# 8 Graphics

## What's in This Set of Notes?

As programmers, we will likely all eventually come across a situation in which we need to display graphics. Graphics may be pictures or perhaps drawings consisting of lines, circles, rectangles etc... For example, if we want to have an application that displays a bar graph, there is no "magical" component in JAVA that does this for us. We will learn here the basics of displaying and manipulating graphics in our JAVA applications.

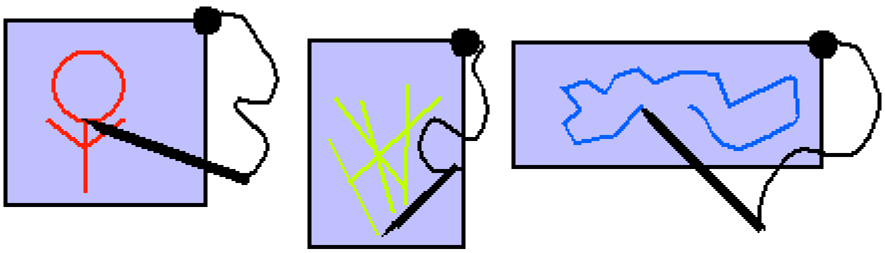
Here are the individual topics found in this set of notes (click on one to go there):



## 8.1 Doing Simple Graphics

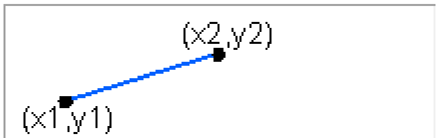
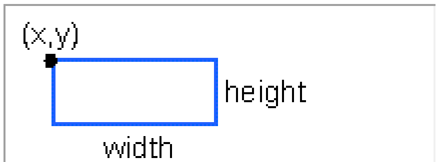
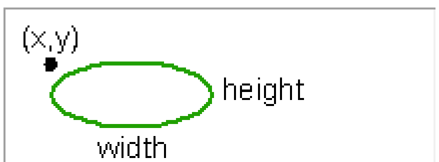
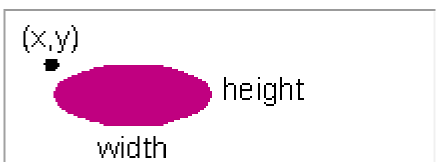
Graphics are used in many applications to display graphs, statistics, diagrams, pictures etc... Some applications are even completely based on graphics such as games, paint programs, MS PowerPoint etc... We have already seen that **ImageIcons** can be used to display images on your application window inside labels, buttons etc... Now we will see how to actually draw our own graphics, as when drawing graphs or diagrams.

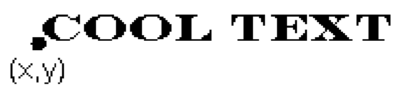
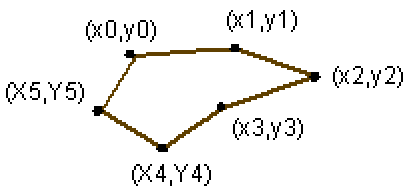
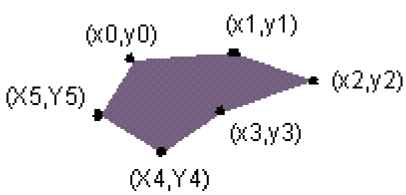
The **java.awt** package has a class called **Graphics** that permits the drawing of various shapes. The class is **abstract** and so there is no constructor. Instead, JAVA provides a **getGraphics()** method that can be sent to any window component which returns an instance of this **Graphics** class (i.e., each component keeps an instance of that class by default). Think of each component having its own "pen" that can only be used to draw in that component's "space", just like the pens attached to kiosks at the bank.

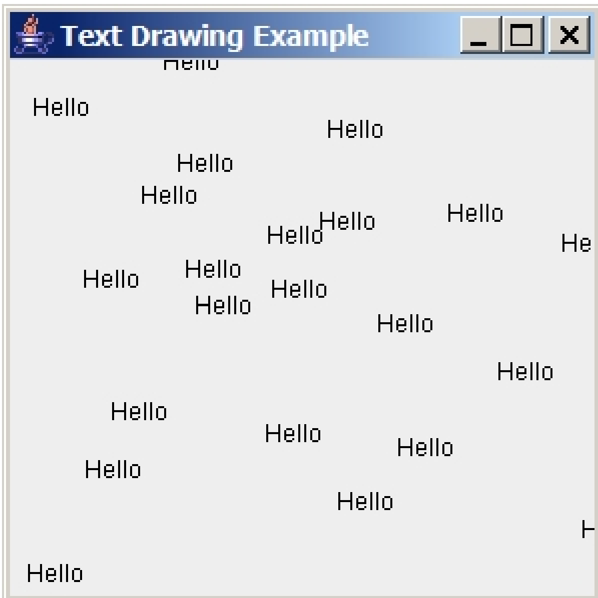


There are a set of drawing functions that allow you to draw onto a component's area. Since a particular graphics object belongs to one specific component, you can only draw on that component with it. Most drawing functions allow you to specify x and y coordinates. The coordinate `(x,y)=(0,0)` is at the top left corner of the component's area. So all coordinates are with respect to the component's area.

Here are just some of the methods available in the **Graphics** class (look in the JDK API for more info):

| | |
|---|---|
|  | `// Draw a line from (x1, y1) to (x2,y2)`<br>`public abstract void drawLine(int x1, int y1, int x2, int y2);` |
|  | `// Draw a rectangle with its top left at (x, y) having the given width and height`<br>`public abstract void drawRect(int x, int y, int width, int height);` |
|  | `// Draw a filled rectangle with its top left at (x, y) having the given width and height`<br>`public abstract void fillRect(int x, int y, int width, int height);` |
|  | `// Erase a rectangular area by filling it in with the background color`<br>`public abstract void clearRect(int x, int y, int width, int height);` |
|  | `// Draw an oval with its top left at (x, y) having the given width and height`<br>`public abstract void drawOval(int x, int y, int width, int height);` |
|  | `// Draw a filled oval with its top left at (x, y) having the given width and height`<br>`public abstract void fillOval(int x, int y, int width, int height);` |

| | |
|---|---|
|  | `// Draw the given String with its bottom left at (x, y)`<br>`public abstract void drawString(String str, int x, int y);` |
|  | `// Draw a polygon with the given coordinates`<br>`public abstract void drawPolygon(int[] x, int[] y, int numEdges);` |
|  | `// Draw a filled polygon with the given coordinates`<br>`public abstract void fillPolygon(int[] x, int[] y, int numEdges);` |
|  | `// Set the foreground and fill color of the Graphics object`<br>`public abstract void setColor(Color c);` |
|  | `// Set the Font for use with drawString`<br>`public abstract void setFont(Font font);` |




## Example:

This code makes a simple **JFrame** and then draws some text on it wherever the user clicks the mouse. As it turns out, we can draw directly to the frame of a window. We don't need to add any components for this example. To the right is a snapshot of the running program.

You will notice three things about this example:

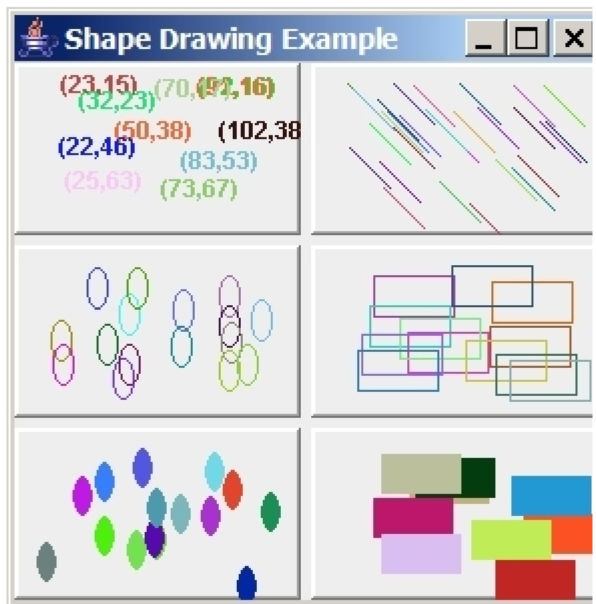
1. The text is drawn such that the bottom left corner of the text appears at the location which the mouse is clicked.
2. The text is erased whenever we alter the size of the window.
3. We can ask a mouseEvent for the x and y position of the mouse.

Below is the code.

```
import java.awt.event.*;
import javax.swing.*;
public class TextDrawingExample extends JFrame {

      public TextDrawingExample (String title) {
          super(title);

          addMouseListener {new MouseAdapter() {
              public void mousePressed(MouseEvent e) {
                  getGraphics().drawString("Hello", e.getX(),
      e.getY());
              }});

          setDefaultCloseOperation(EXIT_ON_CLOSE);
          setSize(300, 300);
      }
      public static void main(String args[]) {
          new TextDrawingExample("Text Drawing
      Example").setVisible(true);
      }

}
```

---

**Example:**




In this example, we will set up six **JLabel**s, each one allowing a different shape to be drawn onto it. We will set up a single event handler for all mouse presses and within that method we will ask which label has been clicked on and then draw the corresponding shape onto the label. The shapes will be drawn with different colors each time. We use **`Math.random()`** to get a random number for creating a random color. To the right is a snapshot of the working program. You will notice that:

1. The **`getGraphics()`** message is sent to the component, not to the frame.
2. The labels have neat little borders which were created as **`BorderFactory.createRaisedBevelBorder()`**. You can take a look at the Java API to find out more about the different kinds of borders that are possible.

Here is the code:

```java
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;
public class ShapeDrawingExample extends JFrame {

    private JLabel labels[];

    public ShapeDrawingExample(String title) {
        super(title);

        setLayout(new GridLayout(3,2,5,5));
        labels = new JLabel[6];
        for (int i=0; i<6; i++) {
            getContentPane().add(labels[i] = new JLabel());
            labels[i].setBorder(BorderFactory.createRaisedBevelBorder());
        }
        addListeners();
        setDefaultCloseOperation(EXIT_ON_CLOSE);
        setSize(300, 300);
    }

    // Add listener for a mouse press
    private void addListeners() {
        MouseAdapter  anAdapter = new MouseAdapter() {
            public void mousePressed(MouseEvent e) {
                JLabel  area = (JLabel)e.getSource();
                Graphics g = area.getGraphics();

                // Get a random color
                g.setColor(new Color((float)Math.random(),
                                     (float)Math.random(),
                                     (float)Math.random()));

                // Find the label that caused this event
                int   labelNumber;
                for (labelNumber=0; labelNumber<6; labelNumber++) {
                    if (area == labels[labelNumber]) break;
                }
                int   x = e.getX();
                int   y = e.getY();

                // Now decide what to draw
                switch (labelNumber) {
                  case 0: g.drawString("(" + String.valueOf(x) + "," +
                                       String.valueOf(y) + ")", x, y);
break;
                  case 1: g.drawLine(x, y, x+20, y+20);  break;
                  case 2: g.drawOval(x, y, 10, 20);  break;
                  case 3: g.drawRect(x, y, 40, 20);  break;
                  case 4: g.fillOval(x, y, 10, 20);  break;
                  case 5: g.fillRect(x, y, 40, 20);  break;
                }
            }};
```

```
        // Add mouse listeners to all labels (for doing something upon mouse
presses)
        for (int i=0; i<6; i++)
            labels[i].addMouseListener(anAdapter);
    }

    public static void main(String args[]) {
        new ShapeDrawingExample("Shape Drawing Example").setVisible(true);
    }
}
```

## 8.2 Repainting Components

You may have noticed in our examples so far that all the drawings we do are erased when the window is resized. When a window is resized, each of the components needs to be redrawn. Every **JComponent** has (or inherits) a `repaint()` method which is called by JAVA automatically when the window is resized in order to redraw the component. JAVA redraws these components as it already knows how to do, but it will not automatically redraw anything that we may have drawn manually, unless we tell it to. In fact, we too can call this `repaint()` method any time we want our component to be redrawn.

The `repaint()` method actually calls a method called `paintComponent(Graphics g)`, which is also inherited from the **JComponent** class. However, the default inherited `paintComponent()` method does not know what you want to be painted. In order to tell it what to actually redraw, you need to override this method by writing your own `paintComponent()` method which will specify exactly how to draw your graphics.

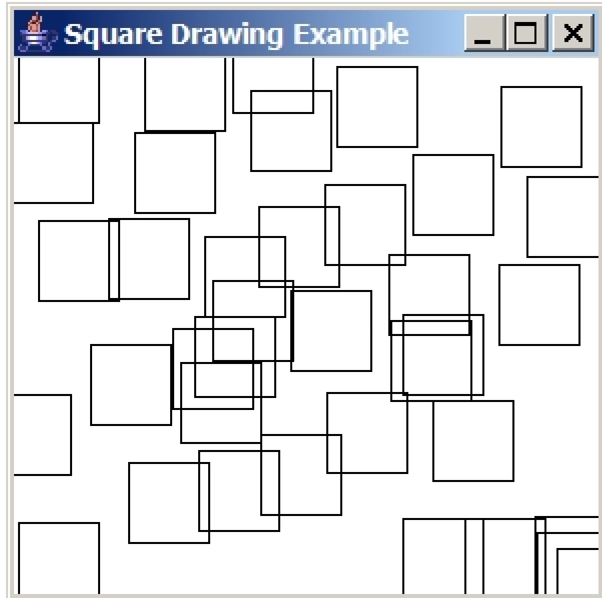
To add this functionality to our previous two examples, we would have to "keep track of" all the graphical shapes that we have been drawing (as well as their attributes, such as location, dimension and colour) so that in our `paintComponent()` method, we can redraw all of them properly each time.

The previous two examples showed how simple graphics can be drawn effortlessly on a frame or on a label. In fact, you can draw on any component. The component that is intended for general purpose drawing is a **JPanel**.

> Note in the older AWT framework of JAVA, a special class called a **Canvas** was used for drawing using a **paint()** method, not the **paintComponent()** method. **JPanel**s in the newer Swing library have all the capabilities of the old Canvas class built-in and should be used instead. In fact if the older **paint()** method is used you can expect bugs, so use the **JPanel**s and **paintComponent()** method instead.

The common strategy in JAVA for drawing on a blank area is to make your own class which is a subclass of **JPanel**. This class should implement, or override, the `paintComponent()` method. When we override this method however, we will be sure to call the **super** method so that the default drawing of the component still occurs.

**Example:**




In this example, we create a subclass of **JPanel** on which we will keep track of mouse click locations and draw 40x40 pixel squares centered at each of these locations. We will override the **`paintComponent()`** method so that the squares will be properly redrawn whenever we (or JAVA) call **`repaint()`** or when the window is resized. The application itself is not so exciting to look at, but rather the underlying concept of painting on the panel is what is important.

In this example, you may notice a couple of things:

- The **`getPoint()`** method is sent to a **MouseEvent** object to obtain the **`Point`** object representing the location that was clicked.
- Since all squares will be the same size, we don't store the size, just their center locations.

Here is the **SquareCanvas** class that does all the hard work:

```
import java.util.*;
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

// This class represents a panel on which 40x40 pixel squares can be drawn.
// The squares are centered around where the user clicks.
public class SquareCanvas extends JPanel implements MouseListener {

    // Keep track of all square center positions
    private ArrayList<Point>  squares;

    // Default constructor
    public SquareCanvas() {
        squares = new ArrayList<Point>();
        setBackground(Color.white);
        addMouseListener(this);
    }

    // This is the method that is responsible for displaying the contents of
the canvas
```

```java
    public void paintComponent(Graphics graphics) {
        // Draw the component as before (i.e., default look)
        super.paintComponent(graphics);

        // Now draw all of our squares
        graphics.setColor(Color.black);
        for (Point center: squares)
            graphics.drawRect(center.x - 20, center.y - 20, 40, 40);
    }

    // These are unused MouseEventHandlers.  Note that we could have
    // used an Adapter class here.  However, a typical drawing
    // application would make use of these other events as well.
    public void mouseClicked(MouseEvent event) {}
    public void mouseEntered(MouseEvent event) {}
    public void mouseExited(MouseEvent event) {}
    public void mouseReleased(MouseEvent event) {}

    // Store the mouse location when it is pressed
    public void mousePressed(MouseEvent event) {
        squares.add(event.getPoint());
        repaint(); // this will call paintComponent()
    }

    public static void main(String args[]) {
        JFrame frame = new JFrame("Square Drawing Example");
        frame.add(new SquareCanvas());
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.setSize(300, 300);
        frame.setVisible(true);
    }
}
```

Notice how we are redrawing the panel by first making a call to **super.paintComponent()**. This ensures that the panel's background is redrawn (i.e., erased) before we start drawing again. If we did not do this call, our squares would still be drawn, but the background color for the window (i.e., white in this case) would not be shown. We would end up with the light gray default background coloring of the **JFrame**.

## 8.3 Displaying Images

We have seen how to draw shapes of different colors onto components, now we will find out how to draw an image on the screen. JAVA lets you load and display both ".gif" files as well as ".jpg" files. We have seen the use of **ImageIcons** with components so that we can display an icon along with text or as a label of a button. Icons, however, are meant to be small images and are not meant for large images. When larger pictures are to be shown, you should use **Image** objects. In fact, the **Image** class is abstract, but there are two useful subclasses. In JAVA, there is much to learn about **Image** objects. There are many classes relating to the manipulation of images and a thorough investigation into these classes is well beyond the scope of this course.

Here, we will look simply at the basic displaying of images in our applications.

A typical scenario is to load and display an image (such as a .gif or .jpg) from a file. Unfortunately, the way images are obtained from files is a platform-specific issue. This means that it is not always done the same way, depending on what machine you run your code. Fortunately, JAVA supplies a **Toolkit** class that has common "special" methods for doing various platform-specific things such as loading images.

We can load an image from the disk by asking the **Toolkit** class for an instance of Toolkit (i.e., default will do fine) and then get the image as follows:

```
Image myImage = Toolkit.getDefaultToolkit().createImage("picture.gif");
```

The code loads and returns an **Image** object from the file entitled **picture.gif** but it does not display the image. We can then display the image by asking a **Graphics** object to draw the image:

```
g.drawImage(anImage, x, y, null);
```

The image is drawn with its top-left corner at (x, y) in this graphics context's coordinate space. The 4th parameter can be any class that implements the **ImageObserver** interface. This interface is used as a means of informing a class when an image is done being loaded or drawn (since images in general may take a while to load or draw ... especially if being loaded from a network). This strategy of informing interested classes of image completion, allows more efficient use of process cycles so that the program does not sit idly by doing nothing while the image is being loaded/drawn. We will keep things simple in our example and set this value to **null** so that nobody is informed when the image is loaded or drawn.

One final issue that we are interested in is with respect to the image size. We may want to create a **JPanel** that has the exact same size of the image (e.g., for use as a background image for the panel). In this case, we can ask an image for its width and height before choosing the size of our panel. There are **getWidth()** and **getHeight()** methods that we can send to our Image object to obtain these values. However, there is one minor issue. While the image is being loaded (which may take a while), the value returned from **getWidth()** and **getHeight()** is -1. So, we have to introduce a delay in our program by waiting until these methods return valid results:

```
while ((anImage.getWidth(null) == -1) && (anImage.getHeight(null)
== -1));
```

Notice as well that these methods take an ImageObserver as a parameter (which we set to null). By using a proper **ImageObserver,** we would not have to put in this delay, but could perform other application-specific tasks while we wait for the image to be loaded.

Now we may set the "preferred size" of the panel. Note that setting the "size" of the panel is not useful since when placed on a frame, the frame's layout manager will automatically resize all of its components.

```
    setPreferredSize(new Dimension(anImage.getWidth(null),
anImage.getHeight(null)));
```

So here is the code we can use to test:

```
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

// This application displays an image
public class ImagePanel extends JPanel {
    private Image anImage;

    public ImagePanel() {
        anImage =
Toolkit.getDefaultToolkit().createImage("altree.gif");

        while ((anImage.getWidth(null) == -1) &&
(anImage.getHeight(null) == -1));
        setPreferredSize(new Dimension(anImage.getWidth(null),
anImage.getHeight(null)));

    }

    public void paintComponent(Graphics g) {
        super.paintComponent(g);
        g.drawImage(anImage, 0, 0, null);
    }

    public static void main(String args[]) {
        JFrame frame = new JFrame("Image Display Test");
        frame.add(new ImagePanel());
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.pack();    // Makes size according to panel's
preference
        frame.setVisible(true);
    }
}
```

Here is the result:


Note that aince we used the panel's **paintComponent()** method to draw the image, the image is drawn as a background and so any components we add to the panel will appear on top of the image.   So you can see that it is quite easy to create a window as shown below simply by adding components to the panel as usual:


There are many more things that you can do with images:

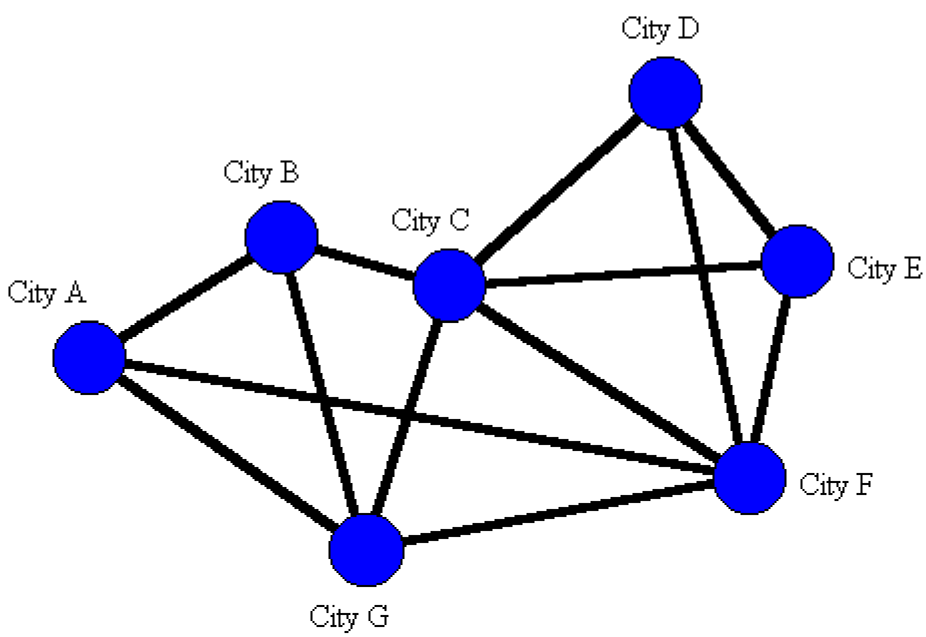
- Shrink/Grow them
- Fade them
- Warp them
- other filters ...

We do not have time to fully investigate these other features of the API library.   Feel free to experiment on your own.

## 8.4 Creating a Simple Graph Editor

This section of the notes describes a step-by-step approach for creating a simple graph editor.  It introduces the notion of "drag and drop" as well as selecting objects.

What is a graph ?  There are many types of graphs.  We are interested in graphs that form topological and/or spatial information.  Our graphs will consist of ***nodes*** and ***edges***.  The nodes may represent cities in a map while the edges may represent roads between cities:




We would like to make a graph editor with the ability to:

- add/remove nodes
- add/remove edges
- move nodes around (edges between them will remain connected)
- "select" groups of nodes and edges for removal or moving
- do some other useful graph-manipulation features

## The Graph Model:

We will begin our application as usual by developing the model.    We know that our graph itself is going to be the model, but we must first think about what components make up the graph. These are the nodes and edges.   We will first implement some basic **node** and **edge** classes.

Let us create a **Node** class. What ***state*** should each node maintain ? Well, it depends on the application that will be using it. Since we know that the graph will be displayed, each node will need to keep track of its **location**. Also, we may wish to **label** nodes (e.g., a city's name). Here is a basic model for the nodes:

```
import java.awt.Point;
public class Node  {
    private String    label;
    private Point     location;

    public Node() { this("",new Point(0,0)); }
    public Node(String aLabel) { this(aLabel, new Point(0,0)); }
    public Node(Point aPoint) { this("", aPoint); }
    public Node(String aLabel, Point aPoint) {
        label = aLabel;
        location = aPoint;
    }

    public String getLabel() { return label; }
    public Point getLocation() { return location; }

    public void setLabel(String newLabel) { label = newLabel; }
    public void setLocation(Point aPoint) { location = aPoint; }
    public void setLocation(int x, int y) { location = new
Point(x, y); }

    // Nodes look like this: label(12,43)
    public String toString() {
        return(label + "(" + location.x + "," + location.y +
")");
    }
}
```

Notice that we don't have much in terms of behaviour ... simply some get/set methods and a **toString()** method. Notice the two different set methods for location. This gives us flexibility in cases where we the coordinates are either **Point** objects or **ints**.

What state do we need for a graph edge ? Well ... they must *start* at some node and *end* at another so we may want to know which nodes these are. Does it make sense for a graph edge to exist when one or both of its endpoints are not nodes ? Probably not. So an edge should keep track of the node from which it starts and the node at which it ends. We will call them **startNode** and **endNode**. What about a label ? Sure ... roads have names (as well as lengths). Here is a basic **Edge** class:

```
public class Edge  {
    private String   label;
    private Node     startNode, endNode;

    public Edge(Node start, Node end) { this("", start, end); }
    public Edge(String aLabel, Node start, Node end) {
        label = aLabel;
        startNode = start;
```

```
            endNode = end;
        }

        public String getLabel() { return label; }
        public Node getStartNode() { return startNode; }
        public Node getEndNode() { return endNode; }

        public void setLabel(String newLabel) { label = newLabel; }
        public void setStartNode(Node aNode) { startNode = aNode; }
        public void setEndNode(Node aNode) { endNode = aNode; }

        // Edges look like this: sNode(12,43) --> eNode(67,34)
        public String toString() {
            return(startNode.toString() + " --> " +
    endNode.toString());
        }
    }
```

Now what about the graph itself ? What do we need for the state of the graph ?
Well ... a graph is just a bunch of nodes and edges.

Still, we have a few choices for representing the Graph:

1. Keep a collection of all nodes AND another collection of all edges
2. Keep only a collection of all nodes
3. Keep only a collection of all edges
4. Keep only 1 node OR 1 edge (this seems weird doesn't it ?)

Let us examine each of these:

1. The 1st strategy would provide quick access for nodes and edges since they are readily available. However, it does take more space than the other strategies.
2. The 2nd strategy allows quick access to nodes, but if we ever needed to get all the edges, we would have to build up the collection, which takes time. This can be done by iterating through all *incident edges* of all nodes and adding the edges (this is slower, but more space efficient). So each node would have to keep track of the edges from/to it.
3. The 3rd strategy is similar to the 2nd except that the edges are efficiently accessible and the nodes are not.
4. The 4th strategy is weird. If we keep one node, we would have to traverse along one of its *incident edges* to the other end and continue in this manner throughout the graph in order to collect all the nodes or edges. However, this will ONLY work if the graph is ***connected*** (i.e., every node can be reached from every other node through a sequence of graph edges).

We will choose the 2nd strategy for our implementation, although you should realize that all three are possible.

Let us examine our **Node** and **Edge** classes a little further and try to imagine additional behaviour that we may want to have.

Notice that each edge keeps track of the nodes that it connects to.  But shouldn't a node also keep track of the edges are connected to it ?  Think of "real life".  Wouldn't it be nice to know which roads lead "into" and "out of" a city ?  Obviously, we can always consult the graph itself and check ALL edges to see if they connect to a given city.  This is NOT what you would do if you had a map though.  You don't find this information out by looking at ALL roads on a map.  You find the city of interest, then look at the roads around that area (i.e., only the ones heading into/out of the city).

The point is ... for time efficiency reasons, we will probably want each node to keep track of the edges that it is connected to.  Of course, we won't make copies of these edges, we will just keep "pointers" to them so the additional memory usage is not too bad.

We should go back and add the following instance variable to the **Node** class:

```
private ArrayList<Edge>    incidentEdges;
```

We will also need the following get method and another for adding an edge:

```
public ArrayList<Edge> incidentEdges() { return incidentEdges; }
public void addIncidentEdge(Edge e) { incidentEdges.add(e); }
```

We will also have to add this line to the last of the **Node** constructors:

```
incidentEdges = new ArrayList<Edge>();
```

While we are making changes to the **Node** class, we will also add another interesting method called `neighbours` that returns the nodes that are connected to the receiver node by a graph edge.  That is, it will return an **ArrayList** of all nodes that share an edge with this receiver node. It is very much like asking: "which cities can I reach from this one if I travel on only one highway ?".

We can obtain these neighbours by iterating through the **incidentEdges** of the receiver and extracting the node at the other end of the edge.  We will have to determine if this other node is the start or end node of the edge:

```
public ArrayList<Node> neighbours() {
    ArrayList<Node> result = new ArrayList<Node>();
    for (Edge e: incidentEdges) {
        if (e.getStartNode() == this)
            result.add(e.getEndNode());
        else
            result.add(e.getStartNode());
    }
    return result;
}
```

As we write this method, it seems that we are writing a portion of code that is *potentially* useful for other situations.  That code is the code responsible for finding the opposite node of an edge. We should extract this code and make it a method for the **Edge** class:

```java
public Node otherEndFrom(Node aNode) {
    if (startNode == aNode)
        return endNode;
    else
        return startNode;
}
```
Now, we can rewrite the **neighbours()** method to use the **otherEndFrom()** method:

```java
public ArrayList<Node> neighbours() {
    ArrayList<Node> result = new ArrayList<Node>();
    for (Edge e: incidentEdges)
        result.add(e.otherEndFrom(this));
    return result;
}
```

Ok. Now we will look at the **Graph** class. We have decided that we were going to store just the nodes, and not the edges. We will also store a label for the graph ... after all ... provinces have names don't they ?

```java
import java.util.*;
public class Graph  {
    private String            label;
    private ArrayList<Node>   nodes;

    public Graph() { this("", new ArrayList<Node>()); }
    public Graph(String aLabel) { this(aLabel, new ArrayList<Node>()); }
    public Graph(String aLabel, ArrayList<Node> initialNodes) {
        label = aLabel;
        nodes = initialNodes;
    }
    public ArrayList<Node> getNodes() { return nodes; }
    public String getLabel() { return label; }
    public void setLabel(String newLabel) { label = newLabel; }

    // Graphs look like this: label(6 nodes, 15 edges)
    public String toString() {
        return(label + "(" + nodes.size() + " nodes, " +
               getEdges().size() + " edges)");
    }
}
```

Let us write a method to return all the edges of the graph. It will have to go and collect all the **Edge** objects from the incident edges of the **Node** objects and return them as an **ArrayList**. Can you foresee a small problem ?

```java
// Get all the edges of the graph by asking the nodes for them
public ArrayList<Edge> getEdges() {
    ArrayList<Edge>  edges = new ArrayList<Edge>();
    for (Node n: nodes) {
        for (Edge e: n.incidentEdges()) {
            if (!edges.contains(e)) //so that it is not added twice
                edges.add(e);
        }
    }
    return edges;
}
```

Now we need methods for adding/removing nodes/edges. Adding a node or edge is easy, assuming that we already have the node or edge:

```
public void addNode(Node aNode) { nodes.add(aNode); }

public void addEdge(Edge anEdge) {
    // ??????  What ?????? ...
}
```

Wait a minute ! How do we add an edge if we do not store them explicitly ? Perhaps we don't want an **addEdge** method that takes an "already created" edge. Instead, we should have an **addEdge** method that takes the **startNode** and **endNode** as parameters, then it creates the edge:

```
public void addEdge(Node start, Node end) {
    // First make the edge
    Edge anEdge = new Edge(start, end);

    // Now tell the nodes about the edge
    start.addIncidentEdge(anEdge);
    end.addIncidentEdge(anEdge);
}
```

There ... that is better. What about removing/deleting a node or edge ? Deleting an **Edge** is easy, we just ask the edge's start and end nodes to remove the edge from their lists. Removing a **Node** is a little more involved since all of the incident edges must be removed as well. After all ... we cannot have edges dangling with one of its **Nodes** missing !

```
public void deleteEdge(Edge anEdge) {
    // Just ask the nodes to remove it
    anEdge.getStartNode().incidentEdges().remove(anEdge);
    anEdge.getEndNode().incidentEdges().remove(anEdge);
}

public void deleteNode(Node aNode) {
    // Remove the opposite node's incident edges
    for (Edge e:   aNode.incidentEdges())
        e.otherEndFrom(aNode).incidentEdges().remove(e);
    nodes.remove(aNode); // Remove the node now
}
```

OK. Let us write some code that now tests the model classes. Here is **static** method for the **Graph** class that creates and returns a graph:

```
public static Graph example() {
    Graph    myMap = new Graph("Ontario and Quebec");
    Node     ottawa, toronto, kingston, montreal;

    myMap.addNode(ottawa = new Node("Ottawa", new Point(250,100)));
    myMap.addNode(toronto = new Node("Toronto", new Point(100,170)));
    myMap.addNode(kingston = new Node("Kingston", new Point(180,110)));
    myMap.addNode(montreal = new Node("Montreal", new Point(300,90)));
    myMap.addEdge(ottawa, toronto);
    myMap.addEdge(ottawa, montreal);
    myMap.addEdge(ottawa, kingston);
    myMap.addEdge(kingston, toronto);
```

```
    return myMap;
}
```

We can test it by writing **Graph.example()** anywhere. This looks fine and peachy, but if we have 100 nodes, we would need 100 local variables (or a big array) just for the purpose of adding edges !! Maybe this would be a better way to write the code:

```
public static Graph example() {
    Graph    myMap = new Graph("Ontario and Quebec");

    myMap.addNode(new Node("Ottawa", new Point(250,100)));
    myMap.addNode(new Node("Toronto", new Point(100,120)));
    myMap.addNode(new Node("Kingston", new Point(200,130)));
    myMap.addNode(new Node("Montreal", new Point(300,70)));
    myMap.addEdge("Ottawa", "Toronto");
    myMap.addEdge("Ottawa", "Montreal");
    myMap.addEdge("Ottawa", "Kingston");
    myMap.addEdge("Kingston", "Toronto");

    return myMap;
}
```

This way, we can access the nodes of the graph by their names (assuming that they are all unique names). How can we make this happen ? We just need to make another **addEdge()** method that takes two **String** arguments and finds the nodes that have those labels. Perhaps we could make a nice little helper method in the **Graph** class that will find a node with a given name (label):

```
public Node nodeNamed(String aLabel) {
    for (Node n:  nodes)
        if (n.getLabel().equals(aLabel)) return n;
    return null; // If we don't find one
}
```

Now we can write another **addEdge()** method that takes **String** parameters representing **Node** names:

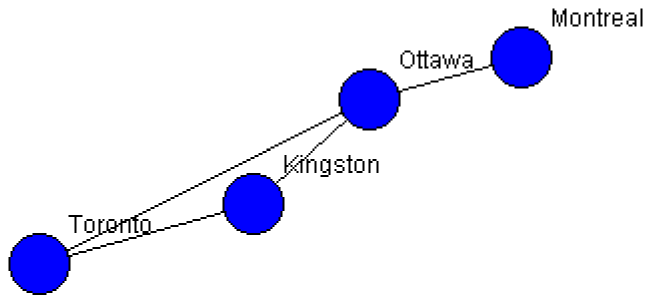
```
public void addEdge(String startLabel, String endLabel) {
    Node start = nodeNamed(startLabel);
    Node end = nodeNamed(endLabel);

    if ((start != null) && (end != null))
        addEdge(start, end);
}
```

Notice the way we share code by making use of the "already existing" **addEdge()** method. Also notice the careful checking for valid node labels. After this new addition, the 2nd **main()** method that we created above will now work.

---

## Displaying the Graph:

If we are going to be displaying the graph, we need to think about how we want to draw it. Here is what we "may" want to see:




So where do we start ? Let us work on writing code that draws each of the graph components separately. We will start by writing methods for drawing **Nodes** and **Edges,** then use these to draw the **Graph.** We can pass around the **Graphics** object that corresponds to the "pen" that belongs to the panel.

Here is a method for the **Node** class that will instruct a **Node** to draw itself using the given **Graphics** object:

```
public void draw(Graphics aPen) {
    int    radius = 15;

    // Draw a blue-filled circle around the center of the node
    aPen.setColor(Color.blue);
    aPen.fillOval(location.x - radius, location.y - radius,
radius * 2, radius * 2);

    // Draw a black border around the circle
    aPen.setColor(Color.black);
    aPen.drawOval(location.x - radius, location.y - radius,
radius * 2, radius * 2);

    // Draw a label at the top right corner of the node
    aPen.drawString(label, location.x + radius, location.y -
radius);
}
```

Notice that we draw the node twice ... once for the blue color ... once for the black border.
Here is now a similar method for the **Edge** class that draws an edge:

```
public void draw(Graphics aPen) {
    // Draw a black line from the center of he startNode to the center of the
endNode
    aPen.setColor(Color.black);
    aPen.drawLine(startNode.getLocation().x, startNode.getLocation().y,
                  endNode.getLocation().x, endNode.getLocation().y);
}
```

When drawing the graph, we should draw edges first, then draw the nodes on top. Why not the other way around ? Here is the corresponding draw method for the **Graph** class:

```
public void draw(Graphics aPen) {
    ArrayList<Edge>    edges = getEdges();

    for (Edge e: edges)  // Draw the edges first
        e.draw(aPen);
    for (Node n: nodes)  // Draw the nodes second
```

```
        n.draw(aPen);
}
```

---

## The User Interface:

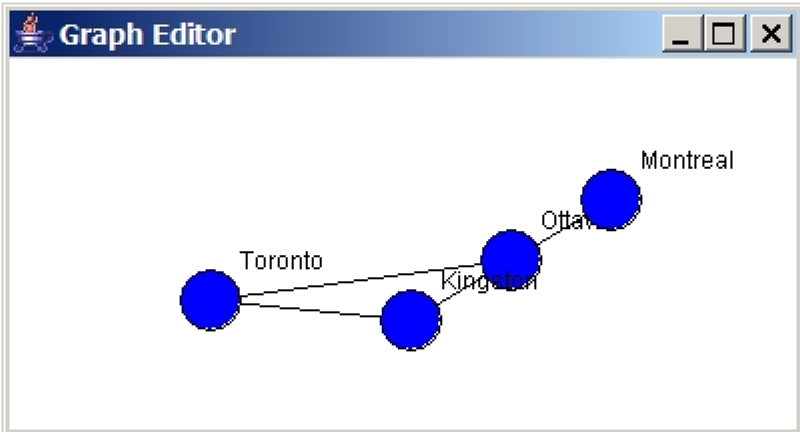
Now we can start the creation of our **GraphEditor** user interface. We will begin by making a panel on which we will display the graph:

```
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;
public class GraphEditor extends JPanel {
    private Graph  aGraph;  // The model (i.e. the graph)

    public GraphEditor() { this(new Graph()); }
    public GraphEditor(Graph g) {
        aGraph = g;
        setBackground(Color.white);
    }

    // This is the method that is responsible for displaying the graph
    public void paintComponent(Graphics aPen) {
        super.paintComponent(aPen);
        aGraph.draw(aPen);
    }
}
```

Now we will make a class called **GraphEditorFrame** that represents a simple view which holds only our **GraphEditor** panel:

```
import javax.swing.*;
public class GraphEditorFrame extends JFrame {
    private GraphEditor  editor;

    public GraphEditorFrame (String title) { this(title, new Graph()); }
    public GraphEditorFrame (String title, Graph g) {
        super(title);
        add(editor = new GraphEditor(g));
        setDefaultCloseOperation(EXIT_ON_CLOSE);
        setSize(600, 400);
    }

    public static void main(String args[]) {
        new GraphEditorFrame("Graph Editor",
Graph.example()).setVisible(true);
    }
}
```

Notice that we can run the example by running the **GraphEditorFrame** class. Our example Ontario/Quebec graph comes up right away ! This is because the **`paintComponent()`** method of **`GraphEditor()`** class is called upon startup.




# Manipulating Nodes:

What kind of action should the user perform to add a node to the graph ? There are many possibilities (i.e., menu options, buttons, mouse clicks). We will allow nodes to be added to the graph via double clicks of the mouse. When the user double-clicks on the panel, a new node will be added at that click location. We must have the **GraphEditor** class implement the ***MouseListener*** interface. When we receive a click count of 2 on a **mouseClick** event, we will add the node at that location. For now, we will leave the other mouse listeners blank:

```
public void mouseClicked(MouseEvent event) {
    // If this was a double-click, then add a node at the mouse
location
    if (event.getClickCount() == 2) {
        aGraph.addNode(new Node(event.getPoint()));
        // We have changed the model, so now we update
        update();
    }
}
public void mousePressed(MouseEvent event) { }
public void mouseReleased(MouseEvent event) { }
public void mouseEntered(MouseEvent event) { }
public void mouseExited(MouseEvent event) { }
```

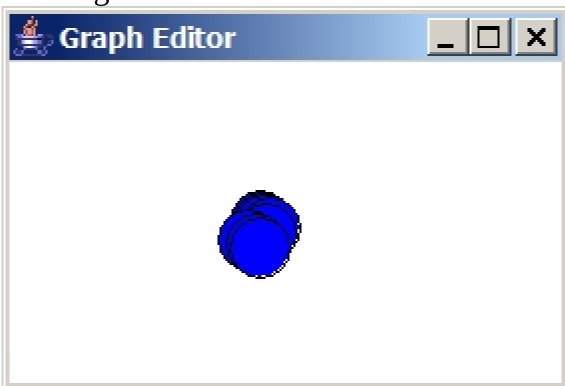
Of course, we will have to add the **MouseListener** in the constructor. We will do this by calling **addEventHandlers()** which we will be adding to later on:

```
public void addEventHandlers() {
    addMouseListener(this);
}
public void removeEventHandlers() {
    removeMouseListener(this);
}
```

The **update()** method itself is quite simple since there is only one component on the window ! It merely calls **`repaint()`** after temporarily disabling the event handlers:

```
public void update() {
    removeEventHandlers();
    repaint();
    addEventHandlers();
}
```

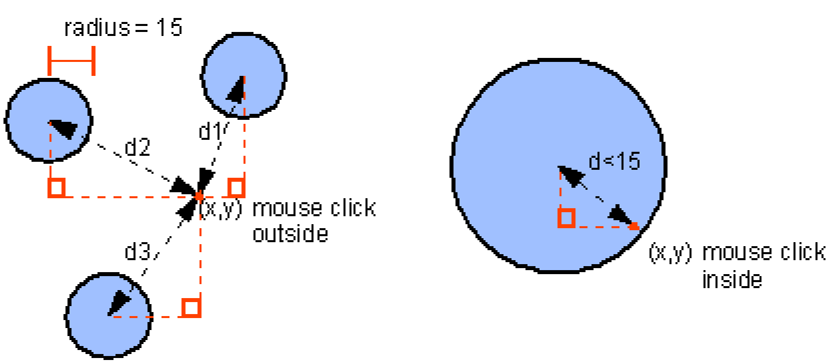
If we run our code, we will notice something that is not so pleasant.   Our strategy of using the double click allows us to add nodes on top of each other, making them possibly indistinguishable:




Perhaps instead of having nodes lying on top of each other, we could check to determine whether or not the user clicks within a node.  Then we can decide to "not add" the node if there is already one there.  What do we do then ... ignore the click ?  Maybe we should cause the node to be somehow "selected" so that we can move it around.  To do this, we will need to add functionality that allows nodes to be selected and unselected.

If we attempt to re-select an "already selected" node, it should probably become unselected (i.e., toggle on/off).  We should make the node appear different as well (perhaps red).  We will need to detect which node has been selected.  This sounds like it could be a nice little helper method in the **Graph** class.

We can just check the distance from the given point to the center of all nodes.  If the distance is <= the radius, then we are inside that node.




In fact, we are not really computing the distance, we are computing the square of the distance.  This is more efficient since we do not need to compute the root.

```
// Return the first node in which point p is contained, if none, return null
public Node nodeAt(Point p) {
    for (Node n:  nodes) {
        Point c = n.getLocation();
        int d = (p.x - c.x) * (p.x - c.x) + (p.y - c.y) * (p.y - c.y);
        if (d <= (15*15)) return n;
    }
```

```
    return null;
}
```

The 15 looks like a "magic" number. It seems like this number may be used a lot. We should define a static constant in the **Node** class. Go back and change the draw method as well to use this new static value:

```
      public static int    RADIUS = 15;
```

Here is the better code:

```
// Return the first node in which point p is contained, if none, return null
public Node nodeAt(Point p) {
    for (Node n:  nodes) {
        Point c = n.getLocation();
        d = (p.x - c.x) * (p.x - c.x) + (p.y - c.y) * (p.y - c.y);
        if (d <= (Node.RADIUS * Node.RADIUS)) return n;
    }
    return null;
}
```

We should go back into our drawing routines and adjust the code so that it uses this new RADIUS constant.

Now since we are allowing **Nodes** to be selected, we will have to somehow keep track of all the selected nodes. We have two choices:

- Let the graph keep track of the selected nodes separately
- Let each node keep track of whether or not it is selected

We will choose the second strategy (do you understand the tradeoffs of each ?).
Add the following instance variable and methods to the **Node** class:

```
private boolean    selected;

public boolean isSelected() { return selected; }
public void setSelected(boolean state) { selected = state; }
public void toggleSelected() { selected = !selected; }
```

Now we should modify the draw method to allow nodes to be selected and unselected:

```
public void draw(Graphics aPen) {

    // Draw a blue or red-filled circle around the center of the node
    if (selected)
        aPen.setColor(Color.red);
    else
        aPen.setColor(Color.blue);
    aPen.fillOval(location.x-RADIUS, location.y-RADIUS, RADIUS*2, RADIUS*2);

    // Draw a black border around the circle
    aPen.setColor(Color.black);
    aPen.drawOval(location.x-RADIUS, location.y-RADIUS, RADIUS*2, RADIUS*2);

    // Draw a label at the top right corner of the node
    aPen.drawString(label, location.x + radius, location.y - radius);
```

```
}
```

Of course, now to make it all work, we must use it in the mouseClicked event handler:

```
public void mouseClicked(MouseEvent event) {
    // If this was a double-click, then add a node at the mouse location
    if (event.getClickCount() == 2) {
        Node     aNode = aGraph.nodeAt(event.getPoint());
        if (aNode == null)
            aGraph.addNode(new Node(event.getPoint()));
        else
            aNode.toggleSelected();
        // We have changed the model, so now we update
        update();
    }
}
```

Now how do we allow nodes to be deleted ? Perhaps, the user must select the node(s) first and then hit the **delete** key. Perhaps when the **delete** key is pressed, ALL of the currently selected nodes should be deleted. So we will make a method that first returns all the selected nodes. We will need to add this method to the **Graph** class which returns a vector of all the selected nodes:

```
// Get all the nodes that are selected
public ArrayList<Node> selectedNodes() {
    ArrayList<Node>   selected = new ArrayList<Node>();
    for (Node n:  nodes)
        if (n.isSelected()) selected.add(n);
    return selected;
}
```

We already took care of the node selection, now we must handle the **delete** key. We should have the **GraphEditor** implement the **KeyListener** interface.

```
public void addEventHandlers() {
    addMouseListener(this);
    addKeyListener(this);
}
public void removeEventHandlers() {
    removeMouseListener(this);
    removeKeyListener(this);
}

      public void keyTyped(KeyEvent event) {}
      public void keyReleased(KeyEvent event) {}

      public void keyPressed(KeyEvent event) {
          if (event.getKeyCode() == KeyEvent.VK_DELETE) {
              for (Node n:  aGraph.selectedNodes())
                      aGraph.deleteNode(n);
              update();
          }
      }
```

There is a SLIGHT problem. It seems that even though we have only one component in our window (i.e., the **JPanel** which is the **GraphEditor** itself), this component does not have the focus by default. In order for the keystrokes to be detectable, the component MUST have the focus. So we will add the following line to the beginning of the **update()** method:

```
public void update() {
    requestFocus();  // Need this for handling KeyPress
    removeEventHandlers();
    repaint();
    addEventHandlers();
}
```

Now, how can we move nodes around once they are created ? Once again, we must decide how we want the interface to work. It is most natural to allow the user to move nodes by pressing the mouse down while on top of a node and holding it down while dragging the node to the new location, then release the mouse button to cause the node to appear in the new location. We will need the mousePressed and mouseDragged events of the **MouseListener** and **MouseMotionListener** interfaces, respectively. Here is what we will have to do:

- When the user presses the mouse (i.e., a "press", not a "click"), then determine if he/she pressed on top of a node.
- If yes, then remember this node as being the one selected, otherwise do nothing
- As the mouse moves (while button being held down), we must update the chosen node's location

We will have to remember which node is being dragged so that we can keep changing its location as the mouse is dragged. We will add an instance variable called **dragNode** to keep this node.

```
 private Node   dragNode;
```

Here are the mousePressed , mouseDragged and mouseReleased event handlers:

```
// Mouse press event handler
public void mousePressed(MouseEvent event) {
    // First check to see if we are about to drag a node
    Node   aNode = aGraph.nodeAt(event.getPoint());
    if (aNode != null) {
        // If we pressed on a node, store it
        dragNode = aNode;
    }
}

// Mouse drag event handler
public void mouseDragged(MouseEvent event) {
    if (dragNode != null)
        dragNode.setLocation(event.getPoint());

    // We have changed the model, so now update
    update();
}

// Mouse release event handler (i.e. stop dragging process)
public void mouseReleased(MouseEvent event) {
    dragNode = null;
}
```

Notice that the pressing of the mouse merely stores the node to be moved. The releasing of the mouse button merely resets this stored node to **null**. All of the moving occurs in the dragging event handler. If we drag the mouse, we just make sure that we had first clicked on a node by examining the stored node just mentioned. If this stored node is not **null**, we then update its position and then update the rest of the graph.

Notice that all the edges connected to a node move along with the node itself. Can you explain why ?

---

# Manipulating Edges:

We have exhausted almost all the fun out of manipulating the graph nodes and we are now left with the "fun" of adding/deleting/selecting and moving edges. First we will consider adding edges. We must decide again on what action the user needs to perform in order to add the edge:

1. We can have the user double-click on the **startNode**, double click on the **endNode** and then have the edge magically appear.
2. We can select any two nodes of the graph and then perform some magic action (menu item, button press, triple click) to cause an edge to appear between the two selected edges.
3. We can click on a node and then drag the mouse to the destination node while showing the created edge as we go.

I hope you will agree that the 3rd approach is nicer in that it is more intuitive and provides the user with a nice user-friendly interface. We will see that this strategy is called ***elastic banding***.

To start, we will need to make the following assumptions:

- When the user presses and holds the mouse button down on a node, this node becomes the **startNode** for the edge to be created.
- As the user moves the mouse (i.e., **mouseDragged** event) a line should be drawn from this **startNode** to the current mouse position.
- When the user lets go of the mouse button on top of a different node, an edge is created between the two.
- We should abort the process of adding an edge if the user releases the mouse button while: a) not on a node or b) on the same node as he/she started.

We will have to modify the `mousePressed` , `mouseDragged` and `mouseReleased` methods.

As it turns out, the `mousePressed` event handler already stores the "start" node in the **dragNode** variable. But now look at the `mouseDragged` event handler. Currently, if we press the mouse on a node and then drag it, this will end up causing the node to be moved. But we need to allow an elastic band edge to be drawn instead of moving the node. So, we now have two behaviours that we want to do from the same action of pressing the mouse on a node. This presents a conflict since we cannot do both behaviours. Let us modify our node-moving behaviour as follows:

- If the node initially clicked on is a **selected** node, then we will move it, otherwise we will assume that an edge is to be added.

The `mousePressed` event handler currently just stores the selected node. There is really nothing more to do there.

But now during the `mouseDragged` event handler, we will have to make a decision so as to either move the node (if it was a selectedNode) or to merely draw an edge from the pressed node to the current mouse location. We cannot however, do the drawing within this method. Why ? Well, our **`paintComponent()`** method does the drawing and will draw over any of our drawing done here!! The drawing doesn't belong here. Drawing should happen in the **`paintComponent()`** method ONLY. All we will do here is just store the current mouse location in an **elasticEndLocation** variable and use it within the **`paintComponent()`** method. Here are the new changes:

```
// Mouse drag event handler
public void mouseDragged(MouseEvent event) {
    if (dragNode != null) {
        if (dragNode.isSelected())
            dragNode.setLocation(event.getPoint());
        else
            elasticEndLocation = event.getPoint();
    }
    // We have changed the model, so now update
    update();
}
```

Here is the updated **`paintComponent()`** method for the **GraphEditor** class:

```
// This is the method that is responsible for displaying the graph
public void paintComponent(Graphics aPen) {
    super.paintComponent(aPen);
    aGraph.draw(aPen);
    if (dragNode != null)
        if (!dragNode.isSelected())
            aPen.drawLine(dragNode.getLocation().x, dragNode.getLocation().y,
                          elasticEndLocation.x, elasticEndLocation.y);
}
```

Notice that this method makes use of the **dragNode** and **elasticEndLocation** variables but still needs to decide whether or not to draw the elastic band line. We draw the elastic line ONLY if we are adding an edge. How do we know we are adding an edge ? Well, we must have pressed on a starting node, so the **dragNode** must not be **null**. Also, that **dragNode** must not be selected, otherwise we are in the middle of a "node moving" operation, not an "edge adding" one.

Our last piece to this trilogy of event handler changes is to have the **mouseReleased** event handler add the new edge ONLY if we let go of the mouse button on top of a node that is not the same as the one we started with. If it is, or we let go somewhere off a node, then we must repaint everything either way to erase the elastic band:

```
// Mouse released event handler (i.e., stop dragging process)
public void mouseReleased(MouseEvent event) {
    // Check to see if we have let go on a node
```

```
            Node    aNode = aGraph.nodeAt(event.getPoint());
            if ((aNode != null) && (aNode != dragNode))
                aGraph.addEdge(dragNode, aNode);

            // Refresh the panel either way
            dragNode = null;
            update();
        }
```

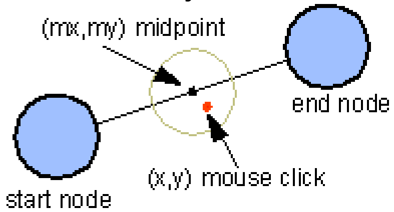
One of our last tasks is to allow edges to be selected and removed. We can similarly add an instance variable and methods to the edge class:

```
private boolean   selected;

public boolean isSelected() { return selected; }
public void setSelected(boolean state) { selected = state; }
public void toggleSelected() { selected = !selected; }
```

Of course ... again we must initialize the instance variable in the constructor. Now we make selected edges appear different (i.e., red).

```
// Draw the edge using the given Graphics object
public void draw(Graphics aPen) {
    // Draw a black or red line from the center of the startNode to the
center of the endNode
    if (selected)
        aPen.setColor(Color.red);
    else
        aPen.setColor(Color.black);
    aPen.drawLine(startNode.getLocation().x, startNode.getLocation().y,
                  endNode.getLocation().x, endNode.getLocation().y);
}
```

To see if an edge has been selected, we will have to decide on where we should click. Perhaps near the midpoint of the edge. But how accurate must we be ? We should allow some tolerance. Maybe a tolerance roughly equivalent to the node's radius is acceptable.




Add the following method to the **Graph** class:

```
// Return the first edge in which point p is near the midpoint; if none,
return null
public Edge edgeAt(Point p) {
    int      midPointX, midPointY;

    for (Edge e:  getEdges()) {
        mX = (e.getStartNode().getLocation().x +
              e.getEndNode().getLocation().x) / 2;
        mY = (e.getStartNode().getLocation().y +
              e.getEndNode().getLocation().y) / 2;
        int distance = (p.x - mX) * (p.x - mX) +
                       (p.y - mY) * (p.y - mY);
        if (distance <= (Node.RADIUS * Node.RADIUS))
```

```
            return e;
    }
    return null;
}
```

Now, upon a double click, we must check for edges. We will first check to see if we clicked on a Node, then if we find that we did not click on a Node, we will check to see if we clicked on an Edge:

```
public void mouseClicked(MouseEvent event) {
    // If this was a double-click, then add/select a node or select an edge
    if (event.getClickCount() == 2) {
        Node aNode = aGraph.nodeAt(event.getPoint());
        if (aNode == null) {
            // We missed a node, now try for an edge midpoint
            Edge anEdge = aGraph.edgeAt(event.getPoint());
            if (anEdge == null)
                aGraph.addNode(new Node(event.getPoint()));
            else
                anEdge.toggleSelected();
        }
        else
            aNode.toggleSelected();

        // We have changed the model, so now we update
        update();
    }
}
```

We can change the keyPressed event handler to delete all selected **Nodes** AND **Edges**. Of course, we will need a method to get the selectedEdges first:

```
// Get all the edges that are selected
public ArrayList<Edge> selectedEdges() {
    ArrayList<Edge>   selected = new ArrayList<Edge>();
    for (Edge e:  getEdges())
        if (e.isSelected()) selected.add(e);
    return selected;
}

public void keyPressed(KeyEvent event) {
    if (event.getKeyCode() == KeyEvent.VK_DELETE) {
        // First remove the selected edges
        for (Edge e:  aGraph.selectedEdges())
            aGraph.deleteEdge(e);

        // Now remove the selected nodes
        for (Node n:  aGraph.selectedNodes())
            aGraph.deleteNode(n);
        update();
    }
}
```

## 8.5 Adding Features to the Graph Editor

We have implemented a basic graph editor. There are many features that can be added. Below are solutions to some added features to the **GraphEditor.** You may want to try to add these features yourself without looking at the solutions.

## Dragging Edges

- Add the following two instance variables to the **GraphEditor** class:

```
private Edge    dragEdge;
private Point   dragPoint;
```

- Add code to the **mousePressed** event handler in the **GraphEditor** class to store the edge to be dragged

```
public void mousePressed(MouseEvent event) {
    // First check to see if we are about to drag a node
    Node   aNode = aGraph.nodeAt(event.getPoint());
    if (aNode != null) {
        // If we pressed on a node, store it
        dragNode = aNode;
    }
    else
        dragEdge = aGraph.edgeAt(event.getPoint());
    dragPoint = event.getPoint();
}
```

- Add code to the **mousePressed** event handler in the **GraphEditor** class to store the edge to be dragged

```
public void mouseDragged(MouseEvent event) {
    if (dragNode != null)  {
        if (dragNode.isSelected())
            dragNode.setLocation(event.getPoint());
        else
            elasticEndLocation = event.getPoint();
    }
    if (dragEdge != null) {
        if (dragEdge.isSelected()) {
            dragEdge.getStartNode().getLocation().translate(
                    event.getPoint().x - dragPoint.x,
                    event.getPoint().y - dragPoint.y);
            dragEdge.getEndNode().getLocation().translate(
                    event.getPoint().x - dragPoint.x,
                    event.getPoint().y - dragPoint.y);
            dragPoint = event.getPoint();
        }
    }

    // We have changed the model, so now update
    update();
}
```

## Moving Groups of Vertices/Edges

- Add the following instance variable to the **GraphEditor** class:

```
private Point   dragPoint;
```

- Add the following line at the bottom of the **mousePressed** event handler in the **GraphEditor** class:

```
dragPoint = event.getPoint();
```

- In the **mouseDragged** event handler for the **GraphEditor** class, change

```
if (dragNode != null)  {
    if (dragNode.isSelected())
        dragNode.setLocation(event.getPoint());
    else
        elasticEndLocation = event.getPoint();
}
```

to this:

```
if (dragNode != null)  {
    if (dragNode.isSelected()) {
        for (Node n:  aGraph.selectedNodes()) {
            n.getLocation().translate(
                event.getPoint().x - dragPoint.x,
                event.getPoint().y - dragPoint.y);
        }
        dragPoint = event.getPoint();
    }
    else
        elasticEndLocation = event.getPoint();
}
```

## Drawing Selected Edges with Different Thicknesses

- Add the following instance variable to the **Edge** class:

```
public static final int    WIDTH = 7;
```

- Modify the **draw()** method in the **Edge** class:

```
public void draw(Graphics aPen) {
    if (selected) {
        aPen.setColor(Color.RED);
        int xDiff =
Math.abs(startNode.getLocation().x -
endNode.getLocation().x);
        int yDiff =
Math.abs(startNode.getLocation().y -
```

```
        endNode.getLocation().y);
                for (int i= -WIDTH/2; i<=WIDTH/2; i++) {
                    if (yDiff > xDiff)

        aPen.drawLine(startNode.getLocation().x+i,
        startNode.getLocation().y,

        endNode.getLocation().x+i, endNode.getLocation().y);
                    else

        aPen.drawLine(startNode.getLocation().x,
        startNode.getLocation().y+i,
                                     endNode.getLocation().x,
        endNode.getLocation().y+i);
                }
            }
            else {
                aPen.setColor(Color.black);
                aPen.drawLine(startNode.getLocation().x,
        startNode.getLocation().y,
                               endNode.getLocation().x,
        endNode.getLocation().y);
            }

        }
```

## Loading and Saving Graphs

- Add the following methods to the **Node** class:

```
    // Save the node to the given file.  Note that the incident
edges are not saved.
    public void saveTo(PrintWriter aFile) {
        aFile.println(label);
        aFile.println(location.x);
        aFile.println(location.y);
        aFile.println(selected);
    }

    // Load a node from the given file.  Note that the incident
edges are not connected
    public static Node loadFrom(BufferedReader aFile) throws
IOException {
        Node   aNode = new Node();

        aNode.setLabel(aFile.readLine());
        aNode.setLocation(Integer.parseInt(aFile.readLine()),
                          Integer.parseInt(aFile.readLine()));

aNode.setSelected(Boolean.valueOf(aFile.readLine()).booleanValue(
));
        return aNode;
    }
```

- Add the following methods to the **Edge** class:

```
// Save the edge to the given file.  Note that the
nodes themselves are not saved.
// We assume here that node locations are unique
identifiers for the nodes.
public void saveTo(PrintWriter aFile) {
    aFile.println(label);
    aFile.println(startNode.getLocation().x);
    aFile.println(startNode.getLocation().y);
    aFile.println(endNode.getLocation().x);
    aFile.println(endNode.getLocation().y);
    aFile.println(selected);
}

// Load an edge from the given file.  Note that the
nodes themselves are not loaded.
// We are actually making temporary nodes here that
do not correspond to the actual
// graph nodes that this edge connects.  We'll have
to throw out these TEMP nodes later
// and replace them with the actual graph nodes that
connect to this edge.
public static Edge loadFrom(BufferedReader aFile)
throws IOException {
    Edge    anEdge;
    String  aLabel = aFile.readLine();
    Node    start = new Node("TEMP");
    Node    end = new Node("TEMP");


start.setLocation(Integer.parseInt(aFile.readLine()),

Integer.parseInt(aFile.readLine()));

end.setLocation(Integer.parseInt(aFile.readLine()),

Integer.parseInt(aFile.readLine()));
    anEdge = new Edge(aLabel, start, end);

anEdge.setSelected(Boolean.valueOf(aFile.readLine()).
booleanValue());

    return anEdge;
}
```

- Add the following methods to the **Graph** class:

```
// Save the graph to the given file.
public void saveTo(PrintWriter aFile) {
    aFile.println(label);

    // Output the nodes
    aFile.println(nodes.size());
    for (Node n:  nodes)
        n.saveTo(aFile);

    // Output the edges
```

```java
        ArrayList<Edge> edges = getEdges();
        aFile.println(edges.size());
        for (Edge e:  edges)
            e.saveTo(aFile);
    }

    // Load a Graph from the given file.  After the nodes and 
edges are loaded,
    // We'll have to go through and connect the nodes and edges 
properly.
    public static Graph loadFrom(BufferedReader aFile) throws 
IOException {
        // Read the label from the file and make the graph
        Graph    aGraph = new Graph(aFile.readLine());

        // Get the nodes and edges
        int numNodes = Integer.parseInt(aFile.readLine());
        for (int i=0; i<numNodes; i++)
            aGraph.addNode(Node.loadFrom(aFile));

        // Now connect them with new edges
        int numEdges = Integer.parseInt(aFile.readLine());
        for (int i=0; i<numEdges; i++) {
            Edge tempEdge = Edge.loadFrom(aFile);
            Node start = 
aGraph.nodeAt(tempEdge.getStartNode().getLocation());
            Node end = 
aGraph.nodeAt(tempEdge.getEndNode().getLocation());
            aGraph.addEdge(start, end);
        }

        return aGraph;
    }
```

- Change the **GraphEditorFrame** class definition to implement the **ActionListener** interface:

```java
public class GraphEditorFrame extends JFrame
implements ActionListener
```

- Add the following methods to the **GraphEditor** class:

```java
public Graph getGraph() { return aGraph; }
public void setGraph(Graph g) { aGraph = g; update(); }
```

- Add the following to the constructor of the **GraphEditorFrame** class:

```java
JMenuBar menubar = new JMenuBar();
setJMenuBar(menubar);
JMenu file = new JMenu("File");
menubar.add(file);
JMenuItem load = new JMenuItem("Load");
JMenuItem save = new JMenuItem("Save");
file.add(load);
```

```
file.add(save);
load.addActionListener(this);
save.addActionListener(this);
```

- Add the following event handler to the **GraphEditorFrame** class:

```
public void actionPerformed(ActionEvent e) {
    JFileChooser chooser = new JFileChooser();
    if (e.getActionCommand().equals("Load")) {
        int returnVal = chooser.showOpenDialog(this);

        if (returnVal == JFileChooser.APPROVE_OPTION) {
            try {
                editor.setGraph(Graph.loadFrom(new
java.io.BufferedReader(
                        new
java.io.FileReader(chooser.getSelectedFile().getAbsoluteFile())))
);
            }
            catch (Exception ex) {
                JOptionPane.showMessageDialog(null,
                        "Error Loading Graph From File !",
                        "Error",
                        JOptionPane.ERROR_MESSAGE);
            }
        }
    }
    else {
        int returnVal = chooser.showSaveDialog(null);

        if (returnVal == JFileChooser.APPROVE_OPTION) {
            try {
                editor.getGraph().saveTo(new
java.io.PrintWriter(
                        new
java.io.FileWriter(chooser.getSelectedFile().getAbsoluteFile())))
;
            }
            catch (java.io.IOException ex) {}
        }
    }
}
```

## Other Features:

There are also other features we can add.   Feel free to experiment with the graph editor:

- showing labels on edges
- adjusting labels so that they don't overlap
- scaling (growing or shrinking) of the graph
- repositioning and resizing the graph so that it always fits in the window, even when the window is reduced.