

COMP 303 - Lecture Notes for Week 4 - Interfaces and Polymorphism

- Slides edited from, Object-Oriented Design Patterns, by Cay S. Horstmann
- Original slides available from: http://www.horstmann.com/design_and_patterns.html
- Modifications made by Laurie Hendren, McGill University
- Topics this week:
 - Interfaces and Polymorphism, Chapter 4
 - Using ant for project builds and maintenance

Chapter Topics

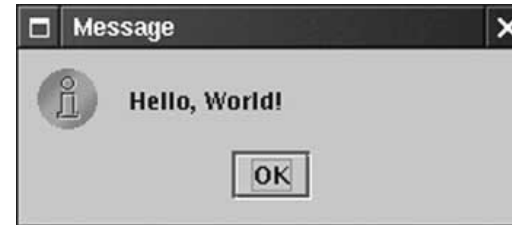
- Displaying an Image
- Polymorphism
- Drawing Shapes
- The Comparable Interface
- The Comparator Interface
- Anonymous Classes
- Frames and User Interface Components
- User Interface Actions
- Timers
- Designing an Interface

Displaying an Image

- Use JOptionPane to display message:

```
JOptionPane.showMessageDialog(null, "Hello, World!");
```

- Note icon to the left



Displaying an Image

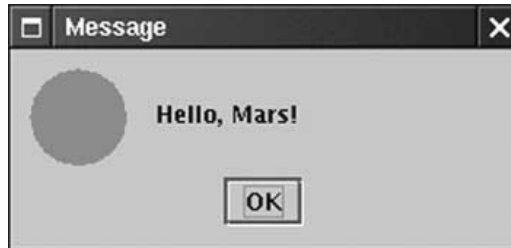
- Can specify arbitrary image file

```
JOptionPane.showMessageDialog(  
    null,  
    "Hello, World!",  
    "Message",  
    JOptionPane.INFORMATION_MESSAGE,  
    new ImageIcon("globe.gif"));
```



Displaying an Image

- What if we don't want to generate an image *file*?
- Fortunately, can use any class that implements *Icon interface type*
- *ImageIcon* is one such class
- Easy to supply your own class



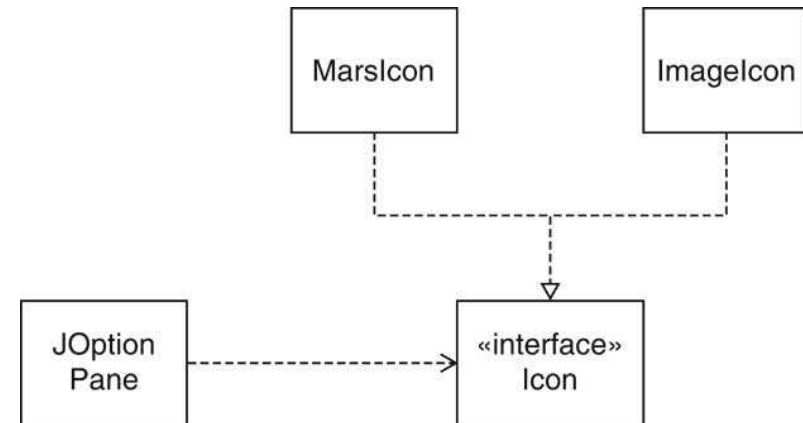
The Icon Interface Type

```
public interface Icon
{
    int getIconWidth();
    int getIconHeight();
    void paintIcon(Component c, Graphics g, int x, int y)
}
```

Interface Types

- No implementation
- Implementing class must supply implementation of all methods
- [Ch4/icon2/MarsIcon.java](#)
- `showMessageDialog` expects *Icon* object
- Ok to pass *MarsIcon*
- [Ch4/icon2/IconTest.java](#)

The Icon Interface Type and Implementing Classes



Polymorphism

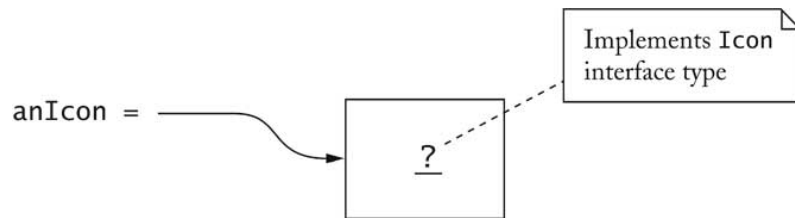
- `public static void showMessageDialog(...Icon anIcon)`
- `showMessageDialog` shows
 - icon
 - message
 - OK button
- `showMessageDialog` must compute size of dialog
- `width = icon width + message size + blank size`
- How do we know the icon width?

```
int width = anIcon.getIconWidth();
```

Polymorphism

- showMessageDialog doesn't know *which* icon is passed
 - ImageIcon?
 - MarsIcon?
 - ...?
- The actual type of anIcon is *not* Icon
- There are no objects of type Icon
- anIcon belongs to a *class* that implements Icon
- That class defines a getIconWidth method

A Variable of Interface Type



Polymorphism

- Which getIconWidth method is called?
- Could be
 - MarsIcon.getIconWidth
 - ImageIcon.getIconWidth
 - ...
- Depends on object to which anIcon reference points, e.g.

```
showMessageDialog(..., new MarsIcon(50))
```
- Polymorphism: Select different methods according to actual object type

Benefits of Polymorphism

- Loose coupling
 - showMessageDialog decoupled from ImageIcon
 - Doesn't need to know about image processing
- Extensibility
 - Client can supply new icon types

Drawing Shapes

- paintIcon method receives *graphics context* of type Graphics
- Actually a Graphics2D object in modern Java versions

```
public void paintIcon(Component c, Graphics g, int x, int y)
{
    Graphics2D g2 = (Graphics2D)g;
    ...
}
```

- Can draw any object that implements Shape interface

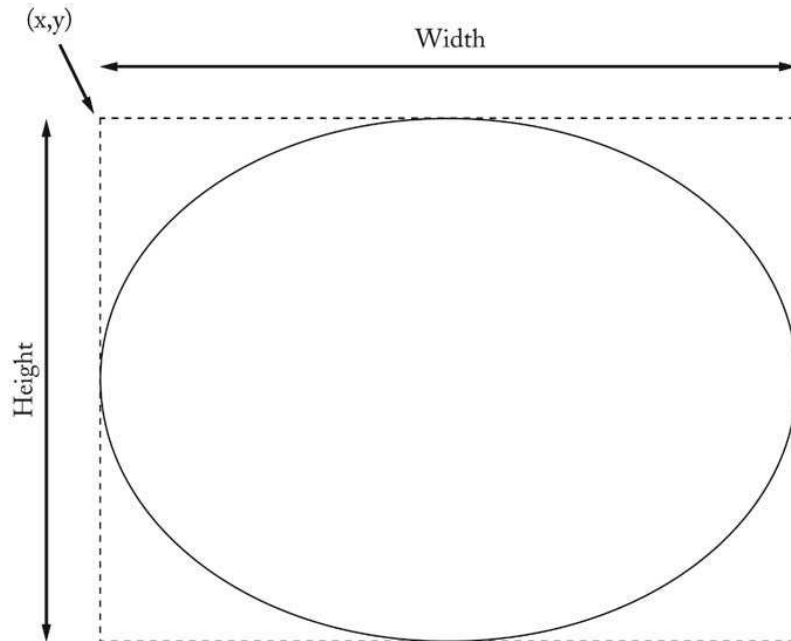
```
Shape s = . . . ;
g2.draw(s);
```

Drawing Rectangles and Ellipses

- Rectangle2D.Double constructed with
 - top left corner
 - width
 - height
- g2.draw(new Rectangle2D.Double(x, y, width, height));

- For `Ellipse2D.Double`, specify bounding box

Drawing Ellipses

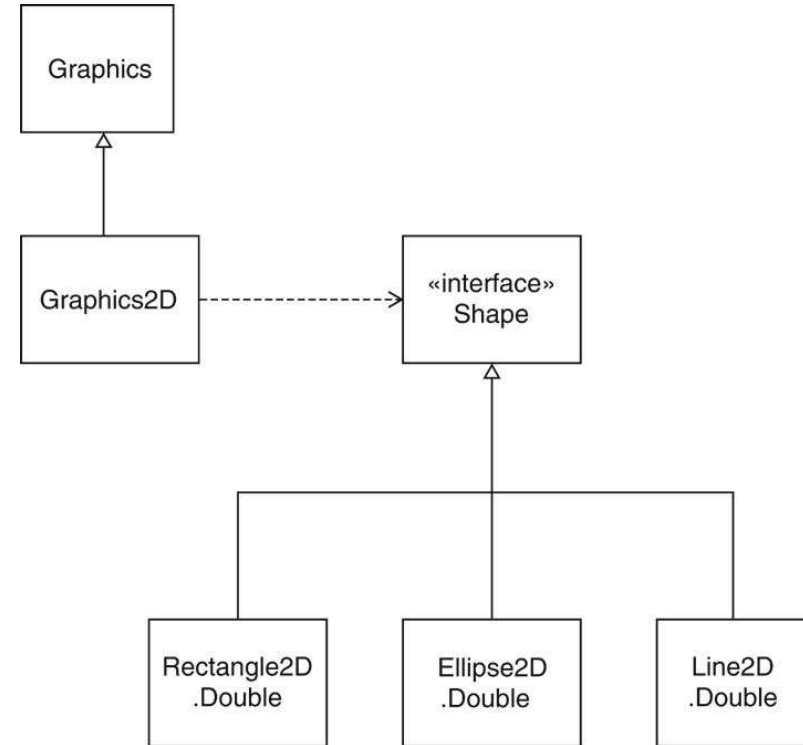


Drawing Line Segments

- `Point2D.Double` is a point in the plane
- `Line2D.Double` joins to points

```
Point2D.Double start = new Point2D.Double(x1, y1);
Point2D.Double end = new Point2D.Double(x2, y2);
Shape segment = new Line2D.Double(start, end);
g2.draw(segment);
```

Relationship Between Shape Classes



Drawing Text

- `g2.drawString(text, x, y);`
- `x, y` are *base point* coordinates

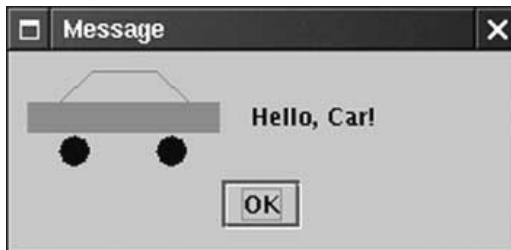


Filling Shapes

- Fill interior of shape

```
g2.fill(shape);
```

- Set color for fills or strokes:
`g2.setColor(Color.red);`
- Program that draws car
[Ch4/icon3/CarIcon.java](#)



The Comparable Interface Type

- Collections has static sort method:

```
ArrayList a = . . .
Collections.sort(a);
```

- Objects in list must implement the Comparable interface type

```
public interface Comparable
{
    int compareTo(Object other);
}
```

- `object1.compareTo(object2)` returns
 - Negative number if object1 less than object2
 - 0 if objects identical
 - Positive number if object1 greater than object2

The Comparable Interface Type

- `sort` method compares and rearranges elements if `(object1.compareTo(object2) > 0)` . . .
- String class implements Comparable interface type: lexicographic (dictionary) order
- Country class: compare countries by area [Ch4/sort1/Country.java](#)
[Ch4/sort1/CountrySortTest.java](#)

The Comparator interface type

- How can we sort countries by name?
- Can't implement Comparable twice!
- Comparator interface type gives added flexibility

```
public interface Comparator
{
    int compare(Object object1, Object object2);
}
```

- Pass comparator object to sort:

```
Collections.sort(list, comp);
```

The Comparator interface type

- [Ch4/sort2/CountryComparatorByName.java](#)
[Ch4/sort2/ComparatorTest.java](#)
- Comparator object is a *function object*
- This particular comparator object has no state
- State can be useful, e.g. flag to sort in ascending or descending order

Anonymous Classes

- No need to name objects that are used only once

```
Collections.sort(countries,  
    new CountryComparatorByName());
```

- No need to name classes that are used only once

```
Comparator comp = new  
    Comparator()  
    {  
        public int compare(Object obj1, Object obj2)  
        {  
            Country country1 = (Country)obj1;  
            Country country2 = (Country)obj2;  
            return country1.getName().compareTo(country2.getName());  
        }  
    };
```

Anonymous Classes

- anonymous **new** expression:
 - - defines anonymous class that implements Comparator
 - defines compare method of that class
 - constructs one object of that class
- Cryptic syntax for very useful feature

Anonymous Classes

- Commonly used in factory methods:

```
public static Comparator comparatorByName() {  
    return new Comparator() {  
        public int compare(Object o1, Object o2) { . . . }  
    };  
}
```

- Collections.sort(a,
Country.comparatorByName());
- Neat arrangement if multiple comparators make sense
(by name, by area, ...)

Frames

- Frame window has *decorations*
 - - title bar
 - close box
 - provided by windowing system
-

```
JFrame frame = new JFrame();  
frame.pack();  
frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);  
frame.show();
```

Adding Components

- Construct components

```
JButton helloButton = new JButton("Say Hello");
```

- Set content pane layout

```
Container contentPane = frame.getContentPane();
container.setLayout(new FlowLayout());
```

- Add components to content pane

```
contentPane.add(helloButton);
```

- [Ch4/frame/FrameTest.java](#)



User Interface Actions

- Previous program's buttons don't have any effect
- Add *listener object(s)* to button
- Belong to class implementing `ActionListener` interface type

```
public interface ActionListener
{
    int actionPerformed(ActionEvent event);
}
```

- Listeners are notified when button is clicked

User Interface Actions

- Add action code into `actionPerformed` method
- Gloss over routine code

```
helloButton.addActionListener(
    new ActionListener()
    {
        public void actionPerformed(ActionEvent event)
        {
            textField.setText("Hello, World!");
        }
    } );
```

- When button is clicked, text field is set

Accessing Variables from Enclosing Scope

- Remarkable: Inner class can access variables from enclosing scope e.g. `textField`
- Can access enclosing instance fields, local variables
- Local variables must be marked `final`
`final JTextField textField = ...;`

User Interface Actions

- Constructor attaches listener:

```
helloButton.addActionListener(listener);
```

- Button remembers all listeners
- When button clicked, button notifies listeners

```
listener.actionPerformed(event);
```

- Listener sets text of text field

```
textField.setText("Hello, World!");
```

- [Ch4/action1/ActionTest.java](#)

Constructing Related Actions

- Write helper method that constructs objects
- Pass variable information as parameters
- Declare parameters `final`

```
public static ActionListener createGreetingButtonListener(
    final String message)
{
    return new
        ActionListener()

```

```

    {
        public void actionPerformed(ActionEvent event)
        {
            textField.setText(message);
        }
    };
}

```

Timers

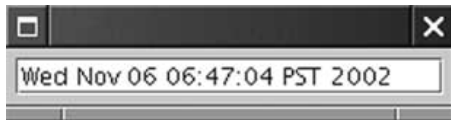
- Supply delay, action listener

```

ActionListener listener = ...;
final int DELAY = 1000; // 1000 millisec = 1 sec
Timer t = new Timer(DELAY, listener);
t.start();

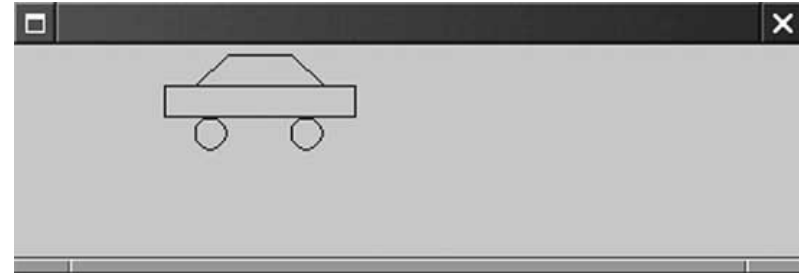
```

- Action listener called when delay elapsed
- [Ch4/timer/TimerTest.java](#)



Defining a New Interface Type

- Use timer to move car shapes
- Draw car with CarShape
- Two responsibilities:
 - Draw shape
 - Move shape
- Define new interface type MoveableShape



CRC Card for the MoveableShape Interface Type

MoveableShape
<i>paint the shape</i>
<i>move the shape</i>

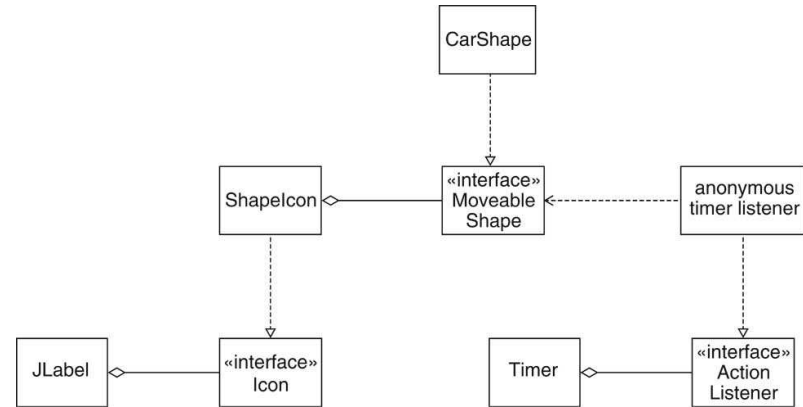
Defining a New Interface Type

- Name the methods to conform to standard library
-

```
public interface MoveableShape
{
    void draw(Graphics2D g2);
    void translate(int dx, int dy);
}
```

-

```
public class CarShape implements MoveableShape
{
    public void translate(int dx, int dy)
    { x += dx; y += dy; }
    . . .
}
```



Implementing the Animation

- Label contains icon that draws shape
- Timer action moves shape, calls `repaint` on label
- Label needs `Icon`, we have `MoveableShape`
- Supply `ShapeIcon` adapter class
- `ShapeIcon.paintIcon` calls `MoveableShape.draw`

Implementing the Animation

- [Ch4/animation/MoveableShape.java](#)
- [Ch4/animation/ShapeIcon.java](#)
- [Ch4/animation/AnimationTest.java](#)
- [Ch4/animation/CarShape.java](#)

Implementing the Animation

```

01: import java.awt.*;
02: import java.awt.geom.*;
03: import javax.swing.*;
04:
05: /**
06:  * An icon that has the shape of the planet Mars.
07:  */
08: public class MarsIcon implements Icon
09: {
10:     /**
11:      * Constructs a Mars icon of a given size.
12:      * @param aSize the size of the icon
13:      */
14:     public MarsIcon(int aSize)
15:     {
16:         size = aSize;
17:     }
18:
19:     public int getIconWidth()
20:     {
21:         return size;
22:     }
23:
24:     public int getIconHeight()
25:     {
26:         return size;
27:     }
28:
29:     public void paintIcon(Component c, Graphics g, int x, int y)
30:     {
31:         Graphics2D g2 = (Graphics2D) g;
32:         Ellipse2D.Double planet = new Ellipse2D.Double(x, y,
33:             size, size);
34:         g2.setColor(Color.RED);
35:         g2.fill(planet);
36:     }
37:
38:     private int size;
39: }

```

```

01: import javax.swing.*;
02:
03: public class IconTest
04: {
05:     public static void main(String[] args)
06:     {
07:         JOptionPane.showMessageDialog(
08:             null,
09:             "Hello, Mars!",
10:             "Message",
11:             JOptionPane.INFORMATION_MESSAGE,
12:             new MarsIcon(50));
13:         System.exit(0);
14:     }
15: }
16:

```

```

01: import java.awt.*;
02: import java.awt.geom.*;
03: import javax.swing.*;
04:
05: /**
06:  * An icon that has the shape of a car.
07:  */
08: public class CarIcon implements Icon
09: {
10:     /**
11:      * Constructs a car of a given width.
12:      * @param width the width of the car
13:      */
14:     public CarIcon(int aWidth)
15:     {
16:         width = aWidth;
17:     }
18:
19:     public int getIconWidth()
20:     {
21:         return width;
22:     }
23:
24:     public int getIconHeight()
25:     {
26:         return width / 2;
27:     }
28:
29:     public void paintIcon(Component c, Graphics g, int x, int y)
30:     {
31:         Graphics2D g2 = (Graphics2D) g;
32:         Rectangle2D.Double body
33:             = new Rectangle2D.Double(x, y + width / 6,
34:                                     width - 1, width / 6);
35:         Ellipse2D.Double frontTire
36:             = new Ellipse2D.Double(x + width / 6, y + width / 3,
37:                                   width / 6, width / 6);
38:         Ellipse2D.Double rearTire
39:             = new Ellipse2D.Double(x + width * 2 / 3, y + width / 3,
40:                                   width / 6, width / 6);
41:
42:         // the bottom of the front windshield
43:         Point2D.Double r1
44:             = new Point2D.Double(x + width / 6, y + width / 6);
45:         // the front of the roof

```

```

46:         Point2D.Double r2
47:             = new Point2D.Double(x + width / 3, y);
48:         // the rear of the roof
49:         Point2D.Double r3
50:             = new Point2D.Double(x + width * 2 / 3, y);
51:         // the bottom of the rear windshield
52:         Point2D.Double r4
53:             = new Point2D.Double(x + width * 5 / 6, y + width / 6);
54:
55:         Line2D.Double frontWindshield
56:             = new Line2D.Double(r1, r2);
57:         Line2D.Double roofTop
58:             = new Line2D.Double(r2, r3);
59:         Line2D.Double rearWindshield
60:             = new Line2D.Double(r3, r4);
61:
62:         g2.fill(frontTire);
63:         g2.fill(rearTire);
64:         g2.setColor(Color.red);
65:         g2.fill(body);
66:         g2.draw(frontWindshield);
67:         g2.draw(roofTop);
68:         g2.draw(rearWindshield);
69:     }
70:
71:     private int width;
72: }
73:
74:

```

```

01: /**
02:  A country with a name and area.
03: */
04: public class Country implements Comparable
05: {
06:     /**
07:      Constructs a country.
08:      @param aName the name of the country
09:      @param anArea the area of the country
10:     */
11:     public Country(String aName, double anArea)
12:     {
13:         name = aName;
14:         area = anArea;
15:     }
16:
17:     /**
18:      Gets the name of the country.
19:      @return the name
20:     */
21:     public String getName()
22:     {
23:         return name;
24:     }
25:
26:     /**
27:      Gets the area of the country.
28:      @return the area
29:     */
30:     public double getArea()
31:     {
32:         return area;
33:     }
34:
35:
36:     /**
37:      Compares two countries by area.
38:      @param otherObject the other country
39:      @return a negative number if this country has a smaller
40:      area than otherCountry, 0 if the areas are the same,
41:      a positive number otherwise
42:     */
43:     public int compareTo(Object otherObject)
44:     {
45:         Country other = (Country) otherObject;

```

```

46:         if (area < other.area) return -1;
47:         if (area > other.area) return 1;
48:         return 0;
49:     }
50:
51:     private String name;
52:     private double area;
53: }

```

```
01: import java.util.*;
02:
03: public class CountrySortTest
04: {
05:     public static void main(String[] args)
06:     {
07:         ArrayList countries = new ArrayList();
08:         countries.add(new Country("Uruguay", 176220));
09:         countries.add(new Country("Thailand", 514000));
10:         countries.add(new Country("Belgium", 30510));
11:         Collections.sort(countries);
12:         // now the array list is sorted by area
13:         for (int i = 0; i < countries.size(); i++)
14:         {
15:             Country c = (Country) countries.get(i);
16:             System.out.println(c.getName() + " " + c.getArea());
17:         }
18:     }
19: }
20:
```

```
01: import java.util.*;
02:
03: public class CountryComparatorByName implements Comparator
04: {
05:     public int compare(Object object1, Object object2)
06:     {
07:         Country country1 = (Country) object1;
08:         Country country2 = (Country) object2;
09:         return country1.getName().compareTo(country2.getName());
10:     }
11: }
```

```

01: import java.util.*;
02:
03: public class ComparatorTest
04: {
05:     public static void main(String[] args)
06:     {
07:         ArrayList countries = new ArrayList();
08:         countries.add(new Country("Uruguay", 176220));
09:         countries.add(new Country("Thailand", 514000));
10:         countries.add(new Country("Belgium", 30510));
11:         Comparator comp = new CountryComparatorByName();
12:         Collections.sort(countries, comp);
13:         // now the array list is sorted by name
14:         for (int i = 0; i < countries.size(); i++)
15:         {
16:             Country c = (Country) countries.get(i);
17:             System.out.println(c.getName() + " " + c.getArea());
18:         }
19:     }
20: }
21:

```

```

01: import java.awt.*;
02: import javax.swing.*;
03:
04: public class FrameTest
05: {
06:     public static void main(String[] args)
07:     {
08:         JFrame frame = new JFrame();
09:
10:         JButton helloButton = new JButton("Say Hello");
11:         JButton goodbyeButton = new JButton("Say Goodbye");
12:
13:         final int FIELD_WIDTH = 20;
14:         JTextField textField = new JTextField(FIELD_WIDTH);
15:         textField.setText("Click a button!");
16:
17:         Container contentPane = frame.getContentPane();
18:         contentPane.setLayout(new FlowLayout());
19:
20:         contentPane.add(helloButton);
21:         contentPane.add(goodbyeButton);
22:         contentPane.add(textField);
23:
24:         frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
25:         frame.pack();
26:         frame.show();
27:     }
28: }

```

```

01: import java.awt.*;
02: import java.awt.event.*;
03: import javax.swing.*;
04:
05: public class ActionTest
06: {
07:     public static void main(String[] args)
08:     {
09:         JFrame frame = new JFrame();
10:
11:         final int FIELD_WIDTH = 20;
12:         final JTextField textField = new JTextField(FIELD_WIDTH);
13:         textField.setText("Click a button!");
14:
15:         JButton helloButton = new JButton("Say Hello");
16:
17:         helloButton.addActionListener(new
18:             ActionListener()
19:             {
20:                 public void actionPerformed(ActionEvent event)
21:                 {
22:                     textField.setText("Hello, World!");
23:                 }
24:             });
25:
26:         JButton goodbyeButton = new JButton("Say Goodbye");
27:
28:         goodbyeButton.addActionListener(new
29:             ActionListener()
30:             {
31:                 public void actionPerformed(ActionEvent event)
32:                 {
33:                     textField.setText("Goodbye, World!");
34:                 }
35:             });
36:
37:         Container contentPane = frame.getContentPane();
38:         contentPane.setLayout(new FlowLayout());
39:
40:         contentPane.add(helloButton);
41:         contentPane.add(goodbyeButton);
42:         contentPane.add(textField);
43:
44:         frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
45:
46:         frame.pack();
47:         frame.show();
48:     }
49: }

```

```

01: import java.awt.*;
02: import java.awt.event.*;
03: import java.util.*;
04: import javax.swing.*;
05: import javax.swing.Timer;
06:
07: /**
08:  This program shows a clock that is updated once per second.
09: */
10: public class TimerTest
11: {
12:     public static void main(String[] args)
13:     {
14:         JFrame frame = new JFrame();
15:
16:         final int FIELD_WIDTH = 20;
17:         final JTextField textField = new JTextField(FIELD_WIDTH);
18:
19:         Container contentPane = frame.getContentPane();
20:         contentPane.setLayout(new FlowLayout());
21:         contentPane.add(textField);
22:
23:         ActionListener listener = new
24:             ActionListener()
25:             {
26:                 public void actionPerformed(ActionEvent event)
27:                 {
28:                     Date now = new Date();
29:                     textField.setText(now.toString());
30:                 }
31:             };
32:         final int DELAY = 1000;
33:         // milliseconds between timer ticks
34:         Timer t = new Timer(DELAY, listener);
35:         t.start();
36:
37:         frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
38:         frame.pack();
39:         frame.show();
40:     }
41: }

```

```

01: import java.awt.*;
02:
03: /**
04:  A shape that can be moved around.
05: */
06: public interface MoveableShape
07: {
08:     /**
09:         Draws the shape.
10:         @param g2 the graphics context
11:     */
12:     void draw(Graphics2D g2);
13:     /**
14:         Moves the shape by a given amount.
15:         @param dx the amount to translate in x-direction
16:         @param dy the amount to translate in y-direction
17:     */
18:     void translate(double dx, double dy);
19: }

```

```

01: import java.awt.*;
02: import java.util.*;
03: import javax.swing.*;
04:
05: /**
06:  An icon that contains a moveable shape.
07: */
08: public class ShapeIcon implements Icon
09: {
10:     public ShapeIcon(MoveableShape shape,
11:         int width, int height)
12:     {
13:         this.shape = shape;
14:         this.width = width;
15:         this.height = height;
16:     }
17:
18:     public int getIconWidth()
19:     {
20:         return width;
21:     }
22:
23:     public int getIconHeight()
24:     {
25:         return height;
26:     }
27:
28:     public void paintIcon(Component c, Graphics g, int x, int y)
29:     {
30:         Graphics2D g2 = (Graphics2D) g;
31:         shape.draw(g2);
32:     }
33:
34:     private int width;
35:     private int height;
36:     private MoveableShape shape;
37: }
38:
39:

```

```

01: import java.awt.*;
02: import java.awt.event.*;
03: import javax.swing.*;
04:
05: /**
06:  This program implements an animation that moves
07:  a car shape.
08: */
09: public class AnimationTest
10: {
11:     public static void main(String[] args)
12:     {
13:         JFrame frame = new JFrame();
14:
15:         final MoveableShape shape
16:             = new CarShape(0, 0, CAR_WIDTH);
17:
18:         ShapeIcon icon = new ShapeIcon(shape,
19:             ICON_WIDTH, ICON_HEIGHT);
20:
21:         final JLabel label = new JLabel(icon);
22:         Container contentPane = frame.getContentPane();
23:         contentPane.setLayout(new FlowLayout());
24:         contentPane.add(label);
25:
26:         frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
27:         frame.pack();
28:         frame.show();
29:
30:         final int DELAY = 100;
31:         // milliseconds between timer ticks
32:         Timer t = new Timer(DELAY, new
33:             ActionListener()
34:             {
35:                 public void actionPerformed(ActionEvent event)
36:                 {
37:                     shape.translate(1, 0);
38:                     label.repaint();
39:                 }
40:             });
41:         t.start();
42:     }
43:

```

```
44: private static final int ICON_WIDTH = 400;
45: private static final int ICON_HEIGHT = 100;
46: private static final int CAR_WIDTH = 100;
47: }
```

```
01: import java.awt.*;
02: import java.awt.geom.*;
03: import java.util.*;
04:
05: /**
06:  * A car that can be moved around.
07: */
08: public class CarShape implements MoveableShape
09: {
10:     /**
11:      * Constructs a car item.
12:      * @param x the left of the bounding rectangle
13:      * @param y the top of the bounding rectangle
14:      * @param width the width of the bounding rectangle
15:      */
16:     public CarShape(int x, int y, int width)
17:     {
18:         this.x = x;
19:         this.y = y;
20:         this.width = width;
21:     }
22:
23:     public void translate(double dx, double dy)
24:     {
25:         x += dx;
26:         y += dy;
27:     }
28:
29:     public void draw(Graphics2D g2)
30:     {
31:         Rectangle2D.Double body
32:             = new Rectangle2D.Double(x, y + width / 6,
33:                 width - 1, width / 6);
34:         Ellipse2D.Double frontTire
35:             = new Ellipse2D.Double(x + width / 6, y + width / 3,
36:                 width / 6, width / 6);
37:         Ellipse2D.Double rearTire
38:             = new Ellipse2D.Double(x + width * 2 / 3, y + width / 3,
39:                 width / 6, width / 6);
40:
41:         // the bottom of the front windshield
42:         Point2D.Double r1
43:             = new Point2D.Double(x + width / 6, y + width / 6);
44:         // the front of the roof
45:         Point2D.Double r2
```