applications need to have a global variable hold different values in different threads. This is often called thread-local storage (TLS) or thread-specific data (TSD). We can fake it using a map keyed on thread IDs (returned by QThread::currentThread()), but a nicer approach is to use the QThreadStorage<T> class.

A common use of QThreadStorage<T> is for caches. By having a separate cache in different threads, we avoid the overhead of locking, unlocking, and possibly waiting for a mutex. For example:

```
QThreadStorage<QMap<int, double> *> cache;

void insertIntoCache(int id, double value)
{
    if (!cache.hasLocalData())
        cache.setLocalData(new QMap<int, double>);
    cache.localData()->insert(id, value);
}

void removeFromCache(int id)
{
    if (cache.hasLocalData())
        cache.localData()->remove(id);
}
```

The cache variable holds one pointer to a QMap<int, double> per thread. (Because of problems with some compilers, the template type in QThreadStorage<T> must be a pointer type.) The first time we use the cache in a particular thread, hasLocalData() returns false and we create the QMap<int, double> object.

In addition to caching, QThreadStorage<T> can be used for global error-state variables (similar to errno), to ensure that modifications in one thread don't affect other threads.

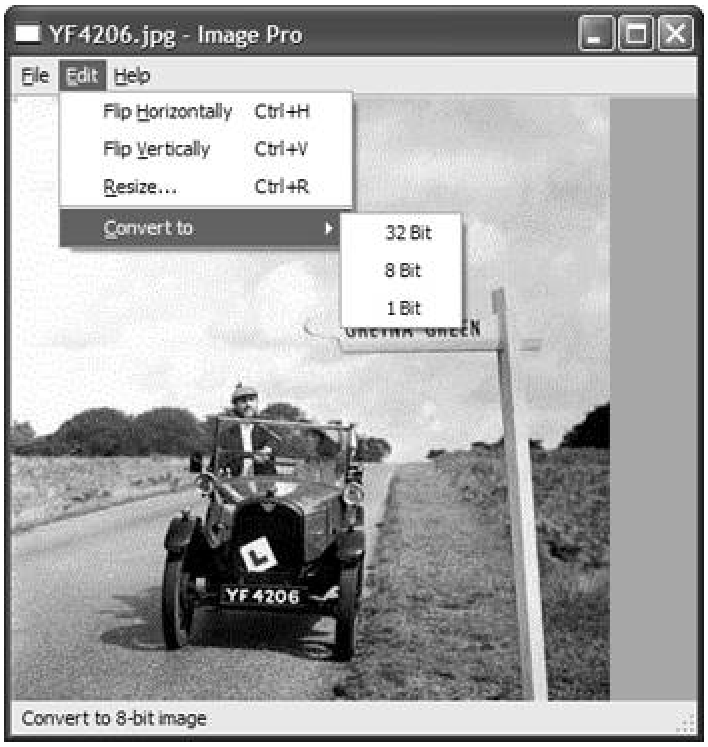
Communicating with the GUI Thread

When a Qt application starts, only one thread is running—the initial thread. This is the only thread that is allowed to create the QApplication object and call exec() on it. For this reason, we normally refer to this thread as the GUI thread. After the call to exec(), this thread is either waiting for an event or processing an event.

The GUI thread can start new threads by creating objects of a QThread subclass, as we did in the previous section. If these new threads need to communicate among themselves, they can use shared variables together with mutexes, semaphores, or wait conditions. But none of these techniques can be used to communicate with the GUI thread, since they would lock the event loop and freeze the user interface.

The solution for communicating from a non-GUI thread to the GUI thread is to use custom events. Qt's event mechanism allows us to define custom event types in addition to the built-in types, and allows us to post events of these types using QApplication::postEvent(). Furthermore, since postEvent() is thread-safe, we can use it from any thread to post events to the GUI thread.

Figure 17.3. The Image Pro application



To illustrate how this works, we will review the code of the Image Pro application, a basic image processing application that allows the user to rotate, resize, and change the color depth of an image. The application uses one non-GUI thread to perform operations on images without locking the event loop. This makes a significant difference when processing large images. The non-GUI thread has a list of tasks, or "transactions", to accomplish, and sends events to the main window to report progress.

```
ImageWindow::ImageWindow(QWidget *parent, const char *name)
    : QMainWindow(parent, name)
{
    thread.setTargetWidget(this);
    ...
}
```

In the ImageWindow constructor, we set the "target widget" of the non-GUI thread to be the ImageWindow. The thread will post progress events to that widget. The thread variable is of type TransactionThread, which we will cover in a moment.

```
void ImageWindow::flipHorizontally()
{
    addTransaction(new FlipTransaction(Horizontal));
}
```

The `flipHorizontally()` slot creates a "flip" transaction and registers it using the private function `addTransaction()`. The `flipVertical()`, `resizeImage()`, `convertTo32Bit()`, `convertTo8Bit()`, and `convertTo1Bit()` functions are similar.

```
void ImageWindow::addTransaction(Transaction *transact)
{
    thread.addTransaction(transact);
    openAct->setEnabled(false);
    saveAct->setEnabled(false);
    saveAsAct->setEnabled(false);
}
```

The `addTransaction()` function adds a transaction to the non-GUI thread's transaction queue and disables the *Open*, *Save*, and *Save As* actions while transactions are being processed.

```
void ImageWindow::customEvent(QCustomEvent *event)
{
    if ((int)event->type() == TransactionStart) {
        TransactionStartEvent *startEvent =
                (TransactionStartEvent *)event;
        infoLabel->setText(startEvent->message);
    } else if ((int)event->type() == AllTransactionsDone) {
        openAct->setEnabled(true);
        saveAct->setEnabled(true);
        saveAsAct->setEnabled(true);
        imageLabel->setPixmap(QPixmap(thread.image()));
        infoLabel->setText(tr("Ready"));
        modLabel->setText(tr("MOD"));
        modified = true;
        statusBar()->message(tr("Done"), 2000);
    } else {
        QMainWindow::customEvent(event);
    }
}
```

The `customEvent()` function is reimplemented from `QObject` to handle custom events. The `TransactionStart` and `AllTransactionsDone` constants are defined in `transactionthread.h` as

```
enum { TransactionStart = 1001, AllTransactionsDone = 1002 };
```

Qt's built-in events have values below 1000. Higher values can be used for custom events.

The data type for custom events is `QCustomEvent`, a `QEvent` subclass that stores a `void` pointer in addition to the event type. For `TransactionStart` events, we use a `QCustomEvent` subclass that stores an additional data member:

```
class TransactionStartEvent : public QCustomEvent
{
public:
    TransactionStartEvent();

    QString message;
};
```

```
TransactionStartEvent::TransactionStartEvent()
    : QCustomEvent(TransactionStart)
{
}
```

In the constructor, we pass the TransactionStart constant to the base class constructor.

Now, let's turn to the TransactionThread class:

```
class TransactionThread : public QThread
{
public:
    void run();
    void setTargetWidget(QWidget *widget);
    void addTransaction(Transaction *transact);
    void setImage(const QImage &image);
    QImage image();

private:
    QWidget *targetWidget;
    QMutex mutex;
    QImage currentImage;
    std::list<Transaction *> transactions;
};
```

The TransactionThread class maintains a list of transactions to process and executes them one after the other in the background.

```
void TransactionThread::addTransaction(Transaction *transact)
{
    QMutexLocker locker(&mutex);
    transactions.push_back(transact);
    if (!running())
        start();
}
```

The addTransaction() function adds a transaction to the transaction queue and starts the transaction thread if it isn't already running.

```
void TransactionThread::run()
{
    Transaction *transact;

    for (;;) {
        mutex.lock();
        if (transactions.empty()) {
            mutex.unlock();
            break;
        }
        QImage oldImage = currentImage;
        transact = *transactions.begin();
        transactions.pop_front();
        mutex.unlock();

        TransactionStartEvent *event = new TransactionStartEvent;
        event->message = transact->messageStr();
        QApplication::postEvent(targetWidget, event);

        QImage newImage = transact->apply(oldImage);
        delete transact;

        mutex.lock();
        currentImage = newImage;
        mutex.unlock();
    }
    QApplication::postEvent(targetWidget,
                            new QCustomEvent(AllTransactionsDone));
}
```

The run() function goes through the transaction queue and executes each transaction in turn (by calling apply() on them). All accesses to the transactions and currentImage member variables are protected with a mutex.

When a transaction is started, we post a TransactionStart event to the target widget (the ImageWindow). When all the transactions have finished processing, we post an AllTransactionsDone event.

```
class Transaction
{
public:
    virtual QImage apply(const QImage &image) = 0;
    virtual QString messageStr() = 0;
};
```

The Transaction class is an abstract base class for operations that the user can perform on an image. It has three concrete subclasses: FlipTransaction, ResizeTransaction, and ConvertDepthTransaction. We will only review FlipTransaction; the other two classes are similar.

```
class FlipTransaction : public Transaction
{
public:
    FlipTransaction(Qt::Orientation orient);

    QImage apply(const QImage &image);
    QString messageStr();

private:
    Qt::Orientation orientation;
};
```

The FlipTransaction constructor takes one parameter that specifies the orientation of the flip (Horizontal or Vertical).

```
QImage FlipTransaction::apply(const QImage &image)
{
    return image.mirror(orientation == Qt::Horizontal,
                        orientation == Qt::Vertical);
}
```

The apply() function calls QImage::mirror() on the QImage it receives as parameter and returns the resulting QImage.

```
QString FlipTransaction::messageStr()
{
    if (orientation == Qt::Horizontal)
        return QObject::tr("Flipping image horizontally...");
    else
        return QObject::tr("Flipping image vertically...");
}
```

The messageStr() returns the message to display in the status bar while the operation is in progress. This function is called in `ImageWindow::customEvent()`, in the GUI thread.

For long-running operations, it might be desirable to report fine-grained progress. We can achieve this by creating an additional custom event and posting it when a certain percentage of the processing is completed.

Using Qt's Classes in Non-GUI Threads

A function is said to be *thread-safe* when it can safely be called from different threads simultaneously. If two thread-safe functions are called from different threads on the same shared data, the result is always defined. By extension, a class is said to be thread-safe when all of its functions can be called from different threads simultaneously without interfering with each other, even when operating on the same object.

Qt's thread-safe classes are `QThread, QMutex, QMutexLocker, QSemaphore, QThreadStorage<T>`, and `QWaitCondition`. In addition, the following functions are thread-safe: `QApplication::postEvent()`, `QApplication::removePostedEvents()`, `QApplication::removePostedEvent()`, and `QEventLoop::wakeUp()`.

Most of Qt's non-GUI classes meet a less stringent requirement: They are *reentrant*. A class is reentrant if different instances of the class can be used simultaneously in different threads. However, accessing the same reentrant object in multiple threads simultaneously is not safe, and such accesses should be protected with a mutex. Reentrant classes are marked as such in the Qt reference documentation. Typically, any C++ class that doesn't reference global or otherwise shared data is reentrant.

`QObject` is reentrant, but none of Qt's `QObject` subclasses are reentrant. One consequence of this is that we cannot directly call functions on a widget from a non-GUI thread. If we want to, say, change the text of a `QLabel` from a non-GUI thread, we must post a custom event to the GUI thread, asking it to change the text for us.

Deleting a `QObject` with `delete` is not reentrant. To delete a `QObject` from a non-GUI thread, we can call `QObject::deleteLater()`, which posts a "deferred delete" event.

`QObject`'s signals and slots mechanism can be used in any thread. When a signal is emitted in one thread, the slots that are connected to it are called immediately, and the execution takes place in the same thread—not in the thread where the receiver object was created. This means that we can't use signals and slots to communicate with the GUI thread from other threads.

The `QTimer` class and the networking classes `QFtp, QHttp, QSocket`, and `QSocketNotifier` all depend on the event loop, so we cannot use them in non-GUI threads. The only networking class available is `QSocketDevice`, the low-level wrapper for the platform-specific networking APIs. A common technique is to use a synchronous `QSocketDevice` in a non-GUI thread. Some programmers find that it leads to simpler code than using `QSocket` (which works asynchronously), and by working in a non-GUI thread, they don't block the event loop.

Qt's SQL and OpenGL modules can also be used in multithreaded applications, but have their own restrictions, which vary from system to system. For details, see http://doc.trolltech.com/3.2/sql-driver.html as well as the *Qt Quarterly* article "Glimpsing the Third Dimension", available online at http://doc.trolltech.com/qq/qq06-glimpsing.html.

Many of Qt's non-GUI classes, including `QImage, QString`, and the container classes, use implicit or explicit sharing as an optimization technique. These classes are reentrant except for their copy constructors and assignment operators. When a copy of an instance of these classes is taken, only a pointer to the internal data is copied. This is dangerous if multiple threads attempt to modify the data simultaneously. In such cases, a solution is to use the QDeepCopy<T> class when performing an assignment to an instance of an implicitly or explicitly shared class. For example:

```
QString password;
QMutex mutex;

void setPassword(const QString &str)
{
    mutex.lock();
    password = QDeepCopy<QString>(str);
    mutex.unlock();
}
```

Qt 4 will probably provide enhanced threading support. Among other things, it is expected that the signal–slot mechanism will be extended to support connections across threads, eliminating the need to use custom events for communicating with the GUI thread. It is also expected that non-GUI classes like QSocket and QTimer will be available in non-GUI threads, and that QDeepCopy<T> will no longer be necessary when copying instances of implicitly and explicitly shared classes across threads.

[Team LiB] PREVIOUS NEXT
[Team LiB] PREVIOUS NEXT

Chapter 18. Platform-Specific Features

In this chapter, we will look at some of the platform-specific options available to Qt programmers. We begin by looking at how to access native APIs such as the Win32 API on Windows, Core Graphics on Mac OS X, and Xlib on X11. We then move on to explore Qt's ActiveQt extension, showing how to use ActiveX controls within Qt/Windows applications and how to create applications that act as ActiveX servers. And in the last section, we explain how to make Qt applications cooperate with the session manager under X11.

In addition to the features presented here, the Enterprise Edition of Qt includes the Qt/Motif extension to ease the migration of Motif and Xt applications to Qt. A similar extension for Tcl/Tk applications is provided by froglogic, and a Microsoft Windows resource converter is available from Klarälvdalens Datakonsult. And for embedded development, Trolltech provides the Qtopia application framework. See the following web pages for details:

- http://doc.trolltech.com/3.2/motif-extension.html
- http://www.froglogic.com/tq/
- http://www.klaralvdalens-datakonsult.se/?page=products&sub=knut

* http://www.trolltech.com/products/qtopia/

[Team LiB]

Interfacing with Native APIs

Qt provides a comprehensive API that caters for most needs on all platforms. But in some circumstances, we may want to use the underlying, platform-specific APIs. In this section, we will show how to use the native APIs for the different platforms supported by Qt to accomplish particular tasks.

On every platform, `QWidget` provides a `winId()` function that returns the window ID (the `HWND` on Windows). `QWidget` also provides a static function called `find()` that returns the `QWidget` with a particular window ID. We can pass this ID to native API functions to achieve platform-specific effects. For example, the following code uses `winId()` to make a `QLabel` semi-transparent on Mac OS X using native Core Graphics functions:[*]

[*] Qt 3.3 will probably provide a function to achieve this without resorting to native API calls.

```
include <qapplication.h>
#include <qlabel.h>
#include <qt_mac.h>

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    QLabel *label = new QLabel("Hello Qt!", 0);
    app.setMainWidget(label);

    CGSWindowRef winRef =
        GetNativeWindowFromWindowRef((WindowRef)label->winId());
    CGSSetWindowAlpha(_CGSDefaultConnection(), winRef, 0.5);

    label->show();
    return app.exec();
}
```

Here's how to achieve the same effect on Windows, using the Win32 API:

```
#define _WIN32_WINNT 0x0501

#include <qapplication.h>
#include <qt_windows.h>

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    QLabel *label = new QLabel("Hello Qt!", 0);
    app.setMainWidget(label);

    int exstyle = GetWindowLong(label->winId(), GWL_EXSTYLE);
    exstyle |= WS_EX_LAYERED;
    SetWindowLong(label->winId(), GWL_EXSTYLE, exstyle);
    SetLayeredWindowAttributes(label->winId(), 0, 128,
                               LWA_ALPHA);

    label->show();
    return app.exec();
}
```

This code assumes that the platform is Windows 2000 or XP. If we wanted the application to compile and run on older versions of Windows that don't support semi-transparency, we could use QLibrary to resolve the SetLayeredWindowAttributes symbol at run-time instead of at link-time:

```
typedef BOOL (__stdcall *PSetLayeredWindowAttributes)
        (HWND, COLORREF, BYTE, DWORD);
PSetLayeredWindowAttributes pSetLayeredWindowAttributes =
        (PSetLayeredWindowAttributes) QLibrary::resolve("user32",
                "SetLayeredWindowAttributes");
if (pSetLayeredWindowAttributes) {
    int exstyle = GetWindowLong(label->winId(), GWL_EXSTYLE);
    exstyle |= WS_EX_LAYERED;
    SetWindowLong(label->winId(), GWL_EXSTYLE, exstyle);
    pSetLayeredWindowAttributes(label->winId(), 0, 128,
                                LWA_ALPHA);
}
```

Qt/Windows uses this technique internally to ensure that Qt applications take advantage of advanced features such as native Unicode support and font transformations where they are available, while still being able to run on old Windows versions.

On X11, there is no standard way to achieve transparency. However, here's how we would modify an X11 window property:

```
Atom atom = XInternAtom(win->x11Display(), "MY_PROPERTY", False);
long data = 1;
XChangeProperty(win->x11Display(), win->winId(), atom, atom,
                32, PropModeReplace, (unsigned char *)&data, 1);
```

Qt/Embedded differs from the other Qt versions in that it is implemented directly on top of the Linux frame buffer, with no native API in between. It also provides its own window system, QWS, which can be configured by subclassing Qt/Embedded-specific classes like QWSDecoration and QWSInputMethod. Another difference of Qt/Embedded is that its size can be reduced by compiling out unused classes and features. For more information about Qt/Embedded, see http://www.trolltech.com/products/embedded/ and http://doc.trolltech.com/3.2/winsystem.html.

If we want to use platform-specific code in an otherwise portable Qt application, we can surround the native code with #if and #endif. For example:

```
#if defined(Q_WS_MAC)
    CGSWindowRef winRef =
        GetNativeWindowFromWindowRef((WindowRef)label->winId());
    CGSSetWindowAlpha(_CGSDefaultConnection(), winRef, 0.5);
#endif
```

Qt defines one of the following four window system symbols: Q_WS_WIN, Q_WS_X11, Q_WS_MAC, and Q_WS_QWS. We must make sure to include at least one Qt header before we use them in applications. Qt also provides preprocessor symbols to identify the operating system:

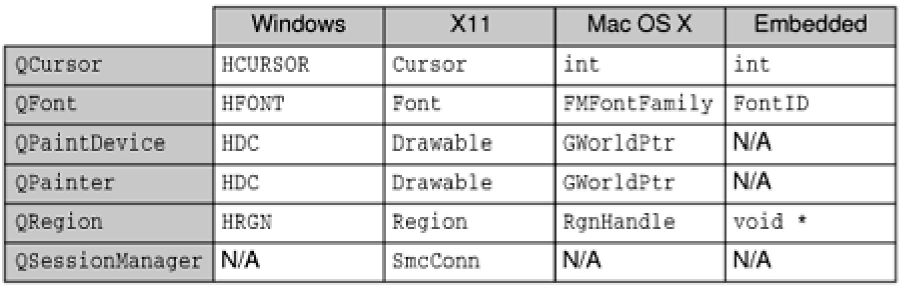
- Q_OS_WIN32
- Q_OS_WIN64
- Q_OS_DGUX
- Q_OS_DYNIX
- Q_OS_LINUX
- Q_OS_LYNX
- Q_OS_QNX6
- Q_OS_RELIANT

- Q_OS_CYGWIN
- Q_OS_MAC
- Q_OS_AIX
- Q_OS_BSDI
- Q_OS_FREEBSD
- Q_OS_HPUX
- Q_OS_HURD
- Q_OS_IRIX
- Q_OS_NETBSD
- Q_OS_OPENBSD
- Q_OS_OSF
- Q_OS_QNX
- Q_OS_SCO
- Q_OS_SOLARIS
- Q_OS_ULTRIX
- Q_OS_UNIXWARE

We can assume that at most one of these will be defined. For convenience, Qt defines Q_OS_WIN when either Win32 or Win64 is detected, and Q_OS_UNIX when any Unix-based operating system (including Mac OS X) is detected. At runtime, we can call QApplication::winVersion() or QApplication::macVersion() to distinguish between different versions of Windows (95, 98, etc.) or Mac OS X (10.0, 10.1, etc.).

Several of Qt's GUI-related classes provide a platform-specific handle() function that returns a low-level handle to the object. Figure 18.1 lists the return type of handle() on different platforms.

Figure 18.1. Platform-specific handle types



	Windows	X11	Mac OS X	Embedded
QCursor	HCURSOR	Cursor	int	int
QFont	HFONT	Font	FMFontFamily	FontID
QPaintDevice	HDC	Drawable	GWorldPtr	N/A
QPainter	HDC	Drawable	GWorldPtr	N/A
QRegion	HRGN	Region	RgnHandle	void *
QSessionManager	N/A	SmcConn	N/A	N/A

The QWidget, QPixmap, QPrinter, and QPicture classes all inherit from QPaintDevice. On X11 and Mac OS X, handle() means the same thing as winId() on a QWidget. On Windows, handle() returns the device context, whereas winId() returns the window handle. Similarly, QPixmap provides a hbm() function that returns a bitmap handle (HBITMAP) on Windows.

On X11, QPaintDevice provides many functions that return various pointers or handles, including x11Display() and x11Screen(). We can use these to set up an X11 graphics context on a QWidget or QPixmap, for example.

Qt applications that need to interface with other toolkits or libraries frequently need to access the low-level events (XEvents on X11, MSGs on Windows and Mac OS X, QWSEvents on Qt/Embedded) before they are converted into QEvents. We can do this by subclassing QApplication and reimplementing the relevant platform-specific event filter, one of winEventFilter(), x11EventFilter(), macEventFilter(), and qwsEventFilter().

We can access the platform-specific events that are sent to a given QWidget by reimplementing one of winEvent(), x11Event(), macEvent(), and qwsEvent(). This can be useful for handling certain types of events that Qt normally ignores, such as joystick events.

For more information about platform-specific issues, including how to get started with Qt/Embedded and how to deploy Qt applications on different platforms, see http://doc.trolltech.com/3.2/winsystem.html.

Using ActiveX

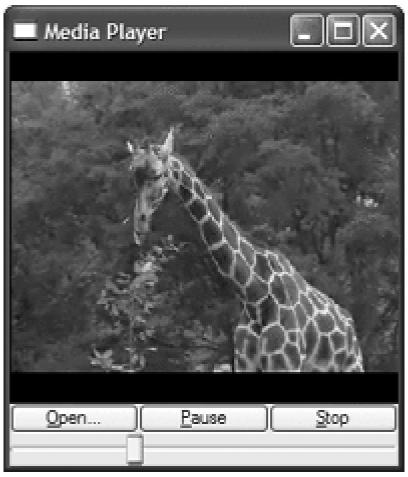
Microsoft's ActiveX technology allows applications to incorporate user interface components provided by other applications or libraries. It is built on Microsoft COM and defines one set of interfaces for applications that use components and another set of interfaces for applications and libraries that provide components.

Qt/Windows Enterprise Edition provides the ActiveQt framework to seamlessly combine ActiveX and Qt. ActiveQt consists of two modules:

- The *QAxContainer* module allows us to use COM objects and to embed ActiveX controls in Qt applications.
- The *QAxServer* module allows us to export custom COM objects and ActiveX controls written using Qt.

Our first example will embed the Windows Media Player in a Qt application using *QAxContainer*. The Qt application adds an *Open* button, a *Play/Pause* button, a *Stop* button, and a slider to the Windows Media Player ActiveX control.

Figure 18.2. The Media Player application



The application's main window is of type PlayerWindow:

```
class PlayerWindow : public QWidget
{
    Q_OBJECT
    Q_ENUMS(ReadyStateConstants)
public:
    enum PlayStateConstants { Stopped = 0, Paused = 1, Playing = 2 };
    enum ReadyStateConstants { Uninitialized = 0, Loading = 1,
                               Interactive = 3, Complete = 4 };

    PlayerWindow(QWidget *parent = 0, const char *name = 0);

protected:
    void timerEvent(QTimerEvent *event);
private slots:
    void onPlayStateChange(int oldState, int newState);
    void onReadyStateChange(ReadyStateConstants readyState);
    void onPositionChange(double oldPos, double newPos);
    void sliderValueChanged(int newValue);
    void openFile();
```

The `PlayerWindow` class inherits from `QWidget`. The `Q_ENUMS()` macro is necessary to tell `moc` that the `ReadyStateConstants` type used in the `onReadyStateChange()` slot is an enum type.

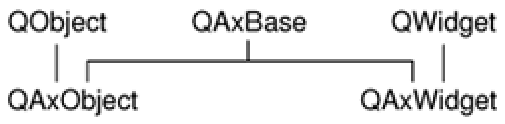
```
private:
    QAxWidget *wmp;
    QToolButton *openButton;
    QToolButton *playPauseButton;
    QToolButton *stopButton;
    QSlider *seekSlider;
    QString fileFilters;
    int updateTimer;
};
```

In the private section, we declare a `QAxWidget *` data member.

```
PlayerWindow::PlayerWindow(QWidget *parent, const char *name)
    : QWidget(parent, name)
{
    ...
    wmp = new QAxWidget(this);
    wmp->setControl("{22D6F312-B0F6-11D0-94AB-0080C74C7E95}");
```

In the constructor, we create a `QAxWidget` object to encapsulate the Windows Media Player ActiveX control. The *QAxContainer* module consists of three classes: `QAxObject` encapsulates a COM object, `QAxWidget` encapsulates an ActiveX control, and `QAxBase` implements the core COM functionality for `QAxObject` and `QAxWidget`.

Figure 18.3. Inheritance tree for the *QAxContainer* module



We call `setControl()` on the `QAxWidget` with the class ID of the Windows Media Player 6.4 control. This will create an instance of the required component. From then on, all the properties, events, and methods of the ActiveX control are available as Qt properties, signals, and slots through the `QAxWidget` object.

The COM data types are automatically converted into the corresponding Qt types, as summarized in Figure 18.4. For example, an in-parameter of type `VARIANT_BOOL` becomes a `bool`, and an out-parameter of type `VARIANT_BOOL` becomes a `bool &`. If the resulting type is a Qt class (`QString`, `QDateTime`, etc.), the in-parameter is a const reference (for example, `const QString &`).

Figure 18.4. Relationship between COM types and Qt types

COM types	Qt type
VARIANT_BOOL	bool
char, short, int, long	int
unsigned char, unsigned short, unsigned int, unsigned long	uint
float, double	double
CY	Q_LLONG
BSTR	QString
DATE	QDateTime
OLE_COLOR	QColor
SAFEARRAY(VARIANT)	QValueList<QVariant>
SAFEARRAY(BYTE)	QByteArray
VARIANT	QVariant
IFontDisp *	QFont
IPictureDisp *	QPixmap

To obtain the list of all the properties, signals, and slots available in a `QAxObject` or `QAxWidget` with their Qt data types, call `generateDocumentation()` or use Qt's `dumpdoc` command-line tool, located in Qt's `extensions\activeqt\example` directory.

```
wmp->setProperty("ShowControls", QVariant(false, 0));
wmp->setSizePolicy(QSizePolicy::Expanding,
                   QSizePolicy::Expanding);
connect(wmp, SIGNAL(PlayStateChange(int, int)),
        this, SLOT(onPlayStateChange(int, int)));
connect(wmp, SIGNAL(ReadyStateChange(ReadyStateConstants)),
        this, SLOT(onReadyStateChange(ReadyStateConstants)));
connect(wmp, SIGNAL(PositionChange(double, double)),
        this, SLOT(onPositionChange(double, double)));
```

After calling `setControl()` in the `PlayerWindow` constructor, we call `setProperty()` to set the `ShowControls` property of the Windows Media Player to `false`, since we provide our own buttons to manipulate the component. The `setProperty()` function is defined in `QObject` and can be used both for COM properties and for normal Qt properties. Its second parameter is of type `QVariant`. Because some C++ compilers don't support the `bool` type properly yet, the `QVariant` constructor that takes a `bool` also has a dummy `int` parameter. For types other than `bool`, the conversion to `QVariant` is automatic.

Next, we call `setSizePolicy()` to make the ActiveX control take all the available space in the layout, and we connect three ActiveX events from the COM component to three slots.

The rest of the `PlayerWindow` constructor follows the usual pattern, except that we connect some Qt signals to slots provided by the COM object (`Play()`, `Pause()`, and `Stop()`).

Let's leave the constructor and look at the `timerEvent()` function:

```
void PlayerWindow::timerEvent(QTimerEvent *event)
{
    if (event->timerId() == updateTimer) {
        double curPos = wmp->property("CurrentPosition").toDouble();
        onPositionChange(-1, curPos);
    } else {
        QWidget::timerEvent(event);
    }
}
```

The timerEvent() function is called at regular intervals while a media clip is playing. We use it to advance the slider. This is done by calling property() on the ActiveX control to obtain the value of the CurrentPosition property as a QVariant and calling toDouble() to convert it to a double. We then call onPositionChange() to perform the update.

We will not review the rest of the code because most of it isn't directly relevant to ActiveX and doesn't show anything that we haven't covered already. The code is included on the CD.

In the .pro file, we need this entry to link with the *QAxContainer* module:

```
LIBS     += -lqaxcontainer
```

One frequent need when dealing with COM objects is to be able to call a COM method directly (as opposed to connecting it to a Qt signal). The easiest way to do this is to call dynamicCall() with the name and signature of the method as first parameter and the arguments to the method as additional parameters. For example:

```
wmp->dynamicCall("TitlePlay(uint)", 6);
```

The dynamicCall() function takes up to eight parameters of type QVariant and returns a QVariant. If we need to pass an IDispatch * or an IUnknown * this way, we can encapsulate the component in a QAxObject and call asVariant() on it to convert it to a QVariant. If we need to call a COM method that returns an IDispatch * or an IUnknown *, or if we need to access a COM property of one of those types, we must use querySubObject() instead:

```
QAxObject *session = outlook.querySubObject("Session");
QAxObject *defaultContacts =
        session->querySubObject("GetDefaultFolder(OlDefaultFolders)",
                                "olFolderContacts");
```

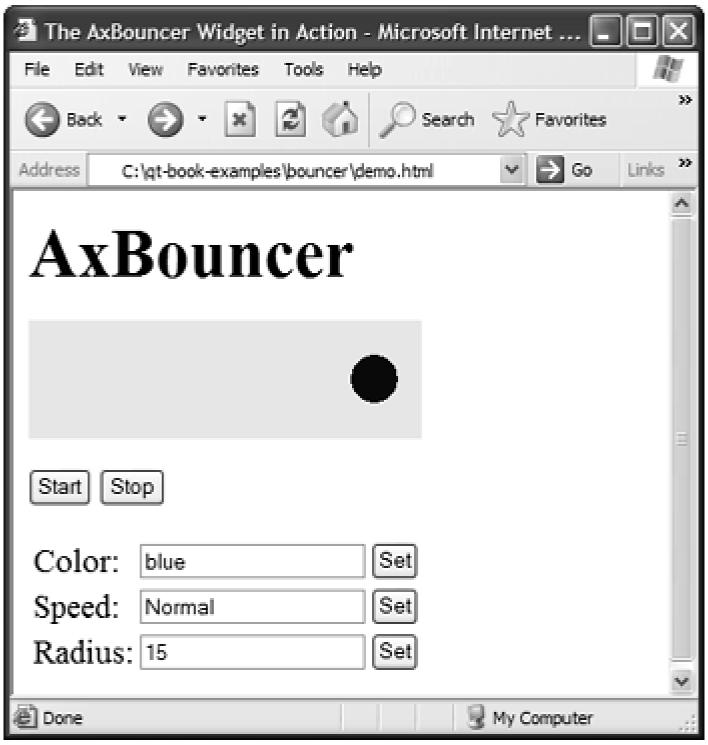
If we want to call functions that have unsupported data types in their parameter list, we can use QAxBase::queryInterface() to retrieve the COM interface and call the function directly. We must call Release() when we have finished using the interface.

If we often need to call such functions, we can subclass QAxObject or QAxWidget and provide member functions that encapsulate the COM interface calls. However, be aware that QAxObject and QAxWidget subclasses cannot define their own properties, signals, and slots.

We will now review the *QAxServer* module. This module enables us to turn a standard Qt program into an ActiveX server. The server can either be a shared library or a stand-alone application. Servers built as shared libraries are often called in-process servers, and stand-alone applications are called out-of-process servers.

Our first *QAxServer* example is an in-process server that provides a widget that shows a ball bouncing left and right. We will also see how to embed the widget in Internet Explorer.

Figure 18.5. The AxBouncer widget in Internet Explorer


The AxBouncer Widget in Action - Microsoft Internet ...
File Edit View Favorites Tools Help
Back
Search
Favorites
Address
C:\qt-book-examples\bouncer\demo.html
Go
Links
AxBouncer
Start
Stop
Color: blue Set
Speed: Normal Set
Radius: 15 Set
Done
My Computer

Here's the beginning of the class definition of the AxBouncer widget:

```
class AxBouncer : public QWidget, public QAxBindable
{
    Q_OBJECT
    Q_ENUMS(Speed)
    Q_PROPERTY(QColor color READ color WRITE setColor)
    Q_PROPERTY(Speed speed READ speed WRITE setSpeed)
    Q_PROPERTY(int radius READ radius WRITE setRadius)
    Q_PROPERTY(bool running READ isRunning)
```

AxBouncer inherits from both QWidget and QAxBindable. The QAxBindable class provides an interface between the widget and an ActiveX client. Any QWidget can be exported as an ActiveX control, but by subclassing QAxBindable we can notify the client when a property's value changes, and we can implement COM interfaces to supplement those already implemented by *QAxServer*.

When doing multiple inheritance involving a QObject-derived class, we must always put the QObject-derived class first so that moc can pick it up.

We declare three read-write properties and one read-only property. The Q_ENUMS() macro is necessary to tell moc that the Speed type is an enum type. The Speed enum is declared in the public section of the class.

```
public:
    enum Speed { Slow, Normal, Fast };

    AxBouncer(QWidget *parent = 0, const char *name = 0);

    void setSpeed(Speed newSpeed);
    Speed speed() const { return ballSpeed; }
    void setRadius(int newRadius);
    int radius() const { return ballRadius; }
    void setColor(const QColor &newColor);
    QColor color() const { return ballColor; }
    bool isRunning() const { return myTimerId != 0; }
    QSize sizeHint() const;
    QAxAggregated *createAggregate();

public slots:
    void start();
    void stop();

signals:
    void bouncing();
```

The AxBouncer constructor is a standard constructor for a widget, with a parent and a name parameter. The QAXFACTORY_DEFAULT() macro, which we will use to export the component, expects a constructor with this signature.

The createAggregate() function is reimplemented from QAxBindable. We will explain it in a moment.

```
protected:
    void paintEvent(QPaintEvent *event);
    void timerEvent(QTimerEvent *event);

private:
    int intervalInMilliseconds() const;

    QColor ballColor;
    Speed ballSpeed;
    int ballRadius;
    int myTimerId;
    int x;
    int delta;
};
```

The protected and private sections of the class are the same as what we would have in a standard Qt widget.

```
AxBouncer::AxBouncer(QWidget *parent, const char *name)
    : QWidget(parent, name, WNoAutoErase)
{
    ballColor = blue;
    ballSpeed = Normal;
    ballRadius = 15;
    myTimerId = 0;
    x = 20;
    delta = 2;
}
```

The AxBouncer constructor initializes the class's private variables.

```
void AxBouncer::setColor(const QColor &newColor)
{
    if (newColor != ballColor && requestPropertyChange("color")) {
        ballColor = newColor;
        update();
        propertyChanged("color");
    }
}
```

The setColor() function sets the value of the color property. It calls update() to repaint the widget.

The unusual part is the requestPropertyChange() and propertyChanged() calls. These functions are inherited from QAxBindable and should ideally be called whenever we change a property. The requestPropertyChange() asks the client's permission to change a property, and returns true if the client allows the change. The propertyChanged() function notifies the client that the property has been changed.

The setSpeed() and setRadius() property setters also follow this pattern, and so do the start() and stop() slots, since they change the value of the running property.

There is one interesting AxBouncer member function left:

```
QAxAggregated *AxBouncer::createAggregate()
{
    return new ObjectSafetyImpl;
}
```

The createAggregate() function is reimplemented from QAxBindable. It allows us to implement COM interfaces that the *QAxServer* module doesn't already implement or to bypass *QAxServer*'s default COM interfaces. Here, we do it to provide the IObjectSafety interface, which is used by Internet Explorer to access a component's safety options. This is the standard trick to get rid of Internet Explorer's infamous "Object not safe for scripting" error message.

Here's the definition of the class that implements the IObjectSafety interface:

```
class ObjectSafetyImpl : public QAxAggregated, public IObjectSafety
{
public:
    long queryInterface(const QUuid &iid, void **iface);

    QAXAGG_IUNKNOWN

    HRESULT WINAPI GetInterfaceSafetyOptions(REFIID riid,
            DWORD *pdwSupportedOptions, DWORD *pdwEnabledOptions);
    HRESULT WINAPI SetInterfaceSafetyOptions(REFIID riid,
            DWORD pdwSupportedOptions, DWORD pdwEnabledOptions);
};
```

The ObjectSafetyImpl class inherits both QAxAggregated and IObjectSafety. The QAxAggregated class is an abstract base class for implementations of additional COM interfaces. The COM object that the QAxAggregated extends is accessible through controllingUnknown(). This COM object is created behind the scenes by the *QAxServer* module.

The QAXAGG_IUNKNOWN macro provides standard implementations of QueryInterface(), AddRef(), and Release(). These implementations simply call the same functions on the controlling COM object.

```
long ObjectSafetyImpl::queryInterface(const QUuid &iid, void **iface)
{
    *iface = 0;
    if (iid == IID_IObjectSafety)
        *iface = (IObjectSafety *)this;
    else
        return E_NOINTERFACE;

    AddRef();
    return S_OK;
}
```

The queryInterface() function is a pure virtual function of QAxAggregated. It is called by the controlling COM object to give access to the interfaces provided by the QAxAggregated subclass. We must return E_NOINTERFACE for interfaces that we don't implement and for IUnknown.

```
HRESULT WINAPI ObjectSafetyImpl::GetInterfaceSafetyOptions(
            REFIID riid, DWORD *pdwSupportedOptions,
            DWORD *pdwEnabledOptions)
{
    *pdwSupportedOptions = INTERFACESAFE_FOR_UNTRUSTED_DATA
                           | INTERFACESAFE_FOR_UNTRUSTED_CALLER;
    *pdwEnabledOptions = *pdwSupportedOptions;
    return S_OK;
}

HRESULT WINAPI ObjectSafetyImpl::SetInterfaceSafetyOptions(REFIID,
            DWORD, DWORD)
{
    return S_OK;
}
```

The GetInterfaceSafetyOptions() and SetInterfaceSafetyOptions() functions are declared in IObjectSafety. We implement them to tell the world that our object is safe for scripting.

Let's now review main.cpp:

```
#include <qaxfactory.h>

#include "axbouncer.h"

QAXFACTORY_DEFAULT(AxBouncer,
                   "{5e2461aa-a3e8-4f7a-8b04-307459a4c08c}",
                   "{533af11f-4899-43de-8b7f-2ddf588d1015}",
                   "{772c14a5-a840-4023-b79d-19549ece0cd9}",
                   "{dbce1e56-70dd-4f74-85e0-95c65d86254d}",
                   "{3f3db5e0-78ff-4e35-8a5d-3d3b96c83e09}")
int main()
{
    return 0;
}
```

The QAXFACTORY_DEFAULT() macro exports an ActiveX control. We can use it for ActiveX servers that export only one control. Otherwise, we must subclass QAxFactory and use a macro called QAXFACTORY_EXPORT(). The next example in this section shows how to do it.

The first argument to QAXFACTORY_DEFAULT() is the name of the Qt class to export. This is also the name under which the control is exported. The other five arguments are the class ID, the interface ID, the event interface ID, the type library ID, and the application ID. We can use standard tools like guidgen or uuidgen to generate these identifiers.

Because the server is a library, we don't need a real main() function. We must still provide a fake implementation to pacify the linker.

Here's the .pro file for our in-process ActiveX server:

```
TEMPLATE         = lib
CONFIG          += activeqt dll
HEADERS          = axbouncer.h \
                   objectsafetyimpl.h
SOURCES          = axbouncer.cpp \
                   main.cpp \
                   objectsafetyimpl.cpp
```

```
RC_FILE           = qaxserver.rc
DEF_FILE          = qaxserver.def
```

The qaxserver.rc and qaxserver.def files referred to in the .pro file are standard files that can be copied from Qt's extensions\activeqt\control directory.

The makefile or Visual C++ project file generated by qmake contains rules to register the server in the Windows registry. To register the server on end user machines, we can use the regsvr32 tool available on all Windows systems.

We can then include the Bouncer component in an HTML page using the <object> tag:

```
<object id="AxBouncer"
        classid="clsid:5e2461aa-a3e8-4f7a-8b04-307459a4c08c">
<b>The ActiveX control is not available. Make sure you have built and
registered the component server.</b>
</object>
```

We can create buttons that invoke slots:

```
<input type="button" value="Start" onClick="AxBouncer.start()">
<input type="button" value="Stop" onClick="AxBouncer.stop()">
```

And we can manipulate the widget using JavaScript or VBScript just like any other ActiveX control. See the demo.html file on the CD for a rudimentary page that uses the ActiveX server.

Our last example is a scriptable Address Book application. The application can serve as a standard Qt/Windows application or an out-of-process ActiveX server. The latter possibility allows us to script the application using, say, Visual Basic.

```
class AddressBook : public QMainWindow
{
    Q_OBJECT
    Q_PROPERTY(int count READ count)
public:
    AddressBook(QWidget *parent = 0, const char *name = 0);
    ~AddressBook() ;

    int count() const;

public slots:
    ABItem *createEntry(const QString &contact) ;
    ABItem *findEntry(const QString &contact) const;
    ABItem *entryAt(int index) const;
    ...
};
```

The AddressBook widget is the application's main window. The property and the slots it provides will be available for scripting.

```
class ABItem : public QObject, public QListViewItem
{
    Q_OBJECT
    Q_PROPERTY(QString contact READ contact WRITE setContact)
    Q_PROPERTY(QString address READ address WRITE setAddress)
    Q_PROPERTY(QString phoneNumber READ phoneNumber
                WRITE setPhoneNumber)
public:
    ABItem(QListView *listView);
    void setContact(const QString &contact);
    QString contact() const { return text (0); }
    void setAddress(const QString &address);
    QString address() const { return text(1); }
    void setPhoneNumber(const QString &number);
    QString phoneNumber() const { return text(2); }
public slots:
    void remove();
};
```

The ABItem class represents one entry in the address book. It inherits from QListViewItem so that it can be shown in a QListView and from QObject so that it can be exported as a COM object.

```
int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    if (!QAxFactory::isServer()) {
        AddressBook addressBook;
        app.setMainWidget(&addressBook);
        addressBook.show();
        return app.exec();
    }
    return app.exec();
}
```

In main(), we check whether the application is being run stand-alone or as a server. The -activex command-line option makes it run as a server. If the application isn't run as a server, we create the main widget and show it as we would normally do in any stand-alone Qt application.

In addition to -activex, ActiveX servers understand the following commandline options:

- -regserver registers the server in the system registry.
- -unregserver unregisters the server from the system registry.
- -dumpidl *file* writes the server's IDL to the specified file.

For the case where the application is run as a server, we need to export the AddressBook and ABItem classes as COM components:

```
QAXFACTORY_EXPORT(ABFactory,
                  "{2b2b6f3e-86cf-4c49-9df5-80483b47f17b}",
                  "{8e827b25-148b-4307-ba7d-23f275244818}")
```

The QAXFACTORY_EXPORT() macro exports a factory for creating COM objects. Since we want to export two types of COM objects, we cannot simply use QAXFACTORY_DEFAULT() as we did in the previous example.

The first argument to QAXFACTORY_EXPORT() is the name of the QAxFactory class that provides the application's COM objects. The other two arguments are the type library ID and the application ID.

```
class ABFactory : public QAxFactory
{
public:
    ABFactory(const QUuid &lib, const QUuid &app);
    QStringList featureList() const;
    QWidget *create(const QString &key, QWidget *parent,
                    const char *name);
    QUuid classID(const QString &key) const;
    QUuid interfaceID(const QString &key) const;
    QUuid eventsID(const QString &key) const;
    QString exposeToSuperClass(const QString &key) const;
};
```

The `ABFactory` class inherits `QAxFactory` and reimplements virtual functions to export the `AddressBook` class as an ActiveX control and the `ABItem` class as a COM component.

```
ABFactory::ABFactory(const QUuid &lib, const QUuid &app)
    : QAxFactory(lib, app)
{
}
```

The `ABFactory` constructor simply forwards its two parameters to the base class constructor.

```
QStringList ABFactory::featureList() const
{
    return QStringList() << "AddressBook" << "ABItem";
}
```

The `featureList()` function returns a list of the COM components provided by the factory.

```
QWidget *ABFactory::create(const QString &key, QWidget *parent,
                           const char *name)
{
    if (key == "AddressBook")
        return new AddressBook(parent, name);
    else
        return 0;
}
```

The `create()` function creates an instance of an ActiveX control. We return a null pointer for `ABItem` because we don't want users to create `ABItem` objects. Furthermore, the return type of `create()` is `QWidget *`, which prevents it from returning COM objects that aren't ActiveX controls.

```
QUuid ABFactory::classID(const QString &key) const
{
    if (key == "AddressBook")
        return QUuid("{588141ef-110d-4beb-95ab-ee6a478b576d}");
    else if (key == "ABItem")
        return QUuid("{bc82730e-5f39-4e5c-96be-461c2cd0d282}");
    else
        return QUuid();
}
```

The `classId()` function returns the class ID for all the classes exported by the factory.

```
QUuid ABFactory::interfaceID(const QString &key) const
{
    if (key == "AddressBook")
        return QUuid("{718780ec-b30c-4d88-83b3-79b3d9e78502}");
    else if (key == "ABItem")
        return QUuid("{c8bc1656-870e-48a9-9937-fbe1ceff8b2e}");
    else
        return QUuid();
}
```

The `interfaceID()` function returns the interface ID for the classes exported by the factory.

```
QUuid ABFactory::eventsID(const QString &key) const
{
    if (key == "AddressBook")
        return QUuid("{0a06546f-9f02-4f14-a269-d6d56ffeb861}");
    else if (key == "ABItem")
        return QUuid("{105c6b0a-3fc7-460b-ae59-746d9d4b1724}");
    else
        return QUuid();
}
```

The `eventsId()` function returns the event interface ID for the classes exported by the factory.

```
QString ABFactory::exposeToSuperClass(const QString &key) const
{
    return key;
}
```

By default, ActiveX controls expose not only their own properties, signals, and slots to clients, but also those of their superclasses up to `QWidget`. We can reimplement the `exposeToSuperClass()` function to return the highest superclass (in the inheritance tree) that we want to expose.

Here, we return the class name of the component("AddressBook" or"ABItem") as the highest superclass to export, meaning that properties, signals, and slots defined in `AddressBook`'s and `ABItem`'s superclasses will not be exported.

This is the `.pro` file for our out-of-process ActiveX server:

```
CONFIG      += activeqt
HEADERS      = abfactory.h \
               abitem.h\
               addressbook.h\
               editdialog.h
SOURCES      = abfactory.cpp\
               abitem.cpp\
               addressbook.cpp\
               editdialog.cpp\
               main.cpp
RC_FILE      = qaxserver.rc
```

The `qaxserver.rc` file referred to in the `.pro` file is a standard file that can be copied from Qt's `extensions\activeqt\control` directory.

Look in the example's `vb` directory for a Visual Basic project that uses the Address Book server.

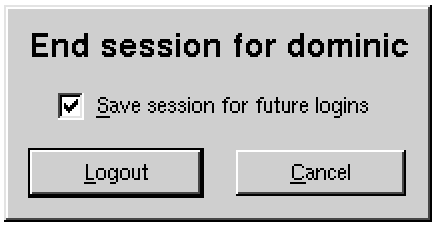
This completes our overview of the ActiveQt framework. The Qt distribution includes additional examples, and the documentation contains information about how to build the *QAxContainer* and *QAxServer* modules and how to solve common interoperability issues.

Session Management

When we log out on X11, some window managers ask us whether we want to save the session. If we say yes, the applications that were running are automatically restarted the next time we log in, with the same screen positions and, ideally, with the same state as they had when we logged out.

The X11-specific component that takes care of saving and restoring the session is called the *session manager*. To make a Qt application aware of the session manager, we must reimplement `QApplication::saveState()` and save the application's state there.

Figure 18.6. Logging out on KDE



End session for dominic

[✓] Save session for future logins

Windows 2000 and XP (and some Unix systems) offer a different mechanism, called hibernation. When the user puts the computer into hibernation, the operating system simply dumps the computer's memory onto disk and reloads it on startup. Applications do not need to do anything or even be aware that this happens.

When the user initiates a shutdown, we can take control just before the shutdown occurs by reimplementing `QApplication::commitData()`. This allows us to save any unsaved data and to interact with the user if required. This works the same way on both X11 and Windows.

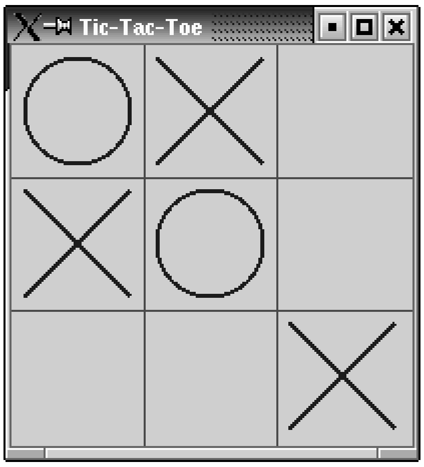
We will explore session management by going through the code of a sessionaware Tic-Tac-Toe application. First, let's look at the `main()` function:

```
int main(int argc, char *argv[])
{
    Application app(argc, argv);
    TicTacToe tic(0, "tic");
    app.setTicTacToe(&tic);
    tic.show();
    return app.exec();
}
```

We create an `Application` object. The `Application` class inherits from `QApplication` and reimplements both `commitData()` and `saveState()` to support session management.

Next, we create a `TicTacToe` widget, make the `Application` object aware of it, and show it. We have called the `TicTacToe` widget "tic". We must give unique names to top-level widgets if we want the session manager to restore the windows' sizes and positions.

Figure 18.7. The Tic-Tac-Toe application



Here's the definition of the Application class:

```
class Application : public QApplication
{
    Q_OBJECT
public:
    Application(int &argc, char *argv[]);

    void setTicTacToe(TicTacToe *tic);
    void commitData(QSessionManager &sessionManager);
    void saveState(QSessionManager &sessionManager);

private:
    TicTacToe *ticTacToe;
};
```

The Application class keeps a pointer to the TicTacToe widget as a private variable.

```
void Application::saveState(QSessionManager &sessionManager)
{
    QString fileName = ticTacToe->saveState();

    QStringList discardCommand;
    discardCommand << "rm" << fileName;
    sessionManager.setDiscardCommand(discardCommand);
}
```

On X11, the saveState() function is called when the session manager wants the application to save its state. The function is available on other platforms as well, but it is never called. The QSessionManager parameter allows us to communicate with the session manager.

We start by asking the TicTacToe widget to save its state to a file. Then we set the session manager's discard command. A *discard command* is a command that the session manager must execute to delete any stored information regarding the current state. For this example, we set it to

```
rm file
```

where *file* is the name of the file that contains the saved state for the session, and rm is the standard Unix command to remove files.

The session manager also has a *restart command*. This is the command that the session manager must execute to restart the application. By default, Qt provides the following restart command:

```
appname -session id_key
```

The first part, *appname*, is derived from argv[0]. The id part is the session ID provided by the session manager; it is guaranteed to be unique among different applications and among different runs of the same application. The *key* part comes in addition to uniquely identify the time at which the state was saved. For various reasons, the session manager can call saveState() multiple times during the same session, and the different states must be distinguished.

Because of limitations in existing session managers, we need to make sure that the application's directory is in the PATH environment variable if we want the application to restart correctly. In particular, if you want to try out the Tic-Tac-Toe example for yourself, you must install it in, say, /usr/bin and invoke it as tictactoe.

For simple applications, including Tic-Tac-Toe, we could save the state as an additional command-line argument to the restart command. For example:

```
tictactoe -state OX-XO-X-O
```

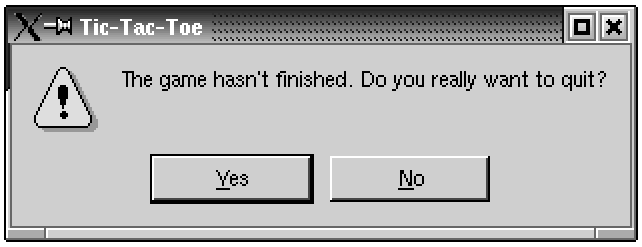
This would save us from storing the data in a file and providing a discard command to remove the file.

```
void Application::commitData(QSessionManager &sessionManager)
{
    if (ticTacToe->gameInProgress()
            && sessionManager.allowsInteraction()) {
        int ret = QMessageBox::warning(ticTacToe, tr("Tic-Tac-Toe"),
                     tr("The game hasn't finished.\n"
                        "Do you really want to quit?"),
                     QMessageBox::Yes | QMessageBox::Default,
                     QMessageBox::No | QMessageBox::Escape);
        if (ret == QMessageBox::Yes)
            sessionManager.release();
        else
            sessionManager.cancel();
    }
}
```

The commitData() function is called when the user logs out. We can reimplement it to pop up a message box warning the user about potential data loss. The default implementation closes all top-level widgets, which results in the same behavior as when the user closes the windows one after another by clicking the *X* button in their title bars. In Chapter 3, we saw how to reimplement closeEvent() to catch this and pop up a message box.

For the purposes of this example, we reimplement commitData() and pop up a message box asking the user to confirm the log out if a game is in progress and if the session manager allows us to interact with the user. If the user clicks *Yes*, we call release() to tell the session manager to continue logging out; if the user clicks *No*, we call cancel() to cancel the log out.

Figure 18.8. "Do you really want to quit?"


Tic-Tac-Toe

The game hasn't finished. Do you really want to quit?

Now let's look at the TicTacToe class:

```
class TicTacToe : public QWidget
{
    Q_OBJECT
public:
    TicTacToe(QWidget *parent = 0, const char *name = 0);

    QSize sizeHint() const;
    bool gameInProgress() const;
    QString saveState() const;

protected:
    void paintEvent(QPaintEvent *event);
    void mousePressEvent(QMouseEvent *event);

private:
    enum { Empty ='-', Cross = 'X', Nought = 'O' };

    void clearBoard();
    void restoreState();
    QString sessionFileName() const;
    QRect cellRect(int row, int col) const;
    int cellWidth() const { return width() / 3;}
    int cellHeight() const { return height() / 3;}

    char board[3][3];
    int turnNumber;
};
```

The TicTacToe class inherits from QWidget and reimplements sizeHint(), paintEvent(), and mousePressEvent(). It also provides the gameInProgress() and saveState() functions that we used in Application.

```
TicTacToe::TicTacToe(QWidget *parent, const char *name)
    : QWidget(parent, name)
{
    setCaption(tr("Tic-Tac-Toe"));
    clearBoard();
    if (qApp->isSessionRestored())
        restoreState();
}
```

In the constructor, we clear the board, and if the application was invoked with the -session option, we call the private function restoreState() to reload the old session.

```
void TicTacToe::clearBoard()
{
    for (int row = 0; row < 3; ++row) {
        for (int col = 0; col < 3; ++col) {
            board[row] [col] = Empty;
        }
    }
    turnNumber = 0;
}
```

In clearBoard(), we clear all the cells and set turnNumber to 0.

```
QString TicTacToe::saveState() const
{
    QFile file(sessionFileName());
    if (file.open(IO_WriteOnly)) {
        QTextStream out(&file);
        for (int row = 0; row < 3; ++row) {
            for (int col = 0; col < 3; ++col) {
                out << board[row] [col];
            }
        }
    }
    return file.name();
}
```

In saveState(), we write the state of the board to disk. The format is straighforward, with 'X'for crosses, 'O' for noughts, and '-' for empty cells.

```
QString TicTacToe::sessionFileName() const
{
    return QDir::homeDirPath() + "/.tictactoe_"
           + qApp->sessionId() +"_" + qApp->sessionKey();
}
```

The sessionFileName() private function returns the file name for the current session ID and session key. This function is used for both saveState() and restoreState(). The file name is derived from the session ID and session key.

```
void TicTacToe::restoreState()
{
    QFile file(sessionFileName());
    if (file.open(IO_ReadOnly)) {
        QTextStream in(&file);
        for (int row = 0; row < 3; ++row) {
            for (int col = 0; col < 3; ++col) {
                in >> board[row][col];
                if (board[row][col] != Empty)
                    ++turnNumber;
            }
        }
    }
    repaint();
}
```

In restoreState(), we load the file that corresponds to the restored session and fill the board with that information. We deduce the value of turnNumber from the number of *X*'s and *O*'s the board.

In the TicTacToe constructor, we called restoreState() if QApplication::isSessionRestored() returned true. In that case, sessionId() and sessionKey() return the same values as when the application's state was saved, and so sessionFileName() returns the file name for that session.

Testing and debugging session management can be frustrating, because we need to log in and out all the time. One way to avoid this is to use the standard xsm utility provided with X11. The first time we invoke xsm, it pops up a session manager window and a terminal. The applications we start from that terminal will all use xsm as their session manager instead of the usual, system-wide session manager. We can then use xsm's window to end, restart, or discard a session, and see if our application behaves as it should. For details about how to do this, see http://doc.trolltech.com/3.2/session.html.

Appendix A. Installing Qt

This appendix explains how to install Qt from the CD onto your system. The CD has editions of Qt 3.2.1 for Windows, Mac OS X, and X11 (for Linux and most versions of Unix). They all include SQLite, a public domain in-process database, together with an experimental driver. The editions of Qt on the CD are provided for your convenience. For serious software development, it is best to download the latest version of Qt from http://www.trolltech.com/download/ or to buy a commercial version.

Trolltech also provides Qt/Embedded for building applications for Linuxbased embedded devices such as PDAs and mobile phones. If you are interested in creating embedded applications, you can obtain Qt/Embedded from Trolltech's download web page.

The example applications used in the book are on the CD in the `examples` directory. In addition, Qt provides many small example applications located in the `examples`, `tools\designer\examples`, and `extensions\activeqt\examples` subdirectories.

A Note on Licensing

Qt is produced in three forms: free, non-commercial, and commercial. The free and non-commercial editions are available free of charge; the commercial editions must be paid for.

The software on the CD is suitable for creating applications for your own educational and personal use.

If you want to distribute the applications that you create with a free or non-commercial edition of Qt, you must comply with the specific terms and conditions laid down in the licenses for the software you use to create the applications. For free editions, the terms and conditions include the requirement to use an open license—for example, the GNU General Public License (GPL). Open licenses like the GPL give the applications' users certain rights, including the right to view and modify the source and to distribute the applications (on the same terms).The non-commercial license has similar provisions. If you want to distribute your applications without source code (to keep your code private) or if you want to apply your own commercial license conditions to your applications, you must buy commercial editions of the software you use to create the applications. The commercial editions of the software allow you to sell and distribute your applications on your own terms.

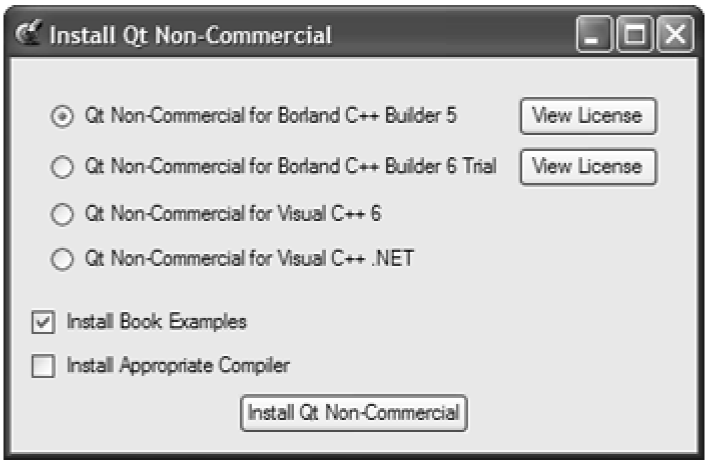
The CD contains a non-commercial version of Qt/Windows, a free edition of Qt/Mac, and a free edition of Qt/X11. It also contains some other non-commercial software, including Borland C++ Builder 5 and a trial version of Borland C++ Builder 6. Each product on the CD has its own specific license conditions; for example, the non-commercial Qt/Windows edition may not be redistributed, and its license isn't compatible with the GPL. The full legal texts of the licenses are included with the packages on the CD, along with information on how to obtain commercial versions.

[Team LiB]

Installing Qt/Windows

When you insert the CD on a Windows machine, a setup program should start automatically. If this doesn't occur, run `setup.exe` located in the CD's root directory.

Figure A.1. Qt/Windows Non-Commercial installer


Install Qt Non-Commercial
Qt Non-Commercial for Borland C++ Builder 5
Qt Non-Commercial for Borland C++ Builder 6 Trial
Qt Non-Commercial for Visual C++ 6
Qt Non-Commercial for Visual C++ .NET
View License
View License
Install Book Examples
Install Appropriate Compiler
Install Qt Non-Commercial

The setup program will ask you which compiler you want to use for Qt development. If you have chosen a Borland compiler, check the *Install Appropriate Compiler* option if you also want to install the compiler. If you check the *Install Book Examples* option, the example applications shown in this book will be installed in `C:\Qt\3.2.1\book` (assuming `C:\Qt\3.2.1` is the location where you installed Qt).

If you choose to install a Borland compiler, note that there may be a delay between the completion of the Borland installation and the start of the Qt installation.

In the Qt installer, check the Set QTDIR option. If you are using Microsoft Visual C++, you must specify Visual Studio's path so that Qt can integrate itself with the development environment.

If you are installing on a Windows 95, 98, or ME system, the compilation step is skipped due to technical limitations in the operating system. The setup program writes the steps needed to build Qt into a batch file and puts a shortcut to the batch file in the Start menu. To build Qt, simply click this shortcut.

Some Windows versions may require a reboot to set the environment variables. If you installed Borland C++ Builder 5, you must update your `PATH` environment variable to include the Borland executable directory (for example, `C:\Borland\Bcc55\bin`). You must also create two configuration files in the Borland executable directory. The first file must be called `bcc32.cfg` and contain the lines

```
-I"C:\Borland\Bcc55\include"
-L"C:\Borland\Bcc55\lib"
```

The second file must be called `ilink32.cfg` and contain the line

```
-L"C:\Borland\Bcc55\lib"
```

If you installed the Borland compiler in a non-default location, you must replace `C:\Borland\Bcc55` with the appropriate path.

[Team LiB]

Installing Qt/Mac

The Mac OS X installation is done from a terminal. To launch a terminal, look in `Applications/Utilities` with Finder.

If your system does not have a C++ compiler installed, you must install one yourself before installing Qt. An easy option is to install GCC from Apple's Developer Tools CD.

1. Unpack the archive file from the CD:

    ```
    cd /Developer
    tar zxf /Volumes/Qt\ 3\ Programming/mac/qt-mac-free-3.2.1.tar.gz
    ```

    The archive is unpacked into `/Developer/qt-mac-free-3.2.1`.

2. Create a symlink from this directory to `/Developer/qt:`

    ```
    ln -sf qt-mac-free-3.2.1 qt
    ```

3. Set up certain environment variables for Qt.

    The variables are set differently depending on which shell you are using. For example, if your user name is `kelly`, you can find out which shell you are using with the `finger` command:

    ```
    finger kelly
    ```

    If your shell is `bash`, `ksh`, `zsh`, or `sh`, add the following lines to the `.profile` file in your home directory:

    ```
    QTDIR=/Developer/qt
    PATH=$QTDIR/bin:$PATH
    MANPATH=$QTDIR/doc/man:$MANPATH
    DYLD_LIBRARY_PATH=$QTDIR/lib:$DYLD_LIBRARY_PATH
    export QTDIR PATH MANPATH DYLD_LIBRARY_PATH
    ```

    If your shell is `csh` or `tcsh`, add the following lines to your `.login` file:

    ```
    setenv QTDIR /Developer/qt
    setenv PATH $QTDIR/bin:$PATH
    setenv MANPATH $QTDIR/doc/man:$MANPATH
    setenv DYLD_LIBRARY_PATH $QTDIR/lib:$DYLD_LIBRARY_PATH
    ```

    If you encounter "undefined variable" problems, change the last two lines above to these:

    ```
    setenv MANPATH $QTDIR/doc/man
    setenv DYLD_LIBRARY_PATH $QTDIR/lib
    ```

    After you have done this, the settings must be activated. The easiest way to do this is to close the terminal window and then open a new terminal window.

4. Execute the `configure` tool in the new terminal with your preferred options to build the Qt library and the tools supplied with it:

   ```
   cd $QTDIR
   ./configure
   ```

   You can run `./configure -help` to get a list of configuration options. For example, you can use the `-thread` option to create a threaded version of the library.

5. Type `make`.

6. Make your applications launchable from Finder.

   If you built Qt using the `-static` option, your executables will contain the Qt library and can be run from Finder automatically. Otherwise, your executables will need to use the Qt library on your system. This is achieved by creating two symlinks:

   ```
   ln -sf $QTDIR/lib/libqt.3.dylib /usr/lib
   ln -sf $QTDIR/lib/libqui.1.dylib /usr/lib
   ```

   If you built a multithreaded version of Qt, replace `libqt.3.dylib` with `libqt-mt.3.dylib` in the first `ln` command above.

   Creating these links may require administrator access; if this is the case, run the commands preceded by `sudo`:

   ```
   sudo ln -sf $QTDIR/lib/libqt.3.dylib /usr/lib
   sudo ln -sf $QTDIR/lib/libqui.1.dylib /usr/lib
   ```

   If you don't have administrator access or just want to install Qt locally, use these links instead:

   ```
   ln -sf $QTDIR/lib/libqt.3.dylib $HOME/lib
   ln -sf $QTDIR/lib/libqui.1.dylib $HOME/lib
   ```

   As mentioned above, if you built a multithreaded version of Qt, replace `libqt.3.dylib` with `libqt-mt.3.dylib`.

If you want to customize how you install Qt or if you encounter problems with installing Qt, refer to the `INSTALL` file in `$QTDIR` for more information.

Installing Qt/X11

To install Qt on X11, you may need to be root, depending on the permissions of the directory where you choose to install Qt.

1. Change directory to where you want to install Qt. For example:

   ```
   cd /usr/local
   ```

2. Unpack the archive file from the CD:

```
cp /cdrom/x11/qt-x11-free3.2.1.tar.gz.
gunzip qt-x11-free-3.2.1.tar.gz
tar xf qt-x11-free-3.2.1.tar
```

   This will create the directory `qt-x11-free-3.2.1`, assuming that your CD-ROM is mounted at `/cdrom`.

3. Set up certain environment variables for Qt.

   The variables are set differently depending on which shell you are using. For example, if your user name is `gregory`, you can find out which shell you are using with the `finger` command:

```
finger gregory
```

   If your shell is `bash, ksh, zsh`, or `sh`, add the following lines to the `.profile` file in your home directory:

```
QTDIR=/usr/local/qt-x11-free-3.2.1
PATH=$QTDIR/bin:$PATH
MANPATH=$QTDIR/doc/man:$MANPATH
LD_LIBRARY_PATH=$QTDIR/lib:$LD_LIBRARY_PATH
export QTDIR PATH MANPATH LD_LIBRARY_PATH
```

   If your shell is `csh` or `tcsh`, add the following lines to your `.login` file:

```
setenv QTDIR /usr/local/qt-x11-free-3.2.1
setenv PATH $QTDIR/bin:$PATH
setenv MANPATH $QTDIR/doc/man:$MANPATH
setenv LD_LIBRARY_PATH $QTDIR/lib:$LD_LIBRARY_PATH
```

   If you encounter "undefined variable" problems, change the last two lines above to these:

```
setenv MANPATH $QTDIR/doc/man
setenv LD_LIBRARY_PATH $QTDIR/lib
```

   Irrespective of which shell you use, if you install Qt on AIX, replace all occurrences of `LD_LIBRARY_PATH` with `LIBPATH`. And if you install Qt on HP-UX, replace `LD_LIBRARY_PATH` with `SHLIB_PATH`.

   After you have done this, you must either login again or re-source the `.profile` or `.login` file before continuing.

4. Execute the `configure` tool with your preferred options to build the Qt library and the tools supplied with it:

```
cd $QTDIR
./configure
```

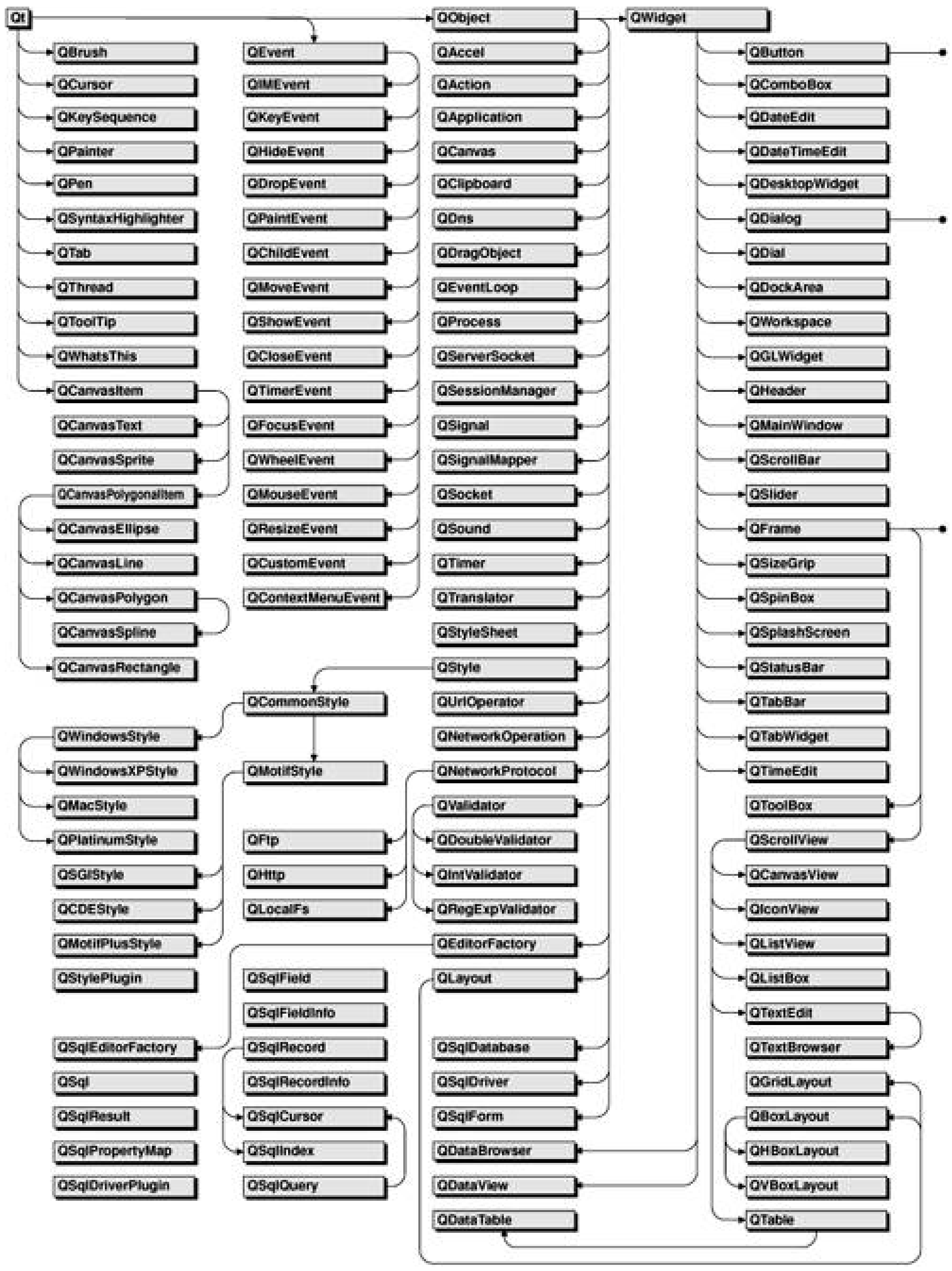
   You can run `./configure -help` to get a list of configuration options. For example, you can use the `-thread` option to create a threaded version of the library.

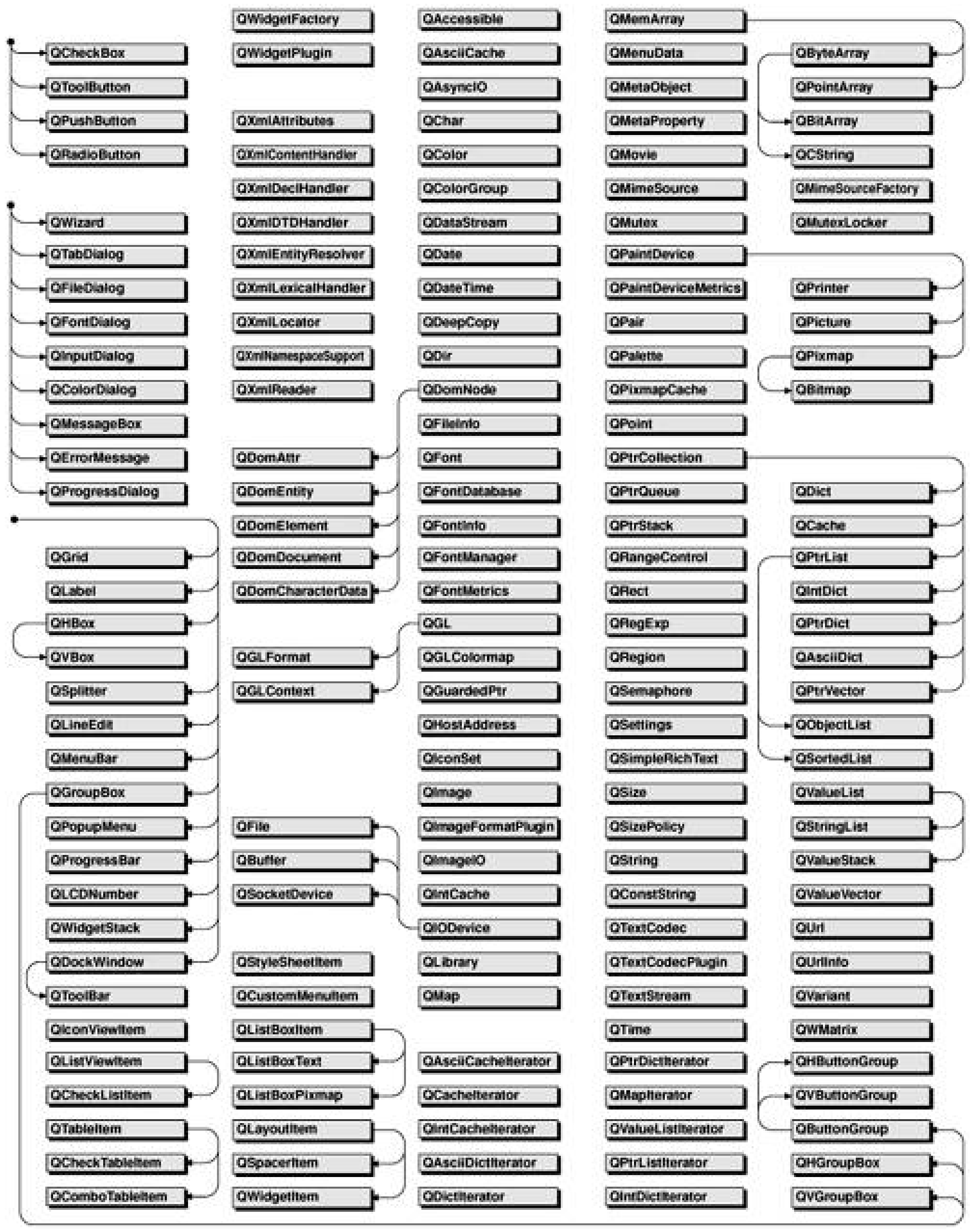
5. Type `make`.

If you want to customize how you install Qt or if you encounter problems with installing Qt, refer to the `INSTALL` file in `$QTDIR` for more information.

Appendix B. Qt's Class Hierarchy

Qt 3.2 provides more than 400 public classes. The class hierarchy depicted on the following pages presents the majority of them, but omits those that are more specialized and those that are infrequently used.





[Team LiB]

PREVIOUS