CS18000: Problem Solving and Object-Oriented Programming

Complex GUIs

(revised 3/31/24)
Video 1
GUI Concept
Constructing Graphical User Interfaces

Frames
Panels
Widgets
Review

• Review from earlier lecture on GUls
  – JOptionPane
  – JFileChooser

• One-shot, pop-up dialogs
Paradigm Shift: User in Charge

• Text-Based Interface: program prompts, user responds

• Graphical User Interface (GUI): user directs program what to do next

• Program must respond to a variety of user-initiated events
  – Keystrokes
  – Button clicks
  – Mouse movements
Model-View-Controller

• A software paradigm for constructing GUIs
• Not rigid: Has many variations
• Divides responsibilities into three pieces:
  – Model: the data (or database) underlying the application
  – View: the GUI components visible to the user
  – Controller: the “glue” that implements the “business rules” of the application
• Controller...
  – updates view when model changes
  – updates model when user interacts with view
• Idea: Separates responsibilities to manage complexity; allows specialists in each area
GUI Concept: Interface Hierarchy

• A GUI is composed of a hierarchical set of interface elements called *components or window gadgets (widgets)*
• At the top-level is...
  – *A frame*
  – A window that interacts with the user’s desktop
• Inside a frame is (among other things)...
  – *A menu bar*
  – *A panel* to layout the top-level components
• Then come the interface widgets...
  – User-interface elements
  – Generally visible to the user
  – Include labels, buttons, text fields, scroll bars, canvases, etc.
  – A panel is also a widget, to permit creation of sub-layouts
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Menu Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>Panel</td>
</tr>
</tbody>
</table>

Frame
GUIs in Java

• Two packages of classes
  – java.awt: original “Abstract Window Toolkit”
  – javax.swing: newer, better and built on AWT
    • These are the “J” classes
    • In most cases, we will use these
Video 2
JFrames and JPanels
Class JFrame

• Basic top-level window
• Interacts with “window manager”
• Houses and lays out interactive controls
• Two approaches to using:
  – Create raw JFrame object (we will use)
  – Extend JFrame then create object (also common)
Example: EmptyFrame

```java
import javax.swing.JFrame;

public class EmptyFrame {
    public static void main(String[] args) {
        JFrame jf = new JFrame("Empty Frame");
        jf.setSize(640, 480);
        jf.setDefaultCloseOperation(
            JFrame.DISPOSE_ON_CLOSE);
        jf.setVisible(true);
    }
}
```
Empty Frame

J Panel

J Frame
JFrame Operations

• `setDefaultCloseOperation`: window close
  – Use `DISPOSE_ON_CLOSE` (graceful shutdown)
  – Not `EXIT_ON_CLOSE` (equivalent to `System.exit()`)
• `setSize`: set width and height (e.g., 640x480)
• `setResizable`: true or false
• `setVisible`: true or false (true also “validates”)
• `setTitle`: String to appear in title bar
• `add`: adds components to the component pane
Panels and Layout Managers

• Panels are used to group widgets for layout
• Panels are hierarchical
  – may contain sub-panels
• Layout managers define the rules
  – how widgets and sub-panels are placed relative to one another
Class JPanel

• Java panel class

• Special features of JFrame
  – `jf.getContentPane()` is a JPanel
  – `jf.add(...)` automatically adds to content pane
  – Default Content pane layout manager is “BorderLayout”
A Java GUI: A Tree of Components

![Diagram of a Java GUI with components: JFrame, JPanel, JButton, JLabel, JTextField, JMenu, JMenuItem, JMenuBar]
Example Layout Manager: BorderLayout

• Divides pane into five regions
  – Center
  – North, East, South, West

• Can add one component to each region

• `jf.add(component, BorderLayout.CENTER)`

• More about layout managers later
North
West Center East
South
Example: Adding Buttons to Borders

```java
JButton jbCenter = new JButton("Center");
JButton jbNorth = new JButton("North");
JButton jbSouth = new JButton("South");
JButton jbEast = new JButton("East");
JButton jbWest = new JButton("West");

jf.add(jbCenter, BorderLayout.CENTER);
jf.add(jbNorth, BorderLayout.NORTH);
jf.add(jbSouth, BorderLayout.SOUTH);
jf.add(jbEast, BorderLayout.EAST);
jf.add(jbWest, BorderLayout.WEST);
```
Widgets for Interaction

• JLabel
• JButton
• JTextField
• JTextArea

Also, radio buttons, scroll bars, toggles, ...
Video 3
Event Handling
Constructing Graphical User Interfaces

Events
Event Handling

• Events connect the user to your program
• Event sources (from the user)
  – Keystrokes
  – Mouse actions (buttons and movement)
• Event listeners (your program)
  – A method in your code
  – Linked to a widget (or other event source)
  – Processes events generated by that widget
Java Event Handling

Event Dispatch Thread (EDT)

Controller

Source: http://www.clear.rice.edu/comp310/JavaResources/GUI/
EDT: The Event Dispatch Thread

• The Java GUI is controlled by its own thread, the EDT

• Typical scenario:
  – Main thread
    • Builds JFrame and lays out interface
    • Makes the JFrame visible
    • Returns from main method; main thread exits
  – EDT continues running
    • Interacts with user
    • Invokes “listeners” (or “call backs”) to handle events

• Thus, your event-handling code runs on the EDT
A Better Way to Launch a JFrame

- In slide 12, JFrame launched from main() method
- This usually works ok, but sometimes runs into problems including deadlock
- It is better to launch the JFrame so that it runs on the EDT
- This is done by using `SwingUtilities.invokeLater(Runnable method)`
- Causes method to be executed on the EDT
import javax.swing.SwingUtilities;
import javax.swing.JFrame;

public class EmptyFrame {
    public static void main(String[] args) {
        // Execute all GUI-related code on the EDT.
        // This causes the run() method to execute inside the EDT.
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                createGUI();
            }
        });
    }
}
Example: EmptyFrame (2)

```java
public void createGUI() {
    JFrame jf = new JFrame("Empty Frame");
    jf.setSize(640, 480);
    jf.setDefaultCloseOperation(
        JFrame.DISPOSE_ON_CLOSE);
    jf.setVisible(true);
}
```
Video 4
ActionListener Interface
Observers ("Listeners") in Java

- ActionListener (buttons)
- MouseListener (component entry/exit)
- MouseMotionListener (component)
- ItemListener (check boxes)
- DocumentListener (text fields)
- KeyListener (text boxes)
 ActionListener Interface

• Must implement:
  – public void actionPerformed(ActionEvent e)

• ActionEvent includes methods:
  – getSource(): widget (object) generating event
  – getActionCommand(): associated string
  – getWhen(): time of event

• source.setActionCommand(String s) sets the String returned by getActionCommand()
Example: PushMe (1)

```java
import javax.swing.SwingUtilities;
import javax.swing.JFrame;
import javax.swing.JButton;
import javax.swing.JLabel;
import java.awt.BorderLayout;
import java.awt.event.ActionListener;
import java.awt.event.ActionEvent;

public class PushMe implements ActionListener {
    static JFrame frame;

    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                createGUI();
            }
        });
    }
}
public void createGUI() {
    frame = new JFrame("Push Me");
    frame.setSize(200, 100);
    frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
    JButton button = centeredButton();
    button.addActionListener(new PushMe());
    frame.setVisible(true);
    frame.setLocationRelativeTo(null);
}
Example: PushMe (3)

```java
class PushMe {
    private JButton b;

    public void actionPerformed(ActionEvent e) {
        JButton b = (JButton) e.getSource();
        if (b.getActionCommand().equals("last time"))
            frame.dispose();
        if (b.getActionCommand().equals("push")) {
            b.setActionCommand("last time");
            b.setText("Push Again");
        }
    }
}
```
Example: PushMe (4)

```java
static JButton centeredButton() {
    String[] location = {
        BorderLayout.NORTH,
        BorderLayout.EAST,
        BorderLayout.SOUTH,
        BorderLayout.WEST
    };
    for (String s : location) {
        frame.add(new JLabel("     "), s);
    }
    JButton jb = new JButton("Push Me");
    jb.setActionCommand("push");
    frame.add(jb);
    return jb;
}
```
Video 1
Source to Listener Relationships
Source to Listener Relationships

• One-to-One
  – One event source sends to one listener
  – Simple
• Many-to-One
  – Many event sources send to one listener
  – Allows single piece of code to handle multiple buttons
• One-to-Many
  – One source sends to many listeners
  – Less used, but allows independent actions on same button press
Using the ActionListener

• Technique 1: Create a named class that implements ActionListener
  – Create object
  – Attach object to one or more buttons
• Technique 2: Create an object of a nested class and attach to a button
• Technique 3: Create an object of an unnamed (anonymous inner) class and attach to a button
Example: Implement ActionListener

```java
public class ListenerTechnique1 implements ActionListener {
    public static void main(String[] args) {
        // initialization omitted
        JButton button = new JButton("Push Me");
        button.addActionListener(new ListenerTechnique1());
        button.setActionCommand("doit");
        // finish and make visible omitted
    }

    public void actionPerformed(ActionEvent ae) {
        System.out.printf("Button pressed: %s\n", ae.getActionCommand());
    }
}
```
Example: Use Nested Class

// this class is nested inside main method (for example)...

class OneShot implements ActionListener {
    public void actionPerformed(ActionEvent ae) {
        System.out.printf("Button pressed: %s\n", ae.getActionCommand());
    }
}

button.addActionListener(new OneShot());
One-Shot ActionListener

• Don’t care about name
• Only want to create one object
• Java allows simplification...

• Declare the method, class, create object, and add action listener all in one step!
• Uses Anonymous Inner Class
Anonymous Inner Class

• Declare the method, class, create object, and add action listener all in one step!

```java
button.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent ae) {
        // do something with ae
    }
});
```
Video 2
Layout Managers
Constructing Graphical User Interfaces

Layout Managers

Worker Threads
Adapter Classes

• Problem
  – Some interfaces have many methods
  – Your use may only need one of them
  – Interface requires implementations for all

• Solution
  – Adapter class provides default (empty) implementations for all
  – You create a subclass of the adapter class, overriding the ones you want to change
Example: MouseAdapter Class

• Provides implementations for
  – mouseEntered(…)
  – mouseClicked(…)
  – mouseExited(…)
  – mousePressed(…)
  – mouseReleased(…)

• You override only the ones you need
Layout Managers

• Containers like JPanel have a Layout Manager
• Layout Manager called by container to position and size each of its “children”
• Several Layout Managers available…
  – BorderLayout (center plus N-E-S-W)
  – FlowLayout (left-to-right, top-to-bottom)
  – GridLayout (m x n grid of equal size)
  – ...others (BoxLayout, GridBagLayout, ...)
• In general, re-layout as sizes change
FlowLayout

• Default layout manager (except for JFrame content pane)
• Added widgets “flow” together, one after another
• By default...
  – Left to right to fill space, then top to bottom
  – Each line is centered
  – Widgets are left at “preferred” size
Example: FlowLayout (1)

```java
import javax.swing.SwingUtilities;
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.JButton;

public class FlowLayoutExample {
    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                createGUI();
            }
        });
    }
}
```
public void createGUI() {
    JFrame frame = new JFrame("FlowLayout Example");
    frame.setSize(500, 300);
    frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);

    JPanel panel = new JPanel(); // defaults to FlowLayout
    for (int i = 1; i <= 10; i++) {
        JButton button = new JButton("Button " + i);
        panel.add(button);
    }

    frame.add(panel);
    frame.setVisible(true);
}
GridLayout

• Created with rows x cols dimensions
• Added widgets are arranged in given number of rows and columns
• Each component takes all the available space within its cell, and each cell is exactly the same size

```java
setLayout(new GridLayout(0,4));
```
• four columns per row, as many rows as it takes
Example: GridLayout (1)

```java
import javax.swing.SwingUtilities;
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.JButton;
import java.awt.GridLayout;

public class GridLayoutExample {
    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                createGUI();
            }
        });
    }
}
```
public void createGUI() {
    JFrame frame = new JFrame("GridLayout Example");
    frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
    JPanel panel = new JPanel(new GridLayout(3, 4));

    for (int i = 1; i <= 12; i++) {
        JButton button = new JButton("Button " + i);
        panel.add(button);
    }

    frame.add(panel);
    frame.pack(); // set top-level window to “right” size to fit
    frame.setVisible(true);
}
### GridLayout Example

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>*</td>
<td>9</td>
<td>0</td>
<td>#</td>
</tr>
</tbody>
</table>
Changing the JFrame’s LayoutManager

What if I don’t want to use BorderLayout for the JFrame’s top level JPanel?

I can set its LayoutManager to any other as shown below...

```java
public void createGUI() {
    JFrame jf = new JFrame();
    JPanel jp = jf.getContentPane();
    jp.setLayout(new FlowLayout());
    jp.add(...); // uses FlowLayout
    ...
}
```
Video 3
BorderFactory
Factory Pattern

• A design pattern for creating objects
• Uses static method rather than “new”
• BorderFactory example:
  – BorderFactory.createLineBorder(Color.RED)
  – BorderFactory.createTitledBorder("Sub Panel")
• Returns a suitable (perhaps “new”) object
• Allows reuse of “read-only” (shared) objects
Example: Using Sub-Panels (1)

```java
import javax.swing.SwingUtilities;
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.JButton;
import javax.swing.BorderFactory;
import javax.swing.border.Border;
import java.awt.Color;

public class SubPanelExample {
    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                createGUI();
            }
        });
    }
}
```
Example: Using Sub-Panels (2)

```java
public void createGUI() {
    JFrame frame = new JFrame("SubPanel Example");
    frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

    JPanel pane1 = new JPanel();
    JPanel pane2 = new JPanel();

    // continued ...
```
Example: Using Sub-Panels (3)

// ... continued

Border b1 = BorderFactory.createLineBorder(Color.RED);
Border b2 = BorderFactory.createTitledBorder("Sub Panel");

pane1.setBorder(b1);
pane2.setBorder(b2);

addButtons(pane2, 5);
addButtons(pane1, 2);
pane1.add(pane2);
addButtons(pane1, 3);

frame.add(pane1);
frame.setVisible(true);
}

// continued ...
Example: Using Sub-Panels (4)

// ... continued

static int counter = 0;

static void addButtons(JPanel pane, int count) {
    for (int i = 1; i <= count; i++)
        pane.add(new JButton("Button "+ ++counter));
}
}
Video 4
Canvas and Graphics Classes
Canvas Class

• A blank rectangular area that can be added to a Component (e.g., a Panel)
• Permits drawing operations by subclassing and overriding “void paint(Graphics g)” method
Graphics Class

• “Knows” how to draw on a given Canvas
• Coordinates in pixels (for our purposes)
  – Upper left is 0,0
  – x moves to right; y moves down
• Graphics context includes
  – Current color
  – Current font (when drawing text)
  – Other properties
Graphics Class Operations

• Call from within paint(), running on EDT
• Examples...
  – g.drawLine(x1, y1, x2, y2)
  – g.drawRect(x, y, width, height)
  – g.fillOval(x, y, width, height)
  – g.drawString(s, x, y)
• When model changes, call repaint(), allowable from non-EDT, which calls paint() later
Example: View (1)

```java
import javax.swing.SwingUtilities;
import javax.swing.JFrame;
import java.awt.Canvas;
import java.awt.Color;
import java.awt.Graphics;

public class View extends Canvas {
    Model model;

    View(Model model) {
        this.model = model;
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                createGUI();
            }
        });
    }
}
```
Example: View (2)

```java
public void createGUI() {
    JFrame frame = new JFrame();
    frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
    frame.setSize(640, 480);
    frame.add(this);
    repaint();
    frame.setVisible(true);
}
// continued...
```
Example: View (3)

// ... continued

/**
 * The paint method is called on the EDT in response to a call to
 * repaint().
 */

public void paint(Graphics g) {
    int x = model.getX();
    int y = model.getY();
    int width = model.getWidth();
    int height = model.getHeight();

    g.setColor(Color.RED);
    g.fillOval(x, y, width, height);
}
}