23 Patterns in 80 Minutes: a Whirlwind Java-centric Tour of the Gang-of-Four Design Patterns

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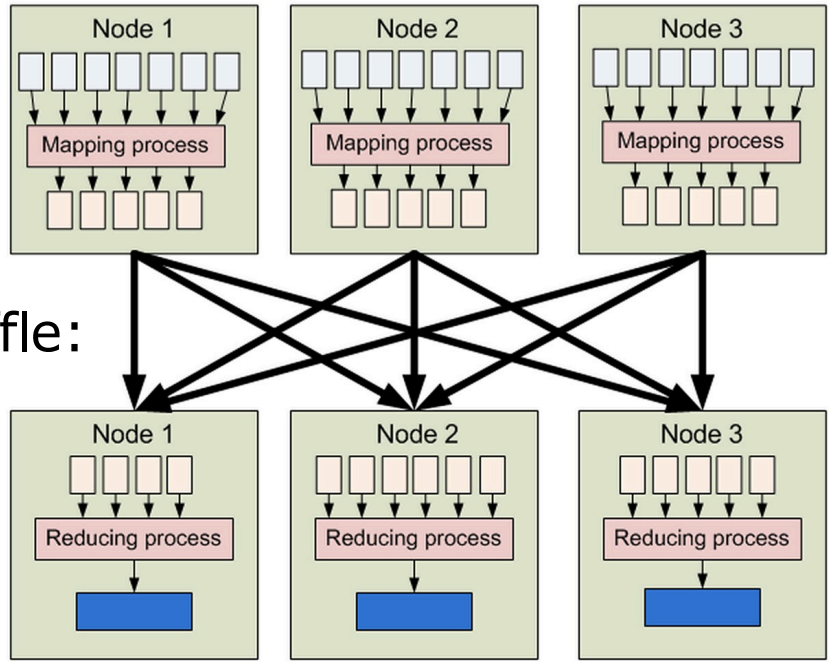
Administrivia

- Homework 6 checkpoint due Friday 5 pm
- Final exam Tuesday, May 3, 5:30-8:30 pm, PH 100
- Final review session Sunday, May, 7-9 pm, DH 1112

Key concept from Tuesday…
MapReduce with key/value pairs (Google style)

- Master
  - Assign tasks to workers
  - Ping workers to test for failures
- Map workers
  - Map for each key/value pair
  - Emit intermediate key/value pairs



Key concept from Tuesday…
MapReduce with key/value pairs (Google style)

- E.g., for each word on the Web, count the number of times that word occurs
  - For Map: `key1` is a document name, `value` is the contents of that document
  - For Reduce: `key2` is a word, `values` is a list of the number of counts of that word

```
f1(String key1, String value):
  for each word w in value:
    EmitIntermediate(w, 1);
```

```
f2(String key2, Iterator values):
  int result = 0;
  for each v in values:
    result += v;
  Emit(key2, result);
```

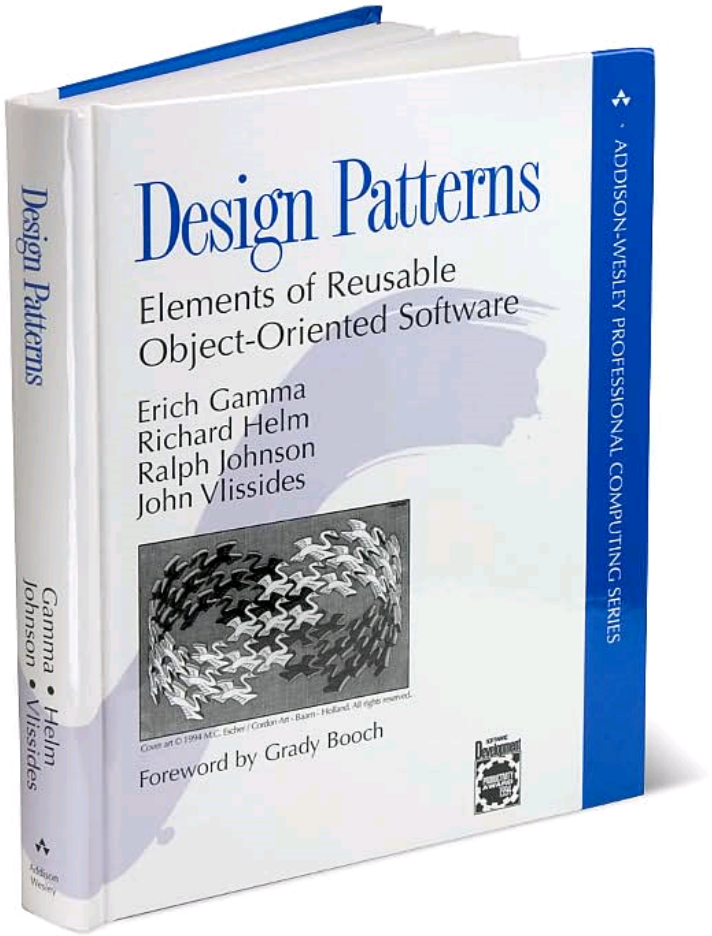
Map: (key1, v1) → (key2, v2)* Reduce: (key2, v2*) → (key3, v3)*

MapReduce: (key1, v1)* → (key3, v3)*

MapReduce: (docName, docText)* → (word, wordCount)*

Outline

I. Creational Patterns
II. Structural Patterns
III. Behavioral Patterns



Pattern Name

- Intent – the aim of this pattern
- Use case – a motivating example
- Key types – the interfaces that define pattern
- JDK – example(s) of this pattern in the JDK

Illustration

- Code sample, diagram, or drawing
  - Time constraints make it impossible to include illustrations from some patterns
- Some patterns lack an illustration ☹

I. Creational Patterns

1. Abstract factory
2. Builder
3. Factory method
4. Prototype
5. Singleton

Abstract Factory

- Intent – Allow creation of families of related objects independent of implementation
- Use case – look-and-feel in a GUI toolkit
- Key type – *Factory* with methods to create each family member
- JDK – Not common

Builder

- Intent – Separate construction of complex object from representation so same creation process can create different representations
- Use case – converting rich text to various formats
- Key types – (Abstract) *Builder*
  - GoF has extra layer of indirection ("Director")
- JDK – `StringBuilder`, `StringBuffer`*
  - But both produce `String`
  - And most builders in the JDK are concrete

My take on Builder

- Emulates named parameters in languages that don't support them
- Reduces exponential $O(2^n)$ creational methods to O(n) by allowing them to be combined freely, at the cost of an intermediate (Builder) object

Builder Illustration

```
NutritionFacts twoLiterDietCoke = new NutritionFacts.Builder(
    "Diet Coke", 240, 8).sodium(1).build();

public class NutritionFacts {
    public static class Builder {
        public Builder(String name, int servingSize,
                int servingsPerContainer) { ... }
        public Builder totalFat(int val)     { totalFat = val; }
        public Builder saturatedFat(int val) { satFat = val; }
        public Builder transFat(int val)     { transFat = val; }
        public Builder cholesterol(int val)  { cholesterol = val; }
        ... // 15 more setters

        public NutritionFacts build() {
            return new NutritionFacts(this);
        }
    }
    private NutritionFacts(Builder builder) { ... }
}
```

Factory Method

- Intent – abstract creational method that lets subclasses decide which class to instantiate
- Use case – creating documents in a framework
- Key types – *Creator*, which contains abstract method to create an instance
- JDK – not common. `Iterable.iterator()`
- Related Static Factory pattern is very common
  - Technically not a GoF pattern, but close enough

Factory Method Illustration

```
public interface Iterable<E> {
    public abstract Iterator<E> iterator();
}

public class ArrayList<E> implements List<E> {
    public Iterator<E> iterator() { ... }
    ...
}

public class HashSet<E> implements Set<E> {
    public Iterator<E> iterator() { ... }
    ...
}
```

Prototype

- Intent – Create an object by cloning another and tweaking as necessary
- Use case – writing a music score editor in a graphical editor framework
- Key types – *Prototype* (AKA Cloneable)
- JDK – `clone`, but don't use it (except on arrays)
  - Java and Prototype pattern are a poor fit

Singleton

- Intent – ensuring a class has only one instance
- Use case – GoF say print queue, file system, company in an accounting system
  - Compelling uses are rare but they do exist
- Key types – Singleton
- JDK – `java.lang.Runtime`

Singleton Illustration

```
public enum Elvis {
    ELVIS;

    public sing(Song song) { ... }

    public playGuitar(Riff riff) { ... }

    public eat(Food food) { ... }

    public take(Drug drug) { ... }
}
```

My take on singleton

- It's an *instance-controlled class*; others include
  - Static utility class (non-instantiable)
  - Enum – one instance per value, all values known at compile time
  - Interned class – one canonical instance per value, new values created at runtime
- There is a duality between singleton and static utility class

II. Structural Patterns

1. Adapter
2. Bridge
3. Composite
4. Decorator
5. Façade
6. Flyweight
7. Proxy

Adapter

- Intent – convert interface of a class into one that another class requires, allowing interoperability
- Use case – numerous, e.g., arrays vs. collections
- Key types – Target, Adaptee, Adapter
- JDK – `Arrays.asList(T[])`

Adapter Illustration

Have this

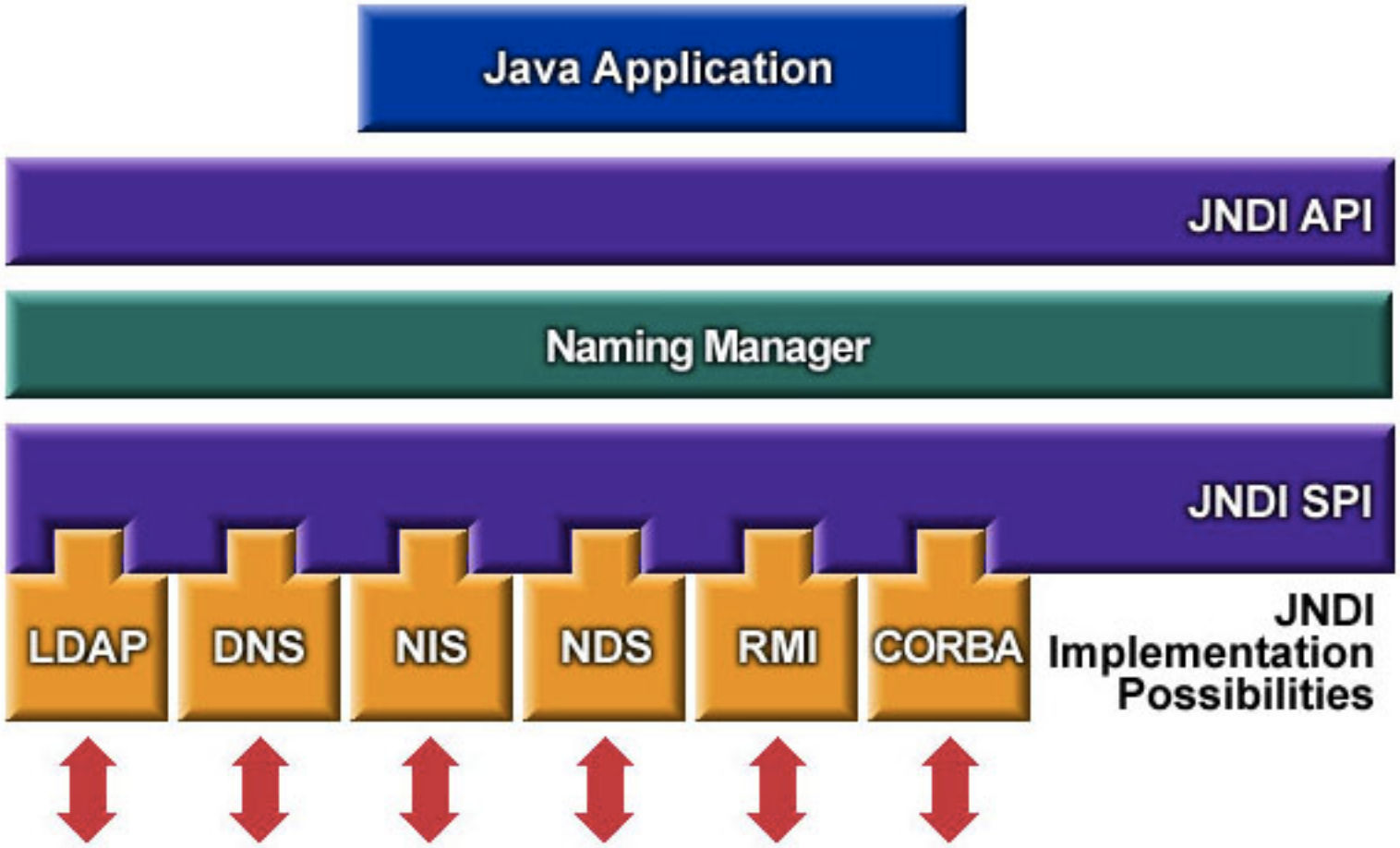
and this?

Use this!

Bridge

- Intent – Decouple an abstraction from its implementation so they can vary independently
- Use case – portable windowing toolkit
- Key types – Abstraction, *Implementor*
- JDK – JDBC, Java Cryptography Extension (JCE)
  - Both are Service Provider Interface (SPI) frameworks
  - SPI *is* Bridge *Implementor*!

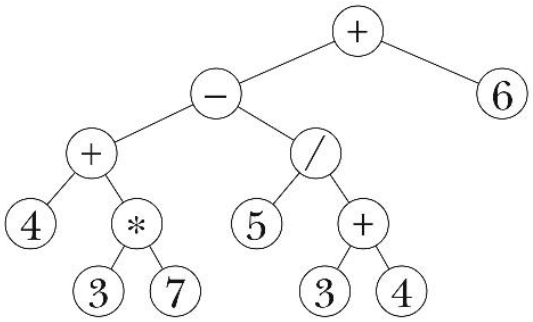
Bridge Illustration



Composite

- Intent – Compose objects into tree structures. Let clients treat primitives & compositions uniformly.
- Use case – GUI toolkit (widgets and containers)
- Key type – *Component* that represents both primitives and their containers
- JDK – `javax.swing.JComponent`

Composite Illustration



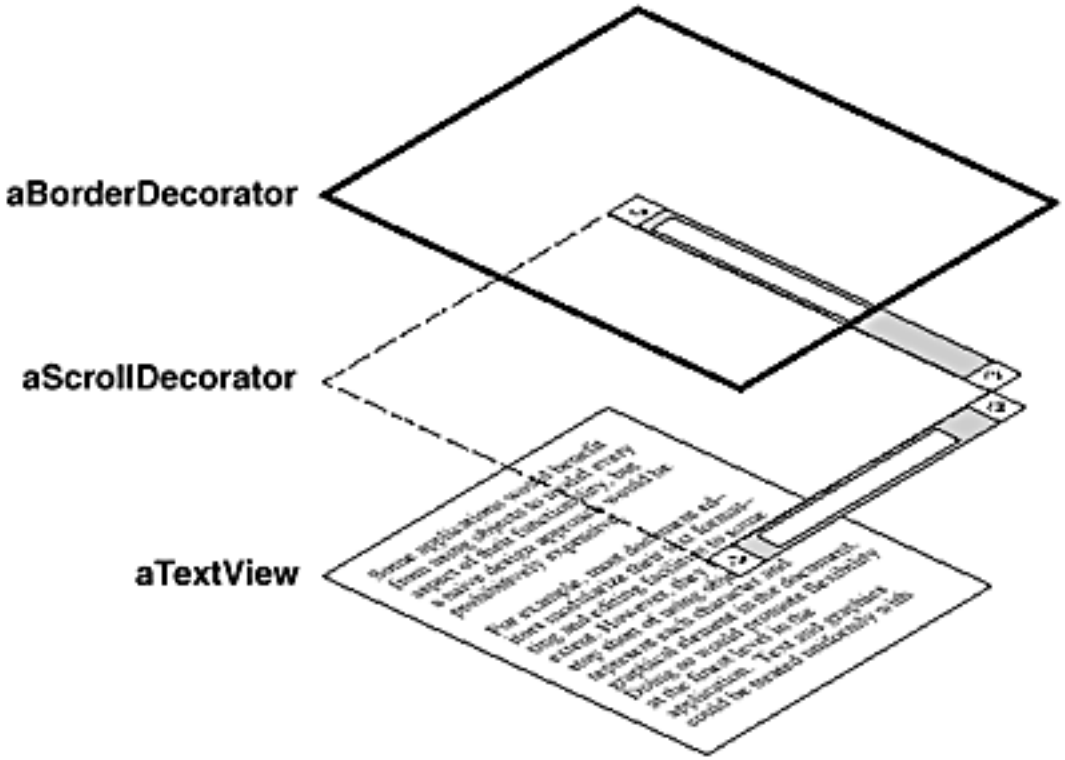

```
public interface Expression {
    double eval();     // Returns value
    String toString(); // Returns infix expression string
}

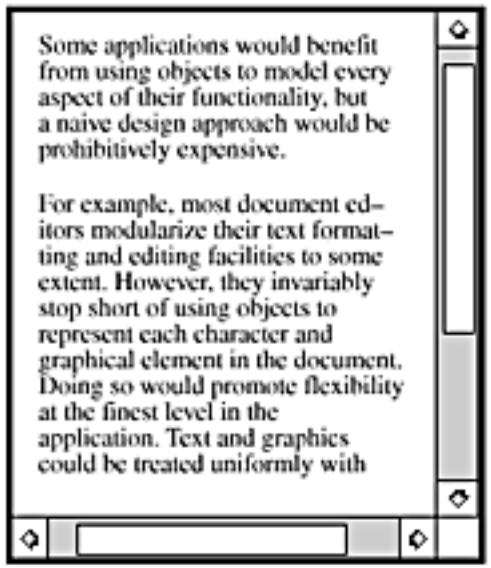
public class UnaryOperationExpression implements Expression {
    public UnaryOperationExpression(
            UnaryOperator operator, Expression operand);
}
public class BinaryOperationExpression implements Expression {
    public BinaryOperationExpression(BinaryOperator operator,
            Expression operand1, Expression operand2);
}
public class NumberExpression implements Expression {
    public NumberExpression(double number);
}
```

Decorator

- Intent – attach features to an object dynamically
- Use case – attaching borders in a GUI toolkit
- Key types – *Component*, implement by decorator and decorated
- JDK – Collections (e.g., `Synchronized` wrappers), java.io streams, Swing components

Decorator Illustration

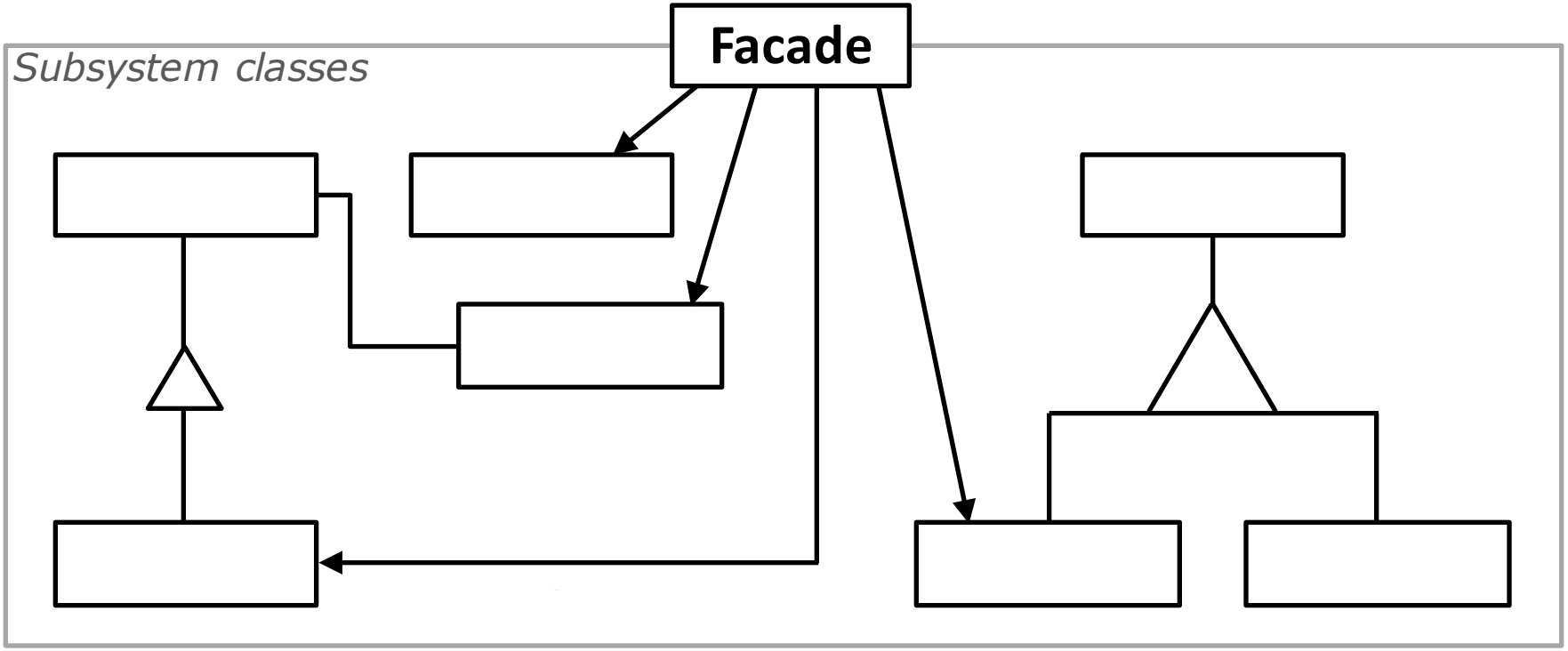




Façade

- Intent – Provide a simple unified interface to a set of interfaces in a subsystem
  - GoF allow for variants where the complex underpinnings are exposed and hidden
- Use case – any complex system; GoF use compiler
- Key types – Façade (the simple unified interface)
- JDK – `java.util.concurrent.Executors`

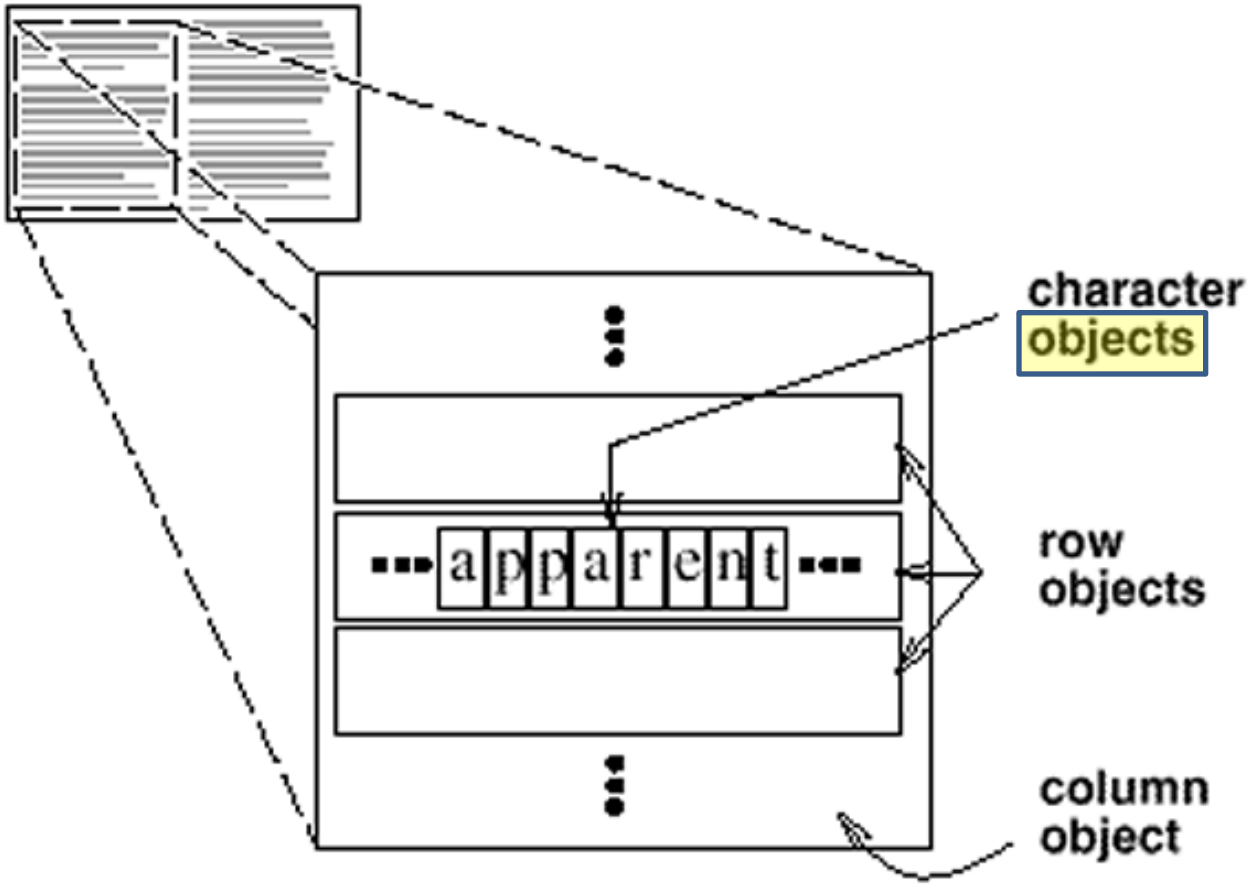
Facade Illustration



Flyweight

- Intent – use sharing to support large numbers of fine-grained objects efficiently
- Use case – characters in a document
- Key types – the Flyweight (instance-controlled!)
  - State can be made *extrinsic* to keep Flyweight sharable
- JDK – Pervasisve! All enums, many others. `j.u.c.TimeUnit` has # units as extrinsic state.

Flyweight Illustration

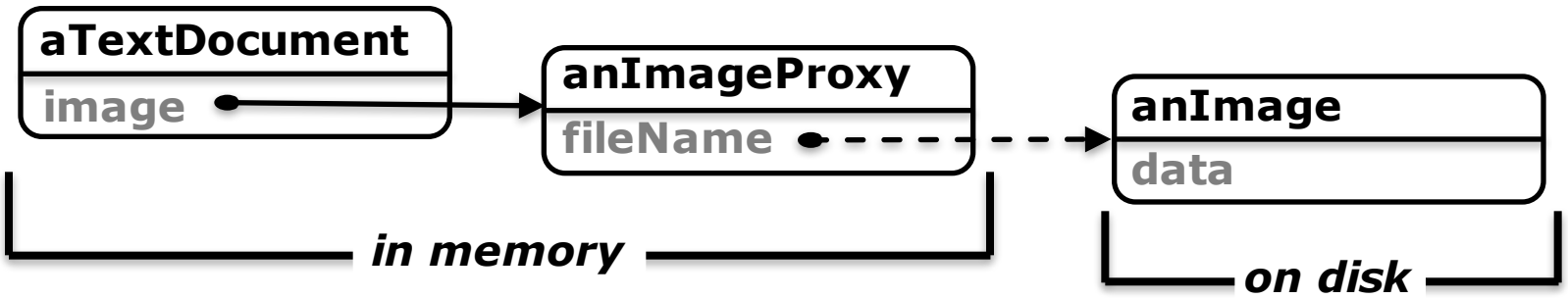


Proxy

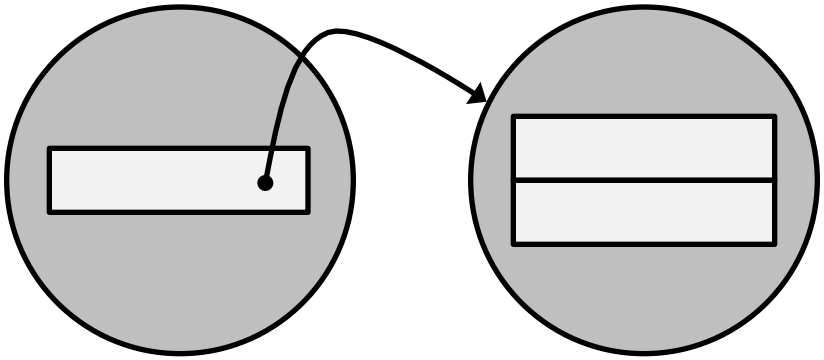
- Intent – surrogate for another object
- Use case – delay loading of images till needed
- Key types – *Subject*, Proxy, RealSubject
- Gof mention several flavors
  - virtual proxy – stand-in that instantiates lazily
  - remote proxy – local representative for remote obj
  - protection proxy – denies some ops to some users
  - smart reference – does locking or ref. counting, e.g.
- JDK – RMI, collections wrappers

Proxy Illustrations

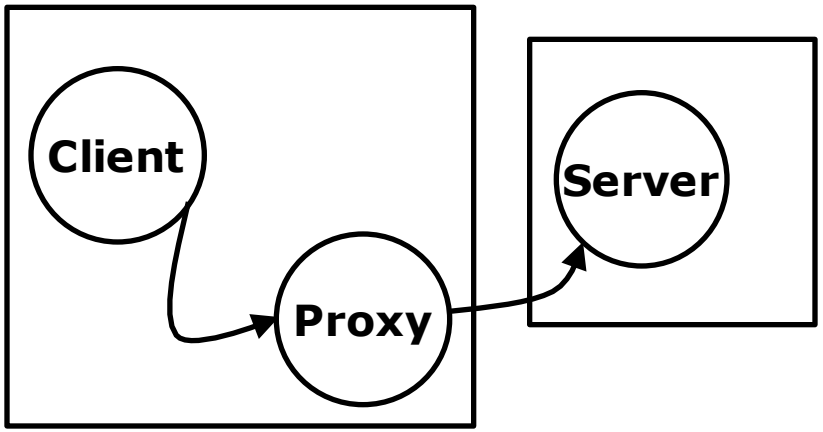
Virtual Proxy



Smart Reference



Remote Proxy



III. Behavioral Patterns

1. Chain of Responsibility
2. Command
3. Interpreter
4. Iterator
5. Mediator
6. Memento
7. Observer
8. State
9. Strategy
10. Template method
11. Visitor

Chain of Responsibility

- Intent – avoid coupling sender to receiver by passing request along until someone handles it
- Use case – context-sensitive help facility
- Key types – *RequestHandler*
- JDK – `Classloader`, `Properties`
- Exception handling could be considered a form of Chain of Responsibility pattern

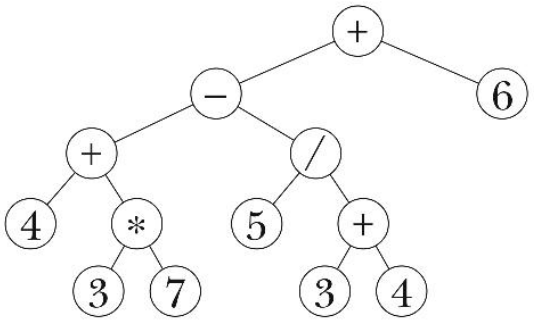
Command

- Intent – encapsulate request as object, letting you parameterize clients with different actions, queue or log requests, etc.
- Use case – menu tree
- Key types – *Command* (an execute method)
- JDK – `Runnable`, executor framework
- Is it Command pattern if you run it more than once? If it takes an argument? Returns a val?

Interpreter

- Intent – Given a language, define class hierarchy for parse tree, recursive method to interpret it
- Use case – regular expression matching
- Key types – *Expression*, *NonterminalExpression*, *TerminalExpression*
- JDK – no uses I'm aware of
  - Our expression evaluator (HW2) is a classic example
- Necessarily uses Composite pattern!

Interpreter Illustration

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public class BinaryOperationExpression implements Expression {
    public BinaryOperationExpression(BinaryOperator operator,
            Expression operand1, Expression operand2);
}
public class NumberExpression implements Expression {
    public NumberExpression(double number);
}
```

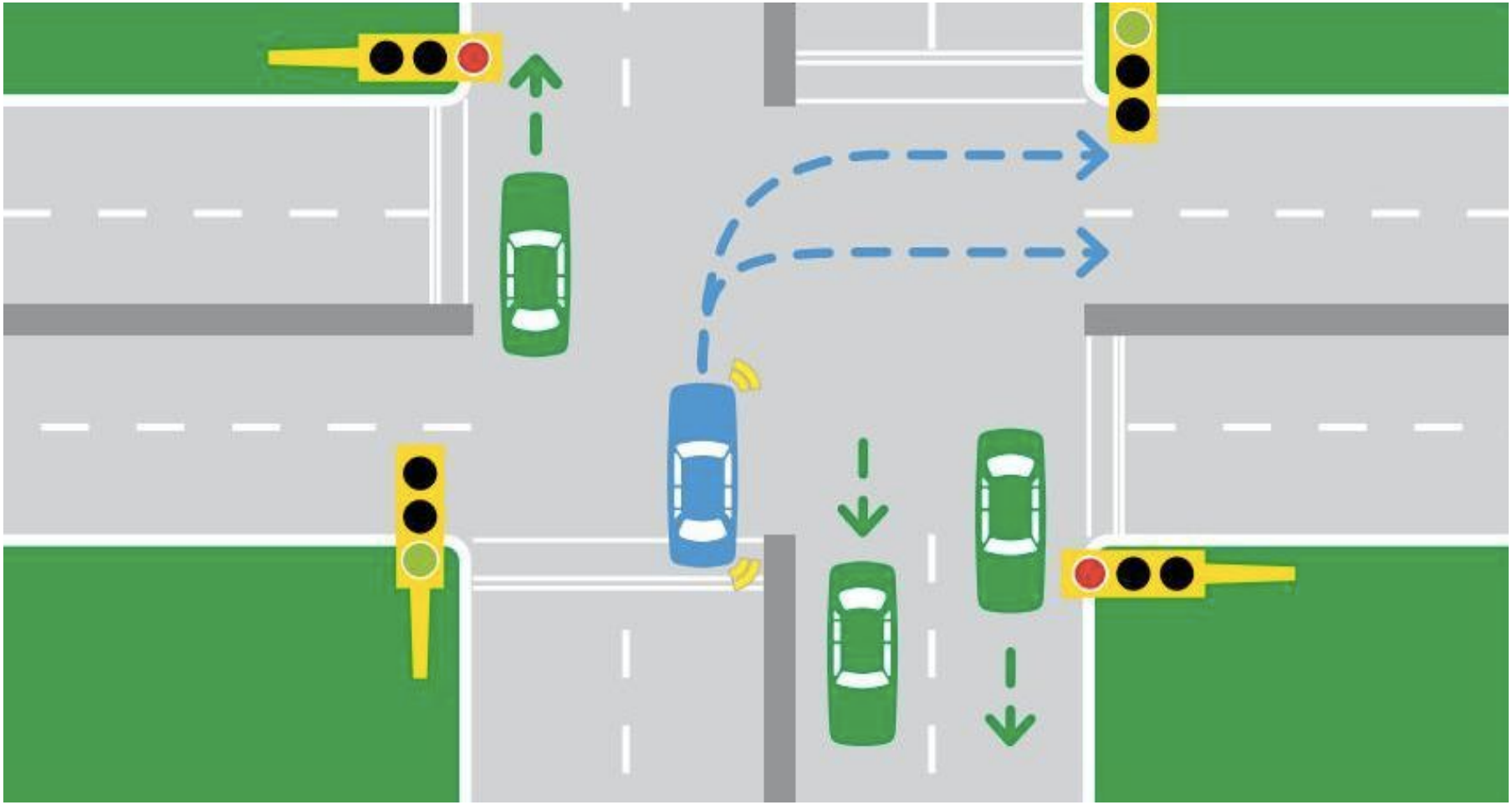
Iterator

- Intent – provide a way to access elements of a collection without exposing representation
- Use case – collections
- Key types – *Iterable*, *Iterator*
  - But GoF recognize internal iteration too
- JDK – Collections, for-each statement, etc.

Mediator

- Intent – Define an object that encapsulate how a set of objects interact to reduce coupling.
  - O(n) couplings instead of O(n!) = O(2^n)
- Use case – dialog box where change in one component affects behavior of others
- Key types – Mediator, components
- JDK – Unclear

Mediator Illustration



Memento

- Intent – Without violating encapsulation, allow client to capture an object's state, and restore
- Use case – undo stack for operations that aren't easily undone, e.g., line-art editor
- Key type – Memento (opaque state object)
- JDK – none that I'm aware of (*not* serialization)

Observer

- Intent – Let objects observe the behavior of other objects so they can stay in sync
- Use case – multiple views of a data object in a GUI
- Key types – *Subject* ("observable"), *Observer*
  - GoF are agnostic on many details!
- JDK – Swing, left and right

State

- Intent – use an object internally to represent the state of another object; delegate method invocations to the state object
- Use case – TCP Connection (which is stateful)
- Key type – *State*
- JDK – none that I'm aware of but
  - Works *great* in Java
  - Use enums as states
  - Use `AtomicReference<State>` to store it

Strategy

- Intent – represent a behavior that parameterizes an algorithm for behavior or performance
- Use case – line-breaking for text compositing
- Key types – *Strategy*
- JDK – `Comparator`

Template method

- Intent – define skeleton of an algorithm or data structure, deferring some decisions to subclasses
- Use case – application framework that lets plugins implement all operations on documents
- Key types – *AbstractClass*, ConcreteClass
- JDK – Skeletal collection impls (e.g., AbstractList)
- Note – template method is dual to strategy, you can mechanically convert one to the other

Template Method Illustration

```
// List adapter for primitive int arrays
public static List<Integer> intArrayList(final int[] a) {
    return new AbstractList<Integer>() {
        public Integer get(int i) {
            return a[i];
        }

        public Integer set(int i, Integer val) {
            Integer oldVal = a[i];
            a[i] = val;
            return oldVal;
        }

        public int size() {
            return a.length;
        }
    };
}
```

Visitor

- Intent – Represent an operation to be performed on elements of an object structure (e.g., a parse tree). Visitor lets you define a new operation without modifying the type hierarchy.
- Use case – type-checking, pretty-printing, etc.
- Key types – *Visitor*, ConcreteVisitor, all the types that get visited
- JDK – None that I'm aware of

More on Visitor

- Visitor is NOT merely traversing a graph structure and applying a method
  - That's Iterator
- The essence of visitor is *double-dispatch*
  - First dynamically dispatch on the Visitor
  - Then on the object being visited

Summary

- Now you know all the Gang of Four patterns
- Definitions can be vague
- Coverage is incomplete
- But they're extremely valuable
  - They gave us a vocabulary
  - And a way of thinking about software
- Look for patterns as you read and write software
  - GoF, non-GoF, and undiscovered