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***

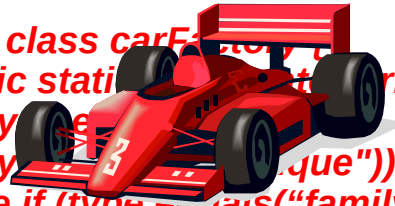
- **Where to use & benefits**
  - ***A class cannot anticipate which subclasses must be created***
  - ***Separate a family of objects using shared interface***
  - ***Hide concrete classes from the client***

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 WithTomato extends PizzaDecorator {
      public WithTomato(Pizza p) { super(p); }
      public int cost() {return super.cost() + 3;}
}
// Driver
Pizza tomatoOlivePizza = new WithTomato(new WithOlive(new LargePizza()));
System.out.println(tomatoOlivePizza.cost());     // returns 12 + 2 + 3

Pizza doubleTomatoPizza = new WithTomato(new WithTomato(new SmallPizza()));
System.out.println(doubleTomatoPizza.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()));