CS193J: Programming in Java
Summer Quarter 2003

Lecture 7
Repaint, Mouse, Advanced Drawing, Object Serialization

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Handouts

- 2 Handouts for today!
  - #17: Advanced Drawing
  - #18: Object Serialization

Recap

- Last Time
  - – HW#1 Feedback
  - – HW#2 Live Demo
    - Link between lecture materials and homework
  - – Inner Classes
  - – Anonymous Inner Classes
  - – Listener model
    - Button Listener Example
  - – Repaint
    - Left off before Repaint example

Lecture-Homework mapping revisited

- HW #2 will use
  - OOP concepts
    - Inheritance, overriding, polymorphism
    - Abstract classes
  - Drawing in Java
    - Layouts
    - paintComponent()
  - Event handling
    - Anonymous Inner classes
  - Repaint (continues Today)
  - Mouse Tracking (Today)
  - Advanced Drawing (Today)
  - Object Serialization (Today/Thursday)

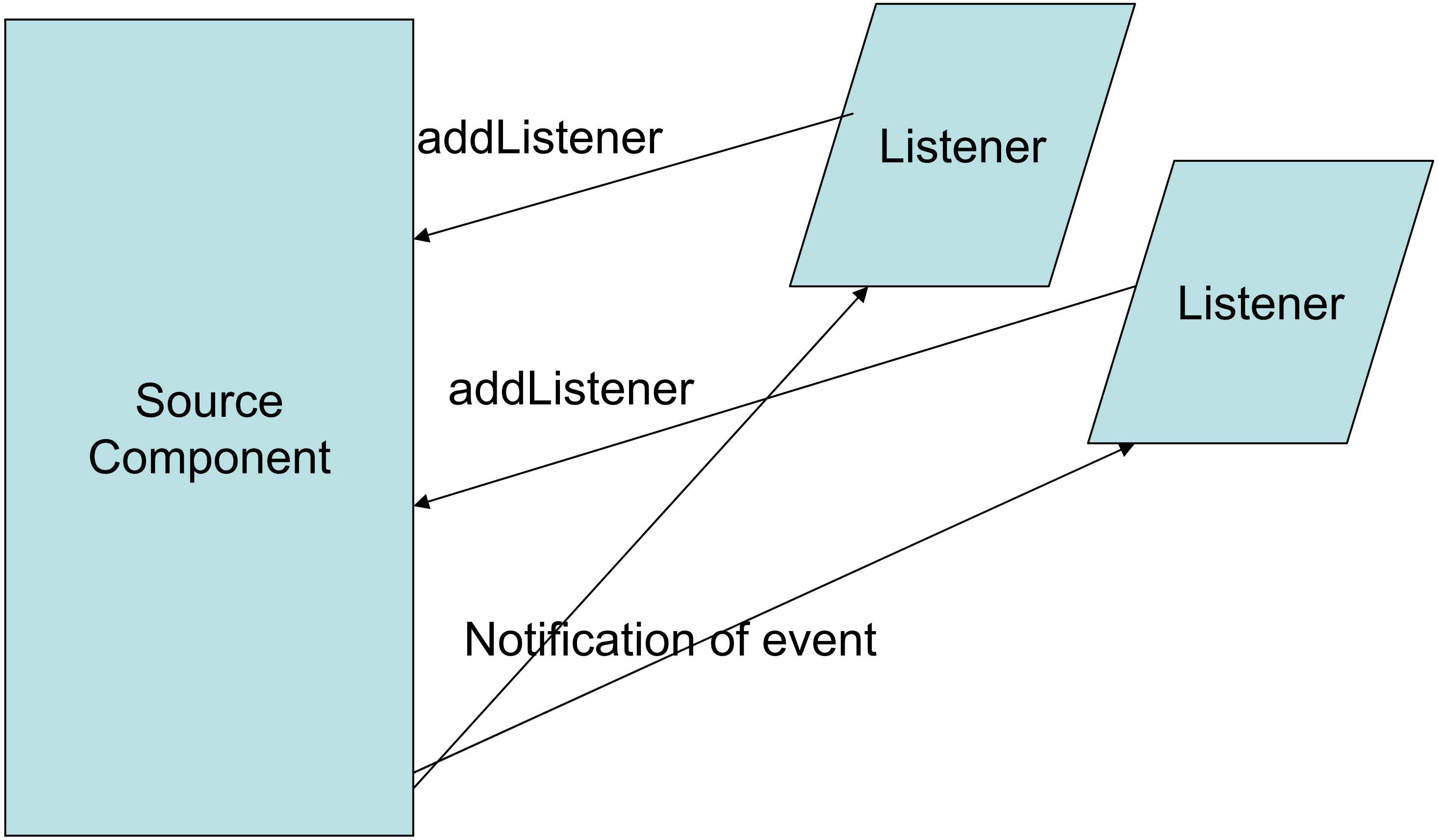
Today

- Continue with Repaint
  - – Repaint example code walkthrough
  - – Erasing
- Mouse Tracking
  - – DotPanel example code walkthrough
- Advanced Drawing
  - – Region based drawing, Blinking, Smart Repaint
- Object Serialization
  - – Cloning
    - Not Dolly, but Java Objects ☺
  - – Serializing

Review

- Control-Listener Theory
  - Source
    - Buttons, controls etc.
  - Listener
    - An Object that wants to know when the control is operated
  - Notification Message
    - A message sent from the source to the listener as a notification that the event has occurred
- Essentially: registering callbacks

Source-Listener Interaction



Using a Button and a Listener #3

- Anonymous Inner class
  - Most common method!
  - Create an Anonymous Inner Class that implements the interface
    - Can be created on the fly inside the method!

```
button = new JButton("Beep");
panel.add(button);
button.addActionListener(
    new ActionListener() {
        public void actionPerformed(ActionEvent e) {
            Toolkit.getDefaultToolkit().beep();
        }
    }
);
```

Button Listener Example

```
public ListenerFrame() {
        super("ListenerFrame");

        JComponent content = (JComponent) getContentPane();
        content.setLayout(new FlowLayout());

        JButton button = new JButton("Beep!");
        content.add(button);

        // ----
        // Creating an action listener in 2 steps...

        // 1. Create an inner class subclass of ActionListener
        ActionListener listener =
                new ActionListener() {
                        public void actionPerformed(ActionEvent e) {
                                Toolkit.getDefaultToolkit().beep();
                        }
                };
```

Button Listener Example

```
// 2. Add the listener to the button
button.addActionListener(listener);

// ----
// Creating a listener in 1 step...

// Create a little panel to hold a button
// and a label
JPanel panel = new JPanel();
content.add(panel);
JButton button2 = new JButton("Yay!");
label = new JLabel("Woo Hoo");
panel.add(button2);
panel.add(label);
```

Button Listener Example

```
// This listener adds a "!" to the label.
        button2.addActionListener(
                new ActionListener() {
                        public void actionPerformed(ActionEvent e) {
                                String text = label.getText();
                                label.setText(text + "!");
                                // note: we have access to "label" of
outer class
                                // we do not have access to local vars
like 'panel',
                                // unless they are declared final.
                        }
                }
        );

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

Repaint (Handout #15)

- Repaint is **asynchronous**
  - It does not do the drawing immediately
    - It “requests” the system to call paintComponent()
  - Behind the scenes
    - The System maintains an event queue
    - repaint() simply adds a request on the event queue
    - The system draw thread will dequeue the draw request and ultimately call paintComponent()
- Do not call paintComponent()!
  - Call repaint() and the system will schedule a call to paintComponent()

Setter Repaint Pattern

- Setters
  - Change the object state
- Whenever object state is changed
  - Call repaint() to keep the pixels in sync

Face Repaint Example

- Default state:
  - Smiley face
  - ivar: boolean angry = false
- paintComponent()
  - Looks at value of angry ivar to change color accordingly
  - Draws the smiley

```
// smiley -- draws in red if angry
public void paintComponent(Graphics g) {

        if (angry) g.setColor(Color.red);
        else g.setColor(Color.blue);
        // draw smiley
}
```

Face Repaint Example

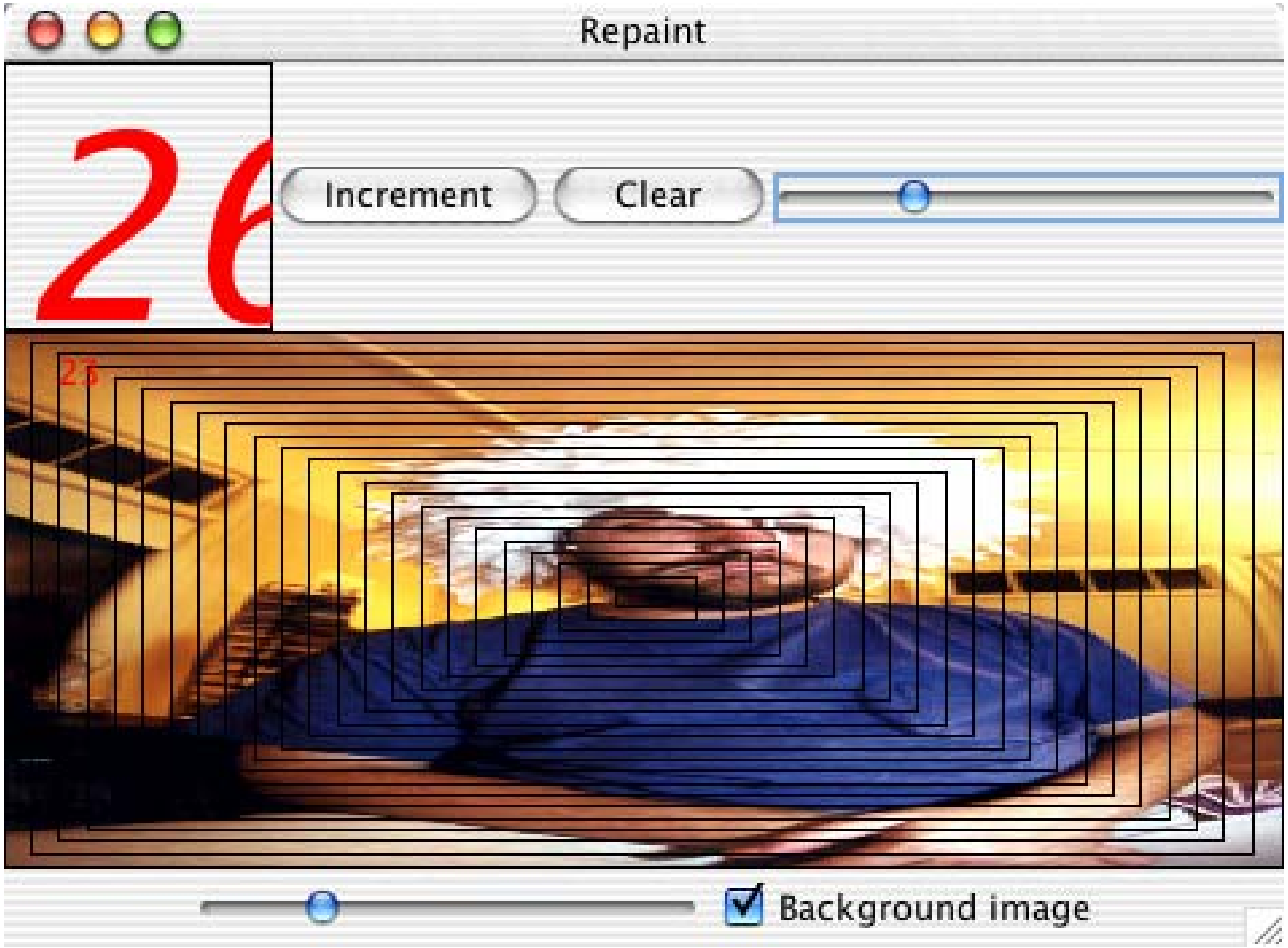
- Setter Repaint Pattern in the example
  - setAngry() should call repaint

```
public void setAngry(boolean angry) {
        this.angry = angry;
        repaint();
  }
```

- Could be intelligent and call repaint only when needed

```
public void setAngry(boolean angry) {
        if (this.angry != angry) {
                this.angry = angry;
                repaint();
        }
  }
```

Repaint Example



Repaint Example Code

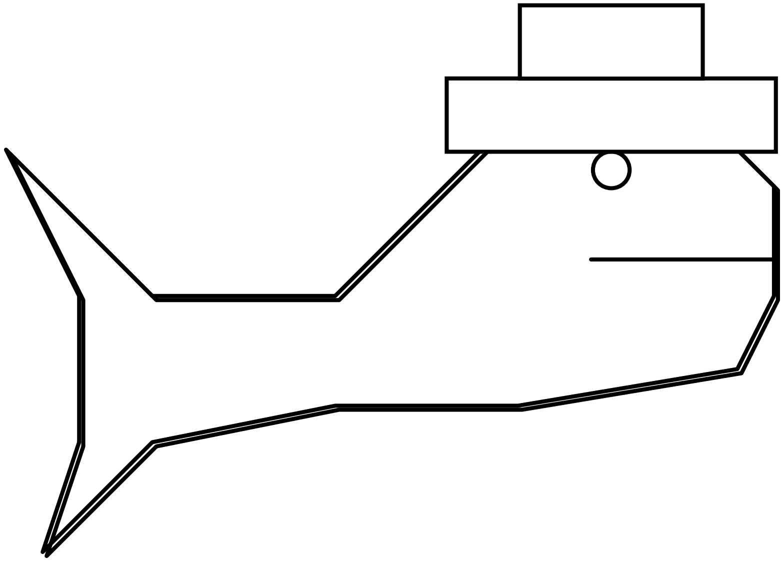
- Code walk through….
  - Widget.java
  - Boxer.java
  - Repaint.java
    - Layout
    - Event handling with listeners

Erasing

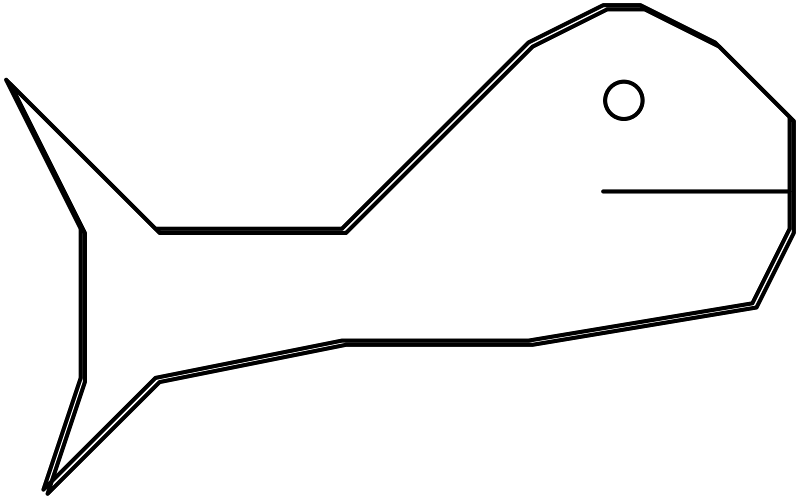
- We do not actively erase in java
  - To erase something, simply don't draw it in paintComponent
- paintComponent starts out with a erased canvas
  - Draws components back to front
    - *What you draw later is drawn on top*
- Again
  - To erase something, just don't draw it

Fish Example

- Fish with a hat



- Fish without a hat



The Fish class…

```
void paintComponent() {
   // draw fish body
   if (hasHat) // draw the hat
}
void setHat(boolean hat) {
   hasHat = hat;
   repaint();
}
```

- Scenario: fish.hasHat is true. Send fish.setHat(false) -- the hat disappears

Boxer example

- Boxer draws the image when image ivar is not null
  - To erase the image – set the image ivar to null and repaint

Smart Repaint

- Painting the screen can be time consuming
  - One approach is to paint only those region which need to be painted
  - System already does this for most events (expose, resize, scroll etc)
- But
  - The programmer can also be intelligent and tell the system which regions need painting
  - Done with repaint(Rectangle r)
    - Repaint just old+new rectangles when a component moves
    - We will see more of this soon…

MouseTracking (Handout #16)

- MouseListener and MouseMotionListener
  - To get notification about mouse event over a component
  - The component itself is the source of the notification
    - Add the listener to the component

Listener vs. Adapter Style

- Problem
  - Listener has a bunch of abstract methods
    - 5 in MouseListener
  - We typically care only about implementing one or two
- Solution
  - “Adapter” classes have empty { } definitions of all methods
  - Only need to implement the ones we care about
    - The adapter catches the others
- Gotcha
  - If you write your method prototype wrong you won’t override the empty { } implementation in the adapter!
    - Example MousePressed() instead of mousePressed()

MouseListener Interface

```
public interface MouseListener extends EventListener {
    /**
     * Invoked when the mouse has been clicked on a component.
       (press+release)
     */
    public void mouseClicked(MouseEvent e);
    /**
     * Invoked when a mouse button has been pressed on a component.
     */
    public void mousePressed(MouseEvent e);
    /**
     * Invoked when a mouse button has been released on a component.
     */
    public void mouseReleased(MouseEvent e);
    /**
     * Invoked when the mouse enters a component.
     */
    public void mouseEntered(MouseEvent e);
    /**
     * Invoked when the mouse exits a component.
     */
    public void mouseExited(MouseEvent e);
}
```

MouseAdapter Class

```
public abstract class MouseAdapter implements MouseListener {
    /**
     * Invoked when the mouse has been clicked on a component.
     */
    public void mouseClicked(MouseEvent e) {}
    /**
     * Invoked when a mouse button has been pressed on a component.
     */
    public void mousePressed(MouseEvent e) {}
    /**
     * Invoked when a mouse button has been released on a component.
     */
    public void mouseReleased(MouseEvent e) {}
    /**
     * Invoked when the mouse enters a component.
     */
    public void mouseEntered(MouseEvent e) {}
    /**
     * Invoked when the mouse exits a component.
     */
    public void mouseExited(MouseEvent e) {}
}
```

Press: MouseListener

- How does a component handle a mouse press?

```
component.addMouseListener(new MouseAdapter() {
        public void mousePressed(MouseEvent e) {
          // called when mouse button first pressed on component
        }
        });
```

Motion: MouseMotionListener

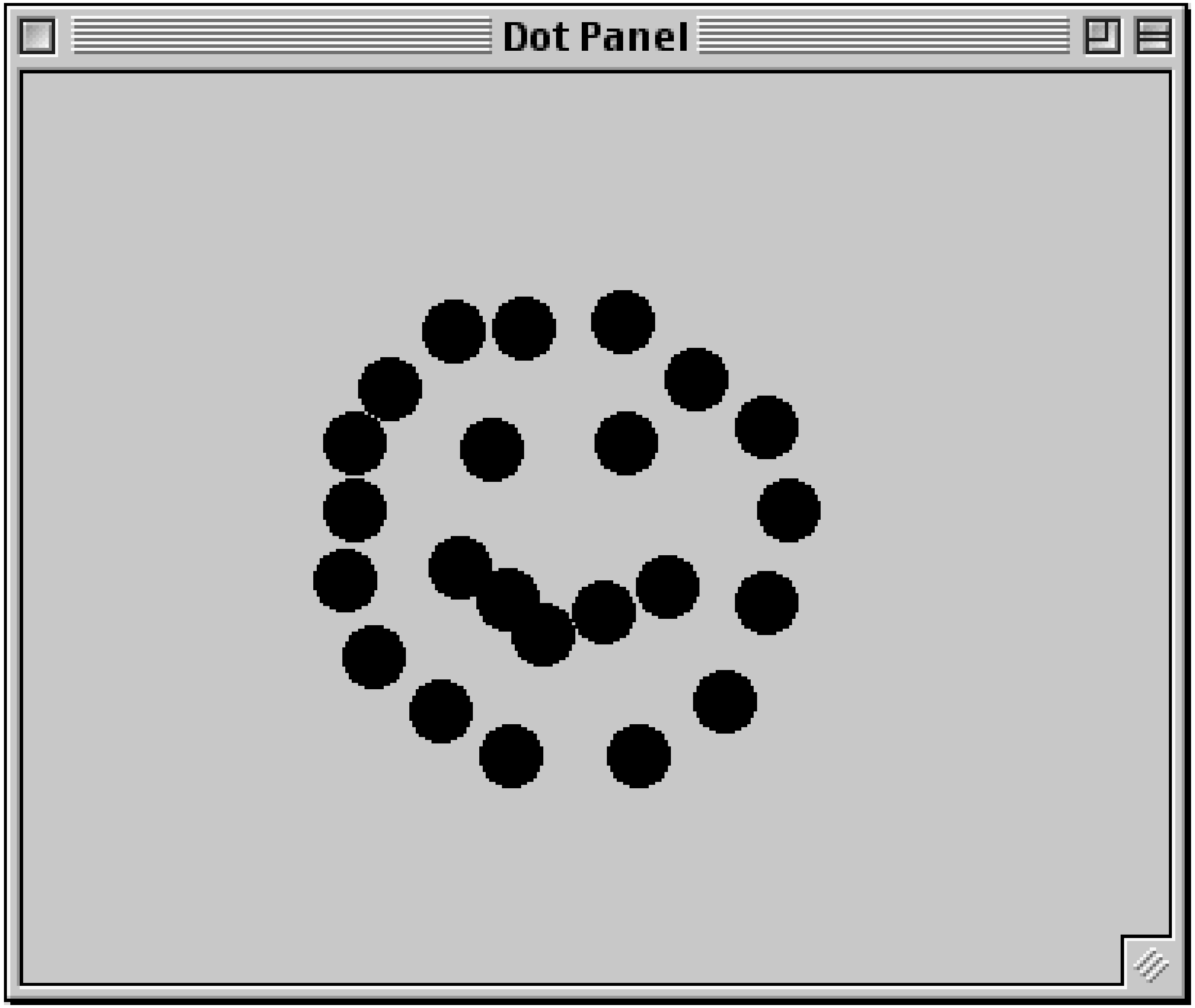
- How does a component detect a mouse movement?

```
component.addMouseMotionListener(new MouseMotionAdapter() {
        public void mouseDragged(MouseEvent e) {
           // called as mouse is dragged, after initial click
        }
        });
```

Delta rule for mouse motion

- Cannot use absolute coordinates for mouse movement!
  - Setting the position to the actual mouse coordinated may result is weird movements
- Correct approach
  - Get the current coordinates
  - Compare to the last known coordinates
    - Compute the delta
  - Apply the delta to the position of the object
- Test-case
  - A click-release with no motion should not change any state in a correct implementation of relative mouse tracking

DotPanel Example



DotPanel Example Code

- Code walkthrough…
  - – DotPanel.java

Advanced Drawing (Handout #17)

- JPanel
  - Simple component that drawls itself
  - Subclass of JComponent
  - Use setBackground to get an automatic background color
  - Use setOpaque(true) in order to tell the system that we are drawing every pixel
    - Optimization since then the system doesn’t draw what is behind us
  - Call super.paintComponent() from paintComponent()
    - Graphics will be erased to background color

Clipping Region

- The 2D region within which the system will accept changes to what is shown on the screen
  - Any pixel changes outside the clipping region are ignored.
- System sets a “clipping region” on the Graphics object before sending paintComponent()
  - Affects all drawing operations
    - Pixels outside clipping region do not get affected
  - By default is set to the bounds of the component
    - Basic drawing case works fine – nothing special needed
    - Room to optimize for better performance

component.getGraphics() -- NO

- component.getGraphics()
  - Almost never right to use component.getGraphics()
  - There may be special cases, but in general, this goes against the system/paintComponent paradigm

Repaint Details

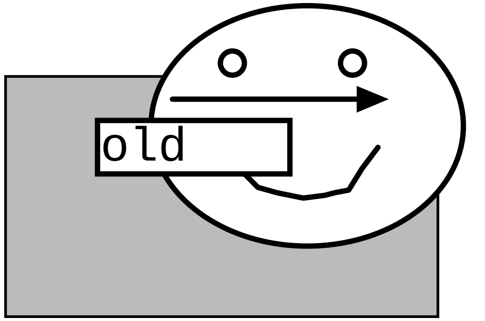
- Repaint call tells system what region to redraw
  - repaint() uses bounds
  - repaint(<Rectangle>) uses a sub-rectangle
- System maintains “update region”
  - A 2D representation of areas that need to be redrawn
  - Repaint call adds a region to the update region
- System paint thread
  - Checks regions to be updated
  - Computes intersection of region vs. components
  - Initiated draw recursion down the component netsting hierarchy
  - Composites pixels back to front

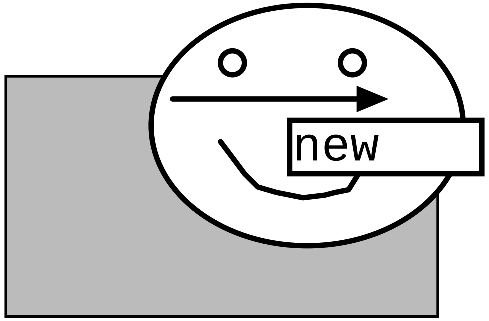
Region Based Drawing

- The drawing area is always expressed as a region not in components
  - Handles intersections and z-order correctly
- Z-order
  - Visual layering of components
- Mechanics
  - Draw all the components that intersect the pixel region
  - Draw the components from back to front

Moving components

- When a component moves
  - Update the old region
    - Redraw any exposed components or erase moved component
  - Update the new region
    - Redraw the component at it's new location





Smart Repaint revisited

- Repaint just the rectangle of the component that needs to be redrawn
  - Not the entire component or window bounds
- Makes the drawing cycle faster
  - Smoother drawing, esp if clipping region is small
- repaint(x, y, width, height) does this
- Must repaint both old and new regions
  - Union of old and new clipping rectangles

Coalescing

- Intelligently combining multiple repaint() requests into a single draw operation
  - – Benefit of asynchronous repaint() calls
- No 1-1 correspondence between repaint() and paintComponent() calls
  - – Multiple repaints can be coalesced by the system and handles by a single paintComponent() call
- Time: Multiple repaint requests are “coalesced” into one draw operation
  - – You can repaint() 3 times, but it just draws once
- Space: Repaint regions may overlap, but the ares of intersection is drawn once
  - – System is maintaining the update region

Coalescing Example

- JSlider in Repaint example
  - As the slide moves it sends multiple setCount() messages to the Widget
    - If we move it quickly it would result in lots of calls
  - However, it doesn’t redraw every state
    - The previous states would all be overwritten by the last state anyway
  - Draws the last state by coalescing the repaint() calls and calling paintComponent less (possibly just once) times

Blinking Animation

- Animation Steps
  - Draw old state on the screen
  - Erase the old state and restore the background
  - Draw the new state on the screen
- Problem
  - Erasing the old state and restoring the background results in a blinking effect! ☹
  - If the redraw is fast, it looks like a “shimmer”
    - Still undesirable

Solution: Double Buffering

- Concept:
  - – Do all the erasing and drawing in memory before copying the final changes to the screen
- Mechanics
  - – Build a pixel buffer offscreen (called offscreen graphics)
  - – Draw the old appearance
  - – Erase offscreen buffer
  - – Draw the new appearance to the offscreen buffer
  - – Copy final bits (aka “blit”) to the onscreen graphics
- Result
  - – Smooth animation since we minimize the changes on the onscreen graphics

Swing is double buffered!

- Swing double buffers automatically
  - All JComponent drawing goes through a offscreen buffer
  - Graphics object passed to paintComponent is pointer to an offscreen buffer
- Makes life easier for us as the programmer!

Smart Repaint Implementation

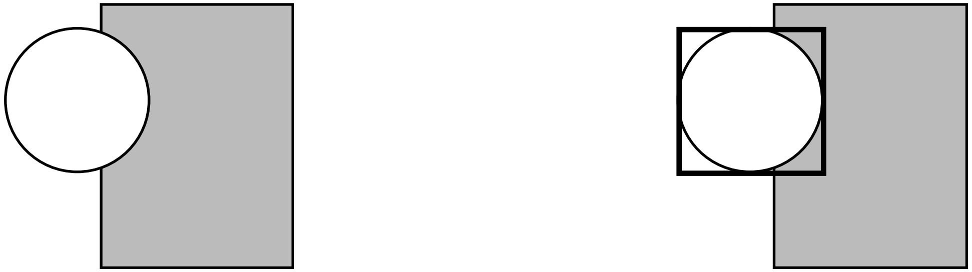
- Start with the region to draw, but make it smaller
- Find intersection of components
- Allocate an offscreen bitmap
  - Exactly the size of the small update region
- Setup the origin and the clip of Graphics g to point to the small offscreen buffer
  - Drawing outside the buffer is clipped, but components do not need to do anything special
- Copy the small buffer to the screen when done
  - Smaller the region, faster the copy

Smart Repaint Conclusion

- Using repaint(rect) to redraw just a region of the component can be a lot pfaster
  - Client components don't need to know what is going on, they just respond to paintComponent()
- Calling repaint(x, y, width, height)
  - System is smart about using an offscreen buffer of the size needed
    - Great potential speedup
- Theme: with little work, JComponent can do some complex drawing

Example #1

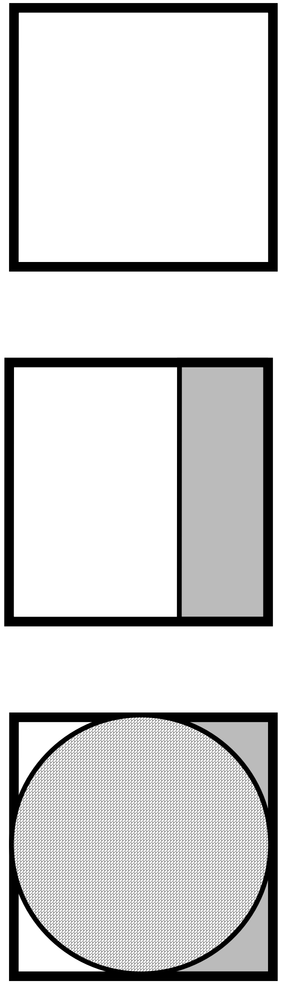
- Circle and rectangle
  - Changing the circle to be filled with a pattern



  - State change → Repaint → Update Region
    - Change the state of the circle to pattern = true
    - Repaint just around the circle
    - Add the square to the update region

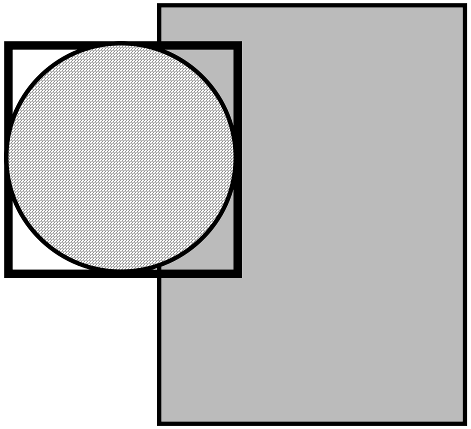
Example #1 continued

- Offscreen drawing
  - – Draw thread notices update region
  - – Creates offscreen buffer of same size
    - Notice how fewer pixels need to be reased
  - – Clipping is set around the buffer
    - Pixels outside clipping region have no effect
  - – Drawthread sends paintComponent() to the components to draw themselves back to front
    - Only the parts that intersect the update region actually draw



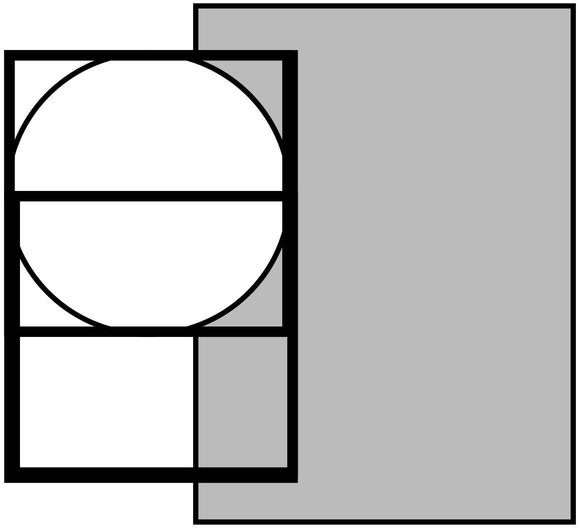
Example #1 continued

- Copy bits
  - Once all the drawing is done draw thread copies the buffer back to the screen with a fast copy ("blit") operation
  - Deletes the offscreen buffer



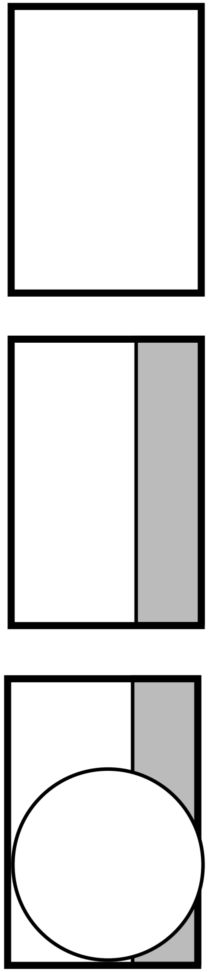
Example #2: moving

- Move circle down
- Repaint
  - Old rectangle
  - New rectangle



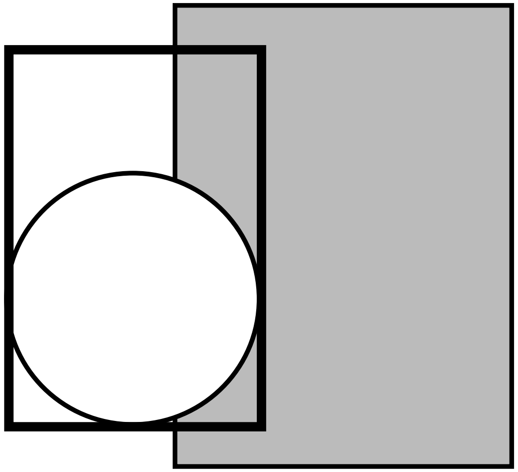
Example #2: Moving continued

- Offscreen graphics
  - – Same as before!



Example #2: Moving continued

- Copy bits to screen
  - Delete offscreen buffer



Objects and Serialization (Handout #18)

- Equals revisited
  - a == b tests for pointer equality only
    - i.e. pointer a and b point to the same location/object
    - This is called “shallow semantics”
  - boolean Object.equals(Object other)
    - Defined in the Object class
      - Default implementation does a == b test (shallow semantics)
    - May override to do “deep comparison”
      - Example: String.equals()

Calling equals()

```
{
    String a = “hello”;
    String b = “hello”;

    (a == b) → false
    (a.equals(b)) → true
    (b.equals(a)) → true
}
```

Equals strategy

- boolean equals(Object other)
  - – Take Object, return boolean
    - Must have exact prototype for overriding to work
  - – Return true on (this == other)
  - – Use (other instanceof Foo) too test class of other
    - False if not same class
  - – Otherwise do a field-by-field comparison of this and other

Student equals() example

```
// in Student class...
boolean equals(Object obj) {
   if (obj == this) return(true);
   if (!(obj instanceof Student)) return(false);
   Student other = (Student)obj;
   return(other.units == units)
}
```

Cloning

- Used to create a copy of an object
  - – Not just another pointer to the same object
  - – Cloned object has it’s own memory space
- Lets say Foo b = a.clone();
    - a == b will return false
    - a.equals(b) will return true!
- Copied object has same state
  - – But its own memory
- We use this in HW#2 for cut-copy-paste!

Cloneable interface

- Used as a merker to indicate that the class implements the clone() method
  - Not compiler enforced
  - Object.clone() is pre-built
    - Create a new instance of the right class
    - Assign all fields over with '=' semantics
- Object.clone() will do above default behavior
  - If class implements the cloneable interface
  - Otherwise, it will through an exception

Implementing clone()

- Implement the Cloneable interface
  - Call the super classes clone method first to copy structure
    - copy = (Class) super.clone()
  - Copy fields where a simple ‘=‘ is not deep enough
    - Example, arrays, arraylists, objects

Alternative approaches

- Copy Constructor
  - MyClass(MyClass myObject)
    - Construct a new instance of MyClass based on the state of MyObject
- "Factory" method
  - Static method that makes new instances
    - static MyClass newInstance(MyClass myObject)
    - May use constructor internally
- Advantage
  - Simpler than Object.clone(), no new concepts
- Disadvantage
  - Client must know the class of the Object

Eq Code example

```
// Eq.java

/*
 Demonstrates a simple class that defines equals and clone.
*/
public class Eq implements Cloneable {
    private int a;
    private int[] values;

    public Eq(int init) {
        a = init;
        values = new int[10];
    }
```

Eq Code example: equals

```
/*
 Does a "deep" compare of this vs. the other object.
*/
public boolean equals(Object other) {
        if (other == this) return(true);
        if (!(other instanceof Eq)) return(false);

        Eq e = (Eq) other;

        // now test if this vs. e
        if (a != e.a) return(false);

        if (values.length != e.values.length) return(false);
        for (int i=0; i<values.length; i++) {
                if (values[i] != e.values[i]) return(false);
        }
        return(true);
}
```

Eq Code example: clone()

```
/*
 Returns a deep copy of the object.
*/
public Object clone() {
    try {
        // first, this creats the new memory and does '=' on all fields
        Eq copy = (Eq)super.clone();

        // copy the array over -- arrays respond to clone() themselves
        copy.values = (int[]) values.clone();
        return(copy);
    }
    catch (CloneNotSupportedException e) {
        return(null);
    }
}
```

Eq Code example

```
    public static void main(String[] args) {
        Eq x = new Eq(1);
        Eq y = new Eq(2);
        Eq z = (Eq) x.clone();

        System.out.println("x == z" + (x==z));       // false
        System.out.println("x.equals(z)" + (x.equals(z)));  // true

    }
}
```

Serialization

- Motivation
  - A lot of code involves boring conversion from a file to memory
    - Write code in 106A to translate by hand
    - HW#1 read ASCII file and required parsing
  - This is a common problem!
- Java’s answer:
  - Serialization
    - Object know how to write themselves out to disk and to read themselves back from disk into memory!
- We use this in HW#2 to load and save!

Serialization / Archiving

- Objects have state in memory
- Serialization is the process of conversting objects into a streamed state (Network, Disk)
  - No notion of an address space
  - No pointers
- Serialization is also called
  - Flattening, Streaming, Dehydrate (rehydrate = read), Archiving

How it works?

- To write out an object
  - ObjectOutputStream out;
  - out.writeObject(obj)
- To read that object back in
  - ObjectInputStream in;
  - obj = in.readObject();
- Must be of the same type
  - class and version

Java: Automatic Serialization

- Serializable Interface
  - By implementing this interface a class declares that is it willing to be read/written by automatic serialization machinery
- Automatic Writing
  - System knows how to recursively write out the state of an object
  - Recursively follows pointers and writes out those objects too!
  - Can handle most built in types
    - int, array, Point etc.
- "transient" keyword to mark a field that should not be serialized
  - Transient fields are returned as null on reading
- Override readObject() and writeObject() for customizations
- Versioning
  - Can detect version changes

Circularity: not an issue

- Serialization machinery will take circular references into account and do the right thing!

Dot example

- Build on DotPanel example!
- saveSerial(File f)
  - Given a file, write the data model to it with Java serialization.
  - Makes an Point[] array of points and writes it which avoids the bother of iteration.
    - We use an array instead of the ArrayList to avoid requiring a 1.2 VM to read the file, although maybe the ArrayList would have been fine
- loadSerial(File f)
  - Inverse of saveSerial.
  - Reads an Point[] array of Points, and adds them to our data model.

Dot example code

```
public void saveSerial(File file)  {
        try {
                ObjectOutputStream out = new ObjectOutputStream(
                        new FileOutputStream(file));

                // Use the standard collection -> array util
                // (the Point[0] tells it what type of array to return)
                Point[] points = (Point[]) dots.toArray(new Point[0]);

                out.writeObject(points);        //  serialization!

                out.close();            // polite to close on the way out
                setDirty(false);
        }
        catch (Exception e) {
                e.printStackTrace();
        }
   }
```

Dot example code

```
private void loadSerial(File file)  {
    try {
        ObjectInputStream in = new ObjectInputStream(new
    FileInputStream(file));

        // Read in the object -- the CT type should be exactly as it was written
        // -- Point[] in this case.
        // Transient fields would be null.
        Point[] points =  (Point[])in.readObject();
        for (int i=0; i<points.length; i++) {
                dots.add(points[i]);
        }

        in.close();             // polite to close on the way out
        setDirty(false);
    } catch (Exception e) {
        e.printStackTrace();
    }
}
```

HW#2 note

- CS193J classes for serialization
  - shield you from the exceptions, but otherwise behave like ObjectOutputStream and ObjectInputStream

```
SimpleObjectWriter w;
SimpleObjectWriter w =
    SimpleObjectWriter.openFileForWriting(filename);
w.writeObject( <object>) -- write an array or object (Point[] in above
    example)
w.close()

SimpleObjectReader r;
SimpleObjectReader r =
    SimpleObjectReader.openFileForReading(filename);
obj = r.readObject() -- returns the object written -- cast to what it is
    (Point [] in above example)
r.close()
```

Summary

- Today
  - Repaint
    - Repaint Example
    - Erasing
  - Mouse Tracking
    - DotPanel Example
  - Advanced Drawing
    - Region based drawing, blinking, smart repaint
  - Object Serialization
    - Cloning and Serializing
- Assigned Work Reminder
  - HW 2: Java Draw
    - Due before midnight on Wednesday, July 23rd, 2003
    - Start early!!