Interactive Graphics

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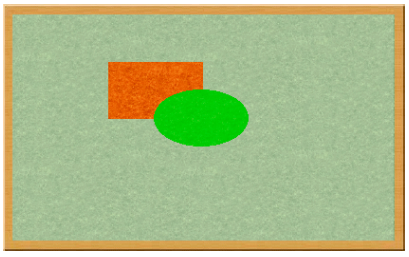
The `acm.graphics` Model

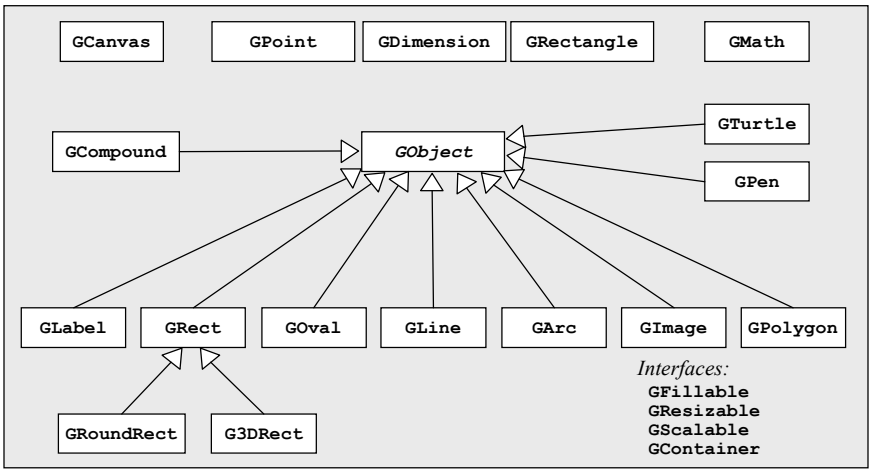
- The `acm.graphics` package uses a ***collage*** model in which you create an image by adding various objects to a canvas.
- A collage is similar to a child's felt board that serves as a backdrop for colored shapes that stick to the felt surface. As an example, the following diagram illustrates the process of adding a red rectangle and a green oval to a felt board:



- Note that newer objects can obscure those added earlier. This layering arrangement is called the ***stacking order***.

Structure of the `acm.graphics` Package

The following diagram shows the classes in the **`acm.graphics`** package and their relationship in the Java class hierarchy:



The `GCanvas` Class

- The **`GCanvas`** class is used to represent the background canvas for the collage model and therefore serves as a virtual felt board. When you use the **`acm.graphics`** package, you create pictures by adding various **`GObject`**s to a **`GCanvas`**.
- For simple applications, you won't actually need to work with an explicit **`GCanvas`** object. Whenever you run a program that extends **`GraphicsProgram`**, the initialization process for the program automatically creates a **`GCanvas`** and resizes it so that it fills the program window.
- Most of the methods defined for the **`GCanvas`** class are also available in a **`GraphicsProgram`**, thanks to an important strategy called ***forwarding***. If, for example, you call the **`add`** method in a **`GraphicsProgram`**, the program passes that message along to the underlying **`GCanvas`** object by calling its **`add`** method with the same arguments.

Methods in the `GCanvas` Class

The following methods are available in both the `GCanvas` and `GraphicsProgram` classes:

`add(`*object*`)`	Adds the object to the canvas at the front of the stack
`add(`*object*`, x, y)`	Moves the object to (*x*, *y*) and then adds it to the canvas
`remove(`*object*`)`	Removes the object from the canvas
`removeAll()`	Removes all objects from the canvas
`getElementAt(`*x*`, `*y*`)`	Returns the frontmost object at (*x*, *y*), or `null` if none
`getWidth()`	Returns the width in pixels of the entire canvas
`getHeight()`	Returns the height in pixels of the entire canvas
`setBackground(`*c*`)`	Sets the background color of the canvas to *c*.

The following methods are available in `GraphicsProgram` only:

`pause(`*milliseconds*`)`	Pauses the program for the specified time in milliseconds
`waitForClick()`	Suspends the program until the user clicks the mouse

The Two Forms of the `add` Method

- The `add` method comes in two forms. The first is simply

```
add(object);
```

  which adds the object at the location currently stored in its internal structure. You use this form when you have already set the coordinates of the object, which usually happens at the time you create it.

- The second form is

```
add(object, x, y);
```

  which first moves the object to the point (*x*, *y*) and then adds it there. This form is useful when you need to determine some property of the object before you know where to put it. If, for example, you want to center a `GLabel`, you must first create it and then use its size to determine its location.

Methods Common to All `GObject`s

`setLocation(`*x*`, `*y*`)`	Resets the location of the object to the specified point
`move(`*dx*`, `*dy*`)`	Moves the object *dx* and *dy* pixels from its current position
`movePolar(`*r*`, `*theta*`)`	Moves the object *r* pixel units in direction *theta*
`getX()`	Returns the *x* coordinate of the object
`getY()`	Returns the *y* coordinate of the object
`getWidth()`	Returns the horizontal width of the object in pixels
`getHeight()`	Returns the vertical height of the object in pixels
`contains(`*x*`, `*y*`)`	Returns `true` if the object contains the specified point
`setColor(`*c*`)`	Sets the color of the object to the `Color` *c*
`getColor()`	Returns the color currently assigned to the object
`setVisible(`*flag*`)`	Sets the visibility flag (`false`=invisible, `true`=visible)
`isVisible()`	Returns `true` if the object is visible
`sendToFront()`	Sends the object to the front of the stacking order
`sendToBack()`	Sends the object to the back of the stacking order
`sendForward()`	Sends the object forward one position in the stacking order
`sendBackward()`	Sends the object backward one position in the stacking order

Sharing Behavior through Interfaces

- In addition to the methods defined for all `GObject`s shown on the preceding slide, there are a few methods that apply to some `GObject` subclasses but not others. You already know, for example, that you can call `setFilled` on either a `GOval` or a `GRect`. At the same time, it doesn't make sense to call `setFilled` on a `GLine` because there is no interior to fill.
- In Java, the best strategy when you have methods that apply to some subclasses but not others is to define an ***interface*** that specifies the shared methods. An interface definition is similar to a class definition except that the interface omits the implementation of each method, retaining only the header line that shows the types of each argument.
- In the `acm.graphics` package, there are three interfaces that define methods for certain `GObject` subclasses: `GFillable`, `GResizable`, and `GScalable`. The methods in these interfaces appear on the next slide.

Methods Defined by Interfaces

GFillable (GArc, GOval, GPolygon, GRect)

setFilled(*flag***)**	Sets the fill state for the object (**false**=outlined, **true**=filled)
isFilled()	Returns the fill state for the object
setFillColor(*c***)**	Sets the color used to fill the interior of the object to *c*
getFillColor()	Returns the fill color

GResizable (GImage, GOval, GRect)

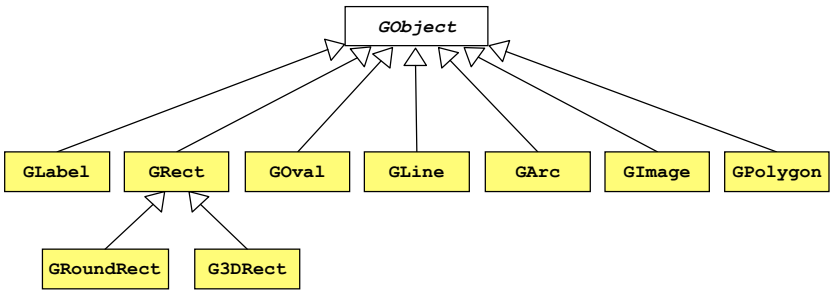
setSize(*width***,** *height***)**	Sets the dimensions of the object as specified
setBounds(*x***,** *y***,** *width***,** *height***)**	Sets the location and dimensions together

GScalable (GArc, GCompound, GLine, GImage, GOval, GPolygon, GRect)

scale(*sf***)**	Scales both dimensions of the object by *sf*
scale(*sx***,** *sy***)**	Scales the object by *sx* horizontally and *sy* vertically

Using the Shape Classes

- The shape classes are the **GObject** subclasses that appear in yellow at the bottom of the hierarchy diagram.



- Each of the shape classes corresponds precisely to a method in the **Graphics** class in the **java.awt** package. Once you have learned to use the shape classes, you will easily be able to transfer that knowledge to Java's standard graphics tools.

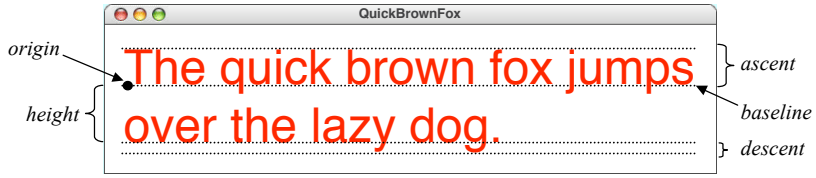
The `GLabel` Class

You've been using the `GLabel` class ever since Chapter 2 and already know how to change the font and color, as shown in the most recent version of the "Hello World" program:

```
public class HelloProgram extends GraphicsProgram {
   public void run() {
      GLabel label = new GLabel("hello, world", 100, 75);
      label.setFont("SansSerif-36");
      label.setColor(Color.RED);
      add(label);
   }
}
```

The Geometry of the `GLabel` Class

- The `GLabel` class relies on a set of geometrical concepts that are derived from classical typesetting:
  - The ***baseline*** is the imaginary line on which the characters rest.
  - The ***origin*** is the point on the baseline at which the label begins.
  - The ***height*** of the font is the distance between successive baselines.
  - The ***ascent*** is the distance characters rise above the baseline.
  - The ***descent*** is the distance characters drop below the baseline.
- You can use the `getHeight`, `getAscent`, and `getDescent` methods to determine the corresponding property of the font. You can use the `getWidth` method to determine the width of the entire label, which depends on both the font and the text.



The GRect Class

- The **GRect** class implements the **GFillable**, **GResizable**, and **GScalable** interfaces but does not otherwise extend the facilities of **GObject**.
- Like every other shape class, the **GRect** constructor comes in two forms. The first includes both the location and the size:

```
new GRect(x, y, width, height)
```

  This form makes sense when you know in advance where the rectangle belongs.

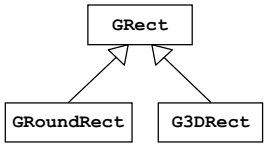
- The second constructor defers setting the location:

```
new GRect(width, height)
```

  This form is more convenient when you want to create a rectangle and then decide where to put it later.

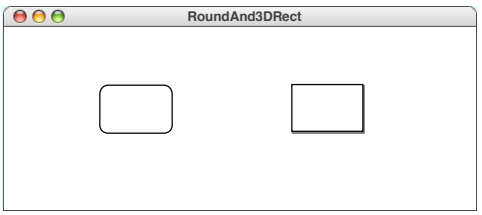
GRoundRect and G3DRect

- As the class hierarchy diagram indicates, the **GRect** class has two subclasses. In keeping with the rules of inheritance, any instance of **GRoundRect** or **G3DRect** is also a **GRect** and inherits its behavior.



- The sample run at the bottom of the screen shows what happens if you execute the following calls:

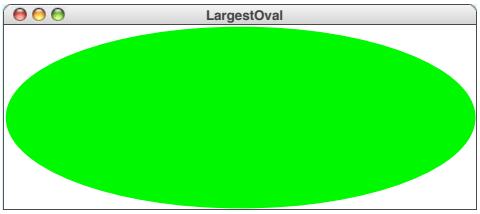
```
add(new GRoundRect(100, 60, 75, 50));
add(new G3DRect(300, 60, 75, 50));
```



The GOval Class

- The **GOval** class represents an elliptical shape defined by the boundaries of its enclosing rectangle.
- As an example, the following **run** method creates the largest oval that fits within the canvas:

```
public void run() {
   GOval oval = new GOval(getWidth(), getHeight());
   oval.setFilled(true);
   oval.setColor(Color.GREEN);
   add(oval, 0, 0);
}
```



The GLine Class

- The **GLine** class represents a line segment that connects two points. The constructor call looks like this:

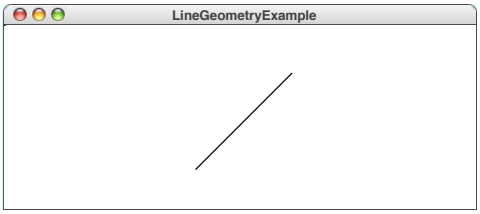
```
new GLine(x0, y0, x1, y1)
```

  The points (x_0, y_0) and (x_1, y_1) are called the ***start point*** and the ***end point***, respectively.
- The **GLine** class does not support filling or resizing but does implement the **GScalable** interface. When you scale a line, its start point remains fixed.
- Given a **GLine** object, you can get the coordinates of the two points by calling **getStartPoint** and **getEndPoint**. Both of these methods return a **GPoint** object.
- The **GLine** class also exports the methods **setStartPoint** and **setEndPoint**, which are illustrated on the next slide.

Setting Points in a `GLine`

The following **`run`** method illustrates the difference between the **`setLocation`** method (which moves both points together) and **`setStartPoint`**/**`setEndPoint`** (which move only one):

```
public void run() {
   GLine line = new GLine(0, 0, 100, 100);
   add(line);
   line.setLocation(200, 50);
   line.setStartPoint(200, 150);
   line.setEndPoint(300, 50);
}
```

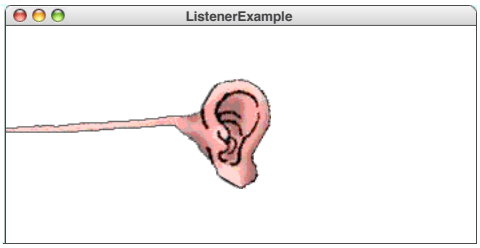


The Java Event Model

- Graphical applications usually make it possible for the user to control the action of a program by using an input device such as a mouse. Programs that support this kind of user control are called ***interactive programs***.
- User actions such as clicking the mouse are called ***events***. Programs that respond to events are said to be ***event-driven***.
- In modern interactive programs, user input doesn't occur at predictable times. A running program doesn't tell the user when to click the mouse. The user decides when to click the mouse, and the program responds. Because events are not controlled by the program, they are said to be ***asynchronous***.
- When you write a Java program, you indicate the events to which you wish to respond by designating some object as a ***listener*** for that event. When the event occurs, a message is sent to the listener, which triggers the appropriate response.

The Role of Event Listeners

- One way to visualize the role of a listener is to imagine that you have access to one of Fred and George Weasley's "Extendable Ears" from the Harry Potter series.
- Suppose that you wanted to use these magical listeners to detect events in the canvas shown at the bottom of the slide. All you need to do is send those ears into the room where, being magical, they can keep you informed on anything that goes on there, making it possible for you to respond.



Responding to Mouse Events

- On a more practical level, the process of making a program respond to mouse events requires the following steps:
  1. Define an **`init`** method that calls **`addMouseListeners`**.
  2. Write new definitions of any listener methods you need.
- The most common mouse events are shown in the following table, along with the name of the appropriate listener method:

`mouseClicked(`*e***`)`**	Called when the user clicks the mouse
`mousePressed(`*e***`)`**	Called when the mouse button is pressed
`mouseReleased(`*e***`)`**	Called when the mouse button is released
`mouseMoved(`*e***`)`**	Called when the user moves the mouse
`mouseDragged(`*e***`)`**	Called when the mouse is dragged with the button down

The parameter *e* is a **`MouseEvent`** object, which gives more data about the event, such as the location of the mouse.

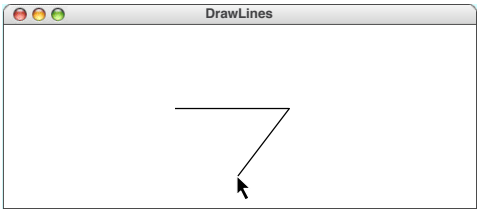
A Simple Line-Drawing Program

In all likelihood, you have at some point used an application that allows you to draw lines with the mouse. In Java, that program takes less than a page of code.

```
public class DrawLines extends GraphicsProgram {
/* Initializes the program by enabling the mouse listeners */
   public void init() {
      addMouseListeners();
   }
/* Called on mouse press to create a new line */
   public void mousePressed(MouseEvent e) {
      line = new GLine(e.getX(), e.getY(), e.getX(), e.getY());
      add(line);
   }
/* Called on mouse drag to extend the endpoint */
   public void mouseDragged(MouseEvent e) {
      line.setEndPoint(e.getX(), e.getY());
   }
/* Private instance variables */
   private GLine line;
}
```

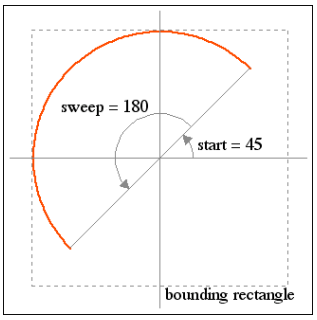
Simulating the **`DrawLines`** Program

– The **`addMouseListeners`** call in **`init`** enables mouse events.
– Depressing the mouse button generates a *mouse pressed* event.
– The **`mousePressed`** call adds a zero-length line to the canvas.
– Dragging the mouse generates a series of *mouse dragged* events.
– Each **`mouseDragged`** call extends the line to the new position.
– Releasing the mouse stops the dragging operation.
– Repeating these steps adds new lines to the canvas.



The `GArc` Class

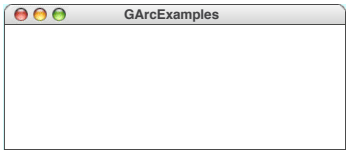
- The `GArc` class represents an arc formed by taking a section from the perimeter of an oval.
- Conceptually, the steps necessary to define an arc are:
  - Specify the coordinates and size of the bounding rectangle.
  - Specify the ***start angle***, which is the angle at which the arc begins.
  - Specify the ***sweep angle***, which indicates how far the arc extends.
- The geometry used by the `GArc` class is shown in the diagram on the right.
- In keeping with Java's graphics model, angles are measured in degrees starting at the +*x* axis (the 3:00 o'clock position) and increasing counterclockwise.
- Negative values for the *start* and *sweep* angles signify a clockwise direction.



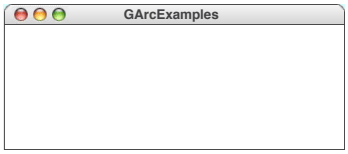
Exercise: `GArc` Geometry

Suppose that the variables `cx` and `cy` contain the coordinates of the center of the window and that the variable `d` is 0.8 times the screen height. Sketch the arcs that result from each of the following code sequences:

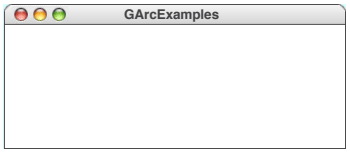
```
GArc a1 = new GArc(d, d, 0, 90);
add(a1, cx - d / 2, cy - d / 2);
```



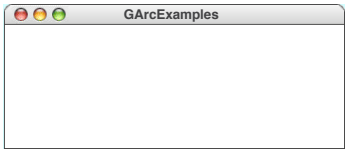

```
GArc a2 = new GArc(d, d, 45, 270);
add(a2, cx - d / 2, cy - d / 2);
```




```
GArc a3 = new GArc(d, d, -90, 45);
add(a3, cx - d / 2, cy - d / 2);
```



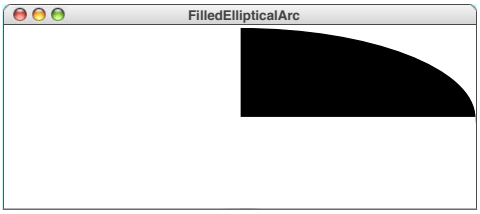

```
GArc a4 = new GArc(d, d, 0, -180);
add(a4, cx - d / 2, cy - d / 2);
```



Filled Arcs

- The **GArc** class implements the **GFillable** interface, which means that you can call **setFilled** on a **GArc** object.
- A filled **GArc** is displayed as the pie-shaped wedge formed by the center and the endpoints of the arc, as illustrated below:

```
public void run() {
   GArc arc = new GArc(0, 0, getWidth(), getHeight(),
                       0, 90);
   arc.setFilled(true);
   add(arc);
}
```



The GImage Class

- The **GImage** class is used to display an image from a file. The constructor has the form

new GImage(*image file***, *x*, *y*)**

where *image file* is the name of a file containing a stored image and *x* and *y* are the coordinates of the upper left corner of the image.

- When Java executes the constructor, it looks for the file in the current directory and then in a subdirectory named **images**.
- To make sure that your programs will run on a wide variety of platforms, it is best to use one of the most common image formats: the Graphical Interchange Format (GIF), the Joint Photographic Experts Group (JPEG) format, or the Portable Network Graphics (PNG) format. Image files using these formats typically have the suffixes **.gif**, **.jpg**, and **.png**.

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  Courtesy NASA/JPL-Caltech

- In some cases, noncommercial use of an image may fall under the "fair use" doctrine, which allows some uses of proprietary material. Even in those cases, however, academic integrity and common courtesy both demand that you cite the source of any material that you have obtained from others.

Example of the `GImage` Class

```
public void run() {
   add(new GImage("EarthFromApollo17.jpg"));
   addCitation("Courtesy NASA/JPL-Caltech");
}
```