Design Pattern

BCS1430

Dr. Ashish Sai

📅 **Week 5 Lecture 1**

💻 **BCS1430.ashish.nl**

📍 **EPD150 MSM Conference Hall**

Structural Design Patterns

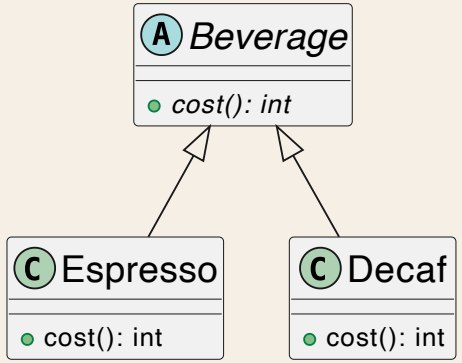
Structural patterns focus on assembling objects and classes into larger structures while maintaining efficiency and flexibility.

All Structural Patterns

Pattern	Description	Covered
Adapter	Allows the interface of an existing class to be used as another interface.	✅
Bridge	Separates an object’s abstraction from its implementation so that they can vary independently.	❌
Composite	Composes objects into tree structures to represent part-whole hierarchies.	❌
Decorator	Attaches additional responsibilities to an object dynamically.	✅
Facade	Provides a unified interface to a set of interfaces in a subsystem.	✅
Flyweight	Uses sharing to support a large number of fine-grained objects efficiently.	❌
Proxy	Provides a surrogate or placeholder for another object to control access to it.	✅

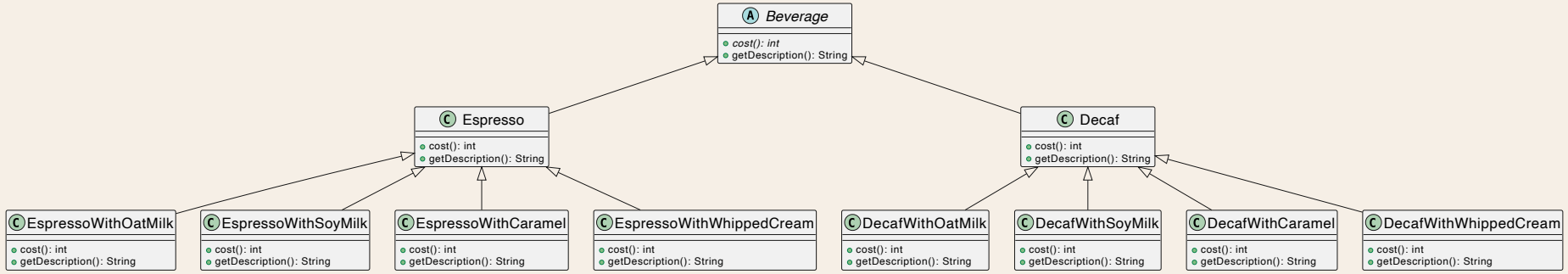
Decorator Pattern

Espresso Yourself Café



- You want to offer an option of add-ons (caramel, soy milk etc)

Oh no!


Beverage
cost(): int
getDescription(): String
Espresso
cost(): int
getDescription(): String
Decaf
cost(): int
getDescription(): String
EspressoWithOatMilk
cost(): int
getDescription(): String
EspressoWithSoyMilk
cost(): int
getDescription(): String
EspressoWithCaramel
cost(): int
getDescription(): String
EspressoWithWhippedCream
cost(): int
getDescription(): String
DecafWithOatMilk
cost(): int
getDescription(): String
DecafWithSoyMilk
cost(): int
getDescription(): String
DecafWithCaramel
cost(): int
getDescription(): String
DecafWithWhippedCream
cost(): int
getDescription(): String

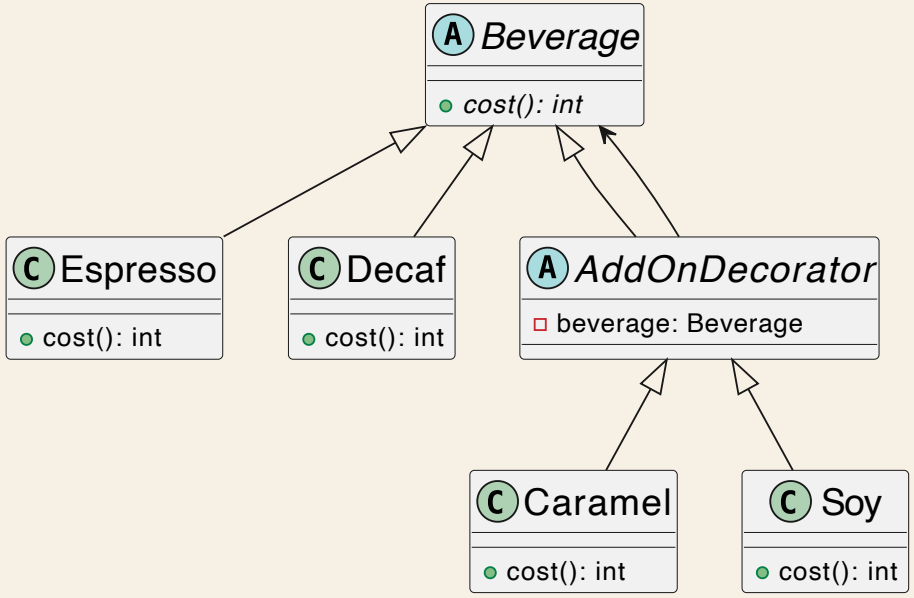
The Problem Statement

- The need to extend the functionality of objects dynamically.
- Avoiding “class explosion” for similar yet distinct objects.
- Example: Different types of coffee in a coffee house application.

Class Explosion Problem

- Multiple classes for each combination of coffee and add-ons (e.g., Espresso with Caramel, Decaf with Soy, etc.).
- Results in a large, unmanageable number of subclasses.

How to solve it?



Introduction to the Decorator Pattern

- Purpose: Dynamically adds behaviors to objects without modifying their structure.
- Key Concept: Wraps additional behaviors around objects to enhance or modify their functionality.

Decorator Pattern: Intent

- Attach new behaviors to objects dynamically.
- Provide a flexible alternative to subclassing for extending functionality.

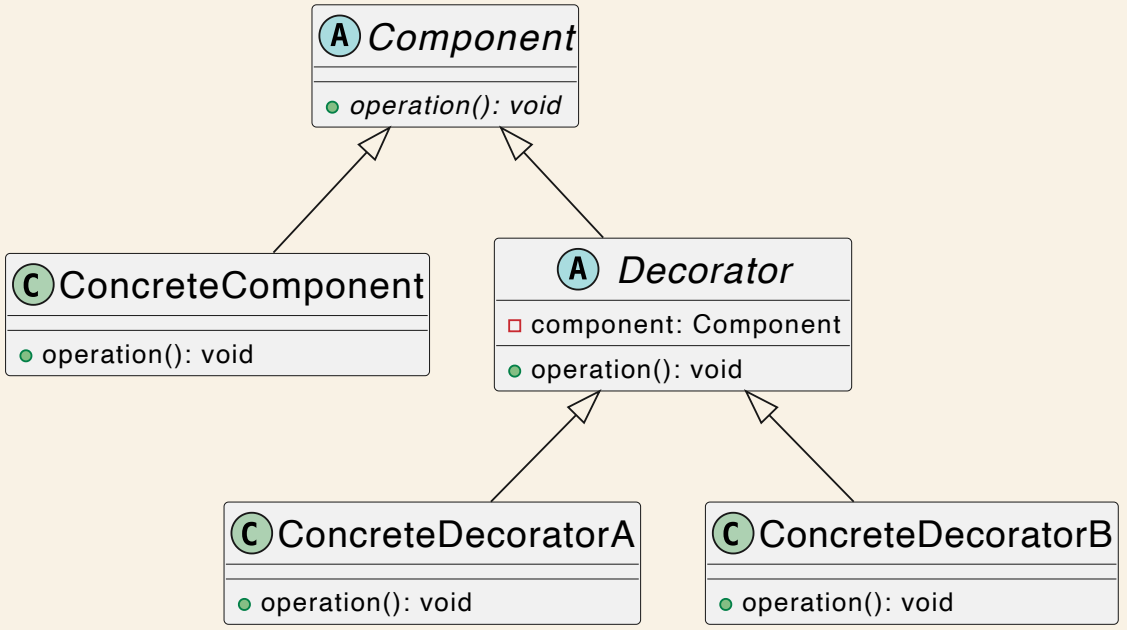
Decorator Pattern: Issues with Subclassing

- Combinatorial explosion of subclasses.
- Inflexibility to combine multiple behaviors dynamically.

How It Works

- Wraps the original object inside objects containing new behaviors.
- Each wrapper (decorator) adds its behavior either before or after delegating to the wrapped object.

Decorator Pattern Structure



Applying Decorator Pattern - Example

- Decorators for each add-on (e.g., caramel, soy milk).

```java
public abstract class Beverage {
    public abstract int cost();
}

public class Espresso extends Beverage {
    public int cost() {
        return 1; // Base cost for Espresso
    }
}

public abstract class AddOnDecorator extends Beverage {
    protected Beverage beverage;
}
```

Concrete Decorators

```java
public class CaramelDecorator extends AddOnDecorator {
    public CaramelDecorator(Beverage beverage) {
        this.beverage = beverage;
    }

    public int cost() {
        return beverage.cost() + 2; // Adding cost of caramel
    }
}

public class SoyDecorator extends AddOnDecorator {
    public SoyDecorator(Beverage beverage) {
        this.beverage = beverage;
    }

    public int cost() {
        return beverage.cost() + 1; // Adding cost of soy
    }
}
```

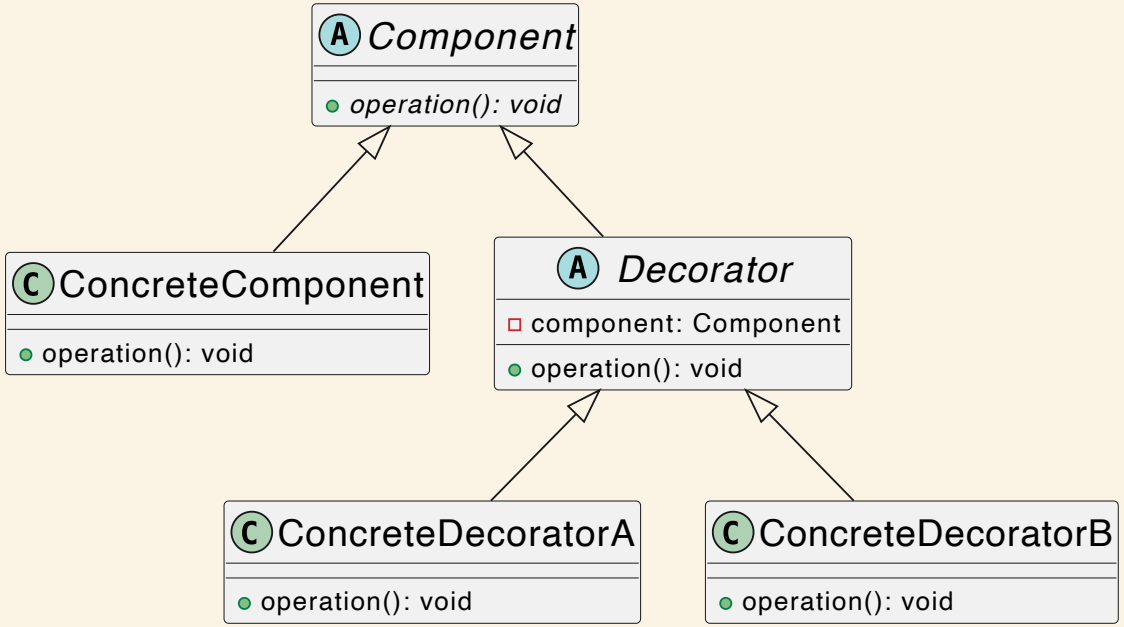
Decorator Pattern in Action

- Creating a coffee with add-ons.
- Calculating the total cost dynamically.

```java
public class CoffeeShop {
    public static void main(String[] args) {
        Beverage beverage = new Espresso();
        beverage = new CaramelDecorator(beverage);
        beverage = new SoyDecorator(beverage);

        System.out.println("Total Cost: " + beverage.cost());
    }
}
```

Decorator Pattern: Decorator Pattern Structure



- **Component:** Common interface for both wrappers and wrapped objects.
- **Concrete Component:** The object being wrapped.
- **Decorator:** Base class for all decorators with a reference to a Component.
- **Concrete Decorators:** Classes that add new behaviors.

Decorator Pattern: Implementing the Decorator Pattern

- Steps for Implementation

1. Define the component interface.
2. Create a concrete component class.
3. Develop a base decorator class.
4. Implement concrete decorators.

Decorator Pattern: Key Considerations

- Ensure all components and decorators implement the component interface.
- Decorators should delegate to the wrapped object and add their behavior.

Another Problem

- You have a different types of data sources (such as Text Files or Database)
- You want to Encrypt the data yous tore or Compress it.

Java Example - Base Component and Decorator

```java
// Component Interface
interface DataSource {
    void writeData(String data);
    String readData();
}

// Concrete Component
class FileDataSource implements DataSource {
    // Implementation details...
}

// Base Decorator
class DataSourceDecorator implements DataSource {
    protected DataSource wrappee;

    DataSourceDecorator(DataSource source) {
        this.wrappee = source;
    }

    public void writeData(String data) {
```

- The base decorator delegates all work to the wrapped component.

Decorator Pattern: Java Example - Concrete Decorators

```java
// Encryption Decorator
class EncryptionDecorator extends DataSourceDecorator {
    EncryptionDecorator(DataSource source) {
        super(source);
    }

    public void writeData(String data) {
        // Encrypt and write data
    }

    public String readData() {
        // Read and decrypt data
        return "decrypted data";
    }
}

// Compression Decorator
class CompressionDecorator extends DataSourceDecorator {
    CompressionDecorator(DataSource source) {
        super(source);
```

- Each decorator adds its behavior either

Decorator Pattern: Using the Decorator Pattern

The Decorator Pattern allows stacking multiple decorators to add several behaviors.

- Dynamic Behavior Addition

```
DataSource basicData = new FileDataSource("data.txt");
DataSource encrypted = new EncryptionDecorator(basicData);
DataSource encryptedCompressed = new CompressionDecorator(encrypted);

// Now 'encryptedCompressed' has both encryption and compression capabilities.
```

- The client code can combine decorators in various configurations at runtime.

Benefits of Decorator Pattern

- Flexibility in adding new functionality.
- Avoids class explosion by using composition over inheritance.
- Easier to maintain and extend.

Limitations of Decorator Pattern

- Can lead to complex code structures.
- Difficulty in debugging, as it introduces layers of abstraction.
- Potential performance issues due to increased object creation.

Decorator Pattern vs Subclassing

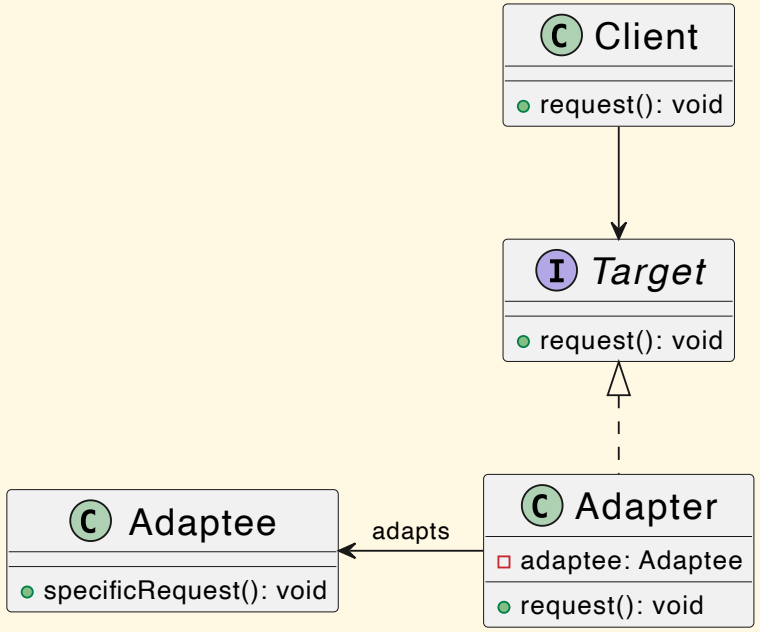
- Decorator Pattern allows for more flexibility than subclassing.
- Avoids rigid class hierarchy.
- Promotes loose coupling and adherence to the Open-Closed Principle.

Adapter Design Pattern

The Adapter Pattern

- Purpose: To make two incompatible interfaces compatible.
- Also known as a “wrapper.”
- Use Case: Connecting new code to legacy code or third-party libraries.

Adapter Pattern UML Diagram



Adapter Pattern Java Example

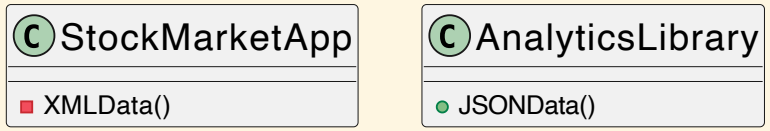
```
1  public class Client {
2    Target target = new Adapter (new Adaptee());
3    target.request();
4  }
5
6  public interface Target {
7    void request();
8  }
9
10 class Adapter implements Target {
11 public Adapter (Adaptee a){
12   this.adaptee = a;
13 }
14 public void request(){
15   this.adaptee.SpecialRequest();
16 }
17
18 }
19
20 class Adaptee {
```

Adapter Pattern: Intent of Adapter Pattern

- The Adapter pattern allows objects with incompatible interfaces to work together.
- It acts as a bridge between two incompatible interfaces, effectively allowing them to communicate.

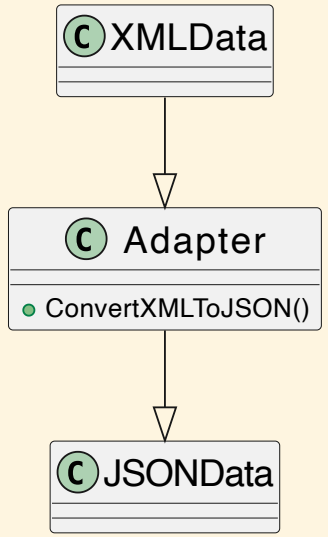
Adapter Pattern: The Problem

- **Scenario:** Stock market monitoring app downloads data in XML.
- **Challenge:** Integration with a 3rd-party analytics library requiring JSON.
- **Problem:** Incompatibility between data formats (XML vs. JSON).



Adapter Pattern: The Solution

Enables collaboration by converting XML interface for Analytics Library compatibility.



Adapter Pattern: Applicability of Adapter Pattern

- **Purpose:** To use an existing class whose interface is incompatible with your code.
- Ideal For:
  - Integrating new classes with old ones.
  - Working with 3rd-party libraries.

Adapter Pattern: Pros and Cons

Pros:

- Single Responsibility Principle: Separates the interface conversion code from the primary business logic.
- Open/Closed Principle: Allows introducing new types of adapters without breaking existing client code.

Cons:

- Increases overall complexity due to the introduction of new interfaces and classes.

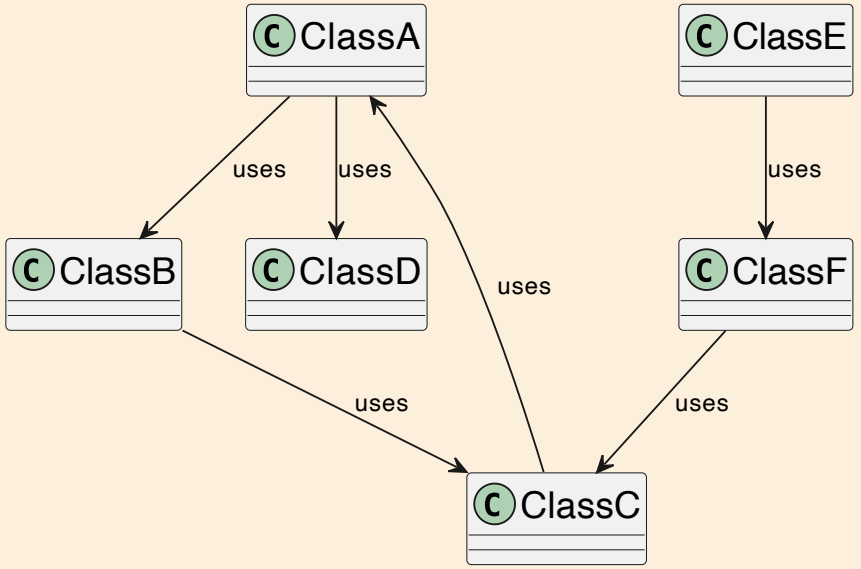
The Facade Pattern

The Facade Pattern - Overview

- **Definition:** Simplifies complex system interactions
- **Purpose:** Provide a unified interface to a set of interfaces in a subsystem
- **Key Principle:** High-level abstraction over complex subsystems
- Example: Starting a car (Key Turn → Engine Start, Lights On, etc.)

Understanding System Complexity

- Multiple classes with intricate interactions
- **Challenge:** Managing complex dependencies and interactions



The Client's Perspective

- **Client:** User of a piece of code, not end-user
- **Problem:** Need to interact with complex subsystems

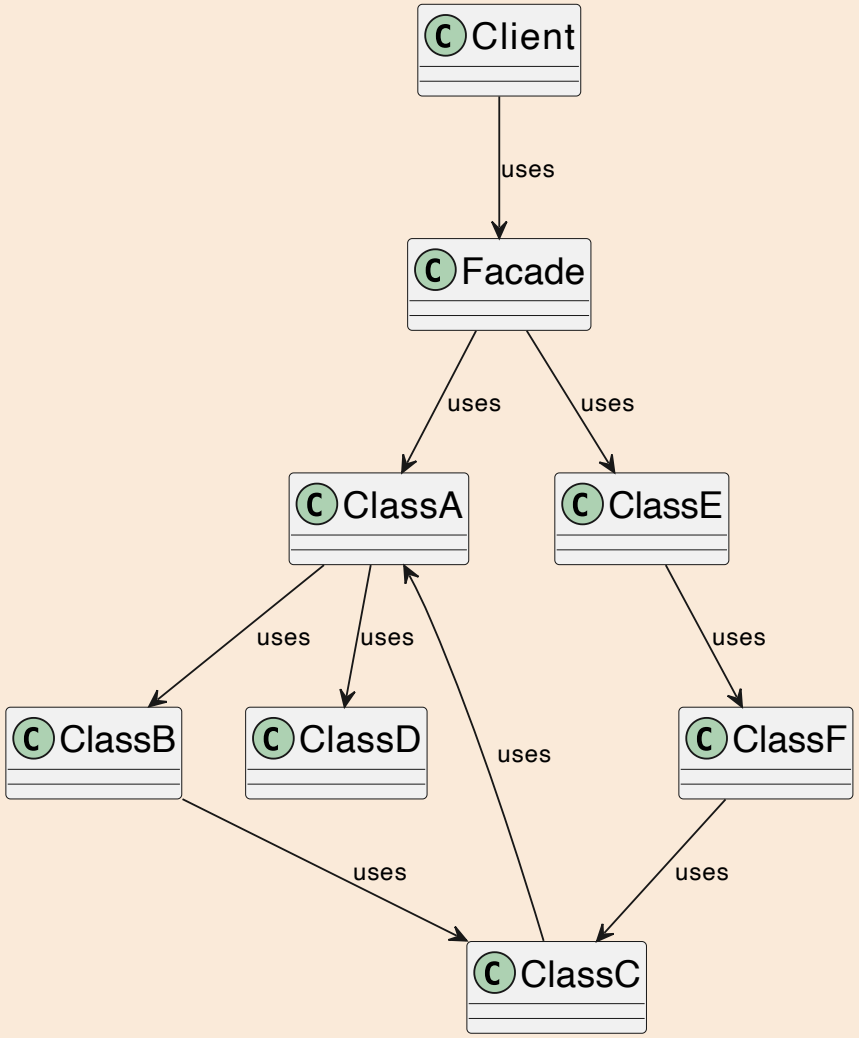
The Need for the Facade Pattern

- **Complexity:** High due to multiple, interdependent classes
- **Solution:** Simplify interaction using a facade

Facade Pattern: Real-World Analogy

Consider an operator in a shop as a facade. They provide you with a simple interface to various services and departments of the shop, hiding the complexities of the subsystems behind the scenes.

Facade Pattern



Facade Pattern Java Example

```java
// Facade Class
public class CarEngineFacade {
    private Ignition ignition;
    private FuelInjector fuelInjector;
    private AirFlowController airFlowController;

    public CarEngineFacade() {
        ignition = new Ignition();
        fuelInjector = new FuelInjector();
        airFlowController = new AirFlowController();
    }

    public void startEngine() {
        fuelInjector.on();
        airFlowController.takeAir();
        ignition.ignite();
        // Other complex interactions
    }

    public void stopEngine() {
```

Advantages of Facade Pattern

- **Simplicity:** Provides simple interface to complex subsystems
- **Decoupling:** Clients interact with facade rather than direct subsystem
- **Maintainability:** Changes in subsystems less likely to affect clients

Facade Pattern: Relations with Other Patterns

- **Adapter vs. Facade:** Adapter wraps one object, while Facade works with an entire subsystem of objects.
- **Facade and Singleton:** Often, a single facade object is sufficient, making it a good candidate for a Singleton.

Proxy Pattern

Introduction to Proxy Pattern

- Provides a surrogate or placeholder for another object.
- Controls access to the original object.
- Use cases: Security, Remote Object Access etc.

Intent of Proxy Pattern

- Purpose: Acts as a substitute to control access to another object.
- Use Cases: Ideal for scenarios needing object access management without changing the object’s behavior.

Proxy Pattern: Real-World Analogy

A real-world analogy for the Proxy pattern is a credit card acting as a proxy for a bank account, which in turn is a proxy for a bundle of cash. Both provide a means for payment but with additional layers of control and convenience.

Types of Proxy Patterns

1. **Remote Proxy:** Facilitates access to objects located in different address spaces.
2. **Virtual Proxy:** Delays the creation and initialization of expensive objects until needed.
3. **Protection Proxy:** Controls access to an object based on access rights.

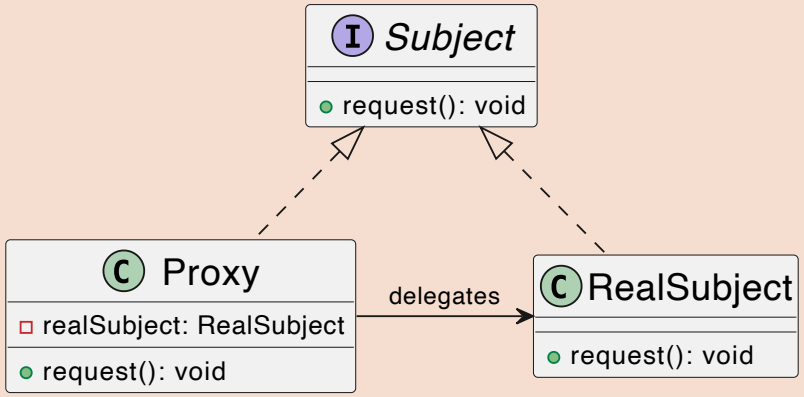
The Problem

- Access management for resource-intensive objects or services.
- Security assurance complexities.
- Simplification of remote service access.

The Solution

- Act as an intermediary for controlling access.
- Add Abstraction: Provides a layer to handle security, manage initialization, and simplify remote access.

Proxy Pattern UML Diagram



Implementation Examples (Virtual Proxy)

```java
public interface Image {
    void display();
}
public class RealImage implements Image {
    private String fileName;
    public RealImage(String fileName) {
        this.fileName = fileName;
        loadFromDisk(fileName);
    }
    @Override
    public void display() {
        System.out.println("Displaying " + fileName);
    }
    private void loadFromDisk(String fileName) {
        System.out.println("Loading " + fileName);
    }
}

public class ProxyImage implements Image {
    private RealImage realImage;
```

Protection Proxy Example in Java

```java
public interface SecureResource {
    void accessResource();
}
public class RealResource implements SecureResource {
    @Override
    public void accessResource() {
        System.out.println("Accessing Secure Resource");
    }
}
public class SecurityProxy implements SecureResource {
    private RealResource realResource;
    private boolean hasAccess;
    public SecurityProxy(boolean hasAccess) {
        this.hasAccess = hasAccess;
        this.realResource = new RealResource();
    }
    @Override
    public void accessResource() {
        if (hasAccess) {
            realResource.accessResource();
```

Applicability of Proxy Pattern

The Proxy Pattern is highly versatile, applicable in situations requiring:

- Lazy initialization (Virtual Proxy)
- Access control (Protection Proxy)
- Remote object access (Remote Proxy)
- Other use cases like logging, caching, or auditing access

Proxy Pattern: Pros and Cons

Pros:

- Control the service object indirectly.
- Manage the lifecycle and initialization of the service.
- Introduce new proxies without changing the service or clients.

Cons:

- Can complicate the code structure with additional classes.
- May introduce latency in the response from the service.

See you tomorrow!