Chapter 3
Programs

The Design and Implementation of Multimedia Software

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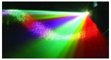
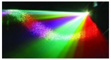
Jones and Bartlett Publishers

www.jbpub.com



About this Chapter

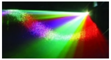
- Thus far the the phrase “software product” has been used instead of the word “program”.
- This chapter develops a (somewhat) formal definition of the word “program”.
- This chapter also discusses a way to unify different types of Java programs (which is especially important in the context of multimedia software products).



A Definition

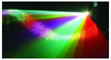
Definition

A *program* in an object-oriented programming language is a group of cooperating classes with a well-defined *entry point* (i.e., a method that should be executed first) and, perhaps, a re-entry point and/or an exit point.



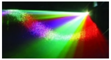
Java Programs with GUIs

	Environment	**Top-Level Container**	**Entry Point**
Application	Operating System	`JFrame`	`main()`
Applet	Browser	`JApplet`	`init()` then `start()`



Application Lifecycle

- When an application is started the `main()` method is executed in a non-daemon thread called the *main thread*.
- A single-threaded application terminates when the `System.exit()` method is called, in response to a platform-specific event such as a `SIGINT` or a `Ctrl-C`, or when the main thread 'drops out of' the `main()` method.
- A multi-threaded application terminates when the `System.exit()` method is called, in response to a platform specific event, or when all non-daemon threads have died.



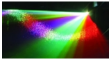
Applet Lifeycyle

- When an HTML page containing an `<applet>` element is loaded for the first time, the appropriate object (i.e., the descendent of the `Applet` class referred to in the `<applet>` element) is constructed, its `init()` and `start()` methods are called in a thread other than the event dispatch thread.

- Each time the user leaves the page containing the applet, the `stop()` method is called (again, not in the event dispatch thread).

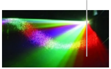
- Similarly, each time the user re-loads the page containing the applet, the `start()` method is called.

- When the browser is shut down, the `destroy()` method is called (again, not in the event dispatch thread).



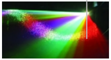
An Application Revisited

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

public class      BadInteractiveRandomMessageSwingApplication
       implements ActionListener, Runnable
{
    // Attributes
    private JLabel                label;

    // The pseudo-random number generator
    private static Random         rng = new Random();

    // String "constants"
    private static final String   CHANGE = "Change";

    // The messages
    private static final String[] MESSAGES = {
       "What a great book.","Bring on the exercises.",
       "Author, author!","I hope it never ends."};

    public static void main(String[] args) throws Exception
    {
       SwingUtilities.invokeAndWait(
                  new BadInteractiveRandomMessageSwingApplication());
    }

    public void actionPerformed(ActionEvent event)
```



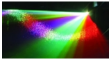
An Application Revisited (cont.)

```
{
   String      actionCommand;

   actionCommand = event.getActionCommand();
   if (actionCommand.equals(CHANGE))
   {
      label.setText(createRandomMessage());
   }
}

private static String createRandomMessage()
{
   return  MESSAGES[rng.nextInt(MESSAGES.length)];
}

public void run()
{
   JButton                   button;
   JFrame                    window;
   JPanel                    contentPane;
   String                    s;

   // Select a message at random
   s = createRandomMessage();

   // Construct the "window"
   window = new JFrame();
   window.setSize(600,400);
```



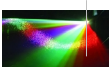
An Application Revisited (cont.)

```
       window.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);

       // Get the container for all content
       contentPane = (JPanel)window.getContentPane();
       contentPane.setLayout(null);

       // Add the message component to the container
       label = new JLabel(s, SwingConstants.CENTER);
       label.setBounds(50,50,500,100);
       contentPane.add(label);

       // Add the button to the container
       button = new JButton(CHANGE);
       button.setBounds(450,300,100,50);
       contentPane.add(button);
       button.addActionListener(this);

       // Make the "window" visible
       window.setVisible(true);
    }
}
```



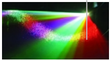
An Applet with the Same Functionality

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

public class      BadInteractiveRandomMessageJApplet
       extends    JApplet
       implements ActionListener
{
    // Attributes
    private JLabel                label;

    // The pseudo-random number generator
    private static Random         rng = new Random();

    // String "constants"
    private static final String   CHANGE = "Change";

    // The messages
    private static final String[] MESSAGES = {
       "What a great book.","Bring on the exercises.",
       "Author, author!","I hope it never ends."};

    public BadInteractiveRandomMessageJApplet()
    {
       super();
    }

    public void actionPerformed(ActionEvent event)
```



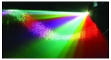
An Applet with the Same Functionality (cont.)

```
{
   String      actionCommand;

   actionCommand = event.getActionCommand();
   if (actionCommand.equals(CHANGE))
   {
      label.setText(createRandomMessage());
   }
}

private static String createRandomMessage()
{
   return  MESSAGES[rng.nextInt(MESSAGES.length)];
}

public void init()
{
   JButton                   button;
   JPanel                    contentPane;
   String                    s;

   // Select a message at random
   s = createRandomMessage();

   // Get the container for all content
   contentPane = (JPanel)getContentPane();
   contentPane.setLayout(null);
```



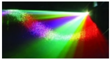
An Applet with the Same Functionality (cont.)

```
        // Add a component to the container
        label = new JLabel(s, SwingConstants.CENTER);
        label.setBounds(50,50,500,100);
        contentPane.add(label);

        // Add the button to the container
        button = new JButton(CHANGE);
        button.setBounds(450,300,100,50);
        button.addActionListener(this);
        contentPane.add(button);
    }
}
```



An Observation

The differences between applications and applets are problematic for multimedia programmers, who must frequently create applications and applets that provide the same functionality.

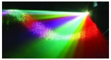


Dealing with this Problem

- Develop distinct applications and applets that share classes (which is not difficult since the general structures of applets and applications are very similar).

  What are the shortcomings?

- Create a unified system that, to the extent possible, makes it possible to used the same 'glue code' (i.e., code that connects the various cooperating classes) in applets and applications.

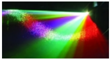


Dealing with this Problem

- Develop distinct applications and applets that share classes (which is not difficult since the general structures of applets and applications are very similar).

    Code Duplication

- Create a unified system that, to the extent possible, makes it possible to used the same ‘glue code’ (i.e., code that connects the various cooperating classes) in applets and applications.



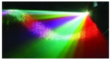
Requirements

F3.1 Applets and applications must have a common programming interface.

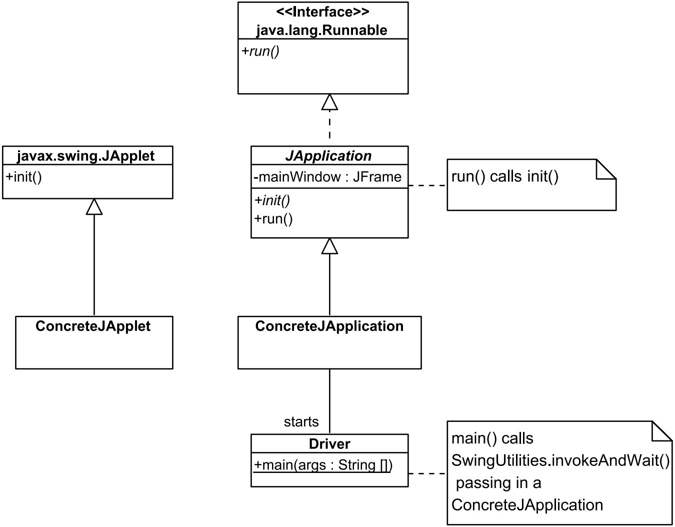
F3.2 Applets and applications must have a common lifecycle.

F3.3 Applets and applications must have a common way to obtain start-up parameters.

N3.4 Transition methods in both applets and applications must be called in the event dispatch thread.



Alternative 1

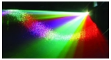


run() calls init()

main() calls SwingUtilities.invokeAndWait() passing in a ConcreteJApplication

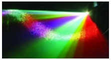
Alternative 1 - The `run()` Method

```
    public final void run()
    {
       constructMainWindow();
       init();
       mainWindow.setVisible(true);
    }
```



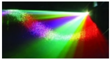
Alternative 1 - The `constructMainWindow()` Method

```
        mainWindow = new JFrame();
        mainWindow.setTitle("Multimedia Software - jblearning.
        mainWindow.setResizable(false);

        contentPane = (JPanel)mainWindow.getContentPane();
        contentPane.setLayout(null);
        contentPane.setDoubleBuffered(false);
```



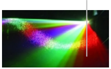
Alternative 1 - The `init()` Method

```
    public abstract void init();
```



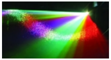
Alternative 1 - An Example

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

import app.JApplication;

public class      BadRandomMessageJApplication
       extends    JApplication
{
    // Attributes
    private JLabel                    label;

    // The pseudo-random number generator
    private static Random             rng = new Random();

    // The messages
    private static final String[] MESSAGES = {
       "What a great book.","Bring on the exercises.",
       "Author, author!","I hope it never ends."};

    public static void main(String[] args) throws Exception
    {
       SwingUtilities.invokeAndWait(
          new BadRandomMessageJApplication(600,400));
    }

    public BadRandomMessageJApplication(int width, int height)
    {
       super(width, height);
```



Alternative 1 - An Example (cont.)

```
    }

    private static String createRandomMessage()
    {
       return  MESSAGES[rng.nextInt(MESSAGES.length)];
    }

    public void init()
    {
       JPanel                    contentPane;
       String                    s;

       // Select a message at random
       s = createRandomMessage();

       // Get the container for all content
       contentPane = (JPanel)getContentPane();
       contentPane.setLayout(null);

       // Add a component to the container
       label = new JLabel(s,SwingConstants.CENTER);
       label.setBounds(50,50,500,100);
       contentPane.add(label);
    }
}
```

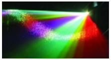


Alternative 1 - Shortcomings

- Requirement 3.3 is not satisfied because the `RootPaneContainer` for an applet (which is the `JApplet` itself) has access to the start-up parameters whereas the `RootPaneContainer` for an application does not.

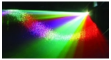
- Requirement 3.4 is also not satisfied because the transition methods (i.e., the `init()`, `start()`, `stop()` and `destroy()` methods) in a `JApplet` are not called in the event dispatch thread.

- It still encourages code duplication.



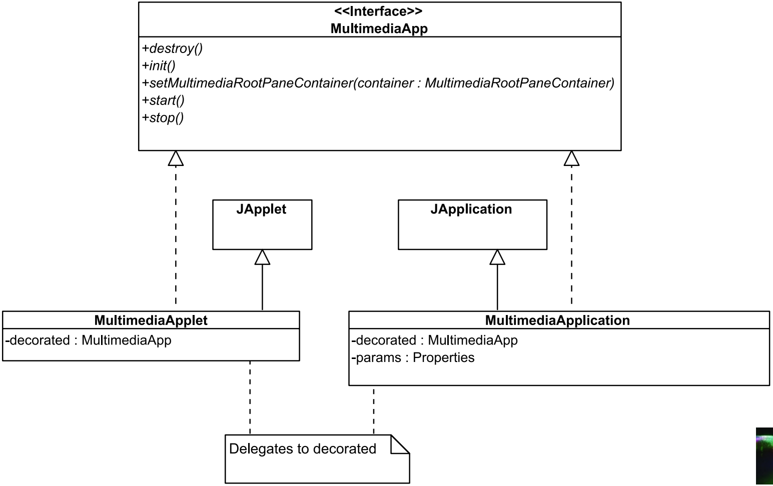
Alternative 1 - Towards Solving the First Shortcoming

```
package app;

import javax.swing.*;

public interface MultimediaRootPaneContainer
       extends   RootPaneContainer
{

    public abstract String getParameter(String name);
}
```



Alternative 2

Use the Decorator Pattern



<<Interface>>
MultimediaApp

+destroy()
+init()
+setMultimediaRootPaneContainer(container : MultimediaRootPaneContainer)
+start()
+stop()

JApplet

JApplication

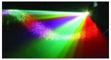
MultimediaApplet

-decorated : MultimediaApp

MultimediaApplication

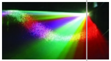
-decorated : MultimediaApp
-params : Properties

Delegates to decorated



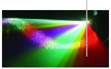
Alternative 2 - MultimediaApp

```
package app;

import javax.swing.*;

public interface MultimediaApp
{
    public abstract void destroy();

    public abstract void init();

    public abstract void setMultimediaRootPaneContainer(
                         MultimediaRootPaneContainer container);

    public abstract void start();

    public abstract void stop();
}
```



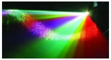
Alternative 2 - AbstractMultimediaApp

```
package app;

import javax.swing.*;

public abstract class      AbstractMultimediaApp
                implements MultimediaApp
{
    protected MultimediaRootPaneContainer rootPaneContainer;

    public void destroy()
    {
    }

    public void init()
    {
    }

    public void setMultimediaRootPaneContainer(
                         MultimediaRootPaneContainer container)
    {
       rootPaneContainer = container;
    }

    public void start()
    {
    }

    public void stop()
```



Alternative 2 - `AbstractMultimediaApp` (cont.)

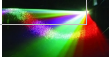
```
    {
    }
}
```



Alternative 2 - MultimediaApplet

Structure

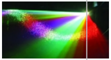
```
package app;

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

public abstract class      MultimediaApplet
                extends    JApplet
                implements MultimediaRootPaneContainer
{
    private MultimediaApp          app;

    public MultimediaApplet(MultimediaApp app)
    {
       super();
       this.app = app;
       setLayout(null);
       app.setMultimediaRootPaneContainer(this);
    }

    protected MultimediaApp getMultimediaApp()
    {
       return app;
    }
}
```



Alternative 2 - MultimediaApplet (cont.)

Satisfying Requirement 3.4

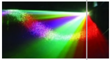
```
    public void destroy()
    {
       if (SwingUtilities.isEventDispatchThread()) app.destroy();
       else
       {
          try {SwingUtilities.invokeAndWait(new DestroyRunnable());}
          catch (Exception e) {}
       }
    }

    public void init()
    {
       if (SwingUtilities.isEventDispatchThread()) app.init();
       else
       {
          try {SwingUtilities.invokeAndWait(new InitRunnable());}
          catch (Exception e) {e.printStackTrace();}
       }
    }

    public void start()
    {
       if (SwingUtilities.isEventDispatchThread()) app.start();
       else
       {
          try {SwingUtilities.invokeAndWait(new StartRunnable());}
          catch (Exception e) {e.printStackTrace();}
       }
```



Alternative 2 - `MultimediaApplet` (cont.)

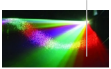
Satisfying Requirement 3.4 (cont.)

```
    private class DestroyRunnable implements Runnable
    {
        public void run()
        {
           app.destroy();
        }
    }

    private class InitRunnable implements Runnable
    {
        public void run()
        {
           app.init();
        }
    }

    private class StartRunnable implements Runnable
    {
        public void run()
        {
           app.start();
        }
    }

    private class StopRunnable implements Runnable
    {
        public void run()
        {
```



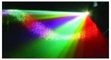
Alternative 2 - An Example

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

import app.*;

public class   RandomMessageApp
       extends AbstractMultimediaApp
{
    // Attributes
    private JLabel                label;

    // The pseudo-random number generator
    private static Random         rng = new Random();

    // The messages
    private static final String[] MESSAGES = {
       "What a great book.","Bring on the exercises.",
       "Author, author!","I hope it never ends."};

    private static String createRandomMessage()
    {
       return  MESSAGES[rng.nextInt(MESSAGES.length)];
    }

    public void init()
    {
       JPanel                    contentPane;
       String                    s;
```



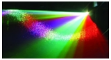
Alternative 2 - An Example (cont.)

```
       // Select a message at random
       s = createRandomMessage();

       // Get the container for all content
       contentPane = (JPanel)rootPaneContainer.getContentPane();
       contentPane.setLayout(null);


       // Add a component to the container
       label = new JLabel(s, SwingConstants.CENTER);
       label.setBounds(50,50,500,100);
       contentPane.add(label);
    }
}
```

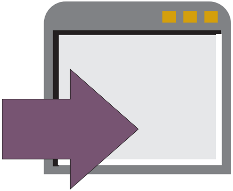


Alternative 2 - The Applet

```
import app.*;

public class    RandomMessageMultimediaApplet
       extends  MultimediaApplet
{
    public RandomMessageMultimediaApplet()
    {
       super(new RandomMessageApp());
    }
}
```



Alternative 2 - The Applet Demo

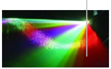


In `examples/chapter`:

RandomMessage.html

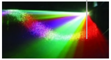
Alternative 2 - `MultimediaApplication`

```
package app;

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

public abstract class      MultimediaApplication
                extends    JApplication
                implements MultimediaRootPaneContainer
{
    private   MultimediaApp app;
    private   Properties    params;

    public MultimediaApplication(String[] args,
                                 MultimediaApp app,
                                 int width, int height)
    {
       super(width, height);

       this.app    = app;
       app.setMultimediaRootPaneContainer(this);

       params      = new Properties();
       for (int i=0; i<args.length; i++)
       {
          params.put(Integer.toString(i), args[i]);
       }
```



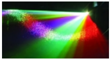
Alternative 2 - MultimediaApplication (cont.)

```
   }
   public void destroy()
   {
      app.destroy();
   }

   protected MultimediaApp getMultimediaApp()
   {
      return app;
   }

   public String getParameter(String name)
   {
      return params.getProperty(name);
   }

   public void init()
   {
      app.init();
   }

   public void start()
   {
      app.start();
   }

   public void stop()
   {
```



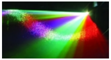
Alternative 2 - `MultimediaApplication` (cont.)

```
       app.stop();
    }
}
```

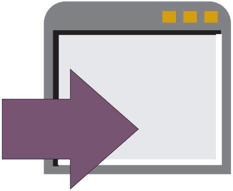


Alternative 2 - The Application

```
import app.*;

import java.util.*;
import javax.swing.*;

public class      RandomMessageMultimediaApplication
       extends    MultimediaApplication
{
    public static void main(String[] args) throws Exception
    {
       SwingUtilities.invokeAndWait(
          new RandomMessageMultimediaApplication(args, 600, 400));
    }

    public RandomMessageMultimediaApplication(String[] args,
                                              int width, int height)
    {
       super(args, new RandomMessageApp(), width, height);
    }
}
```



Alternative 2 - The Application Demo



In `examples/chapter`:

```
java -cp RandomMessage.jar RandomMessageMultimediaApplication
```

Alternative 2 - One Remaining Issue

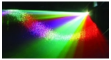
- The Issue:

  A `MultimediaApplet` has its transition methods called by the browser when the page containing the `JApplet` is loaded/unloaded.

  The transition methods in `MultimediaApplication` objects should be called at corresponding times.

- Resolution:

  Make `JApplication` a `WindowListener` on its main window.



Alternative 2 - One Remaining Issue (cont.)

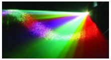
The `constructMainWindow()` Method

```
       mainWindow.setDefaultCloseOperation(
                                 JFrame.DO_NOTHING_ON_CLOSE);
       mainWindow.addWindowListener(this);
```

Alternative 2 - One Remaining Issue (cont.)

The `windowOpened()` Method

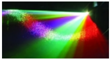
```
    public void windowOpened(WindowEvent event)
    {
       resize();
       start();
    }
```



Alternative 2 - One Remaining Issue (cont.)

The `windowDeiconfied()` Method

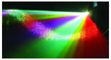
```
public void windowDeiconified(WindowEvent event)
{
   start();
}
```



Alternative 2 - One Remaining Issue (cont.)

The `windowIconified()` Method

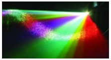
```
    public void windowIconified(WindowEvent event)
    {
       stop();
    }
```



Alternative 2 - One Remaining Issue (cont.)

The `windowClosing()` Method

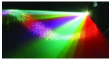
```
public void windowClosing(WindowEvent event)
{
   exit();
}
```



Alternative 2 - One Remaining Issue (cont.)

The `exit()` Method

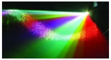
```
private void exit()
{
   int        response;

   response = JOptionPane.showConfirmDialog(mainWindow,
                                  "Exit this application?",
                                  "Exit?",
                                  JOptionPane.YES_NO_OPTION);

   if (response == JOptionPane.YES_OPTION)
   {
      mainWindow.setVisible(false);
      stop();
      mainWindow.dispose();
   }
}
```



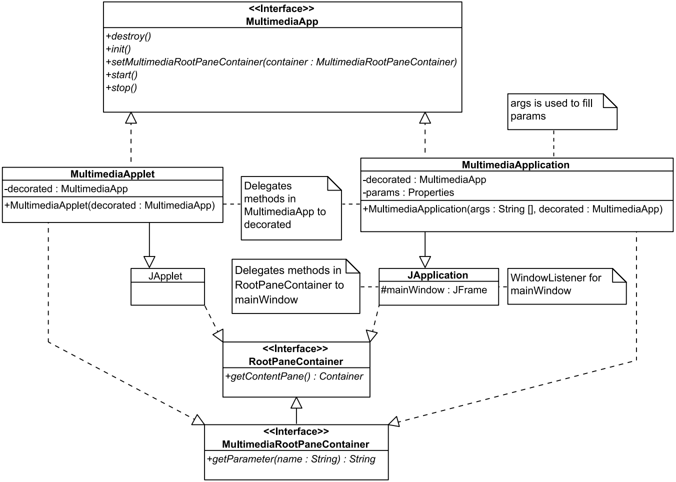
Alternative 2 - One Remaining Issue (cont.)

The `windowClosed()` Method

```
public void windowClosed(WindowEvent event)
{
   destroy();
   System.exit(0);
}
```



Final Design of the Unified System



<<Interface>>
MultimediaApp
+destroy()
+init()
+setMultimediaRootPaneContainer(container : MultimediaRootPaneContainer)
+start()
+stop()

args is used to fill params

MultimediaApplet
-decorated : MultimediaApp
+MultimediaApplet(decorated : MultimediaApp)

Delegates methods in MultimediaApp to decorated

MultimediaApplication
-decorated : MultimediaApp
-params : Properties
+MultimediaApplication(args : String [], decorated : MultimediaApp)

JApplet

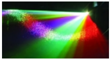
Delegates methods in RootPaneContainer to mainWindow

JApplication
#mainWindow : JFrame

WindowListener for mainWindow

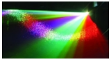
<<Interface>>
RootPaneContainer
+getContentPane() : Container

<<Interface>>
MultimediaRootPaneContainer
+getParameter(name : String) : String



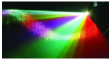
The Issue

- Most multimedia programs, be they applications or applets, need to 'load' resources of various kinds (e.g, artwork, preferences) at run-time.
- This can be problematic because of the different ways in which applets and applications can be 'organized' (e.g., in a `.jar` file, in a packaged set of classes, in an un-packaged set of classes) and 'delivered/installed' (e.g., by an HTTP server, by an installer, as files on a CD/DVD).
- Hence, it can be very difficult for a program to know where resources are.



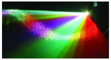
How Does the Interpreter Do It?

- The Java interpreter obtains the byte codes that constitute a class using a `class loader`.
- We can do the same thing using *reflection*.



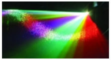
Reflection Basics

- Every interface, class and object in Java has an associated `Class` object that can be used to obtain information about it.
- This information is encapsulated as `Constructor`, `Field`, `Method` , and `Type` objects.



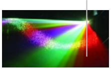
Creating a `ResourceFinder`

- Use the `getResource()` and `getResourceAsStream()` methods in `Class` objects.
- Allow it to use either its class loader or another object's class loader.



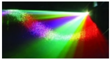
Structure of the `ResourceFinder`

```
package io;

import java.io.*;
import java.net.*;
import java.util.*;


public class ResourceFinder
{
    private Class                 c;

    private ResourceFinder()
    {
       c = this.getClass();
    }

    private ResourceFinder(Object o)
    {
       // Get the Class for the Object that wants the resource
       c = o.getClass();
    }

    public static ResourceFinder createInstance()
    {
       return new ResourceFinder();
    }

    public static ResourceFinder createInstance(Object o)
```



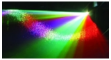
Structure of the `ResourceFinder` (cont.)

```
    {
       return new ResourceFinder(o);
    }
}
```



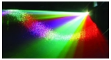
The `findInputStream()` Method

```
    public InputStream findInputStream(String name)
    {
       InputStream    is;

       is    = c.getResourceAsStream(name);

       return is;
    }
```



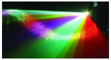
The `findInputStream()` Method

```
public URL findURL(String name)
{
   URL            url;

   url   = c.getResource(name);

   return url;
}
```



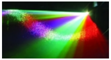
Structure of the `StopWatchApp()`

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

import app.*;
import event.*;

public class      StopWatchApp
       extends    AbstractMultimediaApp
       implements ActionListener, MetronomeListener
{
    private boolean                   running;
    private JLabel                    label;
    private Metronome                 metronome;

    private static final String       START = "Start";
    private static final String       STOP  = "Stop";
}
```



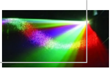
Code that is Unchanged

```
public void actionPerformed(ActionEvent event)
{
   String   actionCommand;

   actionCommand = event.getActionCommand();
   if      (actionCommand.equals(START))
   {
      label.setText("0");
      metronome.reset();
      metronome.start();
      running = true;
   }
   else if (actionCommand.equals(STOP))
   {
      metronome.stop();
      running = false;
   }
}

public void handleTick(int millis)
{
   label.setText(""+millis/1000);
}
```



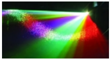
Code Moved from `run()` to `init()`

```
    public void init()
    {
       JButton                   start, stop;
       JPanel                    contentPane;

       running = false;

       contentPane = (JPanel)rootPaneContainer.getContentPane();
       contentPane.setLayout(null);

       label       = new JLabel("0");
       label.setBounds(250,100,100,100);
       contentPane.add(label);

       start = new JButton(START);
       start.setBounds(50,300,100,50);
       start.addActionListener(this);
       contentPane.add(start);


       stop  = new JButton(STOP);
       stop.setBounds(450,300,100,50);
       stop.addActionListener(this);
       contentPane.add(stop);

       metronome = new Metronome(1000, true);
       metronome.addListener(this);
    }
```



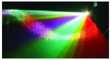
The `start()` and `stop()` Methods

```
public void start()
{
   if (running) metronome.start();
}

public void stop()
{
   if (running) metronome.stop();
}
```



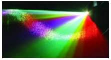
The MultimediaApplication

```
import app.*;

import javax.swing.*;

public class      StopWatchMultimediaApplication
       extends    MultimediaApplication
{
    public static void main(String[] args) throws Exception
    {
       SwingUtilities.invokeAndWait(
          new StopWatchMultimediaApplication(args, 600,400));
    }

    public StopWatchMultimediaApplication(String[] args,
                                          int width, int height)
    {
       super(args, new StopWatchApp(), width, height);
    }
}
```



The `MultimediaApplet`

```
import app.*;

public class      StopWatchMultimediaApplet
       extends    MultimediaApplet
{
    public StopWatchMultimediaApplet()
    {
       super(new StopWatchApp());
    }
}
```



StopWatch Demonstration

In `examples/chapter`:

StopWatchMultimedia.html

```
java -cp StopWatchMultimedia.jar StopWatchMultimediaApplication
```