Java Programming Tutorial

Programming Graphical User Interface (GUI)

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1. Introduction

So far, we have covered the basic programming constructs (such as variables, data types, decision, loop, array and method) and introduced the important concept of Object-Oriented Programming (OOP). As discussed, OOP permits higher level of abstraction than traditional Procedural-Oriented Languages (such as C). You can create high-level abstract data types called *classes* to mimic real-life things. 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 (and re-inventing the wheels) is mission impossible! These graphics classes, developed by expert programmers, are highly complex and involve many advanced *design patterns*. However, re-using them are not so difficult, if you follow the API documentation, samples and templates provided.

I shall assume that you have a good grasp of OOP, including composition, inheritance, polymorphism, abstract class and interface; otherwise, read the earlier articles. I will describe another important OO concept called *nested class* (or *inner class*) in this article.

There are current three sets of Java APIs for graphics programming: AWT (Abstract Windowing Toolkit), Swing and JavaFX.

1. AWT API was introduced in JDK 1.0. Most of the AWT UI components have become obsolete and should be replaced by newer Swing UI 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 consists of Swing, Java2D, Accessibility, Internationalization, and Pluggable Look-and-Feel Support APIs. JFC has been integrated into core Java since JDK 1.2.
3. The latest JavaFX, which was integrated into JDK 8, was meant to replace Swing. JavaFX was moved out from the JDK in JDK 11, but still available as a separate module.

Other than AWT/Swing/JavaFX graphics APIs provided in JDK, other organizations/vendors have also provided graphics APIs that work with Java, such as Eclipse's Standard Widget Toolkit (SWT) (used in Eclipse), Google Web Toolkit (GWT) (used in Android), 3D Graphics API such as Java bindings for OpenGL (JOGL), Java3D, and etc. Furthermore, developers have moved to use technologies such as HTML5 as the basis of webapps.

You need to refer to the "JDK API documentation" for the AWT/Swing APIs (under module `java.desktop`) 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. For 3D graphics, read my 3D articles.

2. Programming GUI with AWT

I shall start with the AWT before moving into Swing to give you a complete picture of Java Graphics.

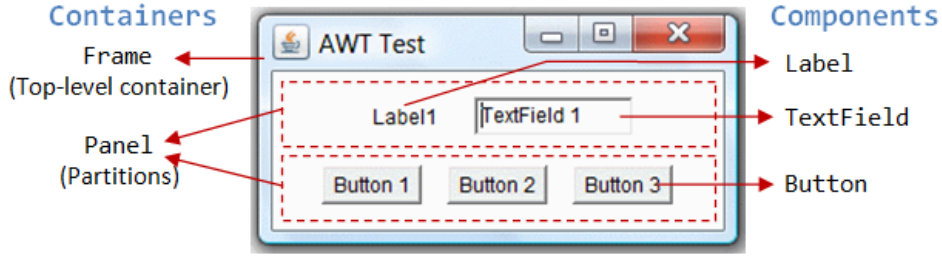
2.1 AWT Packages

AWT is huge! It consists of 12 packages of 370 classes (Swing is even bigger, with 18 packages of 737 classes as of JDK 8). 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` and `Panel`.
   - 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`, `MouseMotionListener`, `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, including Windows, macOS, and Unixes.

2.2 AWT Containers and Components



There are two groups of GUI elements:

1. *Component* (*Widget*, *Control*): Components are elementary GUI entities, such as `Button`, `Label`, and `TextField`. They are also called *widgets*, *controls* in other graphics systems.
2. *Container*: Containers, such as `Frame` and `Panel`, are used to *hold components in a specific layout* (such as `FlowLayout` or `GridLayout`). A container can also hold sub-containers.

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

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

```
Panel pnl = new Panel();          // Panel is a container
Button btn = new Button("Press"); // Button is a component
pnl.add(btn);                     // The Panel container adds a Button component
```

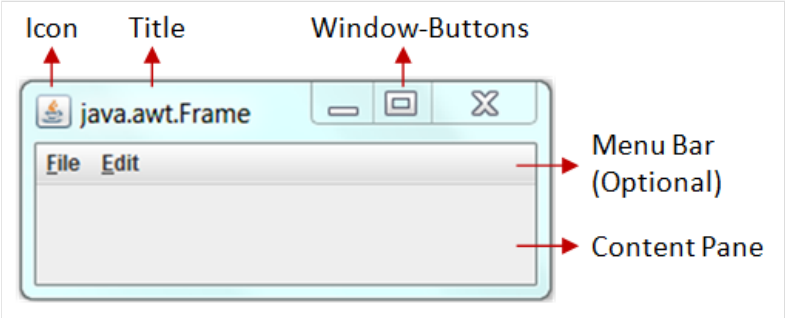
GUI components are also called *controls* (e.g., Microsoft ActiveX Control), *widgets* (e.g., Eclipse's Standard Widget Toolkit, Google Web Toolkit), which allow users to interact with (or control) the application.

2.3 AWT `Container` Classes

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

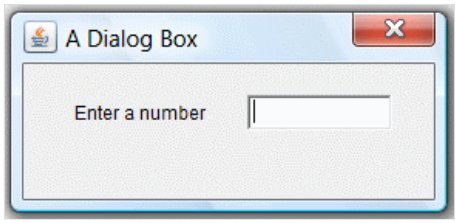
Each GUI program has a *top-level container*. The commonly-used top-level containers in AWT are `Frame`, `Dialog` and `Applet`:

- A `Frame` provides the "main window" for your GUI application. It 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 {

   // private variables
   ......

   // Constructor to setup the GUI components and event handlers
   public MyGUIProgram() { ...... }

   // The entry main() method
   public static void main(String[] args) {
      // Invoke the constructor (to setup the GUI) by allocating an instance
      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 is no longer supported in most of the browsers.



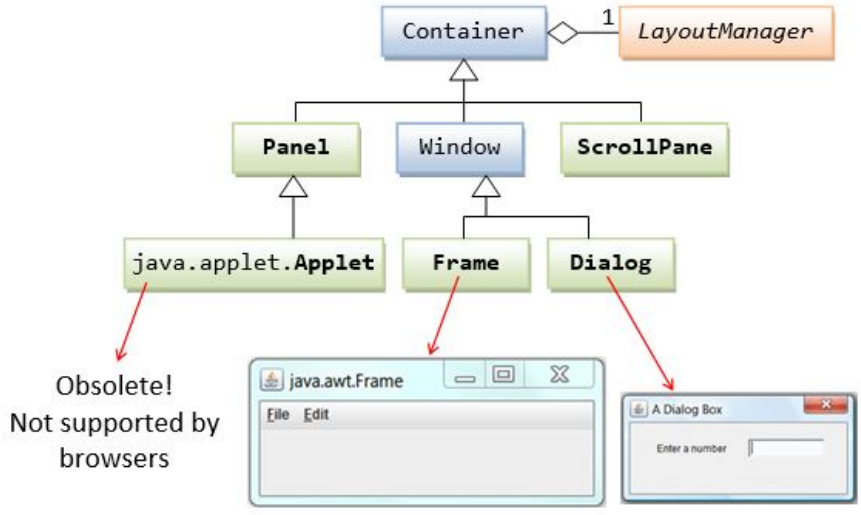
Secondary Containers: `Panel` and `ScrollPane`

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

- `Panel`: a rectangular box used to *layout* a set of related GUI components in pattern such as grid or flow.
- `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:



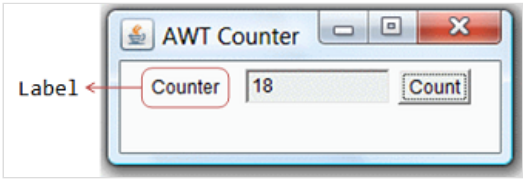
As illustrated, a `Container` has a `LayoutManager` to layout the components in a certain pattern, e.g., flow, grid.

2.4 AWT Component Classes

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

AWT GUI Component: `java.awt.Label`

A `java.awt.Label` provides a descriptive text string. 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) to provide a text description.



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

Constructors

```
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 (`final static` fields)

```
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, as used in the above constructor.

Public Methods

```
// Examples
public String getText();
public void setText(String strLabel);
public int getAlignment();
public void setAlignment(int alignment);  // Label.LEFT, Label.RIGHT, Label.CENTER
```

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* (*name*);
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, NOT 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
lblInput.setText("Enter password"); // Modify the Label's text string
lblInput.getText();                // Retrieve the Label's text string
```

An Anonymous `Label` Instance

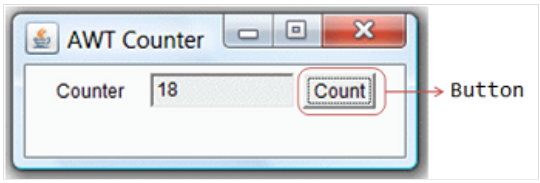
You can create a `Label` without specifying an identifier, called *anonymous instance*. In the case, the Java compiler will assign an *anonymous identifier* for the allocated object. You will not be able to reference an anonymous instance in your program after it is created. This is usually alright for 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.
// You CANNOT reference an anonymous instance to carry out further operations.
add(new Label("Enter Name: ", Label.RIGHT));

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

AWT GUI Component: `java.awt.Button`

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



Constructors

```
public Button(String btnLabel);
   // 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 btnLabel);
   // 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

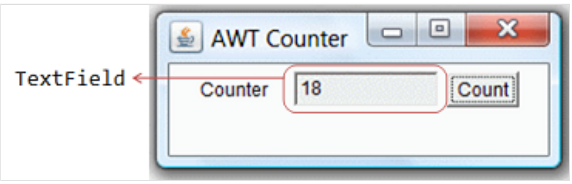
Clicking a button fires a so-called `ActionEvent` and triggers a certain programmed action. I will explain event-handling later.

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
```

AWT GUI Component: `java.awt.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 fires an `ActionEvent`.



Constructors

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

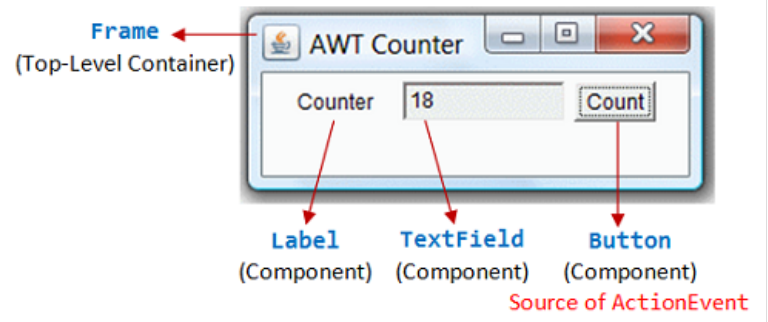
```
TextField tfInput = new TextField(30); // Declare and allocate an TextField instance called tfInput
add(tfInput);                          // "this" Container adds the TextField
TextField tfResult = new TextField();  // Declare and allocate an TextField instance called tfResult
tfResult.setEditable(false) ;          // 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 a few 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` shall display count of `0` initially.

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




```
1  import java.awt.*;        // Using AWT container and component classes
2  import java.awt.event.*;  // Using AWT event classes and listener interfaces
3
4  // An AWT program inherits from the top-level container java.awt.Frame
5  public class AWTCounter extends Frame {
6     private Label lblCount;    // Declare a Label component
7     private TextField tfCount; // Declare a TextField component
8     private Button btnCount;   // Declare a Button component
9     private int count = 0;     // Counter's value
10
11    // Constructor to setup GUI components and event handlers
12    public AWTCounter () {
13       setLayout(new FlowLayout());
14          // "super" Frame, which is a Container, sets its layout to FlowLayout to arrange
15          // the components from left-to-right, and flow to next row from top-to-bottom.
16
17       lblCount = new Label("Counter");  // construct the Label component
18       add(lblCount);                    // "super" Frame container adds Label component
19
20       tfCount = new TextField(count + "", 10); // construct the TextField component with initial text
```

```
21          tfCount.setEditable(false);       // set to read-only
22          add(tfCount);                     // "super" Frame container adds TextField component
23
24          btnCount = new Button("Count");   // construct the Button component
25          add(btnCount);                    // "super" Frame container adds Button component
26
27          BtnCountListener listener = new BtnCountListener();
28          btnCount.addActionListener(listener);
29             // "btnCount" is the source object that fires an ActionEvent when clicked.
30             // The source object adds an instance of BtnCountListener as an ActionEvent listener,
31             //   which provides an ActionEvent handler called actionPerformed().
32             // Clicking "Count" button calls back actionPerformed().
33
34          setTitle("AWT Counter");  // "super" Frame sets its title
35          setSize(300, 100);        // "super" Frame sets its initial window size
36
37          // For inspecting the Container/Components objects
38          // System.out.println(this);
39          // System.out.println(lblCount);
40          // System.out.println(tfCount);
41          // System.out.println(btnCount);
42          setVisible(true);         // "super" Frame shows
43          // System.out.println(this);
44          // System.out.println(lblCount);
45          // System.out.println(tfCount);
46          // System.out.println(btnCount);
47       }
48
49       // The entry main() method
50       public static void main(String[] args) {
51          // Invoke the constructor to setup the GUI, by allocating an instance
52          AWTCounter app = new AWTCounter();
53             // or simply "new AWTCounter();" for an anonymous instance
54       }
55
56       // Define an inner class to handle the "Count" button-click
57       private class BtnCountListener implements ActionListener {
58          // ActionEvent handler - Called back upon button-click.
59          @Override
60          public void actionPerformed(ActionEvent evt) {
61             ++count; // Increase the counter value
62             // Display the counter value on the TextField tfCount
63             tfCount.setText(count + ""); // Convert int to String
64          }
65       }
66    }
```

To exit this program, you have to close the CMD-shell (or press "control-c" on the CMD console); or push the "red" 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 11 to 47 define a constructor, which is used to setup the GUI components and event handlers.
- In Line 13, the `setLayout()` (inherited from the superclass `Frame`) is used to set the layout of the container. `FlowLayout` is used which arranges the 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. We invoke the `add()` method (inherited from the superclass `Frame`) to add these components into container.
- In Line 34-35, we invoke the `setSize()` and the `setTitle()` (inherited from the superclass `Frame`) to set the initial size and the title of the `Frame`. The `setVisible(true)` method (Line 42) is then invoked to show the display.
- Line 27-28 is used to setup the callback event-handler, which will be discussed in length later. In brief, whenever the button is clicked, the `actionPerformed()` will be called. In the `actionPerformed()` (Lines 59-64), the counter value increases by 1 and displayed on the `TextField`.
- In the entry `main()` method (Lines 50-54), an instance of `AWTCounter` is constructed. The constructor is executed to initialize the GUI components and setup the event-handlers. The GUI program then waits for the user action.

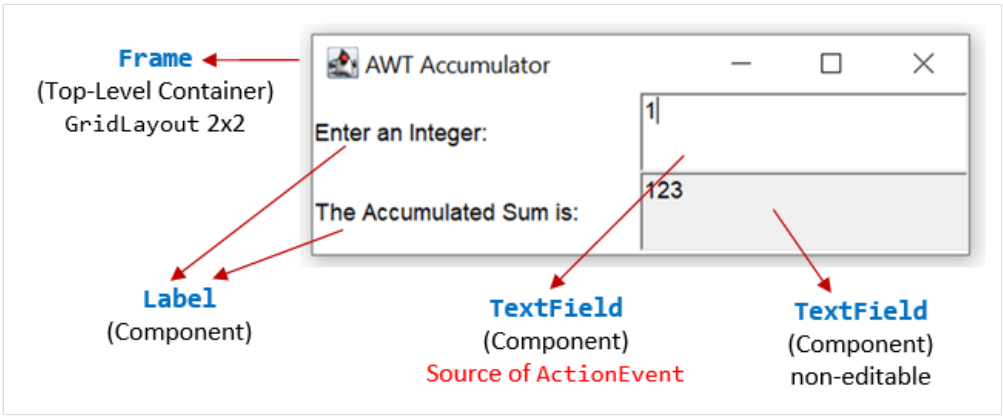
Inspecting Container/Components via `toString()`

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);
//AWTCounter[frame0,93,0,300x100,invalid,hidden,layout=java.awt.FlowLayout,title=AWT Counter,resizable,normal]
   // name (assigned by compiler) is "frame0"; top-left (x,y) at (93,0); width/height is 300x100 (via setSize());
System.out.println(lblCount);
//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 constructor)
System.out.println(tfCount);
//java.awt.TextField[textfield0,0,0,0x0,invalid,text=0,selection=0-0]
   // name is "Textfield0"; text is "0" (assigned in constructor)
System.out.println(btnCount);
//java.awt.Button[button0,0,0,0x0,invalid,label=Count]
   // name is "button0"; label text is "Count" (assigned in constructor)

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

System.out.println(this);
//AWTCounter[frame0,93,0,300x100,invalid,layout=java.awt.FlowLayout,title=AWT Counter,resizable,normal]
System.out.println(lblCount);
//java.awt.Label[label0,31,35,57x23,align=left,text=Counter]
System.out.println(tfCount);
//java.awt.TextField[textfield0,93,35,124x23,text=0,selection=0-0]
System.out.println(btnCount);
//java.awt.Button[button0,222,35,46x23,label=Count]
```

2.6 Example 2: `AWTAccumulator`

In this example, the top-level container is again the typical `java.awt.Frame`. It 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 `GridLayout` of 2 rows 2 columns.



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

```
1  import java.awt.*;        // Using AWT container and component classes
2  import java.awt.event.*;  // Using AWT event classes and listener interfaces
3
4  // An AWT GUI program inherits (customized) from the top-level container
5  //   java.awt.Frame
6  public class AWTAccumulator extends Frame {
7     //private Label lblInput;   // Declare input Label (to use anonymous)
8     //private Label lblOutput;  // Declare output Label (to use anonymous)
9     private TextField tfInput;  // Declare input TextField
10    private TextField tfOutput; // Declare output TextField
11    private int sum = 0;        // Accumulated sum, init to 0
12
13    // Constructor to setup the GUI components and event handlers
14    public AWTAccumulator() {
15       setLayout(new GridLayout(2, 2));
16          // "super" Frame (Container) sets layout to GridLayout of 2 rows 2 columns.
17
18       add(new Label("Enter an Integer: "));  // "super" Frame adds an anonymous Label
19
20       tfInput = new TextField(10); // Construct TextField
21       add(tfInput);                // "super" Frame adds TextField
22
23       tfInput.addActionListener(new TFInputListener());
24          // "tfInput" is the source object that fires an ActionEvent upon entered.
25          // The source add an anonymous instance of TFInputListener as an ActionEvent
26          //   listener, which provides an ActionEvent handler called actionPerformed().
```

```
27          // Hitting "enter" on tfInput invokes actionPerformed().
28
29          add(new Label("The Accumulated Sum is: "));  // "super" Frame adds an anonymous Label
30
31          tfOutput = new TextField(10); // allocate TextField
32          tfOutput.setEditable(false);  // read-only
33          add(tfOutput);                // "super" Frame adds TextField
34
35          setTitle("AWT Accumulator");  // "super" Frame sets title
36          setSize(350, 120);  // "super" Frame sets initial window size
37          setVisible(true);   // "super" Frame shows
38       }
39
40       // The entry main() method
41       public static void main(String[] args) {
42          // Invoke the constructor to setup the GUI, by allocating an anonymous instance
43          new AWTAccumulator();
44       }
45
46       // Define an inner class to handle the input TextField.
47       // An ActionEvent listener must implement ActionListener interface.
48       private class TFInputListener implements ActionListener {
49          // ActionEvent handler - Called back upon hitting "enter" key on TextField
50          @Override
51          public void actionPerformed(ActionEvent evt) {
52             // Get the String entered into the TextField tfInput, convert to int
53             int numberIn = Integer.parseInt(tfInput.getText());
54             sum += numberIn;      // Accumulate numbers entered into sum
55             tfInput.setText("");  // Clear input TextField
56             tfOutput.setText(sum + ""); // Display sum on the output TextField
57                                         // convert int to String
58          }
59       }
60    }
```

Dissecting the `AWTAccumulator.java`

1. An AWT GUI program extends from `java.awt.Frame` (Line 6) - the top-level window container.
2. In the constructor (Line 14), we constructs 4 components - 2 anonymous `java.awt.Labels` and 2 `java.awt.TextFields`. The `Frame` adds the components, in `GridLayout`.
3. `tfInput` (`TextField`) is the source object, which fires an `ActionEvent` upon hitting the Enter key. `tfInput` adds an anonymous instance of `TFInputListener` as an `ActionEvent` handler (Line 23). The listener class needs to implement `ActionListener` interface and provides implementation to method `actionPerformed()`. Whenever an user hits Enter on the `tfInput` (`TextField`), the `actionPerformed()` will be called back.

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 like Visual Basic.

In event-driven programming, a piece of event-handling codes is executed (or *called back* by the graphics subsystem) when an event was fired in response to an user input (such as clicking a mouse button or hitting the ENTER key in a text field).

Callback Methods

In the above examples, the method `actionPerformed()` is known as a *callback* method. In other words, you never invoke `actionPerformed()` in your codes explicitly. The `actionPerformed()` is *called back* by the graphics subsystem under certain circumstances in response to certain user actions.

JavaScript can attach a Callback method to an Event Directly

In some languages, you can directly attach a method (or function) to an event (such as mouse-click). For example, the following JavaScript code (called `JSCounter.html`) implement a counter similar to the `AWTCounter`, with a text label, text field and button:


```
<!DOCTYPE html>
<html lang="en">
<head>
```

```
<meta charset="utf-8">
<title>JavaScript Counter</title></head>
<body>
  <form>
  Count: <input id="tfCount" type="text" value="0">
  <input id="btnCount" type="button" value="Hello"
     onclick=myBtnOnClick() onmouseover=myBtnMouseOver() >
  </form>
<script>
function myBtnOnClick() { tfCount.value++; }
function myBtnMouseOver() { btnCount.value = "Count Up"; }
function myBtnMouseOut() { btnCount.value = "Click Me"; }
btnCount.onmouseout = myBtnMouseOut;  // assign a function to a variable
</script>
</body>
</html>
```

In Java, we CANNOT attach a method to a source object directly, as method is not a first-class object in Java. For example, a Java method cannot accept methods as its arguments and it cannot return a method; you cannot assign a method to a variable, etc. (JavaScript and C language CAN!).

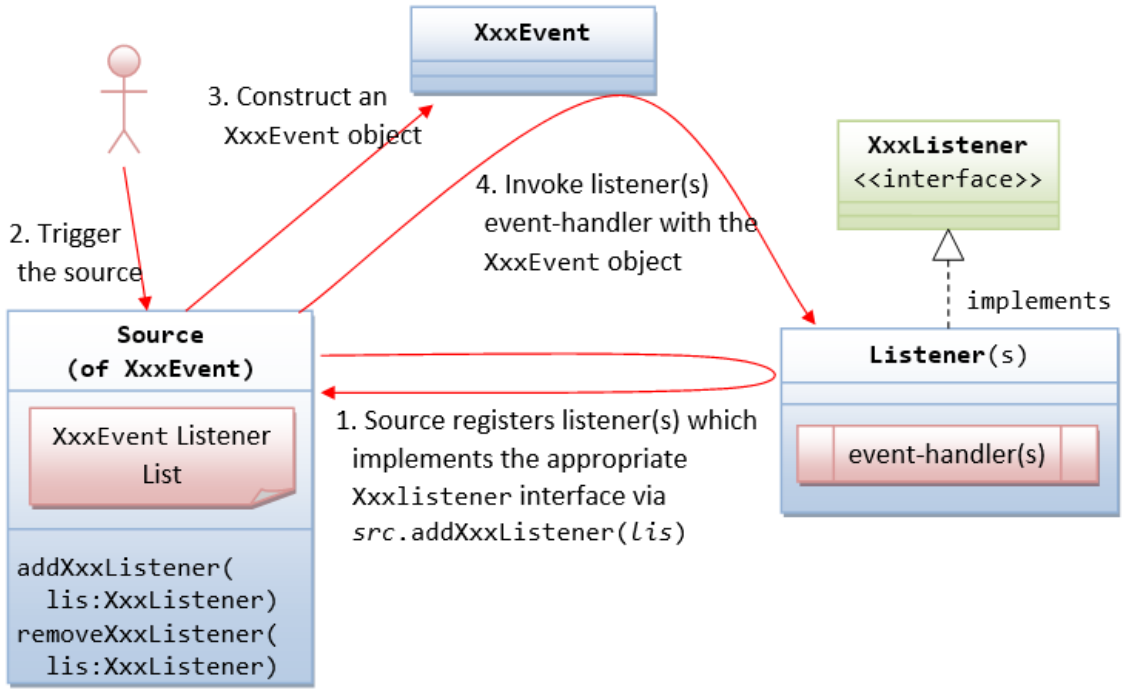
Source, Event and Listener Objects

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

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

The *source* object (such as `Button` and `Textfield`) interacts with the user. Upon triggered, the source object creates an *event* object to capture the action (e.g., mouse-click x and y, texts entered, etc). 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 listener(s), and invoke an appropriate event handler of the listener(s)*.

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*.

   A source fires an event when triggered. For example, clicking a `Button` fires an `ActionEvent`, clicking a mouse button fires `MouseEvent`, typing a key fires `KeyEvent`, and etc.

   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., `ActionEvent`). Firstly, we need to declare an interface called `XxxListener` (e.g., `ActionListener`) containing the names of the handler methods (recall that an `interface` contains only `abstract` methods without implementation). For example, the `ActionListener` interface is declared as follows:

   ```
   // An ActionListener interface, which declares the signature of the handlers
   public interface ActionListener {
   ```

```
   public void actionPerformed(ActionEvent evt);
}
```

Secondly, all `XxxEvent` listeners 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 listener(s) can response to these events appropriately. For example,

```
// An example of MouseListener,  which provides implementation to the event handler methods
class MyActionListener implement ActionListener {
   @Override
   public void actionPerformed(ActionEvent evt)  {
      System.out.println("ActionEvent detected!");
   }
}
```

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

```
public void addActionListener(ActionListener lis);
public void removeActionListener(ActionListener lis);
```

Take note that the `addXxxListenser()` takes a `XxxListener` object as its sole parameter. In other words, it can only add objects of the type `XxxListener`, and its sub-type. Since `XxxListener` is an `interface`, you cannot create instance of `XxxListener`, but need to create instance of a subclass implementing the `XxxListener interface`.

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(XxxListener lis)` method.

2. The source is triggered by a user.
3. The source create a `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 `XxxEvent` listeners in the listener list, the source invokes the appropriate handler on the listener(s), which provides the programmed response.

In summary, *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 hitting the "Enter" key on a `TextField`) fires an `ActionEvent` to all its `ActionEvent` listener(s). An `ActionEvent` listener must implement the `ActionListener` interface, which declares one `abstract` method called `actionPerformed()` as follow:

```
public interface ActionListener {
   public void actionPerformed(ActionEvent evt);
      // Called back upon button-click (on Button), enter-key pressed (on TextField)
}
```

Here are the event-handling steps:

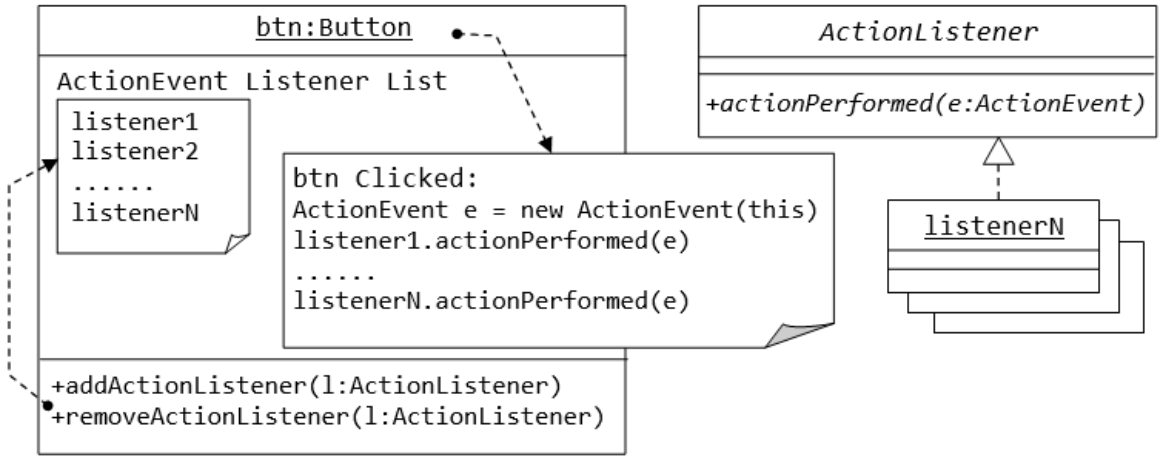
- We identify `btnCount` (of `Button`) as the *source* object.
- Clicking `Button` fires an `ActionEvent` to all its `ActionEvent` listener(s).
- The listener(s) is required to implement `ActionListener` interface, and override the `actionPerformed()` method to provide the response. In Line 56-65, we write an inner class called `BtnCountListener`, which override the `actionPerformed()` to increment and display the count. An *inner class* is a class defined inside an outer class, and it can access the private entities of the outer class. We will elaborate on the inner class in the next section.
- The source object registers listener via the `addActionListener()`. In this example, the *source* `btnCount` (`Button`) adds an instance of `BtnCountListener` as a *listener* via:

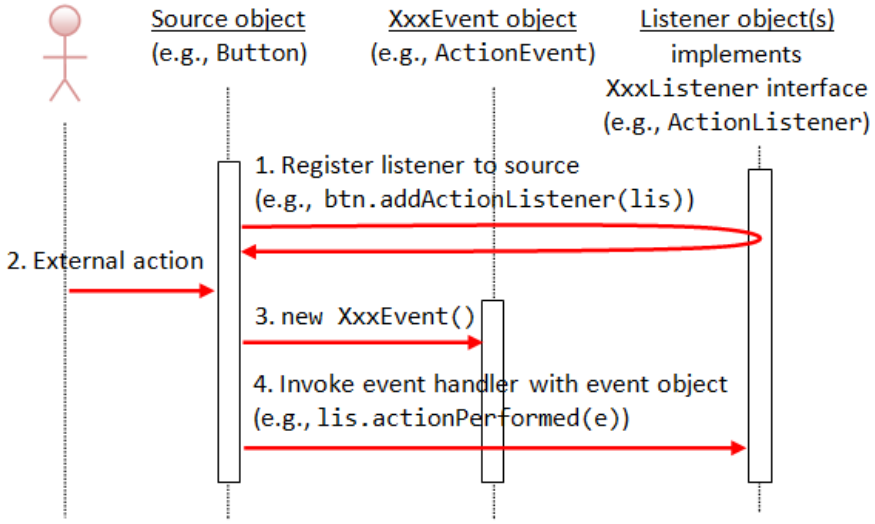
  ```
  BtnCountListener listener = new BtnCountListener();
  btnCount.addActionListener(listener);
  ```

  Note that `addActionListener()` takes an argument of the type `ActionListener`. `BtnCountListener`, which implements `ActionListener` interface (i.e., a subclass of `ActionListener`), is upcasted and passed to the `addActionListener()` method.
- Upon button-click, the `btnCount` creates an `ActionEvent` object, and calls back the `actionPerformed(ActionEvent)` method of all its registered listener(s) with the `ActionEvent` object created:

  ```
  ActionEvent evt = new ActionEvent( ..... );
  listener.actionPerformed(evt);   // for all its listener(s)
  ```

The sequence diagram is as follows:



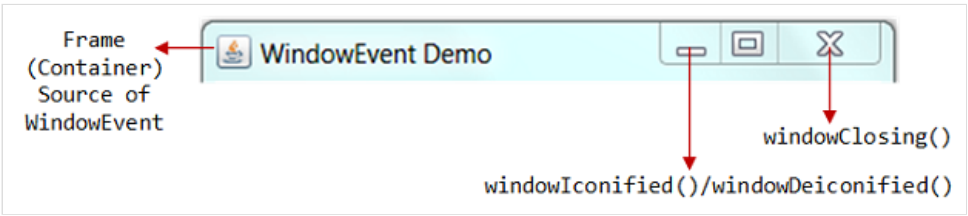


3.2 Revisit Example 2 `AWTAccumulator`: `ActionEvent` and `ActionListener` Interface

In this example,

1. We identify the `tfInput` (of `TextField`) as the source object.
2. Hitting the "Enter" key on a `TextField` fires an `ActionEvent` to all its `ActionEvent` listener(s).
3. In Line 46-59, we define an *inner class* called `TFInputListener` as the `ActionEvent` listener.The `ActionEvent` listener is required to implement the `ActionListener` interface, and override the `actionPerformed()` method to provide the programmed response upon activation.
4. The source object `tfInput` (of `TextField`) registers an anonymous instance of `TFInputListener` as its `ActionEvent` listener via the `tfInput.addActionListener(new TFInputListener())` (Line 23).

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



A `WindowEvent` is fired (to all its `WindowEvent` listeners) 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 `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 evt)
   // 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 evt)
   // Called-back the first time a window is made visible.
```

```
public void windowClosed(WindowEvent evt)
   // Called-back when a window has been closed as the result of calling dispose on the window.
public void windowActivated(WindowEvent evt)
   // Called-back when the Window is set to be the active Window.
public void windowDeactivated(WindowEvent evt)
   // Called-back when a Window is no longer the active Window.
public void windowIconified(WindowEvent evt)
   // Called-back when a window is changed from a normal to a minimized state.
public void windowDeiconified(WindowEvent evt)
   // Called-back when a window is changed from a minimized to a normal state.
```

The following program added support for "close-window button" to "Example 1: AWTCounter".

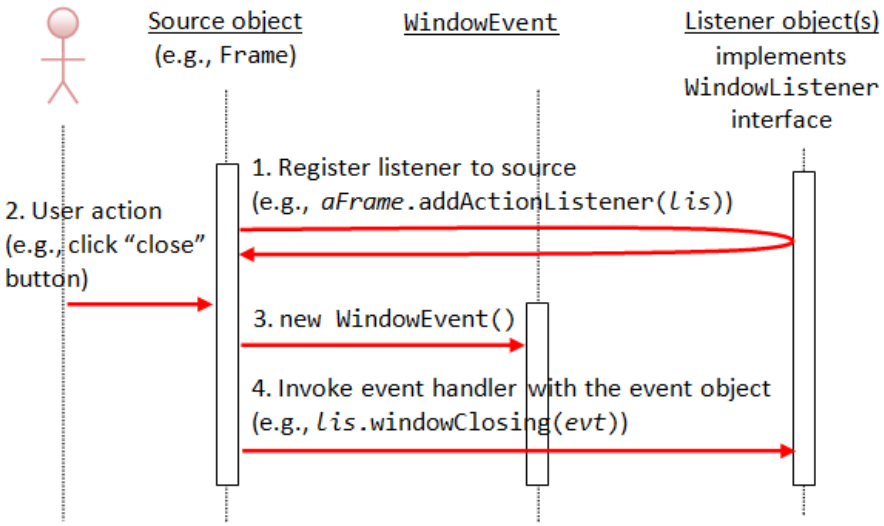
```
import java.awt.*;        // Using AWT containers and components
import java.awt.event.*;  // Using AWT events classes and listener interfaces

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

   private TextField tfCount;  // Declare a TextField component
   private Button btnCount;    // Declare a Button component
   private int count = 0;      // Counter's value

   // Constructor to setup the GUI components and event handlers
   public WindowEventDemo() {
      setLayout(new FlowLayout()); // "super" Frame sets to FlowLayout

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

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

      btnCount = new Button("Count");  // Construct the Button
      add(btnCount);                   // "super" Frame adds Button

      btnCount.addActionListener(new BtnCountListener());
        // btnCount (source object) fires ActionEvent upon clicking
        // btnCount adds an anonymous instance of BtnCountListener
        //   as an ActionEvent listener

      addWindowListener(new MyWindowListener());
        // "super" Frame (source object) fires WindowEvent.
        // "super" Frame adds an anonymous instance of MyWindowListener
        //   as a WindowEvent listener.

      setTitle("WindowEvent Demo"); // "super" Frame sets title
      setSize(300, 100);            // "super" Frame sets initial size
      setVisible(true);             // "super" Frame shows
   }

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

   // Define an inner class to handle ActionEvent of btnCount
   private class BtnCountListener implements ActionListener {
      @Override
      public void actionPerformed(ActionEvent evt) {
         ++count;
         tfCount.setText(count + "");
      }
   }

   // Define an inner class to handle WindowEvent of this Frame
   private class MyWindowListener implements WindowListener {
      // Called back upon clicking close-window button
      @Override
      public void windowClosing(WindowEvent evt) {
         System.exit(0);  // Terminate the program
      }

      // Not Used, BUT need to provide an empty body to compile.
      @Override public void windowOpened(WindowEvent evt) { }
      @Override public void windowClosed(WindowEvent evt) { }
```

```
64          // For Debugging
65          @Override public void windowIconified(WindowEvent evt) { System.out.println("Window Iconified"); }
66          @Override public void windowDeiconified(WindowEvent evt) { System.out.println("Window Deiconified"); }
67          @Override public void windowActivated(WindowEvent evt) { System.out.println("Window Activated"); }
68          @Override public void windowDeactivated(WindowEvent evt) { System.out.println("Window Deactivated"); }
69       }
70    }
```

In this example, 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 the `super Frame` as the source object.
2. The `Frame` fires the `WindowEvent` to all its registered `WindowEvent` listener(s).
3. In Line 53-69, we define an inner class called `MyWindowListener` as the `WindowEvent` listener. It is required to implement the `WindowListener` interface, which declares 7 abstract methods: `windowOpened()`, `windowClosed()`, `windowClosing()`, `windowActivated()`, `windowDeactivated()`, `windowIconified()` and `windowDeiconified()`.
4. We register an anonymous instance of `MyWindowListener` as the `WindowEvent` listener to the source `Frame` via method `addWindowListener(new MyWindowListener())`.
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 for compilation.

The sequence diagram is as follow:

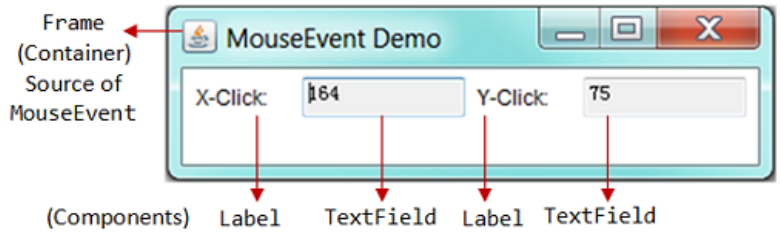


3.4 Example 4: `MouseEvent` and `MouseListener` Interface

A `MouseEvent` is fired 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 evt)
   // Called-back when the mouse-button has been clicked (pressed followed by released) on the source.
public void mousePressed(MouseEvent evt)
public void mouseReleased(MouseEvent evt)
   // 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 evt)
public void mouseExited(MouseEvent evt)
   // Called-back when the mouse-pointer has entered/exited the source.
```




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

```
2  import java.awt.event.*;
3
4  public class MouseEventDemo extends Frame {
5     private TextField tfMouseX; // to display mouse-click-x
6     private TextField tfMouseY; // to display mouse-click-y
7
8     // Constructor - Setup the UI components and event handlers
9     public MouseEventDemo() {
10       setLayout(new FlowLayout()); // "super" frame sets its layout to FlowLayout
11
12       // Label (anonymous)
13       add(new Label("X-Click: ")); // "super" frame adds Label component
14
15       // TextField
16       tfMouseX = new TextField(10); // 10 columns
17       tfMouseX.setEditable(false);  // read-only
18       add(tfMouseX);                // "super" frame adds TextField component
19
20       // Label (anonymous)
21       add(new Label("Y-Click: ")); // "super" frame adds Label component
22
23       // TextField
24       tfMouseY = new TextField(10);
25       tfMouseY.setEditable(false);  // read-only
26       add(tfMouseY);                // "super" frame adds TextField component
27
28       addMouseListener(new MyMouseListener());
29           // "super" frame (source) fires the MouseEvent.
30           // "super" frame adds an anonymous instance of MyMouseListener
31           //   as a MouseEvent listener.
32
33       setTitle("MouseEvent Demo"); // "super" Frame sets title
34       setSize(350, 100);           // "super" Frame sets initial size
35       setVisible(true);            // "super" Frame shows
36    }
37
38    public static void main(String[] args) {
39       new MouseEventDemo();  // Let the constructor do the job
40    }
41
42    // Define an inner class to handle MouseEvent
43    private class MyMouseListener implements MouseListener {
44       // Called back upon mouse clicked
45       @Override
46       public void mouseClicked(MouseEvent evt) {
47          tfMouseX.setText(evt.getX() + "");
48          tfMouseY.setText(evt.getY() + "");
49       }
50
51       // Not used - need to provide an empty body to compile.
52       @Override public void mousePressed(MouseEvent evt) { }
53       @Override public void mouseReleased(MouseEvent evt) { }
54       @Override public void mouseEntered(MouseEvent evt) { }
55       @Override public void mouseExited(MouseEvent evt) { }
56    }
57 }
```

In this example, we setup a GUI with 4 components (two anonynous `Labels` and two non-editable `TextFields`) inside a top-level container `Frame`, arranged in `FlowLayout`.

To demonstrate the `MouseEvent`:

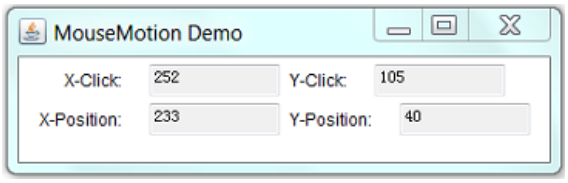
1. We identity `super Frame` as the source object.
2. The `Frame` fires a `MouseEvent` to all its `MouseEvent` listener(s) when you click/press/release a mouse-button or enter/exit with the mouse-pointer.
3. In Line 42-56, we define an inner class called `MyMouseListener` as the `MouseEvent` listener. It 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) coordinates of the mouse click on the two displayed `TextFields`. We ignore all the other handlers (for simplicity - but you need to provide an empty body for compilation).
4. We register an anonymous instance of `MyMouseListener` as the `MouseEvent` listener to `super Frame` (source) via the method `addMouseListener(new MyMouseListener())`.

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 move and drag 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.
```




```
1  import java.awt.*;
2  import java.awt.event.*;
3
4  // An AWT GUI program inherits from the top-level container java.awt.Frame
5  public class MouseMotionDemo extends Frame {
6
7     // To display the (x, y) of the mouse-clicked
8     private TextField tfMouseClickX;
9     private TextField tfMouseClickY;
10    // To display the (x, y) of the current mouse-pointer position
11    private TextField tfMousePositionX;
12    private TextField tfMousePositionY;
13
14    // Constructor to setup the GUI components and event handlers
15    public MouseMotionDemo() {
16       setLayout(new FlowLayout()); // "super" frame sets to FlowLayout
17
18       add(new Label("X-Click: "));
19       tfMouseClickX = new TextField(10);
20       tfMouseClickX.setEditable(false);
21       add(tfMouseClickX);
22       add(new Label("Y-Click: "));
23       tfMouseClickY = new TextField(10);
24       tfMouseClickY.setEditable(false);
25       add(tfMouseClickY);
26
27       add(new Label("X-Position: "));
28       tfMousePositionX = new TextField(10);
29       tfMousePositionX.setEditable(false);
30       add(tfMousePositionX);
31       add(new Label("Y-Position: "));
32       tfMousePositionY = new TextField(10);
33       tfMousePositionY.setEditable(false);
34       add(tfMousePositionY);
35
36       MyMouseListener listener = new MyMouseListener();
37       addMouseListener(listener);
38       addMouseMotionListener(listener);
39         // "super" frame (source) fires MouseEvent.
40         // "super" frame adds an instance of MyMouseListener
41         //   as MouseListener and MouseMotionListener.
42
43       setTitle("MouseMotion Demo"); // "super" Frame sets title
44       setSize(400, 120);            // "super" Frame sets initial size
45       setVisible(true);             // "super" Frame shows
46    }
47
48    // The entry main() method
49    public static void main(String[] args) {
50       new MouseMotionDemo();  // Let the constructor do the job
51    }
52
53    // Define an inner class as both the MouseListener and MouseMotionListener
54    // A Java class can extend one superclass but implement many interfaces
55    private class MyMouseListener implements MouseListener, MouseMotionListener {
56       /* MouseListener handlers */
57       // Called back when a mouse-button has been clicked
```

```
58          @Override
59          public void mouseClicked(MouseEvent evt) {
60             tfMouseClickX.setText(evt.getX() + "");
61             tfMouseClickY.setText(evt.getY() + "");
62          }
63
64          // Not Used, but need to provide an empty body for compilation
65          @Override public void mousePressed(MouseEvent evt) { }
66          @Override public void mouseReleased(MouseEvent evt) { }
67          @Override public void mouseEntered(MouseEvent evt) { }
68          @Override public void mouseExited(MouseEvent evt) { }
69
70          /* MouseMotionEvent handlers */
71          // Called back when the mouse-pointer has been moved
72          @Override
73          public void mouseMoved(MouseEvent evt) {
74             tfMousePositionX.setText(evt.getX() + "");
75             tfMousePositionY.setText(evt.getY() + "");
76          }
77
78          // Not Used, but need to provide an empty body for compilation
79          @Override public void mouseDragged(MouseEvent evt) { }
80       }
81    }
```

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

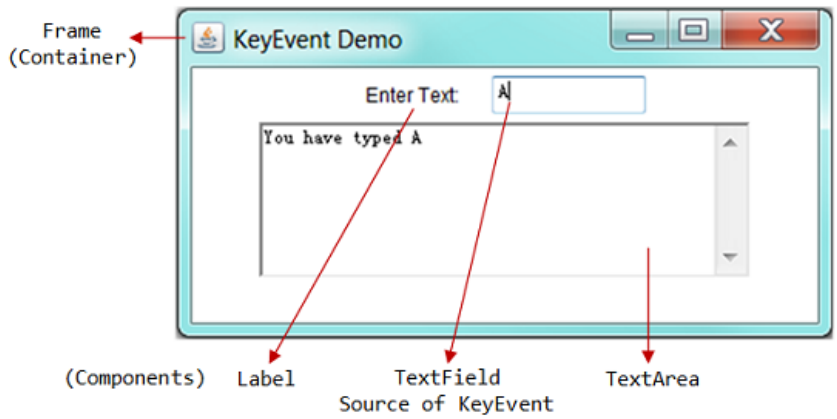
1. We identify the super `Frame` as the source, which fires the `MouseEvent` to its registered `MouseListener` and `MouseMotionListener`.
2. In Line 53-80, we define an inner class called `MyMouseListener` as both the `MouseListener` and `MouseMotionListner`.
3. We register an instance of `MyMouseListener` as the listener to super `Frame` via method `addMouseListener()` and `addMouseMotionListener()`.
4. The `MouseMotionListener` 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 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 or released.
```




```
1  import java.awt.*;
2  import java.awt.event.*;
3
4  // An AWT GUI program inherits from the top-level container java.awt.Frame
5  public class KeyEventDemo extends Frame {
6
```

```
 7     private TextField tfInput;  // Single-line TextField to receive tfInput key
 8     private TextArea taDisplay; // Multi-line TextArea to taDisplay result
 9
10     // Constructor to setup the GUI components and event handlers
11     public KeyEventDemo() {
12        setLayout(new FlowLayout()); // "super" frame sets to FlowLayout
13
14        add(new Label("Enter Text: "));
15        tfInput = new TextField(10);
16        add(tfInput);
17        taDisplay = new TextArea(5, 40); // 5 rows, 40 columns
18        add(taDisplay);
19
20        tfInput.addKeyListener(new MyKeyListener());
21           // tfInput TextField (source) fires KeyEvent.
22           // tfInput adds an anonymous instance of MyKeyListener
23           //   as a KeyEvent listener.
24
25        setTitle("KeyEvent Demo"); // "super" Frame sets title
26        setSize(400, 200);         // "super" Frame sets initial size
27        setVisible(true);          // "super" Frame shows
28     }
29
30     // The entry main() method
31     public static void main(String[] args) {
32        new KeyEventDemo();  // Let the constructor do the job
33     }
34
35     // Define an inner class to handle KeyEvent
36     private class MyKeyListener implements KeyListener {
37        // Called back when a key has been typed (pressed and released)
38        @Override
39        public void keyTyped(KeyEvent evt) {
40           taDisplay.append("You have typed " + evt.getKeyChar() + "\n");
41        }
42
43        // Not Used, but need to provide an empty body for compilation
44        @Override public void keyPressed(KeyEvent evt) { }
45        @Override public void keyReleased(KeyEvent evt) { }
46     }
47  }
```

In this example:

1. We identify the `tfInput` (of `TextField`) as the source object.
2. The source fires a `KeyEvent` when you press/release/type a key to all its `KeyEvent` listener(s).
3. In Line 35-46, we define an inner class called `MyKeyListener` as the `KeyEvent` listener.
4. We register an anonymous instance of `MyKeyListener` as the `KeyEvent` listener to the source `TextField` via method `input.addKeyListener()`.
5. The `KeyEvent` listener needs to implement the `KeyListener` interface, which declares 3 abstract methods: `keyTyped()`, `keyPressed()`, `keyReleased()`.
6. We override the `keyTyped()` to display key typed on the display `TextArea`. We ignore the `keyPressed()` and `keyReleased()`.

4. Nested (Inner) Classes

4.1 Without Inner classes

In our `AWTCounter` example, suppose we would like to write an external ordinary class (say `MyExternalBtnListener`) as our `ActionEvent` listener. This class shall implement `ActionListener` interface and override the `actionPerformed()` method. An example is as follows:

```
import java.awt.*;        // Using AWT container and component classes
import java.awt.event.*;  // Using AWT event classes and listener interfaces

// An AWT program inherits from the top-level container java.awt.Frame
public class AWTCounterExternal extends Frame {
   private Label lblCount;    // Declare a Label component
   private TextField tfCount; // Declare a TextField component
   private Button btnCount;   // Declare a Button component
   private int count = 0;     // Counter's value

   // Constructor to setup GUI components and event handlers
```

```
   public AWTCounterExternal () {
      setLayout(new FlowLayout());
         // "super" Frame, which is a Container, sets its layout to FlowLayout to arrange
         // the components from left-to-right, and flow to next row from top-to-bottom.

      lblCount = new Label("Counter");  // construct the Label component
      add(lblCount);                    // "super" Frame container adds Label component

      tfCount = new TextField(count + "", 10); // construct the TextField component with initial text
      tfCount.setEditable(false);       // set to read-only
      add(tfCount);                     // "super" Frame container adds TextField component

      btnCount = new Button("Count");   // construct the Button component
      add(btnCount);                    // "super" Frame container adds Button component

      MyExternalBtnListener listener = new MyExternalBtnListener();
      btnCount.addActionListener(listener);
         // "btnCount" is the source object that fires an ActionEvent when clicked.
         // The source add an instance of MyExternalBtnListener as an ActionEvent listener,
         //   which provides an ActionEvent handler called actionPerformed().
         // Clicking "btnCount" invokes actionPerformed().

      setTitle("AWT Counter");  // "super" Frame sets its title
      setSize(250, 100);        // "super" Frame sets its initial window size

      // For inspecting the Container/Components objects
      // System.out.println(this);
      // System.out.println(lblCount);
      // System.out.println(tfCount);
      // System.out.println(btnCount);
      setVisible(true);         // "super" Frame shows
      // System.out.println(this);
      // System.out.println(lblCount);
      // System.out.println(tfCount);
      // System.out.println(btnCount);
   }

   // The entry main() method
   public static void main(String[] args) {
      // Invoke the constructor to setup the GUI, by allocating an instance
      AWTCounterExternal app = new AWTCounterExternal();
         // or simply "new AWTCounter();" for an anonymous instance
   }
}

// We write an external class as the Button's ActionEvent listener.
// This class must implement ActionListener interface and override
// the actionPerformed() method.
class MyExternalBtnListener implements ActionListener {
   // ActionEvent handler - Called back upon button-click.
   @Override
   public void actionPerformed(ActionEvent evt) {
      System.out.println("You clicked the button!");

     // Cannot access variables count and tfCount!!!
     // ++count; // Increase the counter value
     // tfCount.setText(count + ""); // Convert int to String
   }
}
```

Can you see the problem? This external class cannot access the variables such as `count` and `tfCount` in the `AWTCounterExternal` class. We can fix this problem, but the solution is messy. An easy solution is to use an inner class instead of an ordinary external class (to be explained in the following sections).

4.2 What are 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 have `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 ordinary 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.

4.3 Example 7: A Named Inner Class as Event Listener (Revisit Example 1 `AWTCounter`)

A nested class is useful if you need a *small* class which relies on the enclosing outer class for its private variables and methods. It is ideal in an event-driven environment for implementing event handlers. This is because the event handling methods (in a listener) often require access to the private variables (e.g., a private `TextField`) of the outer class.

In this example (revisit Example 1 `AWTCounter`), we define an inner class called `BtnCountListener`, and create an instance of `BtnCountListener` as the `ActionEvent` listener for the `btnCount`. The `BtnCountListener` needs to implement the `ActionListener` interface, and override the `actionPerformed()` handler. `BtnCountListener` needs to be defined as an inner class, as it needs to access private variables (`count` and `tfCount`) of the outer class.

```
1  import java.awt.*;
2  import java.awt.event.*;
3
4  // An AWT GUI program inherits from the top-level container java.awt.Frame
5  public class AWTCounter extends Frame {
6
7     // The event-handler actionPerformed() needs to access these "private" variables
8     private TextField tfCount;
9     private Button btnCount;
10    private int count = 0;
11
12    // Constructor to setup the GUI components and event handlers
13    public AWTCounter() {
14       setLayout(new FlowLayout());  // "super" Frame sets to FlowLayout
15       add(new Label("Counter"));    // An anonymous instance of Label
16       tfCount = new TextField("0", 10);
17       tfCount.setEditable(false);   // read-only
18       add(tfCount);                 // "super" Frame adds tfCount
19
20       btnCount = new Button("Count");
21       add(btnCount);                // "super" Frame adds btnCount
22
23       // Construct an anonymous instance of BtnCountListener (a named inner class).
24       // btnCount adds this instance as a ActionListener.
25       btnCount.addActionListener(new BtnCountListener());
26
27       setTitle("AWT Counter");
28       setSize(250, 100);
29       setVisible(true);
30    }
31
32    // The entry main method
33    public static void main(String[] args) {
34       new AWTCounter(); // Let the constructor do the job
35    }
36
37    /**
```

```
38       * BtnCountListener is a "named inner class" used as ActionListener.
39       * This inner class can access private variables of the outer class.
40       */
41      private class BtnCountListener implements ActionListener {
42         @Override
43         public void actionPerformed(ActionEvent evt) {
44            ++count;
45            tfCount.setText(count + "");
46         }
47      }
48   }
```

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.
- The inner class is compiled into `AWTCount$BtnCountListener.class`, in the format of *`OuterClassName$InnerClassName`*`.class`.

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

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 granting them to `public` access.

```
// An ordinary outer class used as ActionListener for the Button
public class BtnCountListener implements ActionListener {
   // private variable
   AWTCounter frame;

   // The constructor takes the AWT Frame as its argument
   public BtnCountListener(AWTCounter frame) {
      this.frame = frame;
   }

   // The event handler can access the private variables thru "frame"
   @Override
   public void actionPerformed(ActionEvent evt) {
      frame.count++;
      frame.tfCount.setText(frame.count + "");
   }
}
```

This code is messy! Inner class provides a much cleaner solution!

4.4 Example 8: 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.

```
1   import java.awt.*;
2   import java.awt.event.*;
3
4   // An AWT GUI program inherits from the top-level container java.awt.Frame
5   public class AWTCounterAnonymousInnerClass extends Frame {
6
7      // The event-handler actionPerformed() needs to access these private variables
8      private TextField tfCount;
9      private Button btnCount;
10     private int count = 0;
11
12     // Constructor to setup the GUI components and event handlers
13     public AWTCounterAnonymousInnerClass () {
14        setLayout(new FlowLayout());  // "super" Frame sets to FlowLayout
15        add(new Label("Counter"));    // An anonymous instance of Label
16        tfCount = new TextField("0", 10);
17        tfCount.setEditable(false);   // read-only
18        add(tfCount);                 // "super" Frame adds tfCount
19
20        btnCount = new Button("Count");
```

```
21          add(btnCount);                // "super" Frame adds btnCount
22
23          // Construct an anonymous instance of an anonymous class.
24          // btnCount adds this instance as a ActionListener.
25          btnCount.addActionListener(new ActionListener() {
26             @Override
27             public void actionPerformed(ActionEvent evt) {
28                ++count;
29                tfCount.setText(count + "");
30             }
31          });
32
33          setTitle("AWT Counter");
34          setSize(250, 100);
35          setVisible(true);
36       }
37
38       // The entry main method
39       public static void main(String[] args) {
40          new AWTCounterAnonymousInnerClass(); // Let the constructor do the job
41       }
42    }
```

Dissecting the Program

- 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 evt) {
      ++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 evt) {
      ++count;
      tfCount.setText(count + "");
   }
}
btnCount.addActionListener(new N());

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

- From JDK 8, you can write the event handler using "Lambda Expression" in a one-liner as follows:

```
btnCount.addActionListener(evt -> tfCount.setText(++count + ""));
```

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:

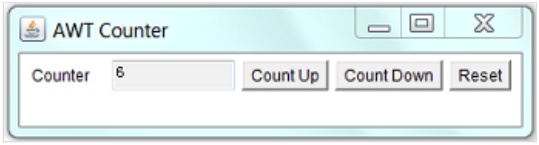
```
new SuperClassName/InterfaceName() {  // extends superclass or implements interface
                                      // invoke the default no-arg constructor or Object[]
  // Implement abstract methods in superclass/interface
  // More methods if necessary
```

```
   ......
}
```

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

4.5 Example 9: 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.




```
1  import java.awt.*;
2  import java.awt.event.*;
3
4  // An AWT GUI program inherits the top-level container java.awt.Frame
5  public class AWTCounter3ButtonsAnonymousIC extends Frame {
6     private TextField tfCount;
7     private Button btnCountUp, btnCountDown, btnReset;
8     private int count = 0;
9
10    // Constructor to setup the GUI components and event handlers
11    public AWTCounter3ButtonsAnonymousIC() {
12       setLayout(new FlowLayout());
13       add(new Label("Counter"));   // an anonymous instance of Label
14       tfCount = new TextField("0", 10);
15       tfCount.setEditable(false);  // read-only
16       add(tfCount);                // "super" Frame adds tfCount
17
18       btnCountUp = new Button("Count Up");
19       add(btnCountUp);
20       // Construct an anonymous instance of an anonymous inner class.
21       // The source Button adds the anonymous instance as ActionEvent listener
22       btnCountUp.addActionListener(new ActionListener() {
23          @Override
24          public void actionPerformed(ActionEvent evt) {
25             ++count;
26             tfCount.setText(count + "");
27          }
28       });
29
30       btnCountDown = new Button("Count Down");
31       add(btnCountDown);
32       btnCountDown.addActionListener(new ActionListener() {
33          @Override
34          public void actionPerformed(ActionEvent evt) {
35             count--;
36             tfCount.setText(count + "");
37          }
38       });
39
40       btnReset = new Button("Reset");
41       add(btnReset);
42       btnReset.addActionListener(new ActionListener() {
43          @Override
44          public void actionPerformed(ActionEvent evt) {
45             count = 0;
46             tfCount.setText("0");
47          }
48       });
49
50       setTitle("AWT Counter");
51       setSize(400, 100);
52       setVisible(true);
53    }
54
55    // The entry main method
56    public static void main(String[] args) {
57       new AWTCounter3ButtonsAnonymousIC();  // Let the constructor do the job
58    }
59 }
```

Dissecting the Program

1. Each of the `Button`s uses one anonymous instance of an anonymous inner class as its `ActionEvent` listener.

4.6 Example 10: Using the Same Listener Instance for All the Buttons

If you use the same instance as the listener for all 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 Button btnCountUp, btnCountDown, btnReset;
   private int count = 0;

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

      // Construct 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 the "named" inner class BtnListener.
      AllButtonsListener listener = new AllButtonsListener();
      // Use the same listener instance for 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
   }

   /**
    * AllButtonsListener is an named inner class used as ActionEvent listener for all the Buttons.
    */
   private class AllButtonsListener implements ActionListener {
      @Override
      public void actionPerformed(ActionEvent evt) {
         // Need to determine which button fired the event.
         // the getActionCommand() returns the Button's label
         String btnLabel = evt.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 components and event handlers
   public AWTCounter3ButtonsGetSource () {
      setLayout(new FlowLayout());
      add(new Label("Counter"));
      tfCount = new TextField("0", 10);
      tfCount.setEditable(false);
      add(tfCount);

      // Construct 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.
      AllButtonsListener listener = new AllButtonsListener();
      // Use the same listener instance 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
   }

   /**
    * AllButtonsListener is a named inner class used as ActionEvent listener for all the Buttons.
    */
   private class AllButtonsListener implements ActionListener {
      @Override
      public void actionPerformed(ActionEvent evt) {
         // Need to determine which button has fired the event.
         Button source = (Button)evt.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 + "");
      }
   }
}
```

5. Event Listener's Adapter Classes

5.1 Example 11: `WindowAdapter` for `WindowListener`

Using `WindowListener` Interface

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 `abstract` methods in order to compile the program. This is tedious, e.g., 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 Button btnCount;
   private int count = 0;

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

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

      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
   }
}
```

Using `WindowAdapter` Superclass

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 Button btnCount;
   private int count = 0;

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

      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.
      // "super" Frame adds the instance as WindowEvent listener.
      addWindowListener(new WindowAdapter() {
         @Override
         public void windowClosing(WindowEvent evt) {
            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
   }
}
```

Clearly, the adapter greatly simplifies the codes.

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. [SKIP] The Legacy "`this`" Listener

If you read some old books, you may find many examples that use "`this`" object as the event listener.

For example,

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

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

   private TextField tfCount;  // Declare a TextField component
   private Button btnCount;    // Declare a Button component
   private int count = 0;      // Counter's value
```

```
13
14      // Constructor to setup the GUI components and event handlers
15      public ThisListenerDemo() {
16         setLayout(new FlowLayout()); // "super" Frame sets to FlowLayout
17
18         add(new Label("Counter"));   // "super" Frame adds an anonymous Label
19
20         tfCount = new TextField("0", 10); // Construct the TextField
21         tfCount.setEditable(false);       // read-only
22         add(tfCount);                     // "super" Frame adds TextField
23
24         btnCount = new Button("Count");  // Construct the Button
25         add(btnCount);                   // "super" Frame adds Button
26
27         btnCount.addActionListener(this);
28           // btnCount (source object) fires ActionEvent upon clicking
29           // btnCount adds "this" object as an ActionEvent listener
30
31         addWindowListener(this);
32           // "super" Frame (source object) fires WindowEvent.
33           // "super" Frame adds "this" object as a WindowEvent listener.
34
35         setTitle("WindowEvent Demo"); // "super" Frame sets title
36         setSize(250, 100);            // "super" Frame sets initial size
37         setVisible(true);             // "super" Frame shows
38      }
39
40      // The entry main() method
41      public static void main(String[] args) {
42         new ThisListenerDemo();  // Let the construct do the job
43      }
44
45      /* ActionEvent handler */
46      @Override
47      public void actionPerformed(ActionEvent evt) {
48         ++count;
49         tfCount.setText(count + "");
50      }
51
52      /* WindowEvent handlers */
53      // Called back upon clicking close-window button
54      @Override
55      public void windowClosing(WindowEvent evt) {
56         System.exit(0);  // Terminate the program
57      }
58
59      // Not Used, BUT need to provide an empty body to compile.
60      @Override public void windowOpened(WindowEvent evt) { }
61      @Override public void windowClosed(WindowEvent evt) { }
62      // For Debugging
63      @Override public void windowIconified(WindowEvent evt) { System.out.println("Window Iconified"); }
64      @Override public void windowDeiconified(WindowEvent evt) { System.out.println("Window Deiconified"); }
65      @Override public void windowActivated(WindowEvent evt) { System.out.println("Window Activated"); }
66      @Override public void windowDeactivated(WindowEvent evt) { System.out.println("Window Deactivated"); }
67   }
```

There is only ONE class in this code. But this code is much harder to understand and seldom used nowadays. Using inner class is a better solution.

7. Layout Managers and Panel

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()` method

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

Container's `getLayout()` method

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

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

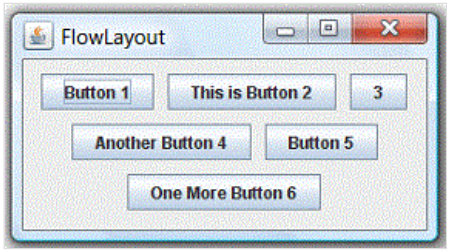
Panel's Initial Layout

`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 pnl = new Panel(new BorderLayout());
```

7.1 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.



Constructors

```
public FlowLayout();
public FlowLayout(int alignment);
public FlowLayout(int alignment, int hgap, int vgap);
  // alignment: 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, alignment = FlowLayout.CENTER
```

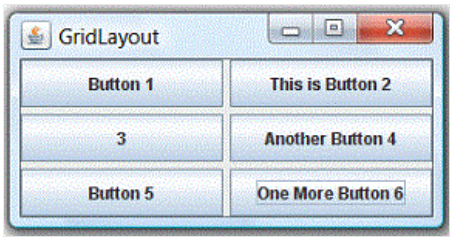
Example

```
1  import java.awt.*;
2  import java.awt.event.*;
3
4  // An AWT GUI program inherits the top-level container java.awt.Frame
5  public class AWTFlowLayoutDemo extends Frame {
6     private Button btn1, btn2, btn3, btn4, btn5, btn6;
7
8     // Constructor to setup GUI components and event handlers
9     public AWTFlowLayoutDemo () {
10       setLayout(new FlowLayout());
11          // "super" Frame sets layout to FlowLayout, which arranges the components
12          // from left-to-right, and flow from top-to-bottom.
13
14       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"); // "super" Frame sets title
      setSize(280, 150);           // "super" Frame sets initial size
      setVisible(true);            // "super" Frame shows
   }

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

7.2 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

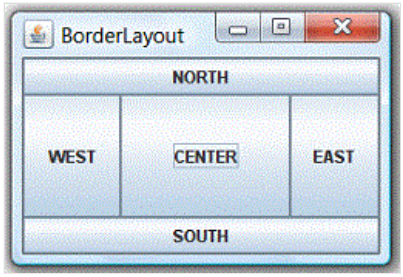
```
public GridLayout(int rows, int columns);
public GridLayout(int rows, int columns, int hgap, int vgap);
      // By default: rows = 1, cols = 0, hgap = 0, vgap = 0
```

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 and event handlers
   public AWTGridLayoutDemo () {
      setLayout(new GridLayout(3, 2, 3, 3));
         // "super" Frame sets layout to 3x2 GridLayout, horizontal and vertical 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"); // "super" Frame sets title
      setSize(280, 150);           // "super" Frame sets initial size
      setVisible(true);            // "super" Frame shows
   }

   // The entry main() method
   public static void main(String[] args) {
```

```
34          new AWTGridLayoutDemo();  // Let the constructor do the job
35       }
36    }
```

7.3 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*`, `*zone*`)`, where *zone* 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`.

You need not place 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
```

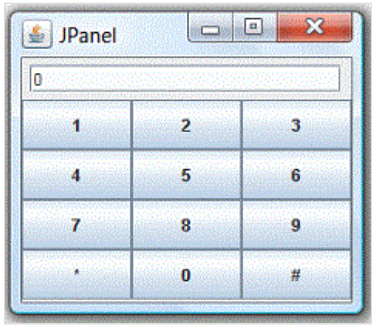
Example

```
1   import java.awt.*;
2   import java.awt.event.*;
3
4   // An AWT GUI program inherits the top-level container java.awt.Frame
5   public class AWTBorderLayoutDemo extends Frame {
6      private Button btnNorth, btnSouth, btnCenter, btnEast, btnWest;
7
8      // Constructor to setup GUI components and event handlers
9      public AWTBorderLayoutDemo () {
10        setLayout(new BorderLayout(3, 3));
11           // "super" Frame sets layout to BorderLayout,
12           // horizontal and vertical gaps of 3 pixels
13
14        // The components are added to the specified zone
15        btnNorth = new Button("NORTH");
16        add(btnNorth, BorderLayout.NORTH);
17        btnSouth = new Button("SOUTH");
18        add(btnSouth, BorderLayout.SOUTH);
19        btnCenter = new Button("CENTER");
20        add(btnCenter, BorderLayout.CENTER);
21        btnEast = new Button("EAST");
22        add(btnEast, BorderLayout.EAST);
23        btnWest = new Button("WEST");
24        add(btnWest, BorderLayout.WEST);
25
26        setTitle("BorderLayout Demo"); // "super" Frame sets title
27        setSize(280, 150);             // "super" Frame sets initial size
28        setVisible(true);              // "super" Frame shows
29     }
30
31     // The entry main() method
32     public static void main(String[] args) {
33        new AWTBorderLayoutDemo();  // Let the constructor do the job
34     }
35  }
```

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

An AWT `Panel` is a rectangular pane, which can be used as sub-container to organized a group of related components in a specific layout (e.g., `FlowLayout`, `BorderLayout`). `Panels` 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;  // Array of 10 numeric Buttons
   private Button btnHash, btnStar;
   private TextField tfDisplay;

   // Constructor to setup GUI components and event handlers
   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 = new Button[10];  // Construct an array of 10 numeric Buttons
      btnNumbers[1] = new Button("1");  // Construct Button "1"
      panelButtons.add(btnNumbers[1]);  // The Panel adds this Button
      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]);
            // You should 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());  // "super" Frame sets to BorderLayout
      add(panelDisplay, BorderLayout.NORTH);
      add(panelButtons, BorderLayout.CENTER);

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

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

7.5 BoxLayout

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

[TODO] Example and diagram

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:

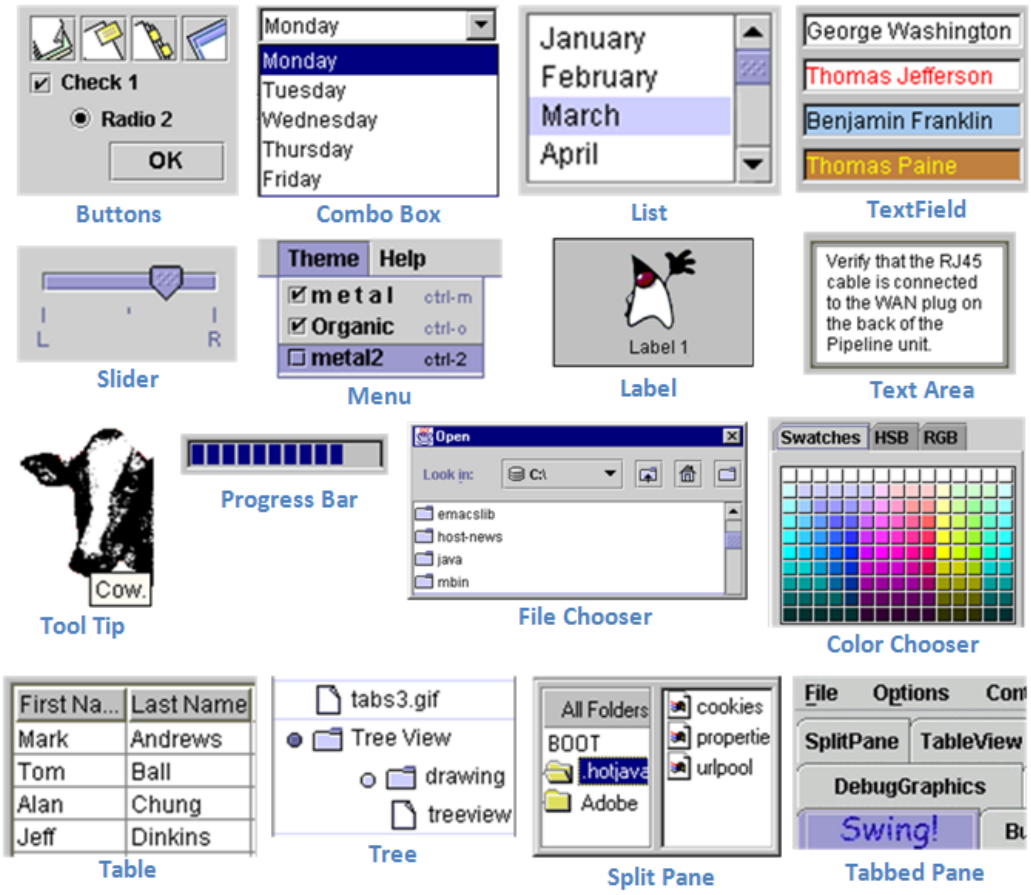
- Swing API: for advanced graphical programming.
- Accessibility API: provides assistive technology for the disabled.
- Java 2D API: for high quality 2D graphics and images.
- Pluggable look and feel supports.
- Drag-and-drop support between Java and native applications.

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).

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 packages of 737 classes as in JDK 1.8) 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).

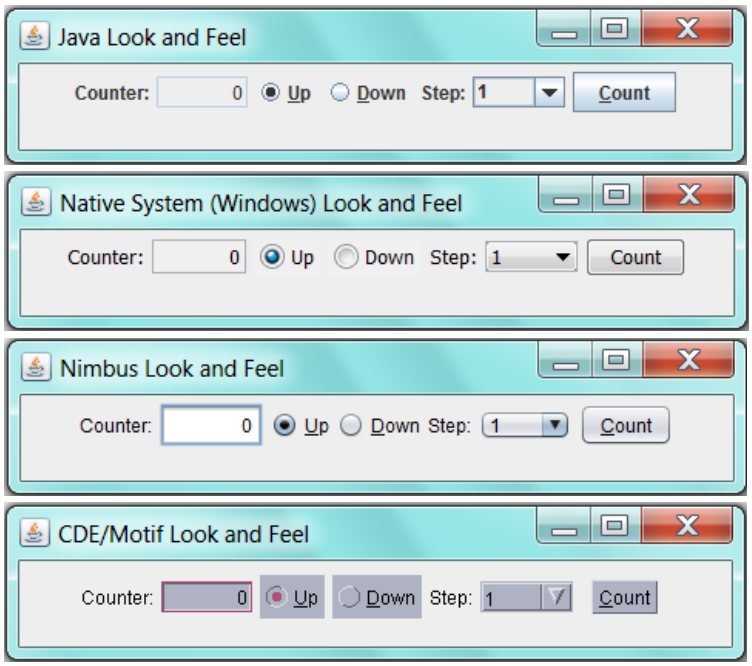


The main features of Swing are (extracted from the Swing website):

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 (`JComponents`) 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 macOS). 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.



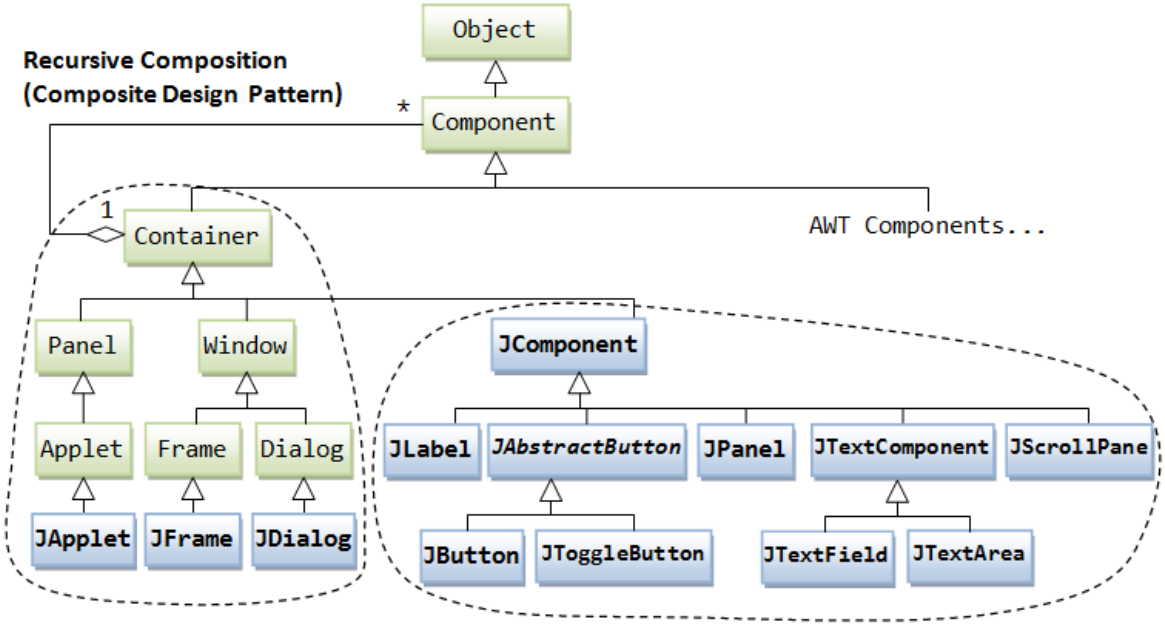
4. Swing supports *mouse-less operation*, i.e., it can operate entirely using keyboard.
5. Swing components support "tool-tips".
6. Swing components are *JavaBeans* – a Component-based Model used in Visual Programming (like Visual Basic). You can drag-and-drop a Swing component into a "design form" using 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 (in particular, container/component and event-handling), switching over to Swing (or any other Graphics packages) is straight-forward.

Swing's Components

Compared with the AWT component 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: *containers* and *components*. A container is used to hold components. A container can also hold containers because it is a (subclass of) component.

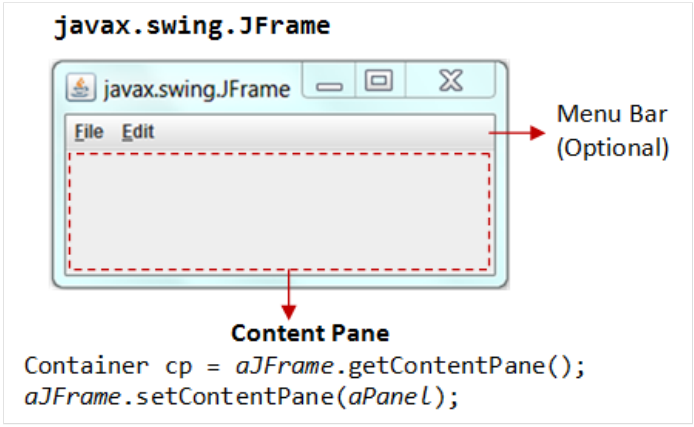
As a rule, do not mix heavyweight AWT components and lightweight Swing components in the same program, as the heavyweight components will always be painted *on top of* the lightweight components.

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 SwingDemo extends JFrame {
   // Constructor
   public SwingDemo() {
      // 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 = 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 SwingDemo extends JFrame {
   // Constructor
   public SwingDemo() {
      // 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
      setContentPane(mainPanel);
      ......
   }
   .......
}
```

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

```
// Suppose that "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`, e.g., `JFrame`, `JButton`, `JTextField`, `JLabel`, etc.
2. A top-level container (typically `JFrame`) is needed. The `JComponents` should not 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.
3. Swing applications uses AWT event-handling classes, e.g., `ActionEvent/ActionListener`, `MouseEvent/MouseListener`, etc.
4. Run the constructor in the Event Dispatcher Thread (instead of Main thread) for thread safety, as shown in the following program template.

8.4 Swing Program Template

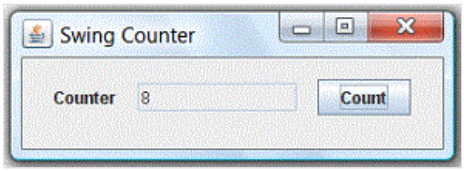
```
1  import java.awt.*;        // Using AWT layouts
2  import java.awt.event.*;  // Using AWT event classes and listener interfaces
3  import javax.swing.*;     // Using Swing components and containers
4
5  // A Swing GUI application inherits from top-level container javax.swing.JFrame
6  public class SwingTemplate extends JFrame {
7
8     // Private instance variables
9     // ......
10
11    // Constructor to setup the GUI components and event handlers
12    public SwingTemplate() {
13       // Retrieve the top-level content-pane from JFrame
14       Container cp = getContentPane();
15
16       // Content-pane sets layout
17       cp.setLayout(new ....Layout());
18
19       // Allocate the GUI components
20       // .....
21
22       // Content-pane adds components
23       cp.add(....);
24
25       // Source object adds listener
26       // .....
27
28       setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
29          // Exit the program when the close-window button clicked
30       setTitle("......");  // "super" JFrame sets title
31       setSize(300, 150);   // "super" JFrame sets initial size
32       setVisible(true);    // "super" JFrame shows
```

```
   }

   // 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 SwingTemplate();  // 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 layouts
import java.awt.event.*; // Using AWT event classes 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 {   // JFrame instead of Frame
   private JTextField tfCount;  // Use Swing's JTextField instead of AWT's TextField
   private JButton btnCount;    // Using Swing's JButton instead of AWT's Button
   private int count = 0;

   // Constructor to setup the GUI components and event handlers
   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());   // The content-pane sets its layout

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

      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 evt) {
            ++count;
            tfCount.setText(count + "");
         }
      });

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

```
50          });
51       }
52    }
```

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

// The above is different from:
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 operations. 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 called 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"

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;  // version 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 layouts
import java.awt.event.*; // Using AWT event classes and listener interfaces
import javax.swing.*;    // Using Swing components and containers

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

   // Constructor to setup the GUI components and event handlers
   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));  // The content-pane sets its layout

      cp.add(new JLabel("Enter an Integer: "));
      tfInput = new JTextField(10);
      cp.add(tfInput);
      cp.add(new JLabel("The Accumulated Sum is: "));
      tfOutput = new JTextField(10);
      tfOutput.setEditable(false);  // read-only
      cp.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 evt) {
            // Get the String entered into the input TextField, convert to int
            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"); // "super" Frame sets title
      setSize(350, 120);  // "super" Frame sets initial size
      setVisible(true);   // "super" 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
         }
      });
```

```
53      }
54  }
```

9. 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.

9.1 NetBeans

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".

9.2 Eclipse

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)
5. Java3D

Latest version tested: JDK 15.0.2
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