

---

# CSE 331

# Software Design & Implementation

Hal Perkins

Spring 2016

Java Graphics and GUIs

(Based on slides by Mike Ernst, Dan Grossman, David Notkin, Hal Perkins, Zach Tatlock)

---

# The plan

---

Today: introduction to Java graphics and Swing/AWT 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

- Some standard terminology and perspective

Credits: material taken from many places; including slides and materials by Ernst, Hotan, Mercer, Notkin, Perkins, Stepp; Reges; 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)

- <http://courses.cs.washington.edu/courses/cse331/12sp/lectures/lect23-GUI.pdf>
- <http://courses.cs.washington.edu/courses/cse331/12sp/lectures/lect24-Graphics.pdf>
- <http://courses.cs.washington.edu/courses/cse331/12sp/lectures/lect23-GUI-code.zip>
- <http://courses.cs.washington.edu/courses/cse331/12sp/lectures/lect24-Graphics-code.zip>

Good book that covers this (and much more): *Core Java* vol. I by Horstmann & Cornell

- There are other decent Java books out there too

# Why study GUIs?

---

- Er, because graphical user interfaces are pretty common (duh 😊)
  - And it's fun!
- Classic example of using inheritance to organize large class libraries
  - The best (?) example of OOP's strengths
- Work with a huge API – and learn how (not) to deal with all of it
- Many core design patterns show up: callbacks, listeners, event-driven programs, decorators, façade

# What not to do...

---

- Don't try to learn the whole library: There's way too much
- Don't memorize – look things up as you need them
- Don't miss the main ideas, fundamental concepts
- Don't get bogged down implementing eye candy

# Main topics to learn

---

## Organization of the AWT/Swing library

- Names of essential widgets/components

## Graphics and drawing

- Repaint callbacks, layout managers, etc.

## Handling user events

## Building GUI applications

- MVC, user events, updates, ...

# A very short history (1)

---

Java's standard libraries have supported GUIs from 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 provides only 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

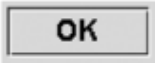




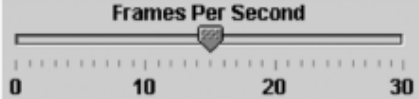

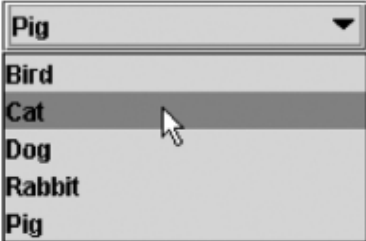
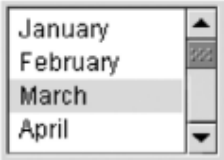
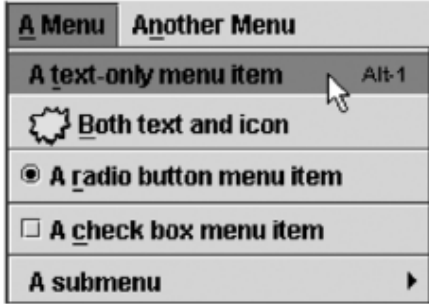
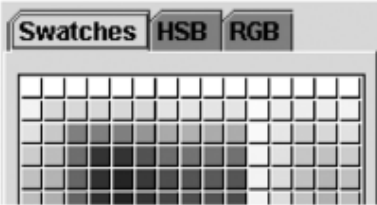





- Called *controls* in many other languages
- Examples: button, text box, label

*container*: A component that hosts (holds) components

- Examples: frame, applet, *panel*, box



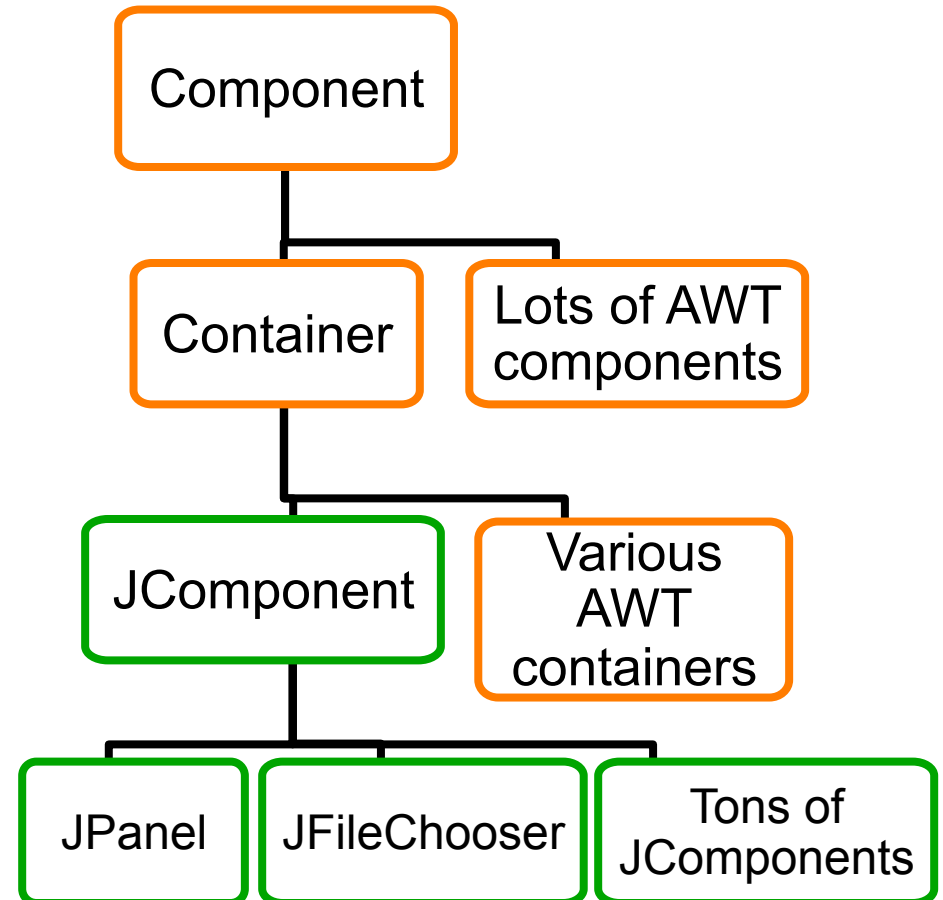
# Some components...

<p>JButton</p> 	<p>JCheckBox</p> 	<p>JRadioButton</p> 	<p>JLabel</p> 																		
<p>JTextField</p> 	<p>JSlider</p> 	<p>JToolBar</p> 																			
<p>JComboBox</p> 	<p>JList</p> 	<p>JMenuBar, JMenu, JMenuItem</p> 																			
<p>JColorChooser</p> 	<p>JFileChooser</p> 	<p>JTable</p> <table border="1" data-bbox="1110 1219 1541 1442"> <thead> <tr> <th>First Name</th> <th>Last Name</th> <th>Favorite F</th> </tr> </thead> <tbody> <tr> <td>Jeff</td> <td>Dinkins</td> <td></td> </tr> <tr> <td>Ewan</td> <td>Dinkins</td> <td></td> </tr> <tr> <td>Amy</td> <td>Fowler</td> <td></td> </tr> <tr> <td>Hania</td> <td>Gajewska</td> <td></td> </tr> <tr> <td>David</td> <td>Gearv</td> <td></td> </tr> </tbody> </table>	First Name	Last Name	Favorite F	Jeff	Dinkins		Ewan	Dinkins		Amy	Fowler		Hania	Gajewska		David	Gearv		<p>JTree</p> 
First Name	Last Name	Favorite F																			
Jeff	Dinkins																				
Ewan	Dinkins																				
Amy	Fowler																				
Hania	Gajewska																				
David	Gearv																				

# Component and container classes

---

- Every GUI-related class descends from **Component**, which contains dozens of basic methods and fields
  - Examples: **getBounds**, **isVisible**, **setForeground**, ...
- “Atomic” components: labels, text fields, buttons, check boxes, icons, menu items...
- Many components are **containers** – things like panels (**JPanel**) that can hold nested subcomponents



# Swing/AWT inheritance hierarchy

---

**Component** (AWT)

**Window**

**Frame**

**JFrame** (Swing)

**JDialog**

**Container**

**JComponent** (Swing)

**JButton**

**JComboBox**

**JMenuBar**

**JPopupMenu**

**JScrollPane**

**JSplitPane**

**JToolBar**

**JTextField**

**JColorChooser**

**JLabel**

**JOptionPane**

**JProgressBar**

**JSlider**

**JTabbedPane**

**JTree**

...

**JFileChooser**

**JList**

**JPanel**

**JScrollbar**

**JSpinner**

**JTable**

**JTextArea**

# Component properties

---

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

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

# Types of containers

---

- Top-level containers: **JFrame**, **JDialog**, ...
  - Often correspond to OS windows
  - Usually 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 **JComponents** 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 do on window close
    - `JFrame.EXIT_ON_CLOSE` terminates application
  - `setSize (int width, int height)`: set size
  - `add (Component c)`: add component to window
  - `setVisible (boolean b)`: 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 superclasses

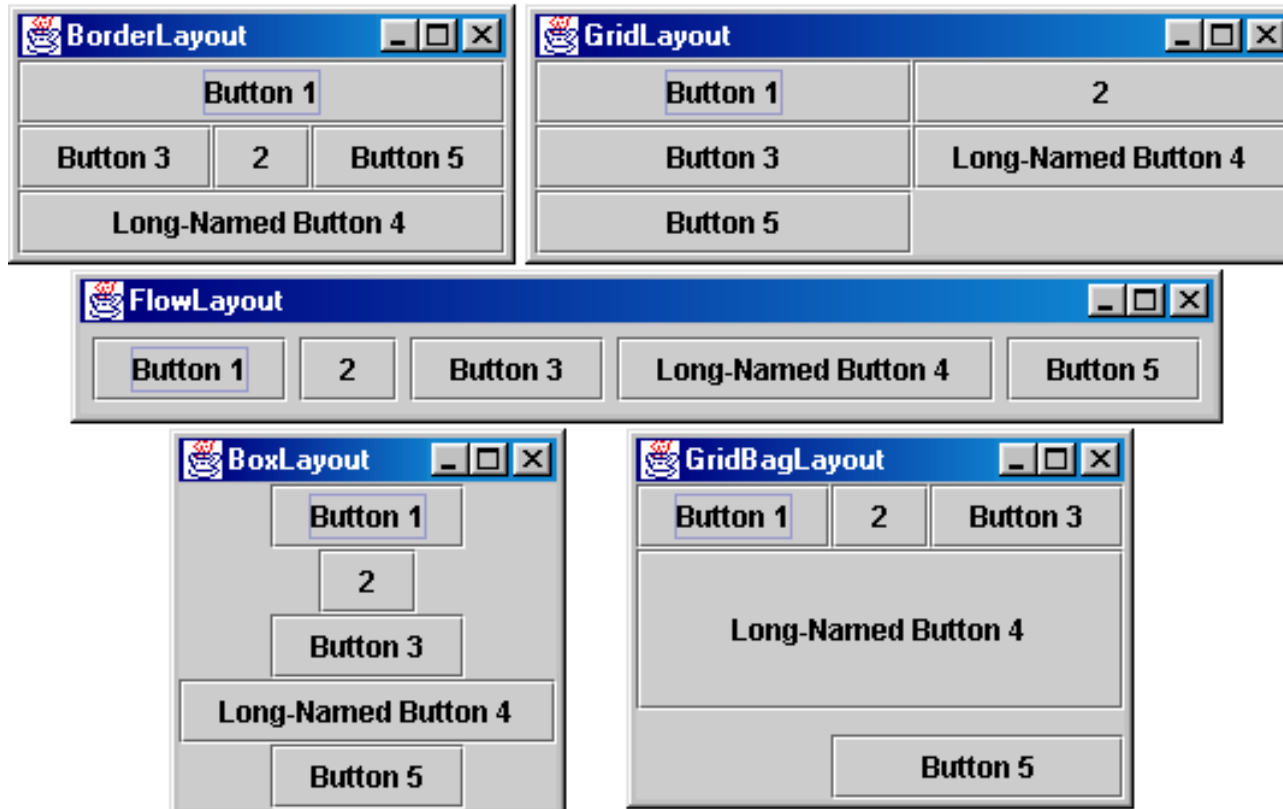
A particularly useful method:

- `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 manger*



# Layout managers

---

Kinds:

- **FlowLayout** (left to right [changeable], top to bottom)
  - Default for **JPanel**
  - Each row centered horizontally [changeable]
- **BorderLayout** (“center”, “north”, “south”, “east”, “west”)
  - Default for **JFrame**
  - No more than one component in each of 5 regions
  - (Of course, component can itself be a container)
- **GridLayout** (regular 2-D grid)
- Others... (some are incredibly complex)

**FlowLayout** and **BorderLayout** should be good enough for now...

# pack ()

---

Once all the components are added to their containers, do this to make the window visible:

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

**pack ()** figures out the sizes of all components and calls the container's 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

Note: As we'll see, *we override* `paintComponent` but we don't call it

# Example

---

`SimplePaintMain.java`

# Graphics methods

---

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

Can also draw images (pictures, etc.):

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

- Use AWT's "Toolkit" to load an image:

```
Image pic =  
    Toolkit.getDefaultToolkit()  
        .getImage(file-name (with path)) ;
```

– Then in `paintComponent`:

```
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` (extends `Graphics` )

- Added an 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`

- Can always cast this parameter from `Graphics` to `Graphics2D`
- `Graphics2D` supports both sets of graphics methods
- Use whichever you like for CSE 331

# So who calls `paintComponent`?

## And when??

---

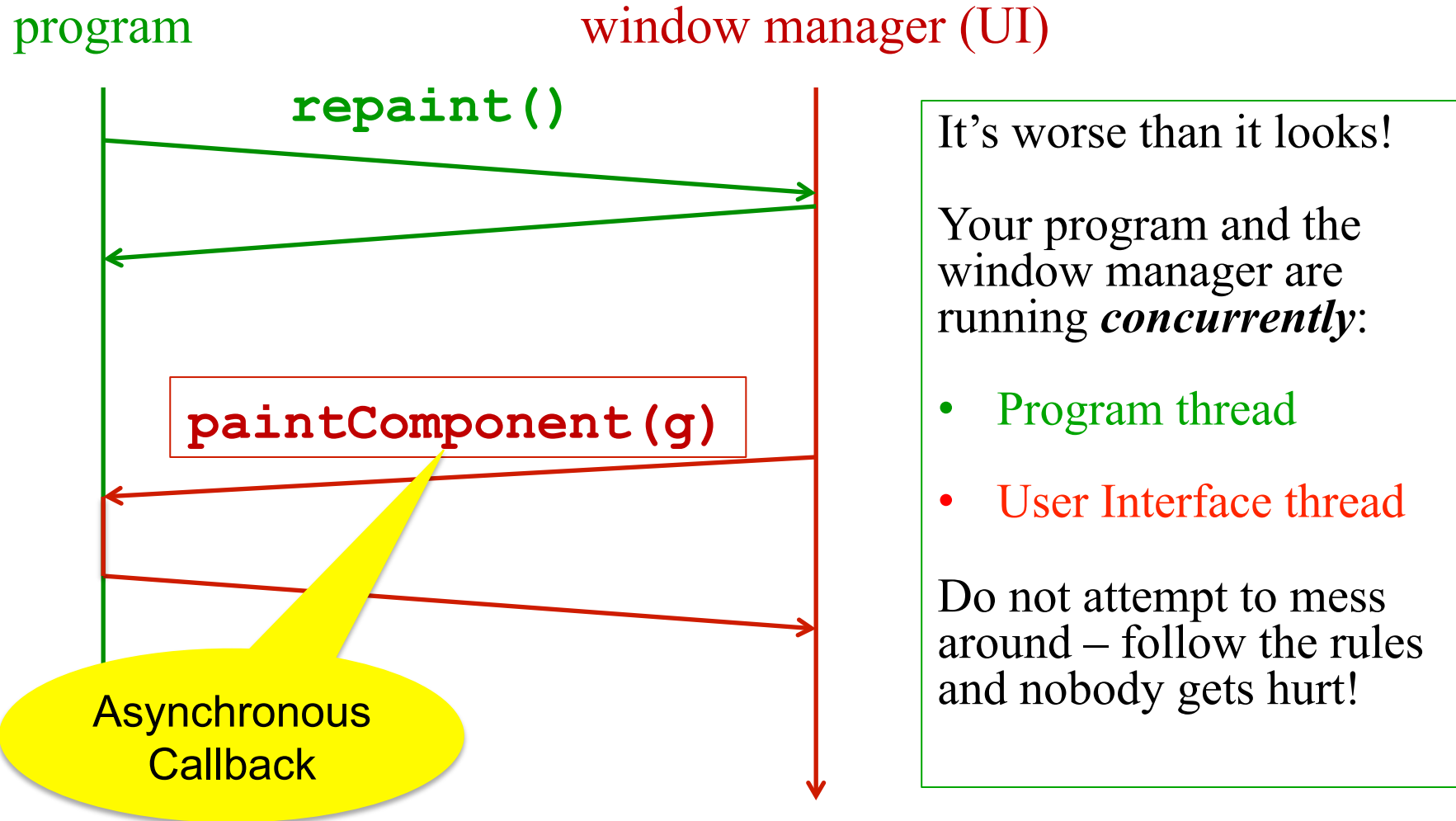
- Answer: the window manager calls `paintComponent` *whenever it wants!!!* (a callback!)
  - When the window is first made visible, and whenever after that some or all of it needs to be *repainted*
- Corollary: `paintComponent` must **always** be ready to repaint regardless of what else is going on
  - 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 call `paintComponent()` only once

# Example

---

**FaceMain.java**

# How repainting happens



# *Crucial* rules for painting

---

- Always override `paintComponent(g)` if you want to draw on a component
- Always call `super.paintComponent(g)` first
- **NEVER, EVER, EVER** call `paintComponent` yourself
- 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 that requires deeper understanding of the GUI library's structure and specification

# What's next – and not

---

Major topic for next lecture is how to handle user interactions

- We already know the core idea: it's a big-time use 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)