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

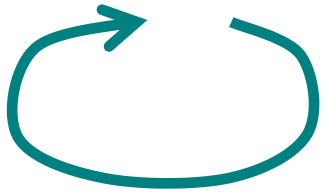
13. **Chain of Responsibility - A way of passing a request between a chain of objects**
14. **Command - Encapsulate a command request as an object**
15. **Interpreter - A way to include language elements in a program**
16. **Iterator - Sequentially access the elements of a collection**
17. **Mediator - 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**

Iterator Example

```
public interface Iterator<V> {
    bool hasNext();
    V next();
    void remove();
}

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

```
public interface PriorityQueue {      // Priority Queue
    void add(Object o);
    int size( );
    Object removeSmallest( );
}
```

Adapter Example

```
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
```



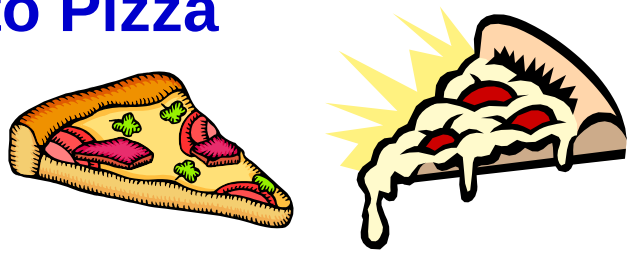
```
public class carFactory {
   public static Car create(String type) {
     if (type.equals("fast"))              return new Ferrari();
     if (type.equals(“antique"))           return new Bentley();
     else if (type.equals(“family”)        return new Explorer();
}   }

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**



Decorator Example

```
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 {
    private Pizza p;
    public PizzaDecorator(Pizza p) {this.p = p;}
    public int cost() { return p.cost(); }
}
```

Decorator Example

```
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()));**