Principles of Software Construction: Objects, Design, and Concurrency

Sub-system reuse

Libraries and frameworks

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Administrivia

- Homework 4c due Thursday night
- Midterm exam next Thursday (November 3rd)
  - Review session Wednesday, November 2nd, 7-9 pm, HH B103

Key concepts from last Thursday…

Get feedback early, often

```
API                vote    notes
=================================================================
Array              yes      But remove binarySearch* and toList
BasicCollection    no       I don't expect lots of collection classes
BasicList          no       see List below
Collection         yes      But cut toArray
Comparator         no
DoublyLinkedList   no       (without generics this isn't worth it)
HashSet            no
LinkedList         no       (without generics this isn't worth it)
List               no       I'd like to say yes, but it's just way
                            bigger than I was expecting
RemovalEnumeration no
Table              yes      BUT IT NEEDS A DIFFERENT NAME
TreeSet            no

I'm generally not keen on the toArray methods because they add complexity

Simiarly, I don't think that the table Entry subclass or the various
views mechanisms carry their weight.
```

Java Collections design conclusion

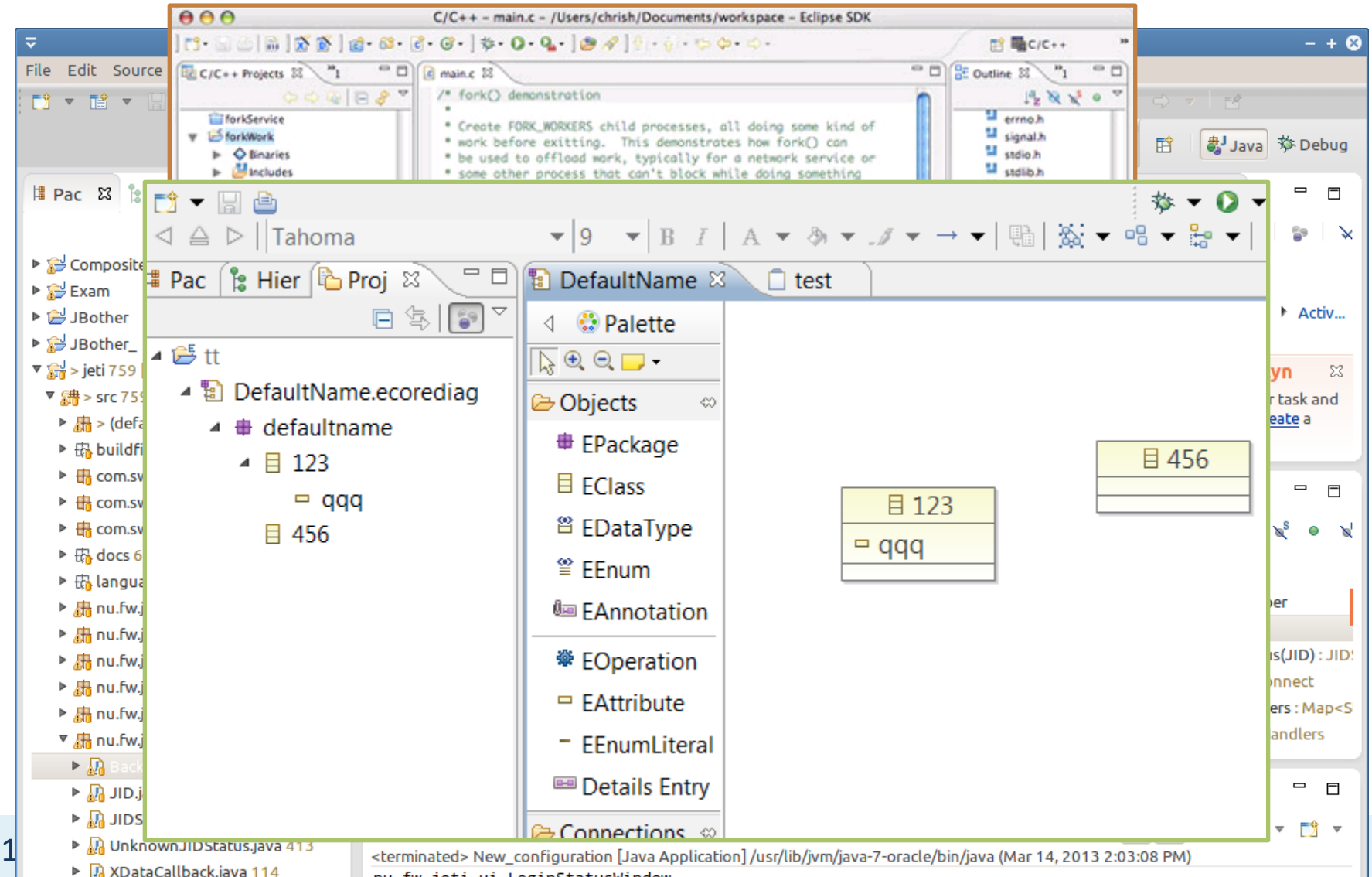
- It takes a lot of work to make something that appears obvious
  - Coherent, unified vision
  - Willingness to listen to others
  - Flexibility to accept change
  - Tenacity to resist change
  - Good documentation!
- It's worth the effort!
  - A solid foundation can last two+ decades

Learning goals for today

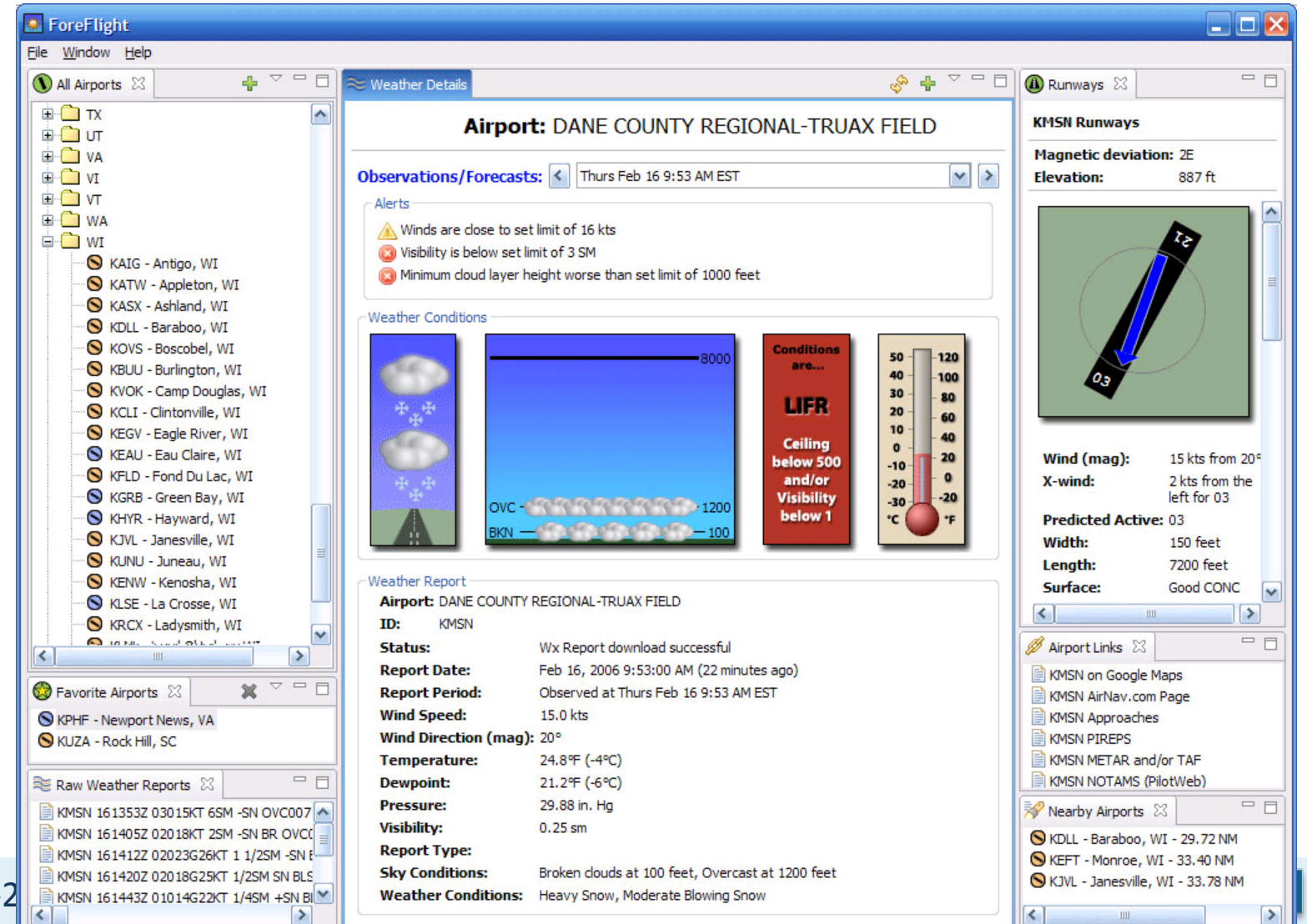
- Describe example well-known example frameworks
- Know key terminology related to frameworks
- Know common design patterns in different types of frameworks
- Discuss differences in design trade-offs for libraries vs. frameworks
- Analyze a problem domain to define commonalities and extension points (cold spots and hot spots)
- Analyze trade-offs in the use vs. reuse dilemma
- Know common framework implementation choices

Today: Libraries and frameworks for reuse

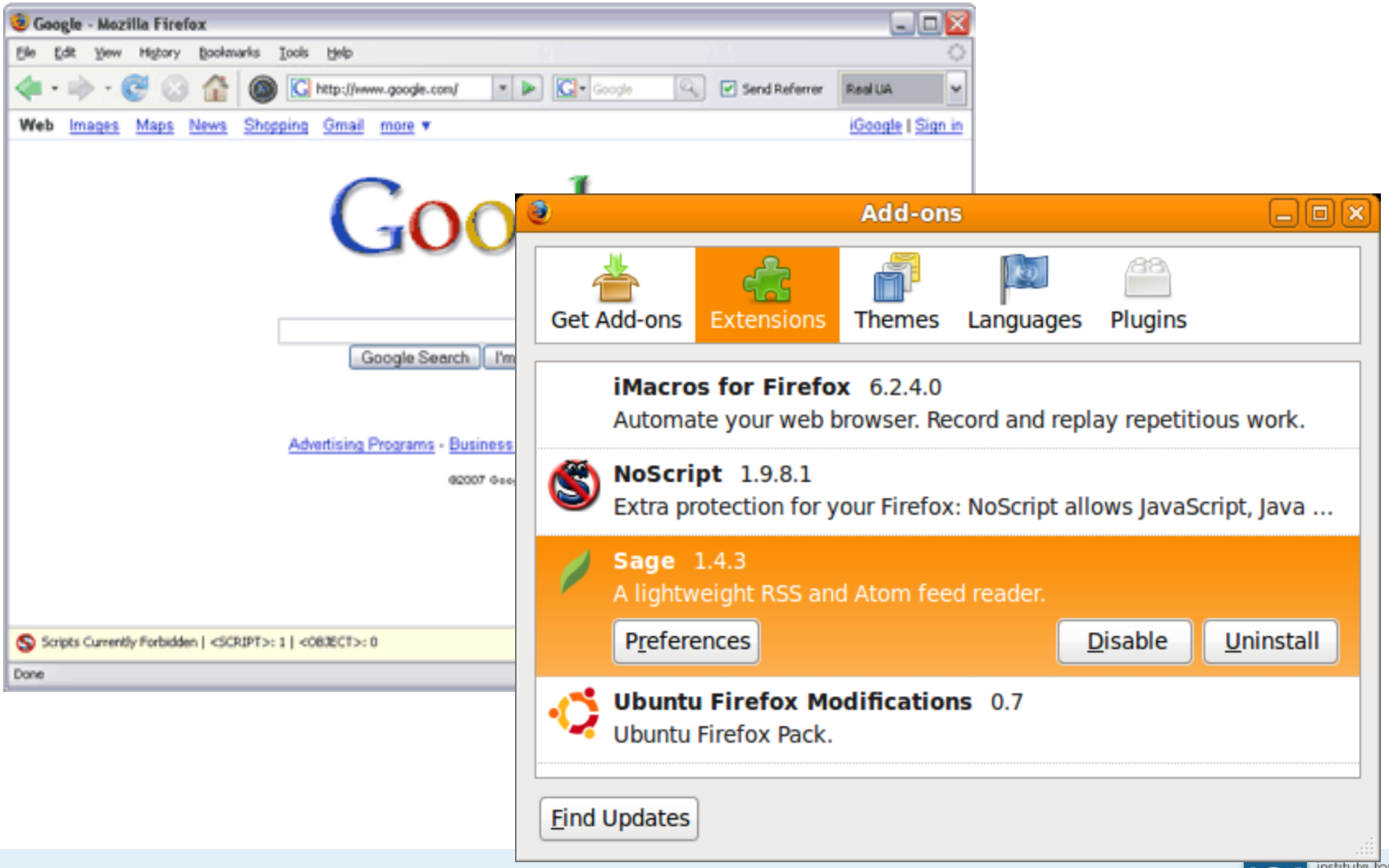
Reuse and variation:
Family of development tools



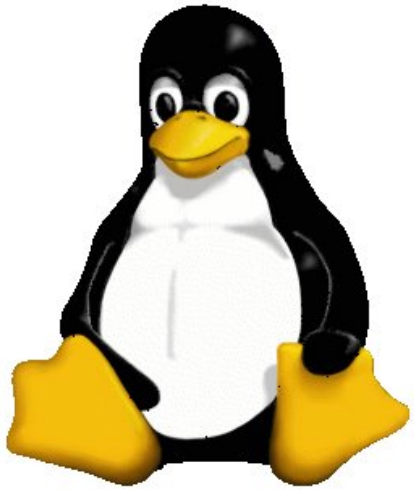
Reuse and variation:
Eclipse Rich Client Platform

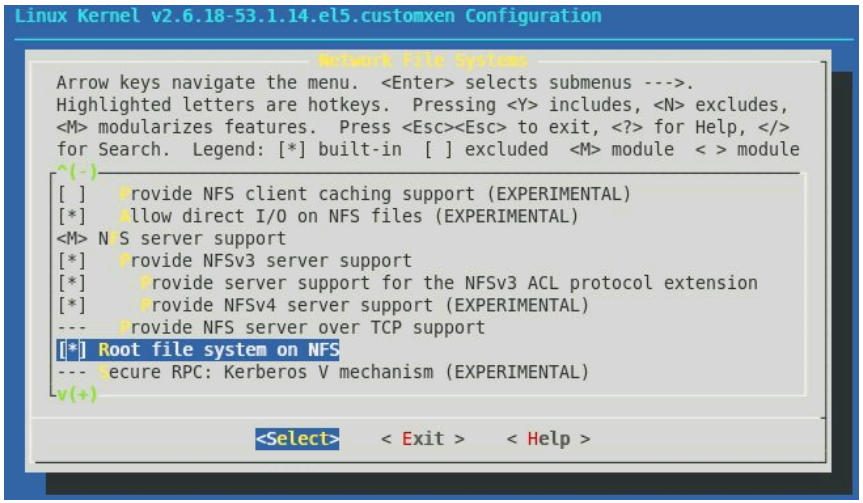


Reuse and variation: Web browser extensions



Reuse and variation: Flavors of Linux





Reuse and variation: Product lines

Earlier in this course: Class-level reuse

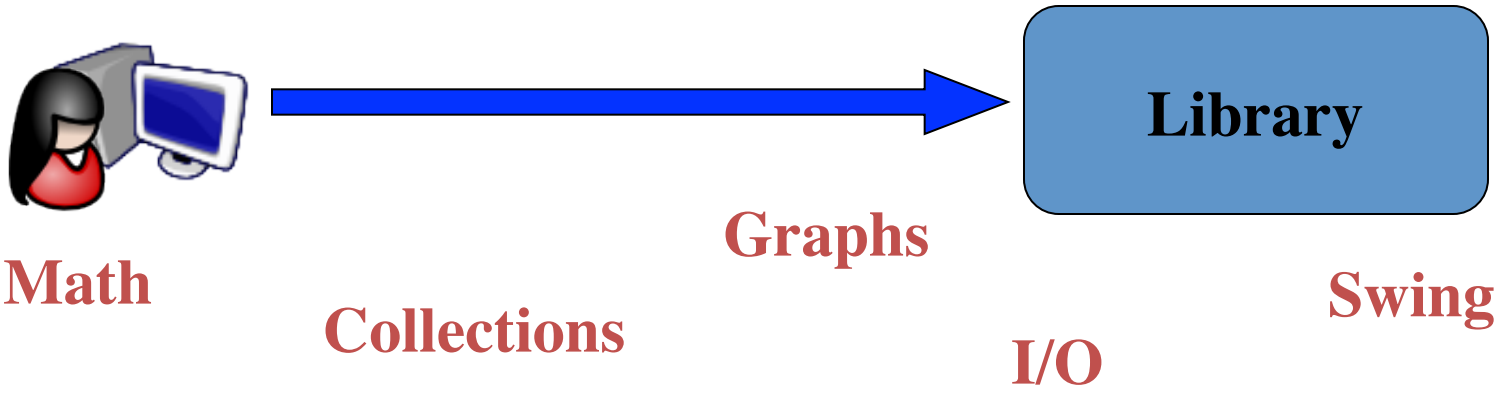
- Language mechanisms supporting reuse
  - Inheritance
  - Subtype polymorphism (dynamic dispatch) for delegation
  - Parametric polymorphism (generics)
- Design principles supporting reuse
  - Small interfaces
  - Information hiding
  - Low coupling
  - High cohesion
- Design patterns supporting reuse
  - Template method, decorator, strategy, composite, adapter, …

Today: Libraries and frameworks for reuse

- Examples, terminology
- Whitebox and blackbox frameworks
- Design considerations
- Implementation details
  - Responsibility for running the framework
  - Loading plugins

Terminology: Libraries

- Library: A set of classes and methods that provide reusable functionality



Terminology: Frameworks

- Framework: Reusable skeleton code that can be customized into an application
- Framework calls back into client code
  - The Hollywood principle: "Don't call us. We'll call you."

```
public MyWidget extends JContainer {

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

/ render component on first view and
resizing
protected void
paintComponent(Graphics g) {
// draw a red box on his
componentDimension d = getSize();
g.setColor(Color.red);
g.drawRect(0, 0, d.getWidth(),
d.getHeight());              }
}
```

your code

Framework

Eclipse **Firefox** **Swing**

Applet **Spring**

A calculator example (without a framework)


```
public class Calc extends JFrame {
  private JTextField textField;
  public Calc() {
      JPanel contentPane = new JPanel(new BorderLayout());
      contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
      JButton button = new JButton();
      button.setText("calculate");
      contentPane.add(button, BorderLayout.EAST);
      textField = new JTextField("");
      textField.setText("10 / 2 + 6");
      textField.setPreferredSize(new Dimension(200, 20));
      contentPane.add(textfield, BorderLayout.WEST);
      button.addActionListener(/* calculation code */);
      this.setContentPane(contentPane);
      this.pack();
      this.setLocation(100, 100);
      this.setTitle("My Great Calculator");
      ...
  }
}
```

A simple example framework

- Consider a family of programs consisting of buttons and text fields only:

- What source code might be shared?

A calculator example (without a framework)


```
public class Calc extends JFrame {
  private JTextField textField;
  public Calc() {
      JPanel contentPane = new JPanel(new BorderLayout());
      contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
      JButton button = new JButton();
      button.setText("calculate");
      contentPane.add(button, BorderLayout.EAST);
      textField = new JTextField("");
      textField.setText("10 / 2 + 6");
      textField.setPreferredSize(new Dimension(200, 20));
      contentPane.add(textfield, BorderLayout.WEST);
      button.addActionListener(/* calculation code */);
      this.setContentPane(contentPane);
      this.pack();
      this.setLocation(100, 100);
      this.setTitle("My Great Calculator");
      ...
  }
}
```

A simple example framework

```
public abstract class Application extends JFrame {
  protected String getApplicationTitle() { return ""; }
  protected String getButtonText() { return ""; }
  protected String getInitialText() { return ""; }
  protected void buttonClicked() { }
  private JTextField textField;
  public Application() {
      JPanel contentPane = new JPanel(new BorderLayout());
      contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
      JButton button = new JButton();
      button.setText(getButtonText());
      contentPane.add(button, BorderLayout.EAST);
      textField = new JTextField("");
      textField.setText(getInitialText());
      textField.setPreferredSize(new Dimension(200, 20));
      contentPane.add(textField, BorderLayout.WEST);
      button.addActionListener((e) -> { buttonClicked(); });
      this.setContentPane(contentPane);
      this.pack();
      this.setLocation(100, 100);
      this.setTitle(getApplicationTitle());
      ...
  }
```

Using the example framework

```
public abstract class Application extends JFrame {
  protected String getApplicationTitle() { return ""; }
  protected String getButtonText() { return ""; }
  protected String getInitialText() { return ""; }
  protected void buttonClicked() { }
```

```
public class Calculator extends Application {
  protected String getApplicationTitle() { return "My Great Calculator"; }
  protected String getButtonText() { return "calculate"; }
  protected String getInititalText() { return "(10 – 3) * 6"; }
  protected void buttonClicked() {
    JOptionPane.showMessageDialog(this, "The result of " + getInput() +
        " is " + calculate(getInput()));
  }
  private String calculate(String text) { ... }
}
```

```
    button.addActionListener((e) -> { buttonClicked(); });
    this.setContentPane(contentPane);
    this.pack();
    this.setLocation(100, 100);
    this.setTitle(getApplicationTitle());
    ...
  }
```

Using the example framework again

```
public abstract class Application extends JFrame {
  protected String getApplicationTitle() { return ""; }
  protected String getButtonText() { return ""; }
  protected String getInitialText() { return ""; }
  protected void buttonClicked() { }
```

```
public class Calculator extends Application {
  protected String getApplicationTitle() { return "My Great Calculator"; }
  protected String getButtonText() { return "calculate"; }
  protected String getInititalText() { return "(10 – 3) * 6"; }
  protected void buttonClicked() {
    JOptionPane.showMessageDialog(this, "The result of " + getInput() +
        " is " + calculate(getInput()));
  }
  private String calculate(String text) { ... }
}
```

```
public class Ping extends Application {
  protected String getApplicationTitle() { return "Ping"; }
  protected String getButtonText() { return "ping"; }
  protected String getInititalText() { return "127.0.0.1"; }
  protected void buttonClicked() { ... }
}
```

General distinction: Library vs. framework

```
public MyWidget extends JContainer {

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

/ render component on first view and
resizing
protected void
paintComponent(Graphics g) {
// draw a red box on his
componentDimension d = getSize();
g.setColor(Color.red);
g.drawRect(0, 0, d.getWidth(),
d.getHeight());              }
}
```

your code

Library

user interacts

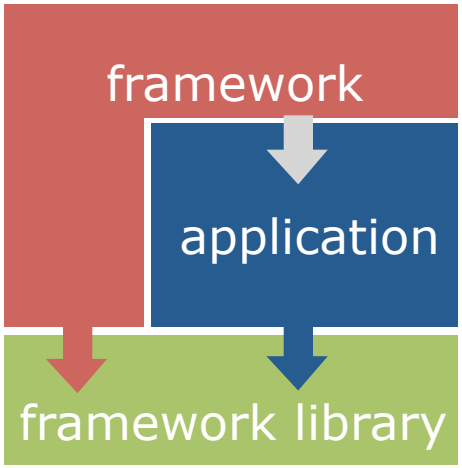
Framework

```
public MyWidget extends JContainer {

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

/ render component on first view and
resizing
protected void
paintComponent(Graphics g) {
// draw a red box on his
componentDimension d = getSize();
g.setColor(Color.red);
g.drawRect(0, 0, d.getWidth(),
d.getHeight());              }
}
```

your code

Libraries and frameworks in practice

- Defines key abstractions and their interfaces
- Defines object interactions & invariants
- Defines flow of control
- Provides architectural guidance
- Provides defaults



credit: Erich Gamma

Framework or library?

- Java Collections
- Eclipse
- The Java Logging Framework
- Java Encryption Services
- Wordpress
- Ruby on Rails

A Scrabble framework?

- In what way is Homework 4 (Scrabble with Stuff) a framework?

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 that gets called in a sequence according to the protocol and the state of the plugin

WHITE-BOX VS BLACK-BOX FRAMEWORKS

Whitebox frameworks

- Extension via subclassing and overriding methods
- Common design pattern(s):
  - Template Method
- Subclass has main method but gives control to framework

Blackbox frameworks

- Extension via implementing a plugin interface
- Common design pattern(s):
  - Strategy
  - Observer
- Plugin-loading mechanism loads plugins and gives control to the framework

Is this a whitebox or blackbox framework?

```
public abstract class Application extends JFrame {
  protected String getApplicationTitle() { return ""; }
  protected String getButtonText() { return ""; }
  protected String getInitialText() { return ""; }
  protected void buttonClicked() { }
```

```
public class Calculator extends Application {
  protected String getApplicationTitle() { return "My Great Calculator"; }
  protected String getButtonText() { return "calculate"; }
  protected String getInititalText() { return "(10 – 3) * 6"; }
  protected void buttonClicked() {
    JOptionPane.showMessageDialog(this, "The result of " + getInput() +
        " is " + calculate(getInput()));
  }
  private String calculate(String text) { ... }
}
```

```
public class Ping extends Application {
  protected String getApplicationTitle() { return "Ping"; }
  protected String getButtonText() { return "ping"; }
  protected String getInititalText() { return "127.0.0.1"; }
  protected void buttonClicked() { ... }
}
```

An example blackbox framework

```
public class Application extends JFrame {
  private JTextField textField;
  private Plugin plugin;
  public Application() { }
  protected void init(Plugin p) {
      p.setApplication(this);
      this.plugin = p;
      JPanel contentPane = new JPa
      contentPane.setBorder(new Be
      JButton button = new JButton();
      button.setText(plugin != null ? plugin.getButtonText() : "ok");
      contentPane.add(button, BorderLayout.EAST);
      textField = new JTextField("");
      if (plugin != null) textField.setText(plugin.getInititalText());
      textField.setPreferredSize(new Dimension(200, 20));
      contentPane.add(textField, BorderLayout.WEST);
      if (plugin != null)
          button.addActionListener((e) -> { plugin.buttonClicked(); } );
      this.setContentPane(contentPane);
      ...
  }
  public String getInput() { return textField.getText(); }
}
```

```
public interface Plugin {
    String getApplicationTitle();
    String getButtonText();
    String getInititalText();
    void buttonClicked() ;
    void setApplication(Application app);
}
```

An example blackbox framework

```
public class Application extends JFrame {
  private JTextField textField;
  private Plugin plugin;
  public Application() { }
  protected void init(Plugin p) {
      p.setApplication(this);
      this.plugin = p;
      JPanel contentPane = new JPa
      contentPane.setBorder(new Be
      JButton button = new JButton();
```

```
public interface Plugin {
    String getApplicationTitle();
    String getButtonText();
    String getInititalText();
    void buttonClicked() ;
    void setApplication(Application app);
}
```

```
public class CalcPlugin implements Plugin {
  private Application app;
  public void setApplication(Application app) { this.app = app; }
  public String getButtonText() { return "calculate"; }
  public String getInititalText() { return "10 / 2 + 6"; }
  public void buttonClicked() {
      JOptionPane.showMessageDialog(null, "The result of "
              + application.getInput() + " is "
              + calculate(application.getInput()));
  }
  public String getApplicationTitle() { return "My Great Calculator"; }
}
```

```
}
```

An aside: Plugins could be reusable too…

```
public class Application extends JFrame implements InputProvider {
  private JTextField textField;
  private Plugin plugin;
  public Application() { }
  protected void init(Plugin p)
      p.setApplication(this);
      this.plugin = p;
      JPanel contentPane = new
      contentPane.setBorder(new
      JButton button = new JButton();
```

```
public interface Plugin {
    String getApplicationTitle();
    String getButtonText();
    String getInititalText();
    void buttonClicked() ;
    void setApplication(InputProvider app);
}
```

```
public class CalcPlugin implements Plugin {
  private InputProvider app;
  public void setApplication(InputProvider app) { this.app = app; }
  public String getButtonText() { retu
  public String getInititalText() { re
  public void buttonClicked() {
      JOptionPane.showMessageDialog(nu
              + application.getInput() + " is "
              + calculate(application.getInput()));
  }
  public String getApplicationTitle() { return "My Great Calculator"; }
}
```

```
public interface InputProvider {
    String getInput();
}
```

```
}
```

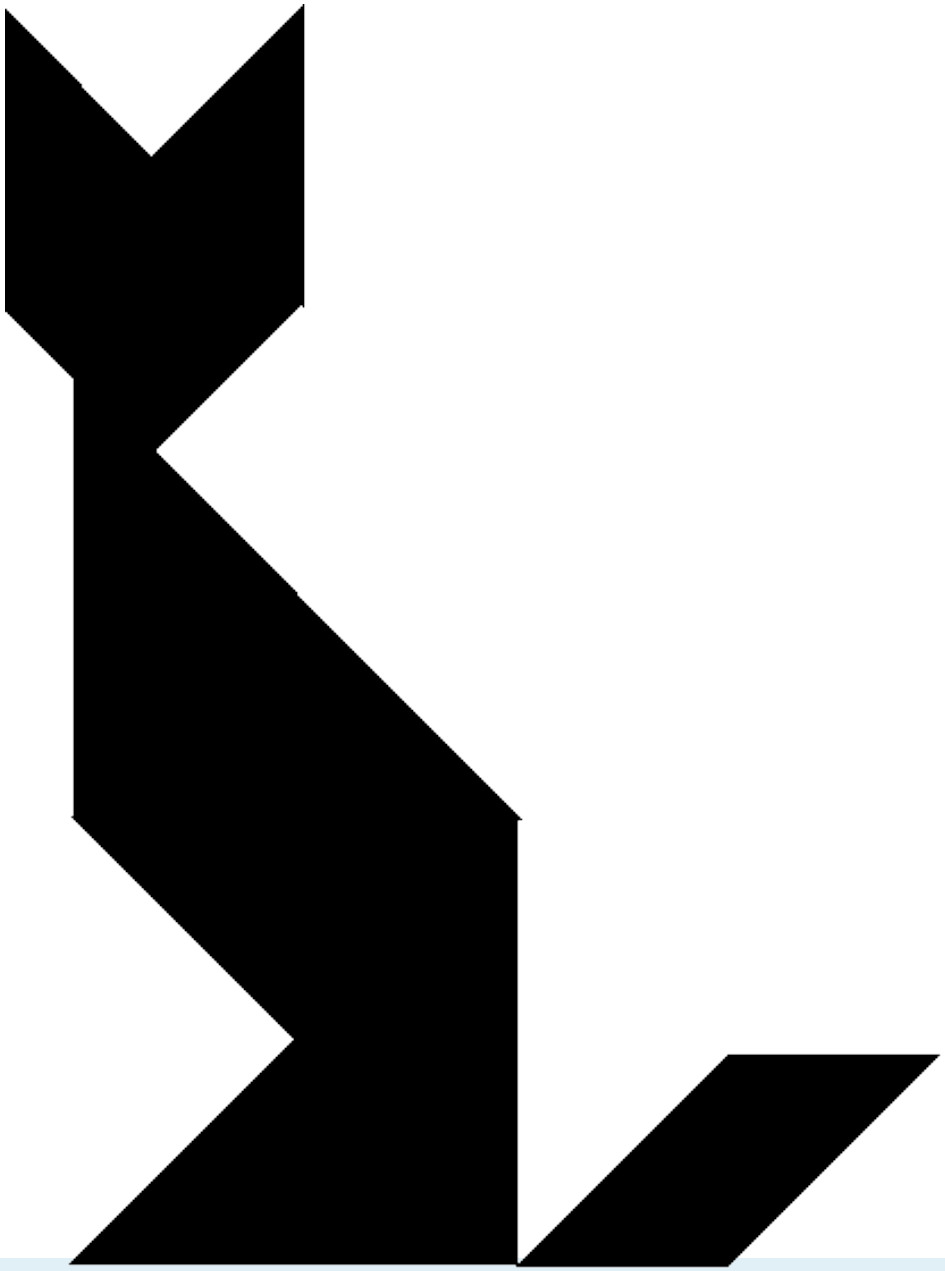
Whitebox vs. blackbox framework summary

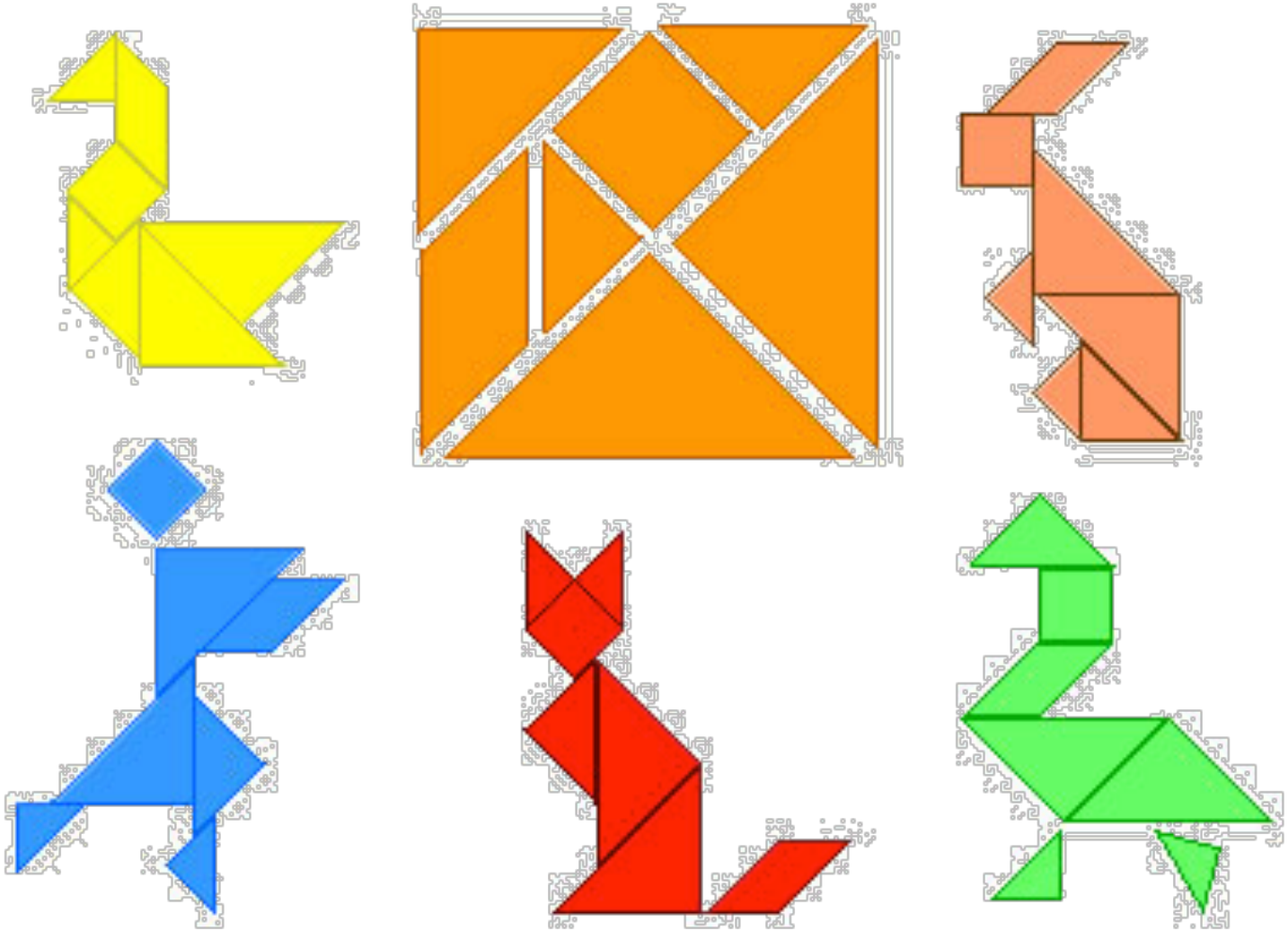
- Whitebox frameworks use subclassing
  - Allows extension of every nonprivate method
  - Need to understand implementation of superclass
  - Only one extension at a time
  - Compiled together
  - Often so-called developer frameworks
- Blackbox frameworks use composition
  - Allows extension of functionality exposed in interface
  - Only need to understand the interface
  - Multiple plugins
  - Often provides more modularity
  - Separate deployment possible (.jar, .dll, …)
  - Often so-called end-user frameworks, platforms

Framework design considerations

- Once designed there is little opportunity for change
- Key decision: Separating common parts from variable parts
  - What problems do you want to solve?
- Possible problems:
  - Too few extension points: Limited to a narrow class of users
  - Too many extension points: Hard to learn, slow
  - Too generic: Little reuse value

USE VS REUSE: DOMAIN ENGINEERING





(one modularization: tangrams)

The use vs. reuse dilemma

- Large rich components are very useful, but rarely fit a specific need
- Small or extremely generic components often fit a specific need, but provide little benefit

“maximizing reuse minimizes use”

C. Szyperski

Domain engineering

- Understand users/customers in your domain
  - What might they need? What extensions are likely?
- Collect example applications before designing a framework
- Make a conscious decision what to support
  - Called *scoping*
- e.g., the Eclipse policy:
  - Interfaces are internal at first
    - Unsupported, may change
  - Public stable extension points created when there are at least two distinct customers

Typical framework design and implementation

- Define your domain
  - Identify potential common parts and variable parts
- Design and write sample plugins/applications
- Factor out & implement common parts as framework
- Provide plugin interface & callback mechanisms for variable parts
  - Use well-known design principles and patterns where appropriate…
- Get lots of feedback, and iterate

Evolutionary design: Extract interfaces from classes

- 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

(credit: Erich Gamma)

FRAMEWORK MECHANICS

Running a framework

- Some frameworks are runnable by themselves
  - e.g. Eclipse
- Other frameworks must be extended to be run
  - Swing, JUnit, MapReduce, Servlets

Methods to load plugins

- Client writes `main()`, creates a plugin and passes it to framework
- Framework writes `main()`, client passes name of plugin as a command line argument or environment variable
- Framework looks in a magic location
  - Config files or .jar files are automatically loaded and processed
- GUI for plugin management

Supporting multiple plugins

- Observer design pattern is commonly used
- Plugins can register for events
- Multiple plugins can react to same events
- Different interfaces for different events possible

```
public class Application {
    private List<Plugin> plugins;
    public Application(List<Plugin> plugins) {
        this.plugins = plugins;
        for (Plugin p : plugins)
            p.setApplication(this);
    }
    public Message processMsg(Message msg) {
        for (Plugin p : plugins)
            msg = p.process(msg);
        ...
        return msg;
    }
}
```

Example: An Eclipse plugin

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

- Plugin 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 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.text
or.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

```
package myeditor.editors;

import org.eclipse.ui.editors.text.TextEditor;

public class XMLEditor extends TextEditor {
        private ColorManager colorManager;

        public XMLEditor() {
                super();
                colorManager = new
                        ColorManager();
                setSourceViewerConfiguratio
                        new
XMLConfiguration(colorManager));
                setDocumentProvider(
                        new XMLDocumentProvi
        }

        public void dispose() {
                colorManager.dispose();
                super.dispose();
        }
}
```

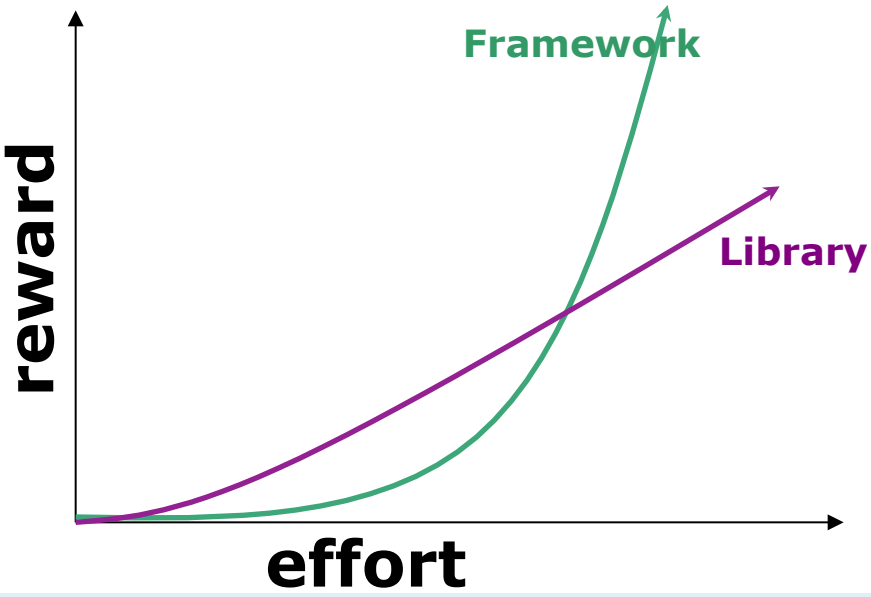
Example: A JUnit Plugin

```
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());
      }
}
```

In JUnit the plugin mechanism is Java annotations

Learning a framework

- Documentation
- Tutorials, wizards, and examples
- Other client applications and plugins
- Communities, email lists and forums



Summary

- Reuse and variation essential
  - Libraries and frameworks
- Whitebox frameworks vs. blackbox frameworks
- Design for reuse with domain analysis
  - Find common and variable parts
  - Write client applications to find common parts
- Revise, revise, revise…