CMSC 132:  
Object-Oriented Programming II

Design Patterns I

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Design Patterns

- Descriptions of **reusable** solutions to common software design problems

- Captures the experience of experts
  - Rationale for design
  - Tradeoffs
  - Codifies design in reusable form

- Example
  - Iterator pattern
Goals

- Solve common programming challenges
- Improve reliability of solution
- Aid rapid software development
- Useful for real-world applications
Observations

- Design patterns are like recipes – generic solutions to expected situations
- Design patterns are language independent
- Recognizing when and where to use design patterns requires familiarity & experience
- Design pattern libraries serve as a glossary of idioms for understanding common, but complex solutions
Observations (cont.)

- Many design patterns may need to fit together
  - Design Patterns (by Gamma et al. 1995, a.k.a. Gang of Four, or GOF) list 23 design patterns
  - Around 250 common OO design patterns

- Design patterns are used throughout the Java Class Libraries
Documentation Format

1. Motivation or context for pattern
2. Prerequisites for using a pattern
3. Description of program structure
4. List of participants (classes & objects)
5. Collaborations (interactions) between participants
6. Consequences of using pattern (good & bad)
7. Implementation techniques & issues
8. Example codes
9. Known uses
10. Related patterns
Types of Design Patterns

Creational
- Deal with the best way to create objects

Structural
- Ways to bring together groups of objects

Behavioral
- Ways for objects to communicate & interact
Creational Patterns

1. Abstract Factory - Creates an instance of several families of classes
2. Builder - Separates object construction from its representation
3. Factory Method - Creates an instance of several derived classes
4. Prototype - A fully initialized instance to be copied or cloned
5. Singleton - A class of which only a single instance can exist
Structural Patterns

6. **Adapter** - Match interfaces of different classes
7. **Bridge** - Separates an object’s interface from its implementation
8. **Composite** - A tree structure of simple and composite objects
9. **Decorator** - Add responsibilities to objects dynamically
10. **Façade** - Single class that represents an entire subsystem
11. **Flyweight** - Fine-grained instance used for efficient sharing
12. **Proxy** - Object representing another object
Behavioral Patterns

13. Chain of Responsibility - A way of passing a request between a chain of objects
14. Command - Encapsulate a command request as an object
15. Interpreter - A way to include language elements in a program
16. Iterator - Sequentially access the elements of a collection
17. Mediator - Defines simplified communication between classes
18. Memento - Capture and restore an object's internal state
Behavioral Patterns (cont.)

19. **Observer** - A way of notifying change to a number of classes

20. **State** - Alter an object's behavior when its state changes

21. **Strategy** - Encapsulates an algorithm inside a class

22. **Template Method** - Defer the exact steps of an algorithm to a subclass

23. **Visitor** - Defines a new operation to a class without changing class
Iterator Pattern

Definition
- Move through collection of objects without knowing its internal representation

Where to use & benefits
- Use a standard interface to represent data objects
- Uses standard iterator built in each standard collection, like List, Sort, or Map
- Need to distinguish variations in the traversal of an aggregate
**Iterator Pattern**

**Example**

- **Iterator for collection**

- **Original**

  - Examine elements of collection directly

- **Using pattern**

  - Collection provides Iterator class for examining elements in collection
public interface Iterator<V> {
    boolean hasNext();
    V next();
}

Iterator<V> it = myCollection.iterator();

while (it.hasNext()) {
    V x = it.next(); // finds all objects
    ... // in collection
}
Singleton Pattern

**Definition**
- One instance of a class or value accessible globally

**Where to use & benefits**
- Ensure unique instance by defining class final
- Access to the instance only via methods provided
Singleton Example

public class Employee {
    public static final int ID = 1234;  // ID is a singleton
}

public final class MySingleton {
    // declare the unique instance of the class
    private static MySingleton uniq = new MySingleton();
    // private constructor only accessed from this class
    private MySingleton() { … }
    // return reference to unique instance of class
    public static MySingleton getInstance() {
        return uniq;
    }
}


Adapter Pattern

Definition

- Convert existing interfaces to new interface

Where to use & benefits

- Help match an interface
- Make unrelated classes work together
- Increase transparency of classes
Adapter Pattern

Example

- Adapter from integer Set to integer Priority Queue
- Original
  - Integer set does not support Priority Queue
- Using pattern
  - Adapter provides interface for using Set as Priority Queue
  - Add needed functionality in Adapter methods
Adapter Example

```java
public interface PriorityQueue {  // Priority Queue
    void add(Object o);
    int size();
    Object removeSmallest();
}
```
public class PriorityQueueAdapter implements PriorityQueue {
    Set s;
    PriorityQueueAdapter(Set s) { this.s = s; }
    public void add(Object o) { s.add(o); }
    int size() { return s.size(); }
    public Integer removeSmallest() {
        Integer smallest = Integer.MAX_VALUE;
        for (Integer i : s) {
            if (i.compareTo(smallest) < 0) {
                smallest = i;
            }
        }
        s.remove(smallest);
        return smallest;
    }
}
Factory Pattern

Definition
- Provides an abstraction for deciding which class should be instantiated based on parameters given

Where to use & benefits
- A class cannot anticipate which subclasses must be created
- Separate a family of objects using shared interface
- Hide concrete classes from the client
Factory Pattern

Example

- Car Factory produces different Car objects

Original

- Different classes implement Car interface
- Directly instantiate car objects
- Need to modify client to change cars

Using pattern

- Use carFactory class to produce car objects
- Can change cars by changing carFactory
Factory Example

class Ferrari implements Car;  // fast car
class Bentley implements Car;   // antique car
class Explorer implements Car;  // family SUV
Car fast = new Ferrari();      // returns fast car

public class carFactory {
    public static Car create(String type) {
        if (type.equals("fast")) return new Ferrari();
        if (type.equals("antique")) return new Bentley();
        else if (type.equals("family")) return new Explorer();
    }
}

Car fast = carFactory.create("fast");  // returns fast car
Decorator Pattern

Definition

- Attach additional responsibilities or functions to an object dynamically or statically

Where to use & benefits

- Provide flexible alternative to subclassing
- Add new function to an object without affecting other objects
- Make responsibilities easily added and removed dynamically & transparently to the object
Decorator Pattern

Example

- Pizza Decorator adds toppings to Pizza
- Original
  - Pizza subclasses
  - Combinatorial explosion in # of subclasses
- Using pattern
  - Pizza decorator classes add toppings to Pizza objects dynamically
  - Can create different combinations of toppings without modifying Pizza class
public interface Pizza {
    int cost();
}

public class SmallPizza implements Pizza {
    int cost() { return 8; }
}

public class LargePizza implements Pizza {
    int cost() { return 12; }
}

public class PizzaDecorator implements Pizza {
    Pizza p;
    PizzaDecorator (Pizza p) { this.p = p; }
    int cost() { return p.cost(); }
}
Decorator Example

```java
public class withOlive extends PizzaDecorator {
    int cost() { return p.cost() + 2; }
}

public class withHam extends PizzaDecorator {
    int cost() { return p.cost() + 3; }
}

Pizza HamOlivePizza = new withHam (new withOlive (new LargePizza()));
... = HamOlivePizza.cost(); // returns 12+2+3

Pizza DoubleHamPizza = new withHam (new withHam (new SmallPizza()));
... = DoubleHamPizza.cost(); // returns 8+3+3
```
Decorator Pattern

Examples from Java I/O

- Interface
  - InputStream
- Concrete subclasses
  - FileInputStream, ByteArrayInputStream
- Decorators
  - BufferedInputStream, DataInputStream
- Code
  ```
  InputStream s = new DataInputStream( new BufferedInputStream (new FileInputStream()));
  ```