Chapter Nine: Interfaces and Polymorphism
Chapter Goals

• To learn about interfaces
• To be able to convert between class and interface references
• To understand the concept of polymorphism
• To appreciate how interfaces can be used to decouple classes
• To learn how to implement helper classes as inner classes
• To understand how inner classes access variables from the surrounding scope
• To implement event listeners in graphical applications
Using Interfaces for Code Reuse

• Use *interface types* to make code more reusable

• In Chapter 6, we created a `DataSet` to find the average and maximum of a set of values (*numbers*)

• What if we want to find the average and maximum of a set of `BankAccount` values?

*Continued*
public class DataSet // Modified for BankAccount objects
{
    // ...
    public void add(BankAccount x)
    {
        sum = sum + x.getBalance();
        if (count == 0 || maximum.getBalance() <
            x.getBalance()) maximum = x;
        count++;
    }

    public BankAccount getMaximum()
    {
        return maximum;
    }

    private double sum;
    private BankAccount maximum;
    private int count;
}
Using Interfaces for Code Reuse

Or suppose we wanted to find the coin with the highest value among a set of coins. We would need to modify the `DataSet` class again:

```java
public class DataSet // Modified for Coin objects
{
    // ...

    public void add(Coin x)
    {
        sum = sum + x.getValue();
        if (count == 0 || maximum.getValue() < x.getValue())
            maximum = x;
        count++;
    }
}

Continued

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Using Interfaces for Code Reuse

```java
public Coin getMaximum()
{
    return maximum;
}

private double sum;
private Coin maximum;
private int count;
```
Using Interfaces for Code Reuse

• The mechanics of analyzing the data is the same in all cases; details of measurement differ

• Classes could agree on a method `getMeasure` that obtains the measure to be used in the analysis

• We can implement a single reusable `DataSet` class whose `add` method looks like this:

```
sum = sum + x.getMeasure();
if (count == 0 || maximum.getMeasure() < x.getMeasure())
    maximum = x;
count++;
```

Continued
What is the type of the variable \( x \)?

\( x \) should refer to any class that has a `getMeasure` method.

In Java, an *interface type* is used to specify required operations:

```java
public interface Measurable {
    double getMeasure();
}
```

Interface declaration lists all methods (and their signatures) that the interface type requires.
Interfaces vs. Classes

An interface type is similar to a class, but there are several important differences:

- All methods in an interface type are abstract; they don't have an implementation
- All methods in an interface type are automatically public
- An interface type does not have instance fields
Generic **DataSet** for Measurable Objects

```java
public class DataSet {
    ...
    public void add(Measurable x) {
        sum = sum + x.getMeasure();
        if (count == 0 || maximum.getMeasure() < x.getMeasure()) {
            maximum = x;
            count++;
        }
    }

    public Measurable getMaximum() {
        return maximum;
    }

    Continued
```
Generic DataSet for Measurable Objects

```java
private double sum;
private Measurable maximum;
private int count;
}
```
Implementing an Interface Type

• Use `implements` keyword to indicate that a class implements an interface type

```java
public class BankAccount implements Measurable {
    public double getMeasure() {
        return balance;
    }
    // Additional methods and fields
}
```

• A class can implement more than one interface type
  
  • *Class must define all the methods that are required by all the interfaces it implements*

*Continued*
Implementing an Interface Type (cont.)

• Use `implements` keyword to indicate that a class implements an interface type

```java
public class BankAccount implements Measurable
{
    public double getMeasure()
    {
        return balance;
    }
    // Additional methods and fields
}
```

• A class can implement more than one interface type
  
  • *Class must define all the methods that are required by all the interfaces it implements*
Interfaces can reduce the coupling between classes

UML notation:
- *Interfaces are tagged with a "stereotype" indicator «interface»*
- *A dotted arrow with a triangular tip denotes the "is-a" relationship between a class and an interface*
- *A dotted line with an open v-shaped arrow tip denotes the "uses" relationship or dependency*

Note that *DataSet* is decoupled

**Figure 1** UML Diagram of the *DataSet* Class and the Classes That Implement the *Measurable* Interface
**Syntax 9.1 Defining an Interface**

```java
class InterfaceName {
    // method signatures
}

Example:

class Measurable {
    double getMeasure();
}

Purpose:
To define an interface and its method signatures. The methods are automatically public.
Syntax 9.2 Implementing an Interface

public class ClassName
implements InterfaceName, InterfaceName, ...
{
    // methods
    // instance variables
}

Example:

public class BankAccount implements Measurable
{
    // Other BankAccount methods
    public double getMeasure()
    {
        // Method implementation
    }
}
Purpose:

To define a new class that implements the methods of an interface.
/**
   * This program tests the DataSet class.
   */

public class DataSetTester
{
  public static void main(String[] args)
  {
    DataSet bankData = new DataSet();

    bankData.add(new BankAccount(0));
    bankData.add(new BankAccount(10000));
    bankData.add(new BankAccount(2000));

    System.out.println("Average balance: "+ bankData.getAverage());
    System.out.println("Expected: 4000");

    Measurable max = bankData.getMaximum();
    System.out.println("Highest balance: "+ max.getMeasure());
    System.out.println("Expected: 10000");
22:     DataSet coinData = new DataSet();
23:
24:     coinData.add(new Coin(0.25, "quarter"));
25:     coinData.add(new Coin(0.1, "dime"));
26:     coinData.add(new Coin(0.05, "nickel"));
27:
28:     System.out.println("Average coin value: ");
29:         + coinData.getAverage());
30:     System.out.println("Expected: 0.133");
31:     max = coinData.getMaximum();
32:     System.out.println("Highest coin value: ");
33:         + max.getMeasure());
34:     System.out.println("Expected: 0.25");
35: }
36: }
Output:
Average balance: 4000.0
Expected: 4000
Highest balance: 10000.0
Expected: 10000
Average coin value: 0.13333333333333333
Expected: 0.133
Highest coin value: 0.25
Expected: 0.25
Suppose you want to use the `DataSet` class to find the `Country` object with the largest population. What condition must the `Country` class fulfill?

**Answer:** It must implement the `Measurable` interface, and its `getMeasure` method must return the population.
Self Check 9.2

Why can't the `add` method of the `DataSet` class have a parameter of type `Object`?

**Answer:** The `Object` class doesn't have a `getMeasure` method, and the `add` method invokes the `getMeasure` method.
Converting Between Class and Interface Types

- You can convert from a class type to an interface type, provided the class implements the interface

```java
BankAccount account = new BankAccount(10000);
Measurable x = account; // OK
```

```java
Coin dime = new Coin(0.1, "dime");
Measurable x = dime; // Also OK
```

- Cannot convert between unrelated types

```java
Measurable x = new Rectangle(5, 10, 20, 30); // ERROR
```

- Because `Rectangle` doesn't implement `Measurable`
Casts

• Add coin objects to `DataSet`
  ```java
 DataSet coinData = new DataSet();
 coinData.add(new Coin(0.25, "quarter"));
 coinData.add(new Coin(0.1, "dime"));
  // Get the largest coin
  Measurable max = coinData.getMaximum();
```

• What can you do with it? It's not of type `Coin`
  ```java
 String name = max.getName();  // ERROR
  ```

• You need a cast to convert from an interface type to a class type

• You know it's a coin, but the compiler doesn't. Apply a cast:
  ```java
 Coin maxCoin = (Coin) max;
 String name = maxCoin.getName();
```

Continued
Casts (cont.)

- If you are wrong and \( \text{max} \) isn't a coin, the compiler throws an exception.

- Difference with casting numbers:
  - When casting number types you agree to the information loss.
  - When casting object types you agree to that risk of causing an exception.
Can you use a cast (BankAccount) \( x \) to convert a Measurable variable \( x \) to a BankAccount reference?

**Answer:** Only if \( x \) actually refers to a BankAccount object.
Self Check 9.4

If both `BankAccount` and `Coin` implement the `Measurable` interface, can a `Coin` reference be converted to a `BankAccount` reference?

**Answer:** No – a `Coin` reference can be converted to a `Measurable` reference, but if you attempt to cast that reference to a `BankAccount`, an exception occurs.
Polymorphism

• Interface variable holds reference to object of a class that implements the interface
  Measurable x;
  x = new BankAccount(10000);
  x = new Coin(0.1, "dime");

• Note that the object to which x refers doesn't have type Measurable; the type of the object is some class that implements the Measurable interface

• You can call any of the interface methods:
  double m = x.getMeasure(

• Which method is called?
Polymorphism

• Depends on the actual object
• If x refers to a bank account, calls `BankAccount.getMeasure`
• If x refers to a coin, calls `Coin.getMeasure`

• Polymorphism (many shapes): Behavior can vary depending on the actual type of an object
• Called *late binding*: resolved at runtime
• Different from overloading; overloading is resolved by the compiler (*early binding*)
public interface Measurable
{
    double getMeasure();
}
public class BankAccount
{
    ...
    public double getMeasure()
    {
        return balance;
    }
    ...
}
public class Coin
{
    ...
    public double getMeasure()
    {
        return value;
    }
    ...
}

This animation demonstrates the phenomenon of polymorphism.
Self Check 9.5

Why is it impossible to construct a Measurable object?

**Answer:** Measurable is an interface. Interfaces have no fields and no method implementations.
Self Check 9.6

Why can you nevertheless declare a variable whose type is Measurable?

**Answer:** That variable never refers to a `Measurable` object. It refers to an object of some class – a class that implements the `Measurable` interface.
What do overloading and polymorphism have in common? Where do they differ?

**Answer:** Both describe a situation where one method name can denote multiple methods. However, overloading is resolved early by the compiler, by looking at the types of the parameter variables. Polymorphism is resolved late, by looking at the type of the implicit parameter object just before making the call.
Using Interfaces for Callbacks

• Limitations of Measurable interface:
  • Can add Measurable interface only to classes under your control
  • Can measure an object in only one way
    E.g., cannot analyze a set of savings accounts both by bank balance and by interest rate

• Callback mechanism: allows a class to call back a specific method when it needs more information

• In previous DataSet implementation, responsibility of measuring lies with the added objects themselves

Continued
Using Interfaces for Callbacks (cont.)

• Alternative: Hand the object to be measured to a method:
  
  ```java
  public interface Measurer
  {
    double measure(Object anObject);
  }
  ```

• `Object` is the "lowest common denominator" of all classes
Using Interfaces for Callbacks

add method asks measurer (and not the added object) to do the measuring:

```java
public void add(Object x) {
    sum = sum + measurer.measure(x);
    if (count == 0 || measurer.measure(maximum) < measurer.measure(x))
        maximum = x;
    count++;
}
```
Using Interfaces for Callbacks

• You can define measurers to take on any kind of measurement
  public class RectangleMeasurer implements Measurer
  {
      public double measure(Object anObject)
      {
          Rectangle aRectangle = (Rectangle) anObject;
          double area = aRectangle.getWidth() *
                       aRectangle.getHeight();
          return area;
      }
  }

• Must cast from Object to Rectangle
  Rectangle aRectangle = (Rectangle) anObject;
  
  Continued
Using Interfaces for Callbacks (cont.)

• Pass measurer to data set constructor:
  Measurer m = new RectangleMeasurer();
  DataSet data = new DataSet(m);
  data.add(new Rectangle(5, 10, 20, 30));
  data.add(new Rectangle(10, 20, 30, 40)); . . .
UML Diagram of Measurer Interface and Related Classes

Note that the Rectangle class is decoupled from the Measurer interface.
/**
 * Computes the average of a set of data values.
 */

public class DataSet
{
    /**
     * Constructs an empty data set with a given measurer.
     * @param aMeasurer the measurer that is used to measure data values
     */
    public DataSet(Measurer aMeasurer)
    {
        sum = 0;
        count = 0;
        maximum = null;
        measurer = aMeasurer;
    }
}

/**
 * Adds a data value to the data set.
 * @param x a data value
 */
Continued
public void add(Object x) {
    sum = sum + measurer.measure(x);
    if (count == 0 || measurer.measure(maximum) < measurer.measure(x)) {
        maximum = x;
        count++;
    }
}

/**<n
 * Gets the average of the added data.
 * @return the average or 0 if no data has been added
 */
public double getAverage() {
    if (count == 0) return 0;
    else return sum / count;
}
/**
 * Gets the largest of the added data.
 * @return the maximum or 0 if no data has been added
 */
public Object getMaximum()
{
    return maximum;
}

private double sum;
private Object maximum;
private int count;
private Measurer measurer;
import java.awt.Rectangle;

/**
 * This program demonstrates the use of a Measurer.
 */

public class DataSetTester2 {
    public static void main(String[] args) {
        Measurer m = new RectangleMeasurer();
        DataSet data = new DataSet(m);
        data.add(new Rectangle(5, 10, 20, 30));
        data.add(new Rectangle(10, 20, 30, 40));
        data.add(new Rectangle(20, 30, 5, 15));
        System.out.println("Average area: " + data.getAverage());
        System.out.println("Expected: 625");
    }
}
21:         Rectangle max = (Rectangle) data.getMaximum();
22:         System.out.println("Maximum area rectangle: " + max);
23:         System.out.println("Expected: java.awt.Rectangle[x=10,y=20,width=30,height=40]");
24:     }
25: }
/**
 * Describes any class whose objects can measure other objects.
 */

public interface Measurer {

    /**
     * Computes the measure of an object.
     * @param anObject the object to be measured
     * @return the measure
     */
    double measure(Object anObject);
}
import java.awt.Rectangle;

/**
 * Objects of this class measure rectangles by area.
 */
public class RectangleMeasurer implements Measurer {
    public double measure(Object anObject) {
        Rectangle aRectangle = (Rectangle) anObject;
        double area = aRectangle.getWidth() * aRectangle.getHeight();
        return area;
    }
}
Output:
Average area: 625
Expected: 625
Maximum area rectangle: java.awt.Rectangle[x=10, y=20, width=30, height=40]
Expected: java.awt.Rectangle[x=10, y=20, width=30, height=40]
Suppose you want to use the `DataSet` class of Section 9.1 to find the longest `String` from a set of inputs. Why can't this work?

**Answer:** The `String` class doesn't implement the `Measurable` interface.
Self Check 9.10

Why does the `measure` method of the `Measurer` interface have one more parameter than the `getMeasure` method of the `Measurable` interface?

**Answer:** A measurer measures an object, whereas `getMeasure` measures "itself", that is, the implicit parameter.
• Trivial class can be defined inside a method

```java
public class DataSetTester3 {
    public static void main(String[] args) {
        class RectangleMeasurer implements Measurer {
            // . . .
        }
        Measurer m = new RectangleMeasurer();
        DataSet data = new DataSet(m);
        // . . .
    }
}
```

Continued
Inner Classes (cont.)

• If inner class is defined inside an enclosing class, but outside its methods, it is available to all methods of enclosing class.

• Compiler turns an inner class into a regular class file:

  DataSetTester$1$RectangleMeasurer.class
### Syntax 9.3 Inner Classes

**Declared inside a method**

```java
class OuterClassName {
    method signature {
        ...
        class InnerClassName {
            // methods
            // fields
        }
        ...
    }
    ...
}
```

**Declared inside the class**

```java
class OuterClassName {

    // methods
    // fields
    accessSpecifier class InnerClassName {
        // methods
        // fields
    }
    ...
}
```

*Continued*
Syntax 9.3 Inner Classes

Example:

```java
public class Tester {
    public static void main(String[] args) {
        class RectangleMeasurer implements Measurer {
            . . .
        }
        . . .
    }
}
```

Purpose:

To define an inner class whose scope is restricted to a single method or the methods of a single class.
import java.awt.Rectangle;

/**
 * This program demonstrates the use of an inner class.
 */
public class DataSetTester3 {
    public static void main(String[] args) {
        class RectangleMeasurer implements Measurer {
            public double measure(Object anObject) {
                Rectangle aRectangle = (Rectangle) anObject;
                double area = aRectangle.getWidth() * aRectangle.getHeight();
                return area;
            }
        }
    }
}

Continued
Measurer m = new RectangleMeasurer();
DataSet data = new DataSet(m);
data.add(new Rectangle(5, 10, 20, 30));
data.add(new Rectangle(10, 20, 30, 40));
data.add(new Rectangle(20, 30, 5, 15));
System.out.println("Average area: " + data.getAverage());
System.out.println("Expected: 625");
Rectangle max = (Rectangle) data.getMaximum();
System.out.println("Maximum area rectangle: " + max);
System.out.println("Expected: java.awt.Rectangle[x=10,y=20,width=30,height=40]");
Self Check 9.11

Why would you use an inner class instead of a regular class?

**Answer:** Inner classes are convenient for insignificant classes. Also, their methods can access variables and fields from the surrounding scope.
Self Check 9.12

How many class files are produced when you compile the \texttt{DataSetTester3} program?

\textbf{Answer:} Four: one for the outer class, one for the inner class, and two for the \texttt{DataSet} and \texttt{Measurer} classes.
A Graphical Software Environment for the Linux Operating System
Events, Event Sources, and Event Listeners

- User interface events include key presses, mouse moves, button clicks, and so on

- Most programs don't want to be flooded by boring events

- A program can indicate that it only cares about certain specific events

- Event listener:
  - Notified when event happens
  - Belongs to a class that is provided by the application programmer
  - Its methods describe the actions to be taken when an event occurs
  - A program indicates which events it needs to receive by installing event listener objects

- Event source:
  - Event sources report on events
  - When an event occurs, the event source notifies all event listeners
Events, Event Sources, and Event Listeners

• Example: Use JButton components for buttons; attach an ActionListener to each button

• ActionListener interface:
  public interface ActionListener
  {
      void actionPerformed(ActionEvent event);
  }

• Need to supply a class whose actionPerformed method contains instructions to be executed when button is clicked

• event parameter contains details about the event, such as the time at which it occurred

Continued
Events, Event Sources, and Event Listeners (cont.)

- Construct an object of the listener and add it to the button:
  ```java
  ActionListener listener = new ClickListener();
  button.addActionListener(listener);
  ```
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;

/**
 * An action listener that prints a message.
 */
public class ClickListener implements ActionListener {
    public void actionPerformed(ActionEvent event) {
        System.out.println("I was clicked.");
    }
}
This program demonstrates how to install an action listener.

```java
public class ButtonViewer {
    public static void main(String[] args) {
        JFrame frame = new JFrame();
        JButton button = new JButton("Click me!");
        frame.add(button);

        ActionListener listener = new ClickListener();
        button.addActionListener(listener);

        frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.setVisible(true);
    }
}
```
23:
24:    private static final int FRAME_WIDTH = 100;
25:    private static final int FRAME_HEIGHT = 60;
26: }

Output:

Figure 3   Implementing an Action Listener
Self Check 9.13

Which objects are the event source and the event listener in the ButtonViewer program?

**Answer:** The button object is the event source. The listener object is the event listener.
Self Check 9.14

Why is it legal to assign a ClickListener object to a variable of type ActionListener?

**Answer:** The ClickListener class implements the ActionListener interface.
Using Inner Classes for Listeners

• Implement simple listener classes as inner classes like this:

```java
JButton button = new JButton(". . .");
// This inner class is declared in the same method as the button variable
ActionListener
class MyListener implements ActionListener
{
    . . .
};
ActionListener listener = new MyListener();
button.addActionListener(listener);
```

• This places the trivial listener class exactly where it is needed, without cluttering up the remainder of the project

• Methods of an inner class can access local variables from surrounding blocks and fields from surrounding classes
Using Inner Classes for Listeners

• Local variables that are accessed by an inner class method must be declared as final

• **Example:** add interest to a bank account whenever a button is clicked:

```java
JButton button = new JButton("Add Interest");
final BankAccount account = new BankAccount(INITIAL_BALANCE);
// This inner class is declared in the same method as the account
// and button variables.
class AddInterestListener implements ActionListener {

Continued
```
Using Inner Classes for Listeners  (cont.)

```java
public void actionPerformed(ActionEvent event)
{
    // The listener method accesses the account variable
    // from the surrounding block
    double interest = account.getBalance() * INTEREST_RATE / 100;
    account.deposit(interest);
}
}
```

ActionListener listener = new AddInterestListener();
button.addActionListener(listener);
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import javax.swing.JButton;
import javax.swing.JFrame;

/**
 * This program demonstrates how an action listener can access
 * a variable from a surrounding block.
 */
public class InvestmentViewer1 {
    public static void main(String[] args) {
        JFrame frame = new JFrame();
        // The button to trigger the calculation
        JButton button = new JButton("Add Interest");
        frame.add(button);
    }
}
20:     // The application adds interest to this bank account
21:     final BankAccount account = new BankAccount(INITIAL_BALANCE);
22:
23:     class AddInterestListener implements ActionListener
24:     {
25:         public void actionPerformed(ActionEvent event)
26:         {
27:             // The listener method accesses the account variable
28:             // from the surrounding block
29:             double interest = account.getBalance()
30:                     * INTEREST_RATE / 100;
31:             account.deposit(interest);
32:             System.out.println("balance: " + account.getBalance());
33:         }
34:     }
35:
36:     ActionListener listener = new AddInterestListener();
37:     button.addActionListener(listener);
frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
frame.setVisible(true);
}

private static final double INTEREST_RATE = 10;
private static final double INITIAL_BALANCE = 1000;

private static final int FRAME_WIDTH = 120;
private static final int FRAME_HEIGHT = 60;

Output:
balance: 1100.0 balance: 1210.0
balance: 1331.0 balance: 1464.1

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Self Check 9.15

Why would an inner class method want to access a variable from a surrounding scope?

**Answer:** Direct access is simpler than the alternative – passing the variable as a parameter to a constructor or method.
Self Check 9.16

Why would an inner class method want to access a variable from a surrounding scope? If an inner class accesses a local variable from a surrounding scope, what special rule applies?

**Answer:** The local variable must be declared as `final`.
Building Applications with Buttons

- Example: investment viewer program; whenever button is clicked, interest is added, and new balance is displayed

![Image of an application with a button](image-url)

**Figure 4** An Application with a Button

*Continued*
Building Applications with Buttons (cont.)

• Construct an object of the JButton class:
  JButton button = new JButton("Add Interest");

• We need a user interface component that displays a message:
  JLabel label = new JLabel("balance: " + account.getBalance());

• Use a JPanel container to group multiple user interface components together:
  JPanel panel = new JPanel(); panel.add(button);
  panel.add(label); frame.add(panel);
Building Applications with Buttons

- **Listener class** adds interest and displays the new balance:

  ```java
  class AddInterestListener implements ActionListener {
      public void actionPerformed(ActionEvent event) {
          double interest = account.getBalance() * INTEREST_RATE / 100;
          account.deposit(interest);
          label.setText("balance=" + account.getBalance());
      }
  }
  ```

- **Add** AddInterestListener as inner class so it can have access to surrounding **final variables** (account and label)
ch09/button3/InvestmentViewer2.java

01: import java.awt.event.ActionEvent;
02: import java.awt.event.ActionListener;
03: import javax.swing.JButton;
04: import javax.swing.JFrame;
05: import javax.swing.JLabel;
06: import javax.swing.JPanel;
07: import javax.swing.JTextField;
08: 
09: /**
10:   * This program displays the growth of an investment.
11:   */
12: public class InvestmentViewer2
13: {
14:   public static void main(String[] args)
15:   {
16:     JFrame frame = new JFrame();
17:     // The button to trigger the calculation
18:     JButton button = new JButton("Add Interest");
19:     Continued
20: // The application adds interest to this bank account
21: final BankAccount account = new BankAccount(INITIAL_BALANCE);
22: // The label for displaying the results
23: final JLabel label = new JLabel("balance: " + account.getBalance());
24: // The panel that holds the user interface components
25: JPanel panel = new JPanel();
26: panel.add(button);
27: panel.add(label);
28: frame.add(panel);
29: class AddInterestListener implements ActionListener
30: {
31:     public void actionPerformed(ActionEvent event)
32:     {
33:         double interest = account.getBalance()
34:             * INTEREST_RATE / 100;
35:     }
36: }
Continued
account.deposit(interest);
label.setText("balance: " + account.getBalance());

ActionListener listener = new AddInterestListener();
button.addActionListener(listener);
frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
frame.setVisible(true);

private static final double INTEREST_RATE = 10;
private static final double INITIAL_BALANCE = 1000;
private static final int FRAME_WIDTH = 400;
private static final int FRAME_HEIGHT = 100;
Self Check 9.17

How do you place the "balance: . . ." message to the left of the "Add Interest" button?

**Answer:** First add label to the panel, then add button.
Self Check 9.18

Why was it not necessary to declare the `button` variable as `final`?

**Answer:** The `actionPerformed` method does not access that variable.
Processing Timer Events

- `javax.swing.Timer` generates equally spaced timer events
- Useful whenever you want to have an object updated in regular intervals
- Sends events to action listener

```java
public interface ActionListener {
    void actionPerformed(ActionEvent event);
}
```
• Define a class that implements the `ActionListener` interface

```java
class MyListener implements ActionListener {
    void actionPerformed(ActionEvent event) {
        // This action will be executed at each timer event
        Place listener action here
    }
}
```

• Add listener to timer

```java
MyListener listener = new MyListener();
Timer t = new Timer(interval, listener);
t.start();
```
01:  import java.awt.Graphics;
02:  import java.awt.Graphics2D;
03:  import java.awt.Rectangle;
04:  import javax.swing.JComponent;
05:  
06:  /**
07:   * This component displays a rectangle that can be moved.
08:   */
09:  public class RectangleComponent extends JComponent
10:  {
11:     public RectangleComponent()
12:     {
13:         // The rectangle that the paint method draws
14:         box = new Rectangle(BOX_X, BOX_Y,
15:                 BOX_WIDTH, BOX_HEIGHT);
16:     }
17:     
18:     public void paintComponent(Graphics g)
19:     {
20:         super.paintComponent(g);
21:         Graphics2D g2 = (Graphics2D) g;
22:         

Continued
ch09/timer/RectangleComponent.java

```java
23:     g2.draw(box);
24: }
25:
26:     /**
27:      * Moves the rectangle by a given amount.
28:      * @param x the amount to move in the x-direction
29:      * @param y the amount to move in the y-direction
30:     */
31:     public void moveBy(int dx, int dy)
32:     {
33:         box.translate(dx, dy);
34:         repaint();
35:     }
36:
37:     private Rectangle box;
38:
39:     private static final int BOX_X = 100;
40:     private static final int BOX_Y = 100;
41:     private static final int BOX_WIDTH = 20;
42:     private static final int BOX_HEIGHT = 30;
43: }
```

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• Displays a rectangle that can be moved

• The `repaint` method causes a component to repaint itself. Call this method whenever you modify the shapes that the `paintComponent` method draws

Continued
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import javax.swing.JFrame;
import javax.swing.Timer;

public class RectangleMover {
    public static void main(String[] args) {
        JFrame frame = new JFrame();
        frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
        frame.setTitle("An animated rectangle");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

        final RectangleComponent component = new RectangleComponent();
        frame.add(component);
        frame.setVisible(true);
    }
}

Continued
class TimerListener implements ActionListener
{
    public void actionPerformed(ActionEvent event)
    {
        component.moveBy(1, 1);
    }
}

EventListener listener = new TimerListener();

final int DELAY = 100; // Milliseconds between timer ticks
Timer t = new Timer(DELAY, listener);
t.start();

private static final int FRAME_WIDTH = 300;
private static final int FRAME_HEIGHT = 400;
Why does a timer require a listener object?

**Answer:** The timer needs to call some method whenever the time interval expires. It calls the `actionPerformed` method of the listener object.
Self Check 9.20

What would happen if you omitted the call to `repaint` in the `moveBy` method?

**Answer:** The moved rectangles won't be painted, and the rectangle will appear to be stationary until the frame is repainted for an external reason.
Mouse Events

• Use a mouse listener to capture mouse events
• Implement the MouseListener interface:

```java
public interface MouseListener {
    void mousePressed(MouseEvent event);
    // Called when a mouse button has been pressed on a component
    void mouseReleased(MouseEvent event);
    // Called when a mouse button has been released on a component
    void mouseClicked(MouseEvent event);
    // Called when the mouse has been clicked on a component
    void mouseEntered(MouseEvent event);
    // Called when the mouse enters a component
```
Mouse Events

```java
void mouseExited(MouseEvent event);
// Called when the mouse exits a component }
```

- `mousePressed, mouseReleased`: called when a mouse button is pressed or released
- `mouseClicked`: if button is pressed and released in quick succession, and mouse hasn't moved
- `mouseEntered, mouseExited`: mouse has entered or exited the component's area
Mouse Events

• Add a mouse listener to a component by calling the addMouseListener method:

```java
public class MyMouseListener implements MouseListener {
    // Implements five methods
}
MouseListener listener = new MyMouseListener();
component.addMouseListener(listener);
```

• Sample program: enhance RectangleComponent – when user clicks on rectangle component, move the rectangle
import java.awt.Graphics;
import java.awt.Graphics2D;
import java.awt.Rectangle;
import javax.swing.JComponent;

public class RectangleComponent extends JComponent {

    public RectangleComponent() {
        // The rectangle that the paint method draws
        box = new Rectangle(BOX_X, BOX_Y, BOX_WIDTH, BOX_HEIGHT);
    }

    public void paintComponent(Graphics g) {
        super.paintComponent(g);
        Graphics2D g2 = (Graphics2D) g;
    }

23:     g2.draw(box);
24: }
25:
26:     /**
27:      * Moves the rectangle to the given location.
28:      * @param x the x-position of the new location
29:      * @param y the y-position of the new location
30:      */
31:     public void moveTo(int x, int y)
32:     {
33:         box.setLocation(x, y);
34:         repaint();
35:     }
36:
37:     private Rectangle box;
38:
39:     private static final int BOX_X = 100;
40:     private static final int BOX_Y = 100;
41:     private static final int BOX_WIDTH = 20;
42:     private static final int BOX_HEIGHT = 30;
43: }
Mouse Events

• Call `repaint` when you modify the shapes that `paintComponent` draws:
  
  ```java
  box.setLocation(x, y); repaint();
  ```

• Mouse listener: if the mouse is pressed, `listener` moves the rectangle to the mouse location class `MousePressListener` implements

  ```java
  public class MousePressListener implements MouseListener {
      public void mousePressed(MouseEvent event) {
          int x = event.getX();
          int y = event.getY();
          component.moveTo(x, y);
      }
  }
  ```

Continued
Mouse Events

• // Do-nothing methods
  public void mouseReleased(MouseEvent event) {}  
  public void mouseClicked(MouseEvent event) {}  
  public void mouseEntered(MouseEvent event) {}  
  public void mouseExited(MouseEvent event) {}  
}

• All five methods of the interface must be implemented; unused methods can be empty
RectangleComponentViewer Program Output

Figure 5  Clicking the Mouse Moves the Rectangle
import java.awt.event.MouseAdapter;
import java.awt.event.MouseEvent;
import javax.swing.JFrame;

public class RectangleComponentViewer {
    public static void main(String[] args) {
        final RectangleComponent component = new RectangleComponent();
        // Add mouse press listener
        class MousePressListener implements MouseListener {
            public void mousePressed(MouseEvent event) {
                int x = event.getX();
                int y = event.getY();
                component.moveTo(x, y);
            }
        }
    }
}

This program displays a RectangleComponent. */
// Do-nothing methods
public void mouseReleased(MouseEvent event) {}
public void mouseClicked(MouseEvent event) {}
public void mouseEntered(MouseEvent event) {}
public void mouseExited(MouseEvent event) {}

MouseListener listener = new MousePressListener();
component.addMouseListener(listener);

JFrame frame = new JFrame();
frame.add(component);
frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
frame.setVisible(true);

private static final int FRAME_WIDTH = 300;
private static final int FRAME_HEIGHT = 400;
Self Check 9.21

Why was the `moveBy` method in the `RectangleComponent` replaced with a `moveTo` method?

**Answer:** Because you know the current mouse position, not the amount by which the mouse has moved.
Self Check 9.22

Why must the `MousePressListener` class supply five methods?

**Answer:** It implements the `MouseListener` interface, which has five methods.