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.
The following diagram shows the classes in the \texttt{acm.graphics} package and their relationship in the Java class hierarchy:

\textbf{Structure of the \texttt{acm.graphics} Package}

The \texttt{GCanvas} Class

- The \texttt{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 \texttt{acm.graphics} package, you create pictures by adding various \texttt{GObject}s to a \texttt{GCanvas}.
- For simple applications, you won’t actually need to work with an explicit \texttt{GCanvas} object. Whenever you run a program that extends \texttt{GraphicsProgram}, the initialization process for the program automatically creates a \texttt{GCanvas} and resizes it so that it fills the program window.
- Most of the methods defined for the \texttt{GCanvas} class are also available in a \texttt{GraphicsProgram}, thanks to an important strategy called forwarding. If, for example, you call the \texttt{add} method in a \texttt{GraphicsProgram}, the program passes that message along to the underlying \texttt{GCanvas} object by calling its \texttt{add} method with the same arguments.
The following methods are available in both the GCanvas and GraphicsProgram classes:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>add(object)</code></td>
<td>Adds the object to the canvas at the front of the stack</td>
</tr>
<tr>
<td><code>add(object, x, y)</code></td>
<td>Moves the object to (x, y) and then adds it to the canvas</td>
</tr>
<tr>
<td><code>remove(object)</code></td>
<td>Removes the object from the canvas</td>
</tr>
<tr>
<td><code>removeAll()</code></td>
<td>Removes all objects from the canvas</td>
</tr>
<tr>
<td><code>getElementAt(x, y)</code></td>
<td>Returns the frontmost object at (x, y), or null if none</td>
</tr>
<tr>
<td><code>getWidth()</code></td>
<td>Returns the width in pixels of the entire canvas</td>
</tr>
<tr>
<td><code>getHeight()</code></td>
<td>Returns the height in pixels of the entire canvas</td>
</tr>
<tr>
<td><code>setBackground(c)</code></td>
<td>Sets the background color of the canvas to c.</td>
</tr>
</tbody>
</table>

The following methods are available in GraphicsProgram only:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pause(milliseconds)</code></td>
<td>Pauses the program for the specified time in milliseconds</td>
</tr>
<tr>
<td><code>waitForClick()</code></td>
<td>Suspends the program until the user clicks the mouse</td>
</tr>
</tbody>
</table>

The Two Forms of the `add` Method

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

  ```java
  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

  ```java
  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

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

Sharing Behavior through Interfaces

- In addition to the methods defined for all GObject 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 (GRect, GOval, GPolygon, GRect)

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>setFilled(flag)</td>
<td>Sets the fill state for the object (false = outlined, true = filled)</td>
</tr>
<tr>
<td>isFilled()</td>
<td>Returns the fill state for the object</td>
</tr>
<tr>
<td>setFillColor(c)</td>
<td>Sets the color used to fill the interior of the object to c</td>
</tr>
<tr>
<td>getFillColor()</td>
<td>Returns the fill color</td>
</tr>
</tbody>
</table>

GResizable (GImage, GOval, GRect)

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>setSize(width, height)</td>
<td>Sets the dimensions of the object as specified</td>
</tr>
<tr>
<td>setBounds(x, y, width, height)</td>
<td>Sets the location and dimensions together</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>scale(sf)</td>
<td>Scales both dimensions of the object by sf</td>
</tr>
<tr>
<td>scale(sx, sy)</td>
<td>Scales the object by sx horizontally and sy vertically</td>
</tr>
</tbody>
</table>

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:

```java
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:

  \[
  \text{new GRect}(x, y, width, height)
  \]

  This form makes sense when you know in advance where the rectangle belongs.
- The second constructor defers setting the location:

  \[
  \text{new GRect}(width, height)
  \]

  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:

  \[
  \text{add(new GRoundRect(100, 60, 75, 50))};
  \text{add(new G3DRect(300, 60, 75, 50))};
  \]
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:

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

The points \((x_0, y_0)\) and \((x_1, y_1)\) are called the start point and the end point, respectively.

The GLine Class

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

```java
new GLine(x_0, y_0, x_1, y_1)
```

- 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):

```java
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:

<table>
<thead>
<tr>
<th>method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mouseClicked(e)</td>
<td>Called when the user clicks the mouse</td>
</tr>
<tr>
<td>mousePressed(e)</td>
<td>Called when the mouse button is pressed</td>
</tr>
<tr>
<td>mouseReleased(e)</td>
<td>Called when the mouse button is released</td>
</tr>
<tr>
<td>mouseMoved(e)</td>
<td>Called when the user moves the mouse</td>
</tr>
<tr>
<td>mouseDragged(e)</td>
<td>Called when the mouse is dragged with the button down</td>
</tr>
</tbody>
</table>

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.

```java
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:

```java
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`. 
Images and Copyrights

• Most images that you find on the web are protected by copyright under international law.

• Before you use a copyrighted image, you should make sure that you have the necessary permissions. For images that appear on the web, the hosting site often specifies what rules apply for the use of that image. For example, images from the www.nasa.gov site can be used freely as long as you include the following citation identifying the source:

  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

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

![Image of Earth from Apollo 17](EarthImage.png)

Courtesy NASA/JPL-Caltech