CMSC 132:
Object-Oriented Programming II

Design Patterns I

Department of Computer Science
University of Maryland, College Park
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
**Iterator Example**

```java
public interface Iterator<V> {
    bool 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
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

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
Decorator Example

```java
class Pizza {
    int cost();
}
class SmallPizza implements Pizza {
    int cost() { return 8; }
}
class LargePizza implements Pizza {
    int cost() { return 12; }
}
class PizzaDecorator implements Pizza {
    private Pizza p;
    public PizzaDecorator(Pizza p) { this.p = p; }
    public int cost() { return p.cost(); }
}
```
Decorator Example

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

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

// Driver
Pizza hamOlivePizza = new WithHam(new WithOlive(new LargePizza()));
System.out.println(hamOlivePizza.cost()); // returns 12 + 2 + 3

Pizza doubleHamPizza = new WithHam(new WithHam(new SmallPizza()));
System.out.println(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()));