

AMSS Lecture 11: Design Patterns (II)

Traian-Florin Șerbănuță

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Agenda

1. Recall
 - 1.1 What are Design Patterns?
 - 1.2 Classification of Patterns
2. Patterns
 - 2.1 **Visitor**
 - 2.2 **Mediator**
 - 2.3 **Bridge**
 - 2.4 **Adapter**
 - 2.5 **Decorator**
 - 2.6 **Proxy**
 - 2.7 **Composite**
3. Wrap-up

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	Builder, Factory, Singleton
Structural	How classes and objects are composed	Adapter, Bridge, Composite, Decorator, Proxy
Behavioral	How objects interact and communicate	Visitor, Mediator, State

Visitor Pattern

Type

Behavioral pattern

Intent

Separate an algorithm from the object structure it operates on by allowing new operations without modifying existing classes.

Problem Solved

How to add new operations to a set of related classes without changing their source code?

Solution

Define a **Visitor** interface with visit methods for each element type.

Elements accept a visitor and delegate the operation to it.

Visitor Pattern — concrete example scenario

Problem

- ▶ You maintain a graphics library containing shapes like Circle and Rectangle.
- ▶ You frequently need to add new operations—such as area calculation, exporting, rendering—
 - ▶ but you want to avoid modifying the existing shape classes every time.

Visitor Pattern — concrete example scenario

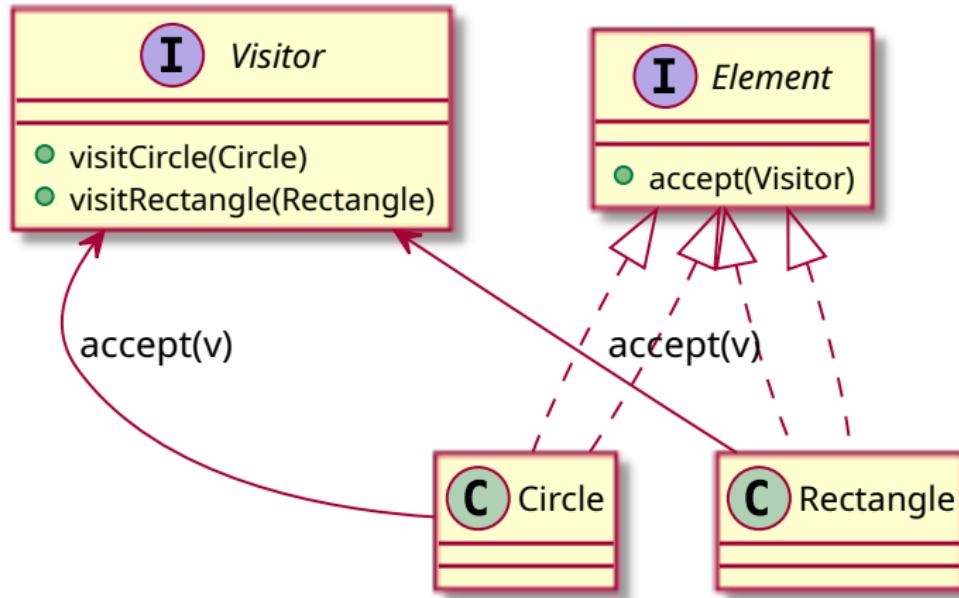
Problem

- ▶ You maintain a graphics library containing shapes like Circle and Rectangle.
- ▶ You frequently need to add new operations—such as area calculation, exporting, rendering—
 - ▶ but you want to avoid modifying the existing shape classes every time.

Solution

The Visitor pattern lets you add new operations by creating new Visitor classes, while the shapes themselves remain unchanged and simply “accept” visitors.

Visitor Pattern — concrete example diagram



Visitor Pattern — concrete example code

Source file

```
// Element
interface Shape {
    void accept(Visitor v);
}

// Concrete Elements
class Circle implements Shape {
    double radius = 5;
    public void accept(Visitor v) { v.visit(this); }
}

class Rectangle implements Shape {
    double width = 4, height = 3;
    public void accept(Visitor v) { v.visit(this); }
}

// Visitor
```

Visitor Pattern Exercise

Task

Design a system for processing elements in an online document editor: Paragraph, Image, and Table.

Define two possible operations: spell-checking and exporting to HTML.

Sketch how the Visitor pattern would let you add these operations without modifying the element classes.

Goal

Practice identifying when Visitor is useful:

when new operations must be added independently of existing structures.

Mediator Pattern

Type

Behavioral pattern

Intent

Define an object that encapsulates how a set of objects interact, promoting loose coupling.

Problem Solved

How to reduce direct dependencies and complex communication between many interacting objects?

Solution

Create a Mediator object that centralizes communication logic. Colleagues communicate only through the mediator.

Mediator Pattern — concrete example scenario

Problem

In a chat application, every user needs to send messages to others. If each user communicated directly with every other user, the system would become highly coupled and difficult to maintain.

Mediator Pattern — concrete example scenario

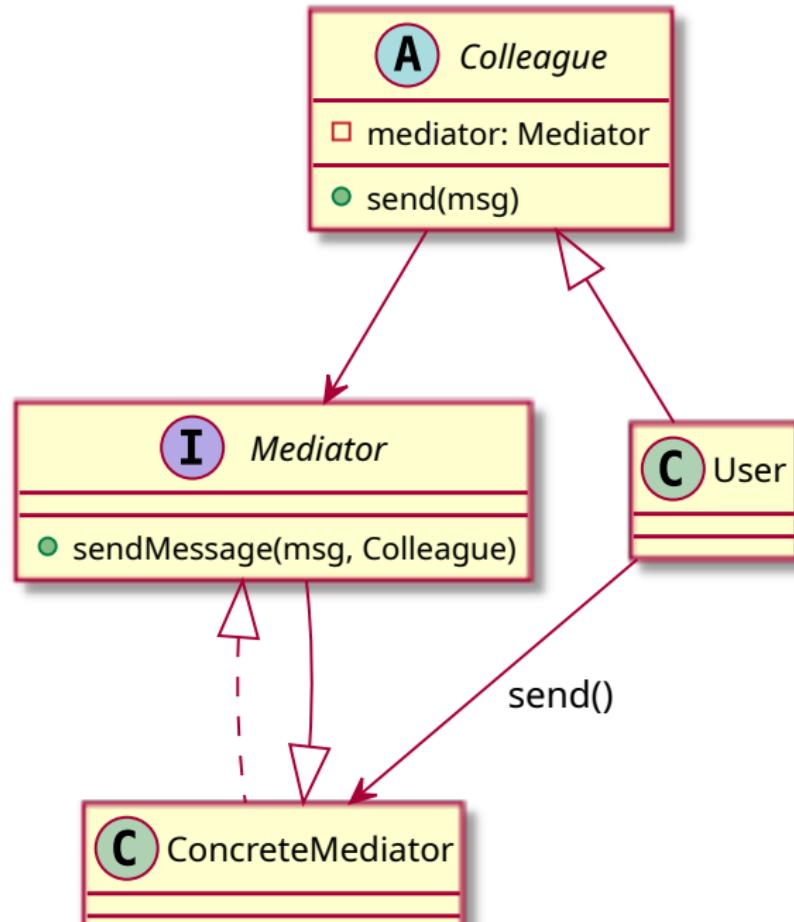
Problem

In a chat application, every user needs to send messages to others. If each user communicated directly with every other user, the system would become highly coupled and difficult to maintain.

Solution

The Mediator pattern introduces a central ChatRoom that manages all communication. Users send messages through the mediator, drastically simplifying interaction.

Mediator Pattern — concrete example diagram



Mediator Pattern — concrete example code

Source file

```
// Mediator
interface ChatMediator {
    void sendMessage(String msg, User user);
}

// Concrete Mediator
class ChatRoom implements ChatMediator {
    public void sendMessage(String msg, User user) {
        System.out.println(user.getName() + ": " + msg);
    }
}

// Colleague
abstract class User {
    protected ChatMediator mediator;
    protected String name;
    User(String name, ChatMediator mediator) {
```

Mediator Pattern Exercise

Task

Imagine a smart home system where devices (lights, thermostat, alarm, blinds) must coordinate actions (e.g., “away mode”).

Design a Mediator that centralizes communication so devices do not directly reference or call each other.

Outline the mediator role and how devices interact with it.

Goal

Recognize situations with complex object interactions and apply a mediator to simplify communication.

Bridge Pattern

Type

Structural pattern

Intent

Decouple an abstraction from its implementation so that the two can vary independently.

Problem Solved

How to avoid a class explosion caused by combining multiple abstractions with multiple implementations?

Solution

Split abstraction and implementation into separate class hierarchies, connecting them via a bridge interface.

Bridge Pattern — concrete example scenario

Problem

You want to build a universal remote-control system that works with different devices

like TVs, Radios, and projectors.

If you directly subclass for every combination (e.g., AdvancedTVRemote, BasicRadioRemote),
you get class explosion.

Bridge Pattern — concrete example scenario

Problem

You want to build a universal remote-control system that works with different devices

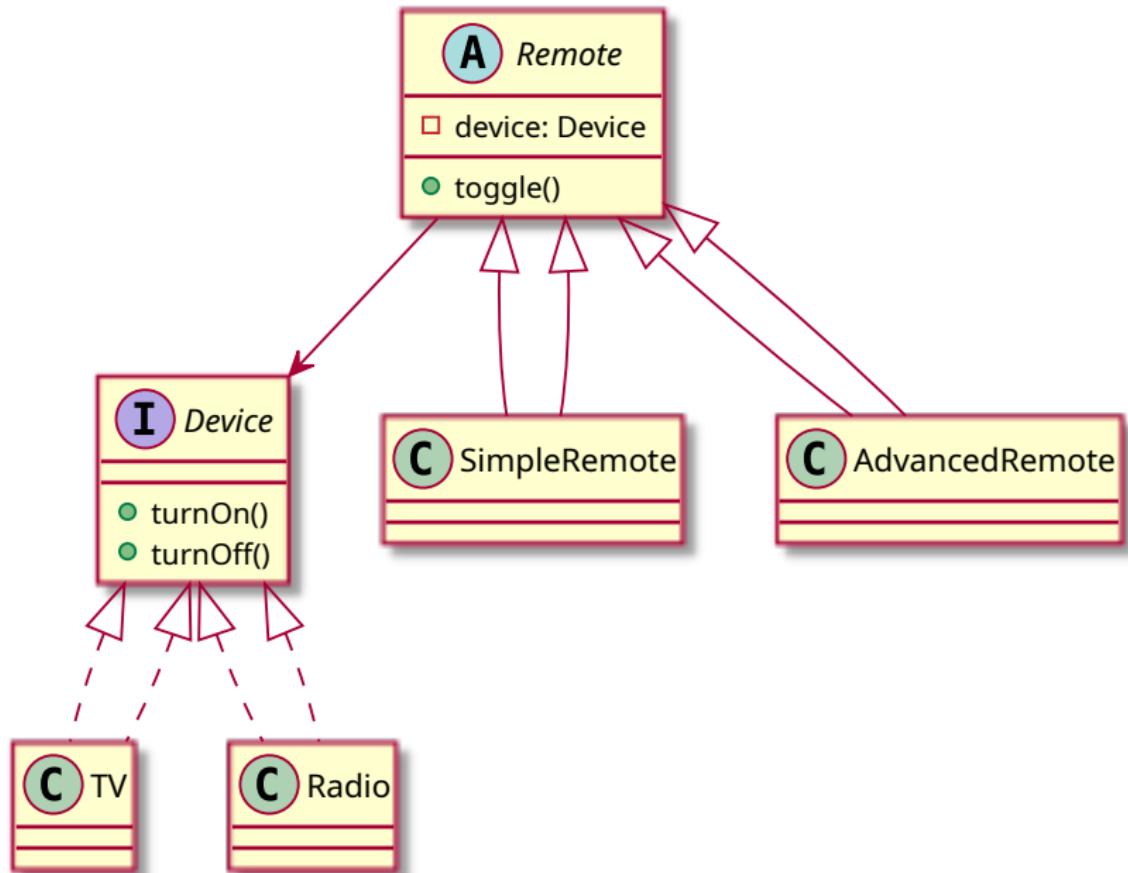
like TVs, Radios, and projectors.

If you directly subclass for every combination (e.g., AdvancedTVRemote, BasicRadioRemote), you get class explosion.

Solution

The Bridge pattern separates the abstraction (Remote) from the implementation (Device), allowing each to evolve independently and avoiding unnecessary subclasses.

Bridge Pattern — concrete example diagram



Bridge Pattern — concrete example code

Source file

```
// Implementor
interface Device {
    void turnOn();
    void turnOff();
}

// Concrete Implementors
class TV implements Device {
    public void turnOn() { System.out.println("TV ON"); }
    public void turnOff() { System.out.println("TV OFF"); }
}

// Abstraction
abstract class Remote {
    protected Device device;
    Remote(Device d) { this.device = d; }
    abstract void toggle();
}
```

Bridge Pattern Exercise

Task

You are building a drawing tool with two dimensions of variability: Shapes (Circle, Rectangle, Line) and Rendering Methods (OpenGL, SVG).

Explain how to apply the Bridge pattern so all shapes can be rendered with any rendering method without class explosion.

Goal

Identify separate dimensions of change and design a usable abstraction/ implementation split.

Adapter Pattern

Type

Structural pattern

Intent

Convert the interface of one class into another interface clients expect.

Problem Solved

How to make incompatible interfaces work together without changing existing code?

Solution

Create an Adapter that wraps an existing class and exposes the desired target interface.

Adapter Pattern — concrete example scenario

Problem

Your media application expects a MediaPlayer interface with a play() method,

but your existing audio engine (LegacyPlayer) only supports playMp3().

You cannot modify the legacy system, but you must integrate it.

Adapter Pattern — concrete example scenario

Problem

Your media application expects a MediaPlayer interface with a play() method,

but your existing audio engine (LegacyPlayer) only supports playMp3().

You cannot modify the legacy system, but you must integrate it.

Solution

The Adapter pattern wraps the incompatible class and exposes the interface the client expects,

allowing the two systems to work together seamlessly.

Adapter Pattern — concrete example code

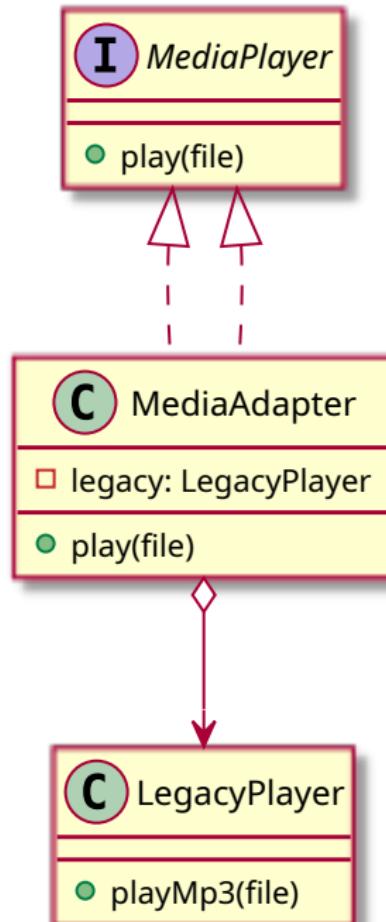
Source file

```
// Target interface
interface MediaPlayer {
    void play(String file);
}

// Adaptee
class LegacyPlayer {
    void playMp3(String filename) {
        System.out.println("Playing MP3: " + filename);
    }
}

// Adapter
class MediaAdapter implements MediaPlayer {
    private LegacyPlayer legacy = new LegacyPlayer();
    public void play(String file) { legacy.playMp3(file); }
}
```

Adapter Pattern — concrete example diagram



Adapter Pattern Exercise

Task

A new external weather service provides data in a completely different format from your current WeatherData interface.

Design an Adapter that lets your system continue using WeatherData while seamlessly integrating the new provider.

Goal

Practice wrapping an incompatible API so existing code works unchanged.

Decorator Pattern

Type

Structural pattern

Intent

Attach additional responsibilities to an object dynamically without modifying its class.

Problem Solved

How to add flexible, combinable features to objects without subclass explosion?

Solution

Wrap objects with decorator classes that implement the same interface and add behavior before/after delegating calls.

Decorator Pattern — concrete example scenario

Problem

A beverage ordering system needs to allow customers to add ingredients

like milk, sugar, or whipped cream to drinks.

Creating a subclass for every combination
(`CoffeeWithMilkAndSugar`, etc.)
would cause a combinational explosion.

Decorator Pattern — concrete example scenario

Problem

A beverage ordering system needs to allow customers to add ingredients

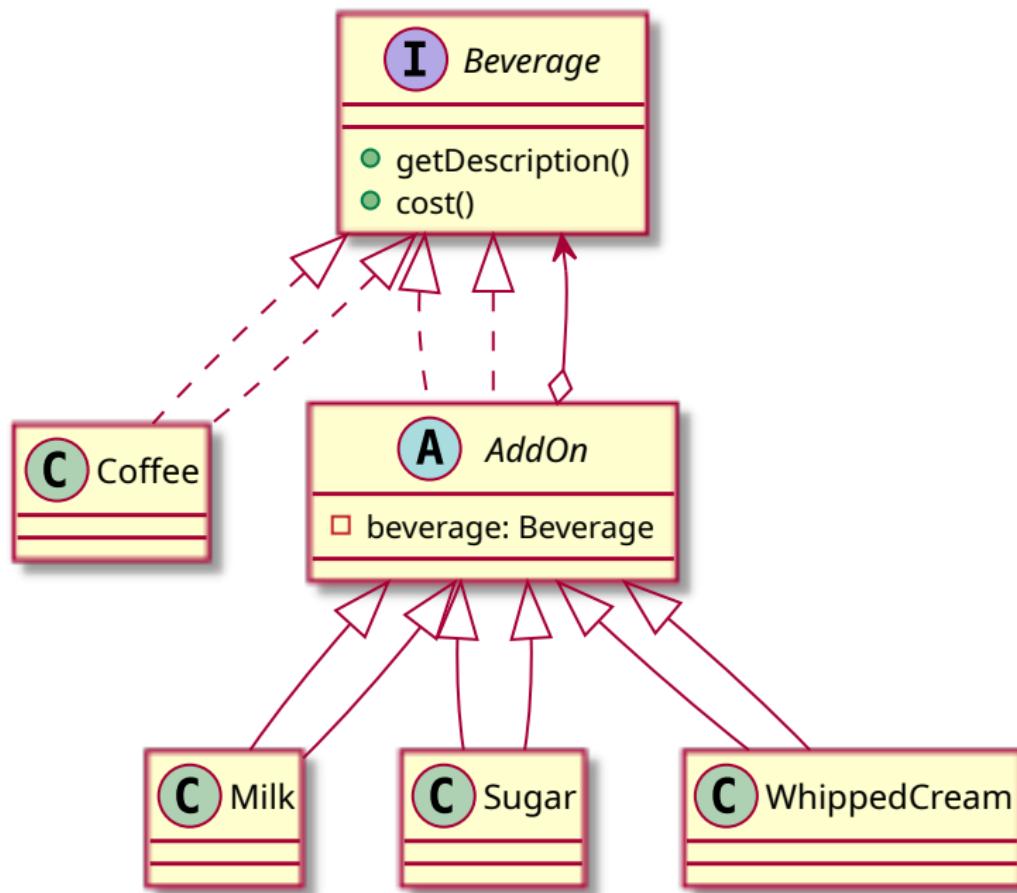
like milk, sugar, or whipped cream to drinks.

Creating a subclass for every combination
(CoffeeWithMilkAndSugar, etc.)
would cause a combinational explosion.

Solution

The Decorator pattern lets you dynamically wrap beverages with add-ons,
mixing and matching features without modifying existing code.

Decorator Pattern — concrete example diagram



Decorator Pattern — concrete example code

Source file

```
// Component
interface Beverage {
    String getDescription();
    double cost();
}

// Concrete Component
class Coffee implements Beverage {
    public String getDescription() { return "Coffee"; }
    public double cost() { return 2.0; }
}

// Decorator
abstract class AddOn implements Beverage {
    protected Beverage beverage;
    AddOn(Beverage b) { beverage = b; }
}
```

Decorator Pattern Exercise

Task

Consider an online text editor where users can apply features such as: Bold, Italic, Underline, Syntax Highlighting.

Describe how you could use Decorators to apply multiple text styles to a plain Text object at runtime, without creating many subclasses.

Goal

Think about dynamic composition of responsibilities using decorators.

Proxy Pattern

Type

Structural pattern

Intent

Provide a surrogate or placeholder for another object to control access to it.

Problem Solved

How to manage access to a resource-heavy or remote object (e.g., lazy loading, caching, security)?

Solution

Implement a proxy that implements the same interface as the real subject and controls access before forwarding requests.

Proxy Pattern — concrete example scenario

Problem

Accessing a real database connection is slow and expensive.
However, you only need the actual connection when a query is executed.

Proxy Pattern — concrete example scenario

Problem

Accessing a real database connection is slow and expensive.

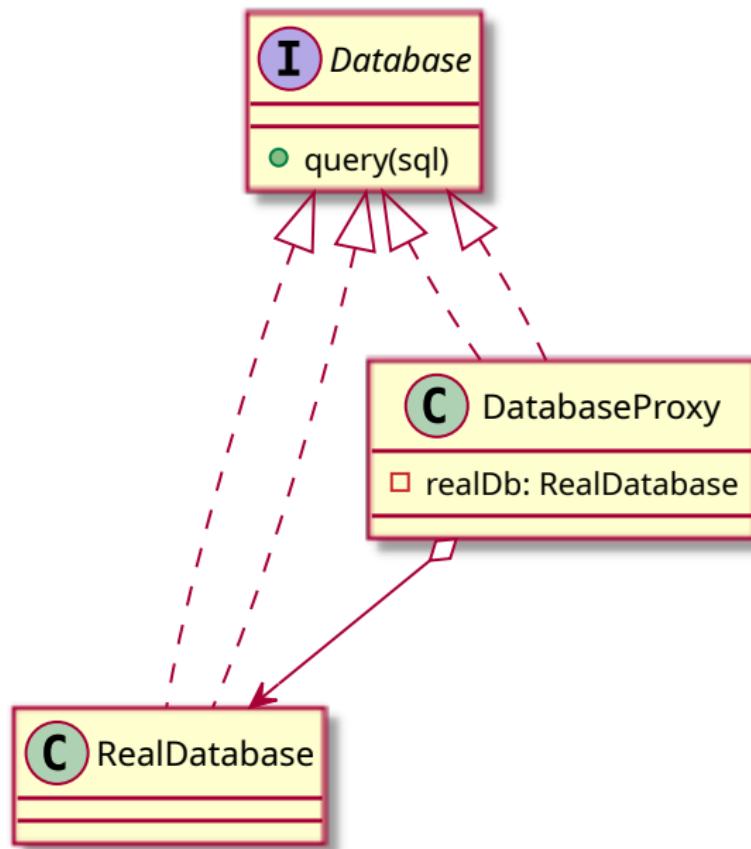
However, you only need the actual connection when a query is executed.

Solution

The Proxy pattern allows you to create a DatabaseProxy that delays the creation of the RealDatabase until it's truly needed (lazy loading),

controlling access and improving performance.

Proxy Pattern — concrete example diagram



Proxy Pattern — concrete example code

Source file

```
// Subject
interface Database {
    void query(String sql);
}

// Real Subject
class RealDatabase implements Database {
    public RealDatabase() {
        System.out.println("Connecting to database...");
    }
    public void query(String sql) {
        System.out.println("Executing query: " + sql);
    }
}

// Proxy
class DatabaseProxy implements Database {
```

Proxy Pattern Exercise

Task

Your application accesses remote image files stored on a cloud server. Design a Proxy that loads the actual image only when it is displayed (for example, when scrolling in a gallery).

Describe the responsibilities of both the proxy and the real image.

Goal

Identify opportunities for lazy loading, access control, and indirection.

Composite Pattern

Type

Structural pattern

Intent

Compose objects into tree structures to represent part–whole hierarchies.

Problem Solved

How to treat individual objects and groups of objects uniformly?

Solution

Define a common component interface.

Leaf objects implement base behavior; composite objects store children and delegate operations recursively.

Composite Pattern — concrete example scenario

Problem

You want to represent a hierarchical file system where folders can contain both files and other folders.

Clients should treat individual files and folder groups uniformly (e.g., calling `show()` on either should work).

Composite Pattern — concrete example scenario

Problem

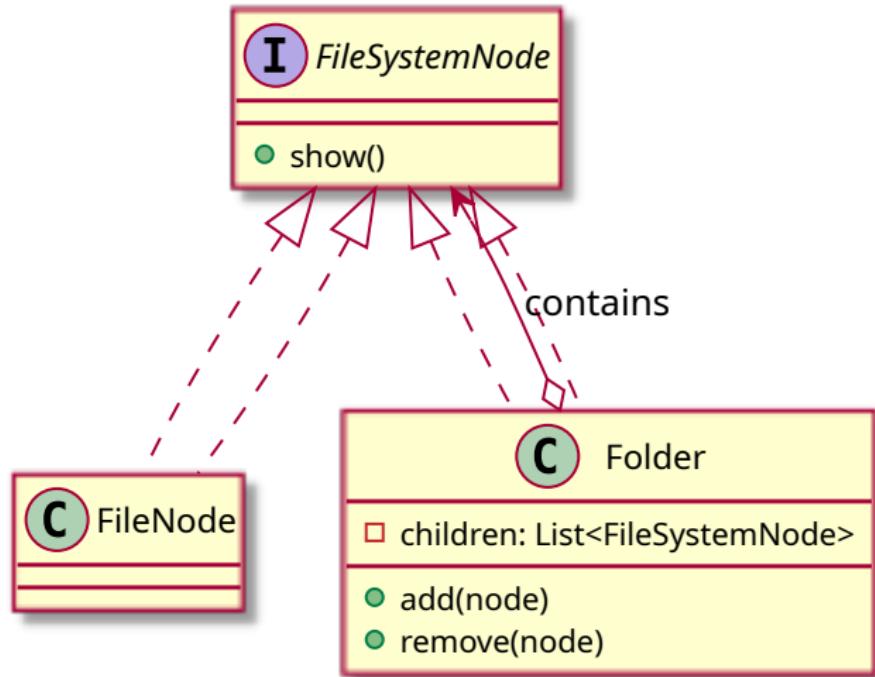
You want to represent a hierarchical file system where folders can contain both files and other folders.

Clients should treat individual files and folder groups uniformly (e.g., calling `show()` on either should work).

Solution

The Composite pattern allows you to build tree structures in which both leaf nodes (files) and composite nodes (folders) share the same interface.

Composite Pattern — concrete example scenario



Composite Pattern — concrete example code

```
// Component
interface FileSystemNode {
    void show();
}

// Leaf
class FileNode implements FileSystemNode {
    private String name;
    FileNode(String name) { this.name = name; }
    public void show() { System.out.println("File: " + name);
}

// Composite
class Folder implements FileSystemNode {
    private String name;
    private java.util.List<FileSystemNode> children = new ...
    Folder(String name) { this.name = name; }
```

Composite Pattern Exercise

Task

You are modeling hierarchical UI components: Buttons, Labels, TextFields, and Containers that hold other components.

Explain how the Composite pattern allows you to treat every UI element uniformly (e.g., calling `render()` or `resize()`).

Sketch the component interface and the composite structure.

Goal

Understand how to represent part–whole hierarchies with recursive composition and uniform treatment.

Wrap-Up

Key Insights

- ▶ **Visitor** – Add new operations to existing class hierarchies *without modifying them* by externalizing behavior into Visitor objects.
- ▶ **Mediator** – Reduce tangled, many-to-many communication by centralizing interaction logic inside a mediator object.
- ▶ **Bridge** – Separate abstraction from implementation to avoid class explosion and allow both sides to vary independently.
- ▶ **Adapter** – Make incompatible interfaces work together by wrapping one interface to match the expectations of another.
- ▶ **Decorator** – Dynamically add responsibilities or behavior to objects at runtime without subclassing or modifying original classes.
- ▶ **Proxy** – Control or enhance access to another object (lazy loading, security, caching)

Wrap-up diagram

