Advanced Programming

Graphical User Interface (GUI)

Human-Machine Interfaces

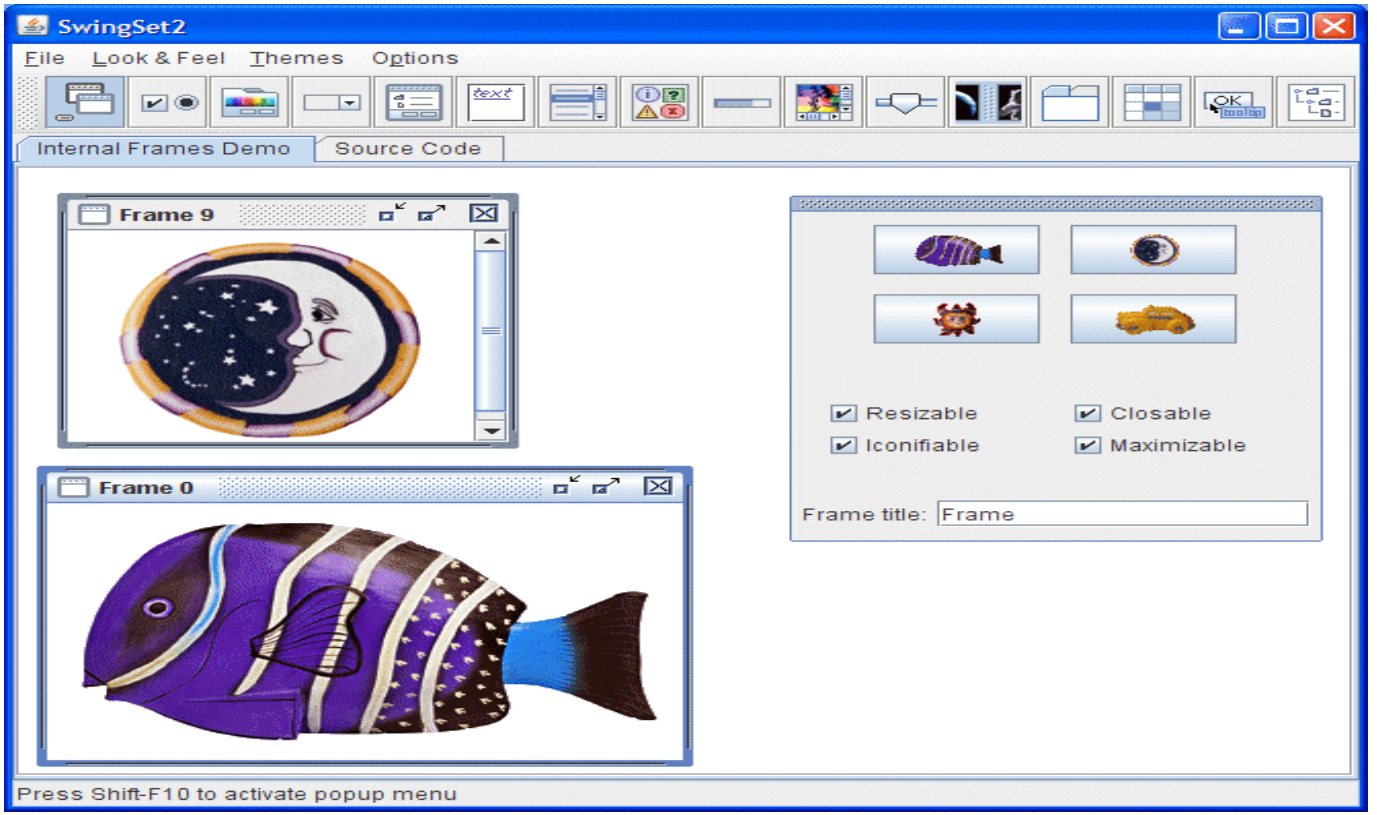
The ways in which a *software system* interacts with its *users*.

- Command Line
- Graphical User Interface - GUI
- Touch User Interface - TUI
- Multimedia (voice, animation, etc.)
- Inteligent (gesture recognition, conversational, etc.)

Graphical User Interfaces

Visual communication between software and users.

- **AWT**(Abstract Windowing Toolkit)
- **Swing** – part of JFC (Java Foundation Classes)
- **SWT** (IBM)
- **Java FX**
- **XUL**
- **...**
  - Java 2D
  - Java 3D



The Stages of Creating a GUI Application

- **Design**
  - Create the **containers**
  - Create and arrange the **components**

- **Functionality**
  - Define the user-components **interaction**
  - Attach **actions** to components
  - Create the action **handlers**

- **Considerations**
  - Programatic – Declarative – Visual
  - Separation between the GUI and application logic

AWT Library

```
import java.awt.*;
public class AWTExample {
  public static void main (String args []) {
    // Create the window (frame)
    Frame f = new Frame("O fereastra");

    // Set the layout of the frame
    f.setLayout (new FlowLayout());

    // Create the components
    Button b1 = new Button("OK");
    Button b2 = new Button("Cancel");

    // Add the components to the frame
    f.add(b1);
    f.add(b2);
    f.pack();

    // Show the frame
    f.setVisible(true);
  }
}
```

AWT is the original Java GUI library.

AWT Components

- Button
- Canvas
- Checkbox
- CheckBoxGroup
- Choice
- Container
- Label
- List
- Scrollbar
- TextComponent
- TextField
- TextArea

AWT Components are **platform-depended**,
each of them having an underlying **native peer**.

Infrastructure

- **Component*s*:** *Button, CheckBox, etc.*
  - A component is an object having a graphical representation that can be displayed on the screen and that can interact with the user. Properties common to all components are:

    location, x, y, size, height, width, bounds, foreground, background, font, visible, enabled,...
- **Container*s*:** *Window, Frame, Dialog, Panel, etc.*
  - A generic component containing other components.
- **LayoutManager*s***: *FlowLayout, GridLayout, etc.*
  - The interface for classes that know how to lay out Containers.
- **EventObject*s***: *ActionEvent, TextEvent, etc.*
  - An event indicates that a component-defined action occurred.

LayoutManager

Relative positioning

A **layout manager** is an object that controls the size and arrangement (position) of components inside a container.

Each *Container* object has a layout manager.

All classes that instantiate objects for managing positioning implements *LayoutManager* interface.

Upon instantiation of a container it is created an implicit layout manager associated with it:

- ➔ frames: *BorderLayout*
- ➔ panels: *FlowLayout*

Absolute positioning

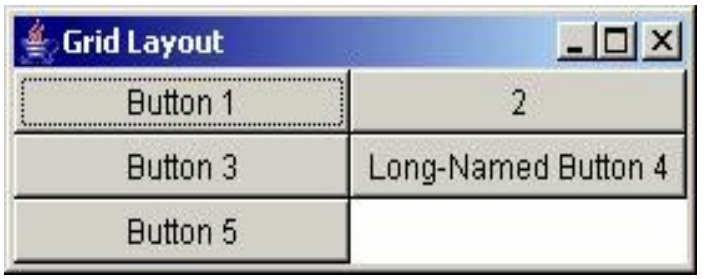
```
container.setLayout(null);
```

Arranging the Components

```
import java.awt.*;
public class TestLayout {
  public static void main ( String args [])

    Frame f = new Frame("Grid Layout");
    f.setLayout (new GridLayout (3, 2));

    Button b1 = new Button (" Button 1");
    Button b2 = new Button ("2");
    Button b3 = new Button (" Button 3");
    Button b4 = new Button ("Long - Named Button 4");
    Button b5 = new Button (" Button 5");
    f.add(b1); f.add (b2); f. add(b3); f.add(b4); f.add(b5);
    f.pack ();
    f.setVisible(true);
  }
}
```




```
    Frame f = new Frame("Flow Layout");
    f.setLayout (new FlowLayout ());
```

BorderLayout

```
import java.awt .*;
public class TestBorderLayout {
  public static void main ( String args []) {

    Frame f = new Frame (" Border Layout ");
    // This is the default for frames
    f.setLayout (new BorderLayout());

    f.add(new Button(" North "), BorderLayout.NORTH );
    f.add(new Button(" South"), BorderLayout.SOUTH );
    f.add(new Button(" East"), BorderLayout.EAST );
    f.add(new Button(" West "), BorderLayout.WEST );
    f.add(new Button(" Center "), BorderLayout.CENTER );
    f.pack ();
    f.setVisible(true);
  }
}
```

User Interactions

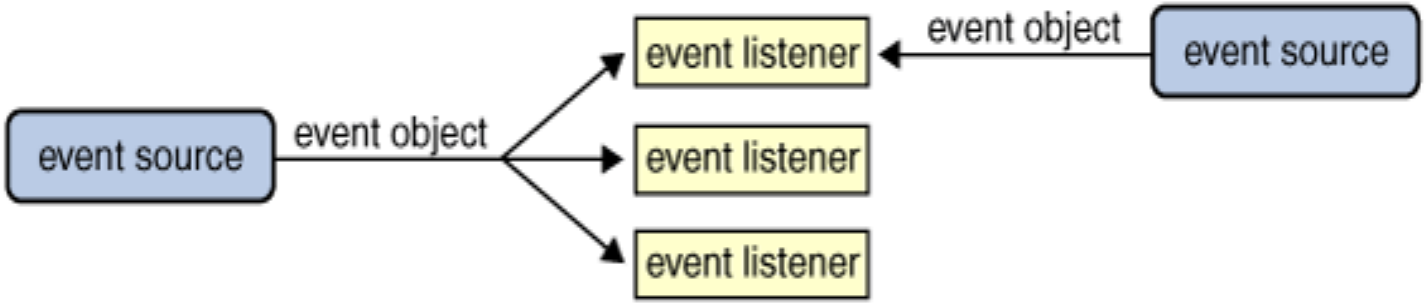
Event-Driven Programming

Event: clicking a button, altering the text, checking an option, closing a frame, etc.

Source: the component that generates an event.

Listener: the responsible for receiving and handling (consuming) events.

many-to-many



Observing the state of an entity within a system *(Publish-Subscribe)*

Using Anonymous Classes

```
class MyFrame extends Frame {
  public MyFrame ( String title ) {
    ...
    button.addActionListener( new ActionListener() {
      @Override
      public void actionPerformed(ActionEvent e) {
        MyFrame.this.setTitle(
           "You pressed the button " + e.getActionCommand());
      }
    });
    ...
  }
}
```

Using Lambda Expressions

```
    ...
    button.addActionListener( (ActionEvent e) -> {
      MyFrame.this.setTitle(
        "You pressed the button " + e.getActionCommand());
    });
    ...
  }
}
```

Using Method References

```
class MyFrame extends Frame {

  public MyFrame ( String title ) {
    ...
    button.addActionListener( this::onButtonPressed );

    checkbox.addItemListener( this::onItemChanged );
    ...
  }

  //Your own, suggestively called, methods

  private void onButtonPressed(ActionEvent e) {
    this.setTitle("You pressed the button");
  }

  private void onItemChanged(ItemEvent e) {
    this.setTitle("Checkbox state: " + check.getState());
  }

}
```

Swing

- **Extends** the core concepts and mechanisms of AWT; *we still have components, containers, layout managers, events and event listeners.*
- **Replaces completely** the AWT componet set, providing a new set of components, capable of sorting, printing, drag and drop and other “cool” features.
- Brings **portability** to the GUI level; no more *native peers*, all components are “pure”.
- Based on **Separable Model-and-View** design pattern.
- **"Component Oriented Programming"**

Swing Components

- **Atomic Components**

  `JLabel, JButton, JCheckBox, JRadioButton, JToggleButton, JScrollBar, JSlider, JProgressBar, JSeparator`
- **Complex Components**

  `JTable, JTree, JComboBox, JSpinner, JList, JFileChooser, JColorChooser, JOptionPane`
- **Text Editing Components**

  `JTextField, JFormattedTextField, JPasswordField, JTextArea, JEditorPane, JTextPane`
- **Menus**

  `JMenuBar, JMenu, JPopupMenu, JMenuItem, JCheckboxMenuItem, JRadioButtonMenuItem`
- **Intermediate Containers**

  `JPanel, JScrollPane, JSplitPane, JTabbedPane, JDesktopPane, JToolBar`
- **High-Level Containers**

  `JFrame, JDialog, JWindow, JInternalFrame, JApplet`

Similarities and Differences with AWT

"J" Convention

`java.awt.Frame - javax.swing.`**`JFrame`**

`java.awt.Button - javax.swing.`**`JButton`**

`java.awt.Label - javax.swing.`**`JLabel`**

New Layout Managers

`BoxLayout, SpringLayout, GroupLayout, OverlayLayout, etc.`

HTML Aware Components

```
JButton simple = new JButton("Dull text");
JButton html = new JButton("<html><u>Cool</u> <i>text</i></html>");
```

JComponent

JComponent is the base class for all Swing components, except top-level containers: JFrame, JDialog, JApplet.

JComponent extends *Container*

- Support for **tool tips** - `setToolTip`
- Support for **borders** - `setBorder`
- Enhanced support for **sizing and positioning**

  `setPreferredSize, ...`
- **Opacitiy** control - `setOpaque`
- **Keyboard bindings**
- "Pluggable" **look and feel**
- Double-Buffering, Support for accessibility, etc.

Swing Architecture

Swing architecture is “rooted” in the MVC design:

- *Model* – the data for the application
- *View* – the visual representation of the data
- *Controller* – takes user input on the view and translates that to changes in the model.

Separable Model Architecture

Model + (Presentation, Control)

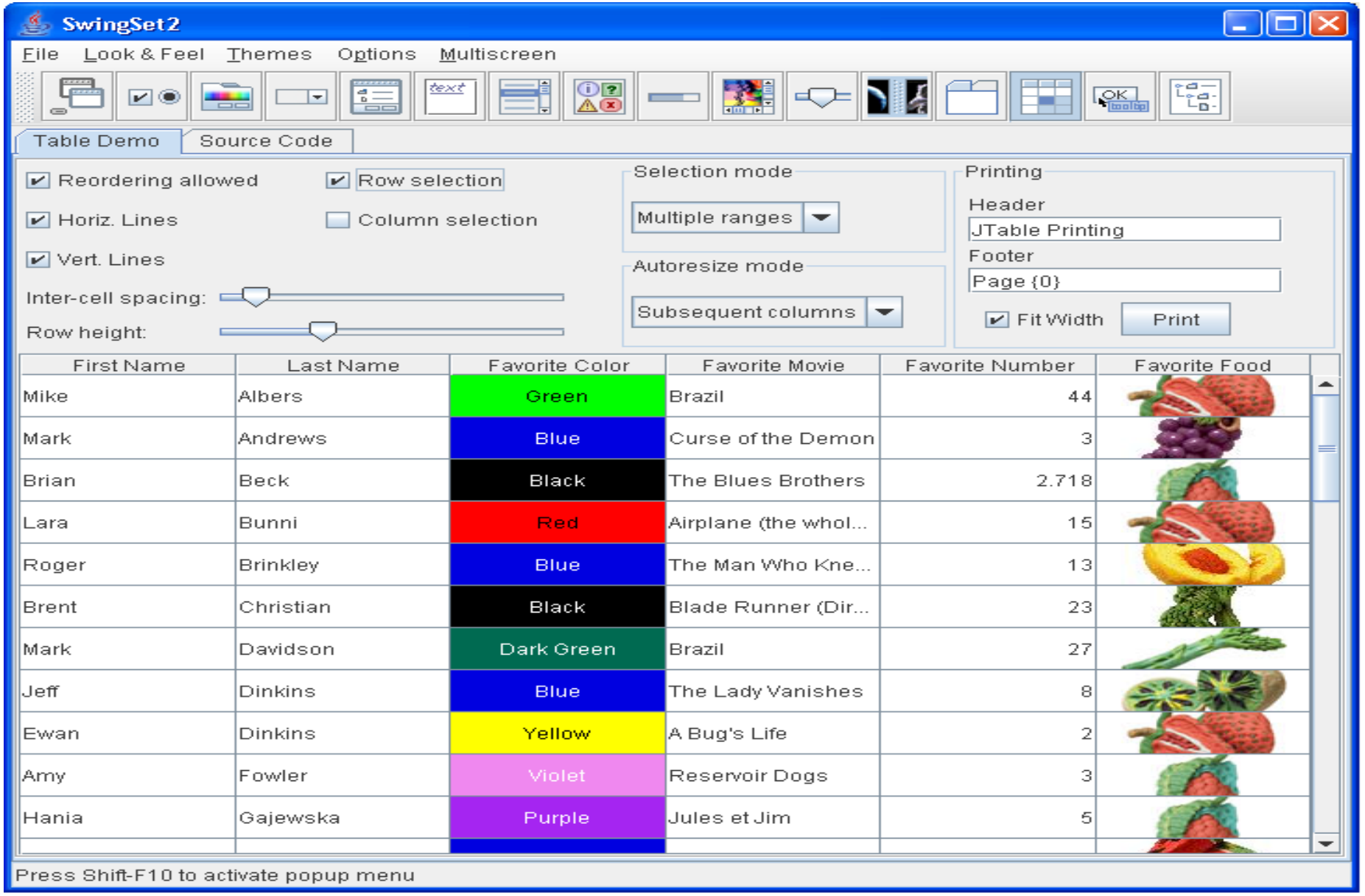
Example: *JTable*

```
class MyTableModel extends AbstractTableModel {
  private String[] columns = {"Nume", "Varsta", "Student"};
  private Object[][] elements = {
    {"Ionescu", new Integer(20), Boolean.TRUE},
    {"Popescu", new Integer(80), Boolean.FALSE}};

  public int getColumnCount() {
    return columns.length;
  }
  public int getRowCount() {
    return elements.length;
  }
  public Object getValueAt(int row, int col) {
    return elements[row][col];
  }
  public String getColumnName(int col) {
    return columns[col];
  }
  public boolean isCellEditable(int row, int col) {
    // Doar numele este editabil
    return (col == 0);
  }
}
```

Customizing the View

CellRenderes and CellEditors



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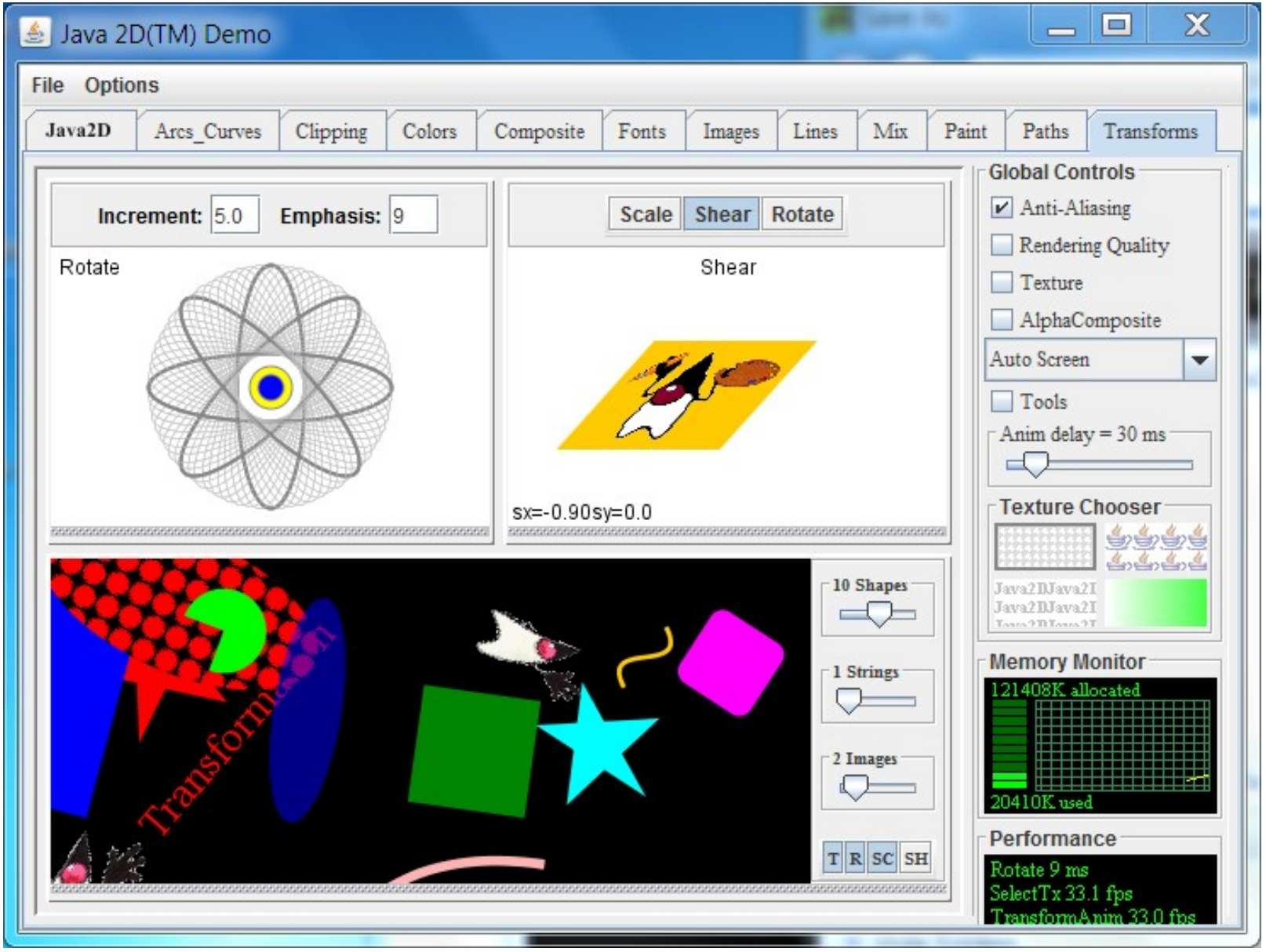


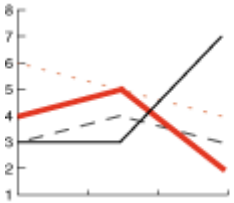
The “Drawing” Concept

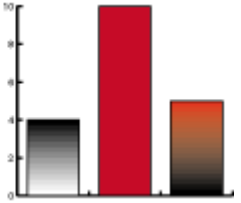
- Graphical interfaces are built using **components**.

  The “system” draws the components automatically:
  - when they are displayed for the first time,
  - at minimize, maximize operations,
  - when resizing the display area;
- The **support methods** for defining the graphical representation of a *Component* are:
  - **void paint(Graphics g)**
  - **void update(Graphics g)**
  - **void repaint()**

Java 2D

- **Two-dimensional graphics, text, and imaging**
- A **uniform rendering model** for display devices and printers
- **Geometric primitives**: any geometric shape
- **Hit detection** on shapes, text, and images
- Ccontrol over how **overlapping** objects are rendered
- Enhanced **color support** that facilitates color management
- Support for **printing** complex documents
- Control of the **quality** of the rendering (hints)





Image

Blur

Sharpen

The *paint* method

This method is called when the contents of the component should be painted; such as when the component is first being shown or is damaged and in need of repair. The *clip rectangle* in the *Graphics* parameter is set to the area which needs to be painted.

```
public class MyFrame extends Frame {
  public MyFrame(String title) {
    super(title);
    setSize(200, 100);
  }

  public void paint(Graphics g) {
    super.paint(g);
    // Apelam metoda paint a clasei Frame
    g.setFont(new Font("Arial", Font.BOLD, 11));
    g.setColor(Color.red);
    g.drawString("DEMO Version", 5, 35);
  }
}
```

The *paintComponent* method

- *JComponent.paint* delegates the work of painting to three protected methods: **paintComponent**, **paintBorder**, and **paintChildren**. They're called in the order listed to ensure that children appear on top of component itself.
- Swing components should just override paintComponent.

```
/* Creating a custom component */
class MyCustomComponent extends JPanel {

    // Define the representation of the component
    public void paintComponent(Graphics g) {
        super.paintComponent(g);
        Graphics2D g2d = (Graphics2D) g;
        ...
    }
    // Methods used by the layout managers
    public Dimension getPreferredSize() { return ... };
    public Dimension getMinimumSize() { return ... }
    public Dimension getMaximumSize() { return ... }
}
```

Creating a Custom Component

```
public class MyComponent extends JPanel {
    private int x, y, radius;
    public MyComponent() {
      init();
    }
    private void init() {
      setPreferredSize(new Dimension(400, 400));
      this.addMouseListener(new MouseAdapter() {
          public void mousePressed(MouseEvent e) {
              x = e.getX(); y = e.getY();
              radius = 50 + (int) (100 * Math.random());
              repaint();
          }
      });
    @Override
    public void paintComponent(Graphics g) {
      super.paintComponent(g);
      g.drawOval(x - radius / 2, y - radius / 2, radius, radius);
    }
}
```

```
JFrame frame = new JFrame("demo");
frame.add(new MyComponent());
frame.pack();
frame.setVisible(true);
```

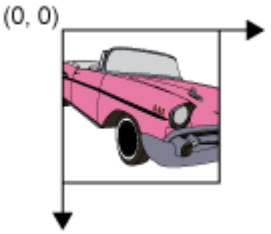
Graphics, Graphics2D

- ***Graphics*** is the base class for all **graphics contexts** that allow an application to draw onto components realized on various devices, as well as onto off-screen images.
- ***Graphics2D*** class extends the *Graphics* class to provide more sophisticated control over geometry, coordinate transformations, color management, and text layout.
- A graphic context offers:
  - Methods for configuring the **drawing properties**:

    color, paintMode, font, stroke, clip, renderingHints, ...
  - **Geometric primitives**
  - Support for working with **texts** and **images**
  - Support for **printing**

Geometric Primitives

- **Coordinates**
  - **User space** – in which graphics primitives are specified
  - Device space – screen, window, or a printer
  - The origin of user space is the upper-left corner



- **Primitives**:
  - `drawLine, drawPolyline, drawOval, fillOval, drawPolygon, fillPolygon, drawRect, fillRect, …`
  - **`draw(Shape), fill(Shape)`**
  - The *Shape interface* provides definitions for objects that represent some form of geometric shape. The Shape is described by a PathIterator object, which can express the outline of the Shape as well as a rule for determining how the outline divides the 2D plane into interior and exterior points.

Working with Texts

- **Font** - A collection of *glyphs* (unique marks that collectively add up to the spelling of a word) → *name, style, size*

```
Label label = new Label("Some text");
label.setFont(new Font("Dialog", Font.PLAIN, 12));

void paint(Graphics g) {
    g.setFont(new Font("Courier", Font.BOLD, 10));
    g.drawString("Another text", 10, 20); }
```

- **FontMetrics** - encapsulates information about the rendering of a particular font on a particular screen.

```
Font f = new Font("Arial", Font.BOLD, 11);
FontMetrics fm = g.getFontMetrics();
int height = fm.getHeight();
int width = fm.stringWidth("frog");
int xWidth = fm.charWidth('g');
```

- **TextLayout** - highlighting, strings with mixed fonts, mixed languages, bidirectional text.

Using Colors

- **Paint interface** defines how color patterns can be generated for Graphics2D operations.
- **Color** encapsulates colors in the sRGB space

Red Green Blue Alpha
(0 – 255, 0.0 – 1.0)

```
Color standardRed = Color.RED;
Color plainWhite = new Color(1.0, 1.0, 1.0);
Color translucentRed = new Color(255, 0, 0, 128);
```

- **SystemColor** encapsulate symbolic colors representing the color of native GUI objects on a system.

```
SystemColor.desktop
```

- **GradientColor** provides a way to fill a *Shape* with a linear color gradient pattern. **Hello world!**
- **TexturePaint** provides a way to fill a *Shape* with a texture that is specified as a *BufferedImage*. **Hello again...**

Using Images

- **Image** is the superclass of all classes that represent graphical images.

- **BufferedImage**
  - Loadind from a file

```
BufferedImage image = ImageIO.read(new File("hello.jpg"))
```

  - Creating in memory (off-screen)

```
BufferedImage image = new BufferedImage(w, h, type);
Graphics g = image.getGraphics();
```

  - Drawing using a graphic context

```
graphics.drawImage(image);
```

  - Saving in a file (GIF, PNG, JPEG, etc.)

```
ImageIO.write(image, "png", new File("drawing.png"));
```

Working with Large Images

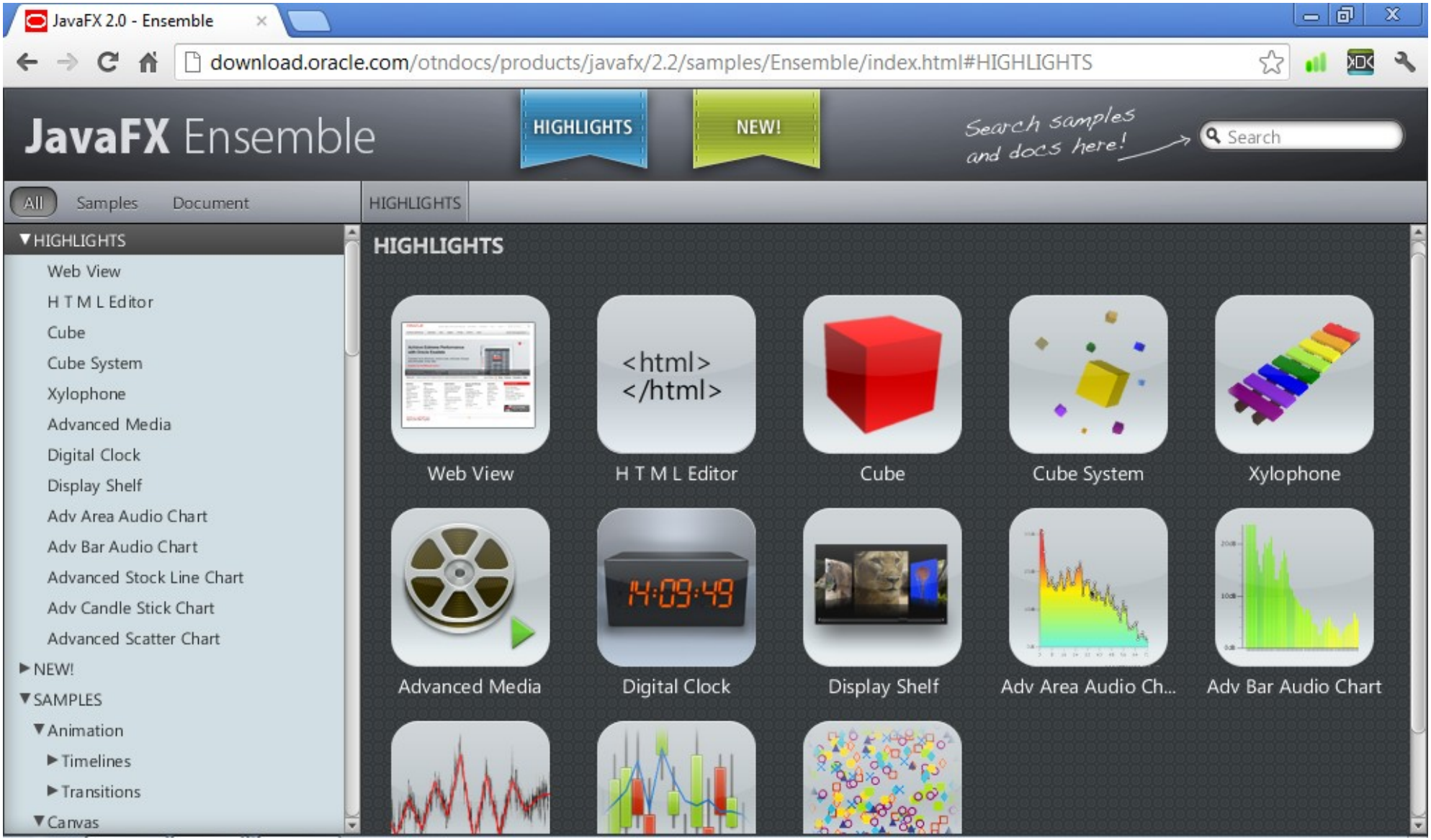
- Displaying a large image

```
BufferedImage img = ImageIO.read(
    new URL("http://www.remoteServer.com/hugeImage.jpg"));
...
public void paint(Graphics g) {
    g.drawImage(img, 0, 0, this);
}
```

- *ImageObserver* - an asynchronous update interface for receiving notifications about information as the *Image* is constructed.

```
public boolean imageUpdate(Image image, int flags, int x, int y,
          int width, int height) {
  // If the image has finished loading, repaint the window.
  if ((flags & ALLBITS) != 0) {
     repaint();
     return false;  // finished, no further notification.
  }
  return true; //not finished loading, need further notification.
}
```

Intermission...



JavaFX

- A set of **graphics** and **media** packages that enables developers to design, create, test, debug, and deploy **rich client applications**.
- **High-performance**, **modern** user interface that features audio, video, graphics, and animation.
- Deployed across **multiple platforms**: desktop, browsers, mobile, etc.
- Coexists with Swing – however, it may replace Swing as the standard GUI library;

JavaFX Key Features

- **FXML** → MVC Pattern Support
- **WebView** (embed web pages within a JavaFX application)
- Built-in UI controls, **CSS** and **Themes** (Modena, Caspian, etc.)
- **3D Graphics** Features (*Shape3D*)
- Multi-touch Support, Hi-DPI support, Rich Text Support
- **Hardware-accelerated** graphics (uses optimally the GPU)
- High-performance media engine (playback of web multimedia content)
- Self-contained application deployment model
- IDEs offer tools for **rapid application development**

  → JavaFX Scene Builder

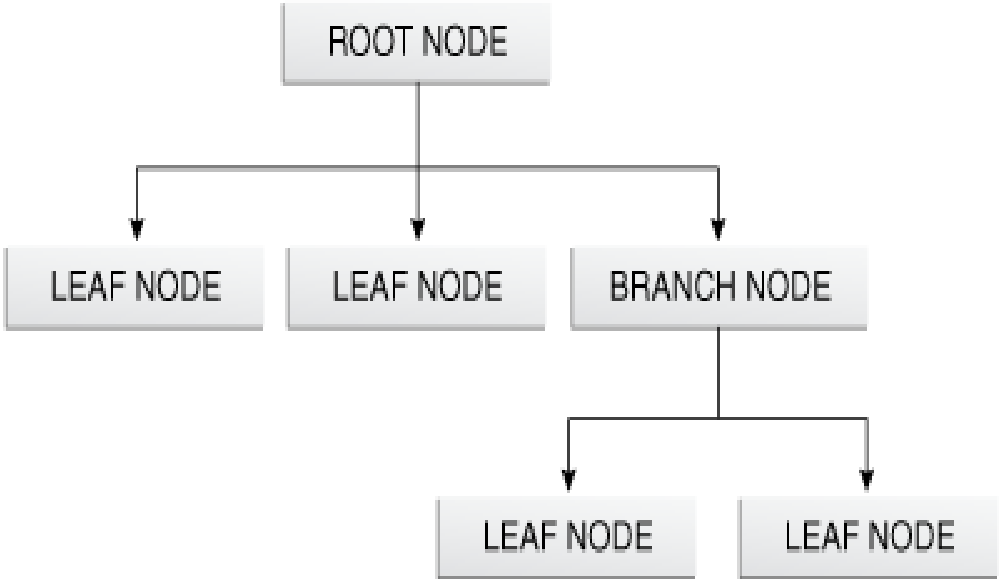
Hello World

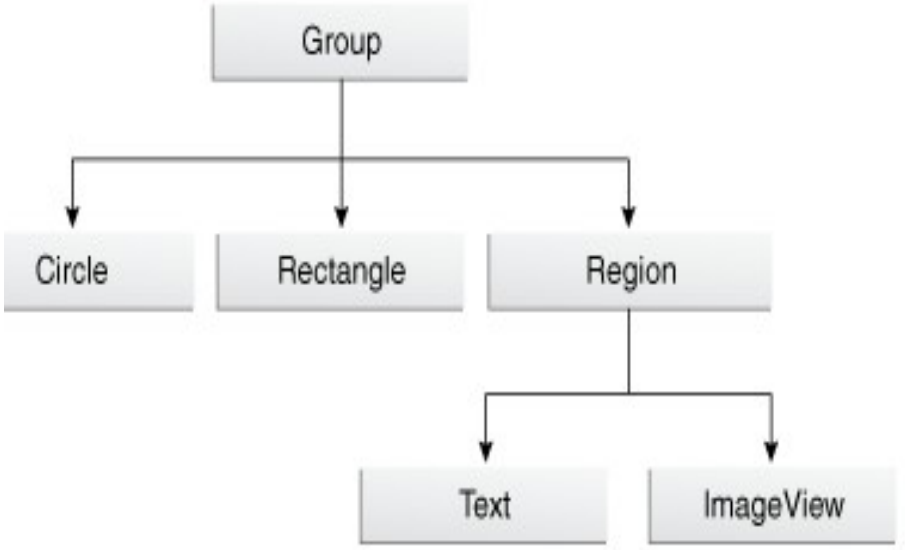
```
//The main class extends Application
public class HelloWorld extends Application {
  @Override
  public void start(Stage primaryStage) { //The main entry point
    Button helloBtn = new Button();
    helloBtn.setText("Hello World!");

    FlowPane root = new FlowPane();
    root.getChildren().add(helloBtn);

    Scene scene = new Scene(root, 300, 250);

     //The UI is defined by a stage and a scene.
    //Stage class is the top-level JavaFX container.
    //The Scene class is the container for all content.

    primaryStage.setTitle("Hello World Application");
    primaryStage.setScene(scene);
    primaryStage.show();
  }
  public static void main(String[] args) {
      launch(args); //not required for JavaFX applications...
  }
}
```

Theater Metaphor

The Scene Graph

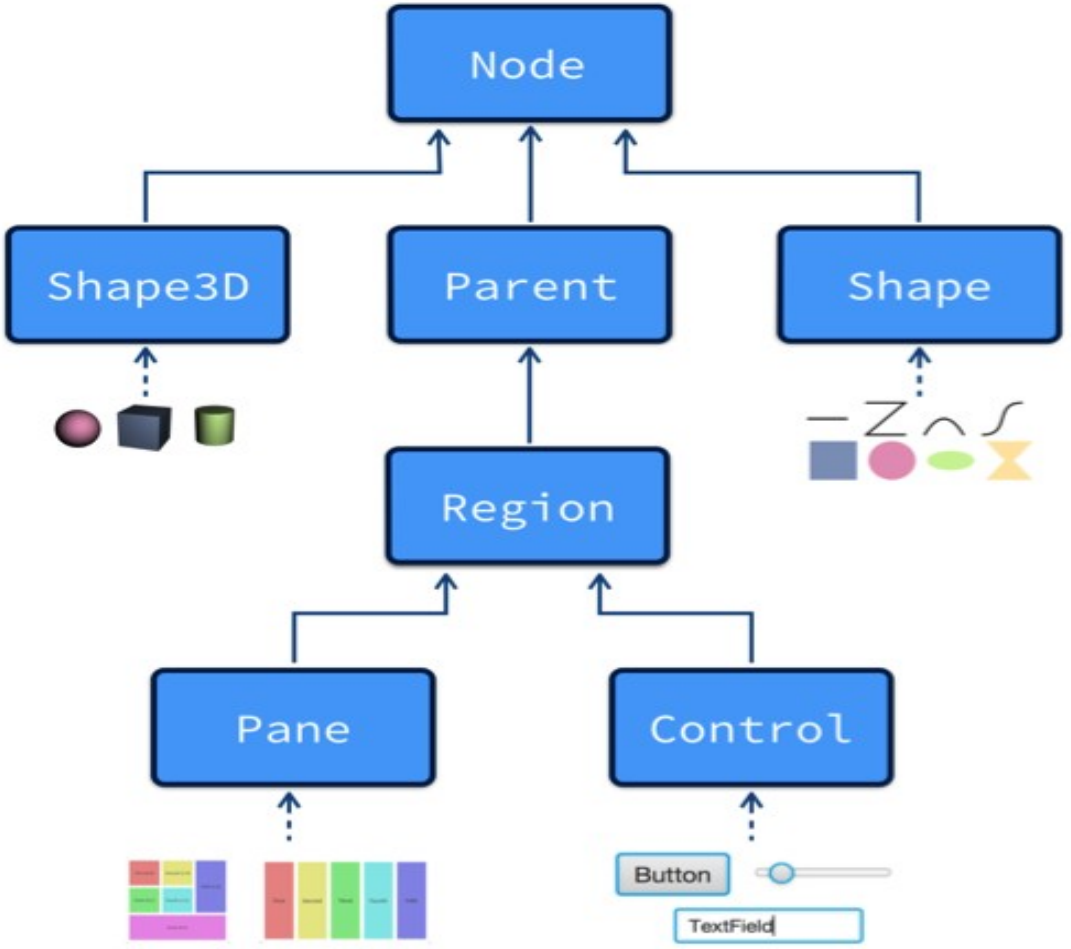
The JavaFX scene graph is a **retained mode** API






```
Group group = new Group();
Rectangle blueSquare = new Rectangle(50, 50);
blueSquare.setFill(Color.BLUE);
group.getChildren().add(blueSquare);

Circle redCircle = new Circle(50, new Color(1,0,0,0.5f));
group.getChildren().add(redCircle);
```

UI Component Hierarchy



javafx.scene.Node
Base class for scene graph nodes.

javafx.scene.Parent
The base class for all nodes that have children in the scene graph

javafx.scene.Region
The base class for all JavaFX Node-based UI Controls, and all layout containers.

javafx.scene.Pane
Base class for layout panes

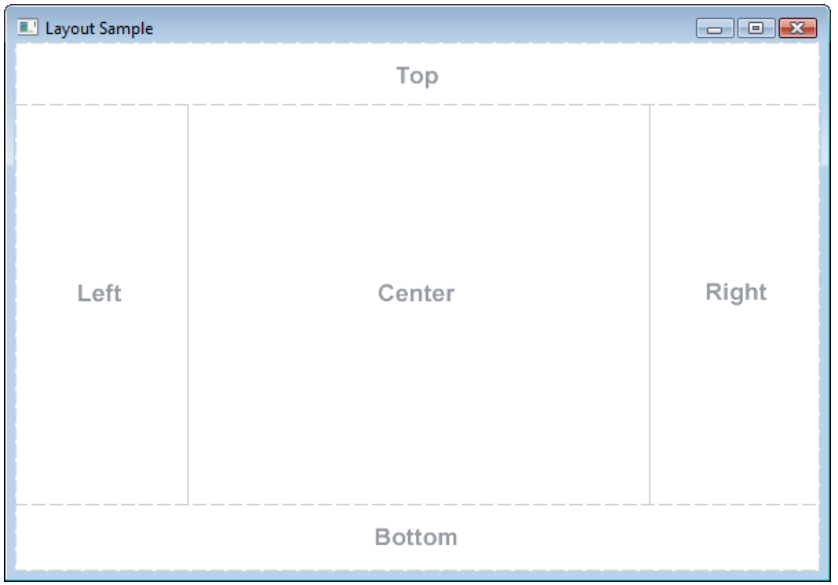
javafx.scene.Control
Base class for all user interface controls.

Each item in the scene graph is called a *Node*.
Each node in the scene graph can be given a **unique id**.
Each node has a **bounding rectangle** and a **style**.
Any Node can have **transformations** applied to it: translation, rotation, scaling, or shearing.

Layout Management

Setting the position and size for UI element.

- A “combo” of a Swing *JPanel* + *LayoutManager*
- *javafx.scene.layout.Pane* - Base class for layout panes; used directly in cases where absolute positioning of children is required.
- Uses **preffered, minimum** and **maximum** properties
- *FlowPane, BorderPane, AnchorPane, StackPane, TilePane, GridPane, TextFlow, HBox, VBox, etc.*




```
borderPane.setCenter(
    new ListView());

borderPane.setBottom(
    new Label("Hello"));
```

Adding Functionality

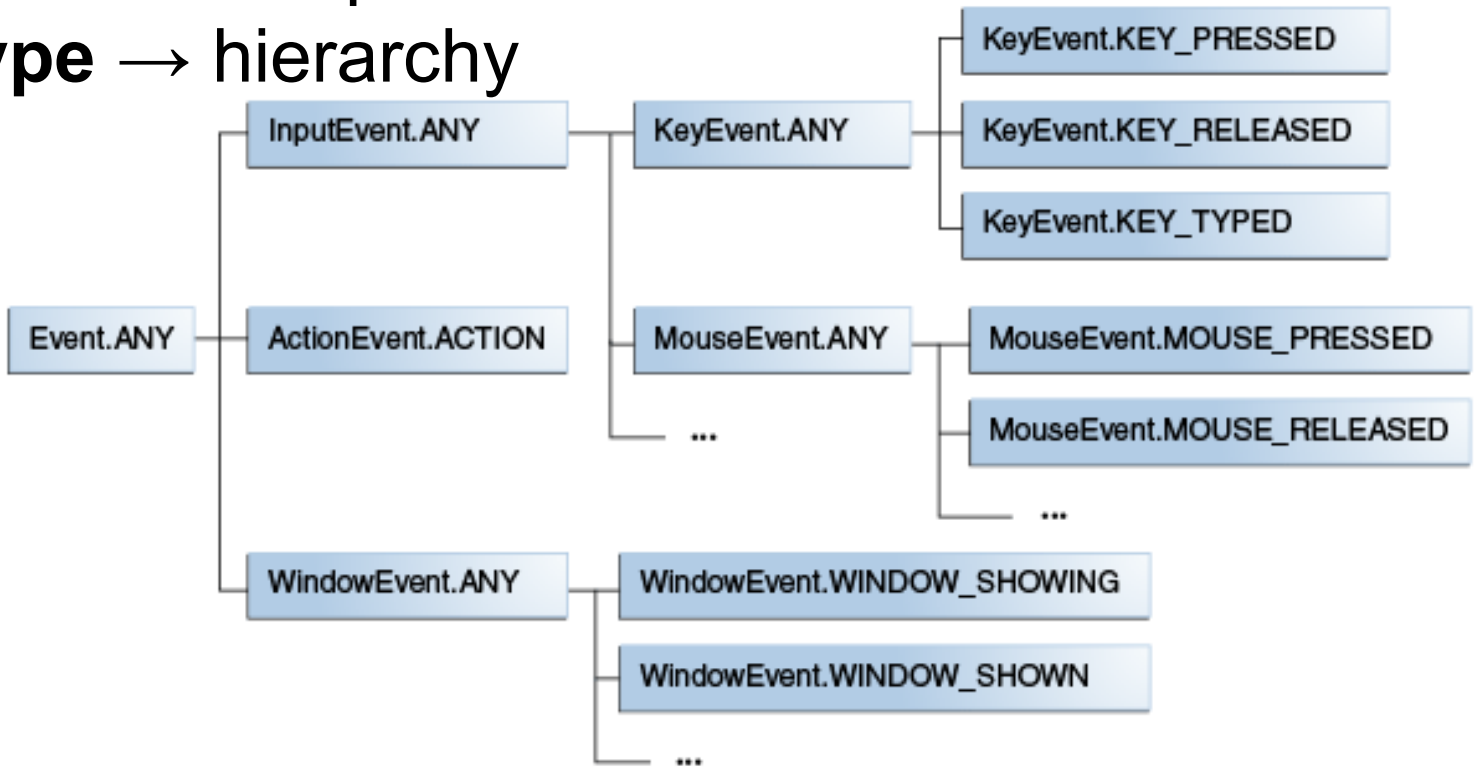
```
public class HelloWorld extends Application {
  @Override
  public void start(Stage primaryStage) {
    Button helloBtn = new Button();
    helloBtn.setText("Hello World!");

    helloBtn.setOnAction(new EventHandler<ActionEvent>() {
      @Override
      public void handle(ActionEvent event) {
        System.out.println("Hello Button was clicked!");
      }
    });

    //The anonymous inner class
    //can be turned into a lambda expression

    Button ciaoBtn = new Button("Ciao Mondo!");
    ciaoBtn.setOnAction((ActionEvent event) -> {
      System.out.println("Ciao Mondo e stato cliccato!");
    });
  }
}
```

JavaFX Events

An event represents an occurrence of something of interest to the application

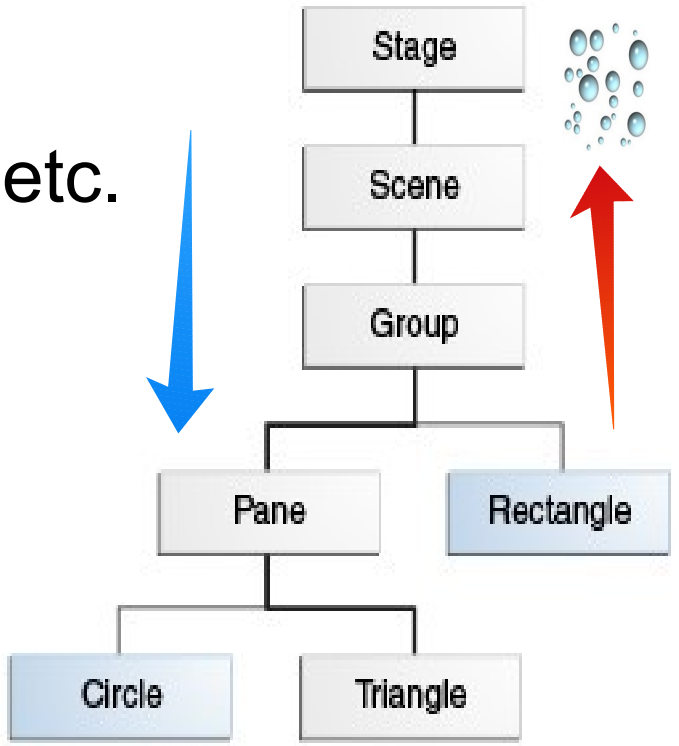
javafx.event.Event - Base class for FX events.

- **source** → *origin* of the event
- **target** → *the path* through which the event will travel when posted.
- **type** → hierarchy



Event Delivery Process

- **Target Selection**
  - the node that has focus,
  - the node location of the cursor, etc.
- **Route Construction**
  - *the event dispatch chain →*
- **Event Capturing**
  - passed **down** to the target
  - **filters** are invoked
- **Event Bubbling**
  - the event returns **up** from the target to the root
  - **handlers** are invoked



Event Handling

Intercepting Filter Design Pattern

- *EventHandler* functional interface
- **Filters** (going down...)

```
redCircle.addEventFilter(
    MouseEvent.MOUSE_CLICKED, (MouseEvent e) -> {
        System.out.println("Click: going down");
        //e.consume();
    });
```

- **Handlers** (going up...)

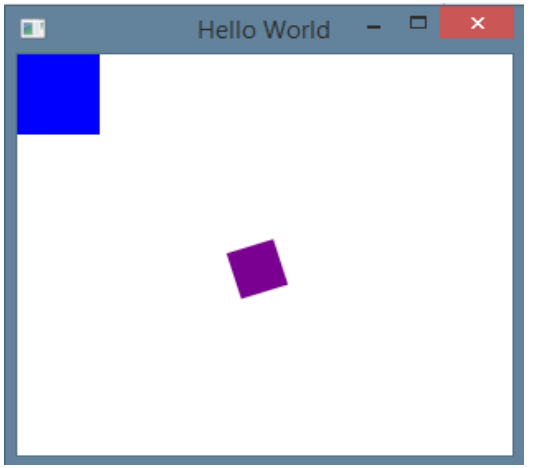
```
redCircle.addEventHandler(
    MouseEvent.MOUSE_CLICKED, (MouseEvent e) -> {
        System.out.println("Click: going up");
    });
```

- **Convenience** methods

```
setOnEvent-type(EventHandler<? super event-class> value)
helloBtn.setOnAction(new EventHandler<ActionEvent>() {…});
redCircle.setOnMouseEntered(new EventHandler<MouseEvent>() {…});
```

Transitions and Animations

```
TranslateTransition translate =
    new TranslateTransition(Duration.millis(750));
translate.setToX(300); translate.setToY(250);

FillTransition fill = new FillTransition(Duration.millis(750));
fill.setToValue(Color.RED);

RotateTransition rotate = new
    RotateTransition(Duration.millis(750));
rotate.setToAngle(360);

ScaleTransition scale =
    new ScaleTransition(Duration.millis(750));
scale.setToX(0.1); scale.setToY(0.1);

ParallelTransition transition =
    new ParallelTransition(blueSquare,
    translate, fill, rotate, scale);
transition.setCycleCount(Timeline.INDEFINITE);
transition.setAutoReverse(true);
transition.play();
```



Pulse

- A **pulse** is an event that indicates to the JavaFX scene graph that it is time to synchronize the state of the elements on the scene graph with Prism.
- A pulse is throttled at 60 frames per seconds (fps) maximum and is fired whenever animations are running or when something in the scene graph is changed. For example, if a position of a button is changed, a pulse is scheduled.
- When a pulse is fired, the state of the elements on the scene graph is synchronized down to the rendering layer.
- A pulse enables application developers a way to handle events asynchronously. This important feature allows the system to batch and execute events on the pulse.
- The Glass Windowing Toolkit is responsible for executing the pulse events. It uses the high-resolution native timers to make the execution.

Styling withs CSS

Cascading Style Sheets

- Define Style Sheets Files

```
.root {
  -fx-background-image: url("background.jpg");
}
.label {
 -fx-font-size: 12px;
 -fx-font-weight: bold;
 -fx-text-fill: #333333;
}
```

- Specify the CSS

```
scene.getStylesheets().add("path/stylesheet.css");
```

- Inline

```
helloBtn.setStyle(
    "-fx-background-color: slateblue; " +
    "-fx-text-fill: white;");
```

FXML

- XML-based language that provides the structure for **building a user interface separate from the application logic of your code**.
- Java (Programatic)

```
BorderPane border = new BorderPane();
Label helloLabel = new Label("Hello");
border.setTop(helloLabel);
Label worldLabel = new Label ("World");
border.setCenter(worldLabel);
```

- FXML (Declarative)

```
<BorderPane>
   <top>
     <Label text="Hello"/>
   </top>
   <center>
     <Label text="World"/>
   </center>
</BorderPane>
```

JavaFX Scene Builder

Using FXML to Create UI

- FXML Loader

```
Parent root = FXMLLoader.load(
    getClass().getResource("example.fxml"));
Scene scene = new Scene(root, 300, 275);
```

- Create the link between **view** and **control**

```
<GridPane fx:controller="FXMLExampleController">
    <Button text="Sign In"
      onAction="#handleSubmitButtonAction"/>
    <Text fx:id="actiontarget" />
</GridPane>
```

- Define the code to handle events

```
public class FXMLExampleController {
  @FXML
  private Text actiontarget;

  @FXML
  protected void handleSubmitButtonAction(ActionEvent event) {
     actiontarget.setText("Sign in button pressed");
  }
}
```

Swing or JavaFX?

- **Swing**
  - Maturity, Stability
  - Component Libraries and Frameworks
  - Large amount of resources
- **JavaFX**
  - Modern, MVC friendly, CSS, FXML
  - Spectacular (3D, Animations, etc.)
  - May not be “rock-solid” in production, yet
  - Not so many resources