

Frameworks

15-214: Principles of Software Construction:
Objects, Design, and Concurrency

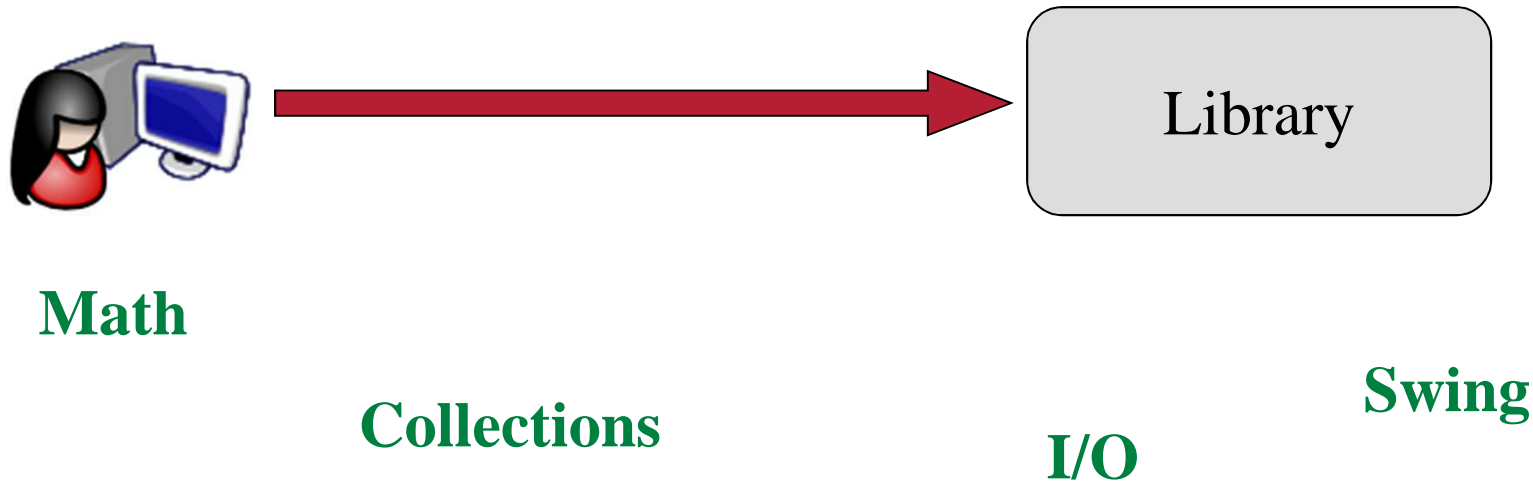
Carnegie Mellon



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.”



Spring

Eclipse

Swing

Applet

But this is an application!

Hey, wasn't this a library?

More terms

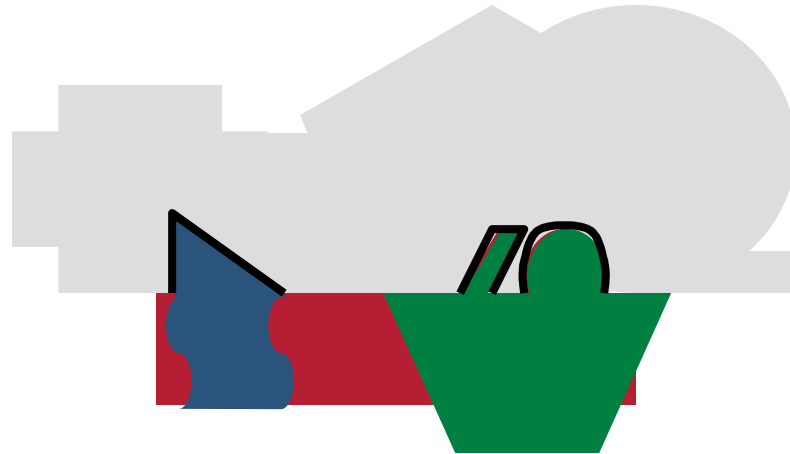
- **API:** Application Programming Interface, the interface of a library or framework
 - **Client:** The code that uses an API
 - **Plugin:** Client code that customizes a framework
 - **Extension point:** A place where a framework supports extension with a plugin
-

More terms

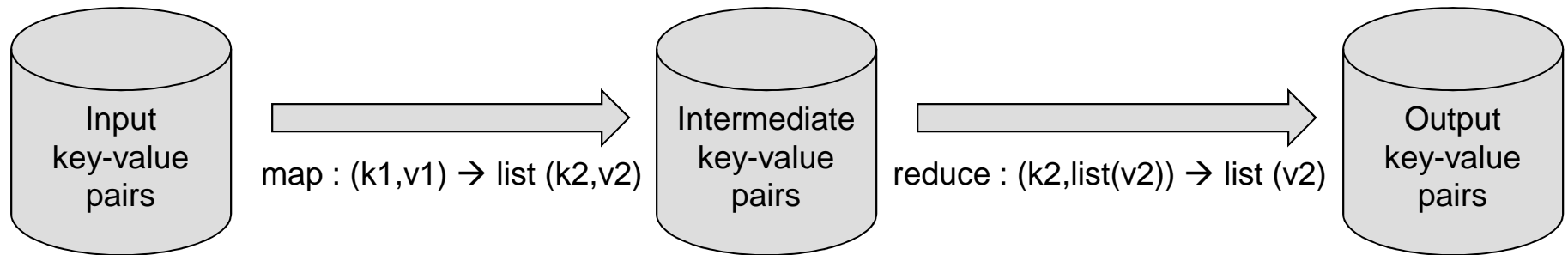
- **Protocol:** The expected sequence of interactions between the API and the client
 - **Callback:** A plugin method that the framework will call to access customized functionality
 - **Lifecycle method:** A callback method of an object that gets called in a sequence according to the protocol and the state of the plugin
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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

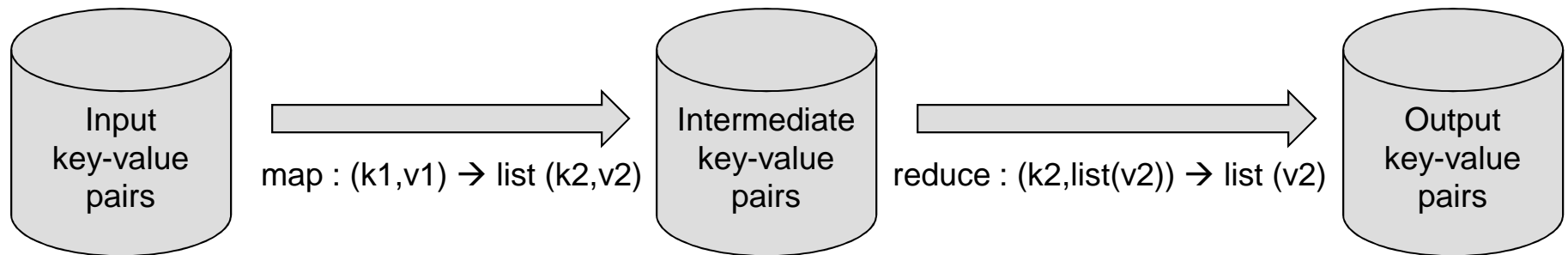


Google's Map-Reduce



- 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 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.Basic
        TextEditorActionContributor"
      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();
        setSourceViewerConfiguration(
            new XMLConfiguration(colorManager));
        setDocumentProvider(
            new XMLDocumentProvider());
    }

    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());
    }
}
```

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.getSystemClassLoader().loadClass(args[0]);  
Plugin p = c.newInstance();
```

 - Framework looks in a magic location
 - Config files or JAR files there are automatically loaded and processed
-

Running a Framework

- Some frameworks are runnable by themselves
 - Other frameworks must be extended to be run
-

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

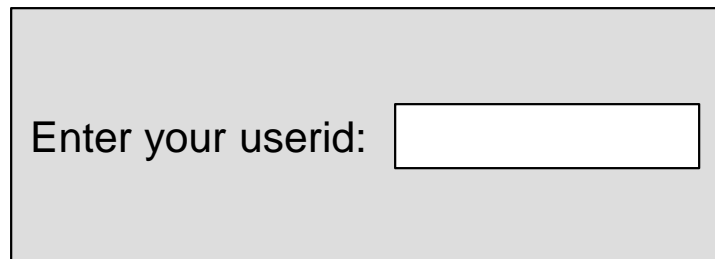
This is no different than the File I/O library!

Swing: Containers and Components

```
// 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

```
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

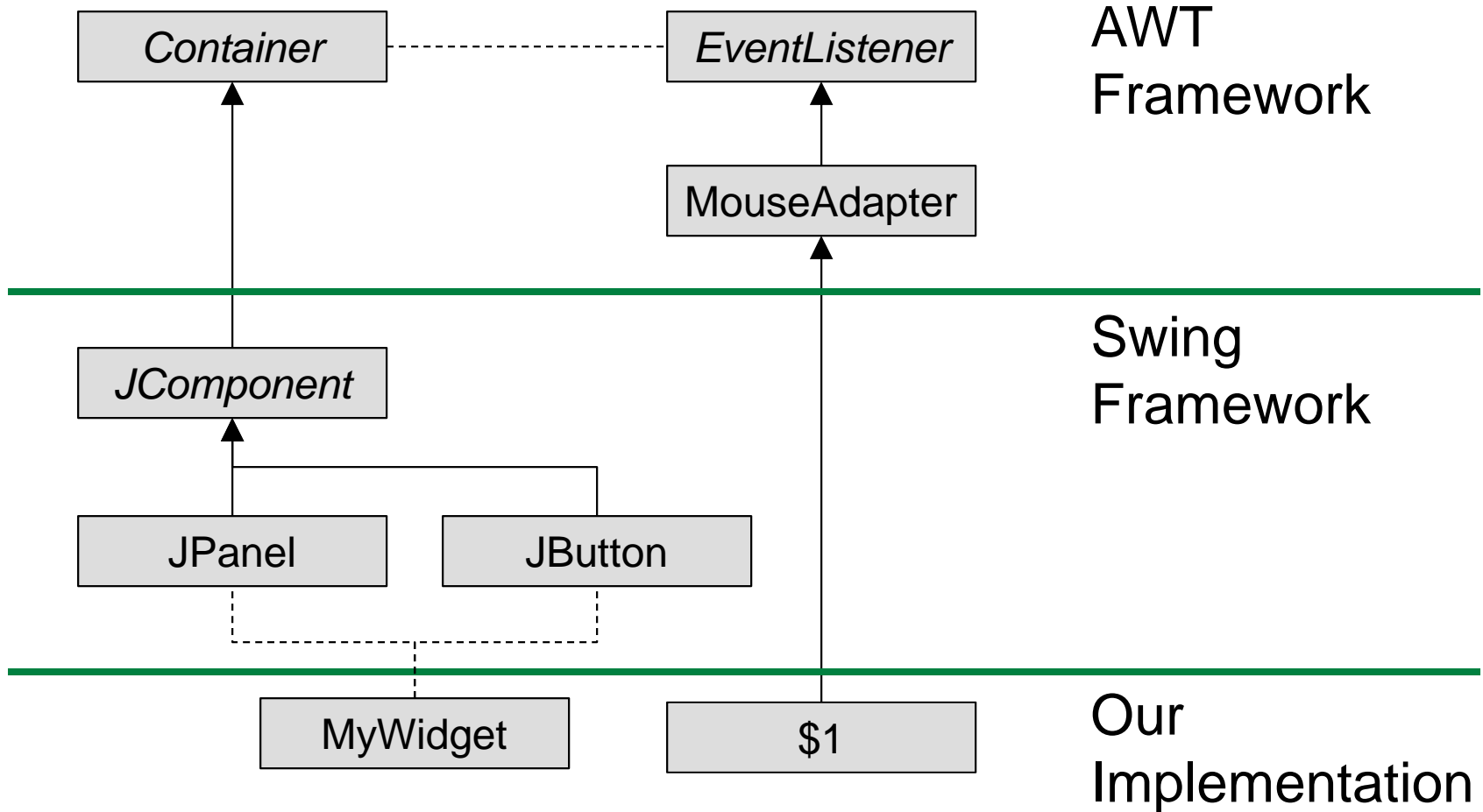
```
// create an anonymous MouseAdapter, which extends
// the MouseListener class

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?



Swing: Custom Components (Reuse)

```
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  
    }  
}
```

Swing: Custom Components

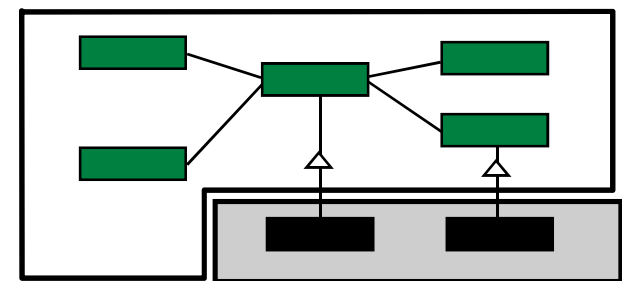
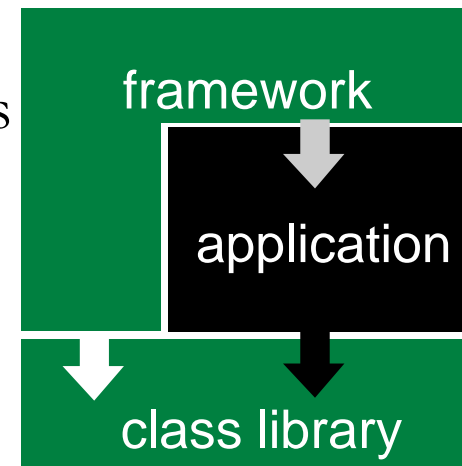
```
public MyWidget extends JContainer {

    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

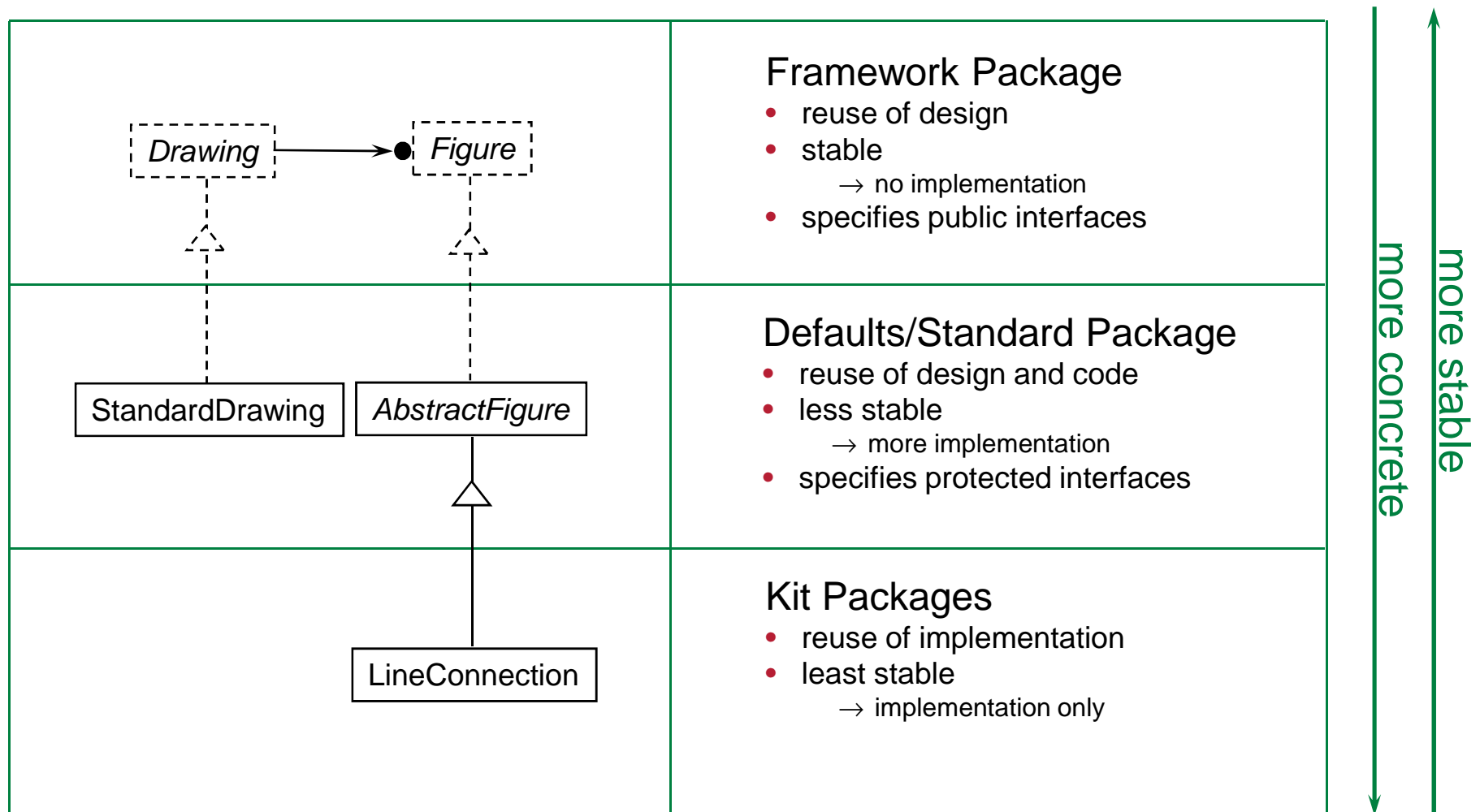


reusing a framework

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)



Evolution: Extract Interface from Class

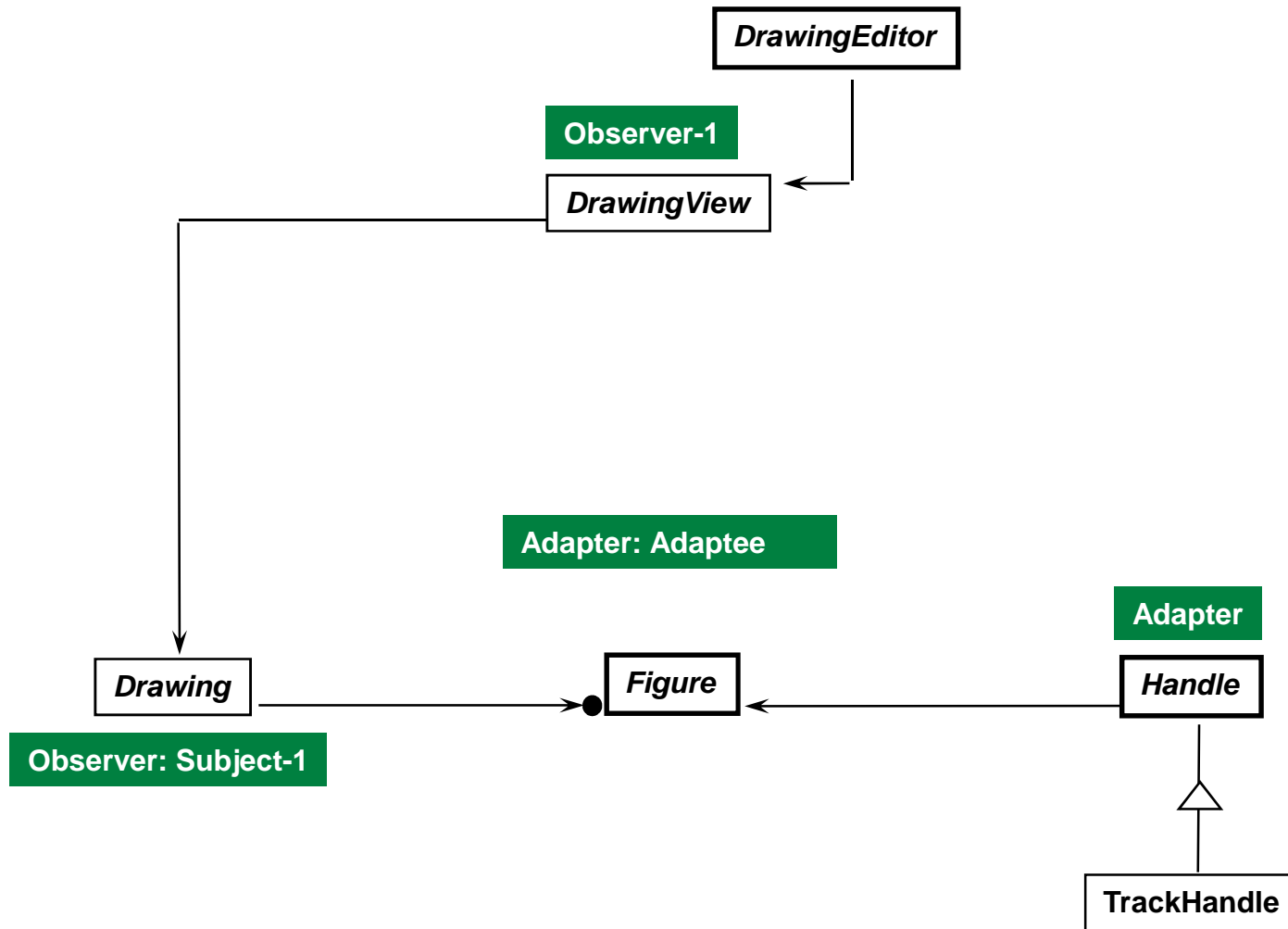
(credit: Erich Gamma)

⇒ 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

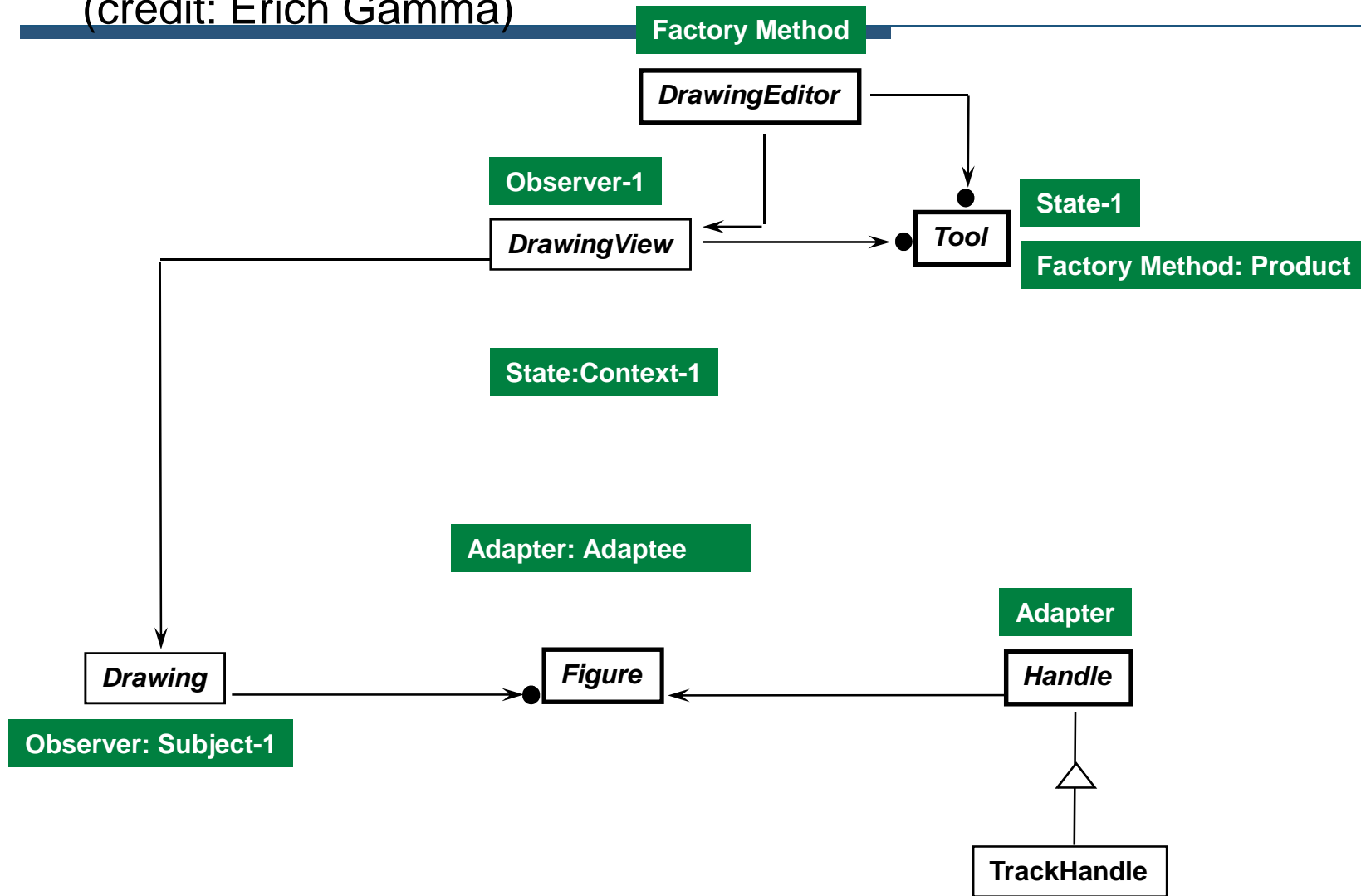
JHotDraw: Design Patterns Summary

(credit: Erich Gamma)



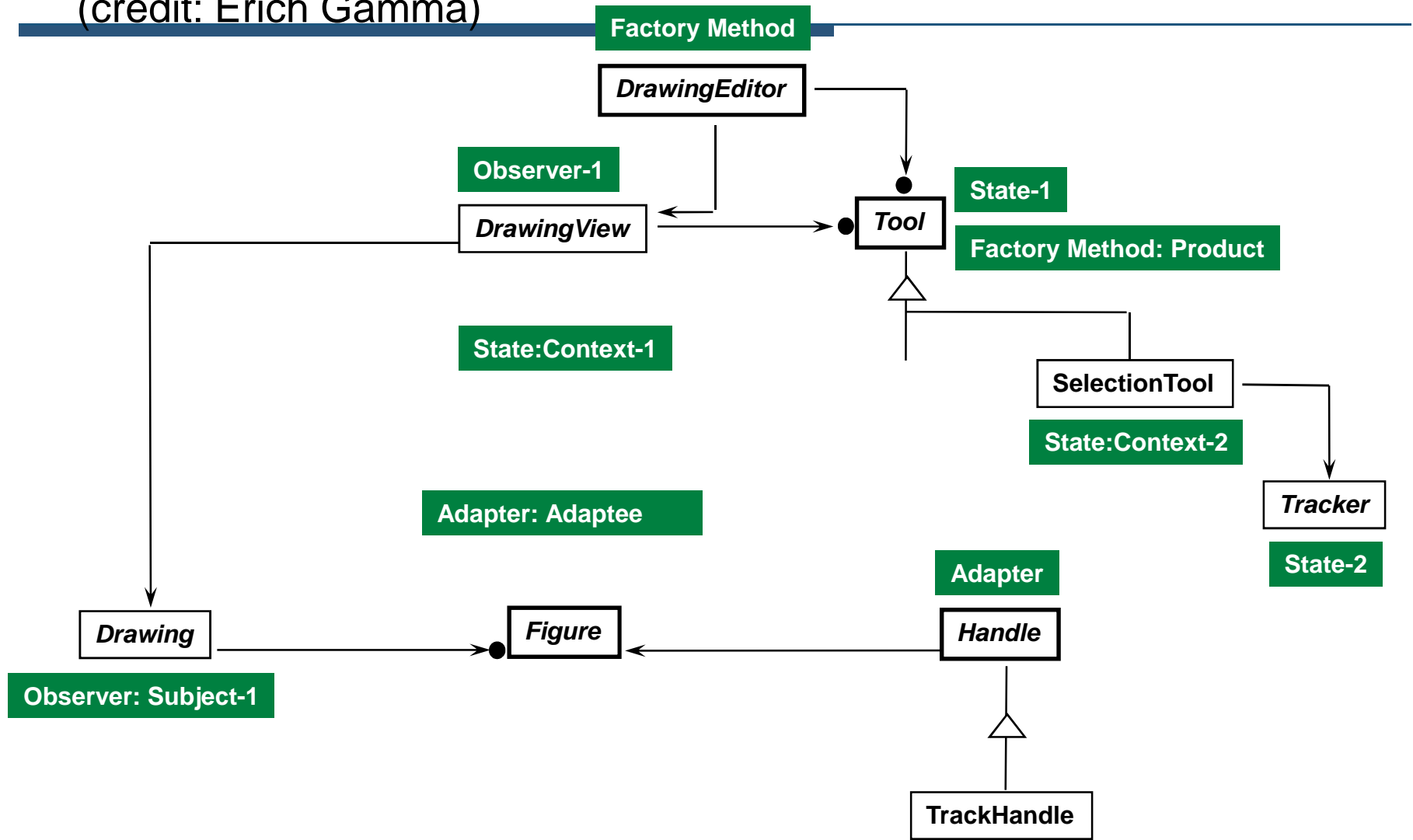
JHotDraw: Design Patterns Summary

(credit: Erich Gamma)



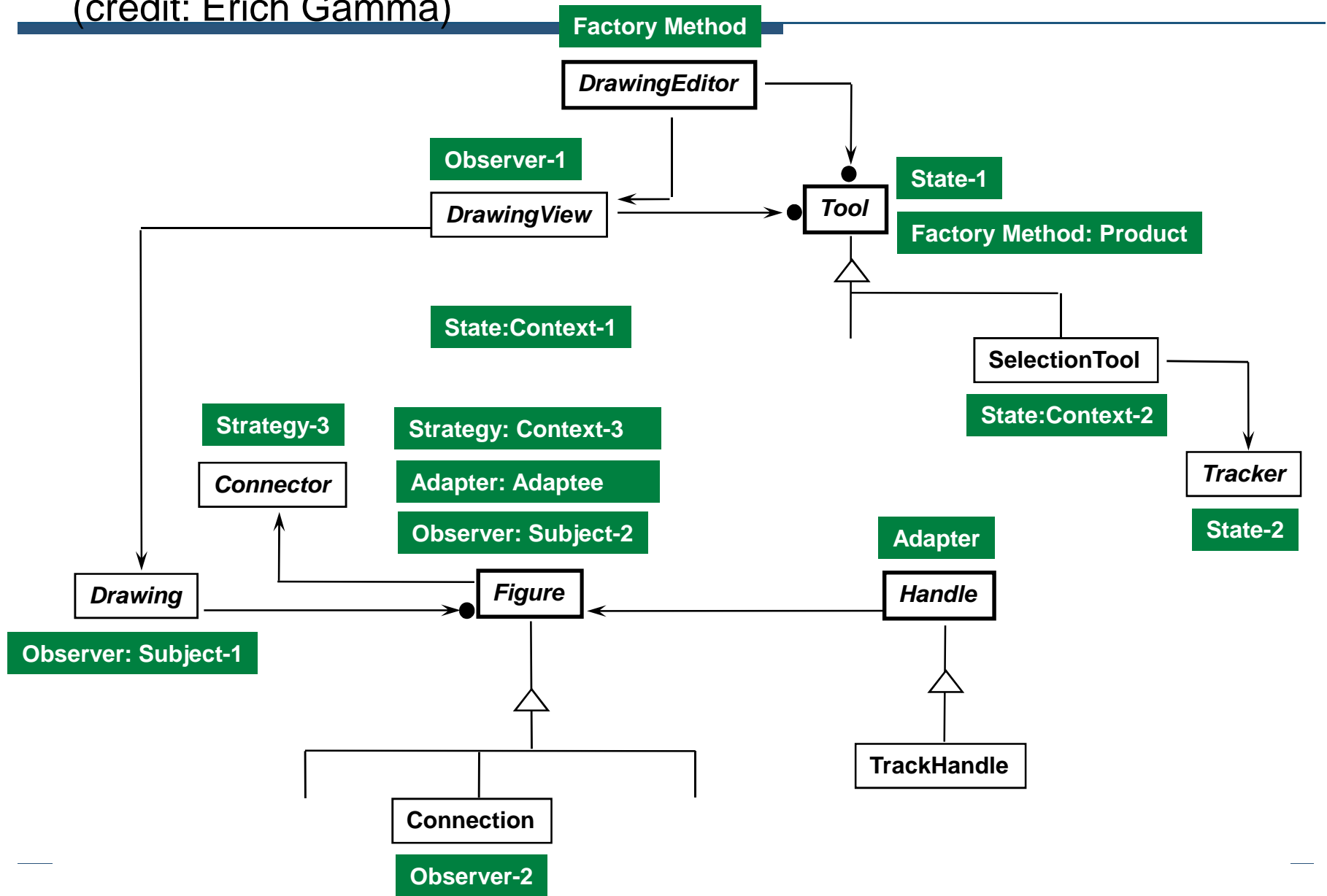
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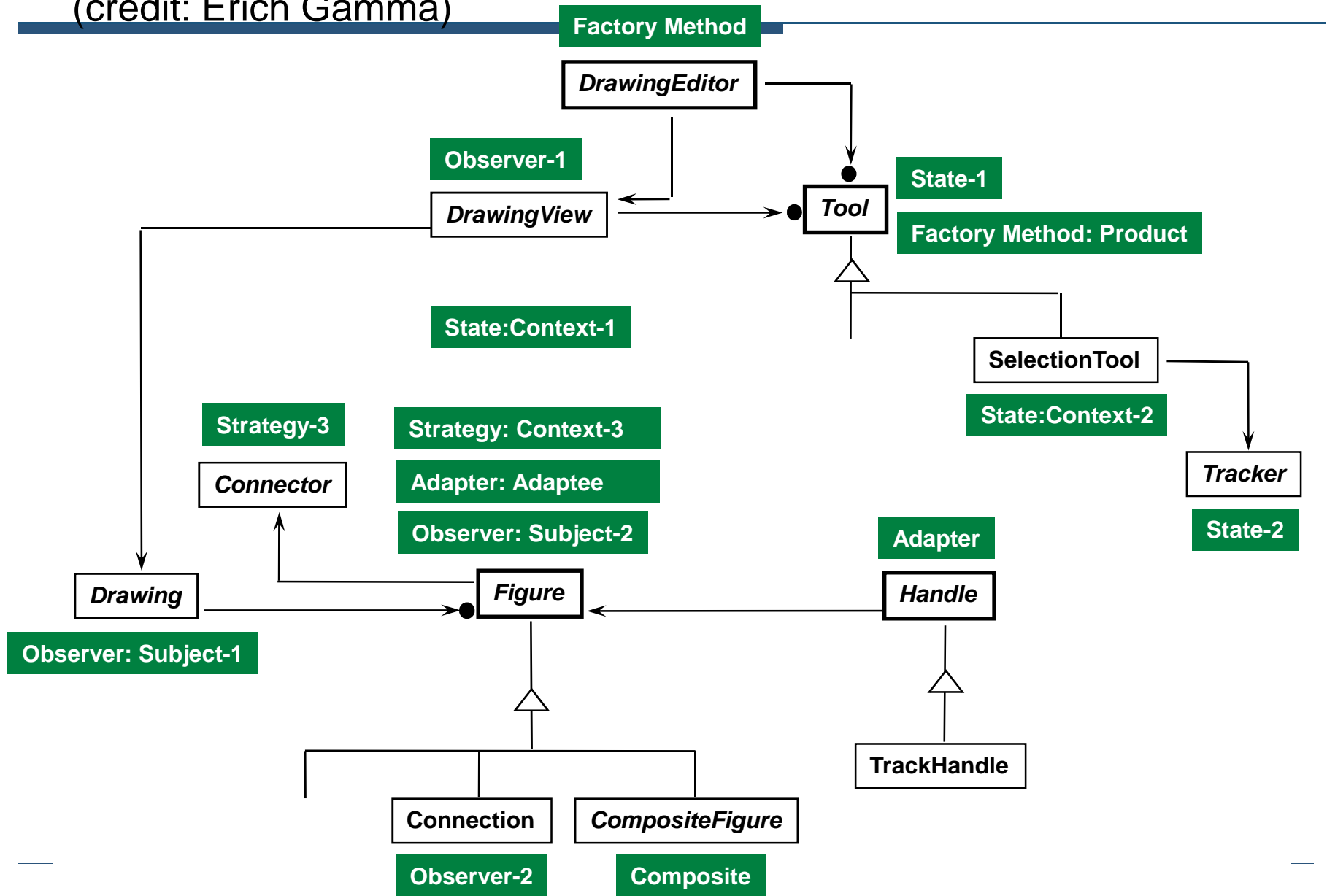
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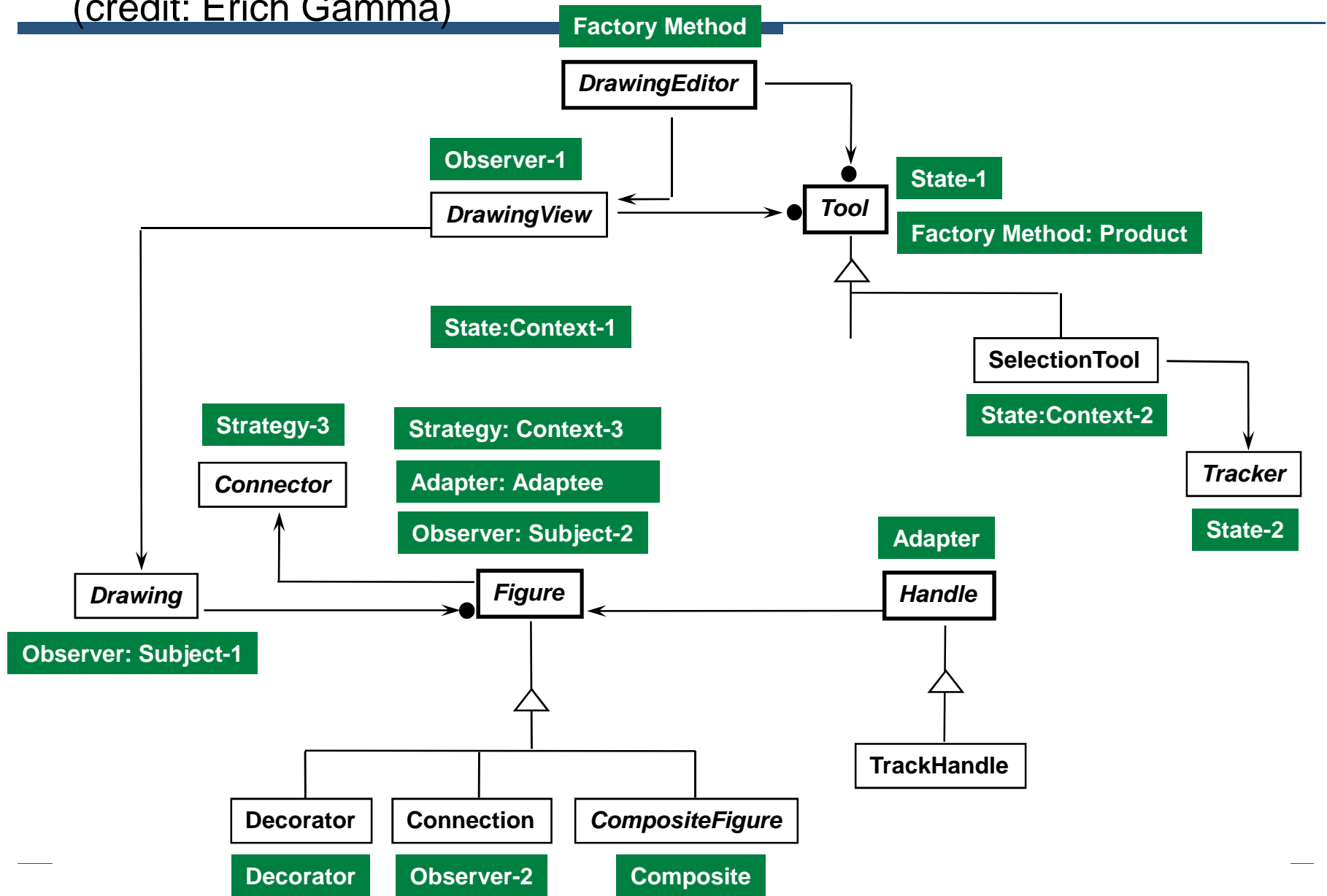
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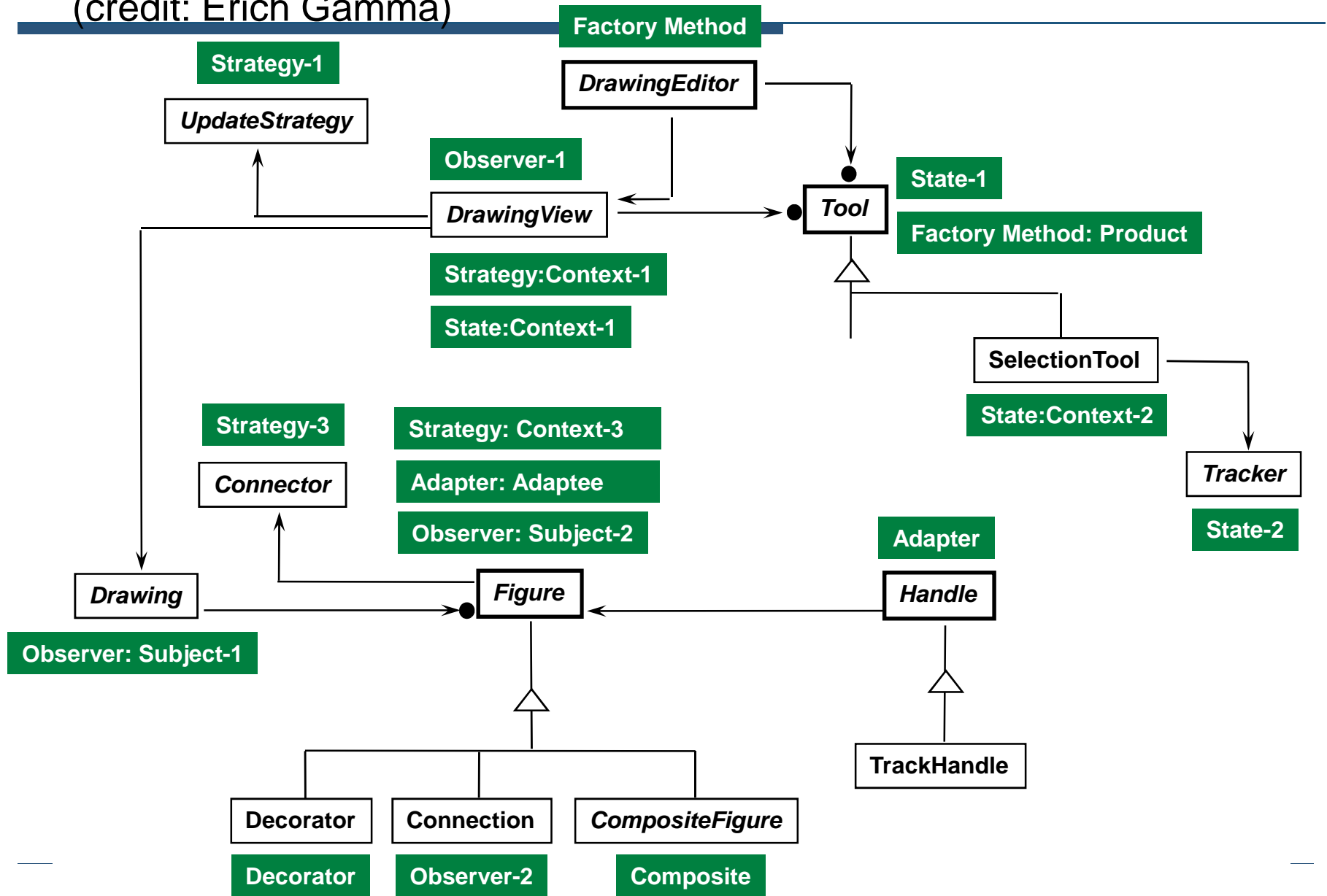
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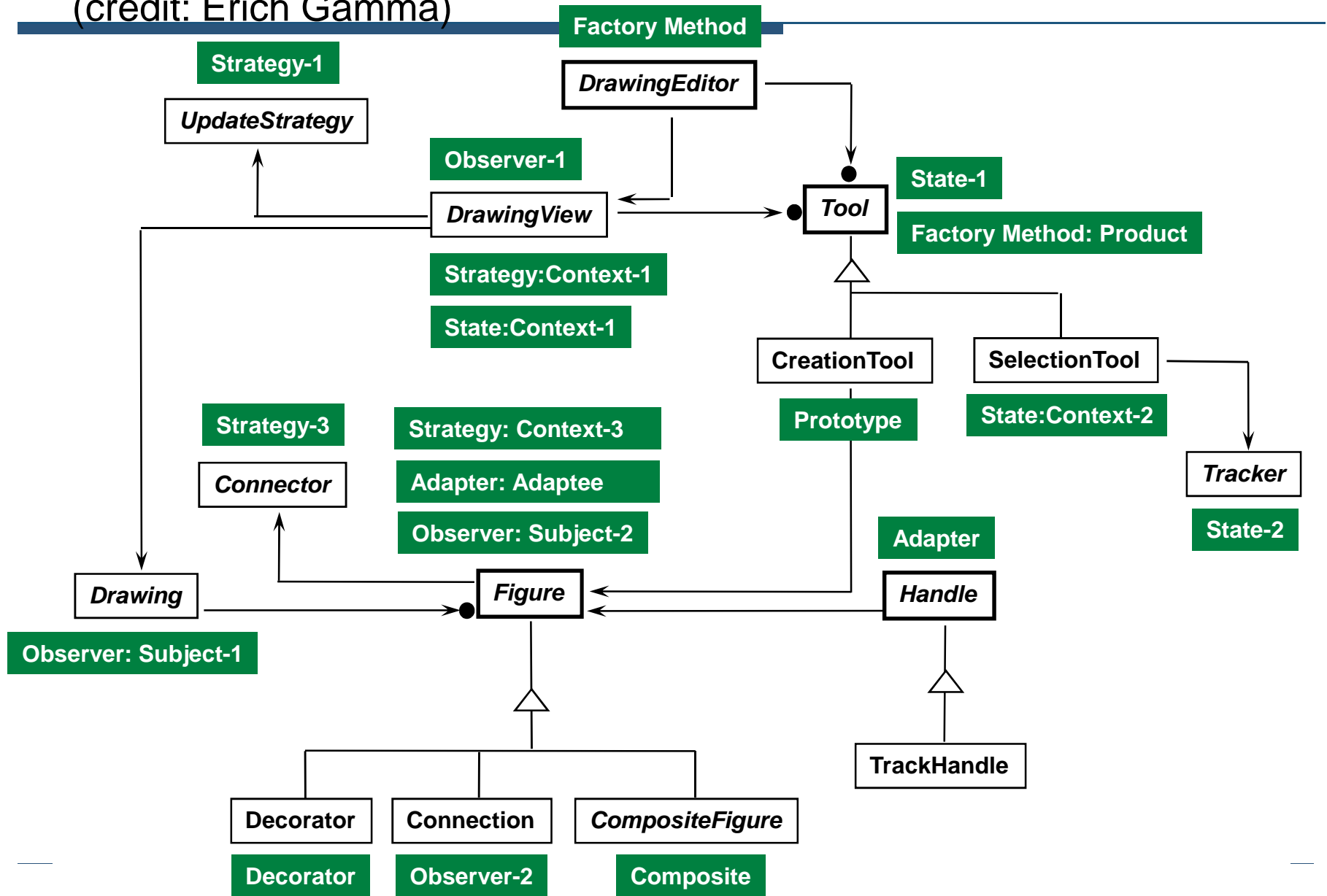
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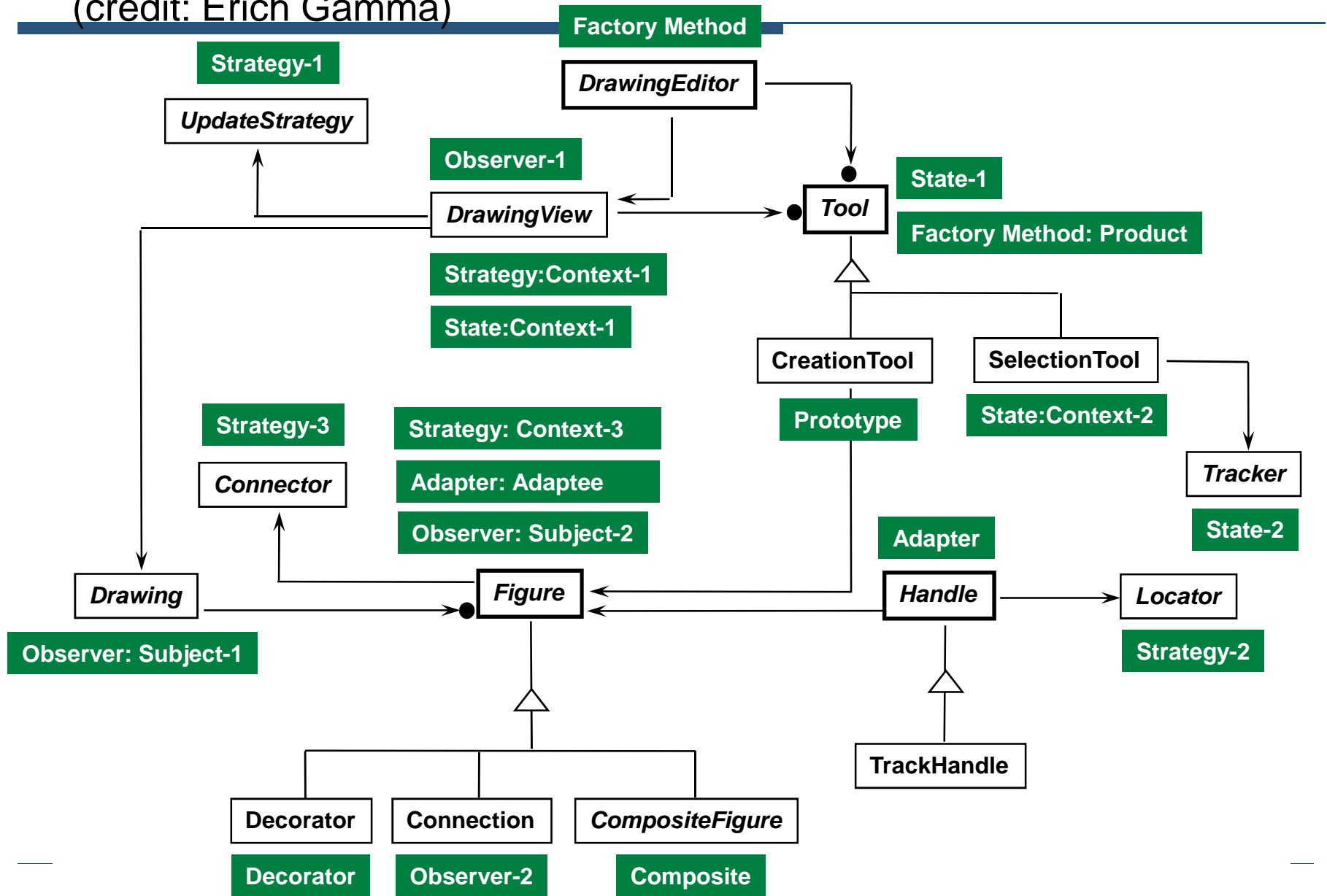
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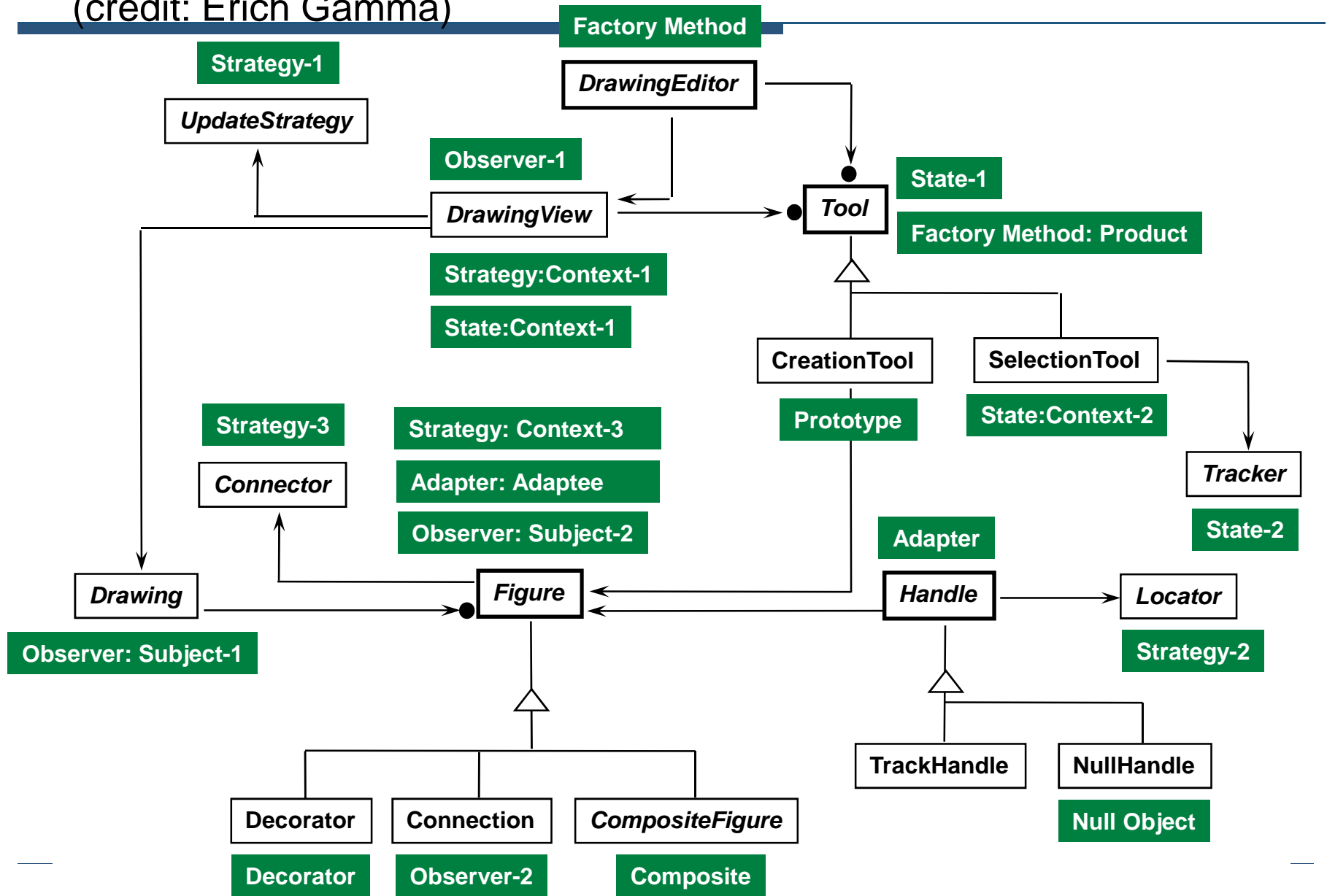
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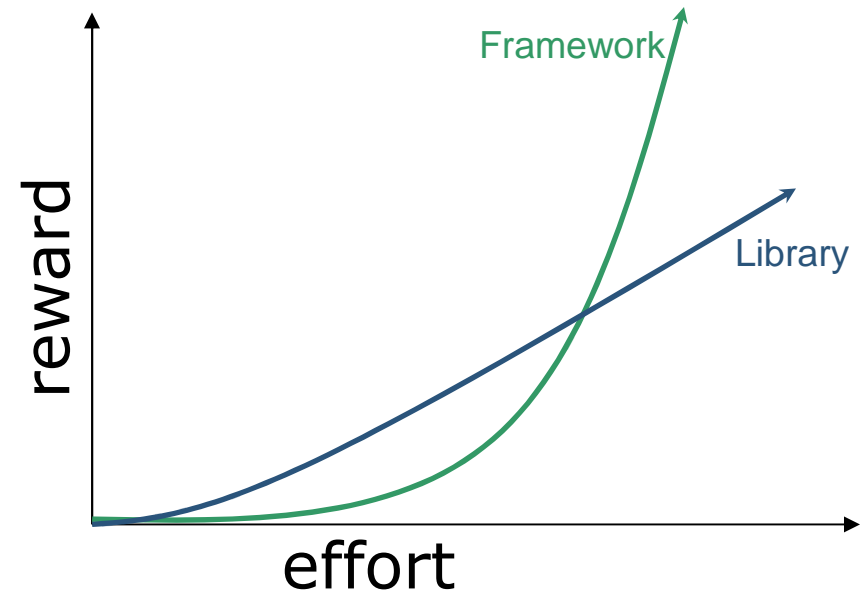
JHotDraw Pattern Experiences

(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

```
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

```
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)....

Dynamically add a control to the page, attempt 3

```
private void Page_Load(object sender, EventArgs e) {  
  
    DropDownList ddl = new DropDownList();  
    if (!IsPostBack()) {  
        ddl.DataSource = ...;  
        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 = ...; //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

```
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 = ...; //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!”

```
<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 = ...;  
    list.DataBind();  
}
```

NullReferenceException at list.DataSource = ...;

Correct code

```
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
-