CSE 331
Software Design & Implementation

Hal Perkins
Autumn 2013
Java Graphics & GUIs
The plan

Today: introduction to Java graphics and Swing/AWT class libraries
Then: event-driven programming and user interaction

None of this is comprehensive – only an overview and guide to what you should expect to be out there.

Credits: material stolen adapted from many places; including slides and materials by Ernst, Hotan, Mercer, Notkin, Perkins, Stepp; Regis, Sun/Oracle docs & tutorial, Horstmann, Wikipedia, others, folklore
References

Very useful start: Sun/Oracle Java tutorials
   http://docs.oracle.com/javase/tutorial/uiswing/
   index.html

Mike Hoton’s slides/sample code from CSE 331 Sp12
(lectures 23, 24 with more extensive widget examples)

A good book that covers this (and much more): Core
Java vol. I by Horstmann & Cornell (but if you’ve got
another favorite, go for it)
Why study GUIs?

It’s how the world works!!

Classic example of using inheritance to organize large class libraries

Work with a huge API – and learn how (not) to deal with all of it

Many core design patterns show up here: callbacks, listeners, event-driven programs, decorators, façade

It’s cool!! It’s fun!!!!
What not to do…

There’s way too much to know all of it

Don’t memorize – look things up as you need them

Focus on the main ideas, fundamental concepts

Don’t get bogged down implementing eye candy
The (more detailed) plan

Organization of the AWT/Swing library

Graphics and drawing
   Repaint callbacks, layout managers, etc.

Handling user events

Building GUI applications
   MVC, user events, updates, &c
A very short history (1)

Graphical user interfaces have existed in Java since the beginning

Original Java GUI: **AWT** (Abstract Window Toolkit)
- Limited set of user interface elements (widgets)
- Mapped Java UI to host system UI widgets
- Lowest common denominator
- “Write once, debug everywhere”
A very short history (2)

**Swing**: Newer GUI library, introduced with Java 2 (1998)

Basic idea: underlying system only provides a blank window. Swing draws all UI components directly; doesn’t use underlying system widgets.

Not a total replacement for AWT. Swing is implemented on top of core AWT classes and both still coexist.

Use Swing, but deal with AWT when you must.
GUI terminology

**window**: A first-class citizen of the graphical desktop
   Also called a top-level container
   examples: frame, dialog box, applet

**component**: A GUI widget that resides in a window
   Also called controls in many other languages
   examples: button, text box, label

**container**: A component that hosts (holds) components
   examples: frame, applet, panel, box
## Components

<table>
<thead>
<tr>
<th>JButton</th>
<th>JCheckBox</th>
<th>JRadioButton</th>
<th>JLabel</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Button" /></td>
<td><img src="image2.jpg" alt="Checkbox" /></td>
<td><img src="image3.jpg" alt="RadioButton" /></td>
<td><img src="image4.jpg" alt="Label" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JTextField</th>
<th>JSlider</th>
<th>JToolBar</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.jpg" alt="TextField" /></td>
<td><img src="image6.jpg" alt="Slider" /></td>
<td><img src="image7.jpg" alt="ToolBar" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JComboBox</th>
<th>JList</th>
<th>JMenuBar, JMenu, JMenuItem</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image8.jpg" alt="ComboBox" /></td>
<td><img src="image9.jpg" alt="List" /></td>
<td><img src="image10.jpg" alt="MenuBar" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JColorChooser</th>
<th>JFileChooser</th>
<th>JTable</th>
<th>JTree</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image11.jpg" alt="ColorChooser" /></td>
<td><img src="image12.jpg" alt="FileChooser" /></td>
<td><img src="image13.jpg" alt="Table" /></td>
<td><img src="image14.jpg" alt="Tree" /></td>
</tr>
</tbody>
</table>
Component & container classes

- Every GUI-related class descends from `Component`, which contains dozens of basic methods and fields
- “Atomic” components: labels, text fields, buttons, check boxes, icons, menu items...
- Many components are `Containers` – things like panels that can hold nested subcomponents
Swing/AWT inheritance hierarchy

Component (AWT)
  Window
    Frame
      JFrame (Swing)
      JDialog
  Container
    JComponent (Swing)
      JButton
      JLabel
      JFileChooser
      JComboBox
      JOptionPane
      JPopupMenu
      JScrollPane
      JSlider
      JSplitPane
      JTabbedPane
      JTextField
      JTextArea
      JScrollPane
      JSpinner
      JToolBar
      JTree
      JTable
      JTextComponent
      ...
Component properties

Zillions. Each has a `get` (or `is`) accessor and a `set` modifier. Ex: `getColor,setFont,isVisible, ...`

<table>
<thead>
<tr>
<th>name</th>
<th>type</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>background</td>
<td>Color</td>
<td>background color behind component</td>
</tr>
<tr>
<td>border</td>
<td>Border</td>
<td>border line around component</td>
</tr>
<tr>
<td>enabled</td>
<td>boolean</td>
<td>whether it can be interacted with</td>
</tr>
<tr>
<td>focusable</td>
<td>boolean</td>
<td>whether key text can be typed on it</td>
</tr>
<tr>
<td>font</td>
<td>Font</td>
<td>font used for text in component</td>
</tr>
<tr>
<td>foreground</td>
<td>Color</td>
<td>foreground color of component</td>
</tr>
<tr>
<td>height, width</td>
<td>int</td>
<td>component's current size in pixels</td>
</tr>
<tr>
<td>visible</td>
<td>boolean</td>
<td>whether component can be seen</td>
</tr>
<tr>
<td>tooltip text</td>
<td>String</td>
<td>text shown when hovering mouse</td>
</tr>
<tr>
<td>size, minimum / maximum / preferred size</td>
<td>Dimension</td>
<td>various sizes, size limits, or desired sizes that the component may take</td>
</tr>
</tbody>
</table>
Types of containers

- **Top-level containers:** JFrame, JDialog, …
  - Often correspond to OS windows
  - Can be used by themselves, but usually as a host for other components
  - Live at top of UI hierarchy, not nested in anything else
- **Mid-level containers:** panels, scroll panes, tool bars
  - Sometimes contain other containers, sometimes not
  - JPanel is a general-purpose component for drawing or hosting other UI elements (buttons, etc.)
- **Specialized containers:** menus, list boxes, …
- Technically, all J-components are containers
JFrame – top-level window

Graphical window on the screen
Typically holds (hosts) other components
Common methods:

- `JFrame(String title)` – constructor, title optional
- `setDefaultCloseOperation(int what)` – what to on window close. `JFrame.EXIT_ON_CLOSE` terminates application when window closed.
- `setSize(int width, int height)` – set size
- `add(Component c)` – add component to window
- `setVisible(boolean v)` – make window visible or not
Example

SimpleFrameMain.java
JPanel – a general-purpose container

Commonly used as a place for graphics, or to hold a collection of button, labels, etc.

Needs to be added to a window or other container

    frame.add(new JPanel(...))

JPanels can be nested to any depth

Many methods/fields in common with JFrame (since both inherit from Component)

    Advice: can’t find a method/field? Check the superclass(es)

Some new methods. Particularly useful:

    setPreferredSize(Dimension d)
Containers and layout

What if we add several components to a container? How are they positioned relative to each other?

Answer: each container has a layout manager.
Layout managers

Kinds:

- **FlowLayout** (left to right, top to bottom) – default for JPanel
- **BorderLayout** ("center", "north", "south", "east", "west") – default for JFrame
- **GridLayout** (regular 2-D grid)
- others... (some are incredibly complex)

The first two should be good enough for now....
Once all the components are added to their containers, do this to make the window visible

```java
pack();
setVisible(true);
```

`pack()` figures out the sizes of all components and calls the layout manager to set locations in the container (recursively as needed)

If your window doesn’t look right, you may have forgotten `pack()`
Example

SimpleLayoutMain.java
Graphics and drawing

So far so good – and very boring…
What if we want to actually draw something? A map, an image, a path, …?
Answer: Override method `paintComponent`

Components like `JLabel` provide a suitable `paintComponent` that (in `JLabel`’s case) draws the label text.
Other components like `JPanel` typically inherit an empty `paintComponent` and can override it to draw things.
Example

SimplePaintMain.java
Graphics methods

Many methods to draw various lines, shapes, etc., ...

Can also draw images (pictures, etc.). Load the image file into an `Image` object and use `g.drawImage(...):

– In the program (`not in paintComponent`):

```java
Image pic =
    Toolkit.getDefaultToolkit()
    .getImage(image path);
```

– Then in `paintComponent`:

```java
g.drawImage(pic, ...);
```
Graphics vs Graphics2D

Class Graphics was part of the original Java AWT
   Has a procedural interface: g.drawRect(...),
   g.fillOval(...)

Swing introduced Graphics2D
   Added a object interface – create instances of
   Shape like Line2D, Rectangle2D, etc., and add
   these to the Graphics2D object

Actual parameter to paintComponent is always a
Graphics2D object. Can always cast it to that class.
Graphics2D supports both sets of graphics methods.
   Use whichever you like for CSE 331
So who calls `paintComponent`? And when??

- **Answer:** the window manager calls `paintComponent` *whenever it wants!!* (a callback!)
  - When the window is first made visible, and whenever after that some or all of it needs to be repainted
- **Corollary:** `paintComponent` must always be ready to repaint
  - regardless of what else is going on
  - You have no control over when or how often
  - You must store enough information to repaint on demand
- **If you want to redraw a window, call `repaint()` from the program (**not** from `paintComponent`)**
  - Tells the window manager to schedule repainting
  - Window manager will call `paintComponent` when it decides to redraw (soon, but maybe not right away)
  - Window manager may combine several quick `repaint()` requests and only call `paintComponent()` once
Example

FaceMain.java
How repainting happens

It’s worse than it looks!

Your program and the window manager are running concurrently:

- Program thread
- User Interface thread

Do not attempt to mess around – follow the rules and nobody gets hurt!
Rules for painting – Obey!

• Always override `paintComponent(g)` if you want to draw on a component
• Always call `super.paintComponent(g)` first
• **NEVER** call `paintComponent` yourself. That means **ABSOLUTELY POSITIVELY NEVER!!!**
• Always paint the entire picture, from scratch
• Use `paintComponent`’s `Graphics` parameter to do all the drawing. **ONLY** use it for that. Don’t copy it, try to replace it, or mess with it. It is quick to anger.
• **DON’T** create new `Graphics` or `Graphics2D` objects

• Fine print: Once you are a certified™ wizard, you may find reasons to do things differently, but you aren’t there yet.
What’s next – and not

Major topic next time is how to handle user interactions

We already know the core idea – it’s a big-time application of the observer pattern

Beyond that you’re on your own to explore all the wonderful widgets in Swing/AWT. Have fun!!!

(But don’t sink huge amounts of time into eye candy)