CS108, Stanford
Winter, 2002-03

Handout #12
Nick Parlante

# Drawing

## Q: How to get Java GUI on screen?

Q: How do you get some GUI components on screen?
A: Create a window (also known as a "frame") object. Install components -- labels, buttons, etc. -- in its content area. The system will manage the window and components, sending them notifications as user events happen (drawing, clicking, typing). The various components will draw themselves and handle events as they wish.

# OOP GUI Systems

## OOP Drawing vs 106 Drawing

In the simple old 106 days, you just start drawing when you want, and the pixels show up somewhere.
Most OOP drawing systems work differently.
We will have objects that correspond to what's on screen. These objects are sent a "draw yourself" message when they should draw.
So to get something on screen, we create an object that knows how to draw itself, and install it on screen.

## 1. Library Class Hierarchy

There is a large, pre-built inheritance hierarchy of classes for common problems -- drawing, controls, windows, scrolling.... These classes are engineered to work together and share a broad set of working assumptions (i.e. to work with these classes, you will need to understand their design a little).

## 2. System: Event -> Notifications

There is a background "system" that manages the basic bookkeeping and orchestration of windows and events. AKA "the system"
"User events" -- clicking, typing, ... events that happen in real time.
The system manages a queue of user events as they happen (realtime), and sends them, one at a time, to the GUI objects as "notification" messages.

## Programming Tasks...

## 1. Instantiate Library Classes (easy)

Many tasks are as simple as constructing and installing system classes -- windows, buttons, labels, etc.
This is the pretty easy -- requires some reading of the library class docs

Pull a library object "off the shelf"

## 2. Subclass Library Classes (hard)

To introduce custom behavior, subclass off a library class and use overriding to insert your custom code

This is a trickier programming problem -- you need a deeper understanding of the superclass implementation in order to do the override "in harmony" with its design.

This relies on the "pop-down" feature of overriding, so that our little bit of code gets called at the right moment.

e.g. Subclass off JComponent and override the paintComponent() method to insert your own drawing code (but keep the JComponent notions of geometry, painting schedule, etc.)

e.g. Subclass off JButton so it beeps when clicked

# Java Swing GUI

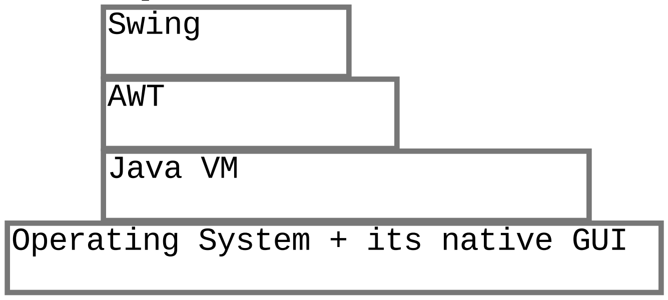
## AWT vs. Swing / JFC

AWT

- Abstract Windowing Toolkit
- Had some implementation problems
- AWT drawing uses "native peers" -- creating an AWT button creates a native peer (Unix, Mac, Win32) button to put on screen, and then tries to keep the AWT button and the peer in sync.
- Advantage: a java app has the "native" appearance for buttons etc.
- Disadvantage: very hard to implement in a reliable way -- keeping peers consistent on all platforms.

Swing

- Also known as JFC
- Implemented in Java -- the rt.jar file contains the java code for swing -- it is the **same** rt.jar running on all platforms.
- Built on the AWT primitives, but done right
- 10x more classes, depth, and functionality than AWT
- Has pluggable look-and-feel feature where buttons, etc can look like the ones for that platform.



## AWT vs. Swing classes

Some old AWT classes are still used, but mostly we will use the modern Swing versions.
e.g. AWT Component is the superclass of JComponent

## Theme: Things Draw Themselves

We will have objects that draw themselves -- labels, buttons, etc.
The system sends components "draw yourself" notifications as needed

## Theme: Layout Manager

A "layout manager" will arrange the size and position of the things on screen.
For now, we'll ignore the layout manager

## JComponent

The Swing superclass of things that draw on screen.
Defines the basic notions of geometry and drawing -- details below

## JLabel

Built in JComponent that displays a little text string
new JLabel("Hello there");

## JFrame

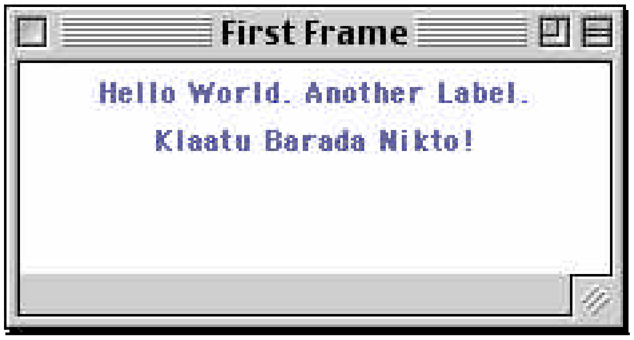
A single window
Has a "content pane" JComponent that contains all components in the frame
Send frame.getContentPane() to get the content pane
By default, closing a frame just hides it. See the code below so that closing a frame actually quits the application

## Content Pane / Layout Manager

Use the add() message to add components to the content pane.
Content pane uses a "Layout Manager" to size and position its components

## First Frame Example

A simple subclass of JFrame that puts 3 labels in its content pane.
(shown here with the Mac OS9 look -- the same Java code can take on the platform look of where it runs)



Hello World. Another Label.
Klaatu Barada Nikto!

## FirstFrame Code

```
// FirstFrame.java
/*
 Demonstrates bringing up a frame with some labels.
*/
import java.awt.*;
import javax.swing.*;
import java.util.*;
import java.awt.event.*;

public class FirstFrame extends JFrame {
   public FirstFrame(String title) {
      super(title);  // superclass ctor takes frame title

      // Get content pane -- contents of the window
      JComponent content = (JComponent) getContentPane();

      // Set to use the "flow" layout
      // (controls the arrangement of the components in the content)
      content.setLayout(new FlowLayout());

      // Background color is a property of all components --
      // set it to white
      content.setBackground(Color.white);

      // Use add() to install components
      content.add(new JLabel("Hello World."));
      content.add(new JLabel("Another Label."));
      content.add(new JLabel("Klaatu Barada Nikto!"));
      content.add(new JButton("Ok"));

      // Force the frame to size/layout its components
      pack();
      setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE); // Java 1.3 or later
      setVisible(true);   // make it show up on screen
   }

   public static void main(String[] args) {
      new FirstFrame("First Frame");
   }
}
```

# JComponent

## JComponent Basics

Drawable
- The superclass of all drawable, on screen things
- Has a size and position on screen -- a "bounds" rectangle
- Draws itself, within its bounds

227 public methods
- Go read through the method documentation page for JComponent once to get a sense of what's there

Class Hierarchy
- JComponent has two superclasses that are AWT classes:
  (AWT) Component -- (AWT ) Container -- JComponent
- There are few times the AWT classes, intrude, but mostly we'll try to conceptually collapse everything down to JComponent.

## Component Location / Size

Size, Location, Bounds
- Each JComponent has its own co-ord system with the origin (0,0) in its upper left corner
- The "bounds" of the component is the rectangle with its upper left corner at (0,0) and extending out to component.getWidth() and component.getHeight(), with x growing to the right and y growing down

Local Co-ord System
- The co-ord system of the component is not changed as the component moves around.
- The component draws and does most other operations relative to its own local coordinate system with (0, 0) at the upper left

Parent container
- The "parent" is the container that a component is in. The parent is itself a component.
- The "location" of a component is the position of its upper-left corner in the co-ord system of the parent

PreferredSize
- The layout manager determines the component size and location. Use setPreferredSize() to indicate your wishes to the layout manager. You can also set min and max sizes that the layout manager will try to respect.

Layout Manager
- Looks at the preferred size of everything, the size of the window, etc. and arranges (size+loc) of everything as best it can.

Typically you do not send setSize(), send setPreferredSize() before the Layout Manager arranges things.
- It is rarely the case that the size of component is set by client code that calls setSize().

Send getWidth, getHeight(), getSize(), getLocation(), getBounds()
- Send these messages to determine the size and location of the component (essentially, its bounds rectangle): (0,0) out to getWidth() getHeight().

You do not get to dictate your geometry -- the LayoutManager does that

## Geometry Methods

(Mostly inherited from Component)

Constructor

Initially, constructs a component is size 0 that has no parent

int getWidth(), getHeight()

Return the size of the component

Dimension getSize([Dimension]);

Like above, but get width / height in a Dimension object (a little slower)

int getX(), getY()

Get the location of the upper left of our co-ord system within our container (in the co-ord system of the container)

Location getLocation([Point])

As above, but in a Location object

get / set PreferredSize(Dimension)

Get or set the preferred size, which the layout manager uses whey sizing and arranging components. The "Dimension" object encapsulates a width and height. See also: setMinimumSize() and setMaximumSize()

Rectangle getBounds([Rectangle])

Returns the current bounds in a Rectangle object

boolean contains(x,y), boolean contains(Point)

Test if the component bounds include the given point

setBounds(Rectangle -or- x,y,w,h)

You probably do not want to call this -- the layout manager is responsible for establishing the bounds

Likewise, do not call setSize()

getParent()

Get a pointer to the parent component

# Drawing

## OOP GUI Drawing Theory

Subclass off JComponent

Override paintComponent() -- draw within the bounds of the component

Install your components in a window -- they draw themselves

## paintComponent(Graphics g)

Notification sent to a JComponent when it should draw itself

Override to provide custom drawing code

Call getWidth() etc. to see the current geometry -- see how big you are

(0,0) is your upper-left corner -- draw yourself within your bounds

Do not need to erase first -- the drawing canvas is already erased to a default before paintComponent() runs

Can call super.paintComponent() for more complex transparent / opaque cases later. In those cases, we will subclass of JPanel instead of the simpler JComponent.

## Simple paintComponent Example

```
public void paintComponent(Graphics g) {
   // super.paintComponent(g);   // not necessary for simple cases

   int width = getWidth();
   int height = getHeight();

   // draw a rect around the bounds of the component
   g.drawRect(0, 0, width-1, height-1);   // -1 since drawRect overhangs by one

   // draw a line from upper-left, to lower-right
   g.drawLine(0, 0, width-1, height-1);
}
```

## See How Big You Are

Send self getWidth(), etc. to see how big you are -- draw to fill that size.

## "Respond To" Draw Style

You don't demand to draw, you respond -- drawing when the system says to draw, dealing with however many pixels the system says you have.

In contrast to the "immediate" draw style you might be used to from C, where you just start drawing on your own schedule.

Passive drawing works better in a windowing system in which **when** to draw is complex.

## No Erase Needed

Don't have to erase first -- the Graphics is already erased for us. We just draw ourselves on the pre-erased Graphics.

Later, we'll see how to control our background, subclassing off JPanel.

## Graphics Object

A drawing context object passed to you -- send it drawing commands to do drawing.

With AWT, Graphics is a simple int-based 2d system.

There is also a more sophisticated Java2D floating point (PDF like) drawing system, but we won't worry about that.

(0,0)

- In the upper left hand corner
- X extends to the right
- Y extends down

g.drawRect(x, y, width, height)

- Draws the frame of a rectangle with its upper left at (x,y)
- Extends past the given width and height by 1 on the right and bottom , so you frequently subtract 1 when calling this. I think they were trying to appease some mathematical elegance with this design, but it fact it was just stupid.

g.fillRect(x, y, width, height)

Uses the current color to fill a colored rect of the given size. Does not overhang the size by one.

drawLine(x1, y1, x2, y2) -- draws a one pixel wide line between the points

drawString(String, x, y)

Draws the string, with the lower left of the text line at x,y. Use the Font class to draw with different font sizing etc.

g.setColor(Color)

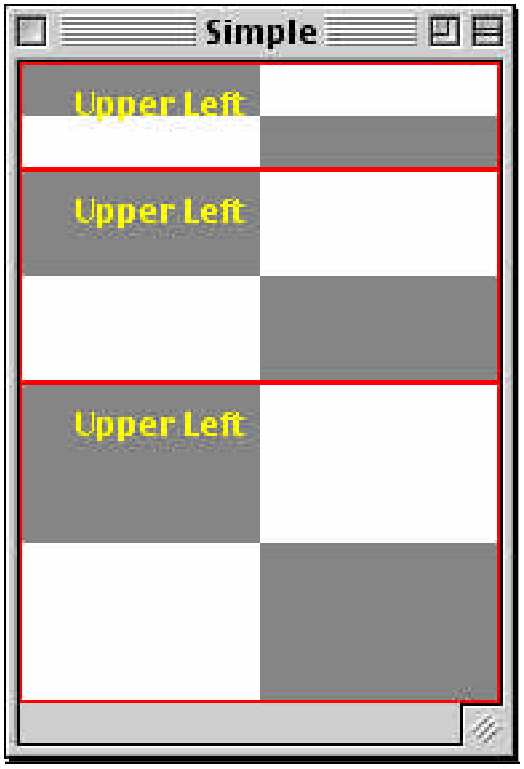
Sets the color for subsequence drawing.

There are constants in the Color class such as Color.black, Color.green, etc.

Component.getGraphics()

You probably never want to call this. Use the Graphics passed in to paintComponent()

## MyComponent Example



```
// MyComponent.java
import java.awt.*;
import javax.swing.*;
import java.util.*;
import java.awt.event.*;

/*
 Demonstrates a component that draws itself
*/
class MyComponent extends JComponent {
   MyComponent(int width, int height) {
      super(); // reminder that we have a super ctor

      // Set the preferred size -- used by the layout mgr
      setPreferredSize(new Dimension(width, height));
```

```
}

/**
 Fills a gray rect in the upper left and lower right quarters.
 Draws a string and a red frame at the bounds.

 Typical paint component:
 -see how big you are
 -draw within your bounds
 -don't need to erase first -- canvas already erased
*/
public void paintComponent(Graphics g) {
   //super.paintComponent(g); // not necessary for simple cases

   // Could use this to get a sense of when drawing happens
   // Toolkit.getDefaultToolkit().beep();

   // see how big we are
   int width = getWidth();
   int height = getHeight();

   // compute midpoint
   int midX = width/2;
   int midY = height/2;

   // draw two filled gray rects
   g.setColor(Color.gray);
   g.fillRect(0, 0, midX, midY);
   g.fillRect(midX, midY, width-midX, height-midY);

   // add a string at (20, 20) -- relative to our own origin
   g.setColor(Color.yellow);
   g.drawString("Upper Left", 20, 20);

   // draw a red rect frame at our bounds
   g.setColor(Color.red);
   g.drawRect(0, 0, width-1, height-1);      // -1 for drawRect
}



/*
 Creates a frame with a few MyComponents in it.
*/
public static void main(String[] args) {
   FirstFrame.main(null);
   JFrame frame = new JFrame("Simple");

   /*
    Note: earlier examples subclassed off JFrame,
    and set things up in its ctor. In this case,
    we are just a client of JFrame, and send it
    messages like getContentPane() and pack().
    Both of these approaches are reasonable.
   */

   // Get the content area of the frame
   JComponent content = (JComponent) frame.getContentPane();
```

```
        content.setBackground(Color.white);

        // The Box layout makes a vertical arrangement.
        // Its components grow and shrink with the window
        content.setLayout(new BoxLayout(content, BoxLayout.Y_AXIS));

        // add a few components
        content.add(new MyComponent(180, 40));
        content.add(new MyComponent(140, 80));
        content.add(new MyComponent(120, 120));

        // Layout manager packs things to fit into the minimum window
        frame.pack();

        // frame.setSize(300, 200); // alternative to pack()

        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.setVisible(true);

    }
}
```

# Layout Managers

## Layout Manager Theory

Like HTML -- policy, not exact pixels
1. Don't set explicit (pixel) sizes or positions of things
2. The layout managers knows the "intent" (policy) of the layout
    e.g. vertical list
3. The layout manager applies the intent to figure the correct size on the fly
Pro: the GUI can work, even though different platforms have fonts with slightly different metrics
Pro: window re-sizing works (the layout manager policy guides how it fits components in to the new window size)
Pro: internationalization -- layouts can adjust as the widths required for labels and buttons change for different languages
Con: new paradigm, can be unwieldy when you just want to say where things are.
Future: the new SpringLayout is supposed to work better for complex layouts

## Flow Layout

Arranges components left-right, top-down like text.

## Box Layout

Aligns components in a line -- either vertically or horizontally
Can install a box layout into an existing JComponent
    comp.setLayout(new BoxLayout(comp, BoxLayout.Y_AXIS));
Or, can create a "Box" component. There are convenience methods Box.createVerticalBox() and Box.createHorizontalBox() that return a Box

component. However, Box is not a JComponent, so the setLayout() technique on a JComponent above is preferable.
Use Box.createVerticalStrut(pixels) to create a little spacer component that be added to the box between components.

## Border Layout

Main content in the center
- e.g. the spreadsheet cells
- Window size changes mostly go to the center

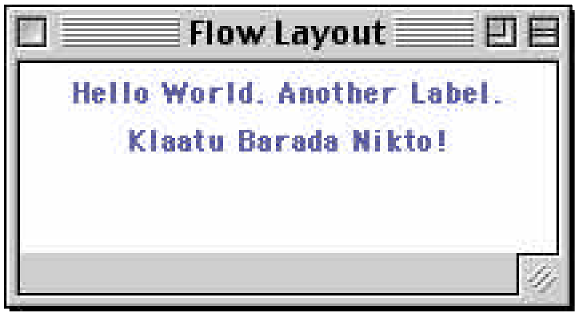
Decorate with 4 things around the outsize -- north, south, east, west
- e.g. the controls around the spreadsheet cells

2nd parameter to add() controls where things go
```
    border.add(comp, BorderLayout.CENTER);   // add comp to center
```

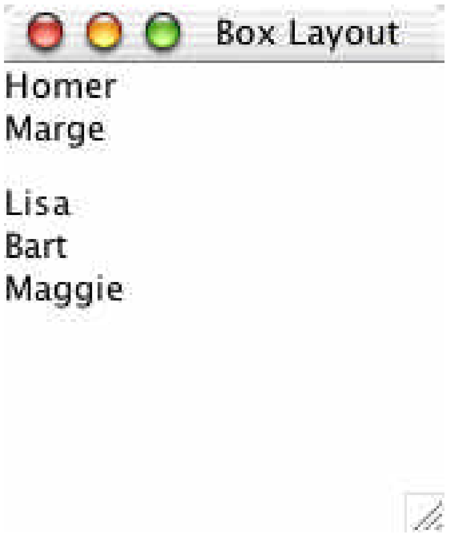
## Nested JPanel

JPanel is a simple component that you can put other components in
Use to group other components -- put them both in a JPanel, and put the JPanel where you want
If you want to control the size taken up by a group of elements, put them in a JPanel and setPreferredSize on the panel
e.g. group a label with a control
e.g. set the layout of the panel to vertical box, put lots of buttons in it, put the panel in the EAST of a border layout

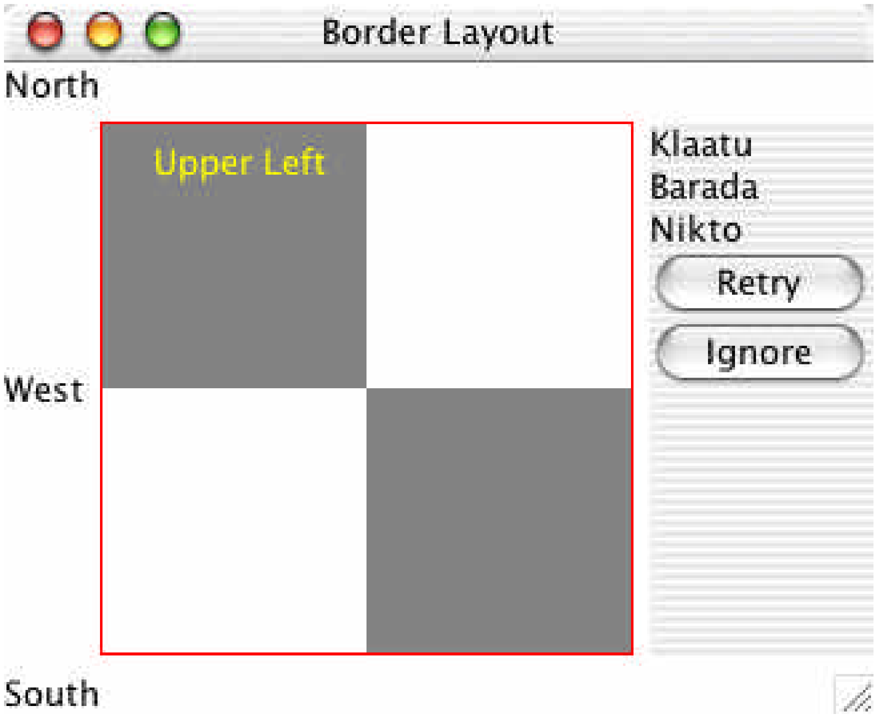
## Layout Example



(OS9 look)



(OSX look)



```
// Layouts.java
/*
 Demonstrates some basic layouts.
*/
import java.awt.*;
import javax.swing.*;
import java.util.*;
import java.awt.event.*;

public class Layouts {

   public static void main(String[] args) {
      // ----
      // 1. Flow Layout
      // Flow layout arranges Left-right top-bottom, like text
      JFrame frame1 = new JFrame("Flow Layout");
      JComponent content = (JComponent) frame1.getContentPane();
      content.setLayout(new FlowLayout());

      // Background color is a property of all components --
      // here I it to white, so it looks better in the handouts
      content.setBackground(Color.white);

      // Use add() to install components
      content.add(new JLabel("Hello World."));
      content.add(new JLabel("Another Label."));
      content.add(new JLabel("Klaatu Barada Nikto!"));

      // Force the frame to size/layout its components
      frame1.pack();
      frame1.setVisible(true);


      // ----
      // 2. Box Layout
      JFrame frame2 = new JFrame("Box Layout");
      JComponent content2 = (JComponent)frame2.getContentPane();
      content2.setBackground(Color.white);

      // The Box layout make a vertical arrangement
      content2.setLayout(new BoxLayout(content2, BoxLayout.Y_AXIS));

      /*
         // Could do it this way instead.
         Box box = Box.createVerticalBox();
         frame2.setContentPane(box);
         // However, the setLayout() method above is preferred
         // because Box is not a JComponent (as of Java 1.2)

      */


      // add a few components
      content2.add(new JLabel("Homer"));
      content2.add(new JLabel("Marge"));

      // add a little spacer
      content2.add(Box.createVerticalStrut(12));

      content2.add(new JLabel("Lisa"));
      content2.add(new JLabel("Bart"));
      content2.add(new JLabel("Maggie"));

      frame2.pack();
      frame2.setVisible(true);


      // ----
      // 3. Border Layout + nested box panel
      JFrame frame3 = new JFrame("Border Layout");
      JComponent content3 = (JComponent)frame3.getContentPane();
      content3.setBackground(Color.white);
```

```
        // Border layout
        // (the 6's are for inter-component spacing)
        content3.setLayout(new BorderLayout(6, 6));

        // Add labels around the edge
        content3.add(new JLabel("North"), BorderLayout.NORTH);
        content3.add(new JLabel("West"), BorderLayout.WEST);
        content3.add(new JLabel("South"), BorderLayout.SOUTH);

        // Add a MyComponent in the center
        content3.add(new MyComponent(200, 200), BorderLayout.CENTER);

        // Create a little panel (box layout)
        // with some labels. Nest it into the EAST
        // (we'll use this strategy to arrange buttons
        // around our main content)
        JPanel panel = new JPanel();
        panel.setLayout(new BoxLayout(panel, BoxLayout.Y_AXIS));
        panel.add(new JLabel("Klaatu"));
        panel.add(new JLabel("Barada"));
        panel.add(new JLabel("Nikto"));
        panel.add(new JButton("Retry"));
        panel.add(new JButton("Ignore"));

        content3.add(panel, BorderLayout.EAST);

        frame3.pack();
        frame3.setVisible(true);
    }
}
```