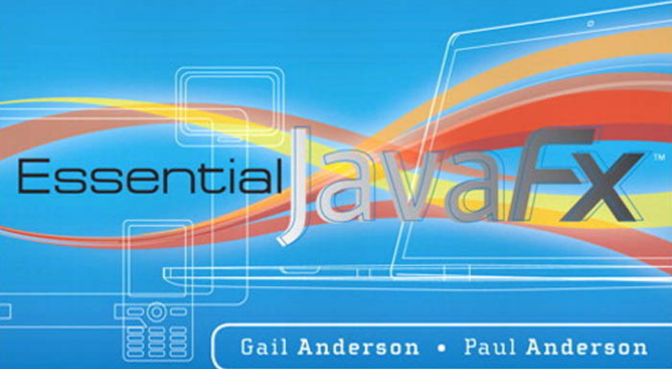
Sun microsystems



Essential JavaFx™

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JavaFx

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Preface

As we complete the final edits and our printing deadline looms, we're excited and grateful to be involved with JavaFX. In February 2009, JavaFX reached the 100,000,000th download of the JavaFX runtime.[1] The ranks of JavaFX developers will undoubtedly grow as more developers see the flexibility and power of JavaFX. This synergy, we believe, will fuel continued development of the language and enhancements to the runtime environment.

This book is designed to get you up to speed quickly with JavaFX. JavaFX is a scripting language. It's not Java, but it's built on top of the Java runtime. You don't need experience with Java to succeed with JavaFX. Indeed, JavaFX's declarative syntax makes life easier if you *don't* think like a developer. Instead, JavaFX encourages you to think like a designer.

What does it mean to "think like a designer"? Basically, it means to visualize the structure of your application or widget and compose your scene out of simple shapes and other building blocks. In JavaFX, you compose a scene by declaring objects.

Let's take an example. Say you visualize a sky with the sun, the sea, and an island (think South Pacific). The sky is the background, reflecting the blues of a bright cloudless day (think of a linear gradient, going from "blue sky" to "azure"). The sun is a Circle, with a radial gradient consisting of yellows and oranges. The island is a quadratic curve (think of a cone-shaped volcano-type island paradise filled with a gradient of rich browns and tropical greens). And there you have your scene, as shown in Figure 1 (in a black and white approximation).[2]

Not only can you declare visual objects with JavaFX, but you can also declare animations. Animations give your objects life. Returning to our island paradise, visualize the beginning of the day. The colors are muted as the morning light slowly gives shape to an ethereal world. The sun rises and the island takes form. The sun continues

1. Jonathan Schwartz's Blog: *JavaFX Hits 100,000,000 Milestone!* February 13, 2009. URL: `http://blogs.sun.com/jonathan/entry/javafx_hits_100_000_000`
2. You'll find widget Island Paradise with the other JavaFX examples on the authors' web site at `http://www.asgteach.com/javafx`.

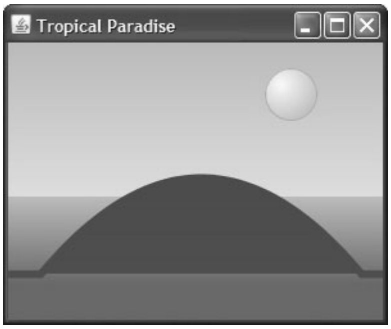


Figure 1. Visualizing an island paradise

higher in the sky and the whole world brightens. When the sun reaches its zenith, the colors of the sea and sky are saturated with "sea green," "azure," and "sky blue." But, it's a temporary brightness. The sun follows its path and eventually falls back into the sea in a glow of warm reds. The sky darkens. The sea fades. Eventually the island disappears. Everything is black. You build these behaviors with animation and a powerful JavaFX language construct called *binding*. (Binding lets you declare dependencies among objects—when a variable changes, JavaFX automatically updates all objects bound to that variable.)

JavaFX animation lets you move objects along a path (the sun rises and sets in an arc) and fade objects in and out with timelines. Our "island paradise" controls day and night with black and red rectangle "filters." These filters color the scene as night, dawn, daytime, evening, dusk, and back to night, all cycling through an accelerated Circadian clock. Animation and binding make it all work.

If you're a Java programmer, you will feel at home in JavaFX with packages and import statements, classes, things called public, and static type checking. (Don't worry about these things if you're not a Java programmer.) If you're a JavaScript programmer, you will appreciate the value of static type checking coupled with a sophisticated type inference engine in JavaFX. (Type inference eases the burden of having to specify types everywhere.) But most importantly, we hope you'll appreciate the simplicity of the JavaFX declarative style. For example, take this one-line JavaFX object "literal."

```
Circle { centerX: 200 centerY: 40 radius: 25 fill: Color.YELLOW }
```

If you think the above describes a yellow circle, then you're on your way! And, if you think perhaps it describes a yellow sun, that's even better.

About the Audience

This book is aimed at developers with some previous programming experience (in any language). We don't assume you know Java and we assume you've never written a JavaFX script before. (The term *script* in this book refers to both the programs you write and the individual files that contain these programs.)

We hope to show you how to use JavaFX effectively. There is a diversity to JavaFX: you can use it to build games, create effective web-service-based widgets, or build snazzy front-ends to your desktop applications. You can use Swing-based components, "native" JavaFX components, or roll your own. You can collaborate with designers and import images and other assets to incorporate into your scene graph. Our aim is to expose some of this diversity so that you can forge ahead with your own successful JavaFX projects.

How to Use This Book

Chapter 1 gets you started with JavaFX. We show you how to download JavaFX and begin building projects with the NetBeans IDE. (We use NetBeans to build our examples, but you can also use Eclipse.)

Chapter 2 gives you a broad overview of JavaFX. It takes you through an example (a Guitar Tuner), pointing out how things are done with JavaFX. If you want to get a "feel" for the language, this chapter introduces you to many trademark JavaFX features.

Chapter 3 through Chapter 5 are "reference-oriented" chapters. Chapter 3 describes the JavaFX language, Chapter 4 describes graphical objects, and Chapter 5 discusses user interface components. These chapters are organized with small examples to help you find information quickly (how do I bind an object or generate a sequence with a for loop?). The language chapter covers everything from JavaFX built-in types to mixin inheritance. Graphical objects are the basic JavaFX shapes you use to build scene graphs and layout objects (islands in the sun, for example). The components chapter shows you the JavaFX Swing components and the JavaFX "native" UI components. We also show you how to build custom UI components in a more advanced section.

Chapter 6 shows you how to design and structure a JavaFX application. It introduces a building-block approach with a nod towards object oriented design principles.

Chapter 7 is all about JavaFX animation and timelines. JavaFX animation is both powerful and flexible. Transitions are "pre-packaged high-level" animations that help build straightforward motions quickly, such as fade-ins and fade-outs, scaling, and moving.

Chapter 8 discusses viewing and manipulating images. One example shows you how to design an animated photo carousel.

Chapter 9 covers web services. JavaFX provides two important utility classes that make it easier to work with web services. An HttpRequest class handles asynchronous web requests and a PullParser class simplifies processing the response data. We take you through several Flickr-based web service API calls.

Chapter 10 discusses the JavaFX mobile environment and explores the differences between desktop JavaFX and the JavaFX mobile runtime. We discuss guidelines for targeting mobile devices and how to make an application mobile-friendly.

About the Examples

You can download the source code for all book examples from the authors' web site at

```
http://www.asgteach.com/javafx
```

In addition, example applications are deployed so you can try them out.

Notational Conventions

We've applied a rather light hand with font conventions in an attempt to keep the page uncluttered. Here are the conventions we follow.

Element	**Font Example**
JavaFX class	Shape, Circle, Color
JavaFX property	`layoutBounds, opacity, height`

JavaFX code	`def sunPath = Path {`
	`    elements: sunElements`
	`    stroke: Color.GRAY`
	`}`

URL	`http://javafx.com/`
file name	**Main.fx**, **Carousel.fx**
key combinations	**Ctrl+Space**
NetBeans menu selections	**Properties** menu item
code within text	The animation varies property `opacity` from . . .

code highlighting
(to show modified or relevant portions)
	`def sunPath = Path {`
	`    elements: sunElements`
	`    stroke: Color.GRAY`
	`}`

2 A Taste of JavaFX

As the preface hints, JavaFX has a combination of features that makes it unique. This chapter gives you a taste of the language and some of these features. Our goal is to choose a representative example so you get a feel for the kinds of programs possible with JavaFX. The example (a guitar tuner) illustrates language constructs while keeping the discussion concrete. We'll veer away from the example at times to illustrate additional JavaFX features that are relevant. While this overview is in no way complete (remember, it's just a taste), we hope to entice you to explore JavaFX further.

The source code for GuitarTuner appears at the end of the chapter (see "Source Code for Project GuitarTuner" on page 36). To keep the text flowing, we'll show snippets from this application throughout the overview.

What You Will Learn

- What makes JavaFX unique as a scripting language
- All about object literals and declarative constructs
- Introducing the JavaFX scene graph
- Declaring variables, properties, and objects
- Initializing objects and object properties
- Basics in container coordinate space and layout
- Creating a custom node
- Manipulating objects with color, effects, and gradients
- Getting things done with binding, event handlers, and animation

2.1 Introducing JavaFX

What is JavaFX? JavaFX is a scripting language with static typing. You can call a Java API as needed from JavaFX and create new object types with classes, but JavaFX also provides an easy declarative syntax. (Declarative means you say what you want and the system figures out how to do it for you.) JavaFX provides properties for manipulating objects within a 2D coordinate system, specifying fill and pen stroke colors, and creating special effects. You can create shapes and lines, manipulate images, play videos and sounds, and define animations.

Let's begin exploring JavaFX by introducing the basics. Our introduction begins with project GuitarTuner where you'll see the main structure of a JavaFX program. Then, you'll explore a few JavaFX language constructs and see how to improve the appearance of your applications. Finally, you'll see how to make applications do things.

JavaFX in a Nutshell

JavaFX is statically typed, meaning program data types are known at compile time. JavaFX also uses type inference. This means you don't have to declare the type of every variable because JavaFX can generally figure it out for you. This gives JavaFX the efficiency of a statically typed language combined with the ease of a declarative language.

2.2 Project GuitarTuner

Project GuitarTuner helps you tune your guitar. It displays a visual guitar fret board with six strings. The letter (note) corresponding to the guitar string appears next to the fret board. When you click a string with the mouse, you'll hear a synthesized guitar note for the selected string as it vibrates visually. Project GuitarTuner uses the Java `javax.sound.midi` API to generate the sounds. Figure 2.1 shows this application running when the A string is vibrating. The corresponding JavaFX graphical objects are labeled.

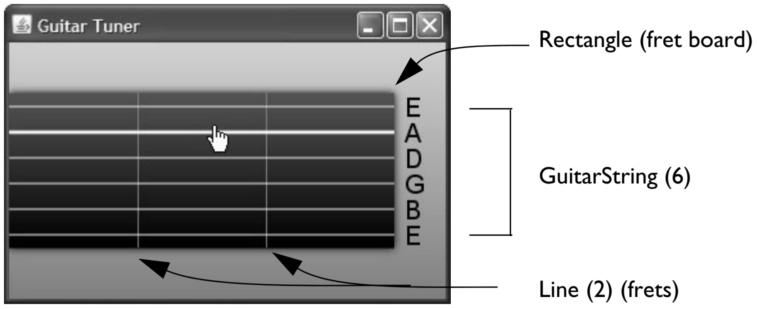


Figure 2.1 JavaFX application GuitarTuner

The Scene Graph Metaphor

JavaFX programs with a graphical user interface define a *stage* and a *scene* within that stage. The stage represents the top level container for all JavaFX objects; that is, the content area for an applet or the frame for a widget. The central metaphor in JavaFX for specifying graphics and user interaction is a *scene graph.* A scene defines a hierarchical node structure that contains all the scene's components. *Nodes* are represented by graphical objects, such as geometric shapes (Circle, Rectangle), text, UI controls, image viewers, video viewers, and user-created objects (such as GuitarString in our example). Nodes can also be containers that in turn hold more nodes, letting you group nodes together in hierarchical structures. (For example, Group is a general-purpose container node, HBox provides horizontal layout alignment, and VBox provides vertical layout alignment.) The scene graph is this hierarchical node structure.

Figure 2.2 shows the scene graph for project GuitarTuner. Compare the visual graphical elements in Figure 2.1 with the scene graph depicted in Figure 2.2.

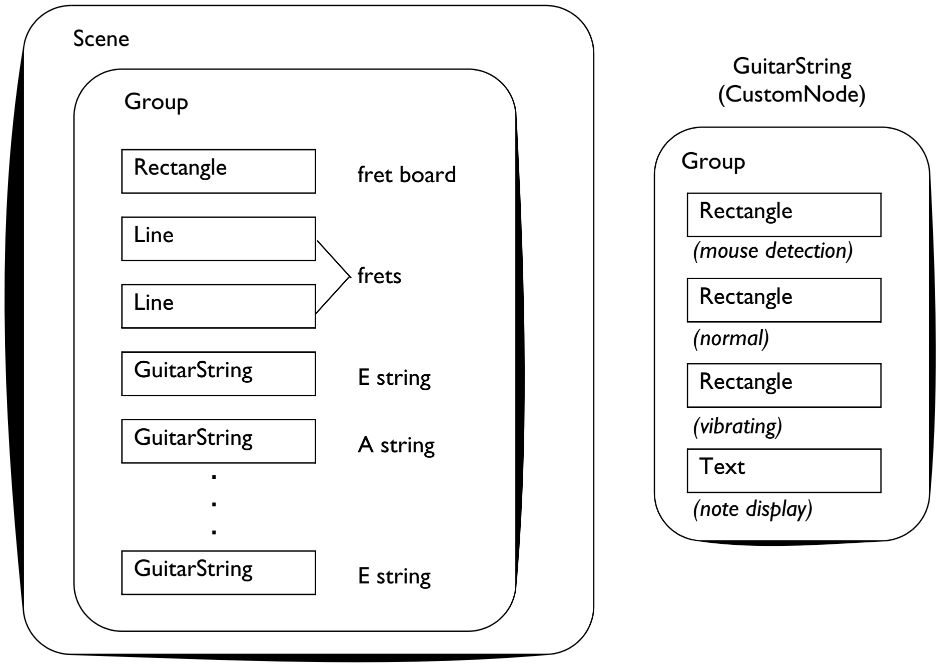


Figure 2.2 Nested Scene Graph for GuitarTuner

In general, to construct a JavaFX application, you build the scene graph, specifying the look and behavior of all its nodes. Then, your application just "runs." Some applications need input to go—user actions that activate animations or affect component properties. Other applications just run on their own. (Building the scene graph is analogous to winding up a toy. When you're done, the application just runs.)

JavaFX Scene Graph

The power of the scene graph is that, not only do you capture the entire structure of your application in a data structure, but you can change the display simply by modifying properties of the objects in the scene graph. (For example, if you change a node's `visible` *property to* `false`*, that node, and any nodes it contains, disappears. If you change a node's location, it moves.)*

Within the scene graph for project GuitarTuner, you see the Scene at the top level, which contains a Group. Within the Group there is a Rectangle for the fret board (the guitar neck), two Line nodes representing frets, and six GuitarStrings. Each GuitarString is in turn its own Group consisting of three Rectangles and a Text node. Nodes that contain other nodes (such as Scene and Group) include a `content` property that holds subnodes. The hierarchical nature of the scene graph means that all nodes at the same level share the same coordinate space. You therefore build node structures (such as GuitarString) that use a relative coordinate system. You'll see shortly why this is useful.

Think Like A Designer

JavaFX encourages you to think like a designer. As a first step, visualize the structure of your application or widget and compose your scene out of simple shapes and other building blocks.

The order of nodes within a parent container affects their rendering. That is, the first node in the container is "drawn" first. The final node is "drawn" last and is on top of the view. Nodes (depending on their placement within the coordinate system) may visually block or "clip" previously drawn nodes. In GuitarTuner, the nodes must be in a specific order. You draw the fret board first, then the frets, and finally the guitar strings, which appear on top.

Changing the relative order of nodes in a container is easy. The `toFront()` function brings a node to the front (top) and the `toBack()` function sends a node to the back (bottom).

Hierarchical Scene Graph

Figure 2.3 also shows a scene graph of project GuitarTuner. Figure 2.2 and Figure 2.3 depict the same structure, but Figure 2.3 shows the hierarchical relationship among the nodes in the scene using a graphical tree view. Nodes at the same level share the same coordinate space. For example, the three Rectangles and Text nodes in the GuitarString share the same coordinate system.

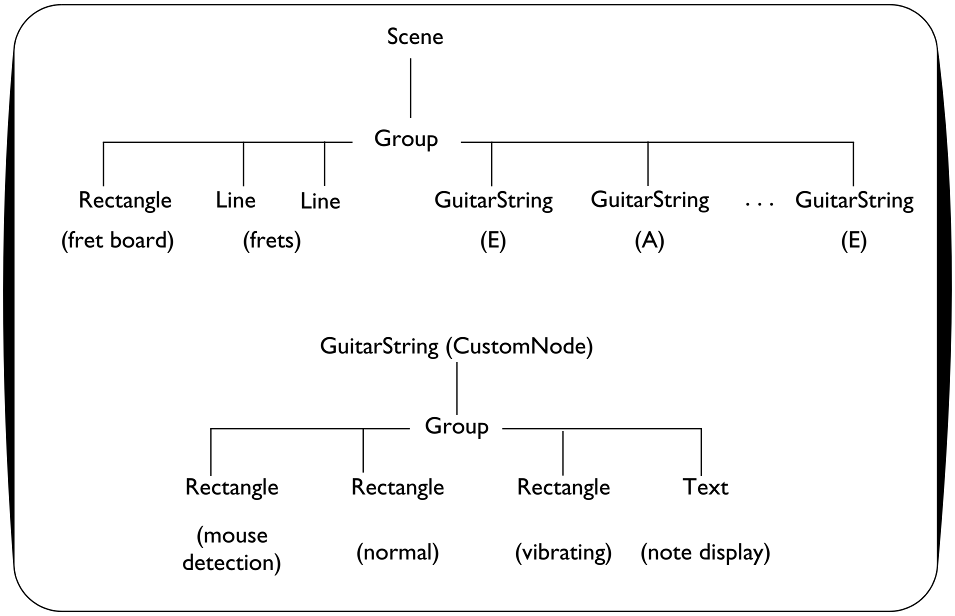


Figure 2.3 Scene Node Graph for project GuitarTuner

2.3 JavaFX Program Structure

JavaFX program structure is simple. For programmers who are used to traditionally compiled programs, programming in JavaFX will feel different. With static typing, JavaFX gives you feedback at compile time when you use types incorrectly. This greatly enhances your ability to write correct code. Furthermore, with the NetBeans IDE, you can access JavaDocs for all JavaFX types (classes) and dynamically query these class properties and functions, essentially getting feedback at edit time.

Let's see how the Stage and Scene form the JavaFX program structure.

Stage and Scene

The Stage is the top-level container and contains the Scene. The Scene, in turn, holds nodes that make up the scene graph. Every JavaFX program that has graphical objects declares a Stage object.

Here is a top-level implementation of the scene graph for GuitarTuner from Figure 2.2 (or Figure 2.3). (We'll look at GuitarString's node graph shortly.)

```
// Stage and Scene Graph
Stage {
   title: "Guitar Tuner"
   Scene {
      // content is sequence of SceneGraph nodes
      content: [
         Group {
            content: [
               Rectangle { ... }
               Line { ... }
               Line { ... }
               GuitarString { ... }
               GuitarString { ... }
               GuitarString { ... }
               GuitarString { ... }
               GuitarString { ... }
               GuitarString { ... }
            ]
         }  // Group
      ]
   }  // Scene
}  // Stage
```

Object Literals

The Stage and Scene objects are instantiated with object literal expressions, or *object literals*. Object literals provide a declarative style of programming. Intuitively, declarative means "tell me what you want, not how to do it." As you will see, the real declarative part of JavaFX is *binding*. We show why this is so powerful later in the chapter.

Object literals require an object (or class) type (such as Stage or Scene) followed by curly braces `{ }`. Any properties you need to initialize appear inside the braces. (Stage has a `title` property and Scene and Group both have `content` properties.) Each property has a name, followed by a colon `:` and an initial value for the property. You separate properties with commas, line breaks, or white space. Here, for example is an object literal that initializes a Rectangle (properties `x` and `y` designate the upper-left corner origin).

```
Rectangle { x: 10, y: 20, height: 15, width: 150 }
```

The above Stage, Scene, and Group objects are defined with object literals. Note that the Scene object nests inside the Stage object. Likewise, a Group nests inside the Scene. Square brackets `[ ]` define a sequence of items for the `content` property in a Scene or Group. Here, the Scene object's `content` property is a sequence of all of the top-level nodes of the Scene. In the GuitarTuner application, this is a Group node (see Figure 2.2 or Figure 2.3). The Group node likewise includes a `content` property with all of its subnodes (Rectangles, Lines, and a custom GuitarString). How you nest these nodes determines the structure of the scene graph.

Here's the top-level implementation for GuitarString from its scene graph in Figure 2.2 (and Figure 2.3).

```
// GuitarString - defined as custom class
Group {
   content: [
      Rectangle { ... }
      Rectangle { ... }
      Rectangle { ... }
      Text { ... }
   ]
}  // Group
```

The GuitarString consists of a Group node whose `content` property defines a sequence containing three rectangles and a Text object. You'll see how this fits into the Guitar-Tuner application later on.

2.4 Key JavaFX Features

GuitarTuner is a fairly typical JavaFX example application. It has a graphical representation and responds to user input by changing some of its visual properties (as well as producing guitar sounds). Let's look at some of the key JavaFX features it uses to give you a broad look at the language.

Signature JavaFX Features

Included in any list of key JavaFX features are binding, node event handlers, and animation. We discuss each of these important constructs in their own section (see "Doing Things" on page 31).

Type Inference

JavaFX provides `def` for read-only variables and `var` for modifiable variables.

```
def numberFrets = 2;       // read-only Integer
var x = 27.5;              // variable Number
var y: Number;             // default value is 0.0
var s: String;             // default value is ""
```

The compiler *infers types* from the values you assign to variables. Read-only `numberFrets` has inferred type `Integer`; variable `x` has inferred type `Number` (`Float`). This means you don't have to specify types everywhere (and the compiler tells you when a type is required.)

Strings

JavaFX supports dynamic string building. Curly braces `{ }` within a String expression evaluate to the contents of the enclosed variable. You can build Strings by concatenating these String expressions and String literals. For example, the following snippet prints "`Greetings, John Doe!`".

```
def s1 = "John Doe";
println("Greetings, {s1}!");     // Greetings, John Doe!
```

Shapes

JavaFX has numerous shapes that help you create scene graph nodes. There are shapes for creating lines (Line, CubicCurve, QuadCurve, PolyLine, Path) and shapes for creating geometric figures (Arc, Circle, Ellipse, Rectangle, Polygon). The GuitarTuner application uses only Rectangle and Line, but you'll see other shape examples throughout this book.

Let's look at shapes Rectangle and Circle. They are both standard JavaFX shapes that extend class Shape (in package `javafx.scene.shape`). You define a Circle by specifying values for its `radius`, `centerX`, and `centerY` properties. With Rectangle, you specify values for properties `height`, `width`, `x`, and `y`.

Shapes share several properties in common, including properties `fill` (type Paint to fill the interior of the shape), `stroke` (type Paint to provide the outline of the shape), and `strokeWidth` (an Integer for the width of the outline).

Here, for example, is a Circle with its center at point `(50,50)`, radius 30, and color `Color.RED`.

```
Circle {
   radius: 30
   centerX: 50
   centerY: 50
   fill: Color.RED
}
```

Here is a Rectangle with its top left corner at point `(30, 100)`, height 30, width 80, and color `Color.BLUE`.

```
Rectangle {
   x: 30, y: 100
   height: 30, width: 80
   fill: Color.BLUE
}
```

All shapes are also Nodes (`javafx.scene.Node`). Node is an all-important class that provides local geometry for node elements, properties to specify transformations (such as translation, rotation, scaling, or shearing), and properties to specify functions for mouse and key events. Nodes also have properties that let you assign CSS styles to specify rendering.[1] We discuss graphical objects in detail in Chapter 4.

Sequences

Sequences let you define a collection of objects that you can access sequentially. You must declare the type of object a sequence will hold or provide values so that its type can be inferred. For example, the following statements define sequence variables of GuitarString and Rectangle objects.

```
var guitarStrings: GuitarString[];
var rectangleSequence: Rectangle[];
```

These statements create read-only sequences with `def`. Here, sequence `noteValues` has an inferred type of `Integer[]`; sequence `guitarNotes` has an inferred type of `String[]`.

```
def noteValues = [ 40,45,50,55,59,64 ];
def guitarNotes = [ "E","A","D","G","B","E" ];
```

Sequences have specialized operators and syntax. You will use sequences in JavaFX whenever you need to keep track of multiple items of the same object type. The GuitarTuner application uses a sequence with a for loop to build multiple Line objects (the frets) and GuitarString objects.

```
    // Build Frets
    for (i in [0..<numberFrets])
       Line { . . . }

    // Build Strings
    for (i in [0..<numberStrings])
       GuitarString { . . . }
```

The notation `[0..<n]` is a sequence literal and defines a range of numbers from `0` to `n-1`, inclusive.

You can declare and populate sequences easily. The following *declarative approach* inserts Rectangles into a sequence called `rectangleSequence`, stacking six Rectangles vertically.

```
    def rectangleSequence = for (i in [0..5])
       Rectangle {
```

1. Cascading Style Sheets (CSS) help style web pages and let designers give a uniform look and feel throughout an application, widget, or entire web site. You can use CSS to similarly style JavaFX nodes. (See “Cascading Style Sheets (CSS)” on page 148 for details on applying styles to JavaFX nodes.)

```
            x: 20
            y: i * 30
            height: 20
            width: 40
         }
```

You can also insert number values or objects into an existing sequence using the `insert` operator. The following *imperative approach* inserts the six Rectangles into a sequence called `varRectangleSequence`.

```
      var varRectangleSequence: Rectangle[];
      for (i in [0..5])
         insert Rectangle {
            x: 20
            y: i * 30
            height: 20
            width: 40
         } into varRectangleSequence;
```

JavaFX Tip

The declarative approach with `rectangleSequence` *is always preferred (if possible). By using* `def` *rather than* `var` *and declaring sequences rather than inserting objects into them, type inference will more likely help you and the compiler can optimize the code more effectively.*

You'll see more uses of sequence types throughout this book.

Calling Java APIs

You can call any Java API method in JavaFX programs without having to do anything special. The GuitarString node "plays a note" by calling function `noteOn` found in Java class SingleNote. Here is GuitarString function `playNote` which invokes SingleNote member function `noteOn`.

```
   function playNote(): Void {
      synthNote.noteOn(note);    // nothing special to call Java methods
      vibrateOn();
   }
```

Class SingleNote uses the Java `javax.sound.midi` package to generate a synthesized note with a certain value (60 is "middle C"). Java class SingleNote is part of project GuitarTuner.

Extending CustomNode

JavaFX offers developers such object-oriented features as user-defined classes, overriding virtual functions, and abstract base classes (there is also "mixin" inheritance).

GuitarTuner uses a class hierarchy with subclass GuitarString inheriting from a JavaFX class called CustomNode, as shown in Figure 2.4.

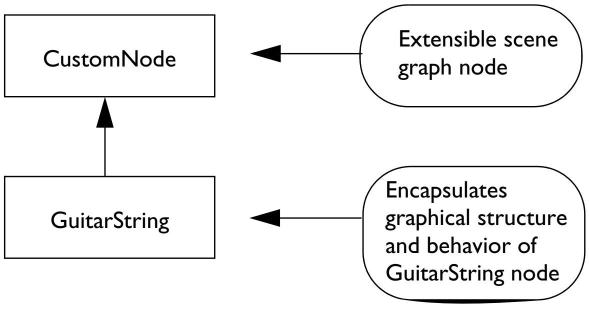

CustomNode
Extensible scene graph node
GuitarString
Encapsulates graphical structure and behavior of GuitarString node

Figure 2.4 GuitarString Class Hierarchy

This approach lets you build your own graphical objects. In order for a custom object to fit seamlessly into a JavaFX scene graph, you base its behavior on a special class provided by JavaFX, *CustomNode*. Class CustomNode is a scene graph node (a type of Node, discussed earlier) that lets you specify new classes that *extend* from it. Just like Java, "extends" is the JavaFX language construct that creates an inheritance relationship. Here, GuitarString extends (*inherits from*) CustomNode. You then supply the additional structure and behavior you need for GuitarString objects and override any functions required by CustomNode. JavaFX class constructs are discussed in more detail in Chapter 3 (see "Classes and Objects" on page 67).

Here is some of the code from GuitarTuner's GuitarString class. The `create` function returns a Node defining the Group scene graph for GuitarString. (This scene graph matches the node structure in Figure 2.2 on page 15 and Figure 2.3 on page 17. Listing 2.2 on page 38 shows the `create` function in more detail.)

```
public class GuitarString extends CustomNode {
   // properties, variables, functions
   . . .
   protected override function create(): Node {
      return Group {
         content: [
            Rectangle { ... }
            Rectangle { ... }
            Rectangle { ... }
            Text { ... }
         ]
      }  // Group
   }
}  // GuitarString
```

Geometry System

In JavaFX, nodes are positioned on a two-dimensional coordinate system with the origin at the upper-left corner. Values for x increase horizontally from left to right and y values increase vertically from top to bottom. The coordinate system is always relative to the parent container.

Layout/Groups

Layout components specify how you want objects drawn relative to other objects. For example, layout component HBox (horizontal box) evenly spaces its subnodes in a single row. Layout component VBox (vertical box) evenly spaces its subnodes in a single column. Other layout choices are Flow, Tile, and Stack (see "Layout Components" on page 119). You can nest layout components as needed.

Grouping nodes into a single entity makes it straightforward to control event handling, animation, group-level properties, and layout for the group as a whole. Each group (or layout node) defines a coordinate system that is used by all of its children. In GuitarTuner, the top level node in the scene graph is a Group which is centered vertically within the scene. The subnodes are all drawn relative to the origin `(0,0)` within the top-level Group. Centering the Group, therefore, centers its contents as a whole.

Benefits of Relative Coordinate Space

Nodes with the same parent share the same relative coordinate space. This keeps any coordinate space calculations for subnodes separate from layout issues of the parent container. Then, when you move the parent, everything under it moves, keeping relative positions intact.

JavaFX Script Artifacts

Defining the Stage and Scene are central to most JavaFX applications. However, JavaFX scripts can also contain package declarations, import statements, class declarations, functions, variable declarations, statements, and object literal expressions. You've already seen how object literal expressions can initialize nodes in a scene graph. Let's discuss briefly how you can use these other artifacts.

Since JavaFX is statically typed, you must use either import statements or declare all types that are not built-in. You'll typically define a package and then specify import statements. (We discuss working with packages in Chapter 3. See "Script Files and Packages" on page 86.) Here is the package declaration and import statements for GuitarTuner.

```
package guitartuner;

import javafx.scene.effect.DropShadow;
import javafx.scene.paint.Color;
import javafx.scene.paint.LinearGradient;

   . . . more import statements . . .

import javafx.stage.Stage;
import noteplayer.SingleNote;
```

If you're using NetBeans, the IDE can generate import statements for you (type **Ctrl+Shift+I** in the editor window).

You'll need script-level variables to store data and read-only variables (`def`) for values that don't change. In GuitarTuner, we define several read-only variables that help build the guitar strings and a variable (`singleNote`) that communicates with the Java midi API. Note that `noteValues` and `guitarNotes` are `def` sequence types.

```
def noteValues = [ 40,45,50,55,59,64 ];
def guitarNotes = [ "E","A","D","G","B","E" ];
def numberFrets = 2;
def numberStrings = 6;
var singleNote =  SingleNote { };
```

When you declare a Stage, you define the nested nodes in the scene graph. Instead of declaring nodes only as object literal expressions, it's also possible to assign these object literals to variables. This lets you refer to them later in your code. (For example, the Scene object literal and the Group object literal are assigned to variables in order to compute the offset for centering the group vertically in the scene.)

```
var scene: Scene;
var group: Group;

scene: scene = Scene { ... }
group = Group { ... }
```

You may also need to execute JavaFX script statements or define utility functions. Here's how GuitarTuner makes the SingleNote object emit a "guitar" sound.

```
singleNote.setInstrument(27);           // "Clean Guitar"
```

Once you set up the Stage and scene graph for an application, it's ready to ready to run.[2] In GuitarTuner, the application waits for the user to pluck (click) a guitar string.

2. Java developers may wonder where function `main()` is. As it turns out, the JavaFX compiler generates a `main()` for you, but from a developer's view, you have just a script file.

2.5 Making Things Look Good

Using JavaFX features that enhance the appearance of graphical objects will help your application look professionally designed. Here are some simple additions you can apply.

Gradients

Gradients lend a depth to surfaces and backgrounds by gradually varying the color of the object's `fill` property. In general, use linear gradients with rectangular shapes and radial gradients with circles and ovals. In GuitarTuner, the background is a linear gradient that transitions from `Color.LIGHTGRAY` (at the top) to the darker `Color.GRAY` (at the bottom) as shown in Figure 2.5. The guitar fret board also uses a linear gradient.

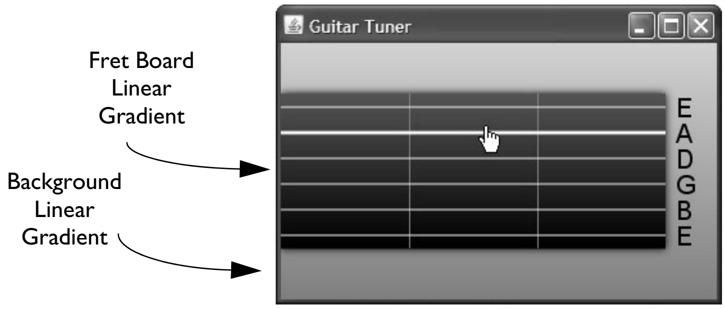


Figure 2.5 Gradients in the GuitarTuner Application

Here is the LinearGradient for the background scene in GuitarTuner, defined for property `fill`. Note that specifying gradients is declarative; you identify the look you want and the system figures out how to achieve it, independent of screen resolution, color depth, etc.

```
fill: LinearGradient {
      startX: 0.0
      startY: 0.0
      endX: 0.0
      endY: 1.0
      proportional: true
      stops: [
            Stop {
               offset: 0.0
               color: Color.LIGHTGRAY
            },
            Stop {
               offset: 1.0
```

```
                color: Color.GRAY
            }
        ]
}
```

The background gradient changes color along the y axis and the color is constant along the x axis (properties `startX` and `endX` are the same). Property `stops` is a sequence of Stop objects containing an `offset` and a `color`. The offset is a value between 0 and 1 inclusive; each succeeding offset must have a higher value than the preceding one.

Property `proportional` indicates whether start and end values are proportional (defined between [0..1] if `true`) or absolute (absolute coordinates if `false`).

Radial gradients work well for circular shapes, as shown in Figure 2.6. Here you see three Circle shapes, all with radial gradients. The first circle defines a gradient with its center in the lower left quadrant (`centerX` is `0.25` and `centerY` is `0.75`). The second circle's gradient is centered (`centerX` and `centerY` are both `0.5`), and the third circle's gradient appears in the upper right quadrant (`centerX` is `0.75` and `centerY` is `0.25`).

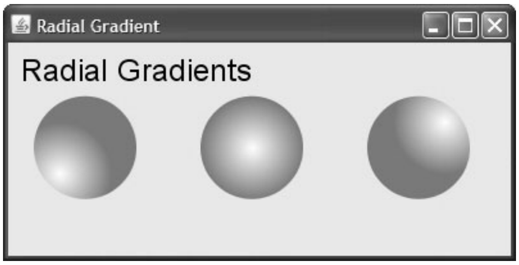


Figure 2.6 Radial Gradients work well with circular shapes

Here is the radial gradient for the middle circle.

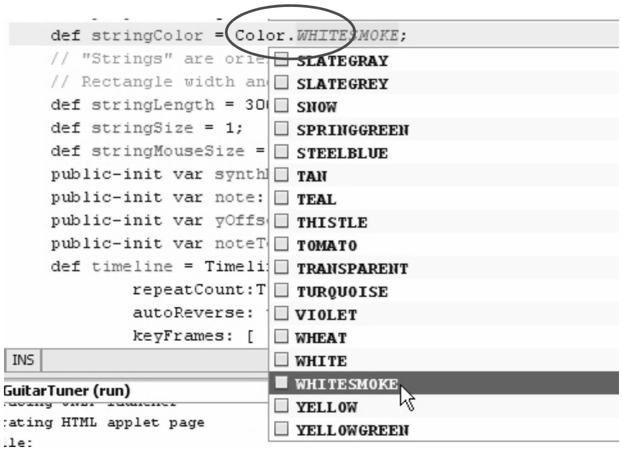
```
fill: RadialGradient {
   centerX: 0.5      // x center of gradient
   centerY: 0.5      // y center of gradient
   radius: 0.5       // radius of gradient
   stops: [
      Stop {
         offset: 0
         color: Color.WHITE
      },
      Stop {
         offset: 1
```

```
            color: Color.DODGERBLUE
        }
    ]
}
```

Note that the gradient is half the size of the circle (`radius` is `0.5`). Making the gradient less than the full size lets the last stop color appear more prominent (the dark color predominates).

Color

You specify a shape's color with property `fill`. JavaFX has many predefined colors ranging alphabetically from `Color.ALICEBLUE` to `Color.YELLOWGREEN`. (In the NetBeans IDE, press **Ctrl+Space** when the cursor is after the dot in `Color` to see a complete list, as shown in Figure 2.7.)



```
    def stringColor = Color.WHITESMOKE;
    // "Strings" are orie
    // Rectangle width an
    def stringLength = 30
    def stringSize = 1;
    def stringMouseSize =
    public-init var synth
    public-init var note:
    public-init var yOffs
    public-init var noteT
    def timeline = Timeli
            repeatCount:T
            autoReverse:
            keyFrames: [
INS
GuitarTuner (run)
:ating HTML applet page
.le:
```

```
SLATEGRAY
SLATEGREY
SNOW
SPRINGGREEN
STEELBLUE
TAN
TEAL
THISTLE
TOMATO
TRANSPARENT
TURQUOISE
VIOLET
WHEAT
WHITE
WHITESMOKE
YELLOW
YELLOWGREEN
```

Figure 2.7 Explore color choices with the NetBeans IDE

You can also specify arbitrary colors with `Color.rgb` (each RGB value ranges from 0 to 255), `Color.color` (each RGB value ranges from 0 to 1), and `Color.web` (a String corresponding to the traditional hexadecimal-based triad). An optional final argument sets the opacity, where 1 is fully opaque and 0 is fully translucent. You can also make a shape transparent by setting its `fill` property to `Color.TRANSPARENT`.

Here are several examples of color settings. Each example sets the opacity to .5, which allows some of the background color to show through.

```
def c1 = Color.rgb(10, 255, 15, .5);        // bright lime green
def c2 = Color.color(0.5, 0.1, 0.1, .5);    // dark red
def c3 = Color.web("#546270", .5);          // dark blue-gray
```

Numeric-based color values (rather than hexadecimal strings or predefined colors) let you write functions and animations that numerically manipulate gradients, colors, or opacity. For example, the following `fill` property gets its `Color.rgb` values from a `for` loop's changing value `i`. The loop produces three different shades of green, depending on the value of `i`.

```
def rectangleSequence = for (i in [0..2])
   Rectangle {
      x: 60 * i
      y: 50
      height: 50
      width: 40
      fill: Color.rgb(10 + (i*50), 100 + (i*40), i*50)
   }
```

Figure 2.8 shows the resulting set of rectangles with different `fill` values.

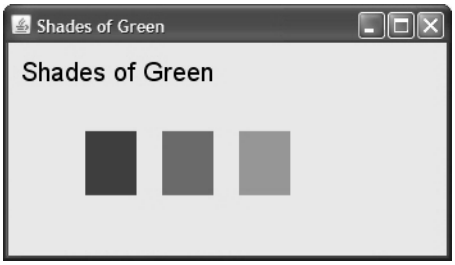


Figure 2.8 Manipulating numeric-based Color values

Rectangles with Arcs

You can soften the corners of Rectangles by specifying properties `arcWidth` and `arcHeight`, as shown in Figure 2.9. The first Rectangle has regular, square corners. The second Rectangle sets `arcHeight` and `arcWidth` to `15`, and the third one uses value `30` for both. Here's the object literal for the third Rectangle.

```
Rectangle {
   x: 180
   y: 0
   height: 70
   width: 60
   arcHeight: 30
   arcWidth: 30
   fill: LinearGradient { . . . }
}
```

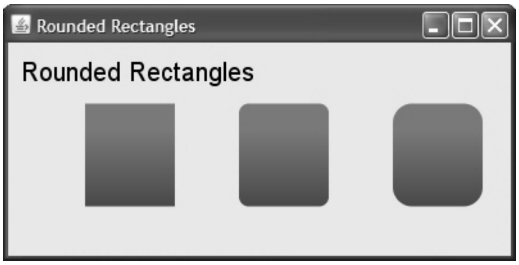


Figure 2.9 Soften Rectangles with rounded corners

DropShadows

One of the many effects you can specify is DropShadow (effects are declarative). Effect DropShadow applies a shadow to its node, giving the node a three-dimensional look. In project GuitarTuner, the fret board (guitar neck) uses a default drop shadow, as follows.

```
effect: DropShadow { }
```

The default object literal provides a drop shadow with these values.

```
effect: DropShadow {
   offsetX: 0.0
   offsetY: 0.0
   radius: 10.0
   color: Color.BLACK
   spread: 0.0
}
```

You can manipulate the location of the shadow by changing `offsetX` and `offsetY`. Negative values for `offsetY` set the shadow above the object and negative values for `offsetX` set the shadow to the left. Positive values for `offsetX` and `offsetY` place the shadow to the right and below, respectively. You can also change a shadow's size (`radius`), color, and spread (how "sharp" the shadow appears). A spread value of 1 means the shadow is sharply delineated. A value of 0 provides a "fuzzy" appearance. Figure 2.10 shows three rectangles with drop shadows that fall below and to the right of the rectangles, using these offsets.

```
effect: DropShadow {
   // shadow appears below and to the right of object
   offsetX: 5.0
   offsetY: 5.0
}
```

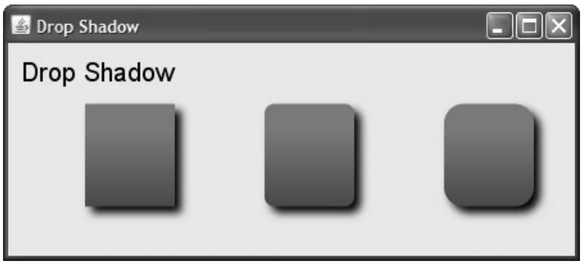


Figure 2.10 Drop shadows provide a three-dimensional effect

2.6 Doing Things

JavaFX has three main constructs for doing things: binding, node properties that define event handlers, and animation. Together, these constructs provide powerful yet elegant solutions for modifying scene graphs based on user input or other events. Let's see how GuitarTuner uses these constructs to get its tasks done.

Binding

Binding in JavaFX is a powerful technique and a concise alternative to specifying traditional callback event handlers. Basically, binding lets you make a property or variable depend on the value of an expression. When you update any of the "bound to" objects in the expression, the dependent object automatically changes. Suppose, for example, we bind `area` to `height` and `width`, as follows.

```
var height = 3.0;
var width = 4.0;
def area = bind height * width;          // area = 12.0

width = 2.5;                             // area = 7.5
height = 4;                              // area = 10.0
```

When either `height` or `width` changes, so does `area`. Once you bind a property (or variable), you can't update it directly. For example, you get a compile-time error if you try to directly update `area`.

```
area = 5;               // compile time error
```

If you make `area` a `var` and provide a binding expression, you'll get a runtime error if you try to update it directly.

In GuitarTuner, the vibrating string changes both its location (property `translateY`) and its thickness (property `height`) at run time to give the appearance of vibration. These properties are bound to other values that control how a guitar string node changes.

```
var vibrateH: Number;
var vibrateY: Number;

Rectangle {
   x: 0.0
   y: yOffset
   width: stringLength
   height: bind vibrateH      // change height when vibrateH changes
   fill: stringColor
   visible: false
   translateY: bind vibrateY  // change translateY when vibrateY changes
}
```

GuitarTuner also uses `bind` to keep the fret board centered vertically by binding property `layoutY` in the top level group.

```
group = Group {
   layoutY: bind (scene.height - group.layoutBounds.height) /
                 2 - group.layoutBounds.minY
   . . .
}
```

Node property `layoutBounds` provides bounds information for its contents. If a user resizes the window, the top level group is automatically centered vertically on the screen. Binding helps reduce event processing code because (here, for example) you don't have to write an event handler to detect a change in the window size.

Binding is Good

Binding is good for many things. For example, you can change the appearance of a node based on changes to the program's state. You can make a component visible or hidden. You can also use binding to declaratively specify layout constraints. Not only does binding produce less code, but the code is less error-prone, easier to maintain, and often easier for the compiler to optimize.

Mouse Events

JavaFX nodes have properties for handling mouse and key events. These properties are set to callback functions that the system invokes when an event triggers. In GuitarTuner, the "mouse detection" rectangle has the following event handler to detect a mouse click event.

```
onMouseClicked: function(evt: MouseEvent): Void {
   if (evt.button == MouseButton.PRIMARY) {
      // play and vibrate selected "string"
   }
}
```

The `if` statement checks for a click of the primary mouse button (generally the left mouse button is primary) before processing the event. The event handler function (shown in the next section) plays the note and vibrates the string.

Animations

JavaFX specializes in animations. (In fact, we dedicate an entire chapter to animation. See Chapter 7 beginning on page 205.) You define animations with timelines and then invoke Timeline functions `play` or `playFromStart` (there are also functions `pause` and `stop`). Timelines consist of a sequence of key frame objects that define a frame at a specific time offset within the timeline. (Key frames are declarative. You say "this is the state of the scene at this key time" and let the system figure out how to render the affected objects.) Within each key frame, you specify values, an action, or both. Traditionally, people think of animations as a way to move objects. While this is true, you'll see that JavaFX lets you animate any writable object property. You could, for instance, use animation to fade, rotate, resize, or even brighten an image.

Figure 2.11 shows a snapshot of a program with simple animation. It moves a circle back and forth across its container.

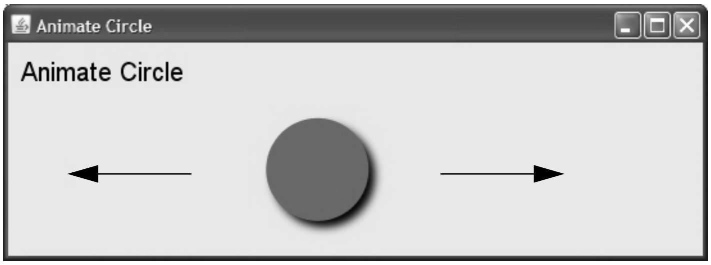


Figure 2.11 Timelines let you specify animations

Here is the timeline that implements this animation using a specialized shorthand notation for KeyFrames. The timeline starts out by setting variable `x` to 0. In gradual, linear increments, it changes `x` so that at four seconds, its value is 350. Now, it performs the action in reverse, gradually changing `x` so that in four more seconds it is back to 0 (`autoReverse` is `true`). This action is repeated indefinitely (or until the timeline is stopped or paused). Constants `0s` and `4s` are Duration literals.

```
var x: Number;
Timeline {
   repeatCount: Timeline.INDEFINITE
   autoReverse: true
   keyFrames: [
      at (0s) { x => 0.0 }
      at (4s) { x => 350 tween Interpolator.LINEAR }
   ]
}.play();              // start Timeline
   . . .
Circle {
   . . .
   translateX: bind x
}
```

The JavaFX keyword `tween` is a key frame operator that lets you specify how a variable changes. Here, we use `Interpolator.LINEAR` for a linear change. That is, `x` doesn't jump from 0 to 350, but gradually takes on values in a linear fashion. Linear interpolation moves the Circle smoothly from 0 to 350, taking four seconds to complete one iteration of the timeline.

JavaFX has other interpolators. Interpolator `DISCRETE` jumps from the value of one key frame to the second. Interpolator `EASEIN` is similar to `LINEAR`, except the rate of change is slower at the onset. Similarly, `EASEOUT` is slower at the finish and `EASEBOTH` provides easing on both ends of the timeline.

To make this animation apply to the Circle node, you bind the Circle's `translateX` property to the variable manipulated by the timeline (`x`). Property `translateX` represents a node's change in the x direction.

Now let's examine how GuitarTuner uses animation to vibrate the guitar string and play its note. Each GuitarString object uses two rectangles to implement its visible behavior. One rectangle is a stationary, thin "string" and represents the string in a static state. This motionless rectangle is always visible in the scene. The second rectangle is only visible when the string is "played." This rectangle expands and contracts its height quickly using animation (a Timeline). This moving rectangle gives users the illusion of a vibrating string.

To get a uniform vibrating effect, the rectangle must expand and contract evenly on the top and bottom. The animation makes the string appear to vibrate by varying the height of the rectangle from 1 to 3 while keeping it vertically centered by varying its `translateY` property between 5 and 4. When the string is clicked, the string's note plays and the rectangle vibrates for the allotted time. When the timeline stops, only the stationary rectangle is visible.

Let’s first look at the timeline that plays the note. This timeline appears in the event handler for the GuitarString node (see the code for GuitarString in Listing 2.2 on page 38).

```
onMouseClicked: function(evt: MouseEvent): Void {
   if (evt.button == MouseButton.PRIMARY) {
      Timeline {
         keyFrames: [
            KeyFrame {
               time: 0s
               action: playNote  // play note and start vibration
            }
            KeyFrame {
               time: 2.8s
               action: stopNote  // stop playing note and stop vibration
            }
         ]
      }.play();                  // start Timeline
   }
}
```

Here, the timeline is an object literal defined inside the event handler, invoked with function `play`. This timeline defines a sequence of KeyFrame objects, where function `playNote` is invoked at time offset `0` seconds and function `stopNote` is invoked at time offset 2.8 seconds (`2.8s`). Here are functions `playNote` and `stopNote`.

```
// play note and start vibration
function playNote(): Void {
   synthNote.noteOn(note);
   vibrateOn();
}

// stop playing note and stop vibration
function stopNote(): Void {
   synthNote.noteOff(note);
   vibrateOff();
}
```

Function `synthNote.noteOn` calls a Java class API to play the guitar string. Function `vibrateOn` causes the string vibration.

```
function vibrateOn(): Void {
   play.visible = true;    // make the vibrating rectangle visible
   timeline.play();        // start the vibration timeline
}
```

Here is the vibration timeline.

```
def timeline = Timeline {
   repeatCount: Timeline.INDEFINITE
   autoReverse: true
   keyFrames: [
        at (0s) { vibrateH => 1.0 }
        at (.01s) { vibrateH => 3.0 tween Interpolator.LINEAR }
        at (0s) { vibrateY => 5.0 }
        at (.01s) { vibrateY => 4.0 tween Interpolator.LINEAR }
     ]
  };
```

This timeline uses the shorthand notation discussed earlier for key frames and animates two variables: `vibrateH` and `vibrateY`. Variable `vibrateH` changes the height of the rectangle that represents the vibrating string. Variable `vibrateY` changes the vertical position of the rectangle to keep it centered as the oscillating height changes.

2.7 Source Code for Project GuitarTuner

Listing 2.1 and Listing 2.2 show the code for class GuitarString in two parts. Listing 2.1 includes the class declarations, functions, class-level variables, and properties for class GuitarString. Note that several variables are declared `public-init`. This JavaFX keyword means that users of the class can provide initial values with object literals, but otherwise these properties are read-only. The default accessibility for all variables is *script-private*, making the remaining declarations private.

Use `def` for read-only variables and `var` for modifiable variables. The GuitarString class also provides utility functions that play a note (`playNote`) or stop playing a note (`stopNote`). Along with the sound, guitar strings vibrate on and off with `vibrateOn` and `vibrateOff`. These functions implement the behavior of the GuitarString class.

Listing 2.1 Class GuitarString—Properties, Variables, and Functions

```
package guitartuner;

import javafx.animation.Interpolator;
import javafx.animation.KeyFrame;
import javafx.animation.Timeline;
import javafx.scene.Cursor;
import javafx.scene.CustomNode;
import javafx.scene.Group;
import javafx.scene.input.MouseButton;
import javafx.scene.input.MouseEvent;
import javafx.scene.Node;
import javafx.scene.paint.Color;
import javafx.scene.shape.Rectangle;
import javafx.scene.text.Font;
import javafx.scene.text.Text;
import noteplayer.SingleNote;

public class GuitarString extends CustomNode {
    // read-only variables
    def stringColor = Color.WHITESMOKE;
    // "Strings" are oriented sideways, so stringLength is the
    // Rectangle width and stringSize is the Rectangle height
    def stringLength = 300;
    def stringSize = 1;
    def stringMouseSize = 15;
    def timeline = Timeline {
        repeatCount: Timeline.INDEFINITE
        autoReverse: true
        keyFrames: [
            at (0s) { vibrateH => 1.0 }
            at (.01s) { vibrateH => 3.0 tween Interpolator.LINEAR }
            at (0s) { vibrateY => 5.0 }
            at (.01s) { vibrateY => 4.0 tween Interpolator.LINEAR }
        ]
    };

    // properties to be initialized
    public-init var synthNote: SingleNote;
    public-init var note: Integer;
    public-init var yOffset: Number;
    public-init var noteText: String;

    // class variables
    var vibrateH: Number;
    var vibrateY: Number;
    var play: Rectangle;

    function vibrateOn(): Void {
        play.visible = true;
        timeline.play();
    }
    function vibrateOff(): Void {
        play.visible = false;
        timeline.stop();
    }
    function playNote(): Void {
        synthNote.noteOn(note);
        vibrateOn();
    }
    function stopNote(): Void {
        synthNote.noteOff(note);
        vibrateOff();
    }
```

Listing 2.2 shows the second part of the code for the GuitarString class.

Every class that extends CustomNode must define a function `create` that returns a Node object.[3] Often the node you return will be a Group, since Group is the most general Node type and can include subnodes. But, you can return other Node types, such as Rectangle (Shape) or HBox (horizontal box) layout node.

The scene graph for GuitarString is interesting because it actually consists of three Rectangle nodes and a Text node. The first Rectangle, used to detect mouse clicks, is completely translucent (its `opacity` is 0). This Rectangle is wider than the guitar string so the user can more easily select it with the mouse. Several properties implement its behavior: property `cursor` lets a user know the string is selected and property `onMouseClicked` provides the event handling code (play the note and vibrate the string).

The second Rectangle node defines the visible string. The third Rectangle node (assigned to variable `play`) "vibrates" by both moving and changing its height. This rectangle is only visible when a note is playing and provides the vibration effect of "plucking" a string. The movement and change in height are achieved with animation and binding. The Text node simply displays the letter (E, A, D, etc.) associated with the guitar string's note.

Listing 2.2 Scene Graph for GuitarString

```
    protected override function create(): Node {
        return Group {
            content: [
                // Rectangle to detect mouse events for string plucking
                Rectangle {
                    x: 0
                    y: yOffset
                    width: stringLength
                    height: stringMouseSize
                    // Rectangle has to be "visible" or scene graph will
                    // ignore mouse events. Therefore, we make it fully
                    // translucent (opacity=0) so it is effectively invisible
                    fill: Color.web("#FFFFF", 0)   // translucent
                    cursor: Cursor.HAND
                    onMouseClicked: function(evt: MouseEvent): Void {
                        if (evt.button == MouseButton.PRIMARY){
                            Timeline {
                                keyFrames: [
                                    KeyFrame {
```

3. Well, almost. If you don't define function `create`, then you must declare the class `abstract`. The Piano example (see "Project Piano" on page 167) uses an abstract class.

```
                                time: 0s
                                action: playNote
                            }
                            KeyFrame {
                                time: 2.8s
                                action: stopNote
                            }
                        ]  // keyFrames

                    }.play();  // start Timeline
                } // if
            }
        }   // Rectangle
        // Rectangle to render the guitar string
        Rectangle {
            x: 0.0
            y: 5 + yOffset
            width: stringLength
            height: stringSize
            fill: stringColor
        }
        // Special "string" that vibrates by changing its height
        // and location
        play = Rectangle {
            x: 0.0
            y: yOffset
            width: stringLength
            height: bind vibrateH
            fill: stringColor
            visible: false
            translateY: bind vibrateY
        }
        Text {      // Display guitar string note name
            x: stringLength + 8
            y: 13 + yOffset
            font: Font {
                size: 20
            }
            content: noteText
        }
    ]
}   // Group
}
}  // GuitarString
```

Listing 2.3 shows the code for **Main.fx**, the main program for GuitarTuner.

Listing 2.3 Main.fx

```
package guitartuner;
import guitartuner.GuitarString;
import javafx.scene.effect.DropShadow;
import javafx.scene.Group;
import javafx.scene.paint.Color;
import javafx.scene.paint.LinearGradient;
import javafx.scene.paint.Stop;
import javafx.scene.Scene;
import javafx.scene.shape.Line;
import javafx.scene.shape.Rectangle;
import javafx.stage.Stage;
import noteplayer.SingleNote;

def noteValues = [ 40,45,50,55,59,64 ];   // numeric value required by midi
def guitarNotes = [ "E","A","D","G","B","E" ];
// guitar note name
def numberFrets = 2;
def numberStrings = 6;
var singleNote =  SingleNote{};
singleNote.setInstrument(27);           // "Clean Guitar"

var scene: Scene;
var group: Group;
Stage {
    title: "Guitar Tuner"
    visible: true
    scene: scene = Scene {
      fill: LinearGradient {
         startX: 0.0
         startY: 0.0
         endX: 0.0
         endY: 1.0
         proportional: true
         stops: [
            Stop {
               offset: 0.0
               color: Color.LIGHTGRAY
            },
            Stop {
               offset: 1.0
               color: Color.GRAY
            }
         ]
        }
        width: 340
        height: 200
        content: [
            group = Group {
                // Center the whole group vertically within the scene
                layoutY: bind (scene.height - group.layoutBounds.height) /
```

```
                              2 - group.layoutBounds.minY
                content: [
                    Rectangle {        // guitar neck (fret board)
                        effect: DropShadow { }
                        x: 0
                        y: 0
                        width: 300
                        height: 121
                        fill: LinearGradient {
                        startX: 0.0
                        startY: 0.0
                        endX: 0.0
                        endY: 1.0
                        proportional: true
                        stops: [
                           Stop {
                              offset: 0.0
                              color: Color.SADDLEBROWN
                           },
                           Stop {
                              offset: 1.0
                              color: Color.BLACK
                           }
                        ]
                     }
                  } // Rectangle
                    for (i in [0..<numberFrets])   // two frets
                        Line {
                            startX: 100 * (i + 1)
                            startY: 0
                            endX: 100 * (i + 1)
                            endY: 120
                            stroke: Color.GRAY
                        }
                    for (i in [0..<numberStrings])   // six guitar strings
                        GuitarString {
                            yOffset: i * 20 + 5
                            note: noteValues[i]
                            noteText: guitarNotes[i]
                            synthNote: singleNote
                        }
                ]
            }
        ]
    }
}
```

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