Chapter 7
Object-Oriented Design

Java Software Solutions

Foundations of Program Design

9th Edition

John Lewis
William Loftus

PEARSON

Object-Oriented Design

- Now we can extend our discussion of the design of classes and objects
- Chapter 7 focuses on:
  - software development activities
  - determining the classes and objects that are needed for a program
  - the relationships that can exist among classes
  - the static modifier
  - writing interfaces
  - the design of enumerated type classes
  - method design and method overloading

Outline

→ **Software Development Activities**

Identifying Classes and Objects

Static Variables and Methods

Class Relationships

Interfaces

Enumerated Types Revisited

Method Design

Testing

Program Development

- The creation of software involves four basic activities:
  - establishing the requirements
  - creating a design
  - implementing the code
  - testing the implementation
- These activities are not strictly linear – they overlap and interact

Requirements

- *Software requirements* specify the tasks that a program must accomplish
  - what to do, not how to do it
- Often an initial set of requirements is provided, but they should be critiqued and expanded
- It is difficult to establish detailed, unambiguous, and complete requirements
- Careful attention to the requirements can save significant time and expense in the overall project

Design

- A *software design* specifies how a program will accomplish its requirements
- A software design specifies how the solution can be broken down into manageable pieces and what each piece will do
- An object-oriented design determines which classes and objects are needed, and specifies how they will interact
- Low level design details include how individual methods will accomplish their tasks

Implementation

- *Implementation* is the process of translating a design into source code
- Novice programmers often think that writing code is the heart of software development, but actually it should be the least creative step
- Almost all important decisions are made during requirements and design stages
- Implementation should focus on coding details, including style guidelines and documentation

Testing

- *Testing* attempts to ensure that the program will solve the intended problem under all the constraints specified in the requirements
- A program should be thoroughly tested with the goal of finding errors
- *Debugging* is the process of determining the cause of a problem and fixing it
- We revisit the details of the testing process later in this chapter

Outline

Identifying Classes and Objects

- The core activity of object-oriented design is determining the classes and objects that will make up the solution
- The classes may be part of a class library, reused from a previous project, or newly written
- One way to identify potential classes is to identify the objects discussed in the requirements
- Objects are generally nouns, and the services that an object provides are generally verbs

Identifying Classes and Objects

- A partial requirements document:

> The user must be allowed to specify each product by its primary characteristics, including its name and product number. If the bar code does not match the product, then an error should be generated to the message window and entered into the error log. The summary report of all transactions must be structured as specified in section 7.A.

- Of course, not all nouns will correspond to a class or object in the final solution

Identifying Classes and Objects

- Remember that a class represents a group (classification) of objects with the same behaviors
- Generally, classes that represent objects should be given names that are singular nouns
- Examples: `Coin`, `Student`, `Message`
- A class represents the concept of one such object
- We are free to instantiate as many of each object as needed

Identifying Classes and Objects

- Sometimes it is challenging to decide whether something should be represented as a class
- For example, should an employee's address be represented as a set of instance variables or as an `Address` object
- The more you examine the problem and its details the more clear these issues become
- When a class becomes too complex, it often should be decomposed into multiple smaller classes to distribute the responsibilities

Identifying Classes and Objects

- We want to define classes with the proper amount of detail
- For example, it may be unnecessary to create separate classes for each type of appliance in a house
- It may be sufficient to define a more general `Appliance` class with appropriate instance data
- It all depends on the details of the problem being solved

Identifying Classes and Objects

- Part of identifying the classes we need is the process of *assigning responsibilities* to each class
- Every activity that a program must accomplish must be represented by one or more methods in one or more classes
- We generally use verbs for the names of methods
- In early stages it is not necessary to determine every method of every class – begin with primary responsibilities and evolve the design

Outline

Static Class Members

- Recall that a static method is one that can be invoked through its class name
- For example, the methods of the `Math` class are static:

```
result = Math.sqrt(25)
```

- Variables can be static as well
- Determining if a method or variable should be static is an important design decision

The static Modifier

- We declare static methods and variables using the `static` modifier
- It associates the method or variable with the class rather than with an object of that class
- Static methods are sometimes called *class methods* and static variables are sometimes called *class variables*
- Let's carefully consider the implications of each

Static Variables

- Normally, each object has its own data space, but if a variable is declared as static, only one copy of the variable exists

```
private static float price;
```

- Memory space for a static variable is created when the class is first referenced
- All objects instantiated from the class share its static variables
- Changing the value of a static variable in one object changes it for all others

Static Methods

```
public class Helper
{
   public static int cube(int num)
   {
      return num * num * num;
   }
}
```

- Because it is declared as static, the `cube` method can be invoked through the class name:

```
value = Helper.cube(4);
```


Static Class Members

- The order of the modifiers can be interchanged, but by convention visibility modifiers come first
- Recall that the `main` method is static – it is invoked by the Java interpreter without creating an object
- Static methods cannot reference instance variables because instance variables don't exist until an object exists
- However, a static method can reference static variables or local variables

Static Class Members

- Static methods and static variables often work together
- The following example keeps track of how many `Slogan` objects have been created using a static variable, and makes that information available using a static method
- See `SloganCounter.java`
- See `Slogan.java`


```
//********************************************************************
//  SloganCounter.java       Author: Lewis/Loftus
//
//  Demonstrates the use of the static modifier.
//********************************************************************

public class SloganCounter
{
   //-----------------------------------------------------------------
   //  Creates several Slogan objects and prints the number of
   //  objects that were created.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Slogan obj;

      obj = new Slogan("Remember the Alamo.");
      System.out.println(obj);

      obj = new Slogan("Don't Worry. Be Happy.");
      System.out.println(obj);
```

continue

continue

```
      obj = new Slogan("Live Free or Die.");
      System.out.println(obj);

      obj = new Slogan("Talk is Cheap.");
      System.out.println(obj);

      obj = new Slogan("Write Once, Run Anywhere.");
      System.out.println(obj);

      System.out.println();
      System.out.println("Slogans created: " + Slogan.getCount());
   }
}
```

continue

```
      obj = new Slc
      System.out.pr

      obj = new Slc
      System.out.pr

      obj = new Slc                                    );
      System.out.pr

      System.out.println();
      System.out.println("Slogans created: " + Slogan.getCount());
   }
}
```

Output

```
Remember the Alamo.
Don't Worry. Be Happy.
Live Free or Die.
Talk is Cheap.
Write Once, Run Anywhere.

Slogans created: 5
```



```
//********************************************************************
//  Slogan.java       Author: Lewis/Loftus
//
//  Represents a single slogan string.
//********************************************************************

public class Slogan
{
   private String phrase;
   private static int count = 0;

   //-----------------------------------------------------------------
   //  Constructor: Sets up the slogan and counts the number of
   //  instances created.
   //-----------------------------------------------------------------
   public Slogan(String str)
   {
      phrase = str;
      count++;
   }
```

continue

continue

```
   //-----------------------------------------------------------------
   //  Returns this slogan as a string.
   //-----------------------------------------------------------------
   public String toString()
   {
      return phrase;
   }

   //-----------------------------------------------------------------
   //  Returns the number of instances of this class that have been
   //  created.
   //-----------------------------------------------------------------
   public static int getCount()
   {
      return count;
   }
}
```

Quick Check

Why can't a static method reference an instance variable?

Because instance data is created only when an object is created.

You don't need an object to execute a static method.

And even if you had an object, which object's instance data would be referenced? (remember, the method is invoked through the class name)

Outline

Class Relationships

- Classes in a software system can have various types of relationships to each other
- Three of the most common relationships:
  - Dependency: A *uses* B
  - Aggregation: A *has-a* B
  - Inheritance: A *is-a* B
- Let's discuss dependency and aggregation further
- Inheritance is discussed in detail in Chapter 9

Dependency

- A *dependency* exists when one class relies on another in some way, usually by invoking the methods of the other
- We've seen dependencies in many previous examples
- We don't want numerous or complex dependencies among classes
- Nor do we want complex classes that don't depend on others
- A good design strikes the right balance

Dependency

- Some dependencies occur between objects of the same class
- A method of the class may accept an object of the same class as a parameter
- For example, the `concat` method of the `String` class takes as a parameter another `String` object

```
str3 = str1.concat(str2);
```


Dependency

- The following example defines a class called `RationalNumber`
- A rational number is a value that can be represented as the ratio of two integers
- Several methods of the `RationalNumber` class accept another `RationalNumber` object as a parameter
- See `RationalTester.java`
- See `RationalNumber.java`

```java
//********************************************************************
//  RationalTester.java       Author: Lewis/Loftus
//
//  Driver to exercise the use of multiple Rational objects.
//********************************************************************

public class RationalTester
{
   //-----------------------------------------------------------------
   //  Creates some rational number objects and performs various
   //  operations on them.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      RationalNumber r1 = new RationalNumber(6, 8);
      RationalNumber r2 = new RationalNumber(1, 3);
      RationalNumber r3, r4, r5, r6, r7;

      System.out.println("First rational number: " + r1);
      System.out.println("Second rational number: " + r2);
```

continue

continue

```java
      if (r1.isLike(r2))
         System.out.println("r1 and r2 are equal.");
      else
         System.out.println("r1 and r2 are NOT equal.");

      r3 = r1.reciprocal();
      System.out.println("The reciprocal of r1 is: " + r3);

      r4 = r1.add(r2);
      r5 = r1.subtract(r2);
      r6 = r1.multiply(r2);
      r7 = r1.divide(r2);

      System.out.println("r1 + r2: " + r4);
      System.out.println("r1 - r2: " + r5);
      System.out.println("r1 * r2: " + r6);
      System.out.println("r1 / r2: " + r7);
   }
}
```


continue

```java
      if (r1.isLike
         System.out
      else
         System.out                              ");

      r3 = r1.recip
      System.out.pr                              r3);

      r4 = r1.add(r
      r5 = r1.subtr
      r6 = r1.multiply(r2);
      r7 = r1.divide(r2);

      System.out.println("r1 + r2: " + r4);
      System.out.println("r1 - r2: " + r5);
      System.out.println("r1 * r2: " + r6);
      System.out.println("r1 / r2: " + r7);
   }
}
```

Output

```
First rational number: 3/4
Second rational number: 1/3
r1 and r2 are NOT equal.
The reciprocal of r1 is: 4/3
r1 + r2: 13/12
r1 - r2: 5/12
r1 * r2: 1/4
r1 / r2: 9/4
```

```
//********************************************************************
//  RationalNumber.java       Author: Lewis/Loftus
//
//  Represents one rational number with a numerator and denominator.
//********************************************************************

public class RationalNumber
{
   private int numerator, denominator;

   //-----------------------------------------------------------------
   //  Constructor: Sets up the rational number by ensuring a nonzero
   //  denominator and making only the numerator signed.
   //-----------------------------------------------------------------
   public RationalNumber(int numer, int denom)
   {
      if (denom == 0)
         denom = 1;

      // Make the numerator "store" the sign
      if (denom < 0)
      {
         numer = numer * -1;
         denom = denom * -1;
      }
```

continue

continue

```
      numerator = numer;
      denominator = denom;

      reduce();
   }

   //-----------------------------------------------------------------
   //  Returns the numerator of this rational number.
   //-----------------------------------------------------------------
   public int getNumerator()
   {
      return numerator;
   }

   //-----------------------------------------------------------------
   //  Returns the denominator of this rational number.
   //-----------------------------------------------------------------
   public int getDenominator()
   {
      return denominator;
   }
```

continue

continue

```
   //-----------------------------------------------------------------
   //  Returns the reciprocal of this rational number.
   //-----------------------------------------------------------------
   public RationalNumber reciprocal()
   {
      return new RationalNumber(denominator, numerator);
   }

   //-----------------------------------------------------------------
   //  Adds this rational number to the one passed as a parameter.
   //  A common denominator is found by multiplying the individual
   //  denominators.
   //-----------------------------------------------------------------
   public RationalNumber add(RationalNumber op2)
   {
      int commonDenominator = denominator * op2.getDenominator();
      int numerator1 = numerator * op2.getDenominator();
      int numerator2 = op2.getNumerator() * denominator;
      int sum = numerator1 + numerator2;

      return new RationalNumber(sum, commonDenominator);
   }
```

continue

continue

```
//-----------------------------------------------------------------
//  Subtracts the rational number passed as a parameter from this
//  rational number.
//-----------------------------------------------------------------
public RationalNumber subtract(RationalNumber op2)
{
   int commonDenominator = denominator * op2.getDenominator();
   int numerator1 = numerator * op2.getDenominator();
   int numerator2 = op2.getNumerator() * denominator;
   int difference = numerator1 - numerator2;

   return new RationalNumber(difference, commonDenominator);
}

//-----------------------------------------------------------------
//  Multiplies this rational number by the one passed as a
//  parameter.
//-----------------------------------------------------------------
public RationalNumber multiply(RationalNumber op2)
{
   int numer = numerator * op2.getNumerator();
   int denom = denominator * op2.getDenominator();

   return new RationalNumber(numer, denom);
}
```

continue

continue

```
//-----------------------------------------------------------------
//  Divides this rational number by the one passed as a parameter
//  by multiplying by the reciprocal of the second rational.
//-----------------------------------------------------------------
public RationalNumber divide(RationalNumber op2)
{
   return multiply(op2.reciprocal());
}

//-----------------------------------------------------------------
//  Determines if this rational number is equal to the one passed
//  as a parameter. Assumes they are both reduced.
//-----------------------------------------------------------------
public boolean isLike(RationalNumber op2)
{
   return ( numerator == op2.getNumerator() &&
            denominator == op2.getDenominator() );
}
```

continue

continue

```
//-----------------------------------------------------------------
//  Returns this rational number as a string.
//-----------------------------------------------------------------
public String toString()
{
   String result;
   if (numerator == 0)
      result = "0";
   else
      if (denominator == 1)
         result = numerator + "";
      else
         result = numerator + "/" + denominator;
   return result;
}
```

continue

continue

```
//-----------------------------------------------------------------
//  Reduces this rational number by dividing both the numerator
//  and the denominator by their greatest common divisor.
//-----------------------------------------------------------------
private void reduce()
{
   if (numerator != 0)
   {
      int common = gcd(Math.abs(numerator), denominator);

      numerator = numerator / common;
      denominator = denominator / common;
   }
}
```

continue

continue

```
   //-----------------------------------------------------------------
   //  Computes and returns the greatest common divisor of the two
   //  positive parameters. Uses Euclid's algorithm.
   //-----------------------------------------------------------------
   private int gcd(int num1, int num2)
   {
      while (num1 != num2)
         if (num1 > num2)
            num1 = num1 - num2;
         else
            num2 = num2 - num1;

      return num1;
   }
}
```


Aggregation

- An *aggregate* is an object that is made up of other objects
- Therefore aggregation is a *has-a* relationship
  - A car *has a* chassis
- An aggregate object contains references to other objects as instance data
- This is a special kind of dependency; the aggregate relies on the objects that compose it

Aggregation

- In the following example, a `Student` object is composed, in part, of `Address` objects
- A student has an address (in fact each student has two addresses)
- See `StudentBody.java`
- See `Student.java`
- See `Address.java`


```java
//********************************************************************
//  StudentBody.java       Author: Lewis/Loftus
//
//  Demonstrates the use of an aggregate class.
//********************************************************************

public class StudentBody
{
   //-----------------------------------------------------------------
   //  Creates some Address and Student objects and prints them.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Address school = new Address("800 Lancaster Ave.", "Villanova",
                              "PA", 19085);
      Address jHome = new Address("21 Jump Street", "Lynchburg",
                             "VA", 24551);
      Student john = new Student("John", "Smith", jHome, school);

      Address mHome = new Address("123 Main Street", "Euclid", "OH",
                             44132);
      Student marsha = new Student("Marsha", "Jones", mHome, school);

      System.out.println(john);
      System.out.println();
      System.out.println(marsha);
   }
}
```



```java
//********************                          **********************
//  StudentBody.java
//
//  Demonstrates the
//********************                          **********************

public class StudentB
{
   //-----------------                          ----------------------
   //  Creates some A                           and prints them.
   //-----------------                          ----------------------
   public static void
   {
      Address school                            er Ave.", "Villanova",
                                                ;
      Address jHome =                           et", "Lynchburg",

      Student john =                            ", jHome, school);

      Address mHome =                           eet", "Euclid", "OH",
                             44132);
      Student marsha = new Student("Marsha", "Jones", mHome, school);

      System.out.println(john);
      System.out.println();
      System.out.println(marsha);
   }
}
```


Output

```
John Smith
Home Address:
21 Jump Street
Lynchburg, VA  24551
School Address:
800 Lancaster Ave.
Villanova, PA  19085

Marsha Jones
Home Address:
123 Main Street
Euclid, OH  44132
School Address:
800 Lancaster Ave.
Villanova, PA  19085
```

```java
//********************************************************************
//  Student.java       Author: Lewis/Loftus
//
//  Represents a college student.
//********************************************************************

public class Student
{
   private String firstName, lastName;
   private Address homeAddress, schoolAddress;

   //-----------------------------------------------------------------
   //  Constructor: Sets up this student with the specified values.
   //-----------------------------------------------------------------
   public Student(String first, String last, Address home,
                  Address school)
   {
      firstName = first;
      lastName = last;
      homeAddress = home;
      schoolAddress = school;
   }
```

continue

continue

```java
   //-----------------------------------------------------------------
   //  Returns a string description of this Student object.
   //-----------------------------------------------------------------
   public String toString()
   {
      String result;

      result = firstName + " " + lastName + "\n";
      result += "Home Address:\n" + homeAddress + "\n";
      result += "School Address:\n" + schoolAddress;

      return result;
   }
}
```



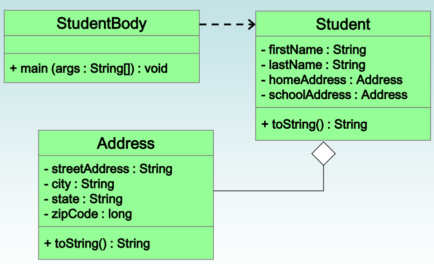
```java
//********************************************************************
//  Address.java       Author: Lewis/Loftus
//
//  Represents a street address.
//********************************************************************

public class Address
{
   private String streetAddress, city, state;
   private long zipCode;

   //-----------------------------------------------------------------
   //  Constructor: Sets up this address with the specified data.
   //-----------------------------------------------------------------
   public Address(String street, String town, String st, long zip)
   {
      streetAddress = street;
      city = town;
      state = st;
      zipCode = zip;
   }
```

continue

continue

```
   //-----------------------------------------------------------------
   //  Returns a description of this Address object.
   //-----------------------------------------------------------------
   public String toString()
   {
      String result;

      result = streetAddress + "\n";
      result += city + ", " + state + "  " + zipCode;

      return result;
   }
}
```


Aggregation in UML



The this Reference

- The `this` reference allows an object to refer to itself
- That is, the `this` reference, used inside a method, refers to the object through which the method is being executed
- Suppose the `this` reference is used inside a method called `tryMe`, which is invoked as follows:

```
obj1.tryMe();
obj2.tryMe();
```

- In the first invocation, the `this` reference refers to `obj1`; in the second it refers to `obj2`

The this reference

- The `this` reference can be used to distinguish the instance variables of a class from corresponding method parameters with the same names
- The constructor of the `Account` class from Chapter 4 could have been written as follows:

```
public Account(String name, long acctNumber,
               double balance)
{
   this.name = name;
   this.acctNumber = acctNumber;
   this.balance = balance;
}
```


Outline

Interfaces

- A Java *interface* is a collection of abstract methods and constants
- An *abstract method* is a method header without a method body
- An abstract method can be declared using the modifier `abstract`, but because all methods in an interface are abstract, usually it is left off
- An interface is used to establish a set of methods that a class will implement

Interfaces

None of the methods in an interface are given a definition (body)

`interface` is a reserved word

```
public interface Doable
{
   public void doThis();
   public int doThat();
   public void doThis2(double value, char ch);
   public boolean doTheOther(int num);
}
```

A semicolon immediately follows each method header

Interfaces

- An interface cannot be instantiated
- Methods in an interface have public visibility by default
- A class formally implements an interface by:
  - stating so in the class header
  - providing implementations for every abstract method in the interface
- If a class declares that it implements an interface, it must define all methods in the interface

Interfaces

`implements` is a reserved word

```
public class CanDo implements Doable
{
   public void doThis()
   {
      // whatever
   }

   public void doThat()
   {
      // whatever
   }

   // etc.
}
```

Each method listed in `Doable` is given a definition

Interfaces

- In addition to (or instead of) abstract methods, an interface can contain constants
- When a class implements an interface, it gains access to all its constants
- A class that implements an interface can implement other methods as well
- See `Complexity.java`
- See `Question.java`
- See `MiniQuiz.java`


```
//********************************************************************
//  Complexity.java       Author: Lewis/Loftus
//
//  Represents the interface for an object that can be assigned an
//  explicit complexity.
//********************************************************************

public interface Complexity
{
   public void setComplexity(int complexity);
   public int getComplexity();
}
```



```
//********************************************************************
//  Question.java       Author: Lewis/Loftus
//
//  Represents a question (and its answer).
//********************************************************************

public class Question implements Complexity
{
   private String question, answer;
   private int complexityLevel;

   //-----------------------------------------------------------------
   //  Constructor: Sets up the question with a default complexity.
   //-----------------------------------------------------------------
   public Question(String query, String result)
   {
      question = query;
      answer = result;
      complexityLevel = 1;
   }
```

continue

continue

```java
   //-----------------------------------------------------------------
   //  Sets the complexity level for this question.
   //-----------------------------------------------------------------
   public void setComplexity(int level)
   {
      complexityLevel = level;
   }

   //-----------------------------------------------------------------
   //  Returns the complexity level for this question.
   //-----------------------------------------------------------------
   public int getComplexity()
   {
      return complexityLevel;
   }

   //-----------------------------------------------------------------
   //  Returns the question.
   //-----------------------------------------------------------------
   public String getQuestion()
   {
      return question;
   }
```

continue

continue

```java
   //-----------------------------------------------------------------
   //  Returns the answer to this question.
   //-----------------------------------------------------------------
   public String getAnswer()
   {
      return answer;
   }

   //-----------------------------------------------------------------
   //  Returns true if the candidate answer matches the answer.
   //-----------------------------------------------------------------
   public boolean answerCorrect(String candidateAnswer)
   {
      return answer.equals(candidateAnswer);
   }

   //-----------------------------------------------------------------
   //  Returns this question (and its answer) as a string.
   //-----------------------------------------------------------------
   public String toString()
   {
      return question + "\n" + answer;
   }
}
```



```java
//********************************************************************
//  MiniQuiz.java       Author: Lewis/Loftus
//
//  Demonstrates the use of a class that implements an interface.
//********************************************************************

import java.util.Scanner;

public class MiniQuiz
{
   //-----------------------------------------------------------------
   //  Presents a short quiz.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Question q1, q2;
      String possible;

      Scanner scan = new Scanner(System.in);

      q1 = new Question("What is the capital of Jamaica?",
                        "Kingston");
      q1.setComplexity(4);

      q2 = new Question("Which is worse, ignorance or apathy?",
                        "I don't know and I don't care");
      q2.setComplexity(10);
```

continue

continue

```
      System.out.print(q1.getQuestion());
      System.out.println(" (Level: " + q1.getComplexity() + ")");
      possible = scan.nextLine();
      if (q1.answerCorrect(possible))
         System.out.println("Correct");
      else
         System.out.println("No, the answer is " + q1.getAnswer());

      System.out.println();
      System.out.print(q2.getQuestion());
      System.out.println(" (Level: " + q2.getComplexity() + ")");
      possible = scan.nextLine();
      if (q2.answerCorrect(possible))
         System.out.println("Correct");
      else
         System.out.println("No, the answer is " + q2.getAnswer());
   }
}
```


contin

Sample Run

```
What is the capital of Jamaica? (Level: 4)
Kingston
Correct

Which is worse, ignorance or apathy? (Level: 10)
apathy
No, the answer is I don't know and I don't care
```

```
;
());
      System.out.println();
      System.out.print(q2.getQuestion());
      System.out.println(" (Level: " + q2.getComplexity() + ")");
      possible = scan.nextLine();
      if (q2.answerCorrect(possible))
         System.out.println("Correct");
      else
         System.out.println("No, the answer is " + q2.getAnswer());
   }
}
```


Interfaces

- A class can implement multiple interfaces
- The interfaces are listed in the `implements` clause
- The class must implement all methods in all interfaces listed in the header

```
class ManyThings implements interface1, interface2
{
   // all methods of both interfaces
}
```

Interfaces

- The Java API contains many helpful interfaces
- The `Comparable` interface contains one abstract method called `compareTo`, which is used to compare two objects
- We discussed the `compareTo` method of the `String` class in Chapter 5
- The `String` class implements `Comparable`, giving us the ability to put strings in lexicographic order

The Comparable Interface

- Any class can implement `Comparable` to provide a mechanism for comparing objects of that type

```
if (obj1.compareTo(obj2) < 0)
   System.out.println ("obj1 is less than obj2");
```

- The value returned from `compareTo` should be negative is `obj1` is less that `obj2`, 0 if they are equal, and positive if `obj1` is greater than `obj2`
- It's up to the programmer to determine what makes one object less than another

The Iterator Interface

- As we discussed in Chapter 5, an iterator is an object that provides a means of processing a collection of objects one at a time
- An iterator is created formally by implementing the `Iterator` interface, which contains three methods
  - The `hasNext` method returns a boolean result – true if there are items left to process
  - The `next` method returns the next object in the iteration
  - The `remove` method removes the object most recently returned by the `next` method

The Iterable Interface

- Another interface, `Iterable`, establishes that an object provides an iterator
- The `Iterable` interface has one method, `iterator`, that returns an `Iterator` object
- Any `Iterable` object can be processed using the for-each version of the `for` loop
- Note the difference: an `Iterator` has methods that perform an iteration; an `Iterable` object provides an iterator on request

Interfaces

- You could write a class that implements certain methods (such as `compareTo`) without formally implementing the interface (`Comparable`)
- However, formally establishing the relationship between a class and an interface allows Java to deal with an object in certain ways
- Interfaces are a key aspect of object-oriented design in Java
- We discuss this idea further in Chapter 10

Outline

Software Development Activities

Identifying Classes and Objects

Static Variables and Methods

Class Relationships

Interfaces

➡ **Enumerated Types Revisited**

Method Design

Testing

Enumerated Types

- In Chapter 3 we introduced enumerated types, which define a new data type and list all possible values of that type:

```
enum Season {winter, spring, summer, fall}
```

- Once established, the new type can be used to declare variables

```
Season time;
```

- The only values this variable can be assigned are the ones established in the `enum` definition

Enumerated Types

- An enumerated type definition is a special kind of class
- The values of the enumerated type are objects of that type
- For example, `fall` is an object of type `Season`
- That's why the following assignment is valid:

```
time = Season.fall;
```


Enumerated Types

- An enumerated type definition can be more interesting than a simple list of values
- Because they are like classes, we can add additional instance data and methods
- We can define an `enum` constructor as well
- Each value listed for the enumerated type calls the constructor
- See `Season.java`
- See `SeasonTester.java`

```java
//********************************************************************
//  Season.java       Author: Lewis/Loftus
//
//  Enumerates the values for Season.
//********************************************************************

public enum Season
{
   winter ("December through February"),
   spring ("March through May"),
   summer ("June through August"),
   fall ("September through November");

   private String span;
```

continue

continue

```java
   //-----------------------------------------------------------------
   //  Constructor: Sets up each value with an associated string.
   //-----------------------------------------------------------------
   Season(String months)
   {
      span = months;
   }

   //-----------------------------------------------------------------
   //  Returns the span message for this value.
   //-----------------------------------------------------------------
   public String getSpan()
   {
      return span;
   }
}
```



```java
//********************************************************************
//  SeasonTester.java       Author: Lewis/Loftus
//
//  Demonstrates the use of a full enumerated type.
//********************************************************************

public class SeasonTester
{
   //-----------------------------------------------------------------
   //  Iterates through the values of the Season enumerated type.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      for (Season time : Season.values())
         System.out.println(time + "\t" + time.getSpan());
   }
}
```

```
//***********                              ***************
//  SeasonTes
//
//  Demonstra
//***********                              ***************

public class
{
   //------------------------------------------------------------
   //  Iterates through the values of the Season enumerated type.
   //------------------------------------------------------------
   public static void main(String[] args)
   {
      for (Season time : Season.values())
         System.out.println(time + "\t" + time.getSpan());
   }
}
```

Output

```
winter  December through February
spring  March through May
summer  June through August
fall    September through November
```


Enumerated Types

- Every enumerated type contains a static method called `values` that returns a list of all possible values for that type
- The list returned from `values` can be processed using a for-each loop
- An enumerated type cannot be instantiated outside of its own definition
- A carefully designed enumerated type provides a versatile and type-safe mechanism for managing data

Outline

Software Development Activities

Identifying Classes and Objects

Static Variables and Methods

Class Relationships

Interfaces

Enumerated Types Revisited

Method Design

Testing

Method Design

- As we've discussed, high-level design issues include:
  - identifying primary classes and objects
  - assigning primary responsibilities
- After establishing high-level design issues, its important to address low-level issues such as the design of key methods
- For some methods, careful planning is needed to make sure they contribute to an efficient and elegant system design

Method Decomposition

- A method should be relatively small, so that it can be understood as a single entity
- A potentially large method should be decomposed into several smaller methods as needed for clarity
- A public service method of an object may call one or more private support methods to help it accomplish its goal
- Support methods might call other support methods if appropriate

Method Decomposition

- Let's look at an example that requires method decomposition – translating English into Pig Latin
- Pig Latin is a language in which each word is modified by moving the initial sound of the word to the end and adding "ay"
- Words that begin with vowels have the "yay" sound added on the end

book → ookbay		table → abletay	
item → itemyay		chair → airchay	

Method Decomposition

- The primary objective (translating a sentence) is too complicated for one method to accomplish
- Therefore we look for natural ways to decompose the solution into pieces
- Translating a sentence can be decomposed into the process of translating each word
- The process of translating a word can be separated into translating words that:
  - begin with vowels
  - begin with consonant blends (sh, cr, th, etc.)
  - begin with single consonants

Method Decomposition

- In a UML class diagram, the visibility of a variable or method can be shown using special characters
- Public members are preceded by a plus sign
- Private members are preceded by a minus sign
- See `PigLatin.java`
- See `PigLatinTranslator.java`


```
//********************************************************************
//  PigLatin.java       Author: Lewis/Loftus
//
//  Demonstrates the concept of method decomposition.
//********************************************************************

import java.util.Scanner;

public class PigLatin
{
   //-----------------------------------------------------------------
   //  Reads sentences and translates them into Pig Latin.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      String sentence, result, another;

      Scanner scan = new Scanner(System.in);
```

continue

continue

```java
      do
      {
         System.out.println();
         System.out.println("Enter a sentence (no punctuation):");
         sentence = scan.nextLine();

         System.out.println();
         result = PigLatinTranslator.translate(sentence);
         System.out.println("That sentence in Pig Latin is:");
         System.out.println(result);

         System.out.println();
         System.out.print("Translate another sentence (y/n)? ");
         another = scan.nextLine();
      }
      while (another.equalsIgnoreCase("y"));
   }
}
```


continue

```java
      do
      {
         Syst
         Syst                                        ation):");
         sent

         Syst
         resu                                        ;
         Syst                                        is:");
         Syst

         Syst
         Syst                                        /n)? ");
         anot
      }
      while
   }
}
```

Sample Run

```
Enter a sentence (no punctuation):
Do you speak Pig Latin

That sentence in Pig Latin is:
oday ouyay eakspay igpay atinlay

Translate another sentence (y/n)? y

Enter a sentence (no punctuation):
Play it again Sam

That sentence in Pig Latin is:
ayplay ityay againyay amsay

Translate another sentence (y/n)? n
```



```java
//********************************************************************
//  PigLatinTranslator.java       Author: Lewis/Loftus
//
//  Represents a translator from English to Pig Latin. Demonstrates
//  method decomposition.
//********************************************************************

import java.util.Scanner;

public class PigLatinTranslator
{
   //-----------------------------------------------------------------
   //  Translates a sentence of words into Pig Latin.
   //-----------------------------------------------------------------
   public static String translate(String sentence)
   {
      String result = "";

      sentence = sentence.toLowerCase();

      Scanner scan = new Scanner(sentence);

      while (scan.hasNext())
      {
         result += translateWord(scan.next());
         result += " ";
      }
```

continue

continue

```
      return result;
   }

   //-----------------------------------------------------------------
   //  Translates one word into Pig Latin. If the word begins with a
   //  vowel, the suffix "yay" is appended to the word.  Otherwise,
   //  the first letter or two are moved to the end of the word,
   //  and "ay" is appended.
   //-----------------------------------------------------------------
   private static String translateWord(String word)
   {
      String result = "";

      if (beginsWithVowel(word))
         result = word + "yay";
      else
         if (beginsWithBlend(word))
            result = word.substring(2) + word.substring(0,2) + "ay";
         else
            result = word.substring(1) + word.charAt(0) + "ay";

      return result;
   }
```

continue

continue

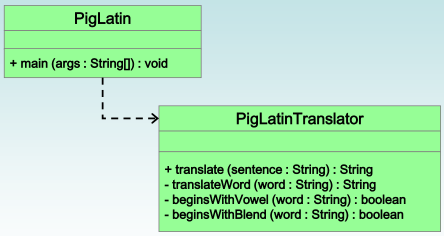
```
   //-----------------------------------------------------------------
   //  Determines if the specified word begins with a vowel.
   //-----------------------------------------------------------------
   private static boolean beginsWithVowel(String word)
   {
      String vowels = "aeiou";

      char letter = word.charAt(0);

      return (vowels.indexOf(letter) != -1);
   }
```

continue

continue

```
   //-----------------------------------------------------------------
   //  Determines if the specified word begins with a particular
   //  two-character consonant blend.
   //-----------------------------------------------------------------
   private static boolean beginsWithBlend(String word)
   {
      return ( word.startsWith("bl") || word.startsWith("sc") ||
               word.startsWith("br") || word.startsWith("sh") ||
               word.startsWith("ch") || word.startsWith("sk") ||
               word.startsWith("cl") || word.startsWith("sl") ||
               word.startsWith("cr") || word.startsWith("sn") ||
               word.startsWith("dr") || word.startsWith("sm") ||
               word.startsWith("dw") || word.startsWith("sp") ||
               word.startsWith("fl") || word.startsWith("sq") ||
               word.startsWith("fr") || word.startsWith("st") ||
               word.startsWith("gl") || word.startsWith("sw") ||
               word.startsWith("gr") || word.startsWith("th") ||
               word.startsWith("kl") || word.startsWith("tr") ||
               word.startsWith("ph") || word.startsWith("tw") ||
               word.startsWith("pl") || word.startsWith("wh") ||
               word.startsWith("pr") || word.startsWith("wr") );
   }
}
```

Class Diagram for Pig Latin



Objects as Parameters

- Another important issue related to method design involves parameter passing
- Parameters in a Java method are *passed by value*
- A copy of the *actual parameter* (the value passed in) is stored into the *formal parameter* (in the method header)
- When an object is passed to a method, the actual parameter and the formal parameter become aliases of each other

Passing Objects to Methods

- What a method does with a parameter may or may not have a permanent effect (outside the method)
- Note the difference between changing the internal state of an object versus changing which object a reference points to
- See `ParameterTester.java`
- See `ParameterModifier.java`
- See `Num.java`

```java
//********************************************************************
//  ParameterTester.java       Author: Lewis/Loftus
//
//  Demonstrates the effects of passing various types of parameters.
//********************************************************************

public class ParameterTester
{
   //-----------------------------------------------------------------
   //  Sets up three variables (one primitive and two objects) to
   //  serve as actual parameters to the changeValues method. Prints
   //  their values before and after calling the method.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      ParameterModifier modifier = new ParameterModifier();

      int a1 = 111;
      Num a2 = new Num(222);
      Num a3 = new Num(333);
```

continue

continue

```java
      System.out.println("Before calling changeValues:");
      System.out.println("a1\ta2\ta3");
      System.out.println(a1 + "\t" + a2 + "\t" + a3 + "\n");

      modifier.changeValues(a1, a2, a3);

      System.out.println("After calling changeValues:");
      System.out.println("a1\ta2\ta3");
      System.out.println(a1 + "\t" + a2 + "\t" + a3 + "\n");
   }
}
```


continue

```java
      System.out                                          es:");
      System.out
      System.out                                          + "\n");

      modifier.c

      System.out                                          s:");
      System.out
      System.out                                          + "\n");
   }
}
```

Output

```
Before calling changeValues:
a1      a2      a3
111     222     333

Before changing the values:
f1      f2      f3
111     222     333

After changing the values:
f1      f2      f3
999     888     777

After calling changeValues:
a1      a2      a3
111     888     333
```

```java
//********************************************************************
//  ParameterModifier.java       Author: Lewis/Loftus
//
//  Demonstrates the effects of changing parameter values.
//********************************************************************

public class ParameterModifier
{
   //-----------------------------------------------------------------
   //  Modifies the parameters, printing their values before and
   //  after making the changes.
   //-----------------------------------------------------------------
   public void changeValues(int f1, Num f2, Num f3)
   {
      System.out.println("Before changing the values:");
      System.out.println("f1\tf2\tf3");
      System.out.println(f1 + "\t" + f2 + "\t" + f3 + "\n");

      f1 = 999;
      f2.setValue(888);
      f3 = new Num(777);

      System.out.println("After changing the values:");
      System.out.println("f1\tf2\tf3");
      System.out.println(f1 + "\t" + f2 + "\t" + f3 + "\n");
   }
}
```

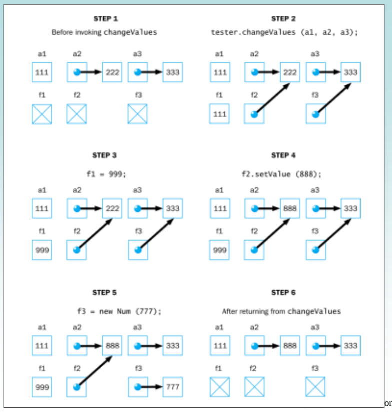


```java
//********************************************************************
//  Num.java       Author: Lewis/Loftus
//
//  Represents a single integer as an object.
//********************************************************************

public class Num
{
   private int value;

   //-----------------------------------------------------------------
   //  Sets up the new Num object, storing an initial value.
   //-----------------------------------------------------------------
   public Num(int update)
   {
      value = update;
   }
```

continue

continue

```java
   //-----------------------------------------------------------------
   //  Sets the stored value to the newly specified value.
   //-----------------------------------------------------------------
   public void setValue(int update)
   {
      value = update;
   }

   //-----------------------------------------------------------------
   //  Returns the stored integer value as a string.
   //-----------------------------------------------------------------
   public String toString()
   {
      return value + "";
   }
}
```



Method Overloading

- Let's look at one more important method design issue: method overloading
- *Method overloading* is the process of giving a single method name multiple definitions in a class
- If a method is overloaded, the method name is not sufficient to determine which method is being called
- The *signature* of each overloaded method must be unique
- The signature includes the number, type, and order of the parameters

Method Overloading

- The compiler determines which method is being invoked by analyzing the parameters

```
float tryMe(int x)
{
   return x + .375;
}

float tryMe(int x, float y)
{
   return x*y;
}
```

Invocation

`result = tryMe(25, 4.32)`

Method Overloading

- The `println` method is overloaded:

```
println(String s)
println(int i)
println(double d)
```

  and so on...

- The following lines invoke different versions of the `println` method:

```
System.out.println("The total is:");
System.out.println(total);
```


Overloading Methods

- The return type of the method is not part of the signature
- That is, overloaded methods cannot differ only by their return type
- Constructors can be overloaded
- Overloaded constructors provide multiple ways to initialize a new object

Outline

Testing

- Testing can mean many different things
- It certainly includes running a completed program with various inputs
- It also includes any evaluation performed by human or computer to assess quality
- Some evaluations should occur before coding even begins
- The earlier we find an problem, the easier and cheaper it is to fix

Testing

- The goal of testing is to find errors
- As we find and fix errors, we raise our confidence that a program will perform as intended
- We can never really be sure that all errors have been eliminated
- So when do we stop testing?
  - Conceptual answer: Never
  - Cynical answer: When we run out of time
  - Better answer: When we are willing to risk that an undiscovered error still exists

Reviews

- A *review* is a meeting in which several people examine a design document or section of code
- It is a common and effective form of human-based testing
- Presenting a design or code to others:
  - makes us think more carefully about it
  - provides an outside perspective
- Reviews are sometimes called *inspections* or *walkthroughs*

Test Cases

- A *test case* is a set of input and user actions, coupled with the expected results
- Often test cases are organized formally into *test suites* which are stored and reused as needed
- For medium and large systems, testing must be a carefully managed process
- Many organizations have a separate Quality Assurance (QA) department to lead testing efforts

Defect and Regression Testing

- *Defect testing* is the execution of test cases to uncover errors
- The act of fixing an error may introduce new errors
- After fixing a set of errors we should perform *regression testing* – running previous test suites to ensure new errors haven't been introduced
- It is not possible to create test cases for all possible input and user actions
- Therefore we should design tests to maximize their ability to find problems

Black-Box Testing

- In *black-box testing*, test cases are developed without considering the internal logic
- They are based on the input and expected output
- Input can be organized into *equivalence categories*
- Two input values in the same equivalence category would produce similar results
- Therefore a good test suite will cover all equivalence categories and focus on the boundaries between categories

White-Box Testing

- *White-box testing* focuses on the internal structure of the code
- The goal is to ensure that every path through the code is tested
- Paths through the code are governed by any conditional or looping statements in a program
- A good testing effort will include both black-box and white-box tests

Summary

- Chapter 7 has focused on:
  - software development activities
  - determining the classes and objects that are needed for a program
  - the relationships that can exist among classes
  - the static modifier
  - writing interfaces
  - the design of enumerated type classes
  - method design and method overloading