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Java Programming Tutorial

Programming Graphical User Interface (GUI)

1. Introduction

So far, we have covered most of the basic constructs of Java and introduced the important concept of Object-Oriented Programming (OOP). As discussed, OOP permits higher level of abstraction than the traditional procedural-oriented languages (such as C and Pascal). OOP lets you think in the problem space rather than the computer's bits and bytes. You can create high-level abstract data types called *classes* to mimic real-life things and represent entities in the problem space. These classes are self-contained and are reusable.

In this article, I shall show you how you can reuse the graphics classes provided in JDK for constructing your own Graphical User Interface (GUI) applications. Writing your own graphics classes (re-inventing the wheels) will take you many years! These graphics classes, developed by expert programmers, are highly complex and involve many advanced Java concepts. However, re-using them are not so difficult, if you follow the API documentation, samples and templates provided.

I shall also describe an important concept called *nested class* (or *inner class*) in this article.

There are two sets of Java APIs for graphics programming: AWT (Abstract Windowing Toolkit) and Swing.

1. AWT API was introduced in JDK 1.0. Most of the AWT components have become obsolete and should be replaced by newer Swing components.
2. Swing API, a much more comprehensive set of graphics libraries that enhances the AWT, was introduced as part of Java Foundation Classes (JFC) after the release of JDK 1.1. JFC, which consists of Swing, Java2D, Accessibility API, Internationalization, and Pluggable Look-and-Feel Support, was an add-on to JDK 1.1 but has been integrated into core Java since JDK 1.2.

Other than AWT/Swing Graphics APIs provided in JDK, others have also provided Graphics APIs that work with Java, such as Eclipse's Standard Widget Toolkit (SWT), Google Web Toolkit (GWT), 3D Graphics API ssuch as Java bindings for OpenGL (JOGL) and Java3D.

You need to check the JDK API specification (http://docs.oracle.com/javase/7/docs/api/index.html) for the AWT and Swing APIs while reading this chapter. The best online reference for Graphics programming is the "Swing Tutorial" @ http://docs.oracle.com/javase/tutorial/uiswing/. For advanced 2D graphics programming, read "Java 2D Tutorial" (@ http://docs.oracle.com/javase/tutorial/2d/index.html).

2. Programming GUI with AWT

Java Graphics APIs - AWT and Swing - provide a huge set of reusable GUI components, such as button, text field, label, choice, panel and frame for building GUI applications. You can simply reuse these classes rather than re-invent the wheels. I shall start with the AWT classes before moving into Swing to give you a complete picture. I have to stress that many AWT component classes are now obsolete. They are used only in exceptional circumstances when the JRE supports only JDK 1.1.

2.1 AWT Packages

AWT is huge! It consists of 12 packages (Swing is even bigger, with 18 packages as of JDK 1.7!). Fortunately, only 2 packages - `java.awt` and `java.awt.event` - are commonly-used.

1. The `java.awt` package contains the *core* AWT graphics classes:
   - GUI Component classes (such as `Button`, `TextField`, and `Label`),
   - GUI Container classes (such as `Frame`, `Panel`, `Dialog` and `ScrollPane`),

- Layout managers (such as `FlowLayout`, `BorderLayout` and `GridLayout`),
- Custom graphics classes (such as `Graphics`, `Color` and `Font`).

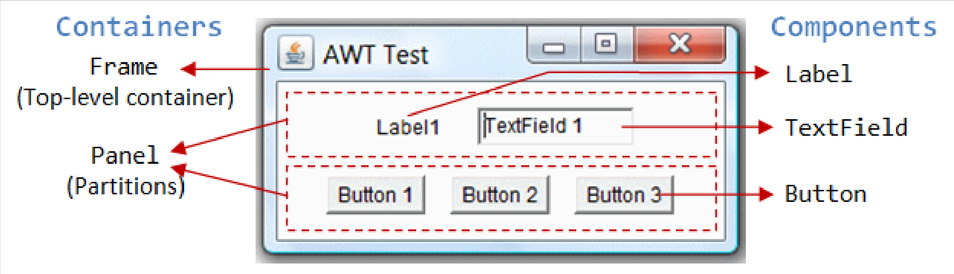
2. The `java.awt.event` package supports event handling:
   - Event classes (such as `ActionEvent`, `MouseEvent`, `KeyEvent` and `WindowEvent`),
   - Event Listener Interfaces (such as `ActionListener`, `MouseListener`, `KeyListener` and `WindowListener`),
   - Event Listener Adapter classes (such as `MouseAdapter`, `KeyAdapter`, and `WindowAdapter`).

AWT provides a *platform-independent* and *device-independent* interface to develop graphic programs that runs on all platforms, such as Windows, Mac, and Linux.

2.2 Containers and Components

There are two types of GUI elements:

1. *Component*: Components are elementary GUI entities (such as `Button`, `Label`, and `TextField`.)
2. *Container*: Containers (such as `Frame`, `Panel` and `Applet`) are used to *hold components in a specific layout*. A container can also hold sub-containers.



GUI components are also called *controls* (Microsoft ActiveX Control), *widgets* (Eclipse's Standard Widget Toolkit, Google Web Toolkit), which allow users to interact with the application via mouse, keyboard, and other forms of inputs such as voice.

In the above example, there are three containers: a `Frame` and two `Panel`s. A `Frame` is the *top-level container* of an AWT GUI program. A `Frame` has a title bar (containing an icon, a title, and the minimize/maximize(restore-down)/close buttons), an optional menu bar and the content display area. A `Panel` is a *rectangular area* (or partition) used to group related GUI components in a certain layout. In the above example, the top-level `Frame` contains two `Panel`s. There are five components: a `Label` (providing description), a `TextField` (for users to enter text), and three `Button`s (for user to trigger certain programmed actions).

In a GUI program, a component must be kept in a container. You need to identify a container to hold the components. Every container has a method called `add(Component c)`. A container (says `aContainer`) can invoke *aContainer*.add(*aComponent*) to add `aComponent` into itself. For example,

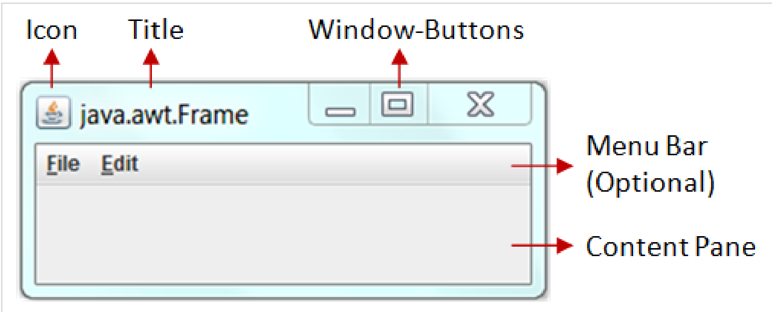
```
Panel panel = new Panel();         // Panel is a Container
Button btn = new Button("Press"); // Button is a Component
panel.add(btn);                   // The Panel Container adds a Button Component
```

2.3 AWT `Container` Classes

Top-Level Containters: `Frame`, `Dialog` and `Applet`

Each GUI program has a *top-level container*. The commonly-used top-level containers in AWT are `Frame`, `Dialog` and `Applet`:

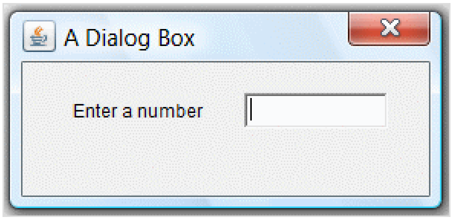
- A `Frame` provides the "main window" for the GUI application, which has a title bar (containing an icon, a title, the minimize, maximize/restore-down and close buttons), an optional menu bar, and the content display area. To write a GUI program, we typically start with a subclass extending from `java.awt.Frame` to inherit the main window as follows:




```
import java.awt.Frame;  // Using Frame class in package java.awt

// A GUI program is written as a subclass of Frame - the top-level container
// This subclass inherits all properties from Frame, e.g., title, icon, buttons, content-pane
public class MyGUIProgram extends Frame {
   // Constructor to setup the GUI components
   public MyGUIProgram() { ...... }

   ......
   ......

   // The entry main() method
   public static void main(String[] args) {
      // Invoke the constructor (to setup the GUI) by allocating an instance
      MyGUIProgram m = new MyGUIProgram();
   }
```

```
}
```

- An AWT `Dialog` is a *"pop-up window"* used for interacting with the users. A `Dialog` has a title-bar (containing an icon, a title and a close button) and a content display area, as illustrated.
- An AWT `Applet` (in package `java.applet`) is the top-level container for an applet, which is a Java program running inside a browser. Applet will be discussed in the later chapter.



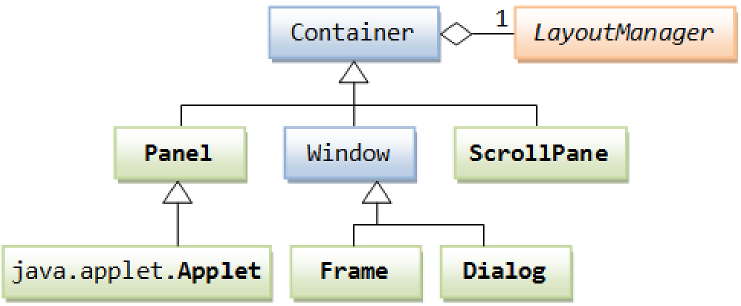
Secondary Containers: `Panel` and `ScrollPane`

Secondary containers are placed inside a top-level container or another secondary container. AWT also provide these secondary containers:

- `Panel`: a rectangular box (partition) under a higher-level container, used to *layout* a set of related GUI components. See the above examples for illustration.
- `ScrollPane`: provides automatic horizontal and/or vertical scrolling for a single child component.
- others.

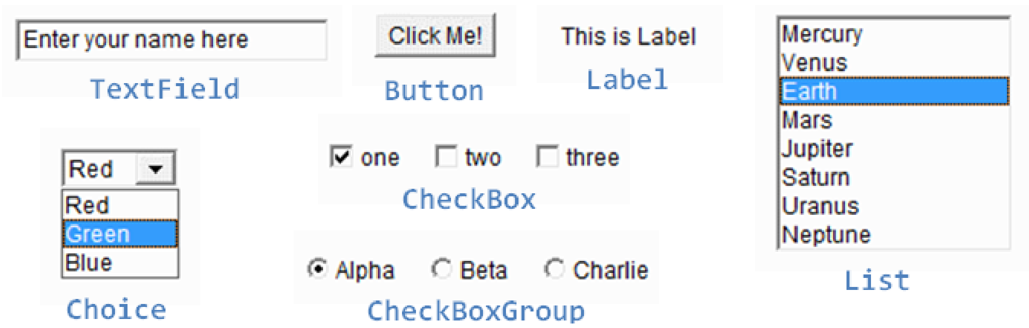
Hierarchy of the AWT `Container` Classes

The hierarchy of the AWT `Container` classes is as follows:



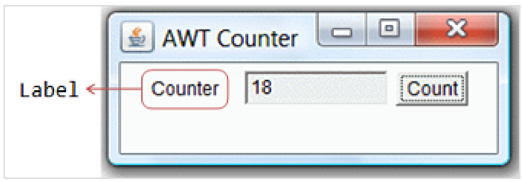
2.4 AWT `Component` Classes

AWT provides many ready-made and reusable GUI components. The frequently-used are: `Button`, `TextField`, `Label`, `Checkbox`, `CheckboxGroup` (radio buttons), `List`, and `Choice`, as illustrated below.



AWT GUI Component: `Label`

A `java.awt.Label` provides a text description message. Take note that `System.out.println()` prints to the system console, not to the graphics screen. You could use a `Label` to label another component (such as text field) or provide a text description.



Check the JDK API specification for `java.awt.Label`.

<u>Constructors</u>

```
public Label(String strLabel, int alignment); // Construct a Label with the given text String, of the text alignment
public Label(String strLabel);                // Construct a Label with the given text String
public Label();                               // Construct an initially empty Label
```

The `Label` class has three constructors:

1. The first constructor constructs a `Label` object with the given text string in the given alignment. Note that three `static` constants `Label.LEFT`, `Label.RIGHT`, and `Label.CENTER` are defined in the class for you to specify the alignment (rather than asking you to memorize arbitrary integer values).
2. The second constructor constructs a `Label` object with the given text string in default of left-aligned.
3. The third constructor constructs a `Label` object with an initially empty string. You could set the label text via the `setText()` method later.

Constants

```
public static final LEFT;    // Label.LEFT
public static final RIGHT;   // Label.RIGHT
public static final CENTER;  // Label.CENTER
```

These three constants are defined for specifying the alignment of the `Label`'s text.

Public Methods

```
// Examples
public String getText();
public void setText(String strLabel);
public int getAlignment();
public void setAlignment(int alignment);
```

The `getText()` and `setText()` methods can be used to read and modify the `Label`'s text. Similarly, the `getAlignment()` and `setAlignment()` methods can be used to retrieve and modify the alignment of the text.

Constructing a Component and Adding the Component into a Container

Three steps are necessary to create and place a GUI component:

1. Declare the component with an *identifier*;
2. Construct the component by invoking an appropriate constructor via the `new` operator;
3. Identify the container (such as `Frame` or `Panel`) designed to hold this component. The container can then add this component onto itself via `aContainer.add(aComponent)` method. Every container has a `add(Component)` method. Take note that it is the container that actively and explicitly adds a component onto itself, instead of the other way.

Example

```
Label lblInput;                     // Declare an Label instance called lblInput
lblInput = new Label("Enter ID");   // Construct by invoking a constructor via the new operator
add(lblInput);                      // this.add(lblInput) - "this" is typically a subclass of Frame or Panel
lblInput.setText("Enter password"); // Modify the Label's text string
lblInput.getText();                 // Retrieve the Label's text string
```

An Anonymous Instance

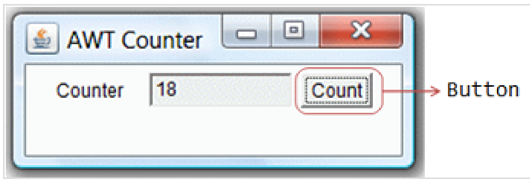
You can create a `Label` without specifying an identifier, called *anonymous instance*. In the case, the Java compiler will assign an *anonymous identifier* for the allocated object. You will not be able to reference an anonymous instance in your program after it is created. This is usually alright for a `Label` instance as there is often no need to reference a `Label` after it is constructed.

Example

```
// Allocate an anonymous Label instance. "this" container adds the instance into itself.
// You CANNOT reference an anonymous instance to carry out further operations.
add(new Label("Enter Name: ", Label.RIGHT));

// Same as
Label lblXxx = new Label("Enter Name: ", Label.RIGHT)); // lblXxx assigned by compiler
add(lblXxx);
```

AWT GUI Component: `Button`

A `java.awt.Button` is a GUI component that triggers a certain programmed *action* upon clicking.



Constructors

```
public Button(String buttonLabel);
   // Construct a Button with the given label
public Button();
   // Construct a Button with empty label
```

The `Button` class has two constructors. The first constructor creates a `Button` object with the given label painted over the button. The second constructor creates a `Button` object with no label.

Public Methods

```
public String getLabel();
   // Get the label of this Button instance
public void setLabel(String buttonLabel);
   // Set the label of this Button instance
public void setEnable(boolean enable);
   // Enable or disable this Button. Disabled Button cannot be clicked.
```

The `getLabel()` and `setLabel()` methods can be used to read the current label and modify the label of a button, respectively.

Note: The latest Swing's `JButton` replaces `getLabel()/setLabel()` with `getText()/setText()` to be consistent with all the components. We will describe Swing later.

Event

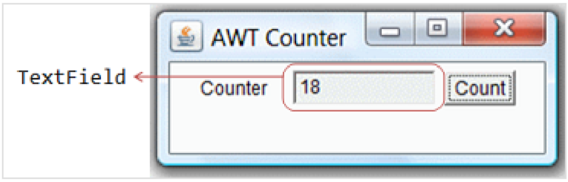
Clicking a button fires a so-called `ActionEvent` and triggers a certain programmed action. I will explain event-handling later.

Example

```
Button btnColor = new Button("Red"); // Declare and allocate a Button instance called btnColor
add(btnColor);                       // "this" Container adds the Button
...
btnColor.setLabel("green");          // Change the button's label
btnColor.getLabel();                 // Read the button's label
...
add(Button("Blue"));    // Create an anonymous Button. It CANNOT be referenced later
```

AWT GUI Component: `TextField`

A `java.awt.TextField` is single-line text box for users to enter texts. (There is a multiple-line text box called `TextArea`.) Hitting the "ENTER" key on a `TextField` object triggers an action-event.



Constructors

```
public TextField(String strInitialText, int columns);
   // Construct a TextField instance with the given initial text string with the number of columns.
public TextField(String strInitialText);
   // Construct a TextField instance with the given initial text string.
public TextField(int columns);
   // Construct a TextField instance with the number of columns.
```

Public Methods

```
public String getText();
   // Get the current text on this TextField instance
public void setText(String strText);
   // Set the display text on this TextField instance
public void setEditable(boolean editable);
   // Set this TextField to editable (read/write) or non-editable (read-only)
```

Event

Hitting the "ENTER" key on a `TextField` fires a `ActionEvent`, and triggers a certain programmed action.

Example

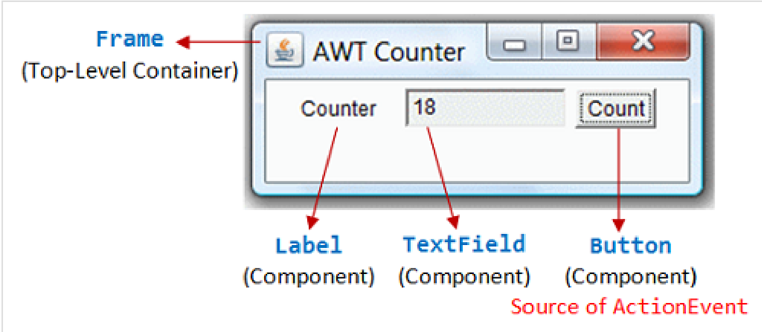
```
TextField tfInput = new TextField(30); // Declare and allocate an TextField instance called tfInput
add(tfInput);                          // "this" Container adds the TextField
TextField tfResult = new TextField();  // Declare and allocate an TextField instance called tfResult
tfResult.setEditable(false) ;          // Set to read-only
add(tfResult);                         // "this" Container adds the TextField
......
// Read an int from TextField "tfInput", square it, and display on "tfResult".
// getText() returns a String, need to convert to int
int number = Integer.parseInt(tfInput.getText());
number *= number;
// setText() requires a String, need to convert the int number to String.
tfResult.setText(number + "");
```

Take note that `getText()/SetText()` operates on `String`. You can convert a `String` to a primitive, such as `int` or `double` via `static` method `Integer.parseInt()` or `Double.parseDouble()`. To convert a primitive to a `String`, simply concatenate the primitive with an empty `String`.

2.5 Example 1: `AWTCounter`

Let's assemble some components together into a simple GUI counter program, as illustrated. It has a top-level container `Frame`, which contains three components - a `Label` "Counter", a non-editable `TextField` to display the current count, and a "Count" `Button`. The `TextField` displays `"0"` initially.

Each time you click the button, the counter's value increases by 1.




```
1  import java.awt.*;        // using AWT containers and components
2  import java.awt.event.*;  // using AWT events and listener interfaces
3
4  // An AWT GUI program inherits the top-level container java.awt.Frame
5  public class AWTCounter extends Frame implements ActionListener {
6     private Label lblCount;    // declare component Label
7     private TextField tfCount; // declare component TextField
8     private Button btnCount;   // declare component Button
9     private int count = 0;     // counter's value
10
11    /** Constructor to setup GUI components */
12    public AWTCounter () {
13       setLayout(new FlowLayout());
14          // "this" Frame sets its layout to FlowLayout, which arranges the components
15          //  from left-to-right, and flow to next row from top-to-bottom.
16
17       lblCount = new Label("Counter"); // construct Label
18       add(lblCount);                   // "this" Frame adds Label
19
20       tfCount = new TextField("0", 10); // construct TextField
21       tfCount.setEditable(false);       // set to read-only
22       add(tfCount);                     // "this" Frame adds tfCount
23
24       btnCount = new Button("Count"); // construct Button
25       add(btnCount);                  // "this" Frame adds Button
26
27       btnCount.addActionListener(this); // for event-handling
28
29       setTitle("AWT Counter");  // "this" Frame sets title
30       setSize(250, 100);        // "this" Frame sets initial window size
31       setVisible(true);         // "this" Frame shows
32    }
33
34    /** The entry main() method */
35    public static void main(String[] args) {
36       // Invoke the constructor to setup the GUI, by allocating an instance
37       AWTCounter app = new AWTCounter();
38    }
39
40    /** ActionEvent handler - Called back when user clicks the button. */
41    @Override
42    public void actionPerformed(ActionEvent evt) {
43       ++count; // increase the counter value
44       // Display the counter value on the TextField tfCount
45       tfCount.setText(count + ""); // convert int to String
46    }
47 }
```

To exit this program, you have to close the CMD-shell (or press "control-c" on the CMD console); or push the "red-square" close button in Eclipse's Application Console. This is because we have yet to write the handler for the `Frame`'s close button. We shall do that in the later example.

Dissecting the `AWTCounter.java`

- The `import` statements (Lines 1-2) are needed, as AWT container and component classes, such as `Frame`, `Button`, `TextField`, and `Label`, are kept in the `java.awt` package; while AWT events and event-listener interfaces, such as `ActionEvent` and `ActionListener` are kept in the `java.awt.event` package.
- A GUI program needs a top-level container, and is often written as a subclass of `Frame` (Line 5). In other words, this class `AWTCounter` *is a* `Frame`, and inherits all the attributes and behaviors of a `Frame`, such as the title bar and content pane.
- Lines 12 to 32 define a constructor, which is used to setup and initialize the GUI components.
- The `setLayout()` method (in Line 13) is invoked without an object and the dot operator, hence, defaulted to "`this`" object, i.e., `this.setLayout()`. The `setLayout()` is inherited from the superclass `Frame` and is used to set the layout of the components inside the container `Frame`. `FlowLayout` is used in this example, which arranges the GUI components in left-to-right and flows into next row in a top-to-bottom manner.
- A `Label`, `TextField` (non-editable), and `Button` are constructed. "`this`" object (`Frame` container) adds these components into it via

this.add() inherited from the superclass Frame.

- The setSize() and the setTitle() (Line 29-30) are used to set the initial size and the title of "this" Frame. The setVisible(true) method (Line 30) is then invoked to show the display.
- The statement btnCount.addActionListener(this) (Line 27) is used to setup the event-handling mechanism, which will be discussed in length later. In brief, whenever the button is clicked, the actionPerformed() will be called. In the actionPerformed() (Lines 41-46), the counter value increases by 1 and displayed on the TextField.
- In the entry main() method (Lines 35-38), an instance of AWTCounter is constructed. The constructor is executed to initialize the GUI components and setup the event-handling mechanism. The GUI program then waits for the user input.

toString()

It is interesting to inspect the GUI objects via the toString(), to gain an insight to these classes. (Alternatively, use a graphic debugger in Eclipse/NetBeans or study the JDK source code.) For example, if we insert the following code before and after the setvisible():

```
System.out.println(this);
System.out.println(lblCount);
System.out.println(tfCount);
System.out.println(btnCount);

setVisible(true);         // "this" Frame shows

System.out.println(this);
System.out.println(lblCount);
System.out.println(tfCount);
System.out.println(btnCount);
```

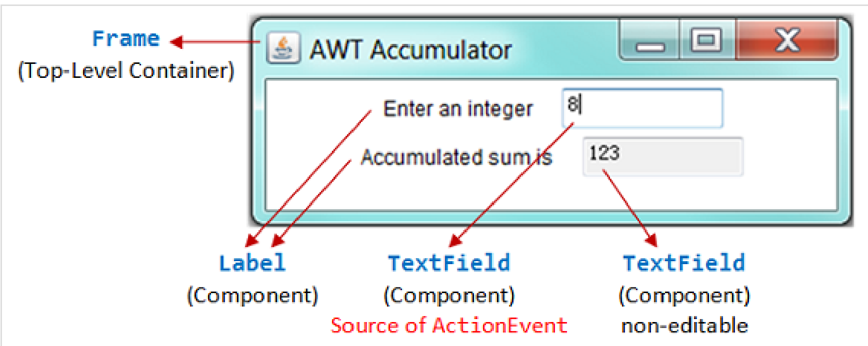
The output (with my comments) are as follows. You could have an insight of the variables defined in the classs.

```
// Before setVisible()
AWTCounter[frame0,0,0,250x100,invalid,hidden,layout=java.awt.FlowLayout,title=AWT Counter,resizable,normal]
      // name (assigned by compiler) is "frame0"; top-left (x,y) at (0,0); width/height is 250x100 (via setSize());
java.awt.Label[label0,0,0,0x0,invalid,align=left,text=Counter]
      // name is "Label0"; align is "Label.LEFT" (default); text is "Counter" (assigned in contructor)
java.awt.TextField[textfield0,0,0,0x0,invalid,text=0,selection=0-0]
      // name is "Textfield0"; text is "0" (assigned in contructor)
java.awt.Button[button0,0,0,0x0,invalid,label=Count]
      // name is "button0"; label text is "Count" (assigned in contructor)
      // Before setVisible(), all components are invalid (top-left (x,y), width/height are invalid)

// After setVisible(), all components are valid
AWTCounter[frame0,0,0,250x100,layout=java.awt.FlowLayout,title=AWT Counter,resizable,normal]
      // valid and visible (not hidden)
java.awt.Label[label0,20,41,58x23,align=left,text=Counter]
      // Top-left (x,y) at (20,41) relative to the parent Frame; width/height = 58x23
java.awt.TextField[textfield0,83,41,94x23,text=0,selection=0-0]
      // Top-left (x,y) at (83,41) relative to the parent Frame; width/height = 94x23; no text selected (0-0)
java.awt.Button[button0,182,41,47x23,label=Count]
      // Top-left (x,y) at (182,41) relative to the parent Frame; width/height = 47x23
```

2.6 Example 2: AWTAccumulator

In this example, the top-level container is again the typical java.awt.Frame, which contains 4 components: a Label "Enter an Integer", a TextField for accepting user input, another Label "The Accumulated Sum is", and another non-editable TextField for displaying the sum. The components are arranged in FlowLayout.

The program shall accumulate the number entered into the *input* TextField and display the sum in the *output* TextField.




```
import java.awt.*;        // using AWT containers and components
import java.awt.event.*;  // using AWT events and listener interfaces

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTAccumulator extends Frame implements ActionListener {
   private Label lblInput;     // declare input Label
   private Label lblOutput;    // declare output Label
   private TextField tfInput;  // declare input TextField
   private TextField tfOutput; // declare output TextField
   private int numberIn;       // input number
   private int sum = 0;        // accumulated sum, init to 0

   /** Constructor to setup the GUI */
```

```
   public AWTAccumulator() {
      setLayout(new FlowLayout());
         // "this" Frame sets layout to FlowLayout, which arranges the components
         //  from left-to-right, and flow to next row from top-to-bottom.

      lblInput = new Label("Enter an Integer: "); // construct Label
      add(lblInput);               // "this" Frame adds Label

      tfInput = new TextField(10); // construct TextField
      add(tfInput);                // "this" Frame adds TextField

      // The TextField tfInput registers "this" object (AWTAccumulator)
      //  as an ActionEvent listener.
      tfInput.addActionListener(this);

      lblOutput = new Label("The Accumulated Sum is: ");  // allocate Label
      add(lblOutput);               // "this" Frame adds Label

      tfOutput = new TextField(10); // allocate TextField
      tfOutput.setEditable(false);  // read-only
      add(tfOutput);                // "this" Frame adds TextField

      setTitle("AWT Accumulator");  // "this" Frame sets title
      setSize(350, 120);  // "this" Frame sets initial window size
      setVisible(true);   // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      // Invoke the constructor to setup the GUI, by allocating an anonymous instance
      new AWTAccumulator();
   }

   /** Event handler - Called back when user hits the enter key on the TextField */
   @Override
   public void actionPerformed(ActionEvent evt) {
      // Get the String entered into the TextField tfInput, convert to int
      numberIn = Integer.parseInt(tfInput.getText());
      sum += numberIn;      // accumulate numbers entered into sum
      tfInput.setText("");  // clear input TextField
      tfOutput.setText(sum + ""); // display sum on the output TextField
                                  // convert int to String
   }
}
```

Dissecting the `AWTAccumulator.java`

[TODO]

`toString()`

Printing the `toString()` after `setVisible()` produces:

```
AWTAccumulator[frame0,0,0,350x120,layout=java.awt.FlowLayout,title=AWT Accumulator,resizable,normal]
java.awt.Label[label0,72,41,107x23,align=left,text=Enter an Integer: ]
java.awt.Label[label1,47,69,157x23,align=left,text=The Accumulated Sum is: ]
java.awt.TextField[textfield0,184,41,94x23,text=,editable,selection=0-0]
java.awt.TextField[textfield1,209,69,94x23,text=,selection=0-0]
```

3. AWT Event-Handling

Java adopts the so-called "Event-Driven" (or "Event-Delegation") programming model for event-handling, similar to most of the visual programming languages (such as Visual Basic and Delphi).

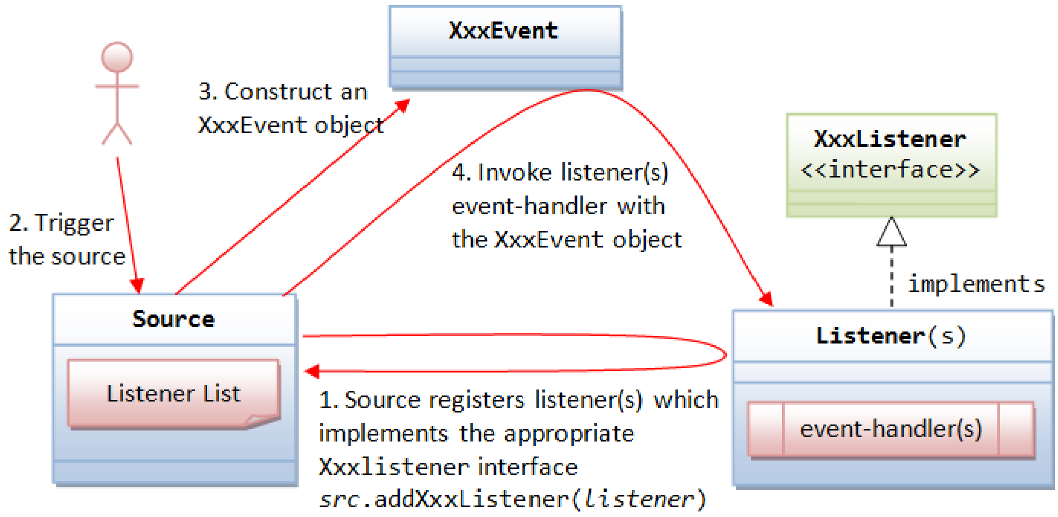
In event-driven programming, a piece of event-handling codes is executed (or called back by the graphics subsystem) when an event has been fired in response to an user input (such as clicking a mouse button or hitting the ENTER key). This is unlike the procedural model, where codes are executed in a sequential manner.

The AWT's event-handling classes are kept in package `java.awt.event`.

Three objects are involved in the event-handling: a *source*, a *listener*(s) and an *event* object.

The *source* object (such as `Button` and `Textfield`) interacts with the user. Upon triggered, it creates an *event* object. This *event* object will be messaged to all the *registered listener* object(s), and an appropriate event-handler method of the listener(s) is called-back to provide the response. In other words, *triggering a source fires an event to all its listeners*.

To express interest for a certain source's event, the listener(s) must be registered with the source. In other words, the listener(s) "subscribes" to a source's event, and the source "publishes" the event to all its subscribers upon activation. This is known as *subscribe-publish* or *observable-observer* design pattern.



The sequence of steps is illustrated above:

1. *The source object registers its listener(s)* for a certain type of *event*.

   How the source and listener understand each other? The answer is via an agreed-upon interface. For example, if a source is capable of firing an event called `XxxEvent` (e.g., `MouseEvent`) involving various operational modes (e.g., mouse-clicked, mouse-entered, mouse-exited, mouse-pressed, and mouse-released). Firstly, we need to declare an interface called `XxxListener` (e.g., `MouseListener`) containing the names of the handler methods. Recall that an `interface` contains only `abstract` methods without implementation. For example,

```
// A MouseListener interface, which declares the signature of the handlers
//  for the various operational modes.
interface MouseListener {
   public void mousePressed(MouseEvent evt);  // Called back upon mouse-button pressed
   public void mouseReleased(MouseEvent evt); // Called back upon mouse-button released
   public void mouseClicked(MouseEvent evt);  // Called back upon mouse-button clicked (pressed and released)
   public void mouseEntered(MouseEvent evt);  // Called back when mouse pointer entered the component
   public void mouseExited(MouseEvent evt);   // Called back when mouse pointer exited the component
}
```

   Secondly, all the listeners interested in the `XxxEvent` must implement the `XxxListener` interface. That is, the listeners must provide their own implementations (i.e., programmed responses) to all the `abstract` methods declared in the `XxxListener` interface. In this way, the listenser(s) can response to these events appropriately. For example,

```
// An example of MouseListener,  which provides implementation to the handler methods
class MyMouseListener implement MouseListener {
   @Override
   public void mousePressed(MouseEvent e)  {
      System.out.println("Mouse-button pressed!");
   }

   @Override
   public void mouseReleased(MouseEvent e) {
      System.out.println("Mouse-button released!");
   }

   @Override
   public void mouseClicked(MouseEvent e)  {
      System.out.println("Mouse-button clicked (pressed and released)!");
   }

   @Override
   public void mouseEntered(MouseEvent e)  {
      System.out.println("Mouse-pointer entered the source component!");
   }

   @Override
   public void mouseExited(MouseEvent e)   {
      System.out.println("Mouse exited-pointer the source component!");
   }
}
```

   Thirdly, in the source, we need to maintain a list of listener object(s), and define two methods: `addXxxListener()` and `removeXxxListener()` to add and remove a listener from this list. The signature of the methods are:

```
public void addXxxListener(XxxListener l);
public void removeXxxListener(XxxListener l);
```

   Take note that all the listener(s) interested in the `XxxEvent` must implement the `XxxListener` interface. That is, they are sub-type of the `XxxListener`. Hence, they can be upcasted to `XxxListener` and passed as the argument of the above methods.

In summary, we identify the source, the event-listener interface, and the listener object. The listener must implement the event-listener interface. The source object then registers listener object via the `addXxxListener()` method:

```
aSource.addXxxListener(alistener);  // aSource registers aListener for XxxEvent
```

2. The source is triggered by a user.
3. The source create an `XxxEvent` object, which encapsulates the necessary information about the activation. For example, the `(x, y)` position of the mouse pointer, the text entered, etc.
4. Finally, for each of the listeners in the listener list, the source invokes the appropriate handler on the listener(s), which provides the programmed response.

In brief, *triggering a source fires an event to all its registered listeners, and invoke an appropriate handler of the listener.*

3.1 Revisit Example 1 (`AWTCounter`): `ActionEvent` and `ActionListener` Interface

Clicking a `Button` (or pushing the "enter" key on a `TextField`) fires an `ActionEvent` to all its listensers. An `ActionEvent` listener must implement `ActionListener` interface, which declares one `abstract` method `actionPerformed()` as follow:

```
interface ActionListener {
   public void actionPerformed(ActionEvent e); // Called back upon button clicked, enter key pressed
}
```

Here are the event-handling steps:

- We identify `Button` (`btnCount`) as the *source* object. Clicking the button fires an `ActionEvent` to all its listeners.
- The listener is required to implement `ActionListener` interface, and override the `actionPerformed()` method. For simplicity, we choose "`this`" object (`AWTCounter`) as the *listener* for the `ActionEvent`. Hence, "`this`" object is required to implement `ActionListener` interface and provide the programmed response in the `actionPerformed()`.

```
public class AWTCounter extends Frame implements ActionListener {
      // "this" is chosen as the ActionEvent listener, hence, it is required
      // to implement ActionListener interface
   ......

   // Implementing ActionListener interface requires this class to provide implementation
   // to the abstract method actionPerformed() declared in the interface.
   @Override
   public void actionPerformed(ActionEvent evt) {
      // Programmed response for the activation
      ++count;
      tfCount.setText(count + "");
   }
}
```

- The source registers listener via the `addActionListener()`. In this example, the *source* `btnCount` (`Button`) adds "`this`" object as a *listener* via:

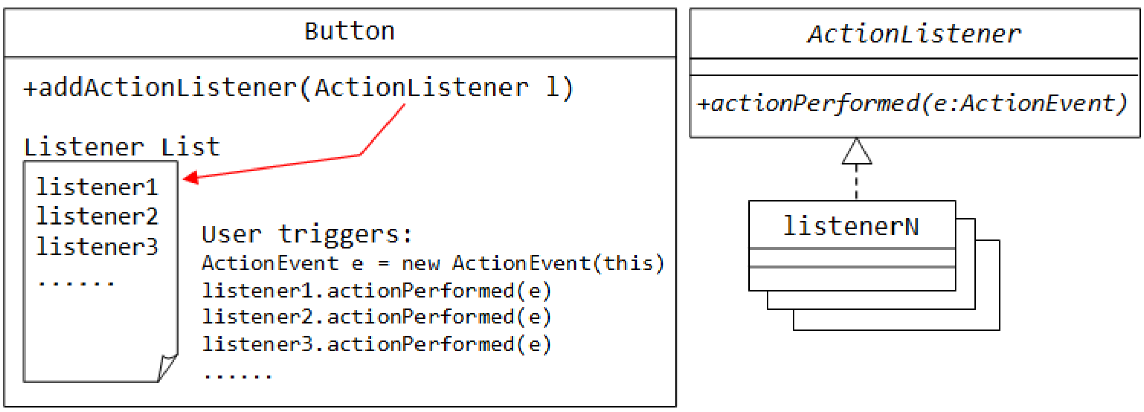
```
btnCount.addActionListener(this);
```

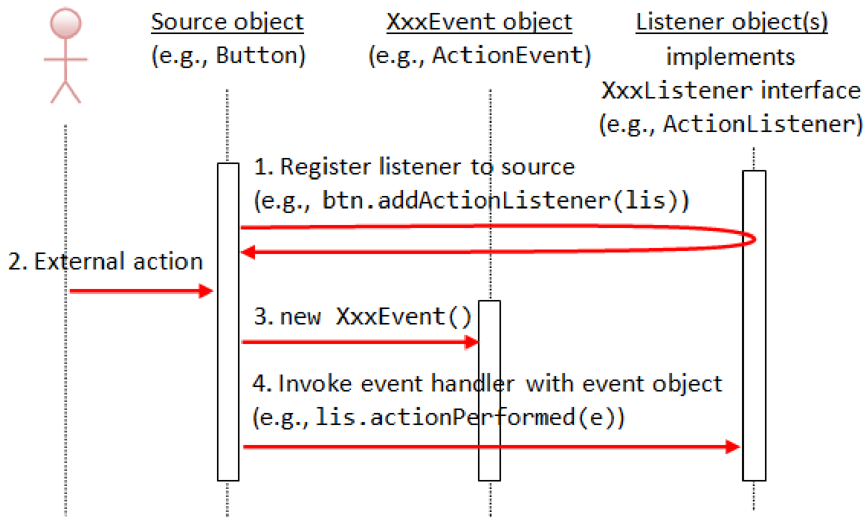
  Note that `addActionListener()` takes an argument of the type `ActionListener`. "`this`", which implements `ActionListener` interface, can be upcasted and pass into `addActionListener()` method.

- When the button is clicked, the `btnCount` creates an `ActionEvent` object, and call back the `actionPerformed(ActionEvent)` method of all the registered listeners with the `ActionEvent` object created:

```
ActionEvent evt = new ActionEvent(...)
this.actionPerformed(evt);
```

The sequence diagram is as follows:





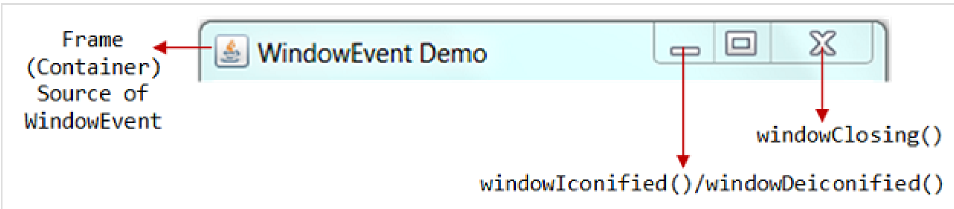
3.2 Revisit Example 2 (`AWTAccumulator`): `ActionEvent` and `ActionListener` Interface

In this example,

1. We identify the `TextField` `tfInput` as the source. Hitting the "ENTER" key on a `TextField` fires an `ActionEvent` to all its listeners.
2. We choose `this` object as the `ActionEvent` listener (for simplicity).
3. The source object `tfInput` (`TextField`) registers the listener (`this` object) via the `tfInput.addActionListener(this)`.
4. The `ActionEvent` listener (`this` object) is required to implement the `ActionListener` interface, and override the `actionPerformed()` method to provide the programmed response upon activation.

3.3 Example 3: `WindowEvent` and `WindowListener` Interface

A `WindowEvent` is fired (to all its `WindowListenser`s) when a window (e.g., `Frame`) has been opened/closed, activated/deactivated, iconified/deiconified via the 3 buttons at the top-right corner or other means. The source of a `WindowEvent` shall be a top-level window-container such as `Frame`.



A `WindowEvent` listener must implement `WindowListener` interface, which declares 7 `abstract` event-handling methods, as follows. Among them, the `windowClosing()`, which is called back upon clicking the window-close button, is the most commonly-used.

```
public void windowClosing(WindowEvent e)
   // Called-back when the user attempts to close the window by clicking the window close button.
   // This is the most-frequently used handler.
public void windowOpened(WindowEvent e)
   // Called-back the first time a window is made visible.
public void windowClosed(WindowEvent e)
   // Called-back when a window has been closed as the result of calling dispose on the window.
public void windowActivated(WindowEvent e)
   // Called-back when the Window is set to be the active Window.
public void windowDeactivated(WindowEvent e)
   // Called-back when a Window is no longer the active Window.
public void windowIconified(WindowEvent e)
   // Called-back when a window is changed from a normal to a minimized state.
public void windowDeiconified(WindowEvent e)
   // Called-back when a window is changed from a minimized to a normal state.
```

The following program added support for "close-window button" to the counter example (Example 1: `AWTCounter`).

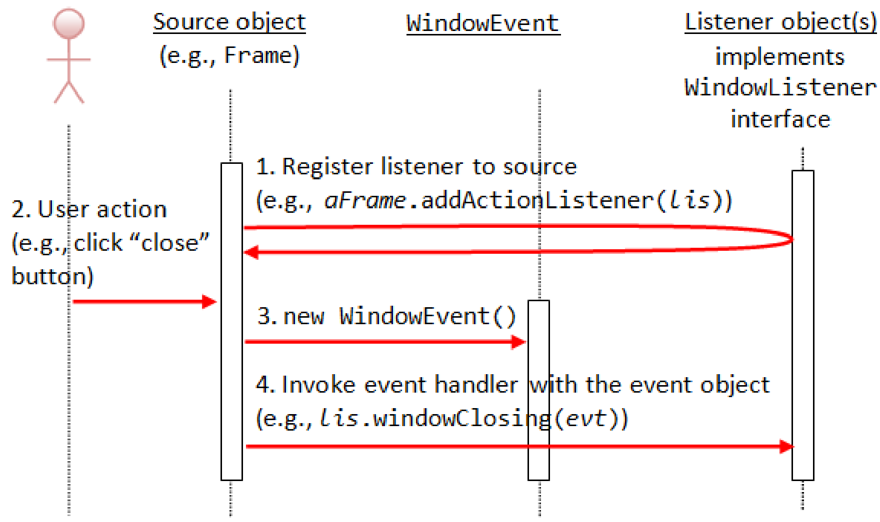
```
import java.awt.*;         // using AWT containers and components
import java.awt.event.*;   // using AWT events and listener interfaces

// An AWT GUI program inherits the top-level container java.awt.Frame
public class WindowEventDemo extends Frame
      implements ActionListener, WindowListener {
      // This class acts as listener for ActionEvent and WindowEvent
      // Java support only single inheritance, where a class can extend
      // one superclass, but can implement multiple interfaces.

   private TextField tfCount;
   private int count = 0;  // Counter's value
```

```java

   /** Constructor to setup the GUI */
   public WindowEventDemo () {
      setLayout(new FlowLayout()); // "this" Frame sets to FlowLayout

      add(new Label("Counter"));   // "this" Frame adds an anonymous Label

      tfCount = new TextField("0", 10); // allocate TextField
      tfCount.setEditable(false);       // read-only
      add(tfCount);                // "this" Frame adds tfCount

      Button btnCount = new Button("Count");  // declare and allocate a Button
      add(btnCount);               // "this" Frame adds btnCount

      btnCount.addActionListener(this);
        // btnCount fires ActionEvent to its registered ActionEvent listener
        // btnCount adds "this" object as an ActionEvent listener
      addWindowListener(this);
        // "this" Frame fires WindowEvent its registered WindowEvent listener
        // "this" Frame adds "this" object as a WindowEvent listener

      setTitle("WindowEvent Demo");  // "this" Frame sets title
      setSize(250, 100);        // "this" Frame sets initial size
      setVisible(true);         // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new WindowEventDemo();  // Let the construct do the job
   }

   /** ActionEvent handler */
   @Override
   public void actionPerformed(ActionEvent evt) {
      ++count;
      tfCount.setText(count + "");
   }

   /** WindowEvent handlers */
   // Called back upon clicking close-window button
   @Override
   public void windowClosing(WindowEvent e) {
      System.exit(0);  // terminate the program
   }

   // Not Used, but need to provide an empty body for compilation
   @Override
   public void windowOpened(WindowEvent e) { }
   @Override
   public void windowClosed(WindowEvent e) { }
   @Override
   public void windowIconified(WindowEvent e) { }
   @Override
   public void windowDeiconified(WindowEvent e) { }
   @Override
   public void windowActivated(WindowEvent e) { }
   @Override
   public void windowDeactivated(WindowEvent e) { }
}
```

For this demo, we shall modify the earlier `AWTCounter` example to handle the `WindowEvent`. Recall that pushing the "close-window" button on the `AWTCounter` has no effect, as it did not handle the `WindowEvent` of `windowClosing()`. We included the `WindowEvent` handling codes in this example.

1. We identify `this Frame` as the source object, which fires the `WindowEvent` to all its registered `WindowEvent` listeners.
2. We select `this` object as the `WindowEvent` listener (for simplicity)
3. We register `this` object as the `WindowEvent` listener to the source `Frame` via method `this.addWindowListener(this)`. It is interesting to note that the source and listener are the same object.
4. The `WindowEvent` listener (`this` object) are required to implement the `WindowListener` interface, which declares 7 abstract methods: `windowOpened()`, `windowClosed()`, `windowClosing()`, `windowActivated()`, `windowDeactivated()`, `windowIconified()`, `windowDeiconified()`.
5. We override the `windowClosing()` handler to terminate the program using `System.exit(0)`. We ignore the other 6 handlers, but required to provide an empty body.

The sequence diagram is as follow:

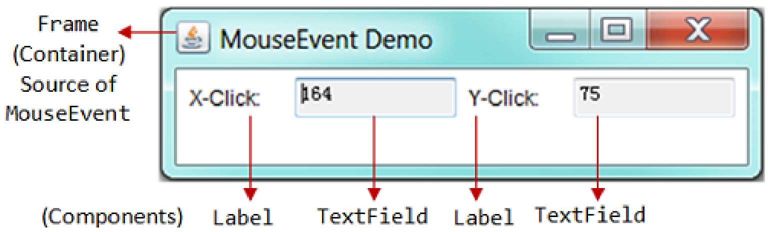


3.4 Example 4: `MouseEvent` and `MouseListener` Interface

A `MouseEvent` is fired to all its registered listeners, when you press, release, or click (press followed by release) a mouse-button (left or right button) at the source object; or position the mouse-pointer at (enter) and away (exit) from the source object.

A `MouseEvent` listener must implement the `MouseListener` interface, which declares the following five `abstract` methods:

```
public void mouseClicked(MouseEvent e)
   // Called-back when the mouse-button has been clicked (pressed followed by released) on the source.
public void mousePressed(MouseEvent e)
public void mouseReleased(MouseEvent e)
   // Called-back when a mouse-button has been pressed/released on the source.
   // A mouse-click invokes mousePressed(), mouseReleased() and mouseClicked().
public void mouseEntered(MouseEvent e)
public void mouseExited(MouseEvent e)
   // Called-back when the mouse-pointer has entered/exited the source.
```




```
import java.awt.*;
import java.awt.event.MouseEvent;
import java.awt.event.MouseListener;

public class MouseEventDemo extends Frame implements MouseListener {

   // Private variables
   private TextField tfMouseX; // to display mouse-click-x
   private TextField tfMouseY; // to display mouse-click-y

   // Constructor - Setup the UI
   public MouseEventDemo() {
      setLayout(new FlowLayout()); // "this" frame sets layout

      // Label
      add(new Label("X-Click: ")); // "this" frame adds component

      // TextField
      tfMouseX = new TextField(10); // 10 columns
      tfMouseX.setEditable(false);  // read-only
      add(tfMouseX); // "this" frame adds component

      // Label
      add(new Label("Y-Click: ")); // "this" frame adds component

      // TextField
      tfMouseY = new TextField(10);
      tfMouseY.setEditable(false);  // read-only
      add(tfMouseY); // "this" frame adds component

      this.addMouseListener(this);
          // "this" frame fires the MouseEvent
          // "this" frame adds "this" object as MouseEvent listener
```

```
      setTitle("MouseEvent Demo"); // "this" Frame sets title
      setSize(350, 100);       // "this" Frame sets initial size
      setVisible(true);        // "this" Frame shows
   }

   public static void main(String[] args) {
      new MouseEventDemo();  // Let the constructor do the job
   }

   // MouseEvent handlers
   @Override
   public void mouseClicked(MouseEvent e) {
      tfMouseX.setText(e.getX() + "");
      tfMouseY.setText(e.getY() + "");
   }

   @Override
   public void mousePressed(MouseEvent e) { }

   @Override
   public void mouseReleased(MouseEvent e) { }

   @Override
   public void mouseEntered(MouseEvent e) { }

   @Override
   public void mouseExited(MouseEvent e) { }
}
```

In this example, we setup a GUI with 4 components (two `Label`s and two non-editable `TextField`s), inside a container `Frame`, arranged in `FlowLayout`.

To demonstrate the `MouseEvent`:

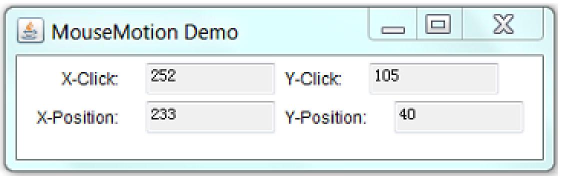
1. We identity `this Frame` as the source object, which fires a `MouseEvent` to all its `MouseEvent` listeners when you click/press/release a mouse-button or enter/exit the mouse-pointer.
2. We select `this` object as the `MouseEvent` listener (for simplicity).
3. We register `this` object as the `MouseEvent` listener to `this Frame` (source) via the method `this.addMouseListener(this)`.
4. The listener (`this` object) is required to implement the `MouseListener` interface, which declares 5 abstract methods: `mouseClicked()`, `mousePressed()`, `mouseReleased()`, `mouseEntered()`, and `mouseExit()`. We override the `mouseClicked()` to display the (x, y) co-ordinates of the mouse click on the two displayed `TextField`s. We ignore all the other handlers (for simplicity - but you need to provide an empty body for compilation).

Try: Include a `WindowListener` to handle the close-window button.

3.5 Example 5: `MouseEvent` and `MouseMotionListener` Interface

A `MouseEvent` is also fired when you moved and dragged the mouse pointer at the source object. But you need to use `MouseMotionListener` to handle the mouse-move and mouse-drag. The `MouseMotionListener` interface declares the following two abstract methods:

```
public void mouseDragged(MouseEvent e)
   // Called-back when a mouse-button is pressed on the source component and then dragged.
public void mouseMoved(MouseEvent e)
   // Called-back when the mouse-pointer has been moved onto the source component but no buttons have been pushed.
```




```
import java.awt.*;
import java.awt.event.MouseEvent;
import java.awt.event.MouseListener;
import java.awt.event.MouseMotionListener;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class MouseMotionDemo extends Frame
      implements MouseListener, MouseMotionListener {
      // This class acts as MouseListener and MouseMotionListener

   // To display the (x, y) coordinates of the mouse-clicked
   private TextField tfMouseClickX;
   private TextField tfMouseClickY;
   // To display the (x, y) coordinates of the current mouse-pointer position
   private TextField tfMousePositionX;
```

```
   private TextField tfMousePositionY;

   /** Constructor to setup the GUI */
   public MouseMotionDemo() {
      setLayout(new FlowLayout()); // "this" frame sets to FlowLayout

      add(new Label("X-Click: "));
      tfMouseClickX = new TextField(10);
      tfMouseClickX.setEditable(false);
      add(tfMouseClickX);
      add(new Label("Y-Click: "));
      tfMouseClickY = new TextField(10);
      tfMouseClickY.setEditable(false);
      add(tfMouseClickY);

      add(new Label("X-Position: "));
      tfMousePositionX = new TextField(10);
      tfMousePositionX.setEditable(false);
      add(tfMousePositionX);
      add(new Label("Y-Position: "));
      tfMousePositionY = new TextField(10);
      tfMousePositionY.setEditable(false);
      add(tfMousePositionY);

      addMouseListener(this);
      addMouseMotionListener(this);
        // "this" frame fires MouseEvent to all its registered MouseListener and MouseMotionListener
        // "this" frame adds "this" object as MouseListener and MouseMotionListener

      setTitle("MouseMotion Demo"); // "this" Frame sets title
      setSize(400, 120);   // "this" Frame sets initial size
      setVisible(true);    // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new MouseMotionDemo();  // Let the constructor do the job
   }

   /** MouseListener handlers */
   // Called back when a mouse-button has been clicked
   @Override
   public void mouseClicked(MouseEvent e) {
      tfMouseClickX.setText(e.getX() + "");
      tfMouseClickY.setText(e.getY() + "");
   }

   // Not Used, but need to provide an empty body for compilation
   @Override
   public void mousePressed(MouseEvent e) { }
   @Override
   public void mouseReleased(MouseEvent e) { }
   @Override
   public void mouseEntered(MouseEvent e) { }
   @Override
   public void mouseExited(MouseEvent e) { }

   /** MouseMotionEvent handlers */
   // Called back when the mouse-pointer has been moved
   @Override
   public void mouseMoved(MouseEvent e) {
      tfMousePositionX.setText(e.getX() + "");
      tfMousePositionY.setText(e.getY() + "");
   }

   // Not Used, but need to provide an empty body for compilation
   @Override
   public void mouseDragged(MouseEvent e) { }
}
```

In this example, we shall illustrate both the `MouseListener` and `MouseMotionListener`.

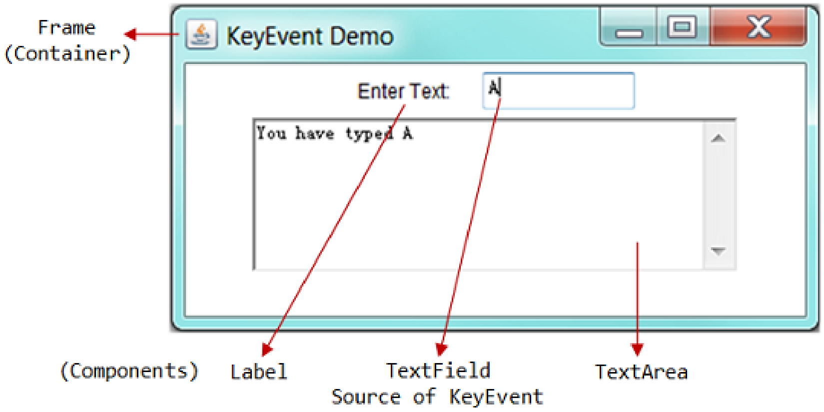
1. We identify `this Frame` as the source, which fires the `MouseEvent` to its registered `MouseListener` and `MouseMotionListener`.
2. We select `this` object as the `MouseListener` and `MouseMotionListner` (for simplicity).
3. We register `this` object as the listener to `this Frame` via method `this.addMouseListener(this)` and `this.addMouseMotionListener(this)`.
4. The `MouseMotionListener` (`this` object) needs to implement 2 abstract methods: `mouseMoved()` and `mouseDragged()` declared in the `MouseMotionListener` interface.
5. We override the `mouseMoved()` to display the (x, y) position of the mouse pointer. We ignore the `MouseDragged()` handler by providing an empty body for compilation.

Try: Include a `WindowListener` to handle the close-window button.

3.6 Example 6: `KeyEvent` and `KeyListener` Interface

A `KeyEvent` is fired (to all its registered `KeyListener`s) when you pressed, released, and typed (pressed followed by released) a key on the source object. A `KeyEvent` listener must implement `KeyListener` interface, which declares three abstract methods:

```
public void keyTyped(KeyEvent e)
   // Called-back when a key has been typed (pressed and released).
public void keyPressed(KeyEvent e)
public void keyReleased(KeyEvent e)
   // Called-back when a key has been pressed/released.
```



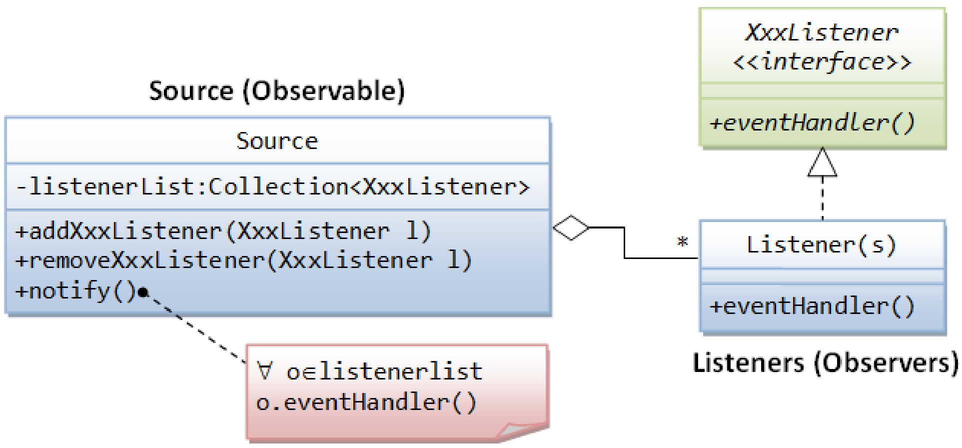

```
import java.awt.*;
import java.awt.event.KeyEvent;
import java.awt.event.KeyListener;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class KeyEventDemo extends Frame implements KeyListener {
      // This class acts as KeyEvent Listener

   private TextField tfInput;  // single-line TextField to receive tfInput key
   private TextArea taDisplay; // multi-line TextArea to taDisplay result

   /** Constructor to setup the GUI */
   public KeyEventDemo() {
      setLayout(new FlowLayout()); // "this" frame sets to FlowLayout

      add(new Label("Enter Text: "));
      tfInput = new TextField(10);
      add(tfInput);
      taDisplay = new TextArea(5, 40); // 5 rows, 40 columns
      add(taDisplay);

      tfInput.addKeyListener(this);
         // tfInput TextField fires KeyEvent to its registered KeyListener
         // It adds "this" object as a KeyEvent listener

      setTitle("KeyEvent Demo"); // "this" Frame sets title
      setSize(400, 200);         // "this" Frame sets initial size
      setVisible(true);          // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new KeyEventDemo();  // Let the constructor do the job
   }

   /** KeyEvent handlers */
   // Called back when a key has been typed (pressed and released)
   @Override
   public void keyTyped(KeyEvent e) {
      taDisplay.append("You have typed " + e.getKeyChar() + "\n");
   }

   // Not Used, but need to provide an empty body for compilation
   @Override
   public void keyPressed(KeyEvent e) { }
   @Override
   public void keyReleased(KeyEvent e) { }
}
```

In this example:

1. We identify the `TextField` (`input`) as the source object, which fires a `KeyEvent` when you press/release/type a key onto it.

2. We select `this` object as the `KeyEvent` listener.
3. We register `this` object as the `KeyEvent` listener to the source `TextField` via method `input.addKeyListener(this)`.
4. The `KeyEvent` listener (`this` object) needs to implement the `KeyListener` interface, which declares 3 abstract methods: `keyTyped()`, `keyPressed()`, `keyReleased()`.
5. We override the `keyTyped()` to display key typed on the display `TextArea`. We ignore the `keyPressed()` and `keyReleased()`.

3.7 Observer Design Pattern (Advanced)



The *Observer* design pattern (aka *Publish-Subscribe* or *Observable-Observer*) is one of the 23 GoF's design patterns. Whenever the source's state changes, it notifies all its registered listener.

The source and listener are *bound* via the interface `XxxListener`, which defines a set of handlers. The source maintain a list of registered listeners, and two methods: `addXxxListener()` and `removeXxxListener()`. Both `addXxxListener()` and `removeXxxListener()` takes an argument of `XxxListener`. Hence, a listener object must implement `XxxListener` in order to be registered. Whenever the source's state changes, it invokes a particular handler of all the registered listeners. The interface guarantees the existence of such handler in the listener.

3.8 Creating Your Own Event (Advanced)

Suppose that we have a source called `Light`, with two operational modes (turn-on and turn-off). The source is capable of notifying its registered listeners, whenever its state changes.

- First, we define the `LightEvent` class (extends from `java.util.EventObject`)
- Next, we define a `LightListener` interface to *bind* the source and its listeners. This interface specifies the signature of the handlers, `lightTurnedOn(LightEvent)` and `lightTurnedOff(LightEvent)`.
- In the source `Light`, we use an `ArrayList` to maintain its listeners, and create two methods: `addLightListner(LightListener)` and `removeLightListener(LightListener)`. An method called `notifyListeners()` is written to invoke the appropriate handlers of each of its registered listeners, whenever the state of the `Light` changes.
- A listener class called `LightWatcher` is written, which implements the `LightListener` interface and provides implementation for the handlers.

Event: `LightEvent.java`

```java
/** LightEvent */
import java.util.EventObject;

public class LightEvent extends EventObject {
   public LightEvent (Object src) {
      super(src);
   }
}
```

Listener Interface: `LightListener.java`

```java
/** The LightListener interface */
import java.util.EventListener;

public interface LightListener extends EventListener {
   public void lightOn(LightEvent evt);  // called-back when the light has been turned on
   public void lightOff(LightEvent evt); // called-back when the light has been turned off
}
```

Source: `Light.java`

```java
/** The Light Source */
import java.util.*;

```

```java
public class Light {
   // Status - on (true) or off (false)
   private boolean on;
   // Listener list
   private List<LightListener> listeners = new ArrayList<LightListener>();

   /** Constructor */
   public Light() {
      on = false;
      System.out.println("Light: constructed and off");
   }

   /** Add the given LightListener */
   public void addLightListener(LightListener listener) {
      listeners.add(listener);
      System.out.println("Light: added a listener");
   }

   /** Add the given LightListener */
   public void removeLightListener(LightListener listener) {
      listeners.remove(listener);
      System.out.println("Light: removed a listener");
   }

   /** Turn on this light */
   public void turnOn() {
      if (!on) {
         on = !on;
         System.out.println("Light: turn on");
         notifyListeners();
      }
   }

   /** Turn off this light */
   public void turnOff() {
      if (on) {
         on = !on;
         System.out.println("Light: turn off");
         notifyListeners();
      }
   }

   /** Fire an LightEvent and notify all its registered listeners */
   private void notifyListeners() {
      LightEvent evt = new LightEvent(this);
      for (LightListener listener : listeners) {
         if (on) {
            listener.lightOn(evt);
         } else {
            listener.lightOff(evt);
         }
      }
   }
}
```

Listener: `LightWatcher.java`

```java
/** An implementation of LightListener class */
public class LightWatcher implements LightListener {
   private int id;  // ID of this listner

   /** Constructor */
   public LightWatcher(int id) {
      this.id = id;
      System.out.println("LightWatcher-" + id + ": created");
   }

   /** Implementation of event handlers */
   @Override
   public void lightOn(LightEvent evt) {
      System.out.println("LightWatcher-" + id
         + ": I am notified that light is on");
   }

   @Override
   public void lightOff(LightEvent evt) {
      System.out.println("LightWatcher-" + id
         + ": I am notified that light is off");
   }
}
```

A Test Driver: `TestLight.java`

```
/** A Test Driver */
public class TestLight {
   public static void main(String[] args) {
      Light light = new Light();
      LightWatcher lw1 = new LightWatcher(1);
      LightWatcher lw2 = new LightWatcher(2);
      LightWatcher lw3 = new LightWatcher(3);
      light.addLightListener(lw1);
      light.addLightListener(lw2);
      light.turnOn();
      light.addLightListener(lw3);
      light.turnOff();
      light.removeLightListener(lw1);
      light.removeLightListener(lw3);
      light.turnOn();
   }
}
```

Below are the expected output:

```
Light: constructed and off
LightWatcher-1: created
LightWatcher-2: created
LightWatcher-3: created
Light: added a listener
Light: added a listener
Light: turn on
LightWatcher-1: I am notified that light is on
LightWatcher-2: I am notified that light is on
Light: added a listener
Light: turn off
LightWatcher-1: I am notified that light is off
LightWatcher-2: I am notified that light is off
LightWatcher-3: I am notified that light is off
Light: removed a listener
Light: removed a listener
Light: turn on
LightWatcher-2: I am notified that light is on
```

4. Nested & Inner Classes

A *nested class* (or commonly called *inner class*) is *a class defined inside another class* - introduced in JDK 1.1. As an illustration, two nested classes `MyNestedClass1` and `MyNestedClass2` are defined *inside* the definition of an outer class called `MyOuterClass`.

```
public class MyOuterClass {   // outer class defined here
   ......
   private class MyNestedClass1 { ... }  // an nested class defined inside the outer class
   public static class MyNestedClass2 { ... }  // an "static" nested class defined inside the outer class
   ......
}
```

A nested class has these properties:

1. A nested class is a proper class. That is, it could contain constructors, member variables and member methods. You can create an instance of a nested class via the `new` operator and constructor.
2. A nested class is a *member* of the outer class, just like any member variables and methods defined inside a class.
3. Most importantly, a nested class can access the `private` members (variables/methods) of the enclosing outer class, as it is at the *same level* as these `private` members. This is the property that makes inner class useful.
4. A nested class can be `private`, `public`, `protected`, or the *default* access, just like any member variables and methods defined inside a class. A `private` inner class is only accessible by the enclosing outer class, and is not accessible by any other classes. [An top-level outer class cannot be declared `private`, as no one can use a `private` outer class.]
5. A nested class can also be declared `static`, `final` or `abstract`, just like any oridinary class.
6. A nested class is NOT a *subclass* of the outer class. That is, the nested class does not inherit the variables and methods of the outer class. It is an *ordinary* self-contained class. [Nonetheless, you could declare it as a subclass of the outer class, via keyword "`extends` *`OuterClassName`*", in the nested class's definition.]

The usages of nested class are:

1. To control visibilities (of the member variables and methods) between inner/outer class. The nested class, being defined inside an outer class, can access `private` members of the outer class.
2. To place a piece of class definition codes *closer* to where it is going to be used, to make the program clearer and easier to understand.
3. For namespace management.

There are 4 types of nested classes:

1. `static` nested class (as a outer class member),

2. non-`static` (instance) inner class (as a outer class member),
3. local inner class (defined inside a method),
4. annoymous local inner class (defined inside a method).

4.1 Static vs. Instance Nested Classes (Advanced)

A nested class can be declared `static` (belonging to the class instead of an instance). Recall that a `static` member can be used without instantiating the class and can be referenced via the classname in the form of *`Classname.memberName`* (e.g., `Math.PI`, `Integer.parseInt()`). Similarly, a `static` nested class can be used without instantiating the outer class and can be referenced via *`OuterClassName.InnerClassName`*.

On the other hand, a non-`static` nested class belongs to an instance of the outer class, just like any instance variable or method. It can be referenced via *`outerClassInstanceName.innerClassInstanceName`*. A non-`static` nested class is formally called an *inner class*.

Example of non-`static` (instance) inner class

In this example, a non-`static` (instance) inner class called `MyInnerClass` is defined inside the outer class. The inner class can access `private` members (variables/methods) of the outer class. This outer class also declares and constructs an instance of inner class as its member variable.

```
public class MyOuterClassWithInnerClass {
   // Private member variable of the outer class
   private String msgOuter = "Hello from outer class";

   // Define an inner class as a member of the outer class
   // This is merely an definition.
   // Not instantiation takes place when an instance of outer class is constructed
   public class MyInnerClass {
      // Private variable of the inner class
      private String msgInner;
      // Constructor of the inner class
      public MyInnerClass(String msgInner) {
         this.msgInner = msgInner;
         System.out.println("Constructing an inner class instance: " + msgOuter);
               // can access private member variable of outer class
      }
      // A method of inner class
      public void printMessage() {
         System.out.println(msgInner);
      }
   }

   // Declare and construct an instance of the inner class, inside the outer class
   MyInnerClass anInner = new MyInnerClass("Hi from inner class");
}
```

Two class files are produced: `MyOuterClassWithInnerClass.class` and `MyOuterClassWithInnerClass$MyInnerClass.class`.

The following test program:

1. Allocates an instance of outer class, which implicitly allocates an inner class (called `anInner`) as its member variable. You can access this inner class via *`outerClassInstanceName.innerClassInstanceName`*.
2. Explicitly constructs another instance of the inner class, under the same outer class instance created in the previous step.
3. Explicitly constructs one more instance of the inner class, under a new instance of outer class. This new outer class instance also implicitly allocates an inner class instance as its member, as seen from the output.

```
public class TestInnerClass {
   public static void main(String[] args) {
      // Construct an instance of outer class, which create anInner
      MyOuterClassWithInnerClass anOuter = new MyOuterClassWithInnerClass();
      // Invoke inner class's method from this outer class instance
      anOuter.anInner.printMessage();

      // Explicitly construct another instance of inner class
      MyOuterClassWithInnerClass.MyInnerClass inner2
           = anOuter.new MyInnerClass("Inner class 2");
      inner2.printMessage();

      // Explicitly construct an instance of inner class, under another instance of outer class
      MyOuterClassWithInnerClass.MyInnerClass inner3
           = new MyOuterClassWithInnerClass().new MyInnerClass("Inner class 3");
      inner3.printMessage();
   }
}
```

```
Constructing an inner class instance: Hello from outer class
Hi from inner class
Constructing an inner class instance: Hello from outer class
Inner class 2
Constructing an inner class instance: Hello from outer class
```

```
Constructing an inner class instance: Hello from outer class
Inner class 3
```

An inner class defintion is merely a definition of a class. The outer class does not create an inner class instance, when it is instantiated. Nonetheless, you could declare it as member of the outer class, as illustrated in the above example. In many situations, we declare the inner class `private`. In this cases, the inner class can only be used (declare and construct) within the outer class.

You can set the inner class to `private` access. In this case, the inner class can only be accessed within the outer class, and not by other classes.

Example of `static` nested class

In this example, a `static` nested class is defined inside the outer class, which can access the `private static` variables of the outer class.

```
public class MyOuterClassWithStaticNestedClass {
   // Private "static" member variable of the outer class
   private static String msgOuter = "Hello from outer class";

   // Define a "static" nested class as a member of the outer class
   // It can access private "static" variable of the outer class
   public static class MyStaticNestedClass {
      // Private variable of inner class
      private String msgInner;
      // Constructor of inner class
      public MyStaticNestedClass(String msgInner) {
         this.msgInner = msgInner;
         System.out.println(msgOuter); // access private member of the outer class
      }
      // A method of inner class
      public void printMessage() {
         System.out.println(msgInner);
      }
   }
}
```

You can access the `static` nested class via the outer classname, in the form of *`OuterClassName.NestedClassName`*, just like any static variables/methods (e.g., `Math.PI`, `Integer.parseInt()`). You can instantiate a `static` nested class without instantiate the outer class, as `static` members are associated with the class, instead of instances.

```
public class TestStaticNestedClass {
   public static void main(String[] args) {
      // Construct an instance of static nested class
      // A "static" nested class, like other "static" members, can be accessed via
      // the Classname.membername
      MyOuterClassWithStaticNestedClass.MyStaticNestedClass aNestedInner =
            new MyOuterClassWithStaticNestedClass.MyStaticNestedClass("Hi from inner class");
      aNestedInner.printMessage();
   }
}
```

```
Hello from outer class
Hi from inner class
```

As seen from the example, a `static` nested class is really like a top-level class with a modified name (*`OuterClassname.InnerClassname`*). It can be used as an extension to package for *namespace management*.

4.2 Local Inner Class Defined Inside a Method (Advanced)

Java allows you to define an inner class inside a method, just like defining a method's local variable. Like local variable, a local inner class does not exist until the method is invoked, and goes out of scope when the method exits.

A local inner class has these properties:

1. A local inner class cannot have access modifier (such as `private` or `public`). It also cannot be declared `static`.
2. A local inner class can access all the variables/methods of the enclosing outer class.
3. A local inner class can have access to the local variables of the enclosing method only if they are declared `final` (to prevent undesirable side-effects).

Example

```
public class MyOuterClassWithLocalInnerClass {
   // Private member variable of the outer class
   private String msgOuter = "Hello from outer class";

   // A member method of the outer class
   public void doSomething() {

      // A local variable of the method
      final String msgMethod = "Hello from method";

      // Define a local inner class inside the method
```

```
      class MyInnerClass {
         // Private variable of the inner class
         private String msgInner;
         // Constructor of the inner class
         public MyInnerClass(String msgInner) {
            this.msgInner = msgInner;
            System.out.println("Constructing an inner class instance: " + msgOuter);
               // can access private member variable of outer class
            System.out.println("Accessing final variable of the method: " + msgMethod);
               // can access final variable of the method
         }
         // A method of inner class
         public void printMessage() {
            System.out.println(msgInner);
         }
      }

      // Create an instance of inner class and invoke its method
      MyInnerClass anInner = new MyInnerClass("Hi, from inner class");
      anInner.printMessage();
   }

   // Test main() method
   public static void main(String[] args) {
       // Create an instance of the outer class and invoke the method.
       new MyOuterClassWithLocalInnerClass().doSomething();
   }
}
```

```
Constructing an inner class instance: Hello from outer class
Accessing final variable of the method: Hello from method
Hi, from inner class
```

4.3 An Annoymous Inner Class (Advanced)

An annoymous inner class is a local inner class (of a method) without assigning an explicit classname. It must either "`extends`" an existing superclass or "`implements`" an interface. It is declared and instantiated in one statement via the `new` keyword.

Example

```
public class MyOuterClassWithAnonymousInnerClass {
   // Private member variable of the outer class
   private String msgOuter = "Hello from outer class";

   // A member method of the outer class
   public void doSomething() {
      // A local variable of the method
      final String msgMethod = "Hello from method";

      Thread thread = new Thread() { // create an instance of an anonymous inner class that extends Thread class
         @Override
         public void run() {
            System.out.println("Constructing an inner class instance: " + msgOuter);
               // can access private member variable of outer class
            System.out.println("Accessing final variable of the method: " + msgMethod);
               // can access final variable of the method
            System.out.println("Hi, from inner class!");
         }
      };
      thread.start();
   }

   // Test main() method
   public static void main(String[] args) {
       // Create an instance of the outer class and invoke the method.
       new MyOuterClassWithAnonymousInnerClass().doSomething();
   }
}
```

```
Constructing an inner class instance: Hello from outer class
Accessing final variable of the method: Hello from method
Hi, from inner class
```

The anonymous inner class definition is equivalent to:

```
public void doSomething()
   ......
   class OuterClassName.n extends Thread {  // where n is a running number of anonymous inner classes
      ......
   }
   Thread thread = new OuterClassName.n();  // create an instance of the anonymous inner class
   ......
```

```
}
```

Clearly, you can only create one instance for each anonymous inner class.

4.4 An Inner Class as Event Listener

A nested class is useful if you require a *small* class that relies on the enclosing outer class for its private variables and methods. It is ideal in the Event-Driven environment for implementing event listeners. This is because the event handling method (in a listener) often requires access to private variables (e.g., a private `TextField`) of the outer class. I shall illustrate this point in the following examples.

In this example (modified from `AWTCounter`), instead of using "`this`" as the `ActionListener` for the button, we define a new class called `BtnCountListener`, and create an instance of `BtnCountListener` as the `ActionListener` for the button `btnCount`. The `BtnCountListener` needs to implement the `ActionListener` interface, and override the `actionPerformed()` handler. Since "`this`" is no long a `ActionListener`, we remove the "`implements ActionListener`" from "`this`" class's definition.

`BtnCountListener` has to be defined as an inner class, as it needs to access private variables (`count` and `tfCount`) of the outer class.

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTCounterNamedInnerClass extends Frame {
   // This class is NOT a ActionListener, hence, it does not implement ActionListener

   // The event-handler actionPerformed() needs to access these private variables
   private TextField tfCount;
   private int count = 0;

   /** Constructor to setup the GUI */
   public AWTCounterNamedInnerClass () {
      setLayout(new FlowLayout());  // "this" Frame sets to FlowLayout
      add(new Label("Counter"));    // anonymous instance of Label
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);   // read-only
      add(tfCount);                 // "this" Frame adds tfCount

      Button btnCount = new Button("Count");
      add(btnCount);                // "this" Frame adds btnCount

      // Construct an anonymous instance of BtnCountListener (a named inner class).
      // btnCount adds this instance as a ActionListener.
      btnCount.addActionListener(new BtnCountListener());

      setTitle("AWT Counter");
      setSize(250, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new AWTCounterNamedInnerClass(); // Let the constructor do the job
   }

   /**
    * BtnCountListener is a "named inner class" used as ActionListener.
    * This inner class can access private variables of the outer class.
    */
   private class BtnCountListener implements ActionListener {
      @Override
      public void actionPerformed(ActionEvent e) {
         ++count;
         tfCount.setText(count + "");
      }
   }
}
```

Dissecting the Program

- An inner class named `BtnCountListener` is used as the `ActionListner`.
- An anonymous instance of the `BtnCountListener` inner class is constructed. The `btnCount` source object adds this instance as a listener, as follows:

  ```
  btnCount.addActionListener(new BtnCountListener());
  ```

- The inner class can access the `private` variable `tfCount` and `count` of the outer class.
- Since "`this`" is no longer a listener, we remove the "`implements ActionListener`" from `this` class' definition.
- The inner class is compiled into `AWTCount$BtnCountListener.class`, in the formet of *`OuterClassName$InnerClassName`*`.class`.

Using an Ordinary (Outer) Class as Listener (Advanced)

Try moving the `BtnCountListener` class outside, and define it as an ordinary class. You would need to pass a reference of the `AWTConnter` into the constructor of `BtnCountListener`, and use this reference to access variables `tfCount` and `count`, through `public` getters or changing them to `public`.

```
// An ordinary outer class used as ActionListener for the Button
public class BtnCountListener implements ActionListener {
   AWTCounter frame;
   public BtnCountListener(AWTCounter frame) {
      this.frame = frame;
   }

   @Override
   public void actionPerformed(ActionEvent e) {
      frame.count++;
      frame.tfCount.setText(frame.count + "");
   }
}
```

Alternatively, you can pass `tfCount` and `count` into the constructor of `BtnCountListener`.

4.5 An Anonymous Inner Class as Event Listener

Instead of using a *named inner class* (called `BtnCountListner` in the previous example), we shall use an inner class without a name, known as *anonymous inner class* as the `ActionListener` in this example.

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTCounterAnonymousInnerClass extends Frame {
   // This class is NOT a ActionListener, hence, it does not implement ActionListener

   // The event-handler actionPerformed() needs to access these private variables
   private TextField tfCount;
   private int count = 0;

   /** Constructor to setup the GUI */
   public AWTCounterAnonymousInnerClass () {
      setLayout(new FlowLayout());  // "this" Frame sets to FlowLayout
      add(new Label("Counter"));    // an anonymous instance of Label
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);   // read-only
      add(tfCount);                 // "this" Frame adds tfCount

      Button btnCount = new Button("Count");
      add(btnCount);                // "this" Frame adds btnCount

      // Construct an anonymous instance of an anonymous class.
      // btnCount adds this instance as a ActionListener.
      btnCount.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            ++count;
            tfCount.setText(count + "");
         }
      });

      setTitle("AWT Counter");
      setSize(250, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new AWTCounterAnonymousInnerClass(); // Let the constructor do the job
   }
}
```

Dissecting the Program

- Again, "`this`" class is NOT used as the `ActionEvent` listener. Hence, we remove the "`implements ActionListener`" from `this` class' definition.
- The anonymous inner class is given a name generated by the compiler, and compiled into `OuterClassName$n.class`, where *n* is a running number of the inner classes of this outer class.
- An anonymous instance of an anonymous inner class is constructed, and passed as the argument of the `addActionListener()` method as follows:

```
btnCount.addActionListener(new ActionListener() {
   @Override
   public void actionPerformed(ActionEvent e) {
      ++count;
      tfCount.setText(count + "");
   }
});
```

The above codes is equivalent to and compiled as:

```
private class N implements ActionListener {  // N is a running number of the inner classes created
   @Override
   public void actionPerformed(ActionEvent e) {
      ++count;
      tfCount.setText(count + "");
   }
}
btnCount.addActionListener(new N());

// Or
N n = new N()
btnCount.addActionListener(n);
```

- The above codes create an anonymous instance of an anonymous inner class, and pass it as the argument for a method. You can also create a named instance of an anonymous inner class, for example,

```
// Create an named instance called drawPanel of an anonymous class extends JPanel
// Upcast to superclass
JPanel drawPanel = new JPanel() {
   @Override
   public void paintComponent(Graphics g) {
      ......
   }
}

// same as
class N extends JPanel {
   @Override
   public void paintComponent(Graphics g) {
      ......
   }
}
JPanel drawPanel = new N();  // upcast
```

Properties of Anonymous Inner Class

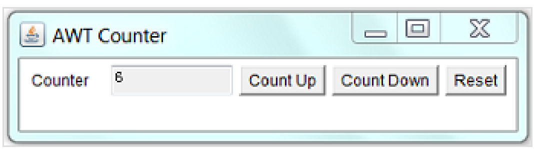
1. The anonymous inner class is define inside a method, instead of a member of the outer class (class member). It is *local* to the method and cannot be marked with access modifier (such as `public`, `private`) or `static`, just like any local variable of a method.
2. An anonymous inner class must always extend a superclass or implement an interface. The keyword "`extends`" or "`implements`" is NOT required in its declaration. An anonymous inner class must implement all the abstract methods in the superclass or in the interface.
3. An anonymous inner class always uses the default (no-arg) constructor from its superclass to create an instance. If an anonymous inner class implements an interface, it uses the `java.lang.Object()`.
4. An anonymous inner class is compiled into a class named `OuterClassName$n.class`, where *n* is a running number of inner classes within the outer class.
5. An instance of an anonymous inner class is constructed via this syntax:

```
new SuperClassName/InterfaceName() {  // extends superclass or implements interface
                                      // invoke the default no-arg constructor or Object[]
  // Implement abstract methods in superclass/interface
  // More methods if necessary
  ......
}
```

The created instance can be assigned to a variable or used as an argument of a method.

4.6 An Anonymous Inner Class for Each Source

Let's modify our `AWTCounter` example to include 3 buttons for counting up, counting down, and reset the count, respectively. We shall attach an anonymous inner class as the listener to each of buttons.




```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTCounter3Buttons extends Frame {
```

```
   private TextField tfCount;
   private int count = 0;

   /** Constructor to setup the GUI */
   public AWTCounter3Buttons () {
      setLayout(new FlowLayout());
      add(new Label("Counter"));   // an anonymous instance of Label
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);  // read-only
      add(tfCount);                // "this" Frame adds tfCount

      Button btnCountUp = new Button("Count Up");
      add(btnCountUp);
      // Construct an anonymous instance of an anonymous inner class.
      // The source Button adds this instance as ActionEvent listener
      btnCountUp.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            ++count;
            tfCount.setText(count + "");
         }
      });

      Button btnCountDown = new Button("Count Down");
      add(btnCountDown);
      btnCountDown.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            count--;
            tfCount.setText(count + "");
         }
      });

      Button btnReset = new Button("Reset");
      add(btnReset);
      btnReset.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            count = 0;
            tfCount.setText("0");
         }
      });

      setTitle("AWT Counter");
      setSize(400, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new AWTCounter3Buttons();  // Let the constructor do the job
   }
}
```

Dissecting the Program

[TODO]

4.7 Using the Same Listener Instance for All the Buttons

If you use the same instance as the listener for the 3 buttons, you need to determine which button has fired the event. It is because all the 3 buttons trigger the same event-handler method.

Using `ActionEvent`'s `getActionCommand()`

In the following example, we use the same instance of a named inner class as the listener for all the 3 buttons. The listener needs to determine which button has fired the event. This can be accomplished via the `ActionEvent`'s `getActionCommonad()` method, which returns the button's label.

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTCounter3Buttons1Listener extends Frame {
   private TextField tfCount;
   private int count = 0;

   /** Constructor to setup the GUI */
   public AWTCounter3Buttons1Listener () {
      setLayout(new FlowLayout());
      add(new Label("Counter"));
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);
```

```
      add(tfCount);

      // Create buttons
      Button btnCountUp = new Button("Count Up");
      add(btnCountUp);
      Button btnCountDown = new Button("Count Down");
      add(btnCountDown);
      Button btnReset = new Button("Reset");
      add(btnReset);

      // Allocate an instance of inner class BtnListener.
      BtnListener listener = new BtnListener();
      // Use the same listener to all the 3 buttons.
      btnCountUp.addActionListener(listener);
      btnCountDown.addActionListener(listener);
      btnReset.addActionListener(listener);

      setTitle("AWT Counter");
      setSize(400, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new AWTCounter3Buttons1Listener();  // Let the constructor do the job
   }

   /**
    * BtnListener is a named inner class used as ActionEvent listener for the buttons.
    */
   private class BtnListener implements ActionListener {
      @Override
      public void actionPerformed(ActionEvent e) {
         // Need to determine which button has fired the event.
         // getActionCommand() returns the button's label
         String btnLabel = e.getActionCommand();
         if (btnLabel.equals("Count Up")) {
            ++count;
         } else if (btnLabel.equals("Count Down")) {
            --count;
         } else {
            count = 0;
         }
         tfCount.setText(count + "");
      }
   }
}
```

Using `getSource()` of `EventObject`

Besides the `getActionCommand()`, which is only available for `ActionEvent`, you can use the `getSource()` method, which is available to all event objects, to retrieve a reference to the source object that has fired the event. `getSource()` returns a `java.lang.Object`. You may need to downcast it to the proper type of the source object. For example,

```
import java.awt.*;
import java.awt.event.*;

public class AWTCounter3ButtonsGetSource extends Frame {
   private TextField tfCount;
   private Button btnCountUp, btnCountDown, btnReset;
   private int count = 0;

   /** Constructor to setup the GUI */
   public AWTCounter3ButtonsGetSource () {
      setLayout(new FlowLayout());
      add(new Label("Counter"));
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);
      add(tfCount);

      // Create buttons
      btnCountUp = new Button("Count Up");
      add(btnCountUp);
      btnCountDown = new Button("Count Down");
      add(btnCountDown);
      btnReset = new Button("Reset");
      add(btnReset);

      // Allocate an instance of inner class BtnListener.
      BtnListener listener = new BtnListener();
      // Use the same listener to all the 3 buttons.
      btnCountUp.addActionListener(listener);
      btnCountDown.addActionListener(listener);
```

```
      btnReset.addActionListener(listener);

      setTitle("AWT Counter");
      setSize(400, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new AWTCounter3ButtonsGetSource();  // Let the constructor do the job
   }

   /**
    * BtnListener is a named inner class used as ActionEvent listener for the buttons.
    */
   private class BtnListener implements ActionListener {
      @Override
      public void actionPerformed(ActionEvent e) {
         // Need to determine which button has fired the event.
         Button source = (Button)e.getSource();
               // Get a reference of the source that has fired the event.
               // getSource() returns a java.lang.Object. Downcast back to Button.
         if (source == btnCountUp) {
            ++count;
         } else if (source == btnCountDown) {
            --count;
         } else {
            count = 0;
         }
         tfCount.setText(count + "");
      }
   }
}
```

4.8 Example of Static Nested Class in JDK: `Point2D`, `Point2D.Double`, `Point2D.Float`, `Point` (Advanced)

The `abstract` class `Point2D` (in package `java.awt.geom` of Java 2D API), which models a 2D point, declares `abstract` methods such as `getX()` and `getY()`. The `Point2D` cannot be instantiated. `Point2D` does not define any instance variable, in particular, the x and y location of the point. This is because it is not sure about the *type* of x and y (which could be `int`, `float`, or `double`). The instance variables, therefore, are left to the implementation subclasses.

Three subclasses were implemented for types of `int`, `float` and `double`, respectively. `Point2D` cannot be designed as a pure abstract-method-only `interface`, as it contains non-abstract methods.

The subclass `Point` defines instance variables x and y in `int` precision and provides implementation to abstract methods such as `getX()` and `getY()`. `Point` (of `int`-precision) is a straight-forward implementation of inheritance and polymorphism. `Point` is a legacy class (since JDK 1.1) and retrofitted when Java 2D was introduced.

Two subclasses `Point2D.Float` and `Point2D.Double` define instance variables x and y in `float` and `double` precision, respectively. These two subclasses, are also declared as `public static` nested class of the outer class `Point2D`. Since they are `static`, they can be referenced as `Point2D.Double` and `Point2D.Float`. They are implemented as nested `static` subclasses within the `Point2D` outer class to keep the codes together and for namespace management. There is no access-control (of private variables of the outer class) involved.

```
package java.awt.geom;
abstract public class Point2D  {

   // abstract methods
   abstract public double getX();
   abstract public double getY();
   abstract public void setLocation(double x, double y);

   public double distance(double x, double y) { ... }
   public double distance(Point2D p) { ... }
   public static double distance(double x1, double y1, double x2, double y2) { ... }
   ......

   public static class Double extends Point2D {
      public double x;
      public double y;

      public Double(double x, double y) { ... }
      @Override public double getX() { return x; }
      @Override public double getY() { return y; }
      @Override public void setLocation(double x, double y) { ... }
      ......
   }

   public static class Float extends Point2D {
      public float x;
```

```
      public float y;
      public Double(float x, float y) { ... }
      @Override public double getX() { ... }
      @Override public double getY() { ... }
      @Override public void setLocation(double x, double y) { ... }
      public void setLocation(float x, float y) { ... }
      ......
   }
}
```

```
package java.awt.geom;
public class Point extends Point2D {
   public int x;
   public int y;
   public Point(int x, int y) { ... }
   @Override public double getX() { return x; }
   @Override public double getY() { return y; }
   @Override public void setLocation(double x, double y) { ... }
   ......
}
```

`Point2D.Double` and `Point2D.Float` are `public static` classes. In other words, they can be used directly without instantiating the outer class, just like any `static` variable or method (which can be referenced directly via the classname, e.g., `Math.PI`, `Math.sqrt()` and `Integer.parseInt()`). Since they are subclass of `Point2D`, they can be upcast to `Point2D`.

```
Point2D.Double p1 = new Point2D.Double(1.1, 2.2);
Point2D.Float p2 = new Point2D.Float(1.1f, 2.2f);
Point p3 = new Point(1, 2);
// Using polymorphism
Point2D p1 = new Point2D.Double(1.1, 2.2);   // upcast
Point2D p2 = new Point2D.Float(1.1f, 2.2f);  // upcast
Point2D p3 = new Point(1, 2);                // upcast
```

Note: These classes were designed before the introduction of generic in JDK 1.5, which supports the passing of type as argument.

4.9 "Cannot refer to a non-final variable inside an inner class defined in a different method" (Advanced)

Java specification 8.1.3: "Any local variable, formal method parameter or exception handler parameter used but not declared in an inner class must be declared final."

By allowing inner class to access non-`final` local variables inside a method, the local variable could be modified by the inner class, and causes a strange side-effect.

Solution:

1. Declare the variable `final` if permissible.
2. Declare the variable outside the method, e.g., as *member variables* of the class, instead of a local variable within a method. Both the method and the inner class could access the variable.
3. Use a wrapper class to wrap the variable inside a class. Declare the instance `final`.

4.10 Referencing Outer-class's "`this`" from Inner-class

Inside the inner class, "`this`" refers to the inner class. To refer to the "`this`" of the outer class, use "*`OuterClassName`*`.this`". But you can reference outer class's members directly without this clumpy syntax. For example,

```
......
public class MyOuterClassName {
   private String msg = "Hello";
   ......
   public MyOuterClassName() {  // constructor
      ......
      Button btn = new Button("TEST");
      btn.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            // Need OuterClassName.this to refer to the outer class.
            // But can reference outer class members (e.g., msg) directly.
            JOptionPane.showMessageDialog(MyOuterClassName.this, msg);
         }
      });
   }
}
```

5. Event Listener's Adapter Class

5.1 WindowListener/WindowAdapter

Refer to the `WindowEventDemo`, a `WindowEvent` listener is required to implement the `WindowListener` interface, which declares 7 `abstract` methods. Although we are only interested in `windowClosing()`, we need to provide an empty body to the other 6 methods in order to compile the program. This is tedious. For example, we can rewrite the `WindowEventDemo` using an inner class implementing `ActionListener` as follows:

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class WindowEventDemoWithInnerClass extends Frame {
   private TextField tfCount;
   private int count = 0;

   /** Constructor to setup the GUI */
   public WindowEventDemoWithInnerClass () {
      setLayout(new FlowLayout());
      add(new Label("Counter"));
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);
      add(tfCount);

      Button btnCount = new Button("Count");
      add(btnCount);
      btnCount.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent evt) {
            ++count;
            tfCount.setText(count + "");
         }
      });

      // Allocate an anonymous instance of an anonymous inner class
      // that implements WindowListener.
      // "this" Frame adds the instance as WindowEvent listener.
      addWindowListener(new WindowListener() {
         @Override
         public void windowClosing(WindowEvent e) {
            System.exit(0);  // terminate the program
         }
         // Need to provide an empty body for compilation
         @Override public void windowOpened(WindowEvent e) { }
         @Override public void windowClosed(WindowEvent e) { }
         @Override public void windowIconified(WindowEvent e) { }
         @Override public void windowDeiconified(WindowEvent e) { }
         @Override public void windowActivated(WindowEvent e) { }
         @Override public void windowDeactivated(WindowEvent e) { }
      });

      setTitle("WindowEvent Demo");
      setSize(250, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new WindowEventDemoWithInnerClass();   // Let the constructor do the job
   }
}
```

An *adapter* class called `WindowAdapter` is therefore provided, which implements the `WindowListener` interface and provides default implementations to all the 7 `abstract` methods. You can then derive a subclass from `WindowAdapter` and override only methods of interest and leave the rest to their default implementation. For example,

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class WindowEventDemoAdapter extends Frame {
   private TextField tfCount;
   private int count = 0;

   /** Constructor to setup the GUI */
   public WindowEventDemoAdapter () {
      setLayout(new FlowLayout());
      add(new Label("Counter"));
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);
      add(tfCount);

      Button btnCount = new Button("Count");
```

```
      add(btnCount);
      btnCount.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent evt) {
            ++count;
            tfCount.setText(count + "");
         }
      });

      // Allocate an anonymous instance of an anonymous inner class
      // that extends WindowAdapter.
      // "this" Frame adds the instance as WindowEvent listener.
      addWindowListener(new WindowAdapter() {
         @Override
         public void windowClosing(WindowEvent e) {
            System.exit(0);  // Terminate the program
         }
      });

      setTitle("WindowEvent Demo");
      setSize(250, 100);
      setVisible(true);
   }

   /** The entry main method */
   public static void main(String[] args) {
      new WindowEventDemoAdapter();   // Let the constructor do the job
   }
}
```

5.2 Other Event-Listener Adapter Classes

Similarly, adapter classes such as `MouseAdapter`, `MouseMotionAdapter`, `KeyAdapter`, `FocusAdapter` are available for `MouseListener`, `MouseMotionListener`, `KeyListener`, and `FocusListener`, respectively.

There is no `ActionAdapter` for `ActionListener`, because there is only one `abstract` method (i.e. `actionPerformed()`) declared in the `ActionListener` interface. This method has to be overridden and there is no need for an adapter.

6. Layout Managers

A container has a so-called *layout manager* to arrange its components. The layout managers provide a level of abstraction to map your user interface on all windowing systems, so that the layout can be *platform-independent*.

AWT provides the following layout managers (in package `java.awt`): `FlowLayout`, `GridLayout`, `BorderLayout`, `GridBagLayout`, `BoxLayout`, `CardLayout`, and others. (Swing added more layout manager in package `javax.swing`, to be described later.)

Container's setLayout()

A container has a `setLayout()` method to set its layout manager:

```
// java.awt.Container
public void setLayout(LayoutManager mgr)
```

To set up the layout of a `Container` (such as `Frame`, `JFrame`, `Panel`, or `JPanel`), you have to:

1. Construct an instance of the chosen layout object, via `new` and constructor, e.g., `new FlowLayout()`)
2. Invoke the `setLayout()` method of the `Container`, with the layout object created as the argument;
3. Place the GUI components into the `Container` using the `add()` method in the correct order; or into the correct zones.

For example,

```
// Allocate a Panel (containter)
Panel p = new Panel();
// Allocate a new Layout object. The Panel container sets to this layout.
p.setLayout(new FlowLayout());
// The Panel container adds components in the proper order.
p.add(new JLabel("One"));
p.add(new JLabel("Two"));
p.add(new JLabel("Three"));
......
```

Container's getLayout()

You can get the current layout via `Container`'s `getLayout()`.

```
Panel awtPanel = new Panel();
System.out.println(awtPanel.getLayout());
      // java.awt.FlowLayout[hgap=5,vgap=5,align=center]
```

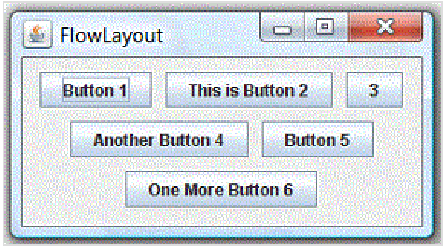
Panel's Inital Layout

`Panel` (and Swing's `JPanel`) provides a constructor to set its initial layout manager. It is because a primary function of `Panel` is to layout a group of component in a particular layout.

```
public void Panel (LayoutManager layout)
   // Construct a Panel in the given layout
   // By default, Panel (and JPanel) has FlowLayout

// For example, create a Panel in BorderLayout
Panel mainPanel = new Panel(new BorderLayout());
```

6.1 FlowLayout

In the `java.awt.FlowLayout`, components are arranged from left-to-right inside the container in the order that they are added (via method `aContainer.add(aComponent)`). When one row is filled, a new row will be started. The actual appearance depends on the width of the display window.



<u>Constructors</u>

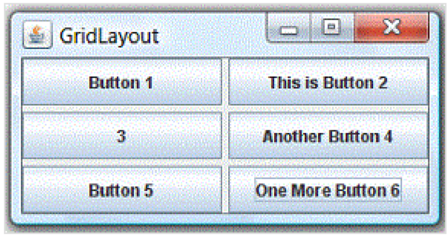
```
public FlowLayout();
public FlowLayout(int align);
public FlowLayout(int align, int hgap, int vgap);
  // align: FlowLayout.LEFT (or LEADING), FlowLayout.RIGHT (or TRAILING), or FlowLayout.CENTER
  // hgap, vgap: horizontal/vertical gap between the components
  // By default: hgap=5, vgap=5, align=CENTER
```

<u>Example</u>

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTFlowLayoutDemo extends Frame {
   private Button btn1, btn2, btn3, btn4, btn5, btn6;

   /** Constructor to setup GUI components */
   public AWTFlowLayoutDemo () {
      setLayout(new FlowLayout());
         // "this" Frame sets layout to FlowLayout, which arranges the components
         // from left-to-right, and flow from top-to-bottom.

      btn1 = new Button("Button 1");
      add(btn1);
      btn2 = new Button("This is Button 2");
      add(btn2);
      btn3 = new Button("3");
      add(btn3);
      btn4 = new Button("Another Button 4");
      add(btn4);
      btn5 = new Button("Button 5");
      add(btn5);
      btn6 = new Button("One More Button 6");
      add(btn6);

      setTitle("FlowLayout Demo"); // "this" Frame sets title
      setSize(280, 150);      // "this" Frame sets initial size
      setVisible(true);       // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new AWTFlowLayoutDemo();  // Let the constructor do the job
   }
}
```

6.2 GridLayout

In `java.awt.GridLayout`, components are arranged in a grid (matrix) of rows and columns inside the `Container`. Components are added in a left-to-right, top-to-bottom manner in the order they are added (via method `aContainer.add(aComponent)`).



Constructors

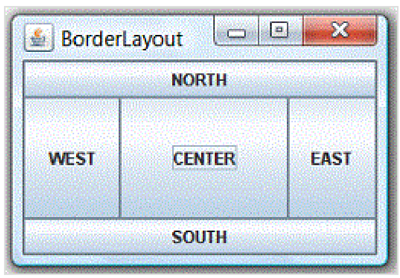
```
public GridLayout(int rows, int columns);
public GridLayout(int rows, int columns, int hgap, int vgap);
      // By default: rows=1, cols=0, hgap=0, vgap=0
```

Example

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTGridLayoutDemo extends Frame {
   private Button btn1, btn2, btn3, btn4, btn5, btn6;

   /** Constructor to setup GUI components */
   public AWTGridLayoutDemo () {
      setLayout(new GridLayout(3, 2, 3, 3));
         // "this" Frame sets layout to 3x2 GridLayout, horizontal and verical gaps of 3 pixels

      // The components are added from left-to-right, top-to-bottom
      btn1 = new Button("Button 1");
      add(btn1);
      btn2 = new Button("This is Button 2");
      add(btn2);
      btn3 = new Button("3");
      add(btn3);
      btn4 = new Button("Another Button 4");
      add(btn4);
      btn5 = new Button("Button 5");
      add(btn5);
      btn6 = new Button("One More Button 6");
      add(btn6);

      setTitle("GridLayout Demo"); // "this" Frame sets title
      setSize(280, 150);      // "this" Frame sets initial size
      setVisible(true);       // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new AWTGridLayoutDemo();  // Let the constructor do the job
   }
}
```

If `rows` or `cols` is 0, but not both, then any number of components can be placed in that column or row. If both the `rows` and `cols` are specified, the `cols` value is ingored. The actual `cols` is determined by the actual number of components and `rows`.

6.3 BorderLayout



In `java.awt.BorderLayout`, the container is divided into 5 zones: `EAST`, `WEST`, `SOUTH`, `NORTH`, and `CENTER`. Components are added using method `aContainer.add(acomponent, aZone)`, where *azone* is either `BorderLayout.NORTH` (or `PAGE_START`), `BorderLayout.SOUTH` (or `PAGE_END`), `BorderLayout.WEST` (or `LINE_START`), `BorderLayout.EAST` (or `LINE_END`), or `BorderLayout.CENTER`. The method `aContainer.add(aComponent)` without specifying the zone adds the component to the `CENTER`.

You need not add components to all the 5 zones. The `NORTH` and `SOUTH` components may be stretched horizontally; the `EAST` and `WEST` components may be stretched vertically; the `CENTER` component may stretch both horizontally and vertically to fill any space left over.

Constructors

```
public BorderLayout();
public BorderLayout(int hgap, int vgap);
      // By default hgap=0, vgap=0
```

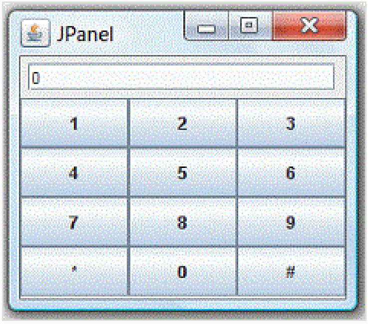
Example

```
import java.awt.*;
```

```
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTBorderLayoutDemo extends Frame {
   private Button btnNorth, btnSouth, btnCenter, btnEast, btnWest;

   /** Constructor to setup GUI components */
   public AWTBorderLayoutDemo () {
      setLayout(new BorderLayout(3, 3));
         // "this" Frame sets layout to BorderLayout,
         // horizontal and vertical gaps of 3 pixels

      // The components are added to the specified zone
      btnNorth = new Button("NORTH");
      add(btnNorth, BorderLayout.NORTH);
      btnSouth = new Button("SOUTH");
      add(btnSouth, BorderLayout.SOUTH);
      btnCenter = new Button("CENTER");
      add(btnCenter, BorderLayout.CENTER);
      btnEast = new Button("EAST");
      add(btnEast, BorderLayout.EAST);
      btnWest = new Button("WEST");
      add(btnWest, BorderLayout.WEST);

      setTitle("BorderLayout Demo"); // "this" Frame sets title
      setSize(280, 150);        // "this" Frame sets initial size
      setVisible(true);         // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new AWTBorderLayoutDemo();  // Let the constructor do the job
   }
}
```

6.4 Using `Panels` as Sub-Container to Organize Components

An AWT `Panel` is a retangular pane, which can be used as sub-container to organized a group of related components in a specific layout (e.g., `FlowLayout`, `BorderLayout`). `Panel`s are secondary containers, which shall be added into a top-level container (such as `Frame`), or another `Panel`.



For example, the following figure shows a `Frame` (in `BorderLayout`) containing two `Panels`, `panelResult` in `FlowLayout` and `panelButtons` in `GridLayout`. `panelResult` is added to the `NORTH`, and `panelButtons` is added to the `CENTER`.

```
import java.awt.*;
import java.awt.event.*;

// An AWT GUI program inherits the top-level container java.awt.Frame
public class AWTPanelDemo extends Frame {
   private Button[] btnNumbers = new Button[10];  // Array of 10 numeric buttons
   private Button btnHash, btnStar;
   private TextField tfDisplay;

   /** Constructor to setup GUI components */
   public AWTPanelDemo () {
      // Set up display panel
      Panel panelDisplay = new Panel(new FlowLayout());
      tfDisplay = new TextField("0", 20);
      panelDisplay.add(tfDisplay);

      // Set up button panel
      Panel panelButtons = new Panel(new GridLayout(4, 3));
      btnNumbers[1] = new Button("1");
      panelButtons.add(btnNumbers[1]);
      btnNumbers[2] = new Button("2");
      panelButtons.add(btnNumbers[2]);
      btnNumbers[3] = new Button("3");
      panelButtons.add(btnNumbers[3]);
      btnNumbers[4] = new Button("4");
      panelButtons.add(btnNumbers[4]);
      btnNumbers[5] = new Button("5");
      panelButtons.add(btnNumbers[5]);
      btnNumbers[6] = new Button("6");
      panelButtons.add(btnNumbers[6]);
      btnNumbers[7] = new Button("7");
      panelButtons.add(btnNumbers[7]);
```

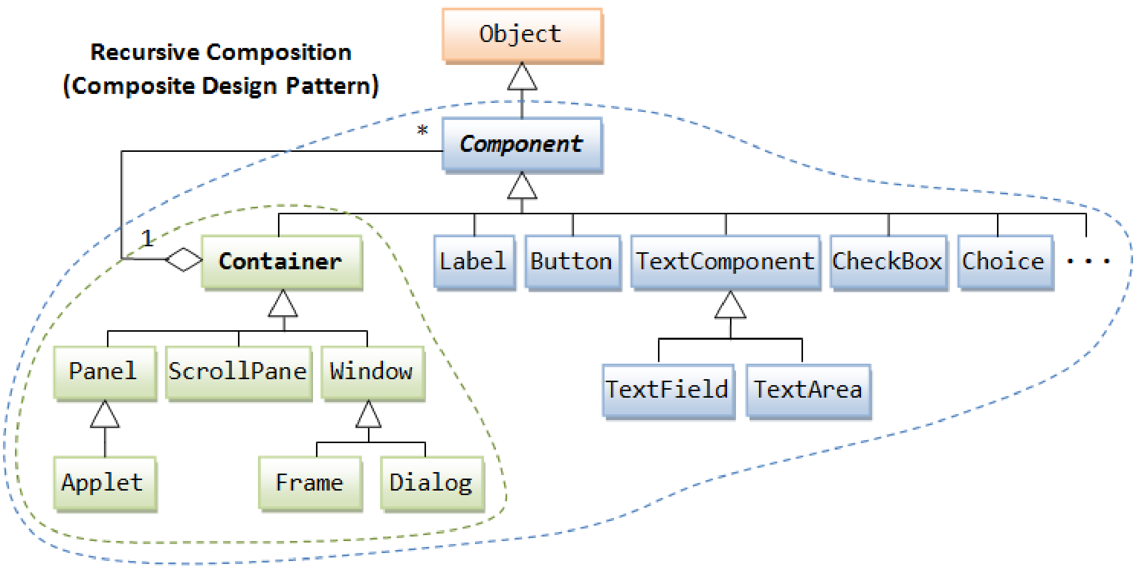
```
      btnNumbers[8] = new Button("8");
      panelButtons.add(btnNumbers[8]);
      btnNumbers[9] = new Button("9");
      panelButtons.add(btnNumbers[9]);
         // Can use a loop for the above statements!
      btnStar = new Button("*");
      panelButtons.add(btnStar);
      btnNumbers[0] = new Button("0");
      panelButtons.add(btnNumbers[0]);
      btnHash = new Button("#");
      panelButtons.add(btnHash);

      setLayout(new BorderLayout());  // "this" Frame sets to BorderLayout
      add(panelDisplay, BorderLayout.NORTH);
      add(panelButtons, BorderLayout.CENTER);

      setTitle("BorderLayout Demo"); // "this" Frame sets title
      setSize(200, 200);         // "this" Frame sets initial size
      setVisible(true);          // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      new AWTPanelDemo();  // Let the constructor do the job
   }
}
```

6.5 BoxLayout

BoxLayout arrange components in a single row or column. It respects components' requests on the minimum sizes.

[TODO] Example and diagram

7. Composite Design Pattern (Advanced)



As mentioned earlier, there are two groups of classes in the AWT hierarchy: containers and components. A container (e.g., `Frame`, `Panel`, `Dialog`, `java.applet.Applet`) holds components (e.g., `Label`, `Button`, `TextField`). A container (e.g., `Frame` and `Panel`) can also hold sub-containers (e.g. `Panel`). Hence, we have a situation that "a container can contain containers or components".

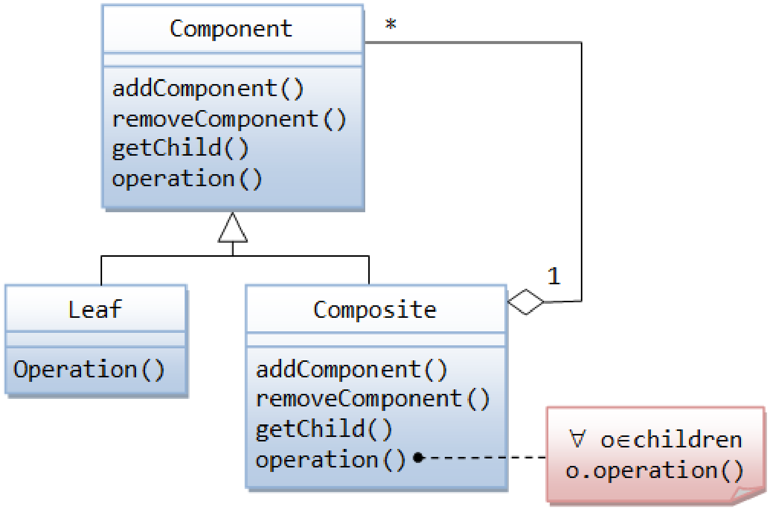
This is quite a common problem: e.g., a directory contains (sub)directories or files; a group contains (sub)groups or elementary elements; the tree structure. A *design pattern* has been proposed for this problem. A design pattern is a proven and possibly the best solution for a specific class of problems.

As shown in the class diagram, there are two sets of relationship between `Container` and `Component` classes.

1. *One-to-many aggregation*: A `Container` contains zero or more `Component`s. Each `Component` is contained in exactly one `Container`.
2. *Generalization (or Inheritance)*: `Container` is a *subclass* of `Component`. In other words, a `Container` is a `Component`, which possesses all the properties of `Component` and can be substituted in place of a `Component`.

Combining both relationships, we have: A `Container` contains `Component`s. Since a `Container` is a `Component`, a `Container` can also contain `Container`s. Consequently, a `Container` can contain `Container`s and `Component`s.

The *Gof* calls this *recursive composition* class design "*composite design pattern*", which is illustrated as follows:



8. Swing

8.1 Introduction

Swing is part of the so-called "Java Foundation Classes (JFC)" (have you heard of MFC?), which was introduced in 1997 after the release of JDK 1.1. JFC was subsequently included as an integral part of JDK since JDK 1.2. JFC consists of:

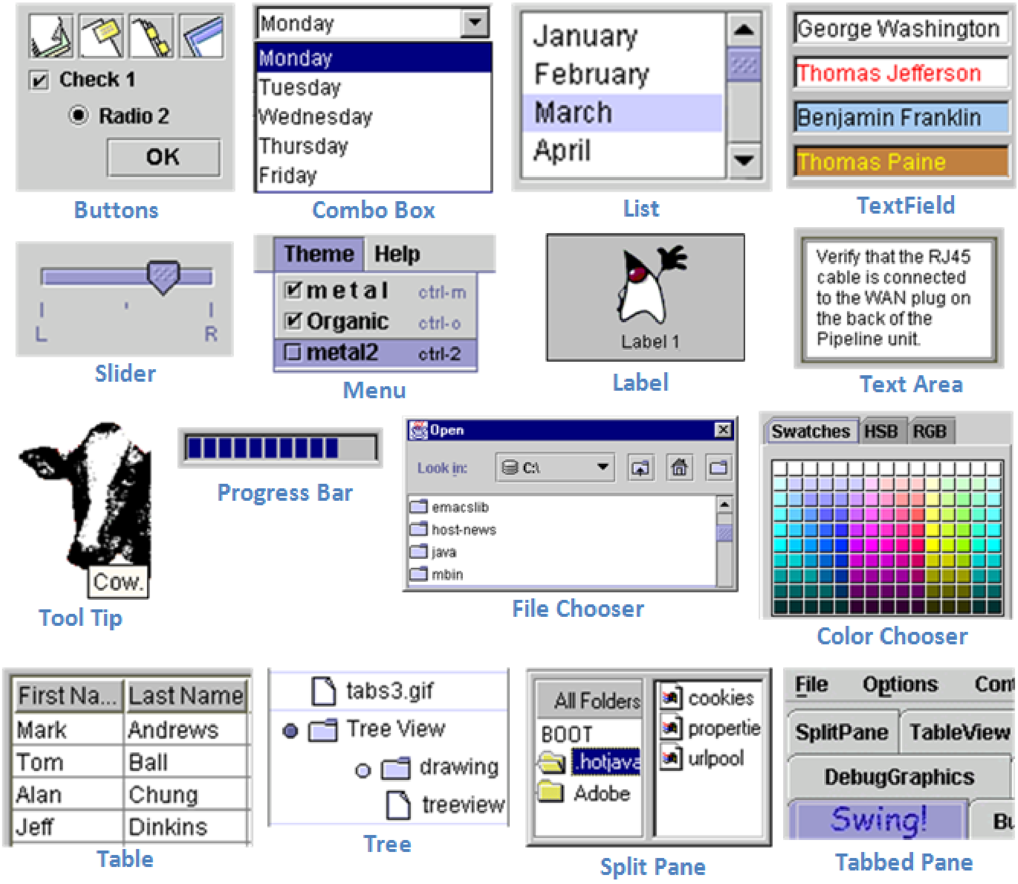
- Swing API: for advanced graphical programming.
- Accessibility API: provides assistive technology for the disabled.
- Java 2D API: for high quality 2D graphics and images.
- Pluggable look and feel supports.
- Drag-and-drop support between Java and native applications.

The goal of Java GUI programming is to allow the programmer to build GUI that looks good on ALL platforms. JDK 1.0's AWT was awkward and non-object-oriented (using many `event.getSource()`). JDK 1.1's AWT introduced event-delegation (event-driven) model, much clearer and object-oriented. JDK 1.1 also introduced inner class and JavaBeans – a component programming model for visual programming environment (similar to Visual Basic and Dephi).

Swing appeared after JDK 1.1. It was introduced into JDK 1.1 as part of an add-on JFC (Java Foundation Classes). Swing is a rich set of easy-to-use, easy-to-understand JavaBean GUI components that can be dragged and dropped as "GUI builders" in visual programming environment. Swing is now an integral part of Java since JDK 1.2.

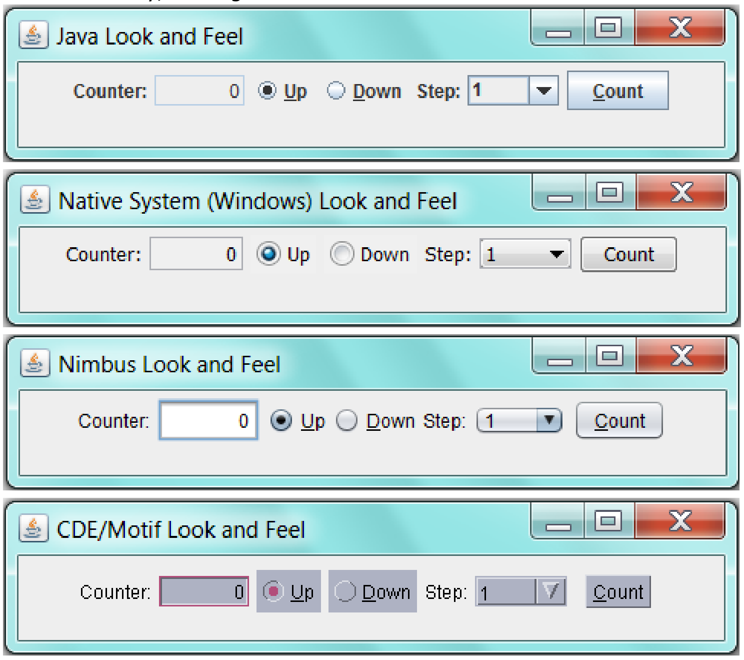
8.2 Swing's Features

Swing is huge (consists of 18 API packages as in JDK 1.7) and has great depth. Compared with AWT, Swing provides a huge and comprehensive collection of reusable GUI components, as shown in the Figure below (extracted form Swing Tutorial).



The main features of Swing are (extracted from the Swing website):

1. Swing is written in pure Java (except a few classes) and therefore is 100% portable.
2. Swing components are *lightweight*. The AWT components are *heavyweight* (in terms of system resource utilization). Each AWT component has its own opaque native display, and always displays on top of the lightweight components. AWT components rely heavily on the underlying windowing subsystem of the native operating system. For example, an AWT button ties to an actual button in the underlying native windowing subsystem, and relies on the native windowing subsystem for their rendering and processing. Swing components (`JComponent`s) are written in Java. They are generally not "weight-down" by complex GUI considerations imposed by the underlying windowing subsystem.
3. Swing components support *pluggable look-and-feel*. You can choose between *Java look-and-feel* and the *look-and-feel of the underlying OS* (e.g., Windows, UNIX or Mac). If the later is chosen, a Swing button runs on the Windows looks like a Windows' button and feels like a Window's button. Similarly, a Swing button runs on the UNIX looks like a UNIX's button and feels like a UNIX's button.



4. Swing supports *mouse-less operation*, i.e., it can operate entirely using keyboard.
5. Swing components support "tool-tips".
6. Swing components are *JavaBeans* – a Component-based Model used in Visual Programming (like Visual Basic). You can drag-and-drop a Swing component into a "design form" using a "GUI builder" and double-click to attach an event handler.
7. Swing application uses AWT event-handling classes (in package `java.awt.event`). Swing added some new classes in package `javax.swing.event`, but they are not frequently used.

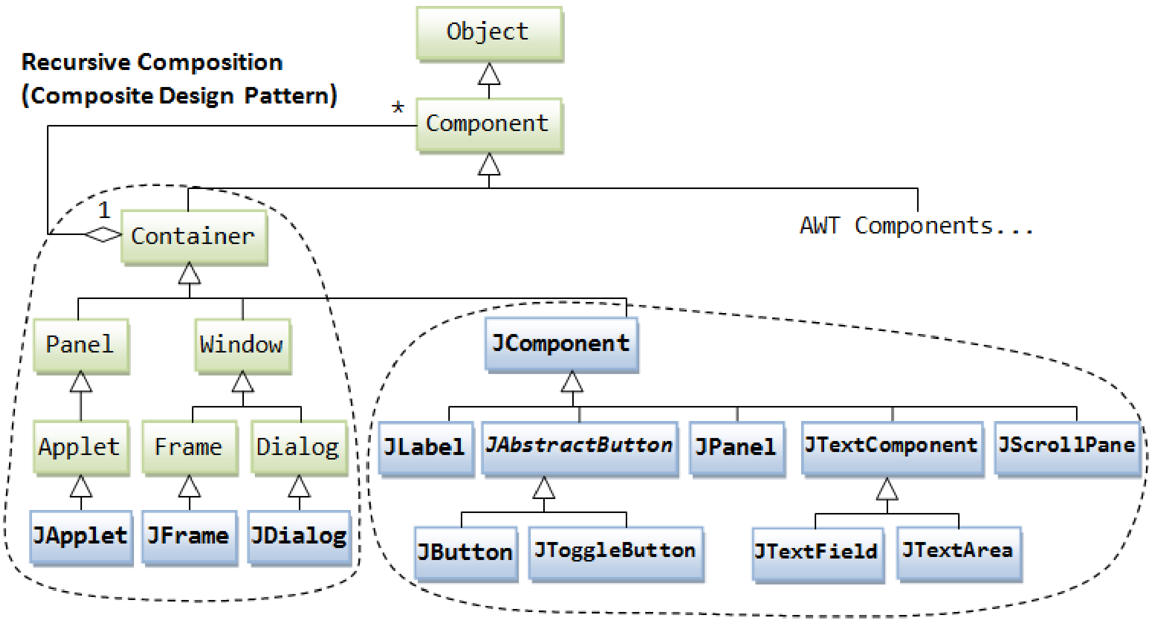
8. Swing application uses AWT's layout manager (such as `FlowLayout` and `BorderLayout` in package `java.awt`). It added new layout managers, such as `Springs`, `Struts`, and `BoxLayout` (in package `javax.swing`).
9. Swing implements *double-buffering* and automatic repaint batching for smoother screen repaint.
10. Swing introduces `JLayeredPane` and `JInternalFrame` for creating Multiple Document Interface (MDI) applications.
11. Swing supports floating toolbars (in `JToolBar`), splitter control, "undo".
12. Others - check the Swing website.

8.3 Using Swing API

If you understood the AWT programming (such as container/component, event-handling, layout manager), switching over to Swing (or any other Graphics packages) is straight-forward.

Swing's Components

Compared with the AWT classes (in package `java.awt`), Swing component classes (in package `javax.swing`) begin with a prefix "`J`", e.g., `JButton`, `JTextField`, `JLabel`, `JPanel`, `JFrame`, or `JApplet`.



The above figure shows the class hierarchy of the swing GUI classes. Similar to AWT, there are two groups of classes: *container*s and *component*s. A container is used to hold components. A container can also hold containers because it is a (subclass of) component.

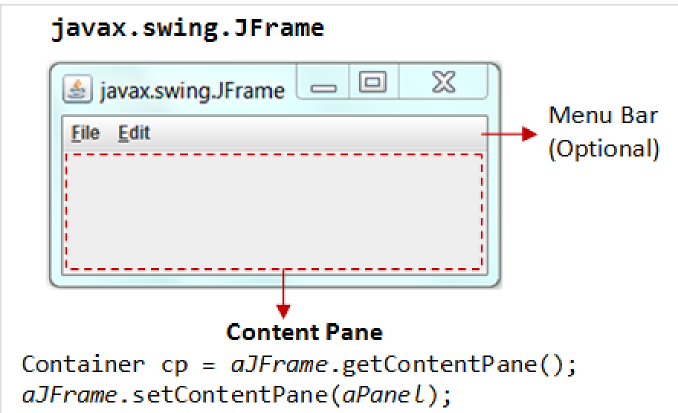
As a rule, do not mix heavyweight AWT components and lightweight Swing components in the same program, as the heavyweight components will always be painted *on top of* the lightweight components.

Swing's Top-Level and Secondary Containers

Just like AWT application, a Swing application requires a *top-level container*. There are three top-level containers in Swing:

1. `JFrame`: used for the application's main window (with an icon, a title, minimize/maximize/close buttons, an optional menu-bar, and a content-pane), as illustrated.
2. `JDialog`: used for secondary pop-up window (with a title, a close button, and a content-pane).
3. `JApplet`: used for the applet's display-area (content-pane) inside a browser's window.

Similarly to AWT, there are *secondary containers* (such as `JPanel`) which can be used to group and layout relevant components.



The Content-Pane of Swing's Top-Level Container

However, unlike AWT, the `JComponents` shall not be added onto the top-level container (e.g., `JFrame`, `JApplet`) directly because they are lightweight components. The `JComponents` must be added onto the so-called *content-pane* of the top-level container. Content-pane is in fact a `java.awt.Container` that can be used to group and layout components.

You could:

1. get the content-pane via `getContentPane()` from a top-level container, and add components onto it. For example,

```
public class TestGetContentPane extends JFrame {
   // Constructor
   public TestGetContentPane() {
      // Get the content-pane of this JFrame, which is a java.awt.Container
      // All operations, such as setLayout() and add() operate on the content-pane
      Container cp = this.getContentPane();
      cp.setLayout(new FlowLayout());
      cp.add(new JLabel("Hello, world!"));
      cp.add(new JButton("Button"));
      ......
   }
   .......
}
```

2. set the content-pane to a `JPanel` (the main panel created in your application which holds all your GUI components) via `JFrame`'s `setContentPane()`.

```
public class TestSetContentPane extends JFrame {
   // Constructor
   public TestSetContentPane() {
      // The "main" JPanel holds all the GUI components
      JPanel mainPanel = new JPanel(new FlowLayout());
      mainPanel.add(new JLabel("Hello, world!"));
      mainPanel.add(new JButton("Button"));

      // Set the content-pane of this JFrame to the main JPanel
      this.setContentPane(mainPanel);
      ......
   }
   .......
}
```

Notes: If a component is added directly into a `JFrame`, it is added into the content-pane of `JFrame` instead, i.e.,

```
// "this" is a JFrame
add(new JLabel("add to JFrame directly"));
// is executed as
getContentPane().add(new JLabel("add to JFrame directly"));
```

Event-Handling in Swing

Swing uses the AWT event-handling classes (in package `java.awt.event`). Swing introduces a few new event-handling classes (in package `javax.swing.event`) but they are not frequently used.

Writing Swing Applications

In summary, to write a Swing application, you have:

1. Use the Swing components with prefix "`J`" in package `javax.swing`.
2. A top-level container (such as `JFrame` or `JApplet`) is needed. The `JComponents` cannot be added directly onto the top-level container. They shall be added onto the *content-pane* of the top-level container. You can retrieve a reference to the content-pane by invoking method `getContentPane()` from the top-level container, or set the content-pane to the main `JPanel` created in your program.

8.4 Swing Program Template

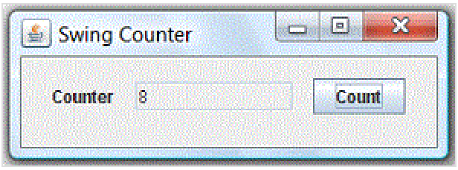
```
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

// A Swing GUI application inherits from top-level container javax.swing.JFrame
public class ...... extends JFrame {

   // private variables
   // ......

   /** Constructor to setup the GUI components */
   public ......() {
      Container cp = this.getContentPane();

      // Content-pane sets layout
      // cp.setLayout(new ....Layout());

      // Allocate the GUI components
      // .....

      // Content-pane adds components
      // cp.add(....);

      // Source object adds listener
      // .....
```

```
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
         // Exit the program when the close-window button clicked
      setTitle("......");  // "this" JFrame sets title
      setSize(300, 150);   // "this" JFrame sets initial size (or pack())
      setVisible(true);    // show it
   }

   /** The entry main() method */
   public static void main(String[] args) {
      // Run GUI codes in Event-Dispatching thread for thread-safety
      SwingUtilities.invokeLater(new Runnable() {
         @Override
         public void run() {
            new ......();  // Let the constructor do the job
         }
      });
   }
}
```

I will explain this template in the following Swing example.

8.5 Swing Example 1: `SwingCounter`

Let's convert the earlier AWT application example into Swing. Compare the two source files and note the changes (which are highlighted). The display is shown below. Note the differences in *look and feel* between the AWT GUI components and Swing's.




```
import java.awt.*;       // Using AWT containers and components
import java.awt.event.*; // Using AWT events and listener interfaces
import javax.swing.*;    // Using Swing components and containers

// A Swing GUI application inherits from top-level container javax.swing.JFrame
public class SwingCounter extends JFrame {
   private JTextField tfCount;  // Use Swing's JTextField instead of AWT's TextField
   private int count = 0;

   /** Constructor to setup the GUI */
   public SwingCounter () {
      // Retrieve the content-pane of the top-level container JFrame
      // All operations done on the content-pane
      Container cp = getContentPane();
      cp.setLayout(new FlowLayout());

      cp.add(new JLabel("Counter"));
      tfCount = new JTextField("0", 10);
      tfCount.setEditable(false);
      cp.add(tfCount);

      JButton btnCount = new JButton("Count");
      cp.add(btnCount);

      // Allocate an anonymous instance of an anonymous inner class that
      //  implements ActionListener as ActionEvent listener
      btnCount.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            ++count;
            tfCount.setText(count + "");
         }
      });

      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);  // Exit program if close-window button clicked
      setTitle("Swing Counter"); // "this" JFrame sets title
      setSize(300, 100);         // "this" JFrame sets initial size
      setVisible(true);          // "this" JFrame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      // Run the GUI construction in the Event-Dispatching thread for thread-safety
      SwingUtilities.invokeLater(new Runnable() {
         @Override
         public void run() {
            new SwingCounter(); // Let the constructor do the job
         }
      });
   }
}
```

JFrame's Content-Pane

The JFrams's method getContentPane() returns the content-pane (which is a java.awt.Containter) of the JFrame. You can then set its layout (the default layout is BorderLayout), and add components into it. For example,

```
Container cp = getContentPane(); // Get the content-pane of this JFrame
cp.setLayout(new FlowLayout());  // content-pane sets to FlowLayout
cp.add(new JLabel("Counter"));   // content-pane adds a JLabel component
......
cp.add(tfCount);    // content-pane adds a JTextField component
......
cp.add(btnCount);   // content-pane adds a JButton component
```

You can also use the JFrame's setContentPane() method to directly set the content-pane to a JPanel (or a JComponent). For example,

```
JPanel displayPanel = new JPanel();
this.setContentPane(displayPanel);
      // "this" JFrame sets its content-pane to a JPanel directly
.....

// The above is different from:
this.getContentPane().add(displayPanel);
      // Add a JPanel into the content-pane. Appearance depends on the JFrame's layout.
```

JFrame's setDefaultCloseOperation()

Instead of writing a WindowEvent listener with a windowClosing() handler to process the "close-window" button, JFrame provides a method called setDefaultCloseOperation() to sets the default operation when the user initiates a "close" on this frame. Typically, we choose the option JFrame.EXIT_ON_CLOSE, which terminates the application via a System.exit().

```
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
```

Running the GUI Construction Codes on the Event-Dispatching Thread

In the previous examples, we invoke the constructor directly in the entry main() method to setup the GUI components. For example,

```
// The entry main method
public static void main(String[] args) {
   // Invoke the constructor (by allocating an instance) to setup the GUI
   new SwingCounter();
}
```

The constructor will be executed in the so-called "Main-Program" thread. This may cause multi-threading issues (such as unresponsive user-interface and deadlock).

It is recommended to execute the GUI setup codes in the so-called "Event-Dispatching" thread, instead of "Main-Program" thread, for thread-safe opearations. Event-dispatching thread, which processes events, should be used when the codes updates the GUI.

To run the constructor on the event-dispatching thread, invoke static method SwingUtilities.invokeLater() to asynchronously queue the constructor on the event-dispatching thread. The codes will be run after all pending events have been processed. For example,

```
public static void main(String[] args) {
   // Run the GUI codes in the Event-dispatching thread for thread-safety
   SwingUtilities.invokeLater(new Runnable() {
      @Override
      public void run() {
         new SwingCounter();  // Let the constructor do the job
      }
   });
}
```

Note: javax.swing.SwingUtilities.invokeLater() is a cover for java.awt.EventQueue.invokeLater() (which is used in the NetBeans' Visual GUI Builder).

At times, for example in game programming, the *constructor* or the main() may contains non-GUI codes. Hence, it is a common practice to create a dedicated method called initComponents() (used in NetBeans visual GUI builder) or createAndShowGUI() (used in Swing tutorial) to handle all the GUI codes (and another method calld initGame() to handle initialization of the game's objects). This GUI init method shall be run in the event-dispatching thread.

Warning Message "The serialization class does not declare a static final serialVersionUID field of type long" (Advanced)

This warning message is triggered because java.awt.Frame (via its superclass java.awt.Component) implements the java.io.Serializable interface. This interface enables the object to be written out to an output stream *serially* (via method writeObject()); and read back into the program (via method readObject()). The serialization runtime uses a number (called serialVersionUID) to ensure that the object read into the program is compatible with the class definition, and not belonging to another version.

You have these options:

1. Simply ignore this warning message. If a `serializable` class does not explicitly declare a `serialVersionUID`, then the serialization runtime will calculate a default `serialVersionUID` value for that class based on various aspects of the class.
2. Add a `serialVersionUID` (Recommended), e.g.

```
private static final long serialVersionUID = 1L;  // verion 1
```

3. Suppress this particular warning via annotation `@SuppressWarmomgs` (in package `java.lang`) (JDK 1.5):

```
@SuppressWarnings("serial")
public class MyFrame extends JFrame { ...... }
```

8.6 Swing Example 2: `SwingAccumulator`

```
import java.awt.*;       // Using AWT containers and components
import java.awt.event.*; // Using AWT events and listener interfaces
import javax.swing.*;    // Using Swing components and containers

// A Swing GUI application inherits the top-level containter javax.swing.JFrame
public class SwingAccumulator extends JFrame {
   private JTextField tfInput, tfOutput;
   private int numberIn;   // input number
   private int sum = 0;    // accumulated sum, init to 0

   /** Constructor to setup the GUI */
   public SwingAccumulator() {
      // Retrieve the content-pane of the top-level container JFrame
      // All operations done on the content-pane
      Container cp = getContentPane();
      cp.setLayout(new GridLayout(2, 2, 5, 5));

      add(new JLabel("Enter an Integer: "));
      tfInput = new JTextField(10);
      add(tfInput);
      add(new JLabel("The Accumulated Sum is: "));
      tfOutput = new JTextField(10);
      tfOutput.setEditable(false);  // read-only
      add(tfOutput);

      // Allocate an anonymous instance of an anonymous inner class that
      //  implements ActionListener as ActionEvent listener
      tfInput.addActionListener(new ActionListener() {
         @Override
         public void actionPerformed(ActionEvent e) {
            // Get the String entered into the input TextField, convert to int
            numberIn = Integer.parseInt(tfInput.getText());
            sum += numberIn;      // accumulate numbers entered into sum
            tfInput.setText("");  // clear input TextField
            tfOutput.setText(sum + ""); // display sum on the output TextField
         }
      });

      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);  // Exit program if close-window button clicked
      setTitle("Swing Accumulator"); // "this" Frame sets title
      setSize(350, 120);  // "this" Frame sets initial size
      setVisible(true);   // "this" Frame shows
   }

   /** The entry main() method */
   public static void main(String[] args) {
      // Run the GUI construction in the Event-Dispatching thread for thread-safety
      SwingUtilities.invokeLater(new Runnable() {
         @Override
         public void run() {
            new SwingAccumulator(); // Let the constructor do the job
         }
      });
   }
}
```

8.7 Using Visual GUI Builder - NetBeans/Eclipse

If you have a complicated layout for your GUI application, you should use a GUI Builder, such as NetBeans or Eclipse to layout your GUI components in a drag-and-drop manner, similar to the popular visual languages such as Visual Basic and Dephi.

- For using NetBeans GUI Builder, read my "Writing Java GUI (AWT/Swing) Application in NetBeans"; or Swing Tutorial's "Learning Swing with the NetBeans IDE".
- For using Eclipse GUI Builder, read "Writing Swing Applications using Eclipse GUI Builder".

LINK TO JAVA REFERENCES & RESOURCES

MORE REFERENCES & RESOURCES

1. "Creating a GUI With JFC/Swing" (aka "The Swing Tutorial") @ http://docs.oracle.com/javase/tutorial/uiswing/.
2. JFC Demo (under JDK demo "`jfc`" directory).
3. Java2D Tutorial @ http://docs.oracle.com/javase/tutorial/2d/index.html.
4. JOGL (Java Binding on OpenGL) @ http://java.net/projects/jogl/.
5. Java3D (@ http://java3d.java.net/).

Latest version tested: JDK 1.7.0_17
Last modified: April, 2013