

CMSC 132: Object-Oriented Programming II



Design Patterns I

Department of Computer Science
University of Maryland, College Park

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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

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Goals

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

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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

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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

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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

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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

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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

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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. **Facade** - Single class that represents an entire subsystem
11. **Flyweight** - Fine-grained instance used for efficient sharing
12. **Proxy** - Object representing another object

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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

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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

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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



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Iterator Pattern

- **Example**
 - Iterator for collection
 - Original
 - Examine elements of collection directly
 - Using pattern
 - Collection provides Iterator class for examining elements in collection

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Iterator Example

```
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
}
```

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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

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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;
    }
}
```

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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

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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

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Adapter Example

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

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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;
    }
}
```

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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

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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

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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
```

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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

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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



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



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Decorator Example

```
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
```

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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());`

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