

# Object-Oriented Language and Theory

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## Lab 9: GUI Programming

### \* Objectives:

In this lab, you will practice with:

- Create a simple GUI application with AWT
- Create a simple GUI application with Swing
- Work with JavaFX

There are current three sets of Java APIs for graphics programming:

1. **AWT** (**A**bstract **W**indowing **T**oolkit) API was introduced in JDK 1.0. Most of the AWT components have become obsolete and should be replaced by newer Swing components.
2. **Swing** API, a much more comprehensive set of graphics libraries that enhances the AWT, was introduced as part of Java Foundation Classes (JFC) after the release of JDK 1.1. JFC 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, is meant to replace Swing.

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) and Java3D.

You need to check the JDK 9 API (<https://docs.oracle.com/javase/9/docs/api/overview-summary.html>) for the AWT/Swing APIs (under module java.desktop) and JavaFX (under modules javafx.\*) 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>.

## 0. Create GUIProject

- Create a Java Project named GUIProject
- Create the following packages in the GUIProject for this lab:

+ `hust.soict.ictglobal.gui.awt`

+ `hust.soict.ictglobal.gui.swing`

+ `hust.soict.ictglobal.gui.javafx`

## 1. A simple GUI application with AWT

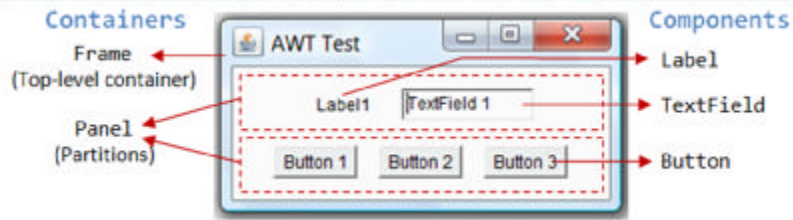
### 1.1 AWT Packages

AWT 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, Mac OS X, and Unixes.

## 1.2 Containers and Components



There are two types of GUI elements:

1. *Component*: Components are elementary GUI entities, such as Button, Label, and TextField.
2. *Container*: Containers, such as Frame 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 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 `c`) can invoke `c.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.

## 1.3. AWTCounter application

Let's assemble a few components together into a simple GUI counter program, as illustrated.

- Create a class **AWTCounter** in **soict.hust.ictglobal.gui.awt** package. 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.
- The sample code is presented below:

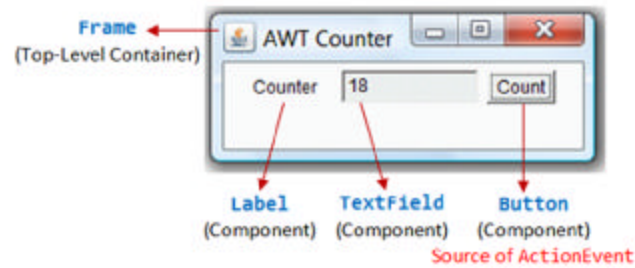
```
1import java.awt.*;           // Using AWT container and component classes
2import java.awt.event.*;     // Using AWT event classes and listener interfaces
3
4// An AWT program inherits from the top-level container java.awt.Frame
5public class AWTCounter extends Frame implements ActionListener {
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     btnCount.addActionListener(this);
28         // "btnCount" is the source object that fires an ActionEvent when clicked.
29         // The source add "this" instance as an ActionEvent listener, which provides
30         // an ActionEvent handler called actionPerformed().
31         // Clicking "btnCount" invokes actionPerformed().
32
33     setTitle("AWT Counter"); // "super" Frame sets its title
34     setSize(250, 100);      // "super" Frame sets its initial window size
35
36     // For inspecting the Container/Components objects
37     // System.out.println(this);
38     // System.out.println(lblCount);
39     // System.out.println(tfCount);
40     // System.out.println(btnCount);
41
42     setVisible(true);        // "super" Frame shows
43
44     // System.out.println(this);
45     // System.out.println(lblCount);
46     // System.out.println(tfCount);
47     // System.out.println(btnCount);
48 }
49
50 // The entry main() method
51 public static void main(String[] args) {
52     // Invoke the constructor to setup the GUI, by allocating an instance
53     AWTCounter app = new AWTCounter();
54     // or simply "new AWTCounter();" for an anonymous instance
55 }
56
57 // ActionEvent handler - Called back upon button-click.
58 @Override
59 public void actionPerformed(ActionEvent evt) {
60     ++count; // Increase the counter value
61     // Display the counter value on the TextField tfCount
62     tfCount.setText(count + ""); // Convert int to String
63 }
64}

```

- Run and test the application by clicking the button Count



## 1.4. Do more practice at home

Visit [https://www3.ntu.edu.sg/home/ehchua/programming/java/j4a\\_gui.html](https://www3.ntu.edu.sg/home/ehchua/programming/java/j4a_gui.html) and practice example from 2 to 5.

## 2. A simple GUI application with Swing

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:

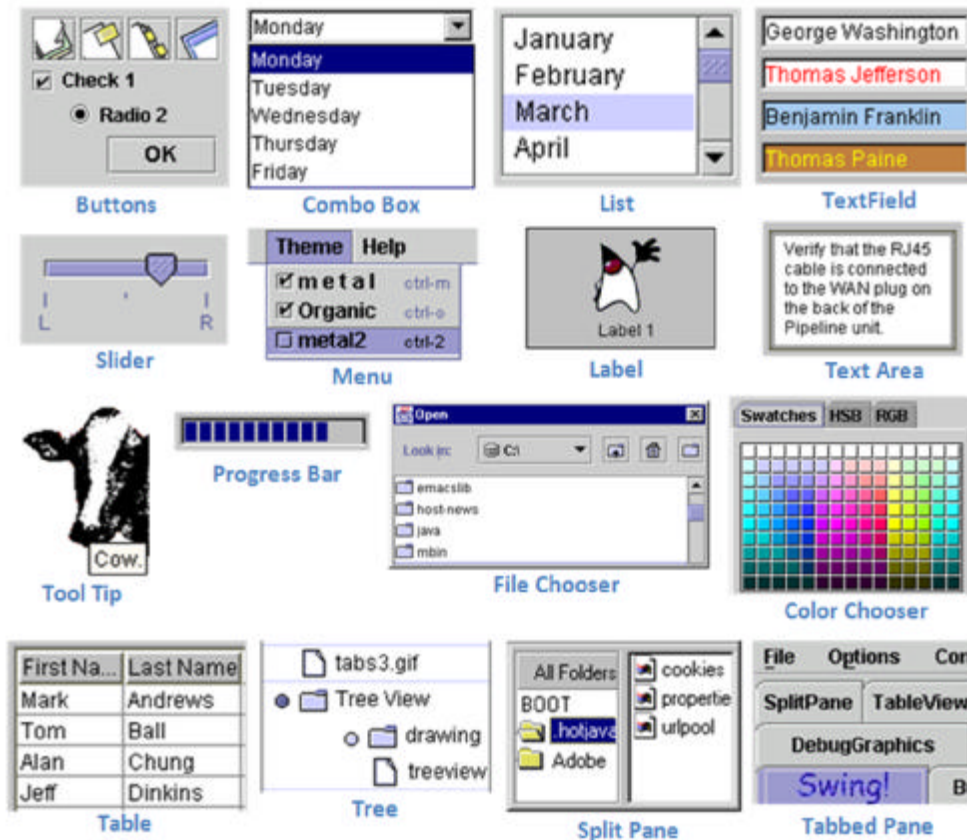
- Swing API: for advanced graphical programming.
- Accessibility API: provides assistive technology for the disabled.
- Java 2D API: for high quality 2D graphics and images.
- Pluggable look and feel supports.
- Drag-and-drop support between Java and native applications.

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.

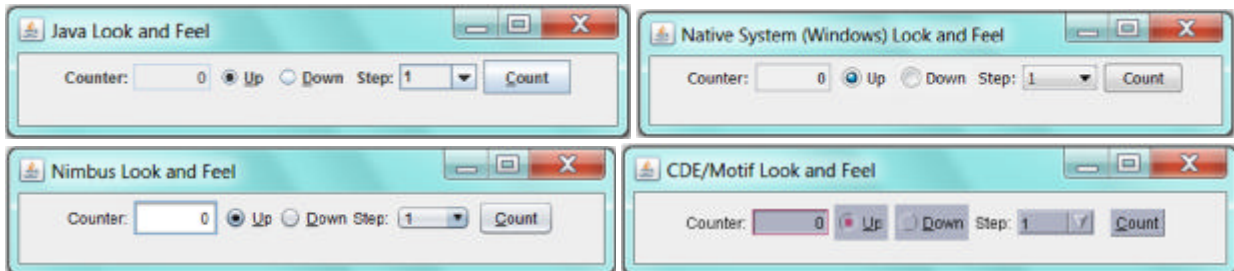
### 2.1 Swing's Features

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 from 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 Mac). If the later is chosen, a Swing button runs on the Windows looks like a Windows' button and feels like a Window's button. Similarly, a Swing button runs on the UNIX looks like a UNIX's button and feels like a UNIX's button.



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



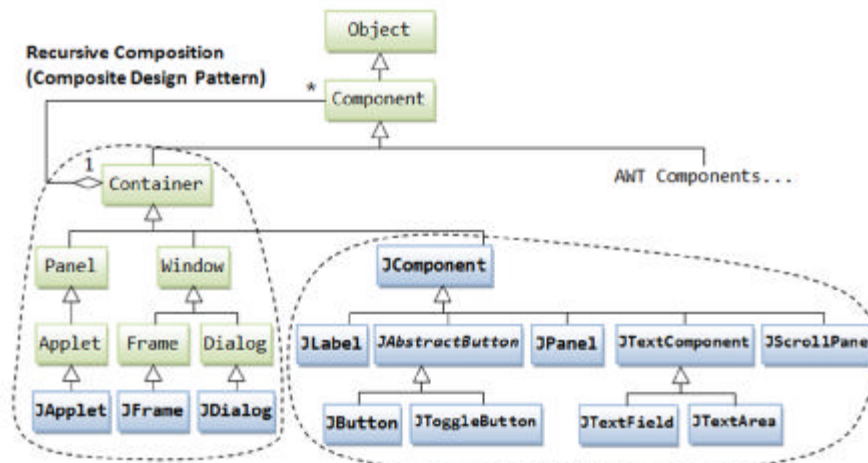
8. Swing application uses AWT's layout manager (such as FlowLayout and BorderLayout in package java.awt). It added new layout managers, such as Springs, Struts, and BoxLayout (in package javax.swing).
9. Swing implements *double-buffering* and automatic repaint batching for smoother screen repaint.
10.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

## 2.2 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

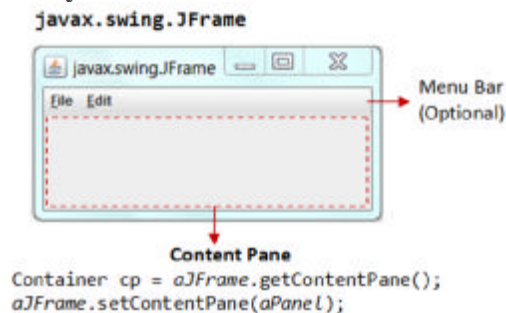
Compared with the AWT component classes (in package java.awt), Swing component classes (in package javax.swing) begin with a prefix "J", e.g., JButton, JTextField, JLabel, JPanel, JFrame, or JApplet.



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:

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

```
1. public class SwingDemo extends JFrame {
2.     // Constructor
3.     public SwingDemo() {
4.         // Get the content-pane of this JFrame, which is a java.awt.Container
5.         // All operations, such as setLayout() and add() operate on the content-pane
6.         Container cp = getContentPane();
7.         cp.setLayout(new FlowLayout());
8.         cp.add(new JLabel("Hello, world!"));
9.         cp.add(new JButton("Button"));
10.        .....
11.    }
12.    .....
13. }
```

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

```
14. public class SwingDemo extends JFrame {
15.     // Constructor
16.     public SwingDemo() {
17.         // The "main" JPanel holds all the GUI components
18.         JPanel mainPanel = new JPanel(new FlowLayout());
19.         mainPanel.add(new JLabel("Hello, world!"));
20.         mainPanel.add(new JButton("Button"));
21.
22.         // Set the content-pane of this JFrame to the main JPanel
23.         setContentPane(mainPanel);
24.         .....
25.     }
26.     .....
27. }
```

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.

## Swing Program Template

```
1import java.awt.*;           // Using AWT layouts
2import java.awt.event.*;     // Using AWT event classes and listener interfaces
3import javax.swing.*;        // Using Swing components and containers
4
5// A Swing GUI application inherits from top-level container javax.swing.JFrame
6public class ..... extends JFrame {
7
8    // Private instance variables
9    // .....
10
11    // Constructor to setup the GUI components and event handlers
12    public .....() {
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
33    }
34
35    // The entry main() method
36    public static void main(String[] args) {
37        // Run GUI codes in Event-Dispatching thread for thread-safety
38        SwingUtilities.invokeLater(new Runnable() {
39            @Override
40            public void run() {
41                new ..... (); // Let the constructor do the job
42            }
43        });
44    }
45}
```



### 2.3. SwingCounter application

- Let's convert the earlier AWT application example into Swing.
- Create a class named **SwingCounter** in the **hust.soict.ictglobal.gui.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.

```
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 SwingCounter extends JFrame { // JFrame instead of Frame
7     private JTextField tfCount; // Use Swing's JTextField instead of AWT's TextField
8     private JButton btnCount;   // Using Swing's JButton instead of AWT's Button
9     private int count = 0;
10
11     // Constructor to setup the GUI components and event handlers
12     public SwingCounter() {
13         // Retrieve the content-pane of the top-level container JFrame
14         // All operations done on the content-pane
15         Container cp = getContentPane();
16         cp.setLayout(new FlowLayout()); // The content-pane sets its layout
17
18         cp.add(new JLabel("Counter"));
19         tfCount = new JTextField("0");
20         tfCount.setEditable(false);
21         cp.add(tfCount);
22
23         btnCount = new JButton("Count");
24         cp.add(btnCount);
25
26         // Allocate an anonymous instance of an anonymous inner class that
27         // implements ActionListener as ActionListener
28         btnCount.addActionListener(new ActionListener() {
29             @Override
30             public void actionPerformed(ActionEvent evt) {
31                 ++count;
32                 tfCount.setText(count + "");
33             }
34         });
35
36         setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE); // Exit program if close-window button clicked
37         setTitle("Swing Counter"); // "super" JFrame sets title
38         setSize(300, 100);        // "super" JFrame sets initial size
39         setVisible(true);         // "super" JFrame shows
40     }
41
42     // The entry main() method
43     public static void main(String[] args) {
```

```

44    // Run the GUI construction in the Event-Dispatching thread for thread-safety
45    SwingUtilities.invokeLater(new Runnable() {
46        @Override
47        public void run() {
48            new SwingCounter(); // Let the constructor do the job
49        }
50    });
51 }
52}

```

### JFrame's Content-Pane

The JFrame's method `getContentPane()` returns the content-pane (which is a `java.awt.Container`) 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 `@SuppressWarnings` (in package `java.lang`) (JDK 1.5):

4. `@SuppressWarnings("serial")`

```
public class MyFrame extends JFrame { ..... }
```

## 2.4. Do more practice at home

Visit [https://www3.ntu.edu.sg/home/ehchua/programming/java/j4a\\_gui.html](https://www3.ntu.edu.sg/home/ehchua/programming/java/j4a_gui.html) and practice example from 6 to 8.

## 3. Working with JavaFX

Put all examples/exercises on the `hust.soict.ictglobal.gui.javafx` package.

Please go to this tutorial <https://o7planning.org/en/11009/javafx> and do the following task, preparing for your mini-project:

- [Install e\(fx\)clipse into Eclipse \(JavaFX Tooling\)](#)

- [Install JavaFX Scene Builder into Eclipse](#)
- [JavaFX Tutorial for Beginners - Hello JavaFX](#)
- Working with some common Layout in JavaFX such as HBox, VBox, FlowPane, BorderPane, GridPane (from 4 to 10)...
- Working with some common controls in JavaFX such as ListView, ComboBox, TableView, TreeView, Menu, TextField, TextArea... (from 11 to 41)
- Working with dialogs and windows in JavaFX (from 42 to 45)
- Working with charts, shapes, effects... in JavaFX (from 46 to 52)