Design Patterns

- Design Patterns are typical reusable solutions to commonly occurring problems in software design.
- Design Patterns are not finished code but templates or blueprints only that we can customize to solve a recurring design problem in our code.
- The pattern is not a specific piece of code, but a general concept for solving a particular problem. We can follow the pattern details & implement a solution that suits the realities of our own program.

Design Pattern Vs Algorithm

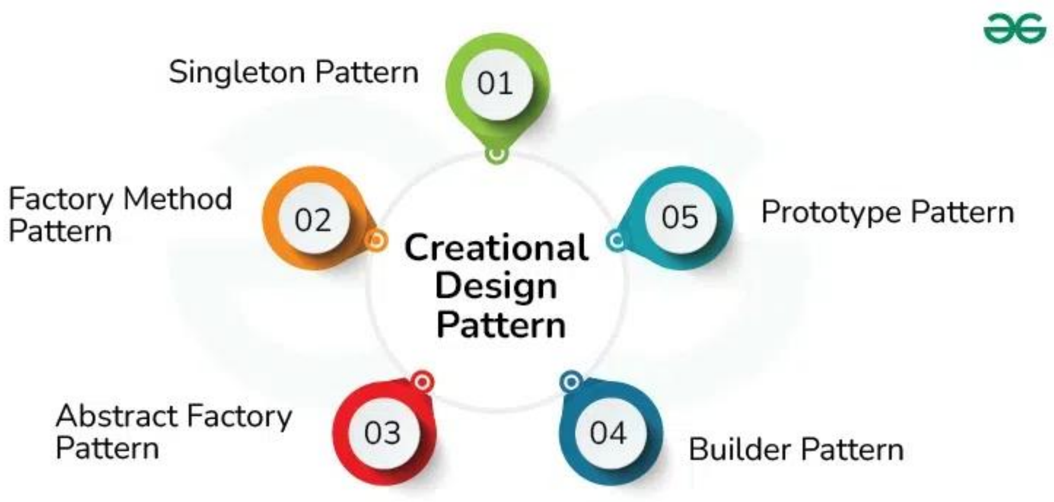
- Both concepts describe typical solutions to some known problems.
- An Algorithm always defines a clear set of actions that can achieve some goal.
- While a Pattern is more high-level description of a solution.

Classification of Patterns

- Design Patterns differ by their complexity, level of detail & scale of applicability to the entire system being designed.
- For e.g., Road Construction – We can make an intersection safer by either installing some traffic lights or building an entire multi-level interchange with underground passages for pedestrians.
- The most basic & low-level patterns are often called **Idioms**. They usually apply only to a single programming language.
- The most universal & high-level patterns are Architectural patterns. Developers can implement these patterns in virtually any language. Unlike other patterns, they can be used to design the architecture of an entire application.

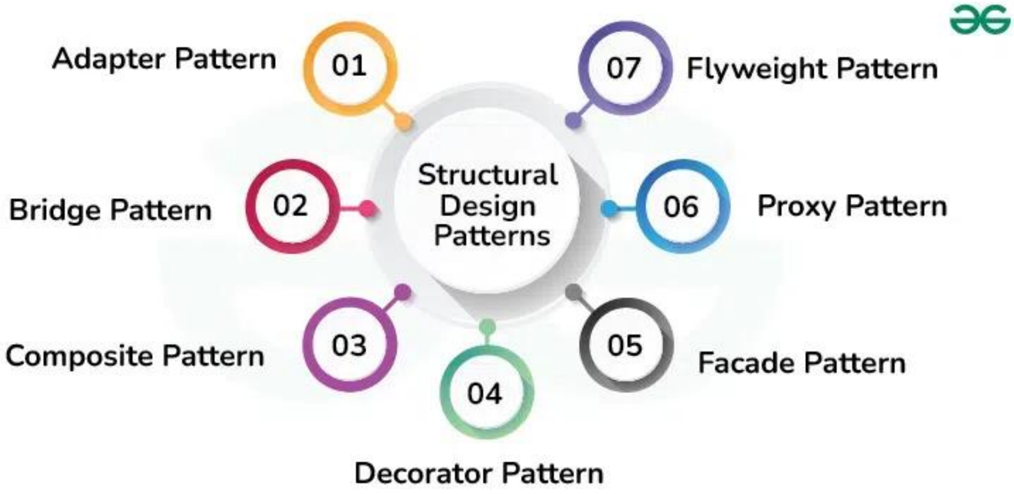
1. Creational Patterns

- They provide object creation mechanisms that increase flexibility & reuse of existing code.
- **Creational Design Patterns** focus on the process of object creation or problems related to object creation. They help in making a system independent of how its objects are created, composed & represented.



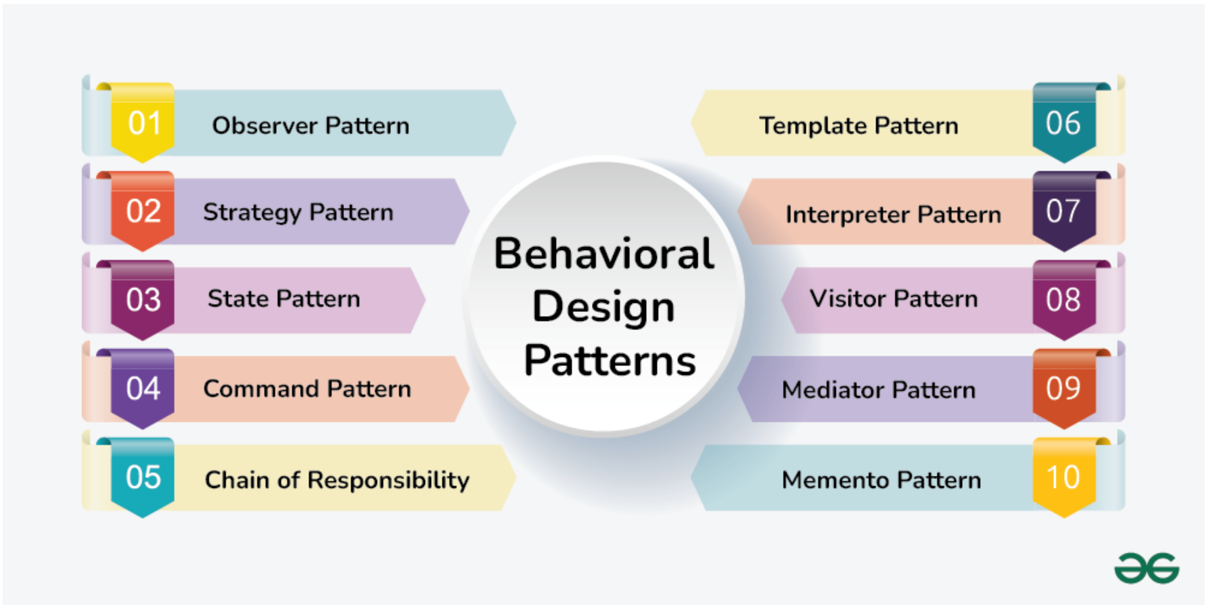
2. Structural Patterns

- They explain how to assemble objects & classes into larger structures, while keeping these structure flexible & efficient.
- Structural Design Patterns solves problems related to how classes & objects are composed/assembled to form larger structures which are efficient & flexible in nature.
- They use inheritance to compose interfaces or implementations.



3. Behavioral Patterns

- They take care of effective communication & the assignment of responsibilities b/w objects.
- Behavioral Design Patterns are concerned with algorithms & the assignment of responsibilities b/w objects.
- They describe not just patterns of objects or classes but also the patterns of communication b/w them.
- These patterns characterize complex control flow that's difficult to follow at run-time.



Creational Design Patterns

1. Factory Method Design Pattern

- Factory method design pattern provides an interface for creating objects in a superclass, but allows subclasses to alter the type of objects that will be created.

2. Abstract Factory Method Design Pattern

3. Builder Design Pattern

- Builder design pattern lets us construct complex objects step by step. This pattern separates the construction of a complex object from its representation, allowing the same construction process to create different representations.

Strategy Design Pattern

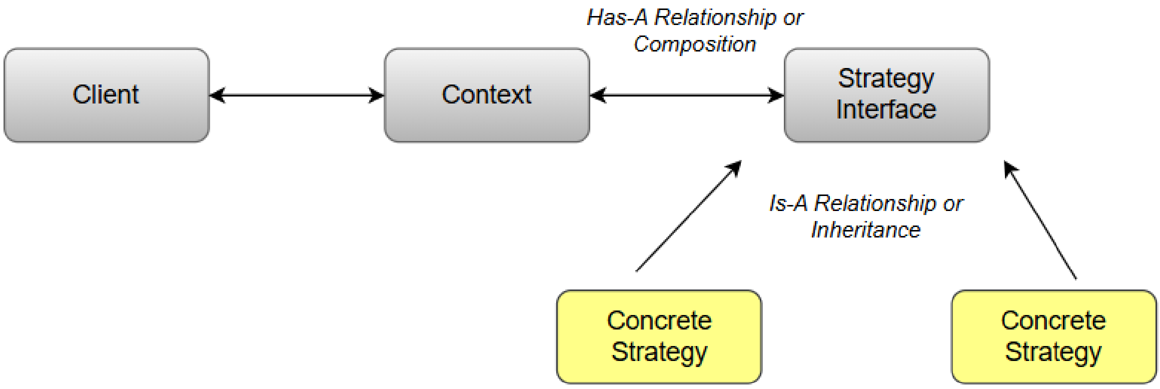
- Strategy Design pattern is a **behavioral Design pattern** that lets us dynamically choose or change the behavior of an object by encapsulating it into different strategies rather than sticking with one.

- In simpler terms, this pattern provides a way to extract the behavior of an object into separate classes that can be swapped in & out at runtime.

- This enable the object to be more flexible & reusable, as different strategies can be easily added or modified without changing the client's core code.

- It is based on the principle of Composition over Inheritance.

Components of Strategy Design Pattern



<u>Note:</u>

- Communications b/w the components happen in a structured & decoupled manner i.e.; the context is not required to be aware of the exact behavior of each strategy.
- As long as they follow the same interface, strategies can be switched without affecting the client or other strategies.

<u>1. Client</u>

- Client is responsible for configuring the appropriate strategy based on the requirement & providing it to the context.
- It creates an instance of the desired concrete strategy & passes it to the context, enabling the context to use the selected strategy to perform the task.

<u>2. Context</u>

- Context acts as a mediator between the clients & strategies and it maintains a reference to a strategy object & calls its methods to perform the task without exposing the actual strategies behavior to client.

<u>3. Strategy Interface</u>

- Strategy interface enables decoupling between the context & the specific/concrete strategies by ensuring that all the strategies follow the same set of rules & can be interchangeable used by the context.
- It can be an abstract class or interface that specifies a set of methods that all concrete strategies must implement.

<u>4. Concrete Strategies</u>

- Concrete strategies are the various implementations of the Strategy interface with each concrete strategy defining a specific algorithm or behavior to the task/method defined by the Strategy interface.
- They are interchangeable & can be selected by the client based on the task requirement.

Use cases

- Avoid Code Duplication – Suppose multiple concrete classes have same functionality, then they can be encapsulated to one generic strategy class.
- Multiple algorithms: e.g., Sorting algorithm – Different sorting algos can be encapsulated into separate strategies & passed to an object that needs sorting.
- Encapsulating algorithms
- Runtime selection
- Reducing conditional statements
- Testing & Extensibility
- Validation rules
- Text formatting
- Database access
- Payment strategy

Benefits

- Improved code flexibility
- Better code reusability
- Encourages better coding practices
- Simplifies testing

Disadvantages

- The application must be aware of all the strategies to select the right one for the right solution.
- The Strategy interface defines a set of features, some of which might be not relevant for some concrete strategies. ----> *Violating the Liskov Substitution Principle* (its solution can be used)
- **Imp:** In most cases, the client/application configures the context with the required strategy object. Therefore, the client needs to create & maintain 2 objects instead of one.

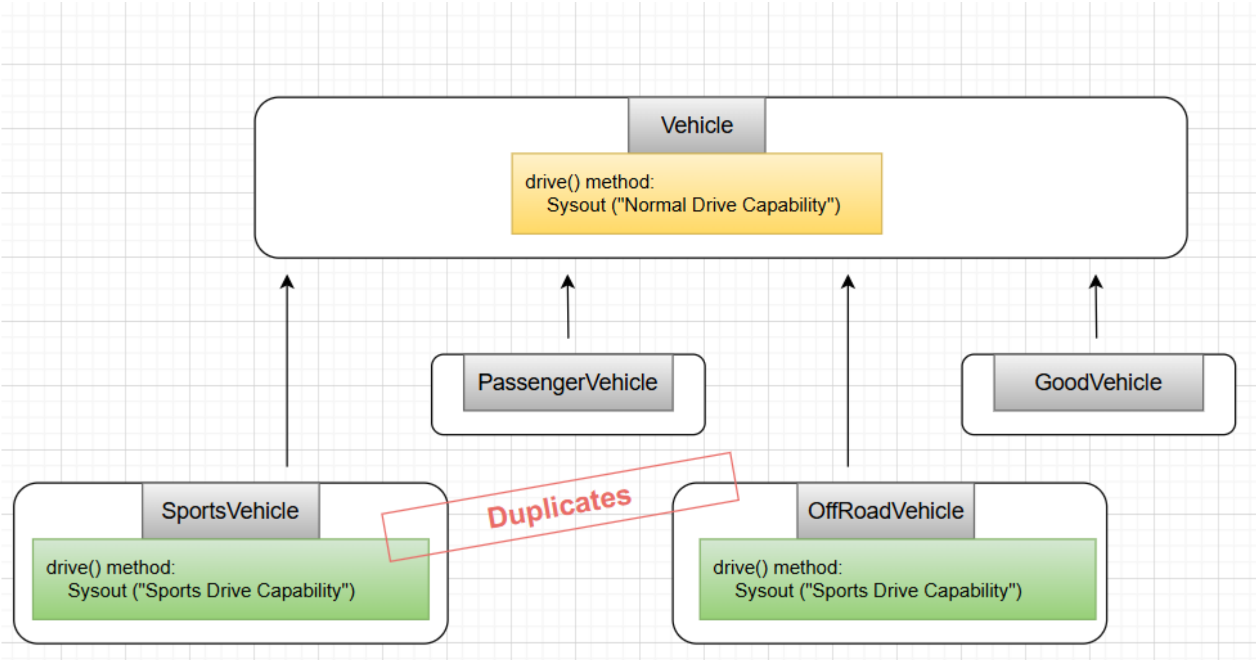
Best Practices for implementing the Strategy Design Pattern

- Keep the interface simple & focused on a single responsibility
- Encapsulate any stateful behavior in the concrete strategy classes, rather than in the context class.
- Use Dependency injection to pass the concrete strategy to the context class, rather than creating it directly in the context class.
- Use an enum or a factory class to provide a centralized place for creating & managing concrete strategy objects.

Example 1: Vehicle

Scenarios:
Suppose we've a "Vehicle" class with drive () method & multiple classes extend Vehicle class & according to their requirement, drive () method is being overridden by these inheritors.

- class **Vehicle**: drive () method – Sysout ("Normal Drive Capability")
- class **SportsVehicle** extends **Vehicle**: Overrides drive () method – Sysout ("Sports Capability")
- class **PassengerVehicle** extends **Vehicle**: uses parent Vehicle class drive () method definition
- class **OffRoadVehicle** extends **Vehicle**: Overrides drive () method – Sysout ("Sports Capability")
- class **GoodsVehicle** extends **Vehicle**: uses parent Vehicle class drive () method definition



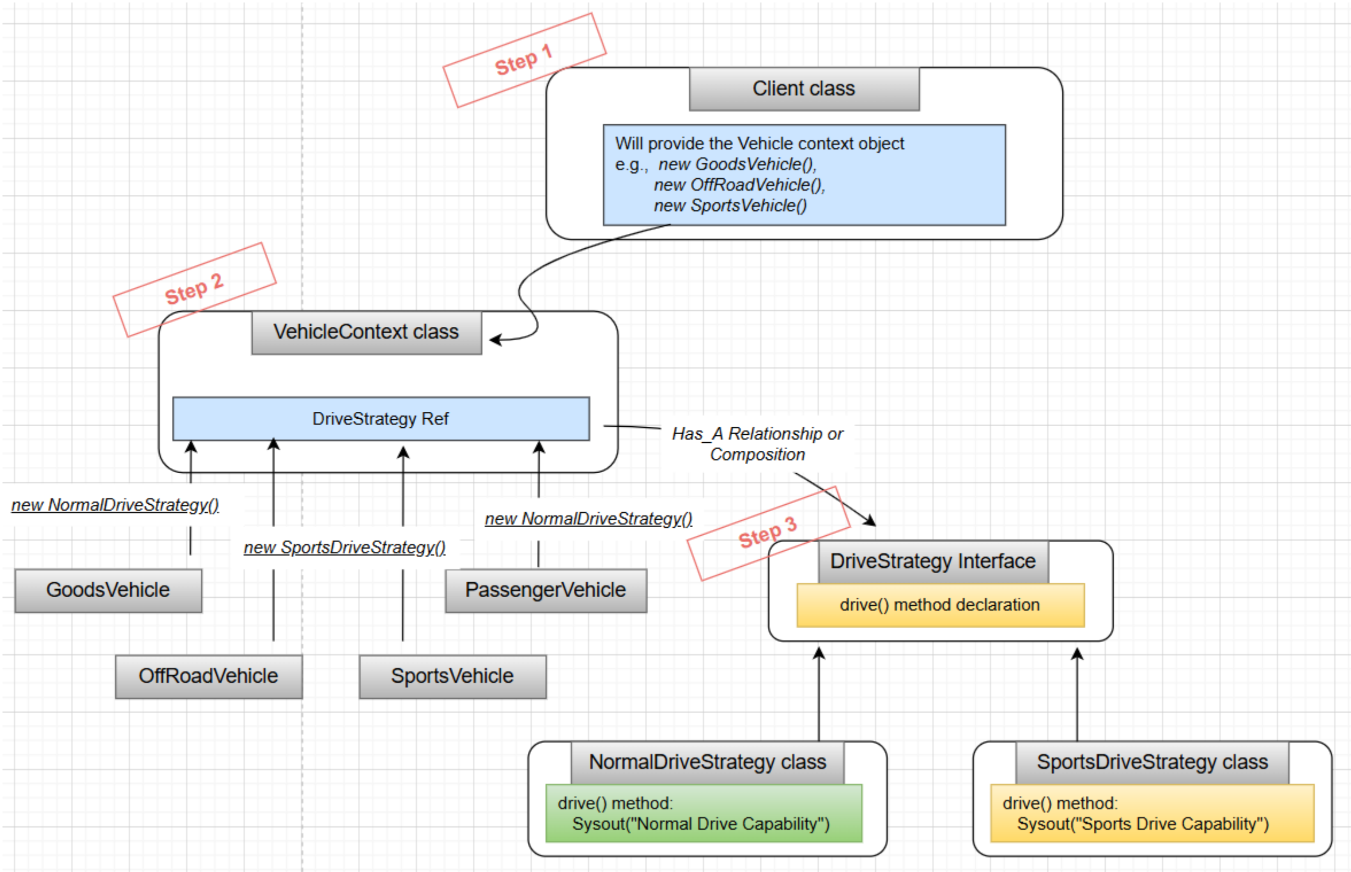
Problem:
Above, we can see SportsVehicle & OffRoadVehicle classes have common definition that is resulting in code duplication.

Solution:
To avoid code duplication, we can use Strategy Design pattern.

Step 1: Client class will provide the Vehicle Context object.
Note: In most of the cases client provides the vehicle context object along with Strategy object but in this specific example, the VehicleContext extensions are providing the actual Strategy object.

Step 2: Based on the Vehicle Context object, a strategy object will be returned.

Step 3: Based on the strategy object, the specific method/behavior will be called.



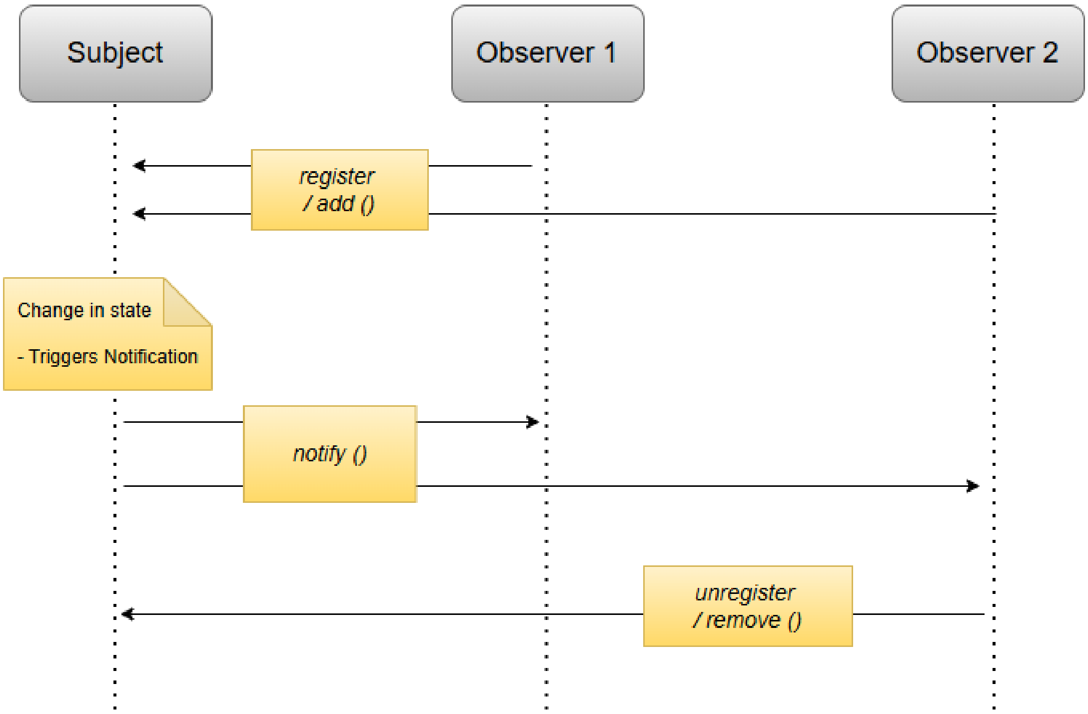
Observer Design Pattern (Publish-Subscribe Pattern)

- Observer Design pattern is a behavioral design pattern that lets us define a subscription mechanism to notify multiple objects (called Observers) about any changes in the state of the object they're observing i.e., one to many dependencies between objects: Observable & Observers.

- In this pattern, many observers (subscriber objects) observe a particular subject (publisher object). Observers register with a subject to be notified when a change is made inside that subject.

- *These objects are loosely coupled* as an observer object can register or unregister from a subject at any point of time.

Components of Observer Design Pattern



Observer Pattern Sequence Diagram

1. Subject / Observable / Publisher

- Subject maintains a list of observers & also provides method to register, unregister & notify observers about any changes in the state of subject / observable / publisher object.
- It can be interface or abstract class.

2. Concrete Subject

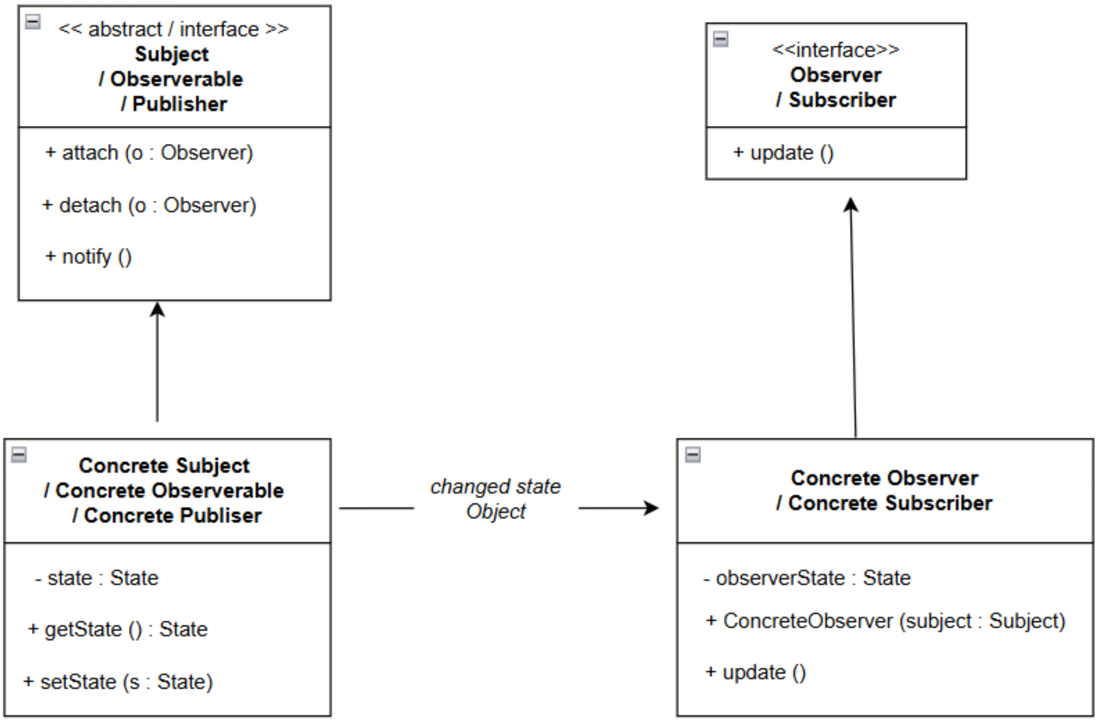
- Concrete subjects are specific implementations of the subject interface.
- They hold the actual state or data under observation & notify the subscribed observers about any changes in the state.
- E.g., if a Weather Station is the Subject, Specific Weather Stations in different locations would be Concrete Subjects.

3. Observer / Subscriber interface

- Observer defines an interface with an update method to ensure that concrete observers receive updates from the subject in a consistent way.
- It can be interface or abstract class.

4. Concrete Observer

- Concrete observers are specific implementations of the observer interface.
- They get registered to the concrete subjects & react when notified of a state change i.e., when the subject's state changes, the concrete observer's update () method is invoked, allowing it to take appropriate actions.
- E.g., A Weather app on smartphone can be a concrete observer that reacts to changes from a weather station.



When to use the Observer Design Pattern?

Below is when to use observer design pattern:

- When you need one object to notify multiple others about changes.
- When you want to keep objects loosely connected, so they don't rely on each other's details.
- When you want observers to automatically respond to changes in the subject's state.
- When you want to easily add or remove observers without changing the main subject.
- When you're dealing with event systems that require various components to react without direct connections.

When not to use the Observer Design Pattern?

Below is when not to use observer design pattern:

- When the relationships between objects are simple and don't require notifications.
- When performance is a concern, as many observers can lead to overhead during updates.
- When the subject and observers are tightly coupled, as it defeats the purpose of decoupling.
- When number of observers is fixed and won't change over time.
- When the order of notifications is crucial, as observers may be notified in an unpredictable sequence.

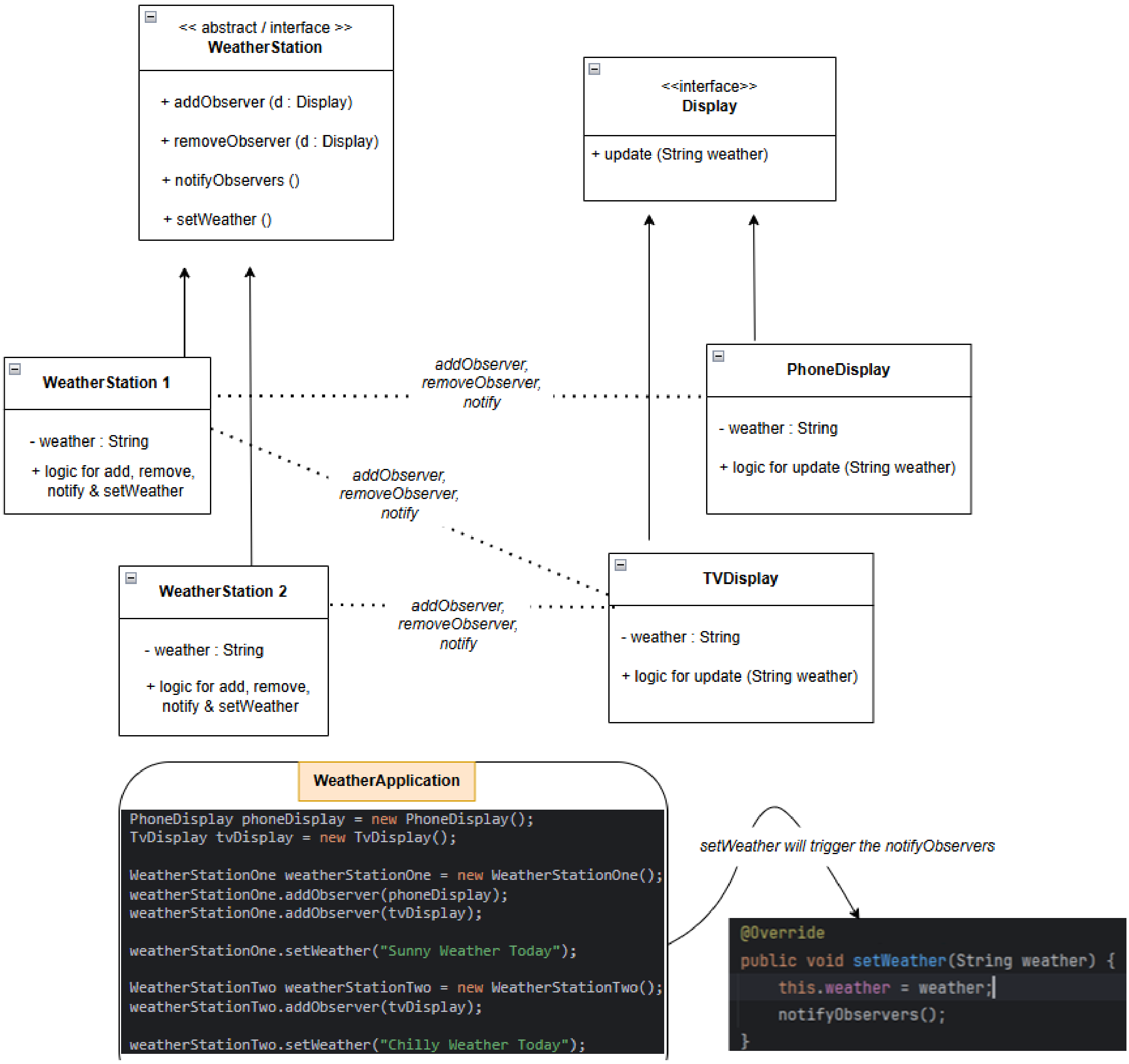
Example1 – Weather Application

Use case:

Design a weather application that will used on TV & Mobile to get current weather update from multiple weather stations.

- TV Display will receive update from Weather station 1 & 2
- Mobile Display will receive update from Weather station 1

Implementation:



Key points:

- Observer: **PhoneDisplay** observes **WeatherStation 1** and **TvDisplay** observes **WeatherStation 1** & **WeatherStation 2**
- **WeatherStation** setWeather () will trigger the notifyObservers () method
- 2 ways to consume weather update in Observers
  1. Pass the state/message through update method arguments
  2. ***Imp**: Observer class can have state/message as property & initialized through constructor injection i.e., Has_A Relationship*

Decorator / Wrapper Design Pattern

- Decorator design pattern is a structural design pattern that let us add new behaviour to individual objects dynamically, without affecting the behaviour of other objects from the same class.

Components of Decorator Design Pattern

1. Component Interface

- It specifies the operations that can be performed on the objects & it is common interface for both concrete components & decorators.
- This can be an abstract class or interface.

2. Concrete Component

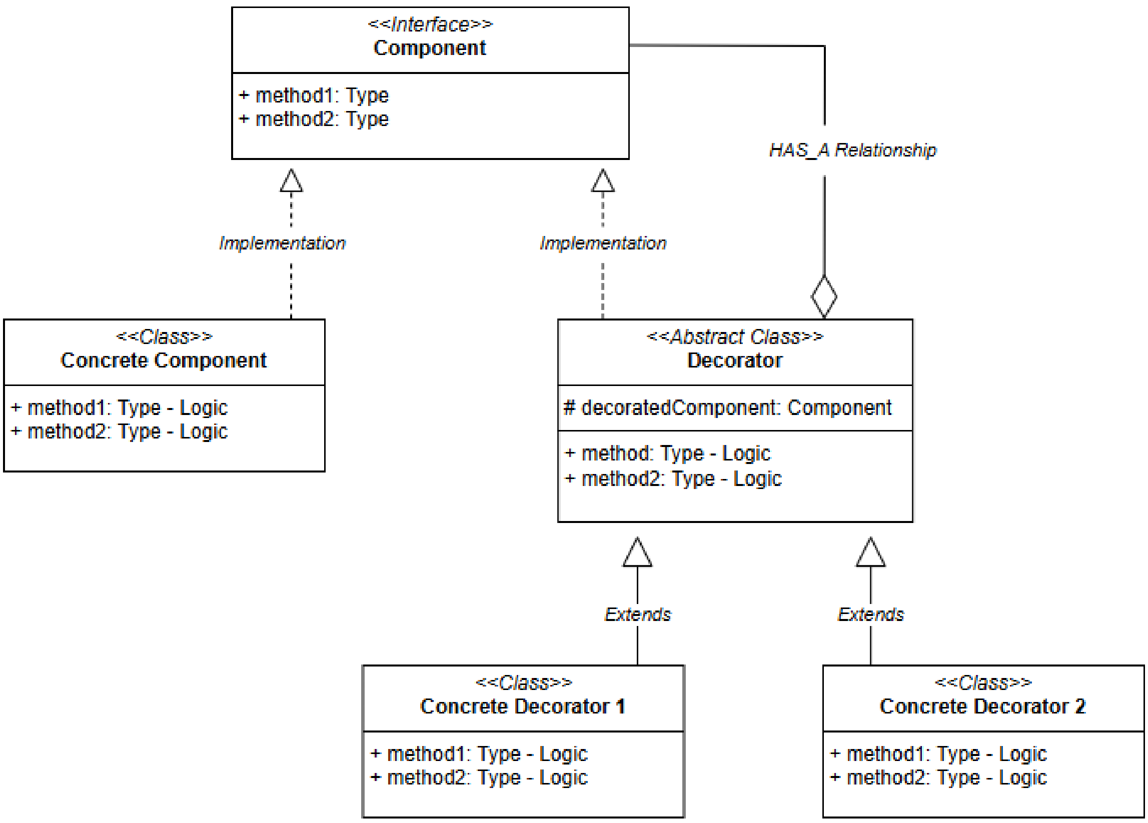
- These are the basic classes that implement the Component interface & add new behavior or responsibilities to Concrete Component objects.

3. Decorator (HAS_A Relationship + IS_A Relationship)

- Decorator is an abstract class that has a reference to component object & also implements the Component interface.
- Decorators are responsible for adding new behaviors to the wrapped Component object.

4. Concrete Decorators

- These are the concrete classes that extends the Decorator class & add a specific behaviors or responsibilities to the already existing Concrete Component objects.



Decorator Design Pattern - Class Diagram

Advantages of Decorator Design Pattern

- **<u>Composition over Inheritance</u>**
  - Unlike traditional inheritance, which can lead to a deep & inflexible class hierarchy, the decorator pattern uses composition.
  - We can compose objects with different decorators to achieve desired functionality, avoiding the drawbacks of inheritance, such as tight coupling & rigid hierarchies.
- **<u>Open-Closed Principle</u>**
  - Using this pattern, we can introduce new functionality to an existing class without changing its source code.
- **<u>Flexibility</u>**
  - It allows us to add or remove responsibilities (i.e., behaviors) from objects at runtime.
  - This flexibility makes it easy to create complex object structures with varying combinations of behaviors.
- **<u>Reusable Code</u>**
  - Decorators are reusable components. We can create a library of decorator classes & apply them to different objects & classes as needed, reducing code duplication.
- **<u>Dynamic Behavior Modification</u>**
  - Decorators can be applied or removed at runtime, providing dynamic behavior modification for objects.
  - This is particularly useful when we need to adapt an object's behavior based on changing requirements or user preferences.
- **<u>Clear Code Structure</u>**
  - The Decorator pattern promotes a clear & structured design, making it easier for developers to understand how different features & responsibilities are added to objects.

Disadvantages of Decorator Design Pattern

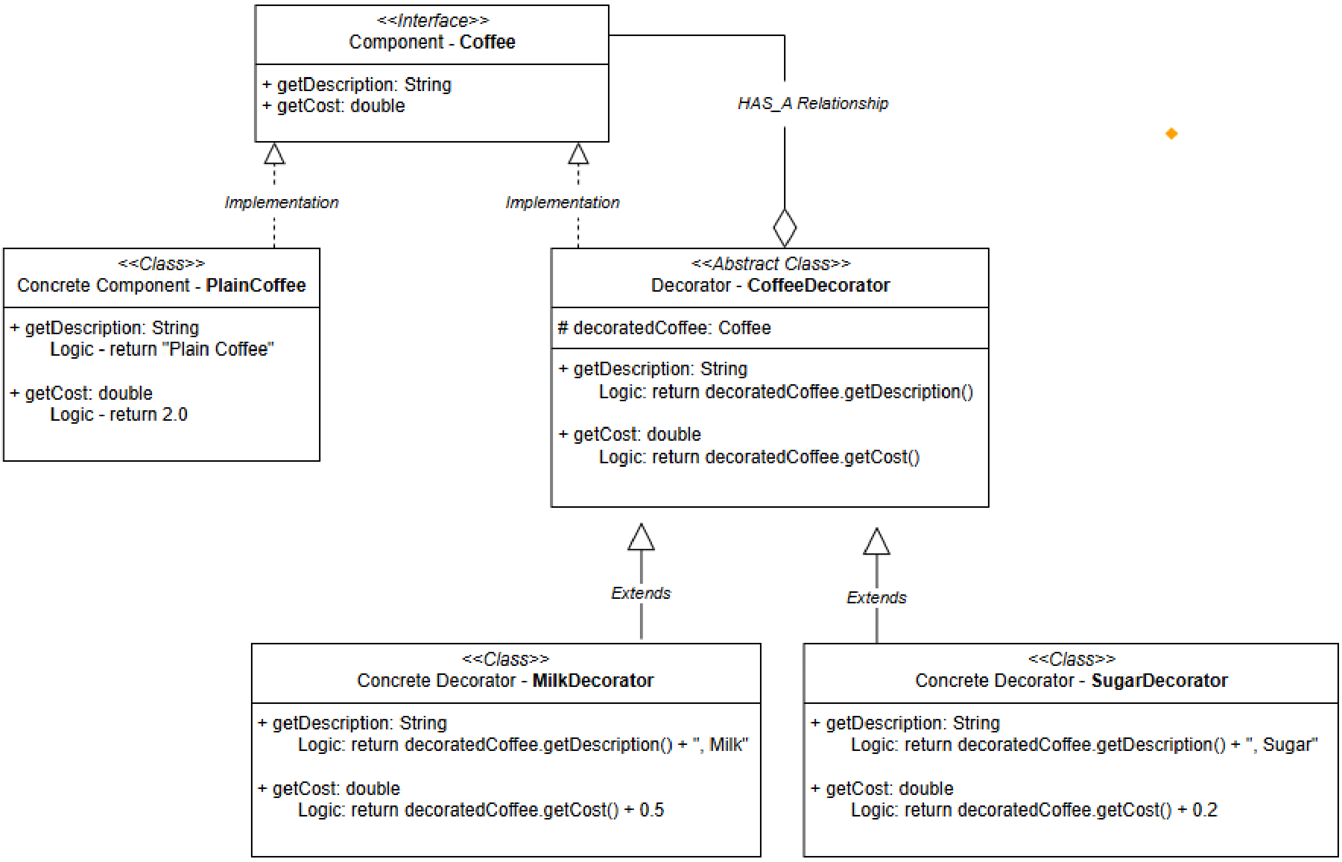
- **<u>Order of Decoration</u>**
  - The order in which decorators are applied can affect the final behavior of the object.
  - If decorators are not applied in correct order, it can lead to unexpected results.
  - Managing the order of decorators can be challenging, especially in complex scenarios.
- **<u>Increased number of classes</u>**
  - When using the decorator pattern, we often end up with a large number of small, specialized decorator classes.
  - This can lead to a proliferation of classes in our codebase, which may increase maintenance overhead.
- **<u>Potential for Overuse</u>**
  - As it's easy to add decorators to objects, there is a risk of overusing the decorator pattern, making the codebase unnecessarily complex.
  - It's important to use decorators effectively & only when they genuinely add value to the design.
- **<u>Complexity</u>**
  - As we add more decorators to an object, the code can become more complex & harder to understand.
  - The nesting of decorators can make the codebase difficult to navigate & debug, especially when there are many decorators involved.
- **<u>Limited Support in some languages</u>**
  - Some Programming language may not provide convenient support for implementing decorators.
  - Implementing the pattern can be more verbose (uses more words) & less intuitive in such language.

Example: Coffee Shop Application

Scenario:

Suppose we're building a coffee shop application where customers can order different types of coffee.

- Each coffee can have various optional add-ons such as milk, sugar, whipped cream etc.
- We want to implement a system where we can dynamically add these add-ons to a coffee order without modifying the coffee classes themselves.



Coffee Machine Application

```java
public class CoffeeMachineApp {
    public static void main(String[] args) {
        // Plain Coffee
        Coffee coffee = new PlainCoffee();
        System.out.println("Description: " + coffee.getDescription());
        System.out.println("Cost: $" + coffee.getCost());

        // Coffee with Milk
        Coffee milkCoffee = new MilkDecorator(new PlainCoffee());
        System.out.println("\nDescription: " + milkCoffee.getDescription());
        System.out.println("Cost: $" + milkCoffee.getCost());

        // Coffee with Sugar & Milk
        Coffee sugarMilkCoffee = new SugarDecorator(new MilkDecorator(new PlainCoffee()));
        System.out.println("\nDescription: " + sugarMilkCoffee.getDescription());
        System.out.println("Cost: $" + sugarMilkCoffee.getCost());
    }
}
```

Output:

Description: Plain Coffee
Cost: $2.0

Description: Plain Coffee, Milk
Cost: $2.5

Description: Plain Coffee, Milk, Sugar
Cost: $2.7