Principles of Software Construction: Objects, Design, and Concurrency

Libraries and Frameworks

(Design for large-scale reuse)

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Earlier in this course: **Class-level** reuse

Language mechanisms supporting reuse

- Inheritance
- Subtype polymorphism (dynamic dispatch)
- Parametric polymorphism (generics)*

Design principles supporting reuse

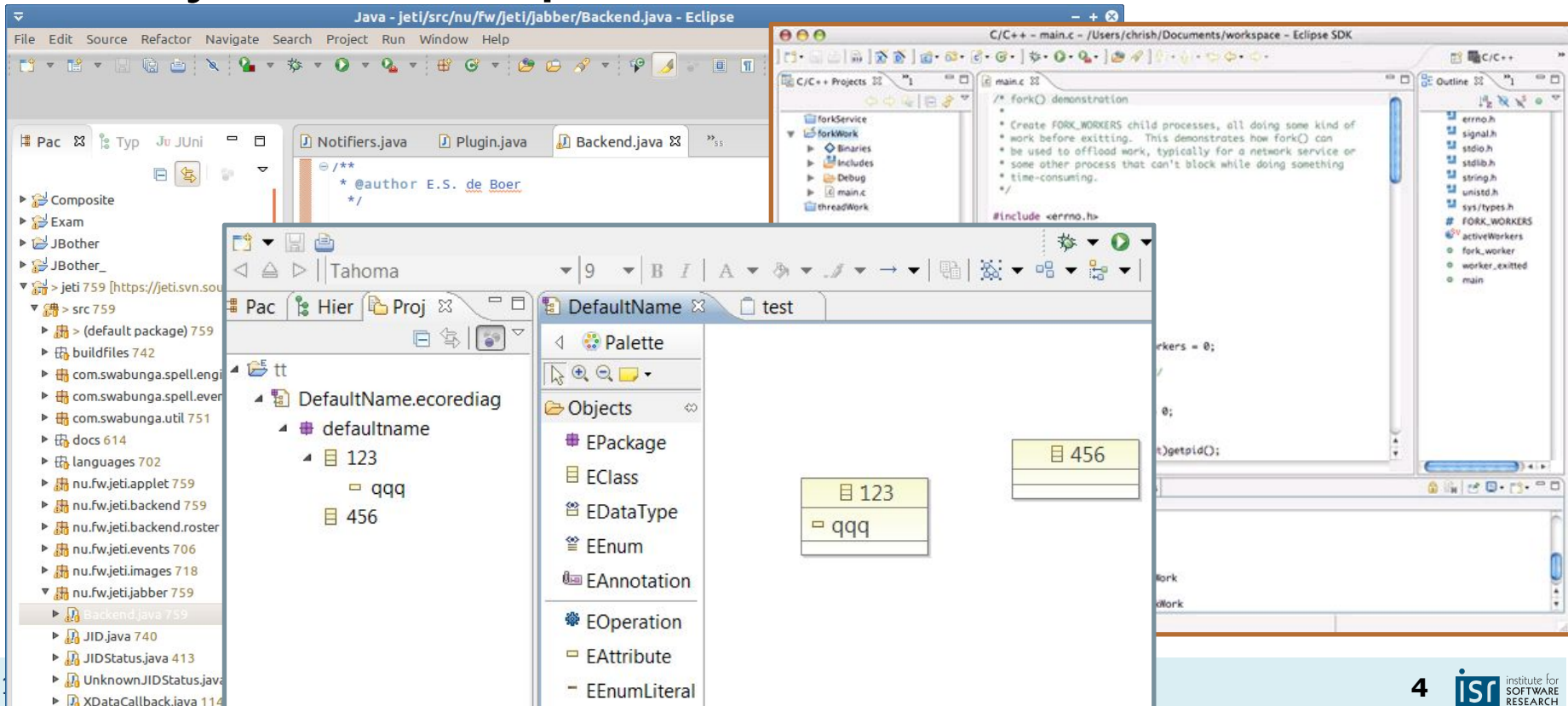
- Small interfaces
- Information hiding
- Low coupling
- High cohesion

Design patterns supporting reuse

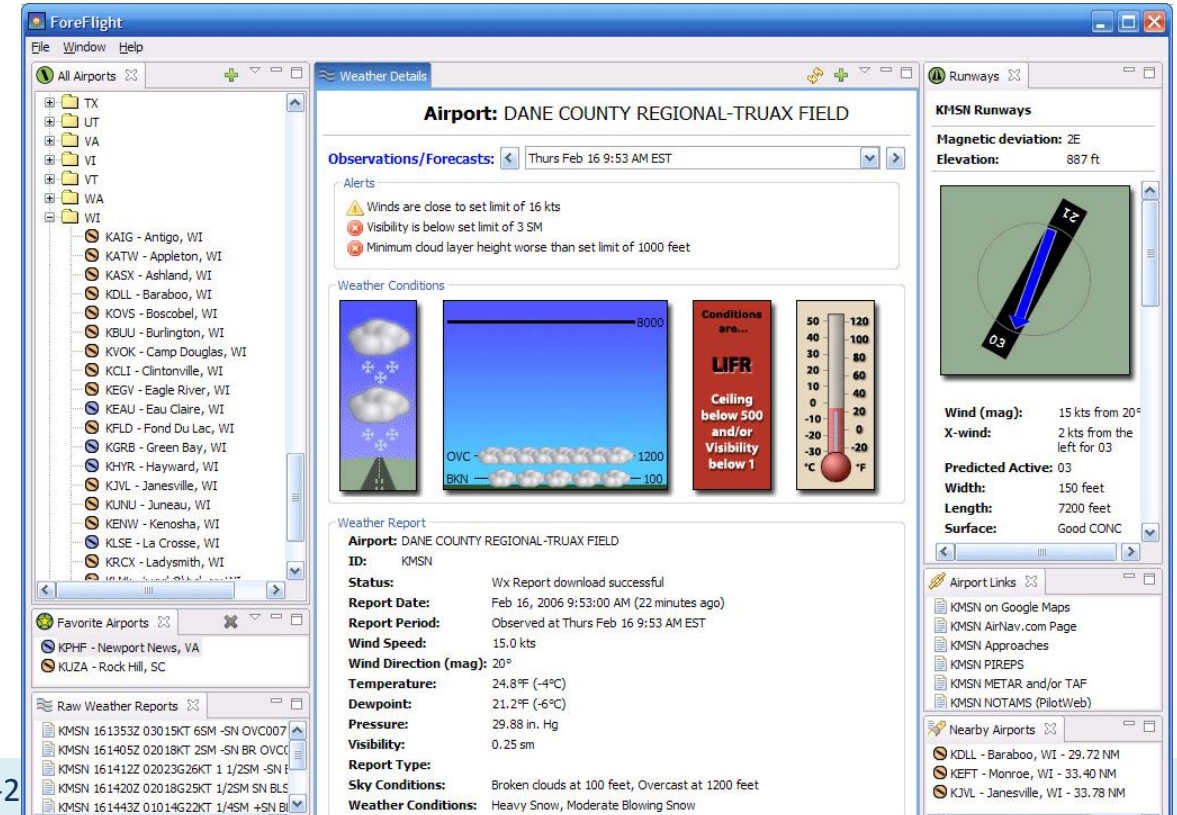
- Template method, decorator, strategy, composite, adapter, …

* Effective Java items 26, 29, 30, and 31

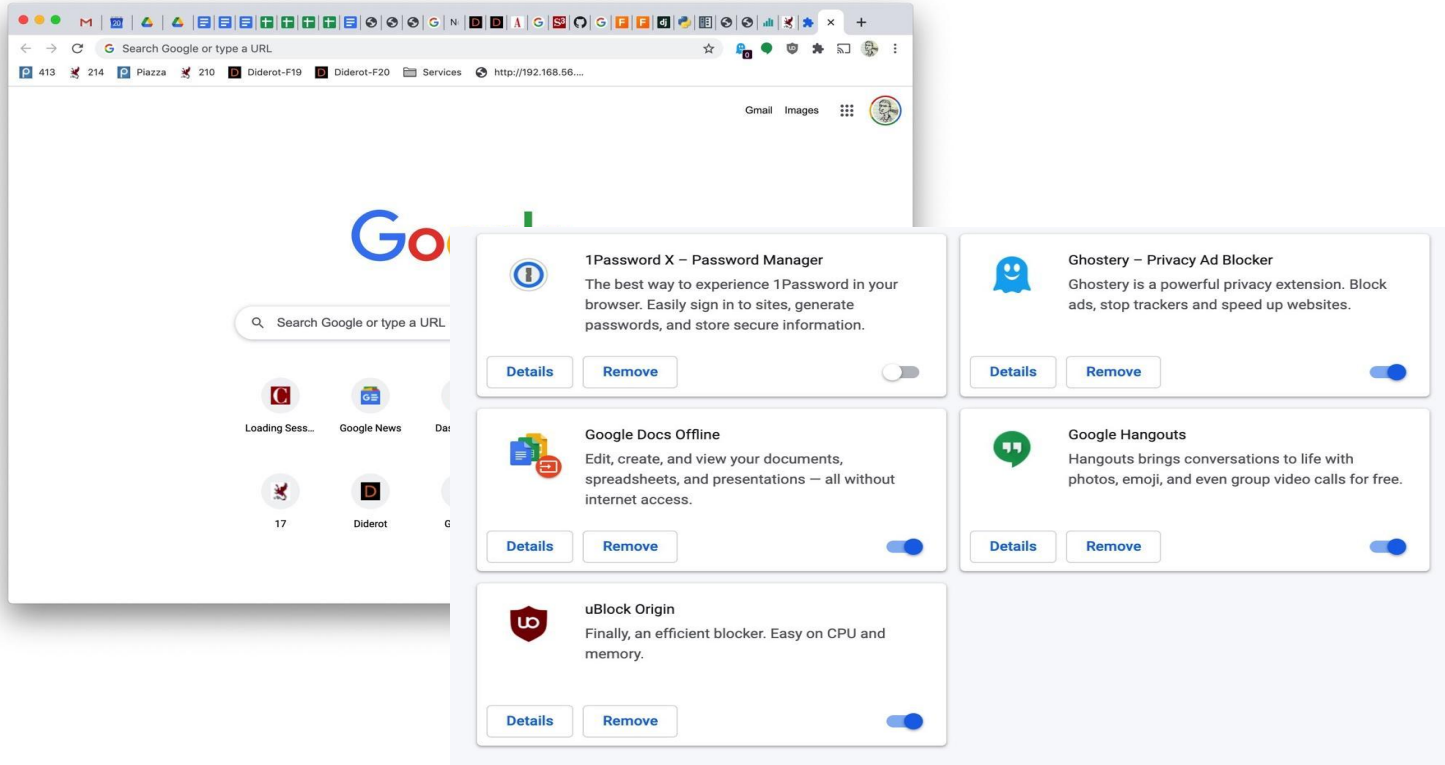
Reuse and variation: Family of development tools



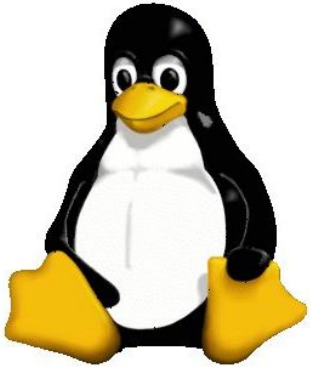
Reuse and variation: Eclipse Rich Client Platform

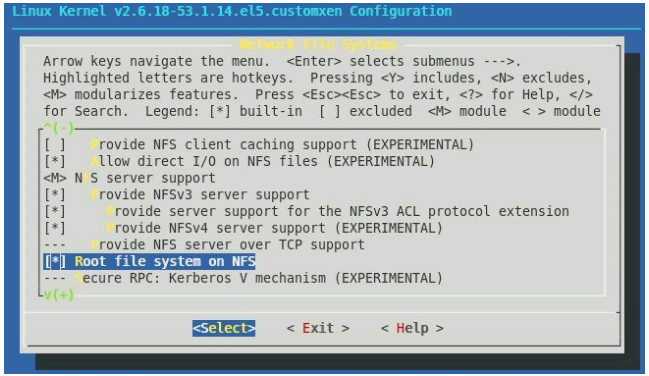


Reuse and variation: Web browser extensions



Reuse and variation: Flavors of Linux





Reuse and variation: Product lines

Today: Reuse **at scale**

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

Today: Reuse **at scale**

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

Terminology: Library

- *Library*: A set of classes and methods that provide reusable functionality
- Client calls library; library executes and returns data
- Client controls
  - Program structure
  - Control flow

```
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 his component
    Dimension d = getSize();
    g.setColor(Color.red);
    g.drawRect(0, 0, d.getWidth(), d.getHeight());
  }
}
```

your code

Library

- E.g.: Math, Collections, Graphs, I/O, Swing

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.”
- Framework controls
  - Program structure
  - Control flow

```
public MyWidget extends JContainer {

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

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

your code

Framework

- E.g.: Eclipse, Firefox, Spring, Swing, IntelliJ, NanoHttpd, Express

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 a button and text field 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));
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      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("");
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      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

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

```java
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) { ... }
}
```

```java
    textField.setPreferredSize(new Dimension(200, 20));
    contentPane.add(textField, BorderLayout.WEST);
    button.addActionListener((e) -> { buttonClicked(); });
    this.setContentPane(contentPane);
    this.pack();
```

Using the example framework again

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

```
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"; }
```

General distinction: Library vs. framework

user interacts

```
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 {

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// draw a red box on his
componentDimension d = getSize();
g.setColor(Color.red);
g.drawRect(0, 0, d.getWidth(),
d.getHeight());}
```
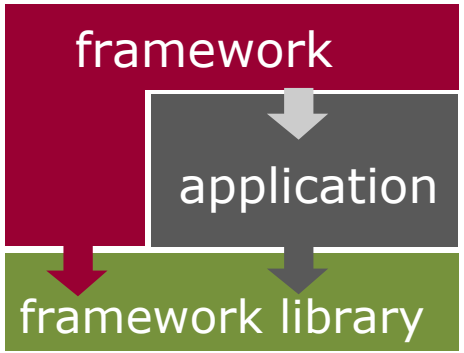

your code

Libraries and frameworks in practice

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



credit: Erich Gamma

Framework or library?

- IntelliJ / VSCode
- Java Collections / Node Streams

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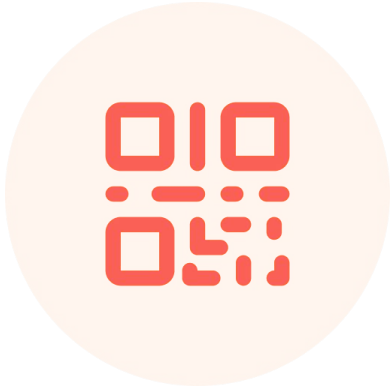

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IntelliJ / VSCode: Framework or library? Motivate (+andrewid)

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Java Collections / Node Streams: Framework or library? Motivate (+andrewid)

ⓘ Start presenting to display the poll results on this slide.

Is Santorini 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

Today: Libraries and frameworks for reuse

- Terminology and examples
- **Whitebox and blackbox frameworks**
- Designing a framework
- Implementation details

WHITE-BOX VS BLACK-BOX* FRAMEWORKS

* outdated terms, not aware of common replacements; maybe Inheritance-Based vs Delegation-Based Frameworks

Whitebox (inheritance-based) frameworks

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

Blackbox (delegation-based) frameworks

- Extension via implementing a plugin interface
- Common design pattern(s):
  - Strategy
  - Command
  - 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 ""; }
```

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

```
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 JPanel(
      contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));
      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 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;
```

```
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 "
              + app.getInput() + " is "
              + calculate(app.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;
```

```
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)
  public String getButtonText() { return "calcula
  public String getInititalText() { return "10 / 2 + 6"; }
  public void buttonClicked() {
      JOptionPane.showMessageDialog(null, "The result of "
              + app.getInput() + " is "
              + calculate(app.getInput()));
  }
  public String getApplicationTitle() { return "My Great Calculator"; }
```

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

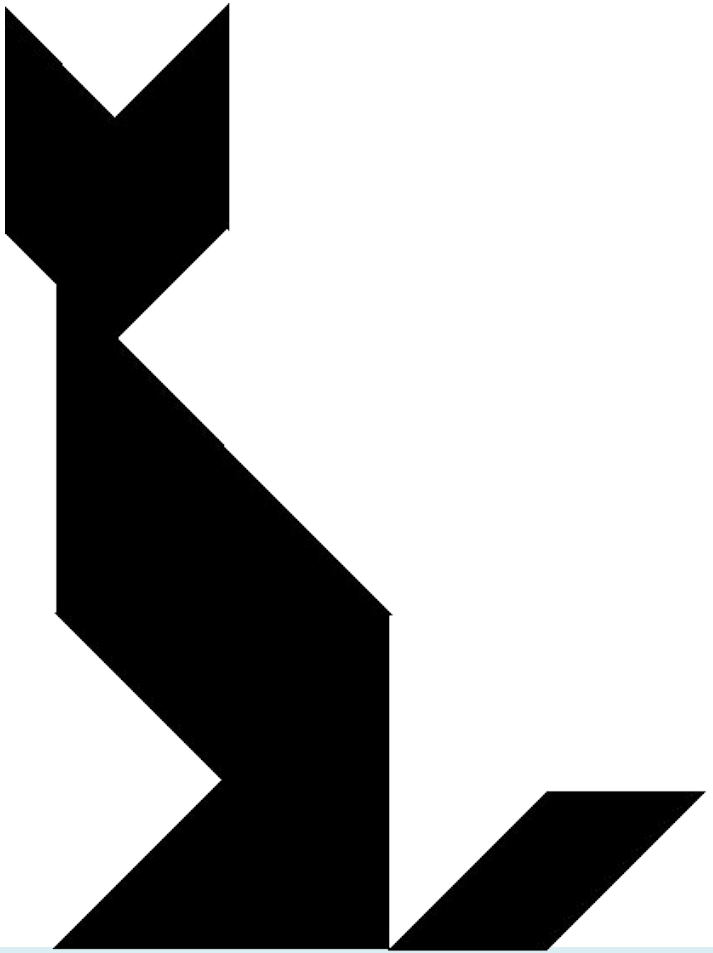
Frameworks summary

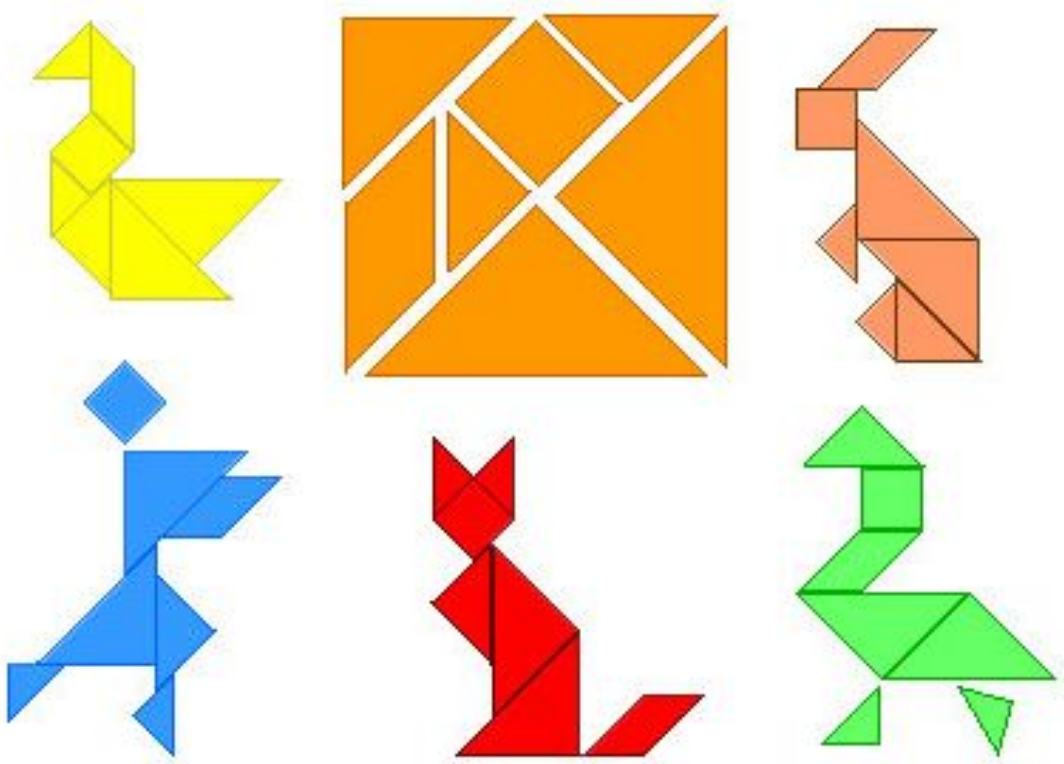
- Whitebox frameworks use subclassing
  - Allows extension of every nonprivate method
  - Need to understand implementation of superclass
  - Only one extension at a time
  - Compiled together
  - Often so-called developer frameworks
- Blackbox frameworks use composition
  - Allows extension of functionality 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 to extend
  - Too generic: Little reuse value

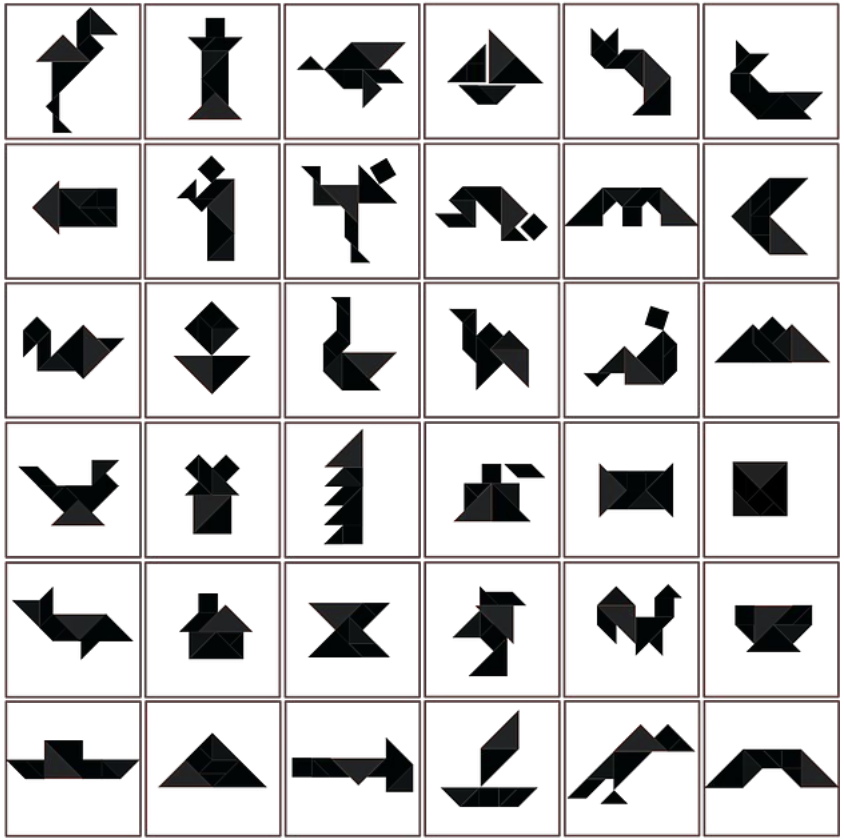
USE VS REUSE: DOMAIN ENGINEERING

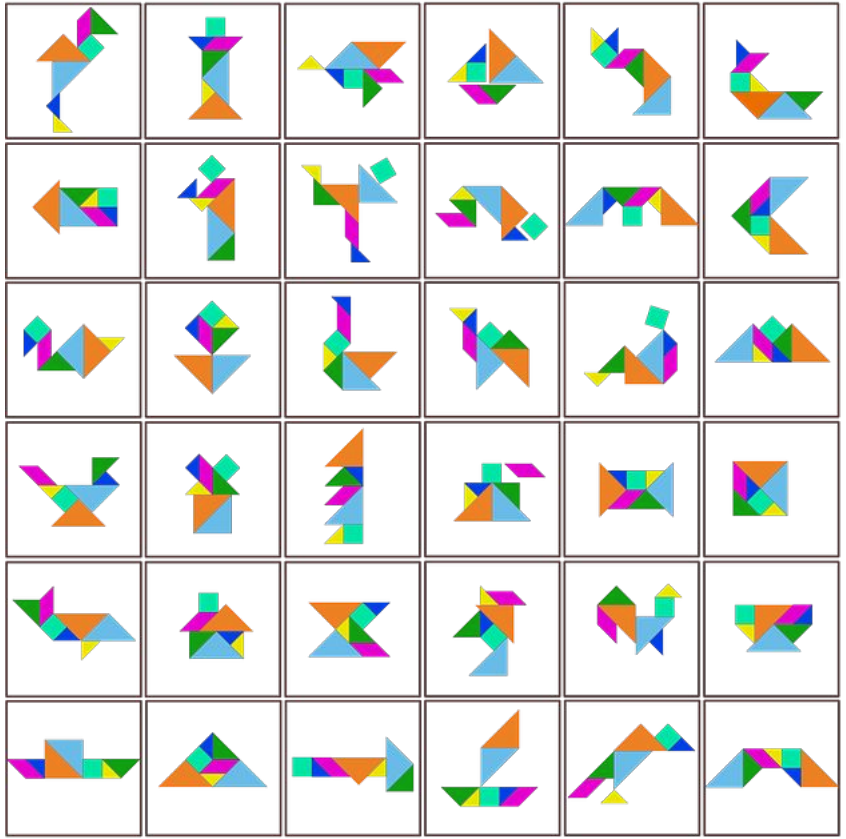




(one modularization: tangrams)

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 *(scoping)*
- e.g., the Eclipse policy:
  - Plugin interfaces are internal at first
    - Unsupported, may change
  - Public stable extension points created when there are at least two distinct customers

The cost of changing a framework

```
public class Application extends JFrame {
        private JTextField textfield;
        private Plugin plugin;
        public Application(Plugin p) { this.plugin=p; p.setA
        protected void init() {
            JPanel contentPane = new JPanel(new BorderLayou
            contentPane.setBorder(new BevelBorder(BevelBord
            JButton button = new JButton();
            if (plugin != null)
                button.setText(plugin.getButtonText());
            else
                butto
            contentPane
            textfield =
            if (plugin
                textf
            textfield.s
            this.setCon
```

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

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

```
class CalcStarter {  public static void main(String[] args) {
        new Application(new CalcPlugin()).setVisible(true); }}
```

The cost of changing a framework

Consider adding an extra method.
Requires changes to *all* plugins!

```
public class Application extends JFrame {
        private JTextField textfield;
        private Plugin plugin;
        public Application(Plugin p) { this.plugin=p; p.setA
        protected void init() {
            JPanel contentPane = new JPanel(new BorderLayou
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                                  ut() + " is "
                                  on.getText())); }
                                  e() { return "My Great Calculator"; }
}
```

```
class CalcStarter {  public static void main(String[] args) {
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```
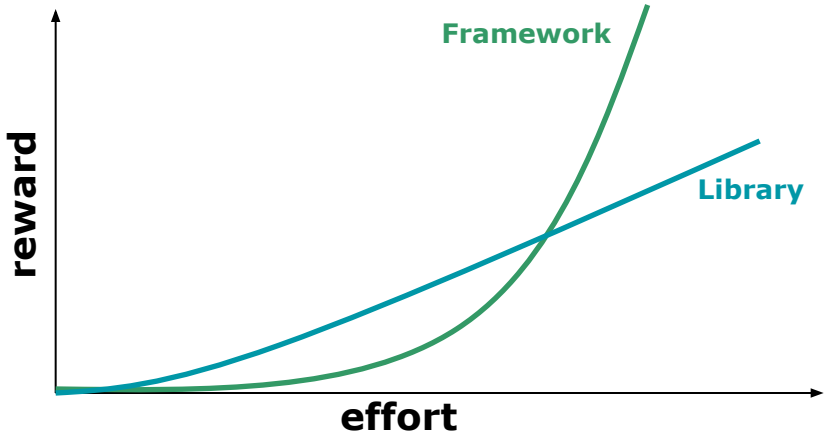

Learning a framework

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



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

(next time)

FRAMEWORK MECHANICS

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