Frameworks

15-214: Principles of Software System Construction

Some material from Ciera Jaspan, Bill Scherlis, Travis Breaux, and Erich Gamma
Terminology: Libraries

- **Library**: A set of classes and methods that provide reusable functionality
- Client calls library to do some task
- Client controls
  - System structure
  - Control flow
- The library executes a function and returns data
Terminology: Frameworks

- **Framework**: Reusable skeleton code that can be customized into an application
- **Framework controls**
  - Program structure
  - Control flow
- **Framework calls back into client code**
  - The Hollywood principle: “Don’t call us; we’ll call you.”

![Diagram showing framework controls and dependencies]

- **But this is an application!**
- **Hey, wasn’t this a library?**
More terms

- **API**: Application Programming Interface, the interface of a library or framework
- **Client**: The code that uses an API
- **Plugin**: Client code that customizes a framework
- **Extension point**: A place where a framework supports extension with a plugin
More terms

• **Protocol**: The expected sequence of interactions between the API and the client

• **Callback**: A plugin method that the framework will call to access customized functionality

• **Lifecycle method**: A callback method of an object that gets called in a sequence according to the protocol and the state of the plugin
Using an API

- Like a partial design pattern
- Framework provides one part
- Client provides the other part
- Very common for plugin trees to exist
- Also common for two frameworks to work better together
Google’s Map-Reduce

- Programming model for processing large data sets
- Example: word count
  - map(URL, contents):
    for each word w in contents
      emit (w, 1)
  - reduce(word, listOfCounts):
    for each count c in listOfCounts
      result += c
    emit result
Google’s Map-Reduce

• Questions
  • Is this a framework? How do you know?
  • What are the benefits?

• Could those benefits be achieved if it were not?
Some Benefits of Map-Reduce

- Automatically parallelizes and distributes computation
- Scales to 1000s of machines, terabytes of data
- Automatically handles failure via re-execution
- Simple programming model
  - Successful: hundreds of plugins
  - Functional model facilitates correctness
Constraints

• Computation must fit the model
  • Not everything can be phrased in terms of map and reduce

• Map and Reduce must be largely functional
  • Side effects allowed but must be atomic and idempotent

• What benefits does the client get in exchange for accepting these restrictions?
Hadoop: Map-Reduce in Java

• See http://hadoop.apache.org/
**Example: An Eclipse Plugin**

- A popular Java IDE
- More generally, a framework for tools that facilitate “building, deploying and managing software across the lifecycle.”

- Plug-in framework based on OSGI standard
- Starting point: Manifest file
  - Plugin name
  - Activator class
  - Meta-data

---

```
Manifest-Version: 1.0
Bundle-ManifestVersion: 2
Bundle-Name: MyEditor Plug-in
Bundle-SymbolicName: MyEditor; singleton:=true
Bundle-Version: 1.0.0
Bundle-Activator: myeditor.Activator
Require-Bundle: org.eclipse.ui,
                org.eclipse.core.runtime,
                org.eclipse.jface.text,
                org.eclipse.ui.editors
Bundle-ActivationPolicy: lazy
Bundle-RequiredExecutionEnvironment: JavaSE-1.6
```
Example: An Eclipse Plugin

- **plugin.xml**
  - Main configuration file
  - XML format
  - Lists extension points

- **Editor extension**
  - extension point: `org.eclipse.ui.editors`
  - file extension
  - icon used in corner of editor
  - class name
  - unique id
    - refer to this editor
    - other plugins can extend with new menu items, etc!

```xml
<?xml version="1.0" encoding="UTF-8"?>
<?eclipse version="3.2"?>
<plugin>
  <extension point="org.eclipse.ui.editors">
    <editor
      name="Sample XML Editor"
      extensions="xml"
      icon="icons/sample.gif"
      contributorClass="org.eclipse.ui.texteditor.BasicTextEditorActionContributor"
      class="myeditor.editors.XMLEditor"
      id="myeditor.editors.XMLEditor">
    </editor>
  </extension>
</plugin>
```
Example: An Eclipse Plugin

- At last, code!
- XMLEditor.java
  - Inherits TextEditor behavior
    - open, close, save, display, select, cut/copy/paste, search/replace, …
    - REALLY NICE not to have to implement this
  - But could have used ITextEditor interface if we wanted to
  - Extends with syntax highlighting
    - XMLDocumentProvider partitions into tags and comments
    - XMLConfiguration shows how to color partitions

```java
package myeditor.editors;
import org.eclipse.ui.editors.text.TextEditor;

public class XMLEditor extends TextEditor {
    private ColorManager colorManager;

    public XMLEditor() {
        super();
        colorManager = new ColorManager();
        setSourceViewerConfiguration(new XMLConfiguration(colorManager));
        setDocumentProvider(new XMLDocumentProvider());
    }

    public void dispose() {
        colorManager.dispose();
        super.dispose();
    }
}
```
Example: a JUnit Plugin

```java
public class SampleTest {
    private List<String> emptyList;

    @Before
    public void setUp() {
        emptyList = new ArrayList<String>();
    }

    @After
    public void tearDown() {
        emptyList = null;
    }

    @Test
    public void testEmptyList() {
        assertEquals("Empty list should have 0 elements", 0, emptyList.size());
    }
}
```

Here the important plugin mechanism is Java annotations.
The Golden Rule of Framework Design

• Extending the framework should NOT require modifying the framework source code!

• Discussion: how can we extend without modification?
  • Client writes main(), creates a plugin, and passes it to framework
  • Framework writes main(), client passes name of plugin
    • E.g. using a command line argument or environment variable
      Class c = ClassLoader.getSystemClass().loadClass(args[0]);
      Plugin p = c.newInstance();
  • Framework looks in a magic location
    • Config files or JAR files there are automatically loaded and processed
Java Swing: It’s a Library!

- Create a GUI using pre-defined containers
  - JFrame, JPanel, JDialog, JMenuBar
- Use a layout manager to organize components in the container
- Add pre-defined components to the layout
  - Components: JLabel, JTextField, JButton

This is no different that the File I/O library!
// create the container
JPanel panel = new JPanel();

// create the label, add to the container
JLabel label = new JLabel();
label.setText(“Enter your userid:" );
panel.add(label);

// create a text field, add to the container
JTextField textfield = new JTextField(16);
panel.add(textfield)
Swing: Layout Managers

```java
panel.setLayout(new GridBagLayout());

GridBagConstraints c = new GridBagConstraints(); // create and position the button
JButton button = new JButton("Click Me!");
c.fill = GridBagConstraints.HORIZONTAL;
c.gridx = 0; // first column
c.gridy = 1; // second row
c.gridwidth = 2; // span two columns
c.weightx = 1.0; // use all horizontal space
c.anchor = GridBagConstraints.WEST;
c.insets = new Insets(0,5,0,5); // add side padding
pane.add(button, c);
```
Swing: Events

// create an anonymous MouseAdapter, which extends
// the MouseListener class

button.add(new MouseAdapter () {
    public void mouseClicked(MouseEvent e) {
        System.err.println("You clicked me! ") +
        "Do it again!"
    }
});

But this extending a class to add custom behaviors, right?
Where is the boundary?
public MyWidget extends JPanel {

    public MyWidget(int param) {
        setLayout(new GridBagLayout());
        GridBagConstraints c = new GridBagConstraints();
        ...
        add(label, c);
        add(textfield, c);
        add(button, c);
    }

    public void setParameter(int param) {
        // update the widget, as needed
    }
}
public MyWidget extends JContainer {

    public MyWidget(int param) {
        // setup internals, without rendering
    }

    // render component on first view and resizing
    protected void paintComponent(Graphics g) {
        // draw a red box on this component
        Dimension d = getSize();
        g.setColor(Color.red);
        g.drawRect(0, 0, d.getWidth(), d.getHeight());
    }
}
**OO Frameworks** (credit: Erich Gamma)

- A customizable set of cooperating classes that defines a reusable solution for a given problem
  - defines key abstractions and their interfaces
  - object interactions
    - invariants
  - flow of control
    - override and be called
    - defaults

- Reuse
  - reuse of design and code
  - reuse of a macro architecture

- Framework provides architectural guidance
Framework Challenges (credit: Erich Gamma)

- frameworks are hard to maintain
- framework enables reuse of both design and implementation
  - easy for clients to add implementation dependencies
  - “what is the framework - what is just default implementation”
- therefore:
  - separation of design from implementation
    “we believe that interface design and functional factoring constitute the key intellectual content of software and that they are far more difficult to create or re-create than code”
    - Peter Deutsch
  - late commitment to implementation
    - but, frameworks still have to work out of the box!
Framework Layering (credit: Erich Gamma)

Framework Package
- reuse of design
- stable
  → no implementation
- specifies public interfaces

Defaults/Standard Package
- reuse of design and code
- less stable
  → more implementation
- specifies protected interfaces

Kit Packages
- reuse of implementation
- least stable
  → implementation only
Evolution: Extract Interface from Class
(credit: Erich Gamma)

⇒ JHotDraw defines framework abstractions as interfaces
  • extracting interfaces is a new step in evolutionary design
    • abstract classes are *discovered* from concrete classes
    • interfaces are *distilled* from abstract classes
  • start once the architecture is stable!
  • remove non-public methods from class
  • move default implementations into an abstract class which implements the interface
JHotDraw: Design Patterns Summary
(credit: Erich Gamma)

Factory Method

DrawingEditor

Observer-1
DrawingView
State:Context-1

Adapter: Adaptee
Drawing
Observer: Subject-1

Tool
State-1
Factory Method: Product
SelectionTool
State:Context-2
Tracker
State-2

Handle
Adapter

Figure

TrackHandle
JHotDraw: Design Patterns Summary

(credit: Erich Gamma)

- Factory Method
  - DrawingEditor
- Observer-1
  - DrawingView
- Tool
  - State-1
    - Factory Method: Product
  - SelectionTool
    - State:Context-2
- Tracker
  - State-2

- Strategy
  - Connector
  - Strategy-3
    - Adapter: Adaptee
      - Observer: Subject-2
    - Observer: Subject-1
- Observer-2
- Handle
  - CompositeFigure
- Connection
  - Composite
- TrackHandle
JHotDraw: Design Patterns Summary
(credit: Erich Gamma)
JHotDraw: Design Patterns Summary
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JHotDraw Pattern Experiences
(credit: Erich Gamma)

• Increased design velocity
  • patterns helped us generate the architecture

• It wasn’t always clear which pattern to apply
  • patterns can be competitors
  • implementing the patterns is easy
  • difficulty is knowing when and why to use them!

• Framework development remains iterative
  • design patterns are targets for refinements and refactoring

• JavaDoc can be used to document the applied patterns
  • javadoc comments may include URLs
  • URLs refer to a pattern description or patlet

• JHotDraw: http://sourceforge.net/projects/jhotdraw
Getting up a framework’s learning curve

- Tips on using frameworks
  - Tutorials, Wizards, and Examples
    - SourceForge, Google Code Search
  - Communities – email lists and forums
    - Eclipse.org
  - Group knowledge dispersal
    - Wiki of resources, Problem/solution log

- Common client trick: Follow the leader
  - Appropriate code from examples – find an “imputed pattern”
    - Search source code
    - Infer compatible intent
    - Identify scope (not too much, not too little)
  - Copy it
    - Tear out the app-specific logic, keep the bureaucracy
    - Insert your own logic into the reused bureaucracy
  - But there’s a problem
    - Classic copy-and-paste problem – looks just like my own code
    - Design intent is lost – “my intention is to use the framework this way”

- Framework designer’s conundrum: complexity vs. capability
Framework Design Exercises

• Think about a framework for:
  • Video playing software
  • Viewing, printing, editing a portable document format
  • Compression and archiving software
  • Instant messaging software
  • Music editing software

• Questions
  • What are the dimensions of variability/extensibility?
  • What interfaces would you need?
  • What are the core methods for each interface?
  • How do you set up the framework?
Bonus slides on Frameworks
Callback challenges

• Simple ASP.NET Page with a drop down list
  • Derive from Page
  • Add the controls
  • Handle any user actions on controls

• 10 simple Page callbacks
  • Many more complex ones
• Where do we add the controls?
• When can I access data?
• Where does the framework expect it to happen?

• PreInit
• Init
• InitComplete
• PreLoad
• Load
• Control events...
• LoadComplete
• PreRender
• SaveStateComplete
• Render
• Close
Dynamically add a control to the page

```csharp
private void Page_Load(object sender, EventArgs e) {
    DropDownList ddl = new DropDownList();
    ddl.DataSource = ...; // accesses another control
    ddl.DataBind();
    addControl(ddl);
}
```

Whoops! Resets the initial data every time, so we lose the user’s selection.
Dynamically add a control to the page, attempt 2

```csharp
private void Page_Load(object sender, EventArgs e) {
    if (!IsPostBack()) {
        DropDownList ddl = new DropDownList();
        ddl.DataSource = ...; // accesses another control
        ddl.DataBind();
        addControl(ddl);
    }
}
```

Ok, now the control entirely disappears when the page refreshes after an action (the postback)....
private void Page_Load(object sender, EventArgs e) {

    DropDownList ddl = new DropDownList();
    if (!IsPostBack()) {
        ddl.DataSource = Relipsis;
        ddl.DataBind();
    }
    addControl(ddl);
}

Ok, the control is there, but there’s no data in it after an update/refresh....
Dynamically add a control to the page, attempt 4

private void Page_PreInit(object sender, EventArgs e) {
    DropDownList ddl = new DropDownList();
    if (!IsPostBack()) {
        ddl.DataSource = Relipsis; // accesses another control
        ddl.DataBind();
    }
    addControl(ddl);
}

Now we get a null reference exception when accessing that other control’s data…
Dynamically add a control to the page, attempt 5

```csharp
DropDownList ddl;

private void Page_PreInit(object sender, EventArgs e) {
    ddl = new DropDownList();
    addControl(ddl);
}

private void Page_Load(object sender, EventArgs e) {
    if (!IsPostBack()) {
        ddl.DataSource = Relipsis; // accesses another control
        ddl.DataBind();
    }
}
```

Finally it works!
Couldn’t they design it better?

- Could have fewer callbacks
  - But it would make it less extensible

- In some cases, could give better errors and warnings
  - But it would give up performance

- Some design choices could map to the developer’s mind more easily
  - But we might lose other quality attributes, like security
Interaction is not limited to your primary code!

• Many methods of interacting with a framework
• Declarative files, such as XML or properties files
• Annotations within code

• If the functionality is supported by all, which do I choose?
• And what happens if they are conflicting?
Choosing an interaction

• Example 1: Internationalization
  • Properties files or directly in code?

• Example 2: Transactions
  • XML file, annotations, or in code?

• Example 3: Database URL
  • XML file, properties file, annotation, or in code?

• Notice that the choice affects how easy the code is to read, how difficult it is to change later, and who can do the change!
Putting controls in a LoginView

- Can specify different controls to be shown when a user is logged in
  - Ex: username and password fields v. “Welcome, Username!”

```xml
<asp:LoginView ID="LoginScreen" runat="server">
    <AnonymousTemplate>
        You can only setup accounts when you are logged in.
    </AnonymousTemplate>
    <LoggedInTemplate>
        <h4>Location</h4>
        <asp:DropDownList ID="LocationList" runat="server"/>
        <asp:Button ID="ChangeButton" runat="server" Text="Change"/>
    </LoggedInTemplate>
</asp:LoginView>
```
Retrieve controls and set them up

LoginView LoginScreen;

private void Page_Load(object sender, EventArgs e) {

    DropDownList list = (DropDownList)
        LoginScreen.FindControl("LocationList");

    list.DataSource = Relipsis;
    list.DataBind();
}

NullReferenceException at list.DataSource = ...;
Correct code

```csharp
LoginView LoginScreen;

private void Page_Load(object sender, EventArgs e) {
    if (this.getRequest().IsAuthenticated()) {
        DropDownList list = (DropDownList)
            LoginScreen.FindControl("LocationList");

        list.DataSource = ...;
        list.DataBind();
    }
}
```
These sound tough to use…why bother?

• Code reuse
  • Eclipse framework: ~2,000,000 LoC
  • Eclipse plugin: 12 LoC
  • … of course you need to know which 12 lines to write

• Maintainability

• Existing knowledge of employees

• External community support

• Large-scale (architectural) reuse

• Built-in quality attributes
Frameworks and Quality Attributes

- Quality attributes
  - Performance
  - Security
  - Scalability
  - *-ility

- All QA’s have tradeoffs with each other

- Old way: hack quality attributes in after development

- New way: Embed quality attributes into the framework
  - More cost effective, less refactoring
  - Handled at high level, not scattered in program

- Works if you know your QA tradeoffs up front
  - This is why those requirements are so important…
Choosing a framework

• Business objectives
• Existing software lock-in
• Ability to match quality attributes and tradeoff decisions
• Costs of learning
• Costs of purchase (or maintenance for homegrown)
Do we build it ourselves?

- Outsourcing the framework
  - Examples: Eclipse, J2EE, ASP.Net, etc
  - Benefits: lower risk, high reuse, community support
  - Costs/risks: compromise of control

- Insourcing the framework
  - Examples: product-line frameworks
  - Benefits: economy of scale, control over system
  - Costs/risks: building and maintenance, requires experts