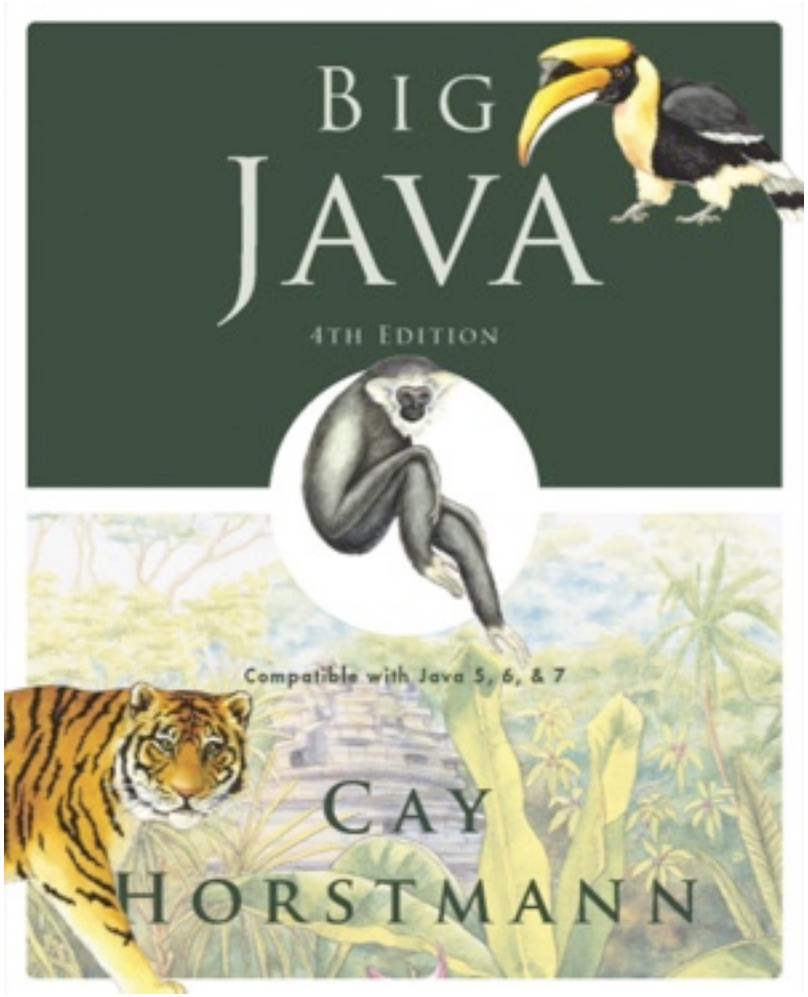
ICOM 4015: Advanced Programming

Lecture 9

Reading: Chapter Nine: Interphases and Polymorphism



Chapter 9 – Interfaces and Polymorphism

Chapter Goals

- To be able to declare and use interface types
- 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 implement event listeners in graphical applications

Using Interfaces for Algorithm 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 *numbers*
- What if we want to find the average and maximum of a set of `BankAccount` values?

Using Interfaces for Algorithm Reuse

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

   public BankAccount getMaximum()
   {
      return maximum;
   }
}
```

Using Interfaces for Algorithm 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:

```
public class DataSet // Modified for Coin objects
{
   private double sum;
   private Coin maximum;
   private int count;
   ...
   public void add(Coin x)
   {
      sum = sum + x.getValue();
      if (count == 0 || maximum.getValue() <
         x.getValue()) maximum = x;
      count++;
   }
```

Using Interfaces for Algorithm Reuse

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

Using Interfaces for Algorithm Reuse

- The algorithm for the data analysis service 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++;
```

Using Interfaces for Algorithm Reuse

- 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:

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

- Interface declaration lists all methods that the interface type requires

Syntax 9.1 Declaring an Interface

Syntax

```
public interface InterfaceName
{
   method signatures
}
```

Example

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

The methods of an interface are automatically public.

No implementation is provided.

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

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

   public Measurable getMaximum()
   {
      return maximum;
   }
}
```

Implementing an Interface Type

- Use `implements` reserved word to indicate that a class implements an interface type:

```
public class BankAccount implements Measurable
{
   public double getMeasure()
   {
      ...
      return balance;
   }
}
```

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

Implementing an Interface Type

- Another example:

```
public class Coin implements Measurable
{
   public double getMeasure()
   {
      return value;
   }
   ...
}
```

Code Reuse

- A service type such as DataSet specifies an interface for participating in the service
- Use interface types to make code more reusable

Figure 1
Attachments Conform to the Mixer's Interface

Syntax 9.2 Implementing an Interface

Syntax

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

Example

```
public class BankAccount implements Measurable
{
   . . .
   public double getMeasure()
   {
      return balance;
   }
   . . .
}
```

List all interface types that this class implements.

BankAccount instance variables

This method provides the implementation for the method declared in the interface.

Other BankAccount methods

UML Diagram of `DataSet` and Related Classes

- 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* from `BankAccount` and `Coin`

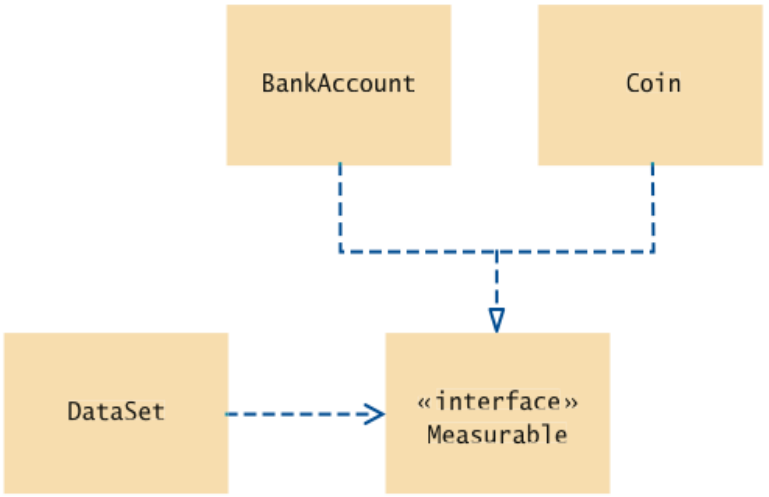


Figure 2 UML Diagram of the `DataSet` Class and the Classes that Implement the `Measurable` Interface

ch09/measure1/DataSetTester.java

```
/**
   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");

      DataSet coinData = new DataSet();
```

Continued

ch09/measure1/DataSetTester.java (cont.)

```
coinData.add(new Coin(0.25, "quarter"));
coinData.add(new Coin(0.1, "dime"));
coinData.add(new Coin(0.05, "nickel"));

System.out.println("Average coin value: " + coinData.getAverage());
System.out.println("Expected: 0.133");
max = coinData.getMaximum();
System.out.println("Highest coin value: " + max.getMeasure());
System.out.println("Expected: 0.25");
}
}
```

ch09/measure1/DataSetTester.java (cont.)

Program Run:

```
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
```

Self Check 9.1

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
- ```
  BankAccount account = new BankAccount(10000);
  Measurable x = account; // OK
  ```
- ```
  Coin dime = new Coin(0.1, "dime");
  Measurable x = dime; // Also OK
  ```
- Cannot convert between unrelated types:

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

  Because `Rectangle` doesn't implement `Measurable`

Variables of Class and Interface Types

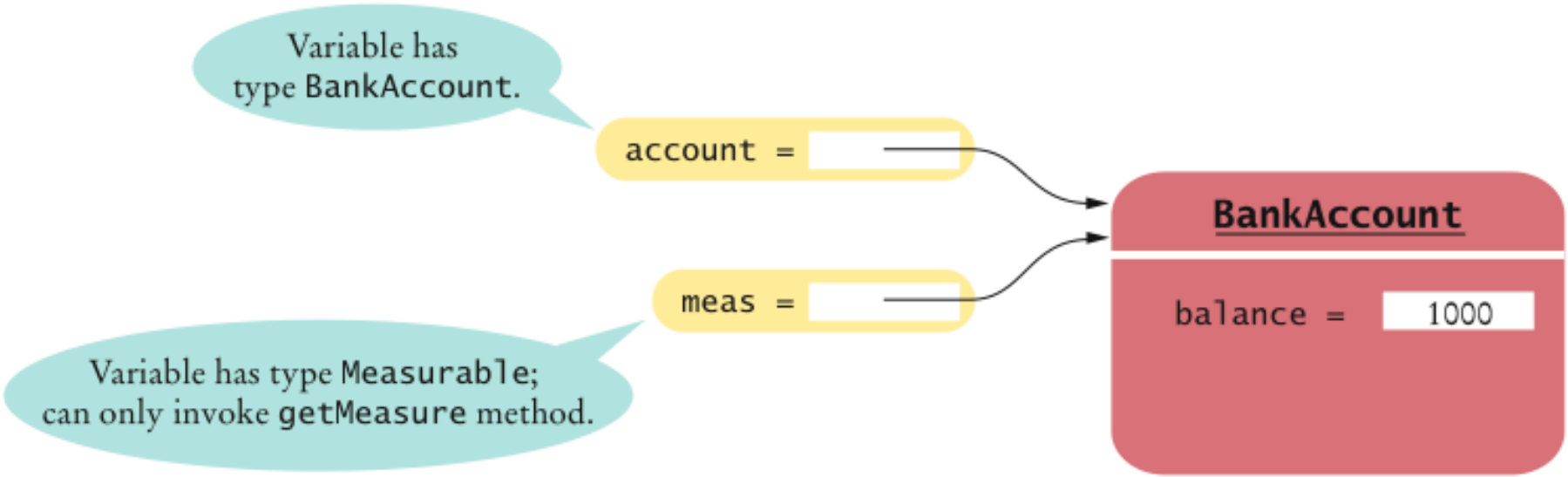


Figure 3 Variables of Class and Interface Types

Casts

- Add `Coin` objects to `DataSet`:

```
DataSet coinData = new DataSet();
coinData.add(new Coin(0.25, "quarter"));
coinData.add(new Coin(0.1, "dime"));
coinData.add(new Coin(0.05, "nickel"));
Measurable max = coinData.getMaximum(); // Get the largest coin
```

- What can you do with `max`? It's not of type `Coin`:

```
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:

```
Coin maxCoin = (Coin) max;
String name = maxCoin.getName();
```

Casts

- If you are wrong and `max` isn't a coin, the program throws an exception and terminates
- 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*

Self Check 9.3

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

- An interface variable holds a reference to object of a class that implements the interface:

```
Measurable meas;
meas = new BankAccount(10000);
meas = new Coin(0.1, "dime");
```

  Note that the object to which `meas` 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 = meas.getMeasure();
```

- Which method is called?

Interface Reference

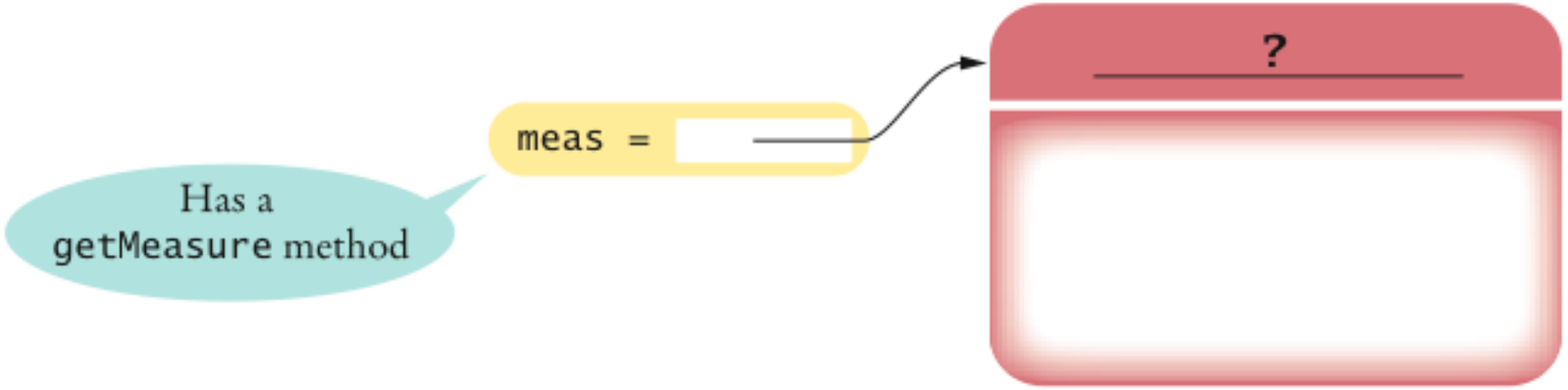


Figure 4 An Interface Reference Can Refer to an Object of Any Class that Implements the Interface

Polymorphism

- When the virtual machine calls an instance method, it locates the method of the implicit parameter's class — called *dynamic method lookup*
- If `meas` refers to a `BankAccount` object, then `meas.getMeasure()` calls the `BankAccount.getMeasure` method
- If `meas` refers to a `Coin` object, then method `Coin.getMeasure` is called
- Polymorphism (many shapes) denotes the ability to treat objects with differences in behavior in a uniform way

Animation 9.1: 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.

Self Check 9.7

What does this code fragment print? Why is this an example of polymorphism?

```
DataSet data = new DataSet();
data.add(new BankAccount(1000));
data.add(new Coin(0.1, "dime"));
System.out.println(data.getAverage());
```

Answer: The code fragment prints 500.05. Each call to `add` results in a call `x.getMeasure()`. In the first call, `x` is a `BankAccount`. In the second call, `x` is a `Coin`. A different `getMeasure` method is called in each case. The first call returns the account balance, the second one the coin value.

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:** a mechanism for specifying code that is executed at a later time
- In previous `DataSet` implementation, responsibility of measuring lies with the added objects themselves

Using Interfaces for Callbacks

- Alternative: Hand the object to be measured to a method of an interface:

```
public interface Measurer
{
   double measure(Object anObject);
}
```

- `Object` is the "lowest common denominator" of all classes

Using Interfaces for Callbacks

- The code that makes the call to the callback receives an object of class that implements this interface:

```
public DataSet(Measurer aMeasurer)
{
   sum = 0;
   count = 0;
   maximum = null;
   measurer = aMeasurer; // Measurer instance variable
}
```

- The measurer instance variable carries out the measurements:

```
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

- A specific callback is obtained by implementing the Measurer interface:

```
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;
```

Using Interfaces for Callbacks

- 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

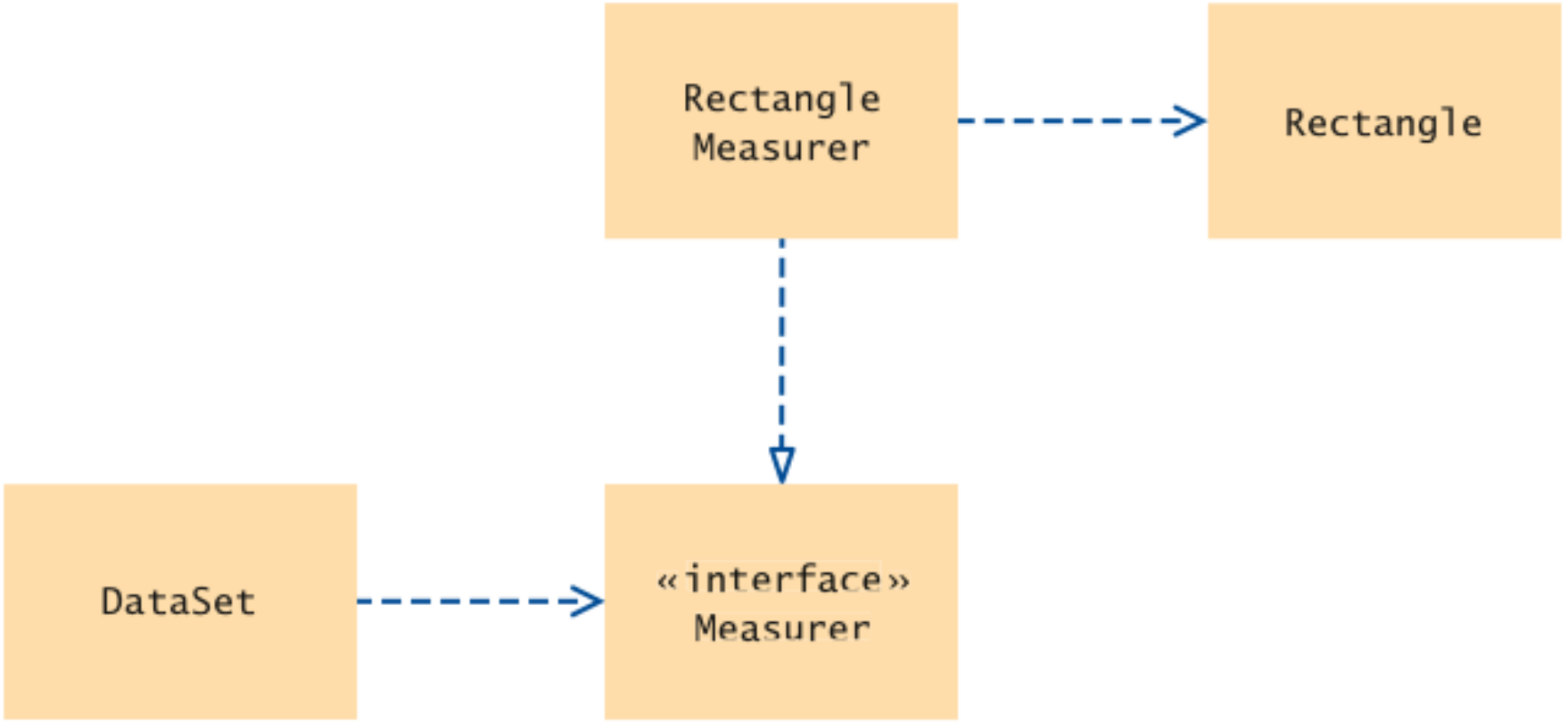


Figure 5 UML Diagram of the DataSet Class and the Measurer Interface

ch09/measure2/Measurer.java

```
/**
   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);
}
```

ch09/measure2/RectangleMeasurer.java

```
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;
   }
}
```

ch09/measure2/DataSet.java

```
/**
   Computes the average of a set of data values.
*/
public class DataSet
{
   private double sum;
   private Object maximum;
   private int count;
   private Measurer measurer;

   /**
      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;
   }
```

Continued

ch09/measure2/DataSet.java (cont.)

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

/**
   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;
}
```

Continued

ch09/measure2/DataSet.java (cont.)

```
   /**
      Gets the largest of the added data.
      @return the maximum or 0 if no data has been added
   */
   public Object getMaximum()
   {
      return maximum;
   }
}
```

ch09/measure2/DataSetTester2.java

```
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");
```

Continued

ch09/measure2/DataSetTester2.java (cont.)

```
         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]");
      }
   }
```

Program Run:

```
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]
```

Self Check 9.8

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 9.9

How can you use the `DataSet` class of this section to find the longest `String` from a set of inputs?

Answer: Implement a class `StringMeasurer` that implements the `Measurer` 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.

Inner Classes

- Trivial class can be declared inside a method:

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

Inner Classes

- If inner class is declared inside an enclosing class, but outside its methods, it is available to all methods of enclosing class:

```
public class DataSetTester3
{
   class RectangleMeasurer implements Measurer
   {
      . . .
   }

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

Inner Classes

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

```
DataSetTester$1$RectangleMeasurer.class
```

ch09/measure3/DataSetTester3.java

```
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;
         }
      }

      Measurer m = new RectangleMeasurer();

      DataSet data = new DataSet(m);
```

Continued

ch09/measure3/DataSetTester3.java (cont.)

```
         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?

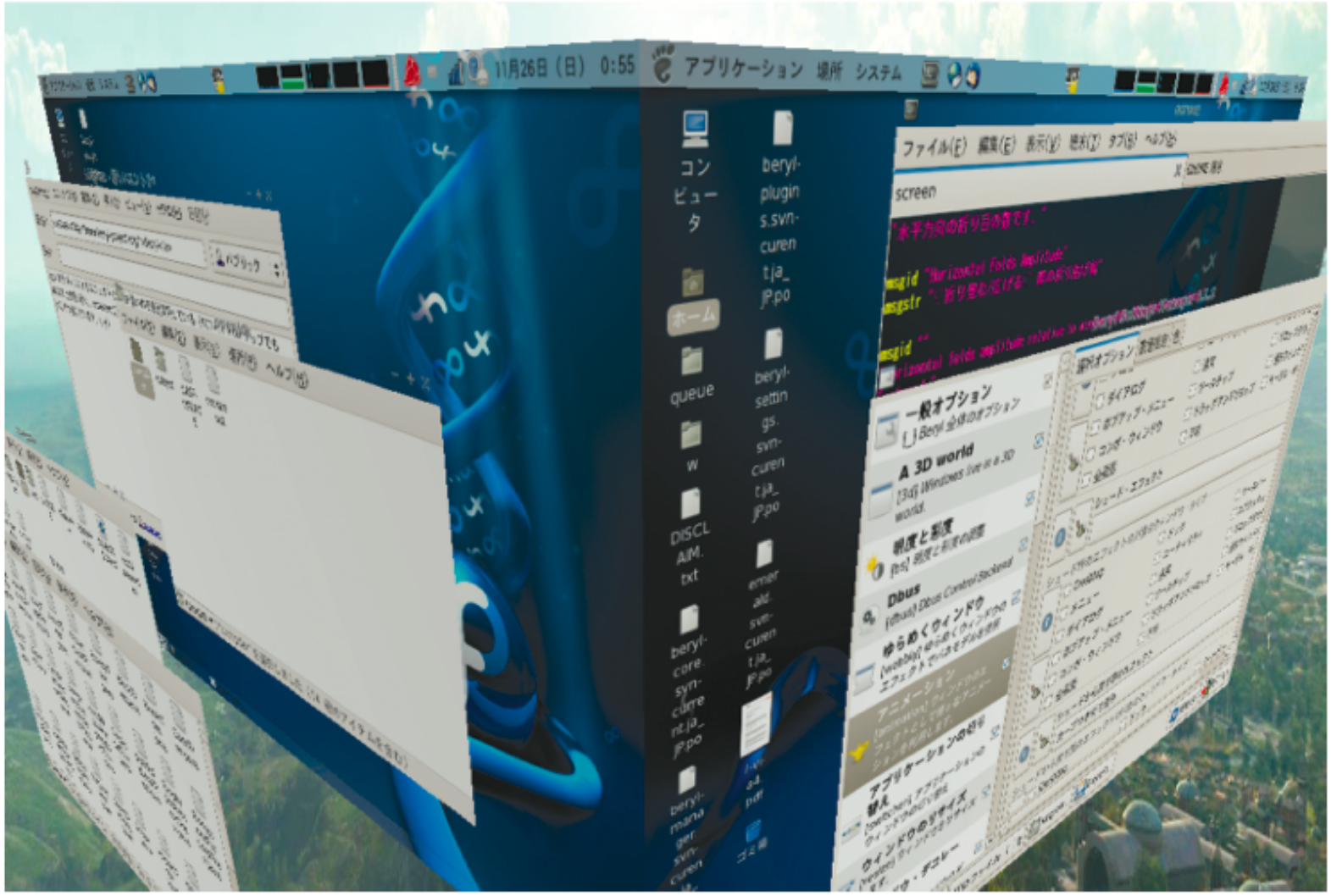
Answer: Inner classes are convenient for insignificant classes. Also, their methods can access variables and fields from the surrounding scope.

Self Check 9.12

How many class files are produced when you compile the `DataSetTester3` program?

Answer: Four: one for the outer class, one for the inner class, and two for the `DataSet` and `Measurer` classes.

Operating Systems



A Graphical Software Environment for the Linux Operating System

Mock Objects

- Want to test a class before the entire program has been completed
- A **mock object** provides the same services as another object, but in a simplified manner
- **Example:** a grade book application, `GradingProgram`, manages quiz scores using class `GradeBook` with methods:

```
public void addScore(int studentId, double score)
public double getAverageScore(int studentId)
public void save(String filename)
```

- Want to test `GradingProgram` without having a fully functional `GradeBook` class

Mock Objects

- Declare an interface type with the same methods that the `GradeBook` class provides
  - *Convention: use the letter `I` as a prefix for the interface name:*

```
public interface IGradeBook
{
   void addScore(int studentId, double score);
   double getAverageScore(int studentId);
   void save(String filename);
   . . .
}
```

- The `GradingProgram` class should *only* use this interface, never the `GradeBook` class which implements this interface

Mock Objects

- Meanwhile, provide a simplified mock implementation, restricted to the case of one student and without saving functionality:

```
public class MockGradeBook implements IGradeBook
{
   private ArrayList<Double> scores;
   public void addScore(int studentId, double score)
   {
      // Ignore studentId
      scores.add(score);
   }
   double getAverageScore(int studentId)
   {
      double total = 0;
      for (double x : scores) { total = total + x; }
      return total / scores.size();
   }
   void save(String filename)
   {
      // Do nothing
   }
   . . .
}
```

Mock Objects

- Now construct an instance of `MockGradeBook` and use it immediately to test the `GradingProgram` class
- When you are ready to test the actual class, simply use a `GradeBook` instance instead
- Don't erase the mock class — it will still come in handy for regression testing

Self Check 9.13

Why is it necessary that the real class and the mock class implement the same interface type?

Answer: You want to implement the `GradingProgram` class in terms of that interface so that it doesn't have to change when you switch between the mock class and the actual class.

Self Check 9.14

Why is the technique of mock objects particularly effective when the `GradeBook` and `GradingProgram` class are developed by two programmers?

Answer: Because the developer of `GradingProgram` doesn't have to wait for the `GradeBook` class to be complete.

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

Events, Event Sources, and Event Listeners

- **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:**
  - *User interface component that generates a particular event*
  - *Add an event listener object to the appropriate event source*
  - *When an event occurs, the event source notifies all event listeners*

Events, Event Sources, and Event Listeners

- Example: A program that prints a message whenever a button is clicked:

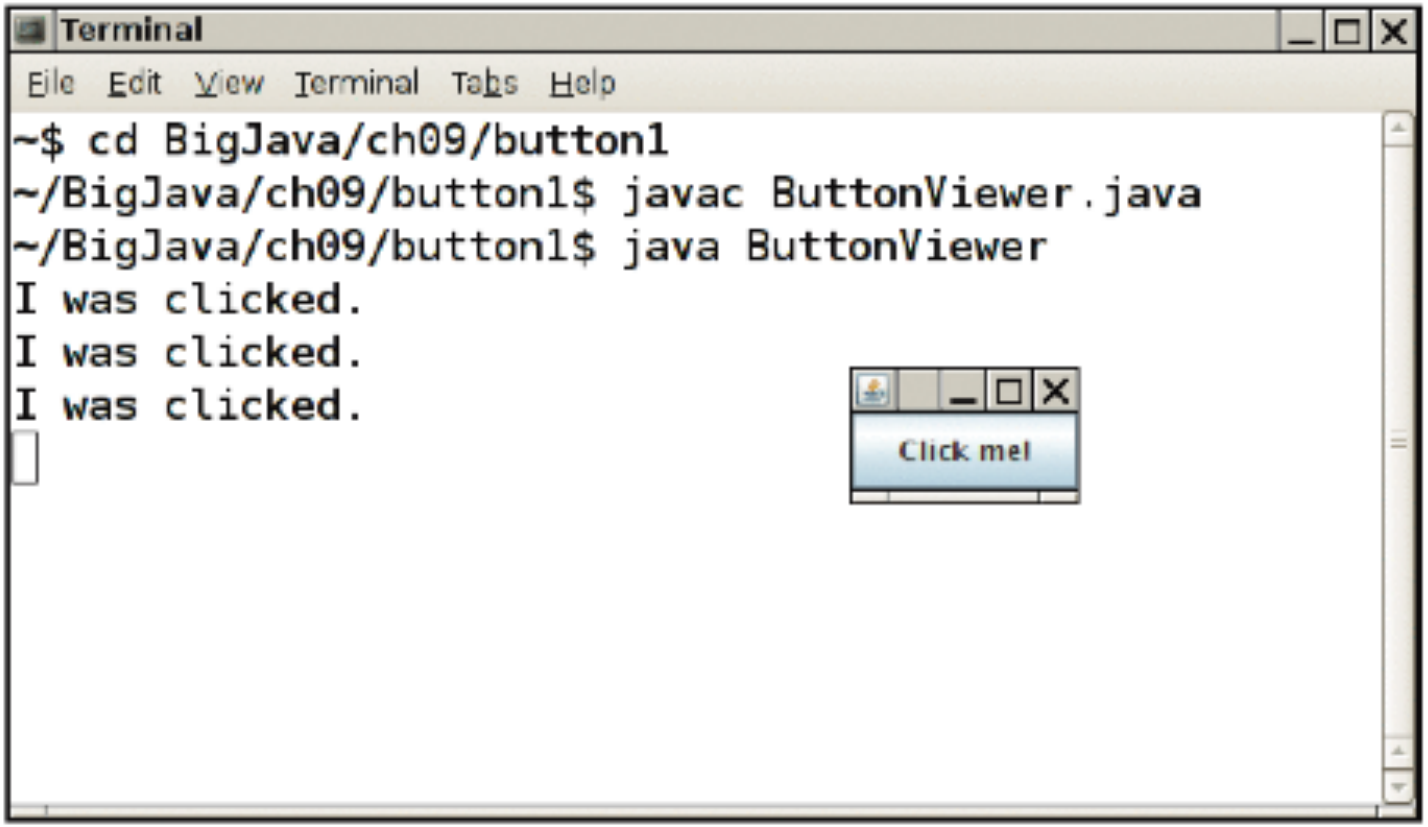


Figure 6 Implementing an Action Listener

Events, Event Sources, and Event Listeners

- 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

Events, Event Sources, and Event Listeners

- Construct an object of the listener and add it to the button:

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

ch09/button1/ClickListener.java

```
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.");
   }
}
```

ch09/button1/ButtonViewer.java

```
import java.awt.event.ActionListener;
import javax.swing.JButton;
import javax.swing.JFrame;

/**
   This program demonstrates how to install an action listener.
*/
public class ButtonViewer
{
   private static final int FRAME_WIDTH = 100;
   private static final int FRAME_HEIGHT = 60;

   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);
```

Continued

ch09/button1/ButtonViewer.java (cont.)

```
        frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.setVisible(true);
    }
}
```

Self Check 9.15

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 9.16

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:

```
JButton button = new JButton("...");
// This inner class is declared in the same method as the
// button variable
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

Using Inner Classes for Listeners

- Methods of an inner class can access the variables from the enclosing scope
  - *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:

Using Inner Classes for Listeners

```
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
{
   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);
```

ch09/button2/InvestmentViewer1.java

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

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

   public static void main(String[] args)
   {
      JFrame frame = new JFrame();
```

Continued

ch09/button2/InvestmentViewer1.java (cont.)

```
// The button to trigger the calculation
JButton button = new JButton("Add Interest");
frame.add(button);

// The application adds interest to this bank account
final BankAccount account = new BankAccount(INITIAL_BALANCE);

class AddInterestListener implements ActionListener
{
   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);
      System.out.println("balance: " + account.getBalance());
   }
}
```

Continued

ch09/button2/InvestmentViewer1.java (cont.)

```
      ActionListener listener = new AddInterestListener();
      button.addActionListener(listener);

      frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
      frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      frame.setVisible(true);
   }
}
```

Program Run:

```
balance: 1100.0
balance: 1210.0
balance: 1331.0
balance: 1464.1
```

Self Check 9.17

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 9.18

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

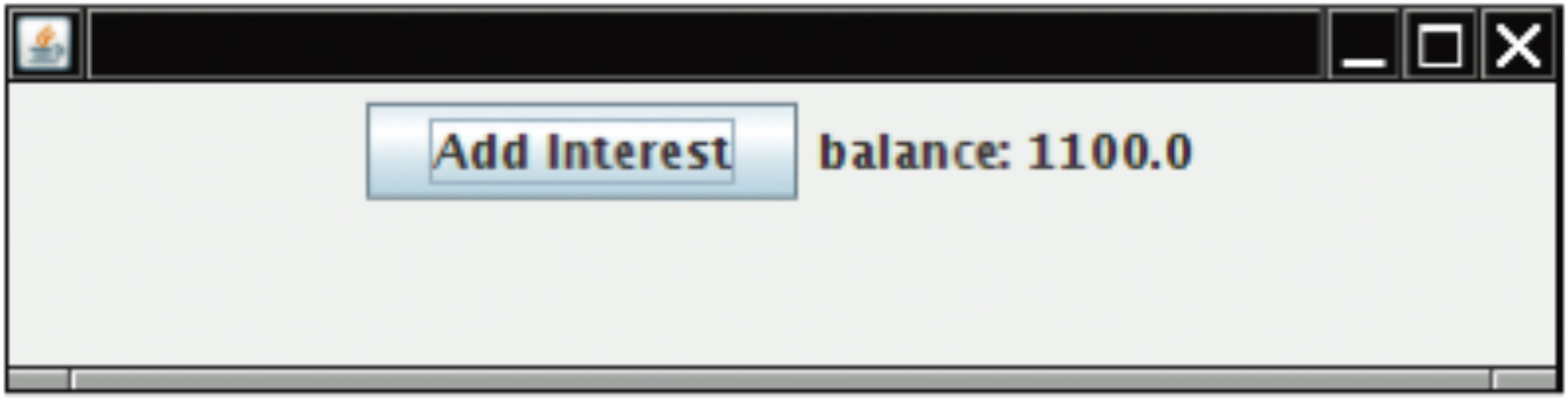


Figure 7 An Application with a Button

Building Applications with Buttons

- 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:

```
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

```
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import javax.swing.JButton;
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;
import javax.swing.JTextField;

/**
   This program displays the growth of an investment.
*/
public class InvestmentViewer2
{
   private static final int FRAME_WIDTH = 400;
   private static final int FRAME_HEIGHT = 100;

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

   public static void main(String[] args)
   {
      JFrame frame = new JFrame();
```

Continued

ch09/button3/InvestmentViewer2.java (cont.)

```
// The button to trigger the calculation
JButton button = new JButton("Add Interest");

// The application adds interest to this bank account
final BankAccount account = new BankAccount(INITIAL_BALANCE);

// The label for displaying the results
final JLabel label = new JLabel("balance: " + account.getBalance());

// The panel that holds the user interface components
JPanel panel = new JPanel();
panel.add(button);
panel.add(label);
frame.add(panel);
```

Continued

ch09/button3/InvestmentViewer2.java (cont.)

```
      class AddInterestListener implements ActionListener
      {
         public void actionPerformed(ActionEvent event)
         {
            double interest = account.getBalance() * INTEREST_RATE / 100;
            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);
   }
}
```

Self Check 9.19

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 9.20

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, sending events to installed action listeners
- Useful whenever you want to have an object updated in regular intervals

Processing Timer Events

- Declare a class that implements the `ActionListener` interface:

```
class MyListener implements ActionListener
{
   void actionPerformed(ActionEvent event)
   {
      Listener action (executed at each timer event)
   }
}
```

- Add listener to timer and start timer:

```
MyListener listener = new MyListener();
Timer t = new Timer(interval, listener);
t.start();
```

ch09/timer/RectangleComponent.java

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

```
import java.awt.Graphics;
import java.awt.Graphics2D;
import java.awt.Rectangle;
import javax.swing.JComponent;

/**
   This component displays a rectangle that can be moved.
*/
public class RectangleComponent extends JComponent
{
   private static final int BOX_X = 100;
   private static final int BOX_Y = 100;
   private static final int BOX_WIDTH = 20;
   private static final int BOX_HEIGHT = 30;
```

Continued

ch09/timer/RectangleComponent.java (cont.)

```
private Rectangle box;

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

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

   g2.draw(box);
}
```

Continued

ch09/timer/RectangleComponent.java (cont.)

```
   /**
      Moves the rectangle by a given amount.
      @param x the amount to move in the x-direction
      @param y the amount to move in the y-direction
   */
   public void moveBy(int dx, int dy)
   {
      box.translate(dx, dy);
      repaint();
   }
}
```

ch09/timer/RectangleMover.java

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

/**
   This program moves the rectangle.
*/
public class RectangleMover
{
   private static final int FRAME_WIDTH = 300;
   private static final int FRAME_HEIGHT = 400;

   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);
```

Continued

ch09/timer/RectangleMover.java (cont.)

```
      final RectangleComponent component = new RectangleComponent();
      frame.add(component);

      frame.setVisible(true);

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

      ActionListener listener = new TimerListener();

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

Self Check 9.21

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 9.22

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:

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

Mouse Events

- `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:

```
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

ch09/mouse/RectangleComponent.java

```
import java.awt.Graphics;
import java.awt.Graphics2D;
import java.awt.Rectangle;
import javax.swing.JComponent;

/**
   This component displays a rectangle that can be moved.
*/
public class RectangleComponent extends JComponent
{
   private static final int BOX_X = 100;
   private static final int BOX_Y = 100;
   private static final int BOX_WIDTH = 20;
   private static final int BOX_HEIGHT = 30;

   private Rectangle box;

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

Continued

ch09/mouse/RectangleComponent.java (cont.)

```
   public void paintComponent(Graphics g)
   {
      Graphics2D g2 = (Graphics2D) g;

      g2.draw(box);
   }

   /**
      Moves the rectangle to the given location.
      @param x the x-position of the new location
      @param y the y-position of the new location
   */
   public void moveTo(int x, int y)
   {
      box.setLocation(x, y);
      repaint();
   }
}
```

Mouse Events

- Call `repaint` when you modify the shapes that `paintComponent` draws:

```
box.setLocation(x, y);
repaint();
```

Mouse Events

- Mouse listener: if the mouse is pressed, `listener` moves the rectangle to the mouse location:

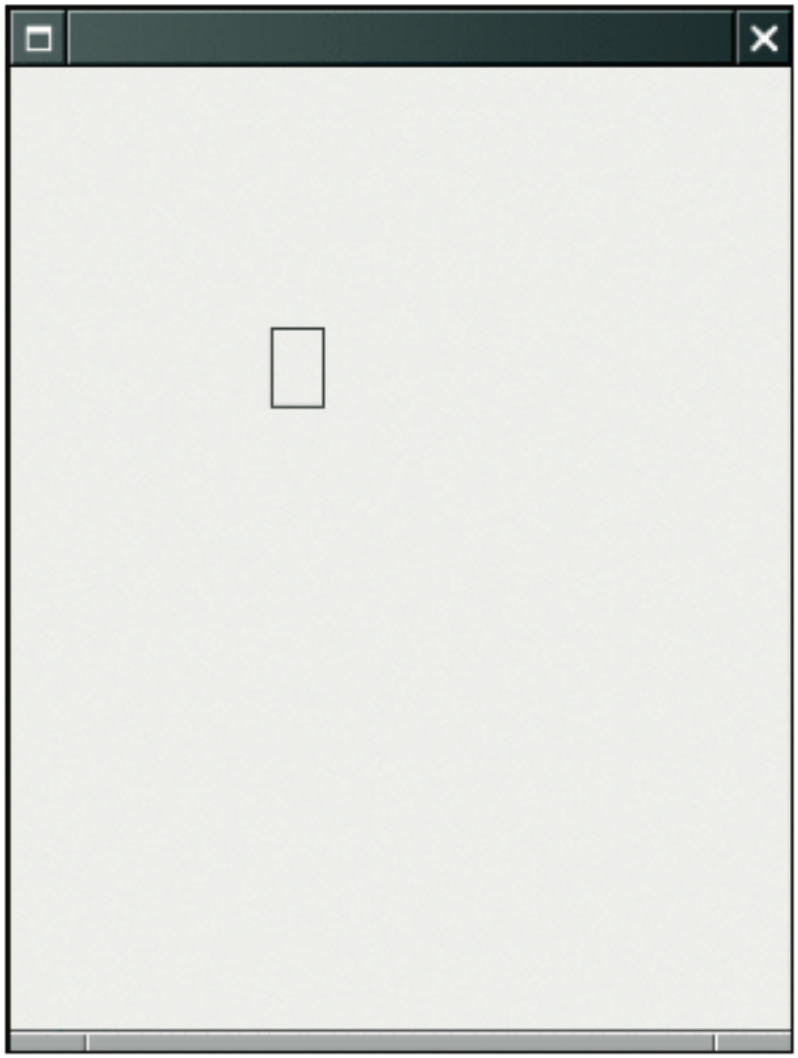
```
class MousePressListener implements MouseListener
{
   public void mousePressed(MouseEvent event)
   {
      int x = event.getX();
      int y = event.getY();
      component.moveTo(x, y);

   }
   // 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 Run

Figure 8
Clicking the Mouse Moves the Rectangle



ch09/mouse/RectangleComponentViewer.java

```
import java.awt.event.MouseListener;
import java.awt.event.MouseEvent;
import javax.swing.JFrame;

/**
   This program displays a RectangleComponent.
*/
public class RectangleComponentViewer
{
   private static final int FRAME_WIDTH = 300;
   private static final int FRAME_HEIGHT = 400;

   public static void main(String[] args)
   {
      final RectangleComponent component = new RectangleComponent();
```

Continued

ch09/mouse/RectangleComponentViewer.java (cont.)

```
// 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);
   }

   // 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);
```

Continued

ch09/mouse/RectangleComponentViewer.java (cont.)

```
         JFrame frame = new JFrame();
         frame.add(component);

         frame.setSize(FRAME_WIDTH, FRAME_HEIGHT);
         frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
         frame.setVisible(true);
      }
   }
```

Self Check 9.23

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 9.24

Why must the `MousePressListener` class supply five methods?

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