CSE 331
Software Design and Implementation

Lecture 18
Java Graphics and GUIs

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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

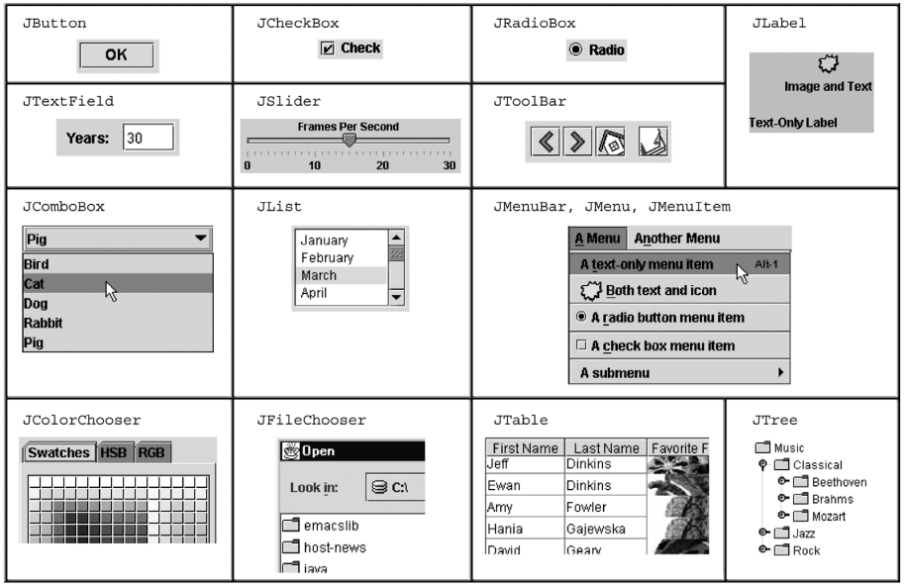
GUI terminology

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

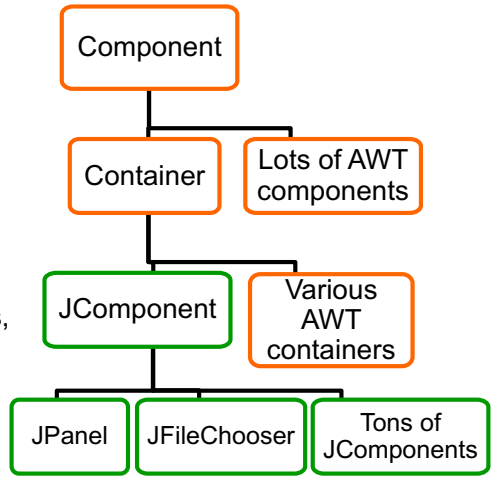
container: A component that hosts (holds) components
- Examples: frame, applet, *panel*, box

Some components…



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	`Color`	background color behind component
border	`Border`	border line around component
enabled	`boolean`	whether it can be interacted with
focusable	`boolean`	whether key text can be typed on it
font	`Font`	font used for text in component
foreground	`Color`	foreground color of component
height, width	`int`	component's current size in pixels
visible	`boolean`	whether component can be seen
tooltip text	`String`	text shown when hovering mouse
size, minimum / maximum / preferred size	`Dimension`	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 **`JComponent`**s 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

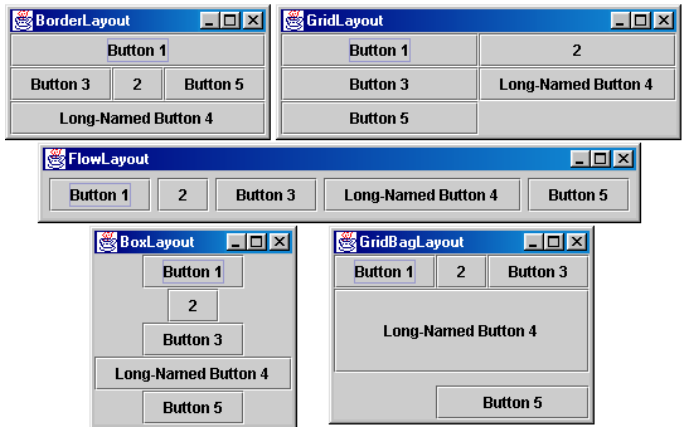
- Commonly used as a place for graphics, or to hold a collection of button, labels, etc.
- Needs to be added to a window or other container:
  `frame.add(new JPanel(…))`
- `JPanel`s can be nested to any depth
- Many methods/fields in common with `JFrame` (since both inherit from `Component`)
  - Advice: 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`**

- 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

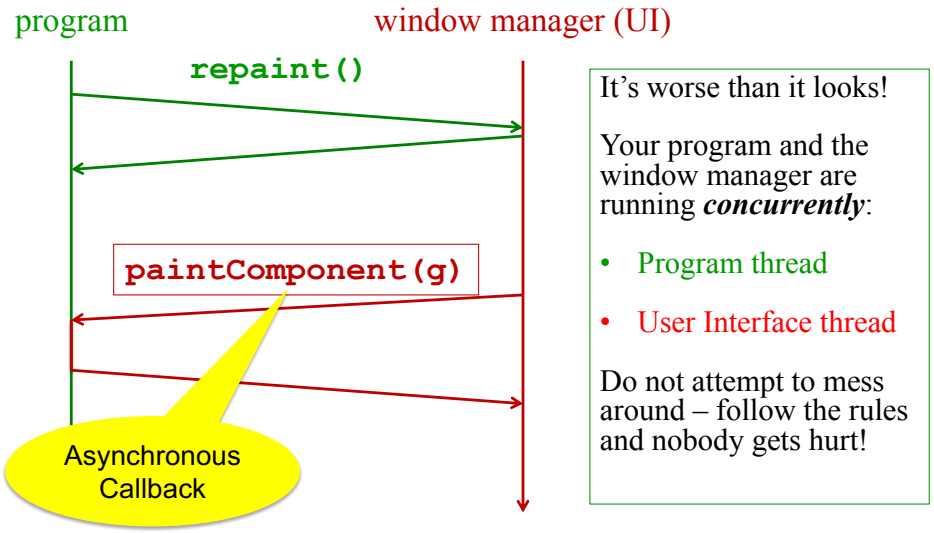
So who calls `paintComponent`? And when??

- 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



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!

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)