All Design Patterns

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NullObjectPattern

Overview (README.md)

Null Object Pattern

What is it?

The Null Object pattern provides an object as a surrogate for the lack of an object. Instead of returning null or checking for null, use a special “null” object that does nothing.

When to use it?

- Avoid null pointer exceptions (NullPointerException)
- Eliminate null checks throughout code
- Provide default behavior for missing objects
- Simplify client code logic

Real-world Example

Vehicle Factory: Return a NullVehicle instead of null when a vehicle type is not found, avoiding null checks in client code.

Key Benefits

✓ Eliminates null checks ✓ Prevents NullPointerException ✓ Simplifies client code ✓ Provides default behavior transparently ✓ Follows Open/Closed Principle

Key Drawbacks

✗ Can hide bugs (silent failures) ✗ May mask incorrect behavior ✗ Adds extra classes (null objects) ✗ Requires discipline to implement correctly

Easy Analogy

Think of it like a backup player on a sports team: When the main player gets injured, instead of having “no player”, you put in a backup player who can do basic things but doesn’t contribute much. Your team keeps running without checking “do we have a player?”

Implementation Notes

- Create a NullObject class that implements the same interface
- Override methods to do nothing or return default values
- Return NullObject instead of null from factory methods
- Use composition where null object provides safe defaults

UML / Class Diagram

Null Object - Class Diagram

Class Relationships

Class	Responsibility	Depends On
Vehicle	Interface defining vehicle behavior (contract)	None
Car	Real implementation of vehicle	Implements Vehicle
NullVehicle	Null object - implements interface but does nothing	Implements Vehicle
VehicleFactory	Creates vehicles or NullVehicle instead of returning null	Returns Vehicle

How to Code This Pattern

1. **Define Interface**: Create `Vehicle` interface
2. **Create Real Class**: `Car` implements `Vehicle` with actual behavior
3. **Create Null Class**: `NullVehicle` implements `Vehicle` with empty methods
4. **Update Factory**: Return `NullVehicle` instead of `null`
5. **No Null Checks**: Client code doesn’t need to check for null

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ObserverPattern

Overview (README.md)

Observer Pattern

What is it?

The Observer pattern defines a one-to-many dependency where when one object changes state, all dependent objects are notified automatically and updated.

When to use it?

- A change to one object requires changing unknown number of other objects
- An object should notify others without assuming who they are
- Model real-world event systems (event listeners, MVC architecture)
- Implement pub-sub systems

Real-world Example

E-commerce Stock System: When product stock changes, all observers (email notifier, SMS notifier, mobile app) are notified automatically.

Key Benefits

✓ Loose coupling between observers and subject ✓ Dynamic subscription/unsubscription ✓ One-to-many communication ✓ Supports event-driven architecture ✓ Easy to extend with new observers

Key Drawbacks

✗ Observer notification order is not guaranteed ✗ All observers are notified even if they don't need the update ✗ Memory leaks if observers not unsubscribed properly ✗ Debugging can be difficult (implicit dependencies)

Easy Analogy

Think of it like YouTube subscriptions: You (Observer) subscribe to a channel (Subject) → When the creator uploads a video (state change), YouTube notifies all subscribers automatically. If you unsubscribe, no more notifications.

Implementation Notes

- **Subject**: Maintains list of observers, notifies on state change
- **Observer**: Interface with update() method
- **ConcreteObserver**: Implements update() to react to changes
- Use weak references to avoid memory leaks
- Consider thread-safety for concurrent observers

UML / Class Diagram

Observer - Class Diagram

Class Relationships

Class	Responsibility	Depends On
StockObserver	Interface for observers receiving notifications	None
EmailNotifier	Concrete observer - sends email when notified	Implements StockObserver
SMSNotifier	Concrete observer - sends SMS when notified	Implements StockObserver
StockSubject	Subject/Observable - notifies all observers on state change	Maintains list of StockObserver

How to Code This Pattern

1. **Create Observer Interface**: Define `update()` method signature
2. **Create Concrete Observers**: `EmailNotifier`, `SMSNotifier` implement `update()`
3. **Create Subject**: Maintain list of observers
4. **Implement attach()**: Add observer to list
5. **Implement detach()**: Remove observer from list
6. **Implement notifyObservers()**: Call `update()` on all observers
7. **On State Change**: Call `notifyObservers()` when data changes

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chainOfResponsibilty

Overview (README.md)

Chain of Responsibility Pattern

What is it?

The Chain of Responsibility pattern allows you to pass requests along a chain of handlers. Each handler decides whether to process the request or pass it to the next handler in the chain.

When to use it?

- Multiple objects may handle a request, and the handler isn't known in advance
- You want to issue requests without specifying the receiver (e.g., logging at different levels)
- You need to dynamically configure the chain of handlers

Real-world Example

Logging System: Different log levels (Debug → Info → Error) where each level handles its corresponding messages and passes others down the chain.

Key Benefits

✓ Decouples sender from receiver ✓ Flexible chain configuration at runtime ✓ Single Responsibility: Each handler handles one responsibility ✓ Open/Closed Principle: Add new handlers without modifying existing ones

Key Drawbacks

✗ Request may not be handled if chain is not properly configured ✗ Difficult to debug (request path not always clear) ✗ Performance overhead from passing through chain

Easy Analogy

Think of it like a complaint handling system in a company: Your complaint goes to the frontdesk → If they can't solve it, they pass to manager → If manager can't solve, they pass to director. Each person (handler) decides if they can handle it or pass it on.

Implementation Notes

- Each handler should have a reference to the next handler
- Handler should process request and decide to pass or not
- Create chain before using it

UML / Class Diagram

Chain of Responsibility - Class Diagram

Class Relationships

Class	Responsibility	Depends On
LogProcessor	Abstract base - defines chain structure and template for logging	nextProcessor (self-reference)
DebugLogProcessor	Handles debug-level log messages	LogProcessor (extends)
InfoLogProcessor	Handles info-level log messages	LogProcessor (extends)
ErrorLogProcessor	Handles error-level log messages	LogProcessor (extends)

How to Code This Pattern

1. **Create Abstract Processor**: Define `LogProcessor` with next processor reference
2. **Implement Processors**: Each concrete class handles specific log level
3. **Build Chain**: Connect processors in order (Debug → Info → Error)
4. **Send Request**: Processor either handles it or passes to next

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mementoPattern

Overview (README.md)

Memento Pattern

What is it?

The Memento pattern captures and stores an object's internal state without exposing it, allowing the object to be restored to that state later.

When to use it?

- Implement undo/redo functionality

- Save checkpoints of an object's state
- Restore previous state without breaking encapsulation
- Maintain history of object states

Real-world Example

Text Editor: Save snapshots of document at different points so users can undo/redo edits without directly accessing internal editor state.

Key Benefits

✓ Preserves encapsulation (internal state stays hidden) ✓ Provides undo/redo functionality ✓ Doesn't violate Single Responsibility Principle ✓ Allows state restoration without side effects

Key Drawbacks

✗ Memory overhead if too many states are stored ✗ Time overhead to create/restore snapshots ✗ More complex implementation than simple state management

Easy Analogy

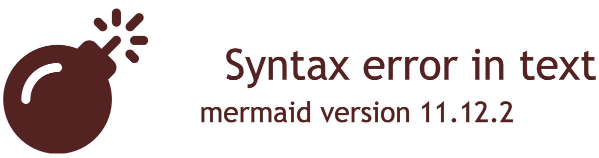
Think of it like Google Docs version history: Your document (Originator) saves snapshots at certain points → Each snapshot is a Memento → Google (CareTaker) keeps all versions → You can click on any version to restore it.

Implementation Notes

- **Originator**: Object whose state we want to save
- **Memento**: Stores snapshot of originator's state
- **CareTaker**: Manages memento objects and restoration logic
- Store mementos in a list for undo/redo operations

UML / Class Diagram

Memento - Class Diagram



Class Relationships

Class	Responsibility	Depends On
Originator	Creates memento snapshots of its state, can restore from memento	Creates Memento
Memento	Immutable snapshot of originator's state at a point in time	None (value object)
CareTaker	Manages collection of mementos, provides history management	Stores/retrieves Memento

How to Code This Pattern

1. **Create Originator**: Add `createMemento()` and `restoreFromMemento()` methods
2. **Create Memento**: Immutable class storing state snapshot
3. **Create CareTaker**: Maintain list of mementos (undo/redo stack)
4. **Save State**: Call `createMemento()` before changes
5. **Restore State**: Call `restoreFromMemento()` to go back

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objectPoolPattern

Overview (README.md)

Object Pool Pattern

What is it?

The Object Pool pattern reuses objects that are expensive to create by maintaining a pool of initialized objects. When needed, objects are borrowed from the pool and returned after use.

When to use it?

- Creating objects is expensive (database connections, threads)
- Frequent object creation/destruction causes performance issues
- Need controlled resource allocation
- Multiple threads need access to limited resources

Real-world Example

Database Connection Pool: Maintain a pool of reusable database connections instead of creating new ones for each request. Connections are borrowed and returned to pool.

Key Benefits

✓ Improved performance (avoid repeated object creation) ✓ Better resource management ✓ Thread-safe connection/resource management ✓ Reduces garbage collection overhead ✓ Predictable resource allocation

Key Drawbacks

✗ Increased memory usage (maintaining pool) ✗ More complex implementation ✗ Synchronization overhead for thread-safety ✗ Risk of resource leaks if not managed properly

Easy Analogy

Think of it like a library lending system: Instead of making a new book for each person, the library has a pool of books. You borrow a book (getConnection) → Use it → Return it (releaseConnection). The next person can reuse the same book.

Implementation Notes

- Maintain available and in-use lists/queues
- Implement acquire() to borrow from pool
- Implement release() to return to pool
- Handle pool exhaustion gracefully
- Ensure proper initialization of pooled objects

UML / Class Diagram

Object Pool - Class Diagram

Class Relationships

Class	Responsibility	Depends On
DBConnection	Represents a database connection that can be reused	None
DBConnectionPoolManager	Manages pool of connections, hands out and accepts returns	Creates/manages DBConnection

How to Code This Pattern

1. **Create Pooled Class**: `DBConnection` with proper initialization/cleanup
2. **Create Pool Manager**: `DBConnectionPoolManager` with queues for available/in-use
3. **Implement getConnection()**: Get from available pool or create new
4. **Implement releaseConnection()**: Return connection to available pool
5. **Handle Pool Exhaustion**: Either wait for available or create new (with limits)
6. **Thread Safety**: Use synchronized collections or locks

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statePattern

Overview (README.md)

State Pattern

What is it?

The State pattern allows an object to alter its behavior when its internal state changes. The object appears to change its class when the state changes.

When to use it?

- Object behavior depends on state and must change at runtime
- Different behaviors for different states
- State transitions are complex
- Avoid large if-else chains checking object state

Real-world Example

ATM Machine: Behavior changes based on states (IdleState → CardInsertedState → PinVerifiedState). Operations allowed depend on current state.

Key Benefits

✓ Eliminates large conditional statements ✓ Single Responsibility: Each state class handles one state ✓ Open/Closed Principle: Add new states without modifying existing ones ✓ Makes state transitions explicit ✓ Improves code readability and maintainability

Key Drawbacks

✗ Creates many state classes (increases complexity) ✗ Overkill for simple state machines ✗ States need access to context (tight coupling possible)

Easy Analogy

Think of it like an ATM machine: IdleState → You insert card (CardInsertedState) → You enter PIN (PinVerifiedState) → You withdraw money. At each state, different operations are allowed. You can't withdraw without entering PIN.

Implementation Notes

- **Context**: Maintains instance of concrete state
- **State**: Interface defining state-specific behavior
- **ConcreteState**: Implements behavior for specific state
- Context delegates calls to current state
- States can change context state via context reference
- Use state pattern for 3+ states or complex transitions

UML / Class Diagram

State - Class Diagram

Class Relationships

Class	Responsibility	Depends On
ATMState	Interface defining operations for a state	None
IdleStateATM	Initial state - only allows card insertion	Implements ATMState
CardInsertedState	Card inserted - only allows PIN entry	Implements ATMState
PinVerifiedState	PIN verified - only allows withdrawal	Implements ATMState
ATM	Context - delegates to current state	Holds reference to ATMState

How to Code This Pattern

1. **Create State Interface**: Define operations like `insertCard()`, `insertPin()`, `withdraw()`
2. **Create Concrete States**: Each state implements the interface
3. **In State Implementation**: Only allow valid operations, change ATM state accordingly
4. **Create Context (ATM)**: Maintain current state, delegate method calls to it
5. **State Transitions**: From within state methods, call `atm.setState(newState)`
6. **Invalid Operations**: Throw exception or do nothing for invalid state transitions

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strategyPattern

Overview (README.md)

Strategy Pattern

What is it?

The Strategy pattern defines a family of algorithms, encapsulates each one, and makes them interchangeable. It lets the algorithm vary independently from clients that use it.

When to use it?

- Many related classes differ only in behavior
- You need different variants of an algorithm
- Avoid conditional statements for algorithm selection
- Need to switch algorithms at runtime

Real-world Example

Vehicle Driving Modes: Normal vehicle drives normally, sports vehicle can switch to sports drive mode. Different driving strategies without changing vehicle class.

Key Benefits

✓ Eliminates conditional statements ✓ Easy to switch algorithms at runtime ✓ Single Responsibility: Each strategy handles one algorithm ✓ Open/Closed Principle: Add new strategies easily ✓ Improved testability (test each strategy independently)

Key Drawbacks

✗ Creates many strategy classes (increases classes count) ✗ Overkill for simple algorithms ✗ Client must know about strategies ✗ Runtime overhead from dynamic dispatch

Easy Analogy

Think of it like choosing different routes to reach your destination: You have a car (Vehicle) → You can use GoogleMaps route (Strategy1) → Or Waze route (Strategy2) → Or local knowledge route (Strategy3). Same destination, different strategies. You can switch anytime.

Implementation Notes

- **Context**: Uses strategy interface, doesn't know concrete strategy
- **Strategy**: Interface defining algorithm contract
- **ConcreteStrategy**: Implements specific algorithm
- Strategy can be set during initialization or at runtime
- Use dependency injection for strategy assignment
- Strategies should be stateless when possible

UML / Class Diagram

Strategy - Class Diagram

Class Relationships

Class	Responsibility	Depends On
DriveStrategy	Interface defining driving algorithms	None
NormalDrive	Concrete strategy - normal driving behavior	Implements DriveStrategy
SportsDrive	Concrete strategy - aggressive driving behavior	Implements DriveStrategy
Vehicle	Context - uses strategy to drive	Holds reference to DriveStrategy

How to Code This Pattern

1. **Create Strategy Interface**: Define `drive()` method
2. **Create Concrete Strategies**: `NormalDrive` and `SportsDrive`
3. **Create Context (Vehicle)**: Maintain reference to strategy
4. **Implement setDriveStrategy()**: Allow changing strategy at runtime
5. **Delegate to Strategy**: `vehicle.drive()` calls `strategy.drive()`
6. **Switch Algorithms**: Change strategy based on user input or conditions

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templatePattern

Overview (README.md)

Template Pattern

What is it?

The Template Pattern defines the skeleton of an algorithm in a method, deferring some steps to subclasses. It lets subclasses redefine certain steps without changing the algorithm's structure.

When to use it?

- Multiple classes have similar algorithm structure
- Want to avoid code duplication
- Define invariant parts in base class, variant parts in subclasses
- Invert control (Hollywood principle: "Don't call us, we'll call you")

Real-world Example

Payment Processing: PaymentFlow template defines steps (validate → charge → confirm). Different payment types (ToFriend, ToMerchant) implement specific steps differently.

Key Benefits

✓ Eliminates code duplication ✓ Single Responsibility: Separate algorithm structure from implementation ✓ Open/Closed Principle: Extend without modifying template ✓ Consistent algorithm execution ✓ Easy to maintain and extend

Key Drawbacks

✗ Class hierarchy may become complex ✗ Violation of Liskov Substitution if subclasses don't follow contract ✗ Tight coupling between base and derived classes ✗ Limited flexibility in algorithm structure

Easy Analogy

Think of it like a cooking recipe: All recipes have basic steps: Prepare ingredients → Cook → Plate up. But within each step, the details differ. Pizza preparation is different from Biryani preparation. The template (steps) stays the same, details vary.

Implementation Notes

- **AbstractClass**: Defines template method with algorithm skeleton

- Template method calls abstract methods (hooks)
- Subclasses override specific abstract methods
- Use final keyword on template method to prevent override
- Consider using hooks (extension points) for optional customization
- Keep base class focused on algorithm structure

UML / Class Diagram

Template Method - Class Diagram

Class Relationships

Class	Responsibility	Depends On
PaymentFlow	Abstract class - defines payment algorithm skeleton (template)	None
PaymentToFriend	Concrete implementation - specific steps for friend payment	Extends PaymentFlow
PaymentToMerchant	Concrete implementation - specific steps for merchant payment	Extends PaymentFlow

How to Code This Pattern

1. **Create Abstract Class**: Define `pay()` as final (can't override)
2. **Define Template Method**: `pay()` calls abstract methods in order
3. **Define Abstract Methods**: `validate()`, `charge()`, `confirm()` (protected/abstract)
4. **Create Concrete Classes**: Implement abstract methods with specific logic
5. **Skeleton in Base**: Algorithm structure stays in base, details in subclasses
6. **Call Order**: Template method controls execution order, subclasses fill in steps

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abstractFacotoryPattern

Overview (README.md)

Abstract Factory Pattern

What is it?

The Abstract Factory pattern provides an interface for creating families of related or dependent objects without specifying their concrete classes.

When to use it?

- System needs to work with multiple families of related objects
- You want to provide a library showing only interfaces, not implementation
- Need to enforce creating products from same family
- Consistency required among products

Real-world Example

Car Manufacturing: Different car types (Economy, Luxury) need matching components (Engine, Tyre). Abstract factory ensures economy cars get economy components.

Key Benefits

✓ Isolates concrete classes from client code ✓ Easy to swap product families ✓ Enforces consistency among related products ✓ Simplifies extending to support new families ✓ Single Responsibility: Separate object creation from usage

Key Drawbacks

✗ More complex than simple factory (multiple factory classes) ✗ Adding new product type requires modifying all factories ✗ Can be overkill for simple scenarios ✗ Indirect object creation increases complexity

Easy Analogy

Think of it like different restaurant chains: McDonalds Factory makes burgers, fries, coke → KFC Factory makes chicken, fries, coke. Both have same product categories but different implementations. Customers don't care, they just ask the factory.

Implementation Notes

- **AbstractFactory**: Declares factory methods for creating products
- **ConcreteFactory**: Implements creation of specific product family
- **AbstractProduct**: Interface for related products
- **ConcreteProduct**: Concrete implementation of products
- Client works with abstract interfaces only
- Use when you have 2+ product families with multiple products each

UML / Class Diagram

Abstract Factory - Class Diagram

Class Relationships

Class	Responsibility	Depends On
CarFactory	Abstract factory interface - declares creation methods	None
EconomyCarFactory	Creates economy family products	Creates Economy*, implements CarFactory
LuxuryCarFactory	Creates luxury family products	Creates Luxury*, implements CarFactory
Car/Engine/Tyre	Product interfaces	None
Economy/Luxury variants	Concrete products for each family	Implement product interfaces

How to Code This Pattern

1. **Create Abstract Factory**: Interface with methods for each product
2. **Create Product Interfaces**: `Car`, `Engine`, `Tyre`
3. **Create Concrete Products**: Economy and Luxury variants
4. **Create Concrete Factories**: Each factory creates its family
5. **Ensure Consistency**: Factory ensures related products are from same family
6. **Client Code**: Use factory interface only, don't know concrete classes

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abstractFactoryDesignPattern

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builderPattern

Overview (README.md)

Builder Pattern

What is it?

The Builder pattern separates the construction of a complex object from its representation, allowing the same construction process to create different representations.

When to use it?

- Object has many optional parameters
- Creating object with many constructor parameters (telescoping constructors problem)
- Want step-by-step construction of complex objects
- Object construction is expensive or multi-step

Real-world Example

Student Registration: Build student objects with many optional fields (name, age, branch, courses). Avoid complex constructor signatures.

Key Benefits

✓ Clear, fluent API (readable code) ✓ Handles many optional parameters elegantly ✓ Immutable objects (once built, cannot change) ✓ Single Responsibility: Separate construction from representation ✓ Flexible construction (different representations possible)

Key Drawbacks

✗ More classes (builder class needed) ✗ More code required compared to simple constructors ✗ Slightly more memory overhead ✗ Overkill for simple objects

Easy Analogy

Think of it like ordering a custom pizza: You don't say "give me all toppings" or "nothing". You build it step by step: "Base → Cheese → Tomato → Pepperoni → Done!". Finally you get your customized pizza.

Implementation Notes

- **Builder**: Nested static class with fluent API
- Use method chaining for readability (return this)
- Implement build() to create final object
- Provide sensible defaults for optional parameters
- Constructor should be private to force builder use
- Consider immutability after building
- Can use lombok @Builder annotation for less boilerplate

UML / Class Diagram

Builder - Class Diagram

Class Relationships

Class	Responsibility	Depends On
Student	Object with multiple optional fields (immutable after building)	Built by StudentBuilder
StudentBuilder	Builds Student step-by-step with fluent API	Creates Student

How to Code This Pattern

1. **Create Product Class**: `Student` with private constructor accepting builder
2. **Create Builder Class**: Nested static class with same fields as product
3. **Implement Fluent Methods**: Each setter returns `this` for chaining
4. **Add Defaults**: Provide sensible default values for optional fields
5. **Implement build()**: Create and return final product
6. **Usage**: `new StudentBuilder().setName("X").setAge(20).build()`
7. **Optional**: Use `@Builder` annotation from Lombok to auto-generate

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factoryPattern

Overview (README.md)

Factory Pattern

What is it?

The Factory pattern provides an interface for creating objects, but lets subclasses decide which class to instantiate. It creates objects without specifying the exact classes to create.

When to use it?

- A class can't anticipate the type of objects it needs to create
- Want to delegate object creation to subclasses
- Object creation logic is complex and needs to be centralized
- Need to decouple object creation from usage

Real-world Example

Shape Creation: Factory creates different shapes (Circle, Rectangle) based on input type. Client doesn't need to know concrete shape classes.

Key Benefits

✓ Decouples client from concrete classes ✓ Centralizes object creation logic ✓ Easy to add new object types ✓ Follows Open/Closed Principle ✓ Simplifies client code

Key Drawbacks

✗ More classes needed (factory + concrete classes) ✗ Can be overkill for simple object creation ✗ Indirection makes code harder to follow ✗ Over-abstraction in simple scenarios

Easy Analogy

Think of it like a car dealership: You go to the dealership (Factory) and ask for a "Honda Civic" (type). The dealership gives you the right car without you worrying how it's built. You just know the interface: "it has 4 wheels, can start and stop".

Implementation Notes

- **Creator/Factory**: Interface with factory method
- **ConcreteCreator**: Implements factory method for specific type
- **Product**: Interface for created objects
- **ConcreteProduct**: Concrete implementation
- Use enums or string identifiers for object type selection
- Can be static method factory instead of inheritance-based
- Ensure all created objects conform to product interface

UML / Class Diagram

Factory Method - Class Diagram

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mermaid version 11.12.2

Class Relationships

Class	Responsibility	Depends On
Shape	Product interface	None
Circle/Rectangle/Square	Concrete products	Implement Shape
ShapeFactory	Creator - factory method for creating shapes	Returns Shape interface

How to Code This Pattern

1. **Create Product Interface**: Define `draw()` method
2. **Create Concrete Products**: `Circle`, `Rectangle`, `Square`
3. **Create Factory Class**: Static method `getShape(String type)`
4. **Implement Factory Logic**: Switch/if-else to create right shape
5. **Return Interface**: Always return `Shape` type, not concrete class
6. **Client Usage**: `Shape shape = ShapeFactory.getShape("circle")`
7. **Encapsulate Creation**: Client doesn't know how to create shapes

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prototypePattern

Overview (README.md)

Prototype Pattern

What is it?

The Prototype pattern creates new objects by copying an existing object (prototype) rather than creating from scratch. Useful when object creation is expensive.

When to use it?

- Object creation is expensive or slow
- Need to avoid subclassing for object creation
- Want to create clones of objects with different states
- Need to decouple object creation from concrete classes

Real-world Example

Network Connection Cloning: Clone existing network connections (shallow/deep cloning) with different configurations instead of creating from scratch.

Key Benefits

✓ Faster object creation (copy existing object) ✓ Avoids expensive initialization ✓ Reduces memory usage in some cases ✓ Decouples client from concrete classes ✓ Flexible cloning strategies

Key Drawbacks

✗ Shallow vs deep cloning complexity ✗ Clone method implementation required for all classes ✗ Circular references complicate deep cloning ✗ Performance overhead from copying large objects

Easy Analogy

Think of it like photocopying documents: You have an original document → You make a photocopy (shallow clone) → But if the original has attachments, the copy references the same attachments. With deep copy, you also copy the attachments.

Implementation Notes

- Implement Cloneable interface
- Override clone() method to create copy
- **Shallow Clone**: Only copy reference fields (uses default clone)
- **Deep Clone**: Create new instances of referenced objects
- Use copy constructor alternative to clone()
- Be careful with mutable fields (may need deep clone)
- Handle CloneNotSupportedException

UML / Class Diagram

Prototype - Class Diagram

Syntax error in text

mermaid version 11.12.2

Class Relationships

Class	Responsibility	Depends On
Cloneable	Interface for cloneable objects	None
NetworkConnection	Implements cloning - supports both shallow and deep	Implements Cloneable

How to Code This Pattern

1. **Implement Cloneable**: Make class implement `Cloneable` interface
2. **Override clone()**: Create and return copy of object
3. **Shallow Clone**: Copy primitive fields, share reference fields
4. **Deep Clone**: Create new instances of referenced objects
5. **Handle Arrays/Lists**: Create new list and add cloned elements
6. **Catch Exception**: Catch `CloneNotSupportedException` in implementation
7. **Usage**: `NetworkConnection copy = original.clone()`
8. **Alternative**: Use copy constructor instead of `clone()`

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singletonDesignPattern

Overview (README.md)

Singleton Pattern

What is it?

The Singleton pattern restricts the instantiation of a class to a single object and provides a global point of access to that instance.

When to use it?

- Only one instance of a class should exist (e.g., database connection, logger)
- Need global access to the instance
- Ensure instance is created only once
- Control access to shared resource

Real-world Example

Database Connection: Only one DB connection instance should exist for the entire application. Singleton ensures single instance and global access.

Key Benefits

✓ Ensures single instance ✓ Global point of access ✓ Lazy initialization possible ✓ Thread-safe implementation available ✓ Prevents multiple instantiation

Key Drawbacks

✗ Difficult to test (global state) ✗ Hidden dependencies (singleton dependency not clear) ✗ Violates Single Responsibility Principle ✗ Not thread-safe in all implementations ✗ Makes code less flexible

Easy Analogy

Think of it like a country's president: There's only ONE president at a time. When you need to talk to the president, you ask for "the president" not "create a new president". Everyone gets the same president instance.

Implementation Notes

- Private constructor to prevent instantiation
- Static instance variable
- Public static getInstance() method
- **Eager Initialization**: Create instance at class loading
- **Lazy Initialization**: Create instance on first access
- **Thread-safe**: Use synchronized block or double-checked locking
- Consider using Enums for thread-safe singleton
- Implement Serializable/Cloneable carefully to maintain singleton

UML / Class Diagram

Singleton - Class Diagram

Syntax error in text

mermaid version 11.12.2

Class Relationships

Class	Responsibility	Depends On
DBConnection	Singleton - only one instance, global access	Self-manages instance

How to Code This Pattern

Eager Initialization (Thread-Safe)

```
class DBConnection {
    private static final DBConnection instance = new DBConnection();

    private DBConnection() { }

    public static DBConnection getInstance() {
        return instance;
    }
}
```

Lazy Initialization (Thread-Safe)

```
class DBConnection {
    private static DBConnection instance;

    private DBConnection() { }

    public static synchronized DBConnection getInstance() {
        if (instance == null) {
            instance = new DBConnection();
        }
        return instance;
    }
}
```

Double-Checked Locking

```
class DBConnection {
    private static volatile DBConnection instance;

    private DBConnection() { }

    public static DBConnection getInstance() {
        if (instance == null) {
            synchronized(DBConnection.class) {
                if (instance == null) {
                    instance = new DBConnection();
                }
            }
        }
        return instance;
    }
}
```

Key Points

- **Private Constructor**: Prevent instantiation from outside
- **Static Instance**: Hold single instance
- **getInstance()**: Return the singleton instance
- **Thread-Safe**: Use synchronized or volatile for concurrency
- **Enum Alternative**: Use enum for automatic singleton

AdapterDesignPattern

Overview (README.md)

Adapter Pattern

What is it?

The Adapter pattern converts the interface of a class into another interface clients expect. It allows incompatible objects to collaborate.

When to use it?

- Have incompatible interfaces that need to work together
- Integrate third-party libraries with different interfaces
- Want to reuse existing class with incompatible interface
- Create bridge between old and new code

Real-world Example

Weight Machine Adapter: Weight machine returns weight in different formats. Adapter converts to pounds/kg format that clients expect.

Key Benefits

✓ Allows collaboration between incompatible objects ✓ Improves code reusability ✓ Follows Single Responsibility Principle ✓ Follows Open/Closed Principle ✓ Helps integrate legacy code

Key Drawbacks

✗ Added complexity with extra adapter class ✗ Can hide design problems in original interfaces ✗ May reduce performance due to indirection ✗ Overkill for simple interface changes

Easy Analogy

Think of it like an electrical adapter: You have a device (WeightMachine) that outputs in kg, but your client needs it in pounds. The adapter converts kg to pounds without changing the original device.

Implementation Notes

- **Target**: Interface clients expect
- **Adaptee**: Existing interface that needs adaptation
- **Adapter**: Converts adaptee interface to target interface
- **Two types**: Class adapter (inheritance) and object adapter (composition)
- Object adapter is preferred (more flexible)
- Keep adapter simple (avoid complex logic)
- Consider whether modification of adaptee is possible

UML / Class Diagram

Adapter - Class Diagram

Class Relationships

Class	Responsibility	Depends On
WeightMachine	Adaptee - existing class with incompatible interface	None
WeightMachineAdapter	Target interface - interface client expects	None
WeightMachineAdapterImpl	Adapter - converts adaptee to target interface	Has WeightMachine, implements Adapter

How to Code This Pattern

Object Adapter (Composition - Recommended)

```
class WeightMachineAdapterImpl implements WeightMachineAdapter {
    private WeightMachine weightMachine;

    public WeightMachineAdapterImpl(WeightMachine wm) {
        # Adapter - Class Diagram

        ```mermaid
        classDiagram
            class WeightMachine {
                +getWeight(): double
            }

            class WeightReader {
                <<interface>>
                +getWeightInPounds(): double
            }

            class WeightMachineAdapterImpl {
                -weightMachine: WeightMachine
                +WeightMachineAdapterImpl(wm: WeightMachine)
                +getWeightInPounds(): double
            }

            %% Relationships
            WeightMachineAdapterImpl --> WeightMachine : uses
            WeightReader <|.. WeightMachineAdapterImpl
        ```

        ## Class Relationships

Class	Responsibility	Depends On
WeightMachine	Adaptee - existing class providing weight in its own units	None
WeightReader	Target interface - what clients expect (weight in pounds)	None
WeightMachineAdapterImpl	Adapter (object adapter) - converts WeightMachine to WeightReader	Uses `WeightMachine`, implements `WeightRe

        ## Plain Explanation

        The client expects `WeightReader` (method `getWeightInPounds()`), but `WeightMachine` only provides `getWeight()`. The adapter (`WeightMachineAd

        ## How to Code This Pattern (Minimal)

        ### Object Adapter (Composition - recommended)
        ```java
```
```

```java
// Target
public interface WeightReader {
    double getWeightInPounds();
}

// Adaptee
public class WeightMachine {
    public double getWeight() { return 50.0; /* kg */ }
}

// Adapter
public class WeightMachineAdapterImpl implements WeightReader {
    private final WeightMachine weightMachine;

    public WeightMachineAdapterImpl(WeightMachine wm) { this.weightMachine = wm; }

    @Override
    public double getWeightInPounds() {
        return weightMachine.getWeight() * 2.20462; // kg -> lb
    }
}
```

Class Adapter (Inheritance — less flexible)

```java
public class WeightMachineAdapter extends WeightMachine implements WeightReader {
    @Override
    public double getWeightInPounds() {
        return getWeight() * 2.20462;
    }
}
```

Key Points

- Use object adapter (composition) when you can: it works with final/adapted classes and is more flexible.
- Use class adapter (inheritance) only when you must inherit and the adaptee's interface is compatible with inheritance.
- Adapter focuses on converting interfaces, not changing behaviour.

DecoratorDesign

Overview (README.md)

Decorator Pattern

What is it?
The Decorator pattern attaches additional responsibilities to an object dynamically. It provides a flexible alternative to subclassing for extending fu

When to use it?
- Add responsibilities to individual objects without affecting others
- Subclassing would create too many classes
- Need to combine multiple behaviors dynamically
- Avoid "explosion" of subclasses

Real-world Example
Ice Cream Shop: Base ice cream (Vanilla, Chocolate) can be decorated with toppings (ChocolateSyrup, ChocoChips). Each decorator adds features.

Key Benefits
✓ More flexible than subclassing
✓ Add/remove responsibilities at runtime
✓ Combine behaviors dynamically
✓ Single Responsibility: Each decorator has one responsibility
✓ Avoids subclass explosion

Key Drawbacks
✗ Many small classes (decorators)
✗ Complex object composition
✗ Decoration order matters (may affect functionality)
✗ Can be overkill for simple additions

Easy Analogy
Think of it like customizing a shirt:
Basic shirt → Add sleeves (decorator) → Add buttons (another decorator) → Add collar (another decorator). Each decorator adds functionality without cha

Implementation Notes
- **Component**: Interface for decorators and concrete objects
- **ConcreteComponent**: Original object being decorated
- **Decorator**: Abstract class maintaining reference to component
- **ConcreteDecorator**: Adds specific responsibility
- Decorator wraps component and delegates calls
- Can wrap decorator with another decorator
- Maintain same interface as component
- Watch order of decoration (may affect results)

UML / Class Diagram

Decorator - Class Diagram

```mermaid
classDiagram
    class IceCream {
        <<interface>>
        +getCost(): double
        +getDescription(): String
    }

    class VanillaIceCream {
        +getCost(): double
        +getDescription(): String
    }

    class IceCreamDecorator {
        <<abstract>>
        -iceCream: IceCream
        +getCost(): double
        +getDescription(): String
    }
```

```
class ChocolateSyrupDecorator {
    +getCost(): double
    +getDescription(): String
}

class ChocoChipsDecorator {
    +getCost(): double
    +getDescription(): String
}

IceCream <|.. VanillaIceCream
IceCream <|.. IceCreamDecorator
IceCreamDecorator <|-- ChocolateSyrupDecorator
IceCreamDecorator <|-- ChocoChipsDecorator
IceCreamDecorator --> IceCream: wraps
```

Class Relationships

Class	Responsibility	Depends On
IceCream	Component interface - defines ice cream operations	None
VanillaIceCream	Concrete component - base ice cream	Implements IceCream
IceCreamDecorator	Abstract decorator - wraps ice cream and adds features	Has IceCream, implements IceCream
ChocolateSyrupDecorator	Concrete decorator - adds chocolate syrup	Extends IceCreamDecorator
ChocoChipsDecorator	Concrete decorator - adds choco chips	Extends IceCreamDecorator

How to Code This Pattern

1. **Create Component Interface**: `IceCream` with `getCost()` and `getDescription()`
2. **Create Concrete Component**: `VanillaIceCream` implements interface
3. **Create Abstract Decorator**: Implements interface, wraps component
4. **Decorator holds Component**: `IceCreamDecorator` has `IceCream` reference
5. **Decorator delegates**: Call wrapped component's methods first, then add own behavior
6. **Create Concrete Decorators**: Each adds specific feature
7. **Stack Decorators**: Can wrap decorator with another decorator

Example Usage

```
IceCream iceCream = new VanillaIceCream();  // cost: 30
iceCream = new ChocolateSyrupDecorator(iceCream);  // cost: 30 + 15 = 45
iceCream = new ChocoChipsDecorator(iceCream);  // cost: 45 + 10 = 55
```

Key Points

- **Wrapper Pattern**: Decorators wrap components
- **Same Interface**: Decorator implements same interface as component
- **Recursive Composition**: Can nest decorators
- **Runtime Addition**: Add features at runtime

ProxyPattern

Overview (README.md)

Proxy Pattern

What is it?

The Proxy pattern provides a surrogate or placeholder for another object to control access to it. Proxy acts on behalf of the real object.

When to use it?

- Defer expensive object creation (lazy initialization)
- Control access to sensitive objects
- Log access to objects
- Cache results of expensive operations
- Restrict operations on objects

Real-world Example

Employee Data Cache Proxy: Real expensive employee data fetches from DB. Proxy caches data in Redis, returning cached results when available.

Key Benefits

✓ Control access to objects ✓ Lazy initialization (create object only when needed) ✓ Add logging/caching without modifying original ✓ Follows Single Responsibility Principle ✓ Transparent to client code

Key Drawbacks

✗ Added complexity with extra proxy class ✗ Performance overhead from proxy indirection ✗ Response time slightly increased ✗ Overkill for simple objects

Easy Analogy

Think of it like a personal assistant: You (Real Subject) are busy. Your assistant (Proxy) handles your calls → If someone asks your salary, assistant checks notes (cache) → If not there, asks you. No one directly bothers you.

Implementation Notes

- **Subject**: Interface for proxy and real object
- **RealSubject**: Actual object being proxied
- **Proxy**: Manages access to real subject
- Proxy implements same interface as subject
- Can control access, cache, or defer creation
- **Types**: Protection proxy, virtual proxy, cache proxy, remote proxy
- Maintain reference to real subject
- Delegate calls to real subject after proxy logic

UML / Class Diagram

Proxy - Class Diagram

Class Relationships

Class	Responsibility	Depends On
Employee	Subject interface - defines operations	None
EmployeeImpl	Real subject - actual expensive object	Implements Employee
EmployeeCacheProxy	Proxy - controls access, adds caching	Has Employee, uses cache
RedisCacheClient	External cache - stores cached data	None

How to Code This Pattern

1. **Create Subject Interface**: `Employee` with `getSalary()`, `getName()`

2. **Create Real Subject**: `EmployeeImpl` does expensive DB operations

3. **Create Proxy**: Implements same interface

```
class EmployeeCacheProxy implements Employee {
    private Employee employee;
    private Map<String, Object> cache;

    public EmployeeCacheProxy(Employee emp) {
        this.employee = emp;
        this.cache = new HashMap<>();
    }

    @Override
    public int getSalary() {
        if (cache.containsKey("salary")) {
            return (int) cache.get("salary");
        }
        int salary = employee.getSalary();
        cache.put("salary", salary);
        return salary;
    }
}
```

4. **Proxy Controls Access**:
   - Cache before delegating
   - Lazy load real object
   - Log/track access
   - Restrict access
5. **Client uses Proxy**: `Employee emp = new EmployeeCacheProxy(...)`

Proxy Types

Type	Purpose
Protection Proxy	Control access (security)
Virtual Proxy	Lazy initialization of expensive objects
Cache Proxy	Cache expensive operations
Remote Proxy	Represent remote object

Key Points

- **Same Interface**: Proxy implements same interface as real object
- **Transparent**: Client doesn't know it's using proxy
- **Add Behavior**: Before/after delegating to real object
- **Control Access**: Decide when and how to delegate

---

bridgePattern

Overview (README.md)

Bridge Pattern

What is it?

The Bridge pattern decouples an abstraction from its implementation so that the two can vary independently. It bridges the gap between abstraction and implementation.

When to use it?

- Abstraction and implementation should be independent
- Changes in implementation shouldn't affect client code
- Want to avoid permanent binding between abstraction and implementation
- Multiple implementations for same abstraction

Real-world Example

Living Things Breathing: Different living things (Dog, Fish, Tree) have different breathing mechanisms (Lungs, Gills, Photosynthesis). Bridge separates living things from breathing processes.

Key Benefits

✓ Decouples abstraction from implementation ✓ Implementation can change without affecting clients ✓ Avoid permanent binding between abstraction and implementation ✓ Improves code maintainability ✓ Follows Open/Closed Principle

Key Drawbacks

✗ More complex design (more classes needed) ✗ Overkill for simple hierarchies ✗ Increased indirection affects performance ✗ Can overcomplicate simple designs

Easy Analogy

Think of it like a car and its engine types: A car is abstraction (LivingThing) → It can be Sedan, SUV (Dog, Fish) → Engine type is implementation (Breathing) → Can be Petrol, Diesel (Lungs, Gills). You can mix any car with any engine.

Implementation Notes

- **Abstraction**: Defines high-level interface
- **RefinedAbstraction**: Extends abstraction
- **Implementor**: Defines lower-level interface
- **ConcreteImplementor**: Implements specific behavior
- Abstraction should contain reference to Implementor
- Use composition instead of inheritance
- Separate abstraction hierarchy from implementation hierarchy

UML / Class Diagram

Bridge - Class Diagram

Class Relationships

Class	Responsibility	Depends On
LivingThing	Abstraction - high-level interface	Uses BreathingProcess
Dog/Fish/Tree	Refined abstractions	Extend LivingThing
BreathingProcess	Implementor interface - low-level interface	None
Lungs/Gill/Photosynthesis	Concrete implementors	Implement BreathingProcess

How to Code This Pattern

1. **Separate Hierarchies**: Keep abstraction and implementation in separate hierarchies
2. **Abstraction contains Implementor**: `LivingThing` has reference to `BreathingProcess`
3. **Concrete Abstractions**: `Dog`, `Fish`, `Tree` extend abstraction
4. **Concrete Implementors**: Implement the implementor interface
5. **Combine dynamically**: `Dog` can use any `BreathingProcess`
6. **Avoid Explosion**: Without bridge, would have Dog-Lungs, Dog-Gills, etc. classes

Key Points

- **Bridge**: Separate abstraction from implementation
- **Two Hierarchies**: One for abstraction, one for implementation
- **Composition**: Abstraction uses composition with implementor
- **Flexibility**: Change implementation independently from abstraction

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compositePattern

Overview (README.md)

Composite Pattern

What is it?

The Composite pattern composes objects into tree structures to represent part-whole hierarchies. It allows clients to treat individual objects and compositions uniformly.

When to use it?

- Represent hierarchical structures (trees)
- Clients should treat individual and composite objects the same way
- Part-whole relationships need to be represented
- File system or menu structures

Real-world Example

File System: Files and directories form a tree. Both can have operations like get size, copy. Composite pattern treats them uniformly.

Key Benefits

✓ Simplifies client code (same treatment for leaf and composite) ✓ Flexible tree structures (easy to add/remove nodes) ✓ Follows Single Responsibility Principle ✓ Follows Open/Closed Principle ✓ Recursive composition is natural

Key Drawbacks

✗ May force inappropriate operations on leaves ✗ Less type safety (both leaf and composite look same) ✗ Complexity increases with tree depth ✗ Performance issues with deep trees

Easy Analogy

Think of it like a folder structure on your computer: Folders contain files and other folders → You can ask any folder/file "what's your size?" → A folder calculates size by adding all children's sizes. Same operation, different implementations.

Implementation Notes

- **Component**: Declares common operations
- **Leaf**: Represents leaf objects (no children)
- **Composite**: Represents composite objects (has children)
- Composite implements add/remove/get children methods
- Both leaf and composite implement component operations
- Watch out for inappropriate operations on leaves
- Consider empty checks for operations on leaves

UML / Class Diagram

Composite - Class Diagram

Syntax error in text
mermaid version 11.12.2

Class Relationships

Class	Responsibility	Depends On
FileSystem	Component interface - defines common operations	None
File	Leaf - represents file with no children	Implements FileSystem
Directory	Composite - contains FileSystem objects (files/folders)	Implements FileSystem, contains FileSystem

How to Code This Pattern

1. **Create Component Interface**: Define `getSize()`, `add()`, `remove()`
2. **Create Leaf Class**: `File` implements interface, `getSize()` returns file size
3. **Create Composite Class**: `Directory` implements interface
4. **Maintain Children**: Directory has list of FileSystem objects
5. **Add/Remove Methods**: Composite implements add() and remove()
6. **Recursive Operations**: `Directory.getSize()` sums all children's sizes
7. **Uniform Treatment**: Both File and Directory are treated as FileSystem

Key Points

- **Leaf**: File - no children, performs actual work
- **Composite**: Directory - can have children
- **Recursive**: Operations work recursively through tree
- **Uniform**: Client treats both File and Directory same way

---

flyweightPattern

Overview (README.md)

Flyweight Pattern

What is it?

The Flyweight pattern uses sharing to support large numbers of fine-grained objects efficiently by sharing common state between multiple objects.

When to use it?

- Application uses large number of similar objects
- Memory usage is a concern
- Intrinsic state can be shared between objects
- Many objects with same properties

Real-world Example

Robot Game: Game has thousands of robots. Instead of creating separate objects, share intrinsic state (sprite type) and keep extrinsic state (position) separate.

Key Benefits

✓ Significantly reduces memory usage ✓ Improves application performance ✓ Centralizes management of shared state ✓ Good for large-scale applications ✓ Transparent to client code

Key Drawbacks

✗ Increased complexity in code ✗ Thread-safety concerns (shared objects) ✗ Performance overhead from object lookup ✗ Intrinsic/extrinsic state separation not always clear

Easy Analogy

Think of it like a multiplayer game with 10,000 soldiers: All soldiers have the same armor type (shared/intrinsic) but different positions (unique/extrinsic). Instead of creating 10,000 objects, create 1 shared soldier object, reuse it with different positions.

Implementation Notes

- **Flyweight**: Interface for shared and unique states
- **ConcreteFlyweight**: Stores intrinsic state (shared)
- **FlyweightFactory**: Creates and manages flyweight objects
- **Client**: Maintains extrinsic state
- Separate intrinsic (shared) from extrinsic (unique) state
- Use factory pattern to create/retrieve flyweights
- Ensure flyweight objects are immutable
- Consider thread-safety for shared objects
- Useful when you have thousands of similar objects

UML / Class Diagram

Flyweight - Class Diagram

Class Relationships

Class	Responsibility	Depends On
IRobot	Flyweight interface - defines robot display method	None
HumanoidRobot/RoboticDogImpl	Concrete flyweights - store intrinsic state (sprite)	Implements IRobot, has shared Sprite
RoboticFactory	Flyweight factory - creates and caches flyweights	Creates and manages IRobot
Sprite	Intrinsic state - shared across many robots (immutable)	None

How to Code This Pattern

1. **Separate Intrinsic/Extrinsic State**:
    - **Intrinsic**: Sprite (shared) - stored in flyweight
    - **Extrinsic**: Position x, y (unique) - passed as parameter
2. **Create Flyweight Interface**: `IRobot` with `display(x, y)`
3. **Create Concrete Flyweights**: Store only intrinsic state

4. **Create Factory**: Cache and reuse flyweights

```
class RoboticFactory {
    private Map<String, IRobot> robots = new HashMap<>();

    public IRobot createRobot(String type) {
        if (!robots.containsKey(type)) {
            robots.put(type, new HumanoidRobot(new Sprite(...)));
        }
        return robots.get(type);
    }
}
```

5. **Client provides extrinsic state**: `robot.display(100, 200)`

Key Points

- **Shared State**: Intrinsic state shared across many objects
- **Unique State**: Extrinsic state kept in client
- **Memory Optimization**: 10,000 robots, 1 sprite = huge savings
- **Immutable**: Flyweight objects must be immutable
- **Factory**: Factory manages caching and reuse