Chapter 4

Writing Classes
Writing Classes

• We've been using predefined classes. Now we will learn to write our own classes to define objects.

• Chapter 4 focuses on:
  ▪ class definitions
  ▪ instance data
  ▪ encapsulation and Java modifiers
  ▪ method declaration and parameter passing
  ▪ constructors
  ▪ graphical objects
  ▪ events and listeners
  ▪ buttons and text fields
Outline

Anatomy of a Class
Encapsulation
Anatomy of a Method
Graphical Objects
Graphical User Interfaces
Buttons and Text Fields
Writing Classes

• The programs we’ve written in previous examples have used classes defined in the Java standard class library

• Now we will begin to design programs that rely on classes that we write ourselves

• The class that contains the main method is just the starting point of a program

• True object-oriented programming is based on defining classes that represent objects with well-defined characteristics and functionality
Classes and Objects

• Recall from our overview of objects in Chapter 1 that an object has state and behavior.

• Consider a six-sided die (singular of dice):
  ▪ It’s state can be defined as which face is showing.
  ▪ It’s primary behavior is that it can be rolled.

• We can represent a die in software by designing a class called Die that models this state and behavior:
  ▪ The class serves as the blueprint for a die object.

• We can then instantiate as many die objects as we need for any particular program.
Classes

• A class can contain data declarations and method declarations

```java
int size, weight;
char category;
```

Data declarations

Method declarations
Classes

- The values of the data define the state of an object created from the class.
- The functionality of the methods define the behaviors of the object.
- For our Die class, we might declare an integer that represents the current value showing on the face.
- One of the methods would “roll” the die by setting that value to a random number between one and six.
Classes

• We’ll want to design the Die class with other data and methods to make it a versatile and reusable resource

• Any given program will not necessarily use all aspects of a given class

• See RollingDice.java (page 157)
• See Die.java (page 158)
The Die Class

- The Die class contains two data values
  - a constant `MAX` that represents the maximum face value
  - an integer `faceValue` that represents the current face value
- The `roll` method uses the `random` method of the `Math` class to determine a new face value
- There are also methods to explicitly set and retrieve the current face value at any time
The `toString` Method

- All classes that represent objects should define a `toString` method
- The `toString` method returns a character string that represents the object in some way
- It is called automatically when an object is concatenated to a string or when it is passed to the `println` method
Constructors

- As mentioned previously, a *constructor* is a special method that is used to set up an object when it is initially created.
- A constructor has the same name as the class.
- The *Die* constructor is used to set the initial face value of each new die object to one.
- We examine constructors in more detail later in this chapter.
Data Scope

- The scope of data is the area in a program in which that data can be referenced (used)

- Data declared at the class level can be referenced by all methods in that class

- Data declared within a method can be used only in that method

- Data declared within a method is called local data

- In the Die class, the variable result is declared inside the toString method -- it is local to that method and cannot be referenced anywhere else
Instance Data

• The `faceValue` variable in the `Die` class is called *instance data* because each instance (object) that is created has its own version of it.

• A class declares the type of the data, but it does not reserve any memory space for it.

• Every time a `Die` object is created, a new `faceValue` variable is created as well.

• The objects of a class share the method definitions, but each object has its own data space.

• That's the only way two objects can have different states.
Instance Data

- We can depict the two Die objects from the RollingDice program as follows:

  ![Diagram of two Die objects with faceValue variables]

Each object maintains its own faceValue variable, and thus its own state.
UML Diagrams

• UML stands for the *Unified Modeling Language*

• *UML diagrams* show relationships among classes and objects

• A UML *class diagram* consists of one or more classes, each with sections for the class name, attributes (data), and operations (methods)

• Lines between classes represent *associations*

• A dotted arrow shows that one class *uses* the other (calls its methods)
A UML class diagram for the `RollingDice` program:
Outline

- Anatomy of a Class
- Encapsulation
- Anatomy of a Method
- Graphical Objects
- Graphical User Interfaces
- Buttons and Text Fields
Encapsulation

• We can take one of two views of an object:
  - internal - the details of the variables and methods of the class that defines it
  - external - the services that an object provides and how the object interacts with the rest of the system

• From the external view, an object is an *encapsulated* entity, providing a set of specific services

• These services define the *interface* to the object
Encapsulation

• One object (called the *client*) may use another object for the services it provides

• The client of an object may request its services (call its methods), but it should not have to be aware of how those services are accomplished

• Any changes to the object's state (its variables) should be made by that object's methods

• We should make it difficult, if not impossible, for a client to access an object’s variables directly

• That is, an object should be *self-governing*
Encapsulation

- An encapsulated object can be thought of as a **black box** -- its inner workings are hidden from the client.

- The client invokes the interface methods of the object, which manages the instance data.
Visibility Modifiers

• In Java, we accomplish encapsulation through the appropriate use of *visibility modifiers*

• A *modifier* is a Java reserved word that specifies particular characteristics of a method or data

• We've used the *final* modifier to define constants

• Java has three visibility modifiers: *public*, *protected*, and *private*

• The *protected* modifier involves inheritance, which we will discuss later
Visibility Modifiers

- Members of a class that are declared with *public visibility* can be referenced anywhere.

- Members of a class that are declared with *private visibility* can be referenced only within that class.

- Members declared without a visibility modifier have *default visibility* and can be referenced by any class in the same package.

- An overview of all Java modifiers is presented in Appendix E.
Visibility Modifiers

• Public variables violate encapsulation because they allow the client to “reach in” and modify the values directly

• Therefore instance variables should not be declared with public visibility

• It is acceptable to give a constant public visibility, which allows it to be used outside of the class

• Public constants do not violate encapsulation because, although the client can access it, its value cannot be changed
Visibility Modifiers

• Methods that provide the object's services are declared with public visibility so that they can be invoked by clients

• Public methods are also called service methods

• A method created simply to assist a service method is called a support method

• Since a support method is not intended to be called by a client, it should not be declared with public visibility
Visibility Modifiers

**Variables**

<table>
<thead>
<tr>
<th>public</th>
<th>private</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Violate encapsulation</strong></td>
<td><strong>Enforce encapsulation</strong></td>
</tr>
</tbody>
</table>

- Public variables violate encapsulation.
- Private variables enforce encapsulation.

**Methods**

<table>
<thead>
<tr>
<th>public</th>
<th>private</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provide services to clients</strong></td>
<td><strong>Support other methods in the class</strong></td>
</tr>
</tbody>
</table>

- Public methods provide services to clients.
- Private methods support other methods in the class.
Accessors and Mutators

• Because instance data is private, a class usually provides services to access and modify data values

• An accessor method returns the current value of a variable

• A mutator method changes the value of a variable

• The names of accessor and mutator methods take the form `getX` and `setX`, respectively, where `X` is the name of the value

• They are sometimes called “getters” and “setters”
Mutator Restrictions

• The use of mutators gives the class designer the ability to restrict a client’s options to modify an object’s state.

• A mutator is often designed so that the values of variables can be set only within particular limits.

• For example, the `setFaceValue` mutator of the `Die` class should have restricted the value to the valid range (1 to `MAX`).

• We’ll see in Chapter 5 how such restrictions can be implemented.
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Method Declarations

• Let’s now examine method declarations in more detail

• A *method declaration* specifies the code that will be executed when the method is invoked (called)

• When a method is invoked, the flow of control jumps to the method and executes its code

• When complete, the flow returns to the place where the method was called and continues

• The invocation may or may not return a value, depending on how the method is defined
Method Control Flow

- If the called method is in the same class, only the method name is needed

```
myMethod();
```
Method Control Flow

- The called method is often part of another class or object

```
main
    obj.doIt();
    helpMe();
```

```
doIt
    helpMe();
```

```
helpMe
```
Method Header

- A method declaration begins with a *method header*

```
char calc (int num1, int num2, String message)
```

- The parameter list specifies the type and name of each parameter.
- The name of a parameter in the method declaration is called a *formal parameter*.
Method Body

• The method header is followed by the \textit{method body}

\begin{verbatim}
char calc (int num1, int num2, String message)
{
    int sum = num1 + num2;
    char result = message.charAt (sum);

    return result;
}
\end{verbatim}

\textbf{sum} and \textbf{result} are local data

The return expression must be consistent with the return type

They are created each time the method is called, and are destroyed when it finishes executing.
The return Statement

• The *return type* of a method indicates the type of value that the method sends back to the calling location

• A method that does not return a value has a *void* return type

• A *return statement* specifies the value that will be returned

  \[
  \text{return expression;}
  \]

• Its expression must conform to the return type
Parameters

• When a method is called, the *actual parameters* in the invocation are copied into the *formal parameters* in the method header

```java
ch = obj.calc (25, count, "Hello");
```

```java
char calc (int num1, int num2, String message)
{
    int sum = num1 + num2;
    char result = message.charAt (sum);

    return result;
}
```
Local Data

• As we’ve seen, local variables can be declared inside a method

• The formal parameters of a method create *automatic local variables* when the method is invoked

• When the method finishes, all local variables are destroyed (including the formal parameters)

• Keep in mind that instance variables, declared at the class level, exists as long as the object exists
Bank Account Example

• Let’s look at another example that demonstrates the implementation details of classes and methods

• We’ll represent a bank account by a class named `Account`

• It’s state can include the account number, the current balance, and the name of the owner

• An account’s behaviors (or services) include deposits and withdrawals, and adding interest
Driver Programs

• A *driver program* drives the use of other, more interesting parts of a program

• Driver programs are often used to test other parts of the software

• The *Transactions class* contains a *main method* that drives the use of the *Account class*, exercising its services

• See *Transactions.java* (page 172)
• See *Account.java* (page 173)
Bank Account Example

acct1

acctNumber: 72354
balance: 102.56
name: "Ted Murphy"

acct2

acctNumber: 69713
balance: 40.00
name: "Jane Smith"
Bank Account Example

- There are some improvements that can be made to the `Account` class
- Formal getters and setters could have been defined for all data
- The design of some methods could also be more robust, such as verifying that the `amount` parameter to the `withdraw` method is positive
Constructors Revisited

- Note that a constructor has no return type specified in the method header, not even `void`.
- A common error is to put a return type on a constructor, which makes it a “regular” method that happens to have the same name as the class.
- The programmer does not have to define a constructor for a class.
- Each class has a `default constructor` that accepts no parameters.
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Graphical Objects

• Some objects contain information that determines how the object should be represented visually

• Most GUI components are graphical objects

• We can have some effect on how components get drawn

• We did this in Chapter 2 when we defined the `paint` method of an applet

• Let's look at some other examples of graphical objects
Smiling Face Example

• The SmilingFace program draws a face by defining the `paintComponent` method of a panel

• See `SmilingFace.java` (page 177)

• See `SmilingFacePanel.java` (page 178)

• The main method of the SmilingFace class instantiates a SmilingFacePanel and displays it

• The SmilingFacePanel class is derived from the JPanel class using inheritance
Smiling Face Example

• Every Swing component has a `paintComponent` method

• The `paintComponent` method accepts a Graphics object that represents the graphics context for the panel

• We define the `paintComponent` method to draw the face with appropriate calls to the Graphics methods

• Note the difference between drawing on a panel and adding other GUI components to a panel
Splat Example

• The Splat example is structured a bit differently

• It draws a set of colored circles on a panel, but each circle is represented as a separate object that maintains its own graphical information

• The paintComponent method of the panel "asks" each circle to draw itself

• See Splat.java (page 180)
• See SplatPanel.java (page 181)
• See Circle.java (page 182)
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Graphical User Interfaces

• A Graphical User Interface (GUI) in Java is created with at least three kinds of objects:
  - components
  - events
  - listeners

• We've previously discussed components, which are objects that represent screen elements
  - labels, buttons, text fields, menus, etc.

• Some components are containers that hold and organize other components
  - frames, panels, applets, dialog boxes
Events

• An event is an object that represents some activity to which we may want to respond

• For example, we may want our program to perform some action when the following occurs:
  ▪ the mouse is moved
  ▪ the mouse is dragged
  ▪ a mouse button is clicked
  ▪ a graphical button is clicked
  ▪ a keyboard key is pressed
  ▪ a timer expires

• Events often correspond to user actions, but not always
Events and Listeners

- The Java standard class library contains several classes that represent typical events.
- Components, such as a graphical button, generate (or fire) an event when it occurs.
- A listener object "waits" for an event to occur and responds accordingly.
- We can design listener objects to take whatever actions are appropriate when an event occurs.
Events and Listeners

A component object may generate an event

A corresponding listener object is designed to respond to the event

When the event occurs, the component calls the appropriate method of the listener, passing an object that describes the event.
GUI Development

• Generally we use components and events that are predefined by classes in the Java class library

• Therefore, to create a Java program that uses a GUI we must:
  ▪ instantiate and set up the necessary components
  ▪ implement listener classes for any events we care about
  ▪ establish the relationship between listeners and components that generate the corresponding events

• Let's now explore some new components and see how this all comes together
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Buttons

• A *push button* is a component that allows the user to initiate an action by pressing a graphical button using the mouse

• A push button is defined by the `JButton` class

• It generates an *action event*

• The `PushCounter` example displays a push button that increments a counter each time it is pushed

• See `PushCounter.java` (page 186)
• See `PushCounterPanel.java` (page 187)
Push Counter Example

• The components of the GUI are the button, a label to display the counter, a panel to organize the components, and the main frame

• The `PushCounterPanel` class is represents the panel used to display the button and label

• The `PushCounterPanel` class is derived from `JPanel` using inheritance

• The constructor of `PushCounterPanel` sets up the elements of the GUI and initializes the counter to zero
Push Counter Example

- The ButtonListener class is the listener for the action event generated by the button.
- It is implemented as an *inner class*, which means it is defined within the body of another class.
- That facilitates the communication between the listener and the GUI components.
- Inner classes should only be used in situations where there is an intimate relationship between the two classes and the inner class is not needed in any other context.
Push Counter Example

- Listener classes are written by implementing a *listener interface*
- The ButtonListener class implements the ActionListener interface
- An interface is a list of methods that the implementing class must define
- The only method in the ActionListener interface is the actionPerformed method
- The Java class library contains interfaces for many types of events
- We discuss interfaces in more detail in Chapter 6
Push Counter Example

• The PushCounterPanel constructor:
  - instantiates the ButtonListener object
  - establishes the relationship between the button and the listener by the call to addActionListener

• When the user presses the button, the button component creates an ActionEvent object and calls the actionPerformed method of the listener

• The actionPerformed method increments the counter and resets the text of the label
Text Fields

• Let's look at another GUI example that uses another type of component

• A text field allows the user to enter one line of input

• If the cursor is in the text field, the text field component generates an action event when the enter key is pressed

• See Fahrenheit.java (page 190)
• See FahrenheitPanel.java (page 191)
Fahrenheit Example

• Like the PushCounter example, the GUI is set up in a separate panel class

• The TempListener inner class defines the listener for the action event generated by the text field

• The FahrenheitPanel constructor instantiates the listener and adds it to the text field

• When the user types a temperature and presses enter, the text field generates the action event and calls the actionPerformed method of the listener

• The actionPerformed method computes the conversion and updates the result label
Summary

• Chapter 4 focused on:
  - class definitions
  - instance data
  - encapsulation and Java modifiers
  - method declaration and parameter passing
  - constructors
  - graphical objects
  - events and listeners
  - buttons and text fields