CSE201: Monsoon 2024
Advanced Programming

Lecture 13: Event Driven Programming using JavaFX

Dr. Arun Balaji Buduru

Head, Center of Technology in Policing

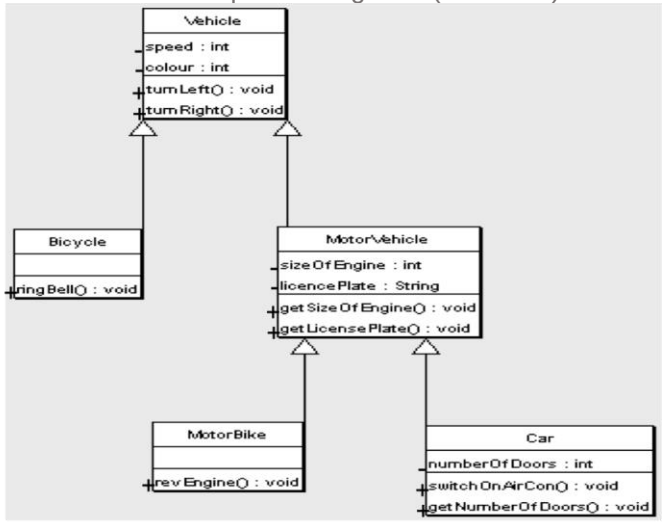
Founding Head, Usable Security Group (USG)

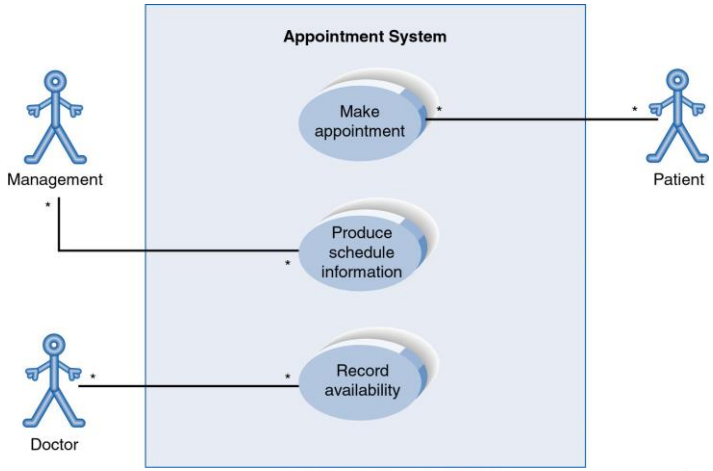
Associate Professor, Dept. of CSE | HCD

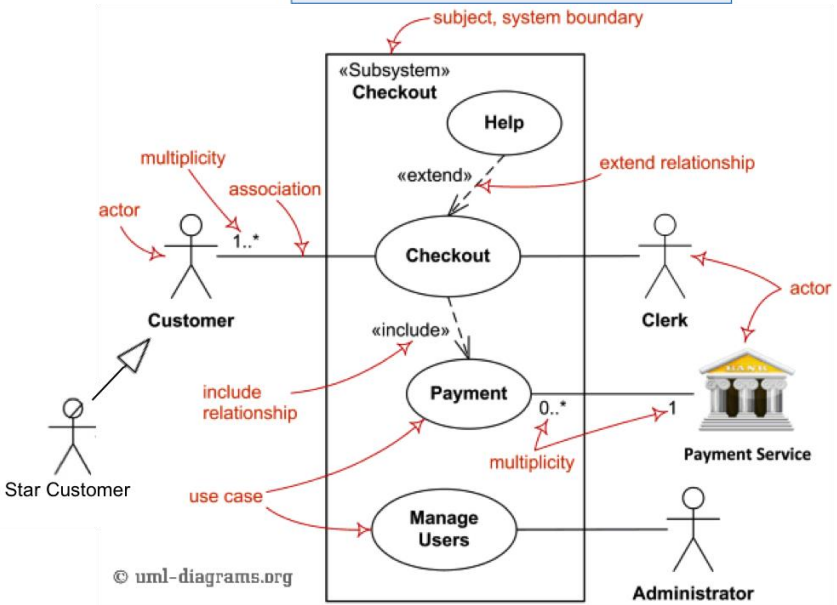
IIIT-Delhi, India

Last Lecture

- Unified Modeling Language (UML)
  - It's used to analyze, design, and implement software-based systems using diagrams
  - Give us the "big picture" view of the project
  - Types of UML diagrams
    - Class diagrams
      - Static structure diagram
      - Relationship between classes
    - Use case diagrams
      - A sequence of action a systems performs that yields a valuable result for an individual user (actor)
    - Sequence diagrams (Lecture 2)







Today's Lecture

- Introduction to JavaFX
- Event driven programming
- *Note that JavaFX is vast and we are only covering very basic concepts in this lecture. For your project you might require some advanced features in JavaFX*

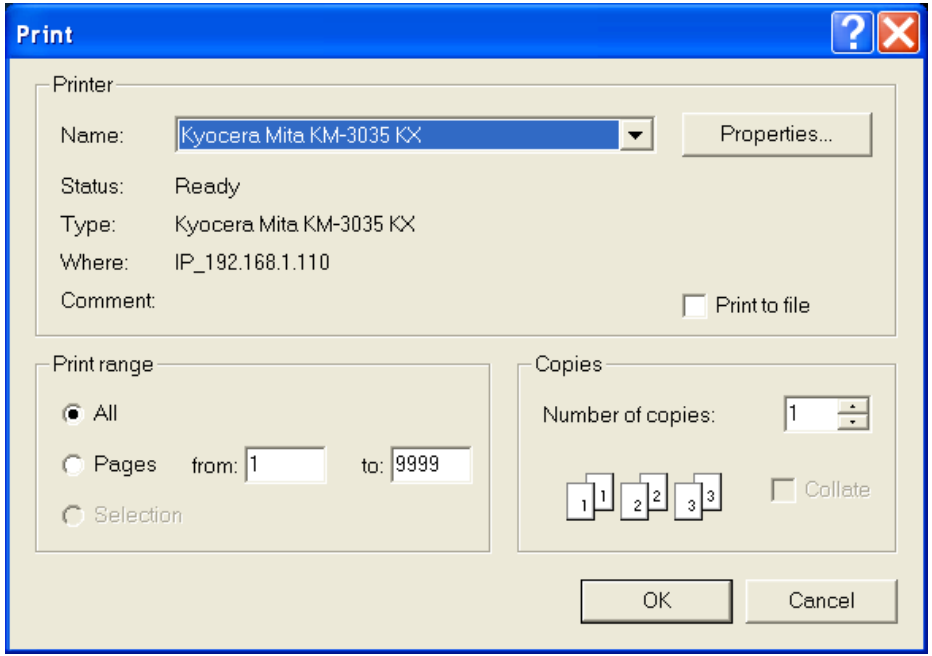
JavaFX slides Acknowledgements: CSE114, Stony Brook University (http://www3.cs.stonybrook.edu/~pfodor/courses/cse114.html)

+ Oracle online documentation

GUI

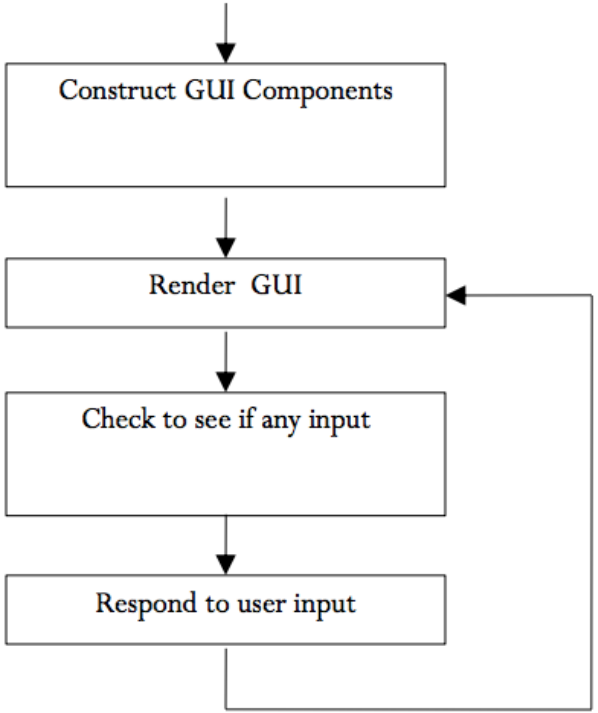
- Graphical User Interface
  - Provides user-friendly human interaction
- History of GUI programming
  - Abstract Window Toolkit
  - Swings
  - JavaFX script
  - JavaFX library

GUI Examples



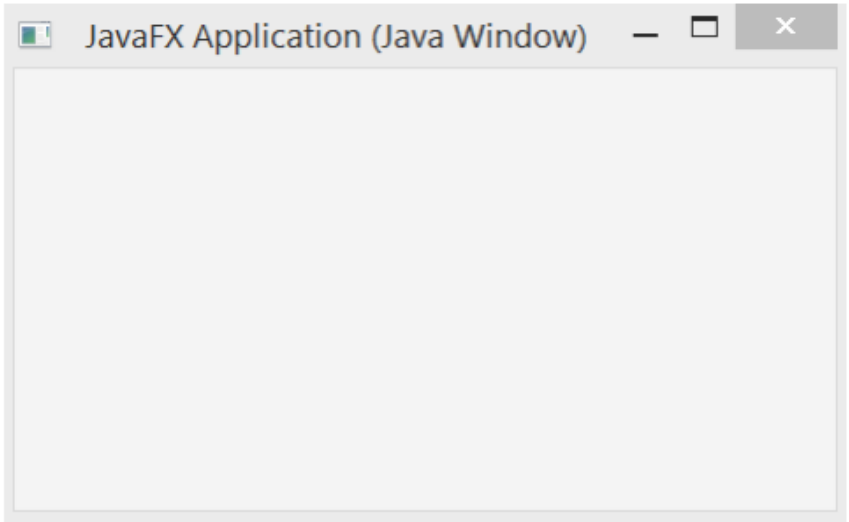
How do GUI Works?

- They loop and respond to events



How does GUI Framework Help?

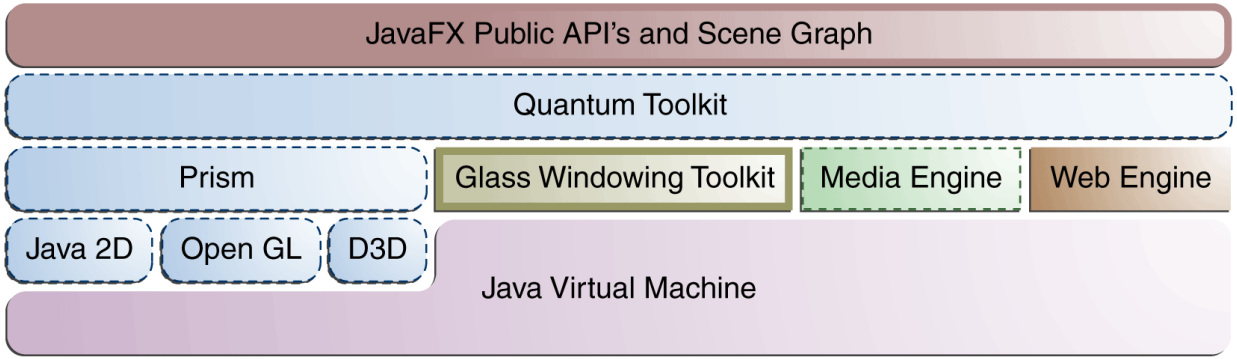
- Provides ready made visible, interactive, customizable components
  - you wouldn’t want to have to code your own window



JavaFX: Simplifies Application Development

- JavaFX library simplifies the building of complex graphically rich client applications
- It provides simple APIs to add graphics, media, web content, UI controls etc., in the applications

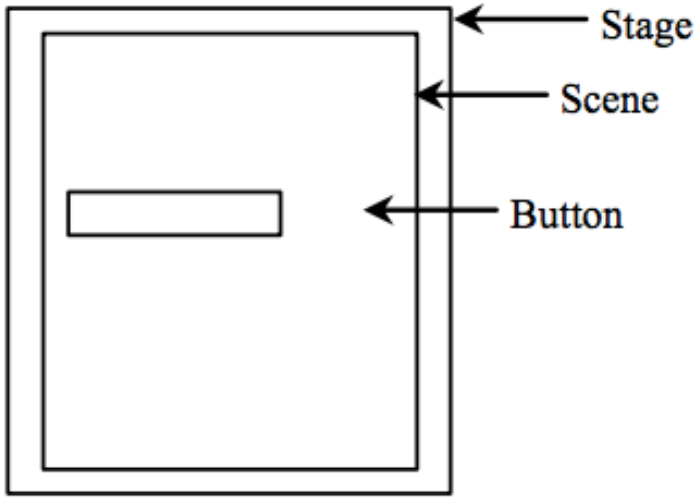
JavaFX Runtime High Level Architecture



- **JavaFX Glossary**

- **Glass Windowing Toolkit**: Provides native operating services, such as managing the windows, timers, etc.
- **Prism**: Graphics pipeline that can run on hardware and software renderers
- **Quantum Toolkit**: Ties Prism and Glass together and makes them available to the JavaFX APIs

Basic Structure of JavaFX



- Class `javafx.stage.Stage` is the top level JavaFX container
- Class `javafx.scene.Scene` class is the container for all content in a scene graph
- Abstract class `javafx.application.Application` is the entry point for JavaFX applications
  - Executes the user application and processes input events
  - User just need to Override the `start` method!
- Components can be created/added programmatically

```
Parent p;
Node n;
p.getChildren().add(n)
```

JavaFX: Hello World

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    //Override the start method in the Application class
    @Override
    public void start(Stage primaryStage) {
        // Set the stage title
        primaryStage.setTitle("MyJavaFX");
        // Create a button and place it in the scene
        Button btn = new Button(”Hello World");
        Scene scene = new Scene(btn, 200, 250);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }

}
```

- The main class for a JavaFX application extends the `javafx.application.Application` abstract class
  - The start() method is the main entry point for all JavaFX applications

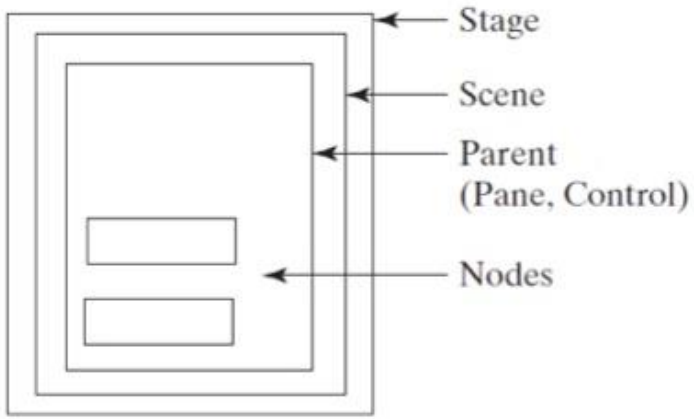
Application’s Life Cycle

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    //Override the start method in the Application class
    @Override
    public void start(Stage primaryStage) {
        // Set the stage title
        primaryStage.setTitle("MyJavaFX");
        // Create a button and place it in the scene
        Button btn = new Button(”Hello World");
        Scene scene = new Scene(btn, 200, 250);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }

}
```

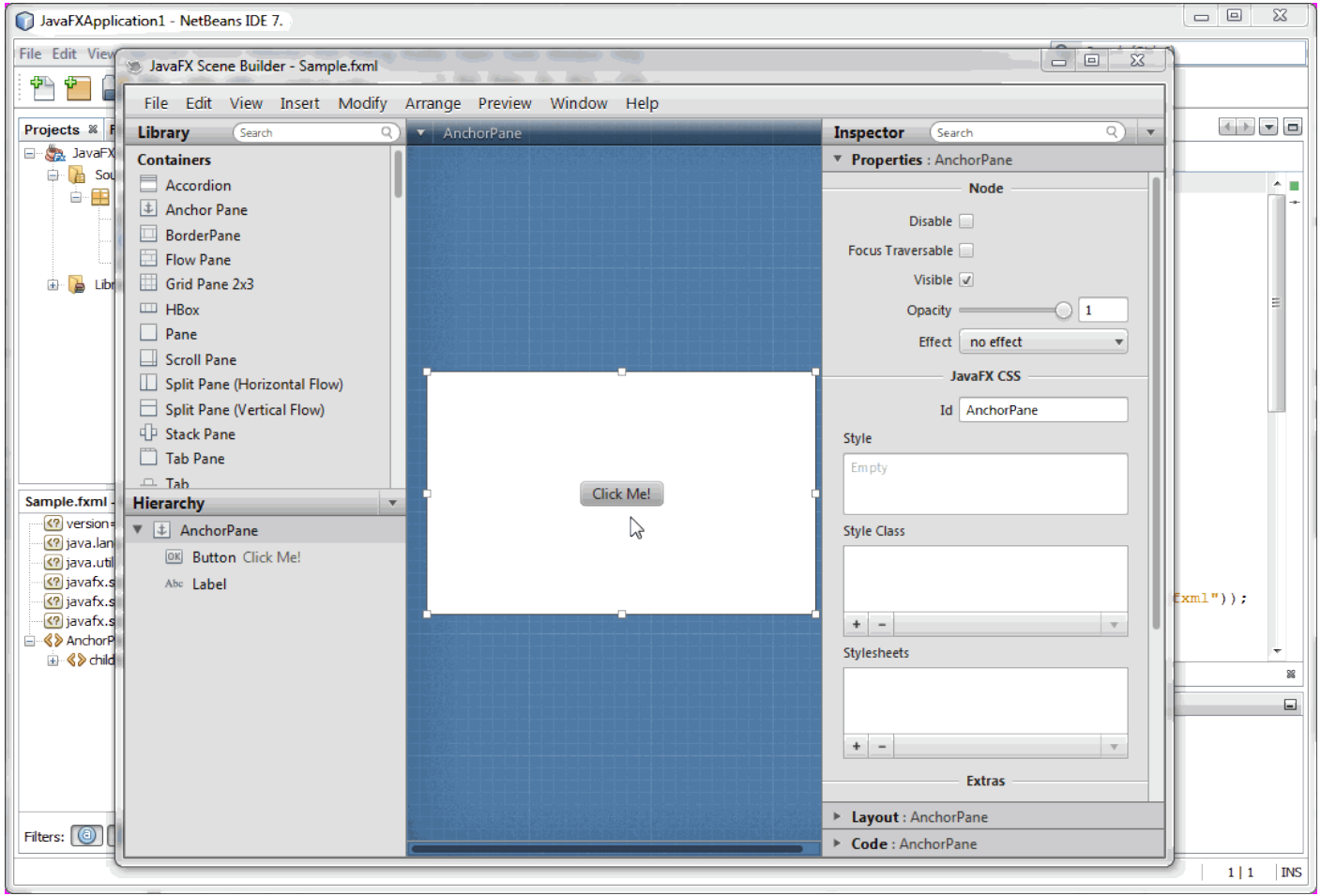
1. Constructs an instance of the specified Application class
2. Calls the concrete method init()
3. Calls start(javafx.stage.Stage) method (must be Overridden)
4. Waits for the application to finish
5. Calls the concrete method stop()

JavaFX: Button in a Pane

```
public class ButtonInPane extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) {
        // Set the stage title
        primaryStage.setTitle(”Button in a Pane");
        // Create a button and place it in the scene
        Button btn = new Button(”OK");
        // Create a pane and place a button in the pane
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        // Create scene with a pane inside it
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
```



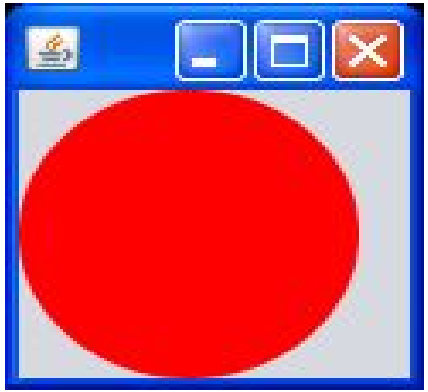
Alternatively: Scene Builder + FXML



- Scene Builder provides a graphical interface for designing and constructing user interfaces
- Scene Builder allows for components to be created, placed, and for many of their properties to be modified
- Saves your layout in an FXML file, which could be read in the Java file to create the GUI

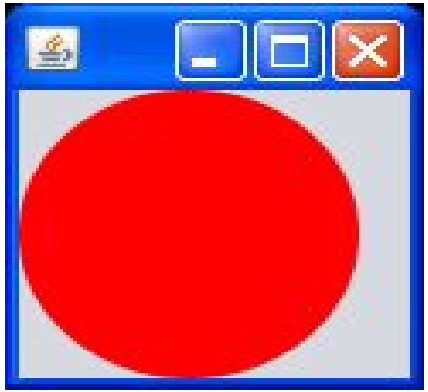
Let's Compare: JavaFX 2.0

```
public class JavaFXTest extends Application {
  @Override public void start(Stage stage) {
    stage.setTitle("FXML Example");
    Group root = new Group();
    Scene scene = new Scene(root,100,100);
    stage.setScene(scene);

    Circle c1 =
      new Circle(50.0f, 50.0f, 50.0f, Color.RED);

    root.getChildren().add(c1);
    stage.setVisible(true);
    stage.show();
  }

  public static void main(String[] args) {
     launch(args);
  }
}
```



Let's Compare: FXML

```
<BorderPane>
  <center>
    <Circle radius="50" centerX="50" centerY="50"/>
  </center>
</BorderPane>
```



```
public class JavaFXTest extends Application {
  @Override public void start(Stage stage) {
    stage.setTitle("FXML Example");
    Parent root = FXMLLoader.load(getClass().getResource("example.fxml"),
        ResourceBundle.getBundle("r.fxml_example"));
    stage.setScene(new Scene(root));
    stage.show();

  }
  public static void main(String[] args) {
     launch(args);
  }
}
```

JavaFX UI Controls

Event Programming

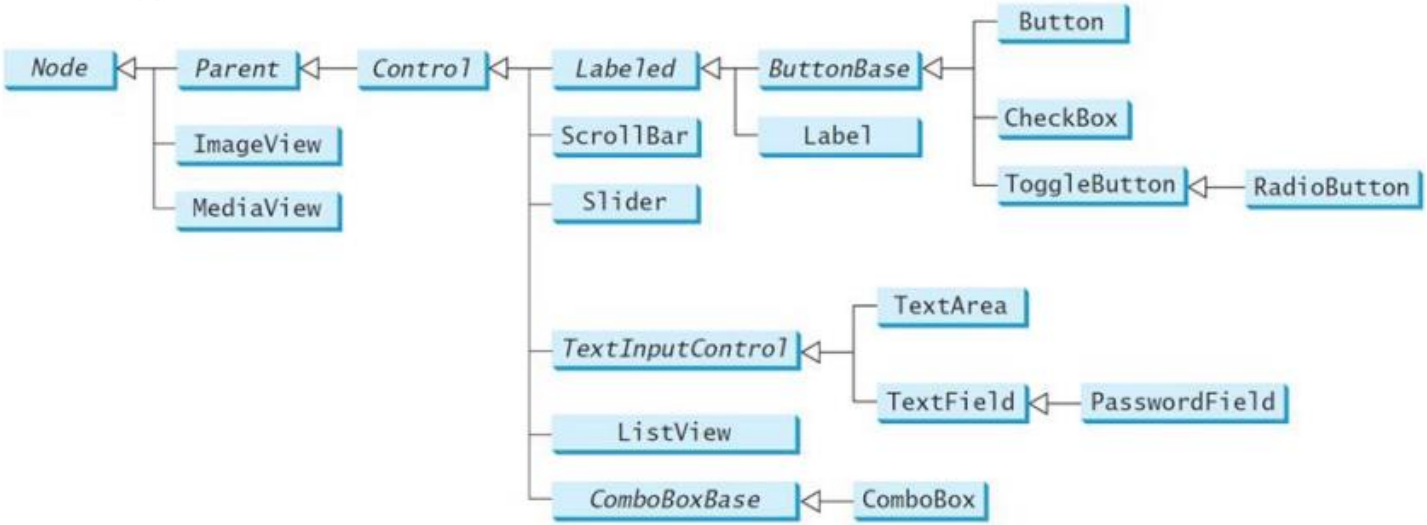
- Procedural programming is executed in procedural/statement order
- In event-driven programming, code is executed upon activation of events
- Operating Systems constantly monitor events
  - Ex: keystrokes, mouse clicks, etc…
- The OS:
  - sorts out these events
  - reports them to the appropriate programs

How to do Event Programming?

- For each control (button, combo box, etc.)
  - define an event handler
  - construct an instance of event handler
  - tell the control who its event handler is
- Event Handler?
  - code with response to event
  - a.k.a. event listener

Java’s Event Handling

- An event source is a GUI control
  - JavaFX: Button, ChoiceBox, etc.
- Different types of sources:
  - can detect different types of events
  - can register different types of listeners (handlers)



Event Creation

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(new HelloEvent());
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}

.........
```

- When the user interacts with a control (source):
  - an event object is constructed
    - Contain information about the event
    - Like what?
      - location of mouse click
      - event source that was interacted with, etc.
  - the event object is sent to all registered listener objects
  - the listener object (handler) responds as you defined it to

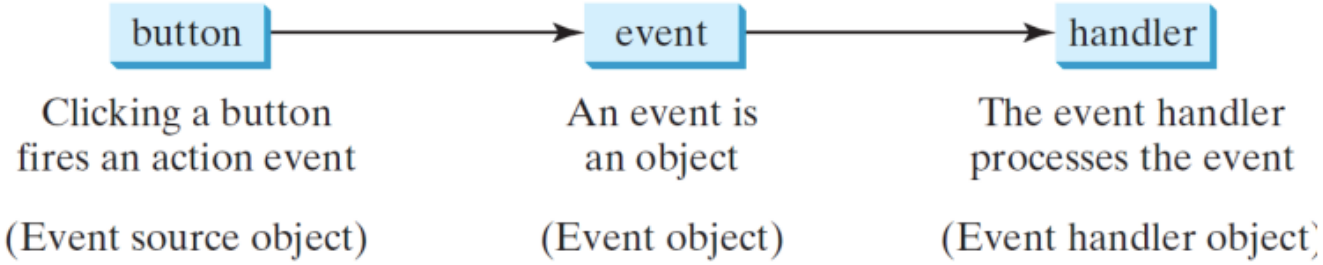
Event Listeners

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(new HelloEvent());
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
class HelloEvent implements EventHandler<ActionEvent> {
     @Override
     public void handle(ActionEvent event) {
         System.out.println("Hello World!");
     }
}
```

- Event listeners (event handler)
  - Defined by you, the application programmer
    - you customize the response
    - How?
      - Inheritance & Polymorphism
  - You define your own listener class
    - implement the appropriate interface
    - define responses in all necessary methods

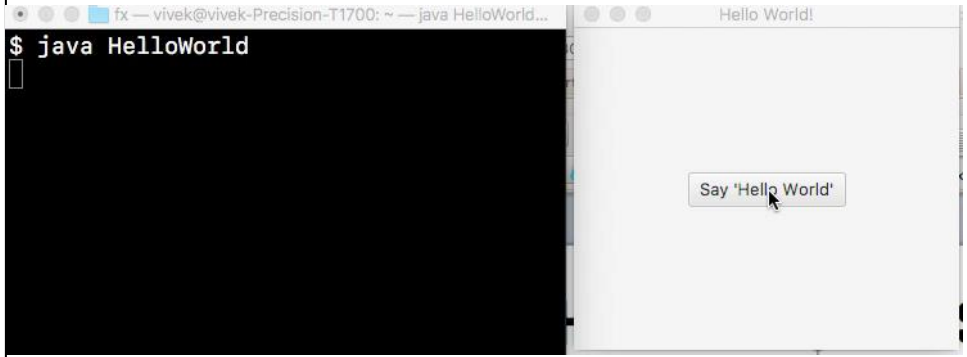
Summary: How to Handle GUI Events

- Source object: button
  - An event is generated by external user actions such as mouse movements, mouse clicks, or keystrokes
- An event can be defined as a type of signal to the program that something has happened
- Listener object contains a method for processing the event.



Working of Our Hello World GUI

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(new HelloEvent());
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
class HelloEvent implements EventHandler<ActionEvent> {
     @Override
     public void handle(ActionEvent event) {
         System.out.println("Hello World!");
     }
}
```



Productivity in Event Programming

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(new HelloEvent());
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
class HelloEvent implements EventHandler<ActionEvent> {
     @Override
     public void handle(ActionEvent event) {
         System.out.println("Hello World!");
     }
}
```

- Can we write this code in much better way?

Productivity in Event Programming (1/3)

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(new HelloEvent());
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
    class HelloEvent implements EventHandler<ActionEvent> {
         @Override
         public void handle(ActionEvent event) {
             System.out.println("Hello World!");
         }
    }
}
```

- Using **inner** classes for creating listener objects

Productivity in Event Programming (2/3)

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(new EventHandler<ActionEvent>() {

            @Override
            public void handle(ActionEvent event) {
                System.out.println("Hello World!");
            }
        });
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
```

- Using **anonymous** inner classes for creating listener objects
  - It combines declaring an inner class and creating an instance of the class in one step
  - An anonymous inner class must always extend a superclass or implement an interface, but it cannot have an explicit extends or implements clause
    - An anonymous inner class must implement all the abstract methods in the superclass or in the interface
  - An anonymous inner class always uses the no-arg constructor from its superclass to create an instance

Productivity in Event Programming (3/3)

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) {
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(e -> {
            System.out.println("Hello World!");
        });
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 300, 250);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
```

- **Using Java 8 lambda expressions to simplify event handling**
  - Lambda expressions can be viewed as an anonymous method with a concise syntax
  - The statements in the lambda expression is all for that method
  - If it contains multiple methods, the compiler will not be able to compile the lambda expression
  - So, for the compiler to understand lambda expressions, the interface must contain exactly one method

BUT, What is a Lambda ???

Let's take a detour…

Collection Elements (1/4)

```
public class Test {
    Map<String, Integer> items =
                new HashMap<String, Integer>();

    public void addElements() { ..... }

    public void print() {
        for(Map.Entry<String, Integer> entry
                    : items.entrySet()) {
            System.out.println(entry.getKey()
                        + ", " + entry.getValue());
        }
    }

}
```

- Till now we know only this way to iterate over a collection (e.g., Map)
- Drawback
  - Slightly inconvenient coding

Collection Elements (2/4)

```
public class Test {
    Map<String, Integer> items =
                new HashMap<String, Integer>();

    public void addElements() { ..... }

    public void print() {
        items.forEach( (k, v) -> {
            System.out.println(k + “, “ + v);
        });
    }

}
```

- Java 8 introduces **forEach** statement to ease iterating over the collection elements
- With **lambda expressions** in Java 8 this code becomes very compact now!

Collection Elements (3/4)

```
public class Test {
    Map<String, Integer> items =
                new HashMap<String, Integer>();

    public void addElements() { ..... }

    public void print() {
        items.forEach( (k, v) -> {
            if("ABC".equals(k)) {
                System.out.println("Hello ABC!");
            }
            System.out.println(k + ", " + v);
        });
    }

}
```

- With lambda expressions in Java 8 this code becomes very compact now!
- You can do some more stuff inside that lambda function!

Collection Elements (4/4)

```
public class Test {
    Map<String, Integer> items =
                new HashMap<String, Integer>();

    public void addElements() { ..... }

    public void print() {
        items.forEach( (String k, Integer v) -> {
            if("ABC".equals(k)) {
                System.out.println("Hello ABC!");
            }
            System.out.println(k + ", " + v);
        });
    }

}
```

- With lambda expressions in Java 8 this code becomes very compact now!
- You can do some more stuff inside that lambda function!
- You can even declare type of variables in lambda function

Productivity in Event Programming (3/3)

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button("Say Hello World");

        btn.setOnAction(e -> {
            System.out.println("Hello World!");
        });
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
        primaryStage.setScene(scene);
        // Display the stage
        primaryStage.show();
    }
}
```

- Using Java 8 **lambda** expressions to simplify event handling
  - Lambda expressions can be viewed as an anonymous method with a concise syntax
  - The statements in the lambda expressions is all for that method
  - If it contains multiple methods, the compiler will not be able to compile the lambda expression
  - So, for the compiler to understand lambda expressions, the interface must contain exactly one method

Now, let's come back to JavaFX…

Productivity in Event Programming (3/3)

```
public class HelloWorld extends Application {
    public static void main(String[] args) {
        launch(args);
    }

    @Override
    public void start(Stage primaryStage) { // entry point
        primaryStage.setTitle("Hello World!");
        Button btn = new Button(“Say Hello World”);

        btn.setOnAction(e -> {
            System.out.println("Hello World!");
        });
        StackPane pane = new StackPane();
        pane.getChildren().add(btn);
        Scene scene = new Scene(pane, 200, 50);
        // Place the scene in the stage
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```

- Using Java 8 **lambda** expressions to simplify event handling
  - Lambda expressions can be viewed as an anonymous method with a concise syntax
  - The statements in the lambda expression is all for that method
  - If it contains multiple methods, the compiler will not be able to compile the lambda expression
  - So, for the compiler to understand lambda expressions, the interface must contain exactly one method