

AMSS Lecture 4: Design Patterns (I)

Virgil-Nicolae Șerbănuță

2025

Agenda

1. What are Design Patterns?
2. Classification of Patterns
3. Patterns
 - 3.1 **Iterator**
 - 3.2 **Builder**
 - 3.3 **Singleton**
 - 3.4 **Observer**
 - 3.5 **Factory Method**
 - 3.6 **State**
4. Wrap-up

THE LIFE OF A SOFTWARE ENGINEER.

CLEAN SLATE. SOLID
FOUNDATIONS. THIS TIME
I WILL BUILD THINGS THE
RIGHT WAY.



THE LIFE OF A SOFTWARE
ENGINEER.

CLEAN SLATE. SOLID
FOUNDATIONS. THIS TIME
I WILL BUILD THINGS THE
RIGHT WAY.



MUCH LATER...

OH MY. I'VE
DONE IT AGAIN,
HAVEN'T I?



What Are Design Patterns?

Definition

Reusable solutions to common software design problems.

Origin

Popularized by the “Gang of Four” (Gamma, Helm, Johnson, Vlissides, 1994).

Purpose

- ▶ Provide shared vocabulary
- ▶ Improve code maintainability
- ▶ Promote reusability and clarity

Example

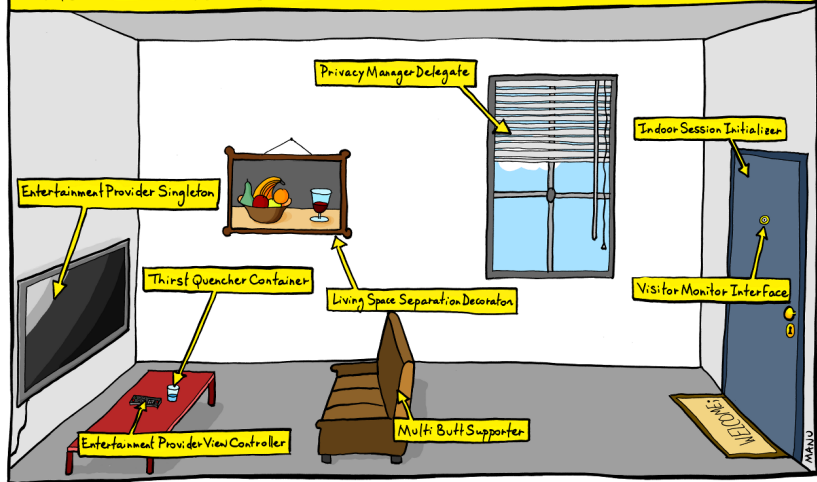
Instead of reinventing how to traverse a collection, we apply the **Iterator** pattern.

Pattern Classification

Design patterns are typically grouped into three main categories:

| Category | Description | Example Patterns |
|-------------------|--------------------------------------|------------------------------------|
| Creational | How objects are created | Singleton, Builder, Factory Method |
| Structural | How classes and objects are composed | Adapter, Bridge, Decorator |
| Behavioral | How objects interact and communicate | Iterator, Observer, State |

THE WORLD SEEN BY AN "OBJECT-ORIENTED" PROGRAMMER.



Iterator Pattern

Type

Behavioral pattern

Intent

Provide a way to access elements of a collection sequentially without exposing its internal structure.

Problem Solved

How to traverse a collection (e.g., list, tree, array) without knowing its implementation?

Solution

Define an `Iterator` interface with methods like `hasNext()` and `next()`.

Iterator Pattern code example

Source file

```
// Step 1: Create the Iterator interface
```

```
interface Iterator {  
    boolean hasNext();  
    Object next();  
}
```

```
// Step 2: Create the Container interface
```

```
interface Container {  
    Iterator getIterator();  
}
```

```
// Step 3: Create a concrete class implementing Container
```

```
class NameRepository implements Container {  
    private String[] names = {"Alice", "Bob", "Charlie", "I"}  
  
    @Override  
    public Iterator getIterator() {
```

Iterator Pattern Exercise

Exercise

Modify 3 lines in the example above to make the iterator a reverse iterator.

Question

How does this custom Iterator differ from Java's built-in `java.util.Iterator`, and when might you still implement your own?

Builder Pattern

Type

Creational pattern

Intent

Separate the construction of a complex object from its representation, so the same construction process can create different representations.

Problem Solved

How can we construct complex objects step by step while keeping the construction logic separate from the representation?

Solution

Use a *Builder* class to encapsulate object creation in multiple steps.

Builder Pattern (concrete example)

Design a Computer class that represents a configurable computer system. The goal is to let users “build” a computer step-by-step, choosing which components to include. A computer may include:

- ▶ CPU (e.g., “Intel i9”, “AMD Ryzen 7”)
- ▶ GPU (e.g., “NVIDIA RTX 4090”, “AMD Radeon RX 7800”)
- ▶ RAM (in GB)
- ▶ Storage (in GB)

You should be able to build objects fluently, like this:

```
Computer gamingPC = new Computer.Builder()  
    .setCPU("Intel i9")  
    .setGPU("NVIDIA RTX 4090")  
    .setRAM(32)  
    .setStorage(2000)  
    .build();  
System.out.println(gamingPC);
```

Builder Pattern (concrete example solution)

Source file

```
// Product class
```

```
class Computer {  
    private String CPU;  
    private String GPU;  
    private int RAM;  
    private int storage;
```

```
// Private constructor - use Builder instead
```

```
private Computer(Builder builder) {  
    this.CPU = builder.CPU;  
    this.GPU = builder.GPU;  
    this.RAM = builder.RAM;  
    this.storage = builder.storage;  
}
```

```
@Override
```

```
public String toString() {
```

Bulder Pattern exercise

Design a Pizza class that represents a customizable pizza order, using the Builder Pattern. Your pizza should have:

- ▶ A size (e.g., Small, Medium, Large)
- ▶ A crust type (e.g., Thin, Thick, Stuffed)
- ▶ A list of toppings (e.g., Cheese, Pepperoni, Mushrooms)
- ▶ A flag for extra cheese

The goal is to make object creation flexible and readable, like this:

```
Pizza pizza = new Pizza.Builder()  
    .setSize("Large")  
    .setCrust("Stuffed")  
    .addTopping("Pepperoni")  
    .addTopping("Mushrooms")  
    .setExtraCheese(true)  
    .build();  
System.out.println(pizza);
```

Singleton Pattern

Type

Creational pattern

Intent

Ensure a class has only one instance, and provide a global point of access to it.

Problem Solved

How can we make sure there is exactly one instance of a class used throughout a system?

Solution

- ▶ Make the constructor private
- ▶ Store a static instance reference
- ▶ Provide a static accessor

Singleton Pattern (concrete example)

Implement a `DatabaseConnection` class that simulates a single, shared connection to a database.

The program should ensure that:

- ▶ Only one instance of the connection is ever created.
- ▶ Any part of the program that requests a connection gets the same instance.

Example use

```
DatabaseConnection conn1 = DatabaseConnection.getInstance();
```

```
DatabaseConnection conn2 = DatabaseConnection.getInstance();
```

```
conn1.query("SELECT * FROM users");
```

```
System.out.println(conn1 == conn2); // should print true
```


Singleton Pattern (concrete example solution)

Source file

```
// Singleton class
```

```
class DatabaseConnection {  
    // Step 1: Create a private static instance of the class  
    private static DatabaseConnection instance;  
  
    // Step 2: Make the constructor private to prevent instantiation  
    private DatabaseConnection() {  
        System.out.println("Connecting to the database...")  
    }  
  
    // Step 3: Provide a public static method to get the singleton instance  
    public static DatabaseConnection getInstance() {  
        if (instance == null) {  
            instance = new DatabaseConnection();  
        }  
        return instance;  
    }  
}
```

Singleton Pattern exercise

Implement a Logger for a simple application. Only one instance of this class should ever exist, and all parts of the program should share it.

Example use

```
Logger logger1 = Logger.getInstance();
```

```
Logger logger2 = Logger.getInstance();
```

```
logger1.log("Starting the app...");
```

```
logger2.log("App is running.");
```

```
// Both should refer to the same instance
```

```
System.out.println(logger1 == logger2); // true
```

Expected output

```
Logger initialized.
```

```
[LOG]: Starting the app...
```

```
[LOG]: App is running.
```

```
true
```

Observer Pattern

Type

Behavioral pattern

Intent

Define a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically.

Problem Solved

How can objects stay in sync without tight coupling between them?

Solution

Introduce a *Subject* that maintains a list of *Observers*; when the Subject changes, it notifies all Observers.

Observer Pattern (concrete example)

Imagine we are building a **Weather Station** system that needs to update several displays (temperature, humidity, forecast) whenever new weather data is available.

Your task is to design the update mechanism between the Weather Station (subject) and its displays (observers).

Observer Pattern (concrete example solution)

Source file

```
import java.util.*;

interface Observer {
    void update(float temperature);
}

interface Subject {
    void attach(Observer o);
    void detach(Observer o);
    void notifyObservers();
}

class WeatherStation implements Subject {
    private List<Observer> observers = new ArrayList<>();
    private float temperature;

    public void attach(Observer o) {
```

Observer Pattern Exercise

Create a simplified Chat Room system. The ChatRoom (the *Subject*) notifies all registered Users (the *Observers*) whenever a new message is sent.

Example use:

```
ChatRoom room = new ChatRoom("Design Patterns");
```

```
User alice = new User("Alice");
```

```
User bob = new User("Bob");
```

```
User charlie = new User("Charlie");
```

```
room.join(alice);
```

```
room.join(bob);
```

```
room.join(charlie);
```

```
room.sendMessage("Alice", "Hey everyone!");
```

```
room.sendMessage("Bob", "Hi Alice!");
```

Observer Pattern Exercise (expected output)

[Alice] says: Hey everyone!

[Notification to Bob] New message in Design Patterns: Alice says
"Hey everyone!"

[Notification to Charlie] New message in Design Patterns: Alice says
"Hey everyone!"

[Bob] says: Hi Alice!

[Notification to Alice] New message in Design Patterns: Bob says
"Hi Alice!"

[Notification to Charlie] New message in Design Patterns: Bob says
"Hi Alice!"

Factory Method Pattern

Type

Creational pattern

Intent

Define an interface for creating an object, but let subclasses decide which class to instantiate.

Problem Solved

How can we delegate the instantiation of related objects without hardcoding specific classes?

Solution

Create a factory interface that defines a method for object creation, implemented by concrete subclasses.

Factory Method Pattern (concrete example)

We need to build a system for creating different types of **documents** (e.g., PDF, Word). Each document has its own creation process, but they share a common interface.

Provide a flexible design to handle this.

Factory Method Pattern (concrete example solution)

Source file

```
abstract class Document {
    public abstract void open();
}

class PDFDocument extends Document {
    public void open() {
        System.out.println("Opening PDF Document");
    }
}

class WordDocument extends Document {
    public void open() {
        System.out.println("Opening Word Document");
    }
}

abstract class Application {
```

Factory Method Pattern Exercise

Implement a **Shape Factory** that can create different kinds of shapes — such as *Circle*, *Rectangle*, and *Square* — based on a given input. The main program should be able to request shapes without knowing their exact classes.

Example use

```
ShapeFactory factory = new ShapeFactory();
```

```
Shape shape1 = factory.getShape("CIRCLE");  
shape1.draw();
```

```
Shape shape2 = factory.getShape("RECTANGLE");  
shape2.draw();
```

Expected output

Drawing a Circle

Drawing a Rectangle

State Pattern

Type

Behavioral pattern

Intent

Allow an object to alter its behavior when its internal state changes. The object will appear to change its class.

Problem Solved

How can we manage an object's behavior that depends on its current state, without long if/else or switch statements?

Solution

Encapsulate state-specific behavior into separate classes and delegate state handling to them.

State Pattern (concrete example)

We're building a **Media Player** that behaves differently depending on whether it's in the *Playing*, *Paused*, or *Stopped* state.

Design the system so that transitions between states change the behavior dynamically.

State Pattern (concrete example solution)

Source file

```
interface State {  
    void play(Player player);  
    void pause(Player player);  
    void stop(Player player);  
}  
  
class PlayingState implements State {  
    public void play(Player player) {  
        System.out.println("Already playing");  
    }  
    public void pause(Player player) {  
        System.out.println("Pausing playback");  
        player.setState(new PausedState());  
    }  
    public void stop(Player player) {  
        System.out.println("Stopping playback");  
        player.setState(new StoppedState());  
    }  
}
```

State Pattern exercise

Implement a Vending Machine that sells a single type of item (e.g., a soda). The machine's behavior depends on its current state:

- ▶ When no coin is inserted, you can't buy anything.
- ▶ When a coin is inserted, you can choose to dispense the item or cancel.
- ▶ When dispensing, it delivers the item and returns to waiting for a new coin.

The vending machine will have three states:

- ▶ NoCoinState – waiting for a coin
- ▶ HasCoinState – coin inserted, waiting for user to select item
- ▶ DispensingState – vending the item

State Pattern exercise (example use)

```
VendingMachine machine = new VendingMachine();  
  
machine.insertCoin();  
machine.pressButton();  
machine.insertCoin();  
machine.returnCoin();  
machine.pressButton();
```

Expected output

```
Coin inserted.  
Dispensing item...  
Please take your item.  
Coin inserted.  
Coin returned.  
Insert coin first.
```


Wrap-Up

Key Takeaways

- ▶ Design patterns capture proven design experience.
- ▶ **Iterator** decouples collection traversal from representation
- ▶ **Builder** separates the construction of an object from representation
- ▶ **Singleton** ensures a class has only one, globally accessible, instance
- ▶ **Observer** decouples state change notification.
- ▶ **Factory Method** delegates object creation to subclasses or factories.
- ▶ **State** encapsulates behavior changes without complex conditionals.