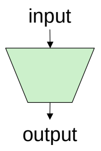
Introduction to GUIs (Graphical User Interfaces)

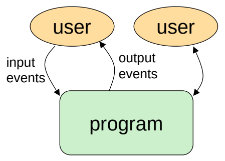
Lecture 18
CS211 – Summer 2008

Interactive Programs

- "Classic" view of computer programs: transform inputs to outputs, stop



- Event-driven programs: interactive, long-running
  - Servers interact with clients
  - Applications interact with user(s)



GUI Motivation

- Interacting with a program
  - Program-Driven
    - Statements execute in sequential, predetermined order
    - Use keyboard or file I/O, but program determines when that happens
    - Usually single-threaded
  - Event-Driven
    - Program waits for user input to activate certain statements
    - Typically uses a GUI (Graphical User Interface)
    - Often multi-threaded
- Design...Which to pick?
  - Program called by another program?
  - Program used at command line?
  - Program interacts often with user?
  - Program used in window environment?

- How does Java do GUIs?

Java Support for Building GUIs

- Java Foundation Classes
  - Classes for building GUIs
  - Major components
    - awt and swing
    - Pluggable look-and-feel support
    - Accessibility API
    - Java 2D API
    - Drag-and-drop Support
    - Internationalization
- Our main focus: Swing
  - Building blocks of GUIs
    - Windows & components
    - User interactions
  - Built upon the AWT (Abstract Window Toolkit)
    - Java event model

- Java's support for cross-platform GUIs is one of its main selling points

Java Foundation Classes

- Pluggable Look-and-Feel Support
  - Controls look-and-feel for particular windowing environment
  - E.g., Java, Windows, Motif, Mac
- Accessibility API
  - Supports assistive technologies such as screen readers and Braille
- Java 2D
  - Drawing
  - Includes rectangles, lines, circles, images, ...
- Drag-and-drop
  - Support for drag and drop between Java application and a native application
- Internationalization
  - Support for other languages

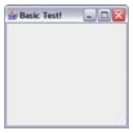
GUI Statics and GUI Dynamics

- Statics: what's drawn on the screen
  - Components
    - buttons, labels, lists, sliders, menus, ...
  - Containers: components that contain other components
    - frames, panels, dialog boxes, ...
  - Layout managers: control placement and sizing of components

- Dynamics: user interactions
  - Events
    - button-press, mouse-click, key-press, ...
  - Listeners: an object that responds to an event
  - Helper classes
    - **`Graphics`**, **`Color`**, **`Font`**, **`FontMetrics`**, **`Dimension`**, ...

Creating a Window

```java
import javax.swing.*;

public class Basic1 {
   public static void main(String[] args) {
      //create the window
      JFrame f = new JFrame("Basic Test!");
      //quit Java after closing the window
      f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      f.setSize(200, 200); //set size in pixels
      f.setVisible(true); //show the window
   }
}
```

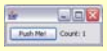


Creating a Window Using a Constructor

```java
import javax.swing.*;

public class Basic2 extends JFrame {

   public static void main(String[] args) {
      new Basic2();
   }

   public Basic2() {
      setTitle("Basic Test2!"); //set the title
      //quit Java after closing the window
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      setSize(200, 200); //set size in pixels
      setVisible(true); //show the window
   }
}
```

A More Extensive Example

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

public class Intro extends JFrame {

   private int count = 0;
   private JButton myButton = new JButton("Push Me!");
   private JLabel label = new JLabel("Count: " + count);

   public Intro() {
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      setLayout(new FlowLayout(FlowLayout.LEFT)); //set layout manager
      add(myButton); //add components
      add(label);
      label.setPreferredSize(new Dimension(60, 10));

      myButton.addActionListener(new ActionListener() {
         public void actionPerformed(ActionEvent e) {
            count++;
            label.setText("Count: " + count);
         }
      });

      pack();
      setVisible(true);
   }

   public static void main(String[] args) {
      try {
         UIManager.setLookAndFeel(UIManager.getSystemLookAndFeelClassName());
      } catch (Exception exc) {}
      new Intro();
   }
}
```



GUI Statics

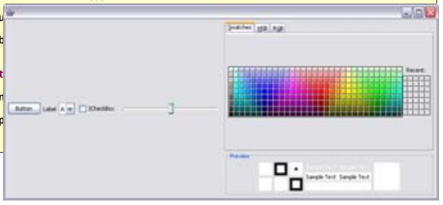
- Determine which components you want
- Choose a top-level container in which to put the components (`JFrame` is often a good choice)
- Choose a layout manager to determine how components are arranged
- Place the components

Components = What You See

- Visual part of an interface
- Represents something with position and size
- Can be *painted* on screen and can receive events
- Buttons, labels, lists, sliders, menus, ...

Component Examples

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

public class ComponentExamples extends JFrame {

   public ComponentExamples() {
      setLayout(new FlowLayout(FlowLayout.LEFT));
      add(new JButton("Button"));
      add(new JLabel("Label"));
      add(new JComboBox(new String[] { "A", "B", "C" }));
      add(new JCheckBox("JCheckBox"));
      add(new JSlider(0, 100));
      add(new JColorChooser());

      setDefau
      pack();
      setVisib
   }

   public stat
      try {
         UIMan
      } catch
      new Comp
   }
}
```



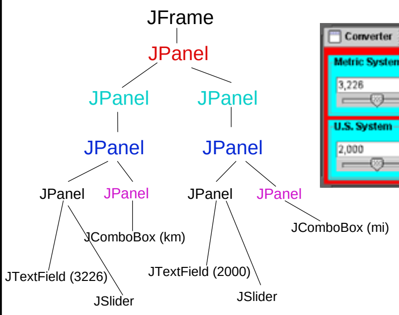
More Components

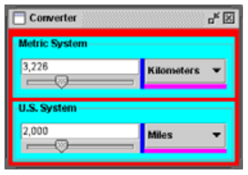
- **`JFileChooser`**: allows choosing a file
- **`JLabel`**: a simple text label
- **`JTextArea`**: editable text
- **`JTextField`**: editable text (one line)
- **`JScrollBar`**: a scrollbar
- **`JPopupMenu`**: a pop-up menu
- **`JProgressBar`**: a progress bar
- Lots more!

Containers

- A container is a *component* that
  - Can hold other components
  - Has a *layout manager*
- Heavyweight vs. lightweight
  - A *heavyweight* component interacts directly with the host system
  - **`JWindow`**, **`JFrame`**, and **`JDialog`** are heavyweight
  - Except for these top-level containers, Swing components are mostly lightweight
- There are three basic *top-level* containers
  - **`JWindow`**: top-level window with no border
  - **`JFrame`**: top-level window with border and (optional) menu bar
  - **`JDialog`**: used for dialog windows
- An important lightweight container
  - **`JPanel`**: used mostly to organize objects within other containers

A Component Tree





Layout Managers

- A layout manager controls placement and sizing of components in a container
  - If you do not specify a layout manager, the container will use a default:
    - **`JPanel`** default = **`FlowLayout`**
    - **`JFrame`** default = **`BorderLayout`**
- Five common layout managers:
  - **`BorderLayout`**, **`BoxLayout`**, **`FlowLayout`**, **`GridBagLayout`**, **`GridLayout`**
- General syntax: `container.setLayout(new LayoutMan());`
- Examples:

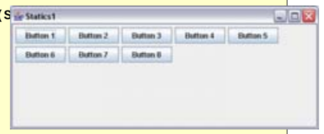
```
JPanel p1 = new JPanel(new BorderLayout());

JPanel p2 = new JPanel();
p2.setLayout(new BorderLayout());
```

Some Example Layout Managers

- **`FlowLayout`**
  - Components placed from left to right in order added
  - When a row is filled, a new row is started
  - Lines can be centered, left-justified or right-justified (see **`FlowLayout`** constructor)
- **`GridLayout`**
  - Components are placed in grid pattern (number of rows & columns specified in constructor)
  - Grid is filled left-to-right, then top-to-bottom
- **`BorderLayout`**
  - Divides window into five areas: North, South, East, West, Center
- Adding components
  - **`FlowLayout`** and **`GridLayout`** use **`container.add(component)`**
  - **`BorderLayout`** uses **`container.add(component, index)`** where **`index`** is one of
    - **`BorderLayout.North, BorderLayout.South, BorderLayout.East, BorderLayout.West, BorderLayout.Center`**

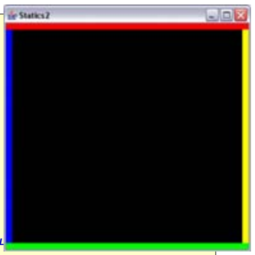
`FlowLayout` Example

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

public class Statics1 {
   public static void main(S
      new S1GUI();
   }
}

class S1GUI {
   private JFrame f;

   public S1GUI() {
      f = new JFrame("Statics1");
      f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      f.setSize(500, 200);
      f.setLayout(new FlowLayout(FlowLayout.LEFT));
      for (int b = 1; b < 9; b++)
         f.add(new JButton("Button " + b));
      f.setVisible(true);
   }
}
```



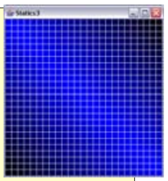
BorderLayout Example

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

public class Statics2 {
   public static void main(String[] args) { new
}

class ColoredJPanel extends JPanel {
   Color color;
   ColoredJPanel(Color color) {
      this.color = color;
   }
   public void paintComponent(Graphics g) {
      g.setColor(color);
      g.fillRect(0, 0, 400, 400);
   }
}

class S2GUI extends JFrame {
   public S2GUI() {
      setTitle("Statics2");
      setDefaultCloseOperation(JFrame.EXIT_ON_CL
      setSize(400, 400);
      add(new ColoredJPanel(Color.RED), BorderLayout.NORTH);
      add(new ColoredJPanel(Color.GREEN), BorderLayout.SOUTH);
      add(new ColoredJPanel(Color.BLUE), BorderLayout.WEST);
      add(new ColoredJPanel(Color.YELLOW), BorderLayout.EAST);
      add(new ColoredJPanel(Color.BLACK), BorderLayout.CENTER);
      setVisible(true);
   }
}
```



GridLayout Example

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

public class Statics3 {
   public static void main(String[] args) { new S3GUI(); }
}

class S3GUI extends JFrame {
   static final int DIM = 25;
   static final int SIZE = 12;
   static final int GAP = 1;

   public S3GUI() {
      setTitle("Statics3");
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      setLayout(new GridLayout(DIM, DIM, GAP, GAP));
      for (int i = 0; i < DIM * DIM; i++) add(new MyPanel());
      pack();
      setVisible(true);
   }

   class MyPanel extends JPanel {
      MyPanel() { setPreferredSize(new Dimension(SIZE, SIZE)); }
      public void paintComponent(Graphics g) {
         float gradient =
            1f - ((float)Math.abs(getX() - getY()))/(float)((SIZE + GAP) * DIM);
         g.setColor(new Color(0f, 0f, gradient));
         g.fillRect(0, 0, getWidth(), getHeight());
      }
   }
}
```



More Layout Managers

- **`CardLayout`**
  - Tabbed index card look from Windows
- **`GridBagLayout`**
  - Most versatile, but complicated
- Custom
  - Can define your own layout manager
  - But best to try Java's layout managers first...
- Null
  - No layout manager
  - Programmer must specify absolute locations
  - Provides great control, but can be dangerous because of platform dependency

AWT and Swing

- AWT
  - Initial GUI toolkit for Java
  - Provided a “Java” look and feel
  - Basic API: **`java.awt.*`**
- Swing
  - More recent (since Java 1.2) GUI toolkit
  - Added functionality (new components)
  - Supports look and feel for various platforms (Windows, Motif, Mac)
  - Basic API: **`javax.swing.*`**
- Did Swing replaced AWT?
  - Not quite: both use the AWT event model

Code Examples

- Intro.java
  - Button & counter
- Basic1.java
  - Create a window
- Basic2.java
  - Create a window using a constructor
- Calculator.java
  - Shows use of **`JOptionPane`** to produce standard dialogs
- ComponentExamples.java
  - Sample components
- Statics1.java
  - **`FlowLayout`** example
- Statics2.java
  - **`BorderLayout`** example
- Statics3.java
  - **`GridLayout`** example
- LayoutDemo.java
  - Multiple layouts

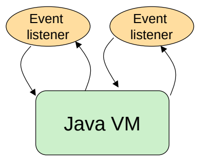
GUI Dynamics

GUI Statics and GUI Dynamics

- Statics: what's drawn on the screen
  - Components
    - buttons, labels, lists, sliders, menus, ...
  - Containers: components that contain other components
    - frames, panels, dialog boxes, ...
  - Layout managers: control placement and sizing of components
- Dynamics: user interactions
  - Events
    - button-press, mouse-click, key-press, ...
  - Listeners: an object that responds to an event
  - Helper classes
    - **`Graphics`**, **`Color`**, **`Font`**, **`FontMetrics`**, **`Dimension`**, ...

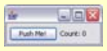
Dynamics Overview

- Dynamics = causing and responding to actions
  - What actions? *events*
    - Need to write code that knows what to do when an event occurs
  - In Java, you specify what happens by providing an *object* that "hears" the event
    - In other languages, you specify what happens in response to an event by providing a *function*
- What objects do we need?
  - *Events*
  - *Event listeners*



Brief Example Revisited

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

public class Intro extends JFrame {

   private int count = 0;
   private JButton myButton = new JButton("Push Me!");
   private JLabel label = new JLabel("Count: " + count);

   public Intro() {
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      setLayout(new FlowLayout(FlowLayout.LEFT)); //set layout manager
      add(myButton); //add components
      add(label);
      label.setPreferredSize(new Dimension(60, 10));

      myButton.addActionListener(new ActionListener() {
         public void actionPerformed(ActionEvent e) {
            count++;
            label.setText("Count: " + count);
         }
      });

      pack();
      setVisible(true);
   }

   public static void main(String[] args) {
      try {
         UIManager.setLookAndFeel(UIManager.getSystemLookAndFeelClassName());
      } catch (Exception exc) {}
      new Intro();
   }
}
```



Brief Example Revisited

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

public class Intro extends JFrame {

   private int count = 0;
   private JButton myButton = new JButton("Push Me!");
   private JLabel label = new JLabel("Count: " + count);

   public Intro() {
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      setLayout(new FlowLayout(FlowLayout.LEFT)); //set layout manager
      add(myButton); //add components
      add(label);
      label.setPreferredSize(new Dimension(60, 10));

      myButton.addActionListener(new ActionListener() {
         public void actionPerformed(ActionEvent e) {
            count++;
            label.setText("Count: " + count);
         }
      });

      pack();
      setVisible(true);
   }

   public static void main(String[] args) {
      try {
         UIManager.setLookAndFeel(UIManager.getSystemLookAndFeelClassName());
      } catch (Exception exc) {}
      new Intro();
   }
}
```

The Java Event Model

- Timeline
  - User (or program) does something to a component
    - clicks on a button, resizes a window, ...
  - Java issues an *event object* describing the event
  - A special type of object (a listener) "hears" the event
    - The listener has a method that "handles" the event
    - The handler does whatever the programmer programmed
- What you need to understand
  - *Events*: How components issue events
  - *Listeners*: How to make an object that listens for events
  - *Handlers*: How to write a method that responds to an event

Events

- An Event is a Java object
  - It represents an action that has occurred – mouse clicked, button pushed, menu item selected, key pressed, ...
  - Events are normally created by the Java runtime system
    - You can create your own events, but this is unusual
- Most events are in **`java.awt.event`**
  - Some events are in **`javax.swing.event`**
- All events are subclasses of **`AWTEvent`**

```
AWTEvent
   ActionEvent
   ComponentEvent
      InputEvent
         MouseEvent
         KeyEvent
```

Types of Events

- Each Swing Component can generate one or more types of events
  - The type of event depends on the component
    - Clicking a `JButton` creates an `ActionEvent`
    - Clicking a `JCheckbox` creates an `ItemEvent`
  - The different kinds of events include different information about what has occurred
    - All events have method **`getSource()`** which returns the object (e.g., the button or checkbox) on which the Event initially occurred
    - An **`ItemEvent`** has a method **`getStateChange()`** that returns an integer indicating whether the item (e.g., the checkbox) was *selected* or *deselected*

Event Listeners

- **`ActionListener`**, **`MouseListener`**, **`WindowListener`**, ...
- Listeners are Java interfaces
  - Any class that implements that interface can be used as a listener
- To be a listener, a class must implement the interface
  - Example: an **`ActionListener`** must contain a method
    `public void actionPerformed(ActionEvent e)`

Implementing Listeners

- Which class should be a listener?
  - Java has no restrictions on this, so *any* class that implements the listener will work
- Typical choices
  - Top-level container that contains whole GUI
    `public class GUI implements ActionListener`
  - Inner classes to create specific listeners for reuse
    `private class LabelMaker implements ActionListener`
  - Anonymous classes created on the spot
    `b.addActionListener(new ActionListener() {...});`

Listeners and Listener Methods

- When you implement an interface, you must implement all the interface's methods
  - Interface **`ActionListener`** has one method:
    `void actionPerformed(ActionEvent e)`
  - Interface **`MouseInputListener`** has seven methods:

```
void mouseClicked(MouseEvent e)
void mouseEntered(MouseEvent e)
void mouseExited(MouseEvent e)
void mousePressed(MouseEvent e)
void mouseReleased(MouseEvent e)
void mouseDragged(MouseEvent e)
void mouseMoved(MouseEvent e)
```

Registering Listeners

- How does a component know which listener to use?
- You must *register* the listeners
  - This connects listener objects with their source objects
  - Syntax: **`component.addTypeListener(Listener)`**
  - You can register as many listeners as you like
- Example:

```
b.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        count++;
        label.setText(generateLabel());
    }
});
```

Example 1: The Frame is the Listener

```
import javax.swing.*; import java.awt.*; import java.awt.event.*;
public class ListenerExample1 extends JFrame implements ActionListener {
    private int count;
    private JButton b = new JButton("Push Me!");
    private JLabel label = new JLabel("Count: " + count);
    public static void main(String[] args) {
        JFrame f = new ListenerExample1();
        f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        f.setSize(200,100);
        f.setVisible(true);
    }
    public ListenerExample1() {
        setLayout(new FlowLayout(FlowLayout.LEFT));
        add(b); add(label);
        b.addActionListener(this);
    }
    public void actionPerformed(ActionEvent e) {
        count++;
        label.setText("Count: " + count);
    }
}
```

Example 2: The Listener is an Inner Class

```
import javax.swing.*; import java.awt.*; import java.awt.event.*;
public class ListenerExample2 extends JFrame {
    private int count;
    private JButton b = new JButton("Push Me!");
    private JLabel label = new JLabel("Count: " + count);
    class Helper implements ActionListener {
        public void actionPerformed(ActionEvent e) {
            count++;
            label.setText("Count: " + count);
        }
    }
    public static void main(String[] args) {
        JFrame f = new ListenerExample2();
        f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        f.setSize(200,100); f.setVisible(true);
    }
    public ListenerExample2() {
        setLayout(new FlowLayout(FlowLayout.LEFT));
        add(b); add(label); b.addActionListener(new Helper());
    }
}
```

Example 3: The Listener is an Anonymous Class

```
import javax.swing.*; import java.awt.*; import java.awt.event.*;
public class ListenerExample3 extends JFrame {
    private int count;
    private JButton b = new JButton("Push Me!");
    private JLabel label = new JLabel("Count: " + count);
    public static void main (String[] args) {
        JFrame f = new ListenerExample3();
        f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        f.setSize(200,100); f.setVisible(true);
    }
    public ListenerExample3() {
        setLayout(new FlowLayout(FlowLayout.LEFT));
        add(b); add(label);
        b.addActionListener(new ActionListener() {
            public void actionPerformed (ActionEvent e) {
                count++;
                label.setText("Count: " + count);
            }
        });
    }
}
```

Adapters

- Some listeners (e.g., **`MouseInputListener`**) have lots of methods; you don't always need all of them
  - For instance, you may be interested only in mouse clicks
- For this situation, Java provides *adapters*
  - An *adapter* is a predefined class that implements all the methods of the corresponding Listener
    - Example: **`MouseInputAdapter`** is a class that implements all the methods of interface **`MouseInputListener`**
  - The adapter methods *do nothing*
  - To easily create your own listener, you *extend* the adapter class, *overriding* just the methods that you actually need

Using Adapters

```
import javax.swing.*; import javax.swing.event.*;
import java.awt.*; import java.awt.event.*;
public class AdapterExample extends JFrame {
    private int count; private JButton b = new JButton("Mouse Me!");
    private JLabel label = new JLabel("Count: " + count);
    class Helper extends MouseInputAdapter {
        public void mouseEntered(MouseEvent e) {
            count++;
            label.setText("Count: " + count);
        }
    }
    public static void main(String[] args) {
        JFrame f = new AdapterExample();
        f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        f.setSize(200,100); f.setVisible(true);
    }
    public AdapterExample() {
        setLayout(new FlowLayout(FlowLayout.LEFT));
        add(b); add(label); b.addMouseListener(new Helper());
    }
}
```

Notes on Events and Listeners

- A single component can have many listeners
- Multiple components can share the same listener
  - Can use **`event.getSource()`** to identify the component that generated the event
- For more information on designing listeners, see **`http://java.sun.com/docs/books/tutorial/uiswing/events/generalrules.html`**
- For more information on designing GUIs, see **`http://java.sun.com/docs/books/tutorial/uiswing/`**

GUI Drawing and Painting

- For a drawing area, extend **`JPanel`** and override the method **`public void paintComponent(Graphics g)`**
- **`paintComponent`** contains the code to completely draw *everything* in your drawing panel
- Do not call **`paintComponent`** directly – instead, request that the system redraw the panel at the next convenient opportunity by calling **`myPanel.repaint()`**
- **`repaint()`** requests a call **`paintComponent()`** "soon"
  - **`repaint(ms)`** requests a call within ms milliseconds
    - Avoids unnecessary repainting
    - 16ms is a good default value

Java Graphics

- The **`Graphics`** class has methods for colors, fonts, and various shapes and lines
  - **`setColor(Color c)`**
  - **`drawOval(int x, int y, int width, int height)`**
  - **`fillOval(int x, int y, int width, int height)`**
  - **`drawLine(int x1, int y1, int x2, int y2)`**
  - **`drawString(String str, int x, int y)`**
- Take a look at
  - **`java.awt.Graphics`** (for basic graphics)
  - **`java.awt.Graphics2D`** (for more sophisticated control)
  - The 2D Graphics Trail: **`http://java.sun.com/docs/books/tutorial/2d/index.html`**