

Java Music Systems: JMSL and JSyn

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Class #2 — Java Class interactions and inheritance, graphics, exceptions

• Inheritance

Object Oriented Programming languages like Java feature hierarchical class inheritance. A new class which extends an existing class inherits all the properties of that class (ie. its class variables and methods). If you are writing an Applet, for example, called `MyFirstApplet`, you simply declare it as:

```
public class MyFirstApplet extends java.applet.Applet
```

The Java word “extends” means “inherits from”. So, `MyFirstApplet` will inherit all the properties of the `Applet` class, including its security model, its ability to access media via URL’s, its ability to be run in a web browser, etc. This functionality has already been written into `Applet`, so you, the programmer, do not have to reinvent that wheel. `MyFirstApplet` is called a *subclass* of `Applet`. `Applet` is the *superclass* of `MyFirstApplet`.

• Adding methods to subclasses

A class that inherits from another can add methods and class variables of its own that never existed before. For example, `MyFirstApplet` might have the following method added to it:

```
public void greeting() {
    System.out.println("Pleased to meet you");
}
```

This `greeting()` method was not built into the `Applet` class by Sun Microsystems. It is a new method that the programmer decided to add. Now `MyFirstApplet` has more functionality than `Applet`.

• Overriding methods

Java also allows you to “override” methods. Overriding means redefining a method inherited from the superclass to do something different in the subclass. The `init()` and `start()` methods of `Applet` are good examples. `Applet` is built so that it will execute the `init()` method when it is first loaded into a browser. Once loaded, `start()` is fired. The stock `init()` and `start()` methods do nothing. By defining them as below, you take advantage of overriding them to do something useful for you.

```
public void init() {
    setBackground(Color.pink);
    repaint();
}

public void start() {
    AudioClip sound = getAudioClip(getCodeBase(), "screech.au");
    sound.play(); // play an 8bit sound clip natively by Java
}
```

• Constructors

An **object** is a particular instance of a **class**. When the program calls **new** on a class, an object is created. When an object is instantiated with **new**, a unique method called a constructor is executed. A constructor method is specified to have the exact same name as the class it serves. For example, this method would be the constructor of a class named `Stegosauria`.

```
public Stegosauria () {
    hasSpikes = true; // class variable inherited from Thyreophoria
    numberOfSpikes = 4; // sets up default count
}
```

When your program calls `Stegosauria myStegosaurus = new Stegosauria ();`, the Java virtual machine allocates memory for a new object of type `Stegosauria`, then runs the constructor declared above. The constructor can do anything, including print out messages notifying you that a new object is coming to life. Typically it is used to do some initial setup that is needed to get the object into shape and ready to go.

An object can have any number of constructors, each with a different “method signature” (see *overloading* below). Depending on how `new` is called, one of these constructors will be executed. For example:

```
public Stegosauria (int numSpikes) {
    hasSpikes = true;
    numberOfSpikes = numSpikes;    // might be 14 for Kentrosaurus
}
```

Now the programmer has a choice creating a new `Stegosaurus` with the default number of spikes by calling:

```
Stegosauria myStegosaurus = new Stegosauria ();
...or specify the number directly in the constructor by calling:
Stegosauria myKentrosaurus = new Stegosauria (14);
```

Note that the constructor method that actually executes is chosen by the method signature used above (ie, either passing an int parameter or not).

Method signatures cannot differ simply by the parameter names. Java cannot tell the difference between

```
public Stegosauria (int numSpikes)
...and...
public Stegosauria (int numPlates)
```

...since these have the same method signature. There would be no way of knowing whether `new Stegosauria(10)` referred to the number of spikes or the number of plates. This is not a shortcoming of Java since a human wouldn't know what 10 referred to either.

• Accessor and Mutator methods

Java classes have “class variables” which hold data unique to an object. If a class has a variable of type `int` (ie a whole number), that variable can hold a value that is different from object to object.

Changing and retrieving the values of class variables is best done with methods, rather than by accessing the variable directly. This is in the spirit of hiding the implementation of a class from the programmer. The idea is to program to an object's **interface** rather than its **implementation**. Then, if the implementation of data retrieval changes, well-written code won't break. Accessors and mutators, then, are the interfaces to class variables in Java programs.

For example:

```
public class Stegosauria extends Thyreophora {
    private long age; // how many years ago this particular specimen lived
    private int numberOfSpikes;

    // mutator method, changes the value of a class variable
    public void setAge(long years) {
        age = years;
    }

    // accessor method, allows you to retrieve age
    public long getAge() {
        return age;
    }
}
```

```
}  
}
```

In the example above, the programmer who instantiates an object of type `Stegosauria`, can only access its age through the `getAge()` method, and can only change it through `setAge()`. The programmer cannot directly change the age variable hiding under the hood. Why is this a good thing? A year after this Java implementation is published, there may be a new way to estimate the age of a `Stegosauria` fossil. Getting an age may involve logging into a database, running some fossil data through a query, and retrieving an extremely accurate age estimate. As long as the code you've written simply calls `getAge()`, it will not care whether `Stegosauria` logs into a database (new version) or simply returns a local variable (old version).

• Overloading

Overloading is the technique whereby the same method name can be reused, but its action differs based on the parameter list it is passed, called the "method signature". In JMSL's `JMSLRandom` class, for example, the `choose()` method is heavily overloaded.

Calling `JMSLRandom.choose()` returns a random double in the range [0.0 .. 1.0).

Calling `JMSLRandom.choose(10)` returns a random int in the range [0..10).

Calling `JMSLRandom.choose(10, 20)` returns a random int in the range [10..20)

Overloading methods is easy: just declare and implement each method with a unique parameter list.

For example:

```
/** @return area of a square */  
public int getArea(int side) {  
    return side * side;  
}  
  
/** @return area of a rectangle */  
public int getArea(int length, int width) {  
    return length * width;  
}
```

• Static class variables and methods

A variable or a method that is declared `static` does not require an instance of an object to be accessed. For example, the `JMSLRandom` class does not require that you first create an object of type `JMSLRandom` before you can use `choose()`. The `choose()` method is declared `static`, so you can simply call `JMSLRandom.choose()`.

A class variable that is declared `static` contains the same value for every active object of that type. If any object changes this value, all objects will be affected. To use a horrific example, the number of customers served that is displayed under McD*nalds's golden arches, can be thought of as a static variable. The number is the same for all instances of McD*nalds. The store manager, and list of employees, location, etc, are of course non-static, as they belong to a particular instance of the McD*nalds class. But if "10 gazillion served" changes to "11 gazillion served", this value changes for all instances of McD*nalds.

Static variables are more than a convenience saving you time by not having to declaring an object first. They are a way of managing changes that can be accessed over a population of objects. An `int` variable called `fooCount`, for example, would be a good use of static variable which is incremented in a class's constructor. Then, each object's name could be unique by appending that `int` onto a `String` prefix.

Example:

```

package javamusic;

public class Foo {
    private static int fooCount;
    private String name;

    /** every time this constructor is called, the
    object instance will be named Foo_#,
    and # is incremented. */

    public Foo() {
        name = "Foo_" + fooCount++;
    }

    public String getName() {
        return name;
    }

    public static void main(String args[] ) {
        Foo[] fooList = new Foo[10];

        for (int i=0; i<fooList.length; i++) {
            fooList[i] = new Foo();
        }

        for (int i=0; i<fooList.length; i++) {
            System.out.println(fooList[i].getName());
        }
    }
}

```

Graphics in Java

Java's Graphics class has a large catalog of methods with which you can program graphic drawing, such as `setColor()`, `drawLine()`, and `fillRect()`. Look up this class in the Java docs and you will see the wealth of choices. More recent versions of Java have Graphics2D which provides more sophisticated control over image manipulation and rendering, such as antialiased drawing. We will restrict ourselves to the simpler Graphics model here, to get you up and running.

A useful class for drawing is `java.awt.Canvas`. Canvas is simply a Component with a rectangular surface. You can add() a Canvas to a Layout like any other Component such as Button, Label, TextField, etc. Use `setSize(w, h)` to set the dimensions of the canvas you need.

Drawing directly into a Canvas's Graphics object

This approach is good if you simply want to draw directly into a canvas, as opposed to, for example, animating a graphic by drawing on top of an picture.

Build your GUI layout as usual. When you are ready to draw, call `getGraphics()` on your canvas and draw to that Graphics object, like so:

```

Canvas myCanvas;
...
myCanvas = new Canvas();
myCanvas.setSize(400, 400);
...
Graphics g = myCanvas.getGraphics();
g.setColor(Color.blue);
g.drawLine( 0, 0, 100, 200);
...

```

The code excerpt above draws a blue line from the top left corner of the canvas (0, 0), to the point 100 pixels to the **right**, and 200 pixels **down**.

Of course you can draw algorithmically by performing calculations and passing the results of those calculations to these routines, such as:

```
...
Graphics g = myCanvas.getGraphics();
g.setColor(Color.blue);
for (int i=0; i<10; i++) {
    g.drawLine(0, 0, i, 200);
}
...
```

What does the above do?

Following is a complete working example of an applet that draws randomly colored rectangles into a canvas's Graphics object.

```
package com.didkovsky.javamusic;

import java.awt.*;
import java.awt.event.*;

/**
 * <p>Title: CrazyRectanglesApplet</p>
 * <p>Graphics example. Draw randomly colored and randomly sized rectangles at
 * random locations on a Canvas.</p>
 * <p>Copyright: Copyright (c) Nick Didkovsky, 2003</p>
 * <p>Company: Punos Music</p>
 * @author Nick Didkovsky, didkovn@mail.rockefeller.edu
 * @version 1.0
 */

public class CrazyRectanglesApplet
    extends java.applet.Applet
    implements ActionListener {

    Canvas myCanvas;
    Button goButton;
    Button clearButton;
    public static final int CANVAS_WIDTH = 500;
    public static final int CANVAS_HEIGHT = 400;

    public void init() {
        setLayout(new BorderLayout());
        myCanvas = new Canvas();
        myCanvas.setBackground(Color.yellow);
        myCanvas.setSize(CANVAS_WIDTH, CANVAS_HEIGHT);
        add(BorderLayout.SOUTH, myCanvas);

        Panel topPanel = new Panel();
        topPanel.setLayout(new FlowLayout());

        goButton = new Button("GO");
        topPanel.add(goButton);
        goButton.addActionListener(this);

        clearButton = new Button("CLEAR");
        topPanel.add(clearButton);
        clearButton.addActionListener(this);

        add(BorderLayout.NORTH, topPanel);
    }

    public void actionPerformed(ActionEvent e) {
        Object source = e.getSource();
        if (source == goButton) {
```

```

        drawRectangles();
    }
    if (source == clearButton) {
        Graphics g = myCanvas.getGraphics();
        g.setColor(Color.yellow);
        g.fillRect(0, 0, CANVAS_WIDTH, CANVAS_HEIGHT);
    }
}

public void drawRectangles() {
    Graphics g = myCanvas.getGraphics();
    for (int i = 0; i < 100; i++) {
        int xPosition = (int) (Math.random() * CANVAS_WIDTH);
        int yPosition = (int) (Math.random() * CANVAS_HEIGHT);
        int randomWidth = (int) (Math.random() * 100);
        int randomHeight = (int) (Math.random() * 100);
        int red = (int) (Math.random() * 256);
        int green = (int) (Math.random() * 256);
        int blue = (int) (Math.random() * 256);
        System.out.println(red + ", " + green + ", " + blue);
        Color myColor = new Color(red, green, blue);
        g.setColor(myColor);
        g.fillRect(xPosition, yPosition, randomWidth, randomHeight);
    }
}

/** Here's a trick to check your applets in a main() method.
    Instantiate an applet and put it in a Frame.
    Don't forget to call init() and start() on your applet
    explicitly since there's no browser to do this
    automatically.
    */

public static void main(String args[]) {
    Frame f = new Frame("Click to close");
    CrazyRectanglesApplet applet = new CrazyRectanglesApplet();
    applet.init();
    f.add(applet);
    f.pack();
    f.setVisible(true);
    f.addWindowListener(new WindowAdapter() {
        public void windowClosing(WindowEvent e) {
            System.exit(0);
        }
    });
    applet.start();
}
}

```

Using an offscreen image to generate smooth animation

Musical Graphics Example: <http://www.algomusic.com/jmsl/examples/MandelMusic.shtml>

Sometimes you want to animate changes to an image over time, and want it to be animated smoothly. You could redraw every frame by drawing directly into the Canvas's Graphics object, but that would result in jerky animation since every drawing command would be seen happening in real time.

The solution is to do your drawing into the Graphics object of an offscreen Image. When that drawing is done, 'paste' that offscreen image all at once into the Canvas. This action is typically done in a component's paint() method, which is called whenever you want a component to be repainted. Your code never calls paint() directly. Instead, it called repaint() which calls paint() behind the scenes.

The following example illustrates. A background image is drawn and a solid colored ball travels across it.

First we present a subclass of **Canvas** which provides an offscreen drawing context available to other classes.

```
package com.didkovsky.javamusic;

import java.awt.*;

/**
 * <p>Title: DrawingCanvas</p>
 * <p>Description: A canvas with offscreen graphics context. Draw into this context and
 call repaint() for smooth animation updates</p>
 * <p>Copyright: Copyright (c) 2003 Nick Didkovsky</p>
 * <p>Company: Punos Music </p>
 * @author Nick Didkovsky, didkovn@mail.rockefeller.edu
 * @version 1.0
 */

public class DrawingCanvas extends Canvas {

    Image offscreenImage;
    Graphics offscreenGraphics;
    int width;
    int height;

    public DrawingCanvas(int w, int h) {
        super();
        this.width = w;
        this.height = h;
        setSize(width, height);
    }

    /** Get the offscreen graphics context. Draw into it and call repaint() */
    public Graphics getOffscreenGraphics() {
        return offscreenGraphics;
    }

    /** The default version of update() clears the screen. Override to simply call paint()
    */
    public void update(Graphics g) {
        paint(g);
    }

    public void paint(Graphics g) {
        if (offscreenImage == null || offscreenGraphics == null) {
            offscreenImage = this.createImage(width, height);
            offscreenGraphics = offscreenImage.getGraphics();
            System.out.println("created image and offscreen graphics");
        }

        if (offscreenImage != null) {
            g.drawImage(offscreenImage, 0, 0, width, height, this);
        } else {
            System.out.println("no image to draw ");
        }
    }
}
```

Now we present the **Applet** itself which, 15 times per second, draws a background image and blue oval travelling over it. A checkbox is included. When that checkbox is unchecked, the graphics context into which the applet draws is the graphics of the canvas itself. When checked, the graphics is that of the offscreen image. In this mode, when the drawing is done, it calls `repaint()` on the canvas.

Note that since this applet does something over time, we want it to pause between tasks in a loop. A good way to do this in Java is using Threads. The applet implements the Runnable interface, which requires that all timing related activity happens in a run() method. Threads are the basis for scheduling events over time in Java, which later, you will see are at the heart of JMSL.

```
package com.didkovsky.javamusic;

import java.awt.*;
import java.awt.event.*;
/**
 * <p>Title: AnimationApplet</p>
 * <p>Description: </p>
 * <p>Copyright: Copyright (c) 2003</p>
 * <p>Company: </p>
 * @author not attributable
 * @version 1.0
 */

public class AnimationApplet extends java.applet.Applet implements ActionListener,
Runnable {

    DrawingCanvas myCanvas;
    boolean keepGoing;
    Button goButton;
    Button stopButton;
    public static final int CANVAS_WIDTH = 500;
    public static final int CANVAS_HEIGHT = 400;
    public static final int BALL_WIDTH = 30;
    public static final int BALL_HEIGHT = 20;

    Thread runner;

    /** When unchecked, draw directly to the Canvas graphics. When checked, draw to
    offscreen graphics for flicker-free animation */
    Checkbox smoothAnimationCheckbox;

    public void init() {
        setLayout(new BorderLayout());
        myCanvas = new DrawingCanvas(CANVAS_WIDTH, CANVAS_HEIGHT);
        add(BorderLayout.CENTER, myCanvas);

        Panel topPanel = new Panel();
        topPanel.setLayout(new FlowLayout());

        goButton = new Button("GO");
        topPanel.add(goButton);
        goButton.addActionListener(this);

        stopButton = new Button("STOP");
        topPanel.add(stopButton);
        stopButton.addActionListener(this);

        topPanel.add(smoothAnimationCheckbox = new Checkbox("Smooth Animation"));

        add(BorderLayout.NORTH, topPanel);
    }

    /** Override applet start() */
    public void start() {
        keepGoing = false;
    }

    /** Override applet stop() */
    public void stop() {
        stopAnimation();
    }

    public void actionPerformed(ActionEvent e) {
        Object source = e.getSource();
    }
}
```

```

        if (source == goButton) {
            startAnimation();
        }
        if (source == stopButton) {
            stopAnimation();
        }
    }

    private void drawBackground(Graphics g) {
        if (g != null) {
            g.setColor(Color.white);
            g.fillRect(0, 0, CANVAS_WIDTH, CANVAS_HEIGHT);
            int steps = 50;
            int stepSize = CANVAS_WIDTH / steps;
            for (int i = 0; i < steps; i++) {
                if (i % 2 == 0) {
                    g.setColor(Color.yellow);
                }
                else {
                    g.setColor(Color.red);
                }
                g.drawLine(i * stepSize, 0, i * stepSize, CANVAS_HEIGHT);
            }
        }
    }

    private void drawCharacter(Graphics g, int x, int y) {
        if (g != null) {
            g.setColor(Color.blue);
            g.fillArc(x, y, BALL_WIDTH, BALL_HEIGHT, 0, 360);
        } else {
            System.out.println("NULL, cannot animate character");
        }
    }

    private void startAnimation() {
        if (runner == null) {
            runner = new Thread(this);
            keepGoing = true;
            runner.start();
        }
    }

    private void stopAnimation() {
        keepGoing = false;
        if (runner != null) {
            try {
                runner.join(1000);
                runner = null;
            }
            catch (InterruptedException e) {}
        }
    }

    public void run() {
        int x = CANVAS_WIDTH / 2;
        int y = CANVAS_HEIGHT / 2;
        int xStep = 2;
        int yStep = 2;
        int fps = 15;

        // will be either canvas graphics or offscreen graphics
        Graphics g;
        while (keepGoing) {
            if (smoothAnimationCheckbox.getState()) {
                g = myCanvas.getOffscreenGraphics();
            } else {
                g = myCanvas.getGraphics();
            }
        }
    }
}

```

```

    }

    drawBackground(g);
    drawCharacter(g, x, y);

    if (smoothAnimationCheckbox.getState()) {
        myCanvas.repaint();
    }

    pause(1000 / fps);

    // update x, y and bounce off the walls if reach boundary
    x += xStep;
    y += yStep;
    if (x == 0 || x == CANVAS_WIDTH-BALL_WIDTH) {
        xStep *= -1;
    }
    if (y == 0 || y == CANVAS_HEIGHT-BALL_HEIGHT) {
        yStep *= -1;
    }
}

private void pause(int millis) {
    try {
        Thread.sleep(millis);
    }
    catch (InterruptedException e) {}
}

/** Here's a trick to check your applets in a main() method.  Instantiate an applet
and put it in a Frame.
 * Don't forget to call init() and start() on your applet explicitly since there's
no browser to do this
 * automatically.
 */

public static void main(String args[]) {
    Frame f = new Frame("Click to close");
    AnimationApplet applet = new AnimationApplet();
    applet.init();
    f.add(applet);
    f.pack();
    f.setVisible(true);
    f.addWindowListener(new WindowAdapter() {
        public void windowClosing(WindowEvent e) {
            System.exit(0);
        }
    });
    applet.start();
}
}

```

Handling errors with Java's Exceptions

Java provides a nice way to catch errors which might happen at runtime. If you execute some code that might cause an error (like trying to open a file that does not exist), you bracket all that code in a try {} block, and follow it with a catch(Exception e) {} block.

Java's Exception class has many subclasses, such as IOException, ArrayIndexOutOfBoundsException, and NumberFormatException. It is very hip to catch the exception you specifically expect in your code rather than catching Exception in general.

Example follows:

```

import java.net.*;
import java.io.*;
import java.awt.*;

/** Open a file on server and echo contents in Applet
    @author Nick Didkovsky
 */

public class ReadURL extends java.applet.Applet {

    TextArea textArea;

    public void init() {
        textArea = new TextArea("Contents of file on server:\n", 20, 40);
        add(textArea);
    }

    // opens a file on server and echoes contents to console
    public void start() {
        System.out.println("starting up...");
        try {
            URL url = new URL(getDocumentBase(), "../../cgi-bin/hub1");
            DataInputStream in = new DataInputStream(url.openStream());
            readAndEcho(in);
            in.close();
        }
        catch (MalformedURLException e1) {
            System.out.println("Bad URL in ReadWriteURL's start(): " + e1);
        }
        catch (IOException e2) {
            System.out.println("Error reading file in ReadWriteURL's start() " + e2);
        }
    }

    void readAndEcho(DataInputStream in) {
        try {
            while (true) {
                byte b = in.readByte();
                textArea.appendText((char)b+"");
            }
        }
        catch (EOFException e1) {
            System.out.println("That's all folks!");
        }
        catch (IOException e2) {
            System.out.println("Error in ReadWriteURL's readAndEcho() " + e2);
        }
    }
}

```

Extra Credit Homework:

Create an applet that does some random drawing under user-specified constraints of your own choosing. The user should be able to use TextFields to enter constraints and a button to initiate the drawing. For example, one TextField might be used to specify the minimum X value of a randomly drawn line, while another might be used to specify the maximum value. Clicking “go” might generate 20 lines with endpoints randomly chosen within these constraints.

To generate a random number between [0..1) use `Math.random()`

Scale this range up to choose random x, y endpoints between [0..100) :

```

int x1 = (int)(Math.random() * 100);
int y1 = (int)(Math.random() * 100);
int x2 = (int)(Math.random() * 100);
int y2 = (int)(Math.random() * 100);
g.drawLine(x1, y1, x2, y2);

```