Composite Design Pattern in Java

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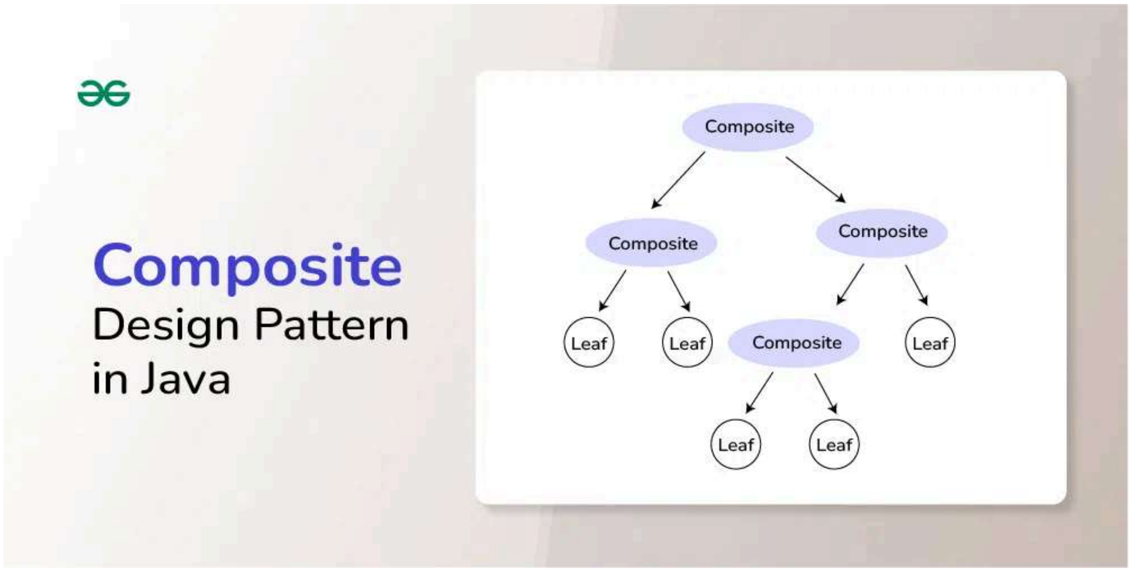
The Composite Design Pattern is a structural design pattern that lets you compose objects into tree-like structures to represent part-whole hierarchies. It allows clients to treat individual objects and compositions of objects uniformly. In other words, whether dealing with a single object or a group of objects (composite), clients can use them interchangeably.

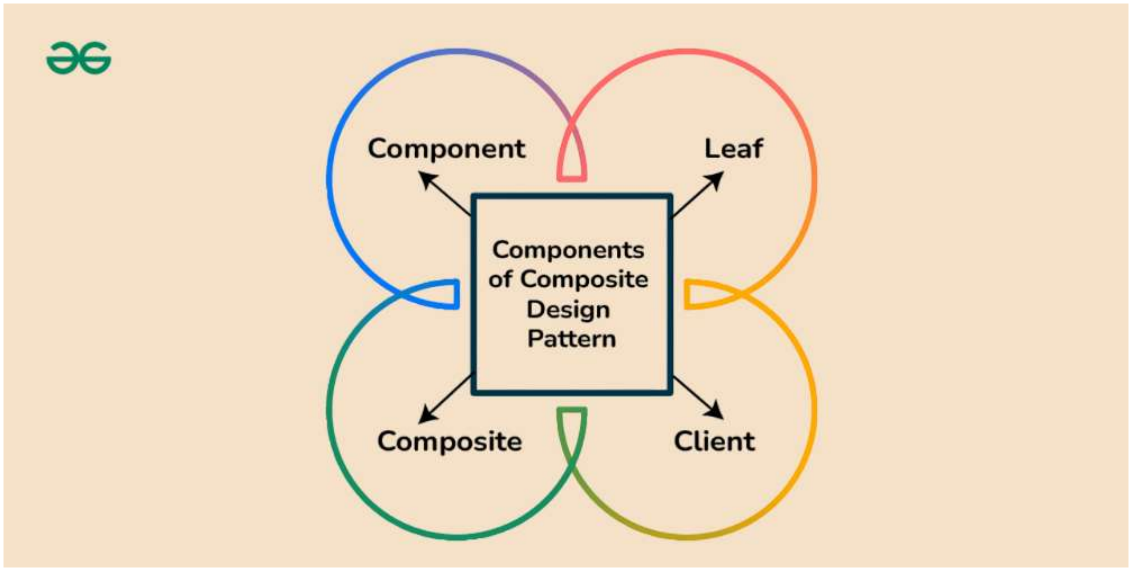
> *As described by the Gang of four, "Compose objects into tree structure to represent **part-whole hierarchies**. Composite lets client treat individual objects and compositions of objects uniformly".*



The key concept is that you can manipulate a single instance of the object just as you would manipulate a group of them. The operations you can perform on all the composite objects often have the least common denominator relationship.

Important Topics for the Composite Design Pattern in Java

Components of Composite Design Pattern



1. Component

The component declares the interface for objects in the composition and for accessing and managing its child components. This is like a blueprint that tells us what both individual items (leaves) and groups of items (composites) should be able to do. It lists the things they all have in common.

2. Leaf

Leaf defines behavior for primitive objects in the composition. This is the basic building block of the composition, representing individual objects that don't have any child components. Leaf elements implement the operations defined by the Component interface.

3. Composite

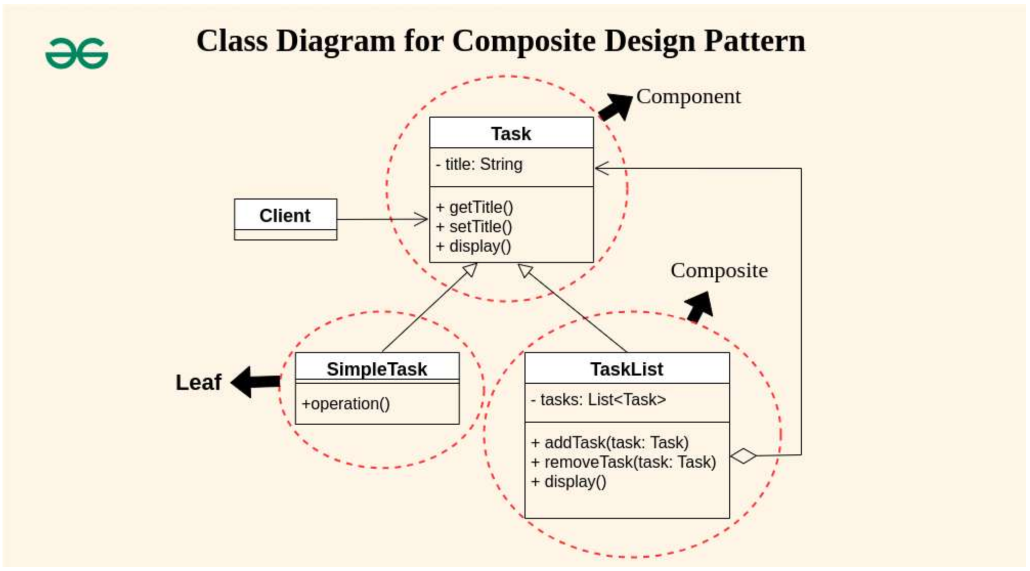
Composite stores child components and implements child-related operations in the component interface. This is a class that has child components, which can be either leaf elements or other composites. A composite class implements the methods declared in the Component interface, often by delegating the operations to its child components.

4. Client

The client manipulates the objects in the composition through the component interface. The client uses the component class interface to interact with objects in the composition structure. If the recipient is a leaf then the request is handled directly. If the recipient is a composite, then it usually forwards the request to its child components, possibly performing additional operations before and after forwarding.

Composite Design Pattern example in Java

> *Imagine you are building a project management system where tasks can be either simple tasks or a collection of tasks (subtasks) forming a larger task.*



1. Task (Component)

- Represents the common interface for both simple tasks and task lists.
- Defines methods such as `getTitle()`, `setTitle()`, and `display()`.

```
// Component
```

```java

public interface Task {
    String getTitle();
    void setTitle(String title);
    void display();
}
```

2. SimpleTask (Leaf)

- Represents an individual task with a title.
- Implements the `Task` interface.

```java
// Leaf

public class SimpleTask implements Task {
    private String title;

    public SimpleTask(String title) {
        this.title = title;
    }

    @Override
    public String getTitle() {
        return title;
    }

    @Override
    public void setTitle(String title) {
        this.title = title;
    }

    @Override
    public void display() {
        System.out.println("Simple Task: " + title);
    }
}
```

3. TaskList (Composite)

- Represents a collection of tasks, which can include both simple tasks and other task lists.
- Implements the `Task` interface but also has a list of tasks (`List<Task>`).
- Defines methods to add, remove, and display tasks.

```java
import java.util.ArrayList;
import java.util.List;

// Composite

public class TaskList implements Task {
    private String title;
    private List<Task> tasks;

    public TaskList(String title) {
        this.title = title;
        this.tasks = new ArrayList<>();
    }

    @Override
    public String getTitle() {
        return title;
    }

    @Override
    public void setTitle(String title) {
        this.title = title;
    }

    public void addTask(Task task) {
        tasks.add(task);
    }

    public void removeTask(Task task) {
        tasks.remove(task);
    }

    @Override
    public void display() {
        System.out.println("Task List: " + title);
        for (Task task : tasks) {
            task.display();
        }
    }
}
```

4. TaskManagementApp (Client)

- Represents the application that uses the Composite Design Pattern to manage tasks.
- It creates a mix of simple tasks and task lists, showcasing how the Composite pattern allows treating both individual tasks and task collections uniformly.
- The created tasks are displayed in a hierarchical structure to illustrate the pattern's flexibility and uniform handling of different task types.

```java
// Client

public class TaskManagementApp {
    public static void main(String[] args) {
        // Creating simple tasks
        Task simpleTask1 = new SimpleTask("Complete Coding");
        Task simpleTask2 = new SimpleTask("Write
Documentation");

        // Creating a task list
        TaskList projectTasks = new TaskList("Project Tasks")
        projectTasks.addTask(simpleTask1);
        projectTasks.addTask(simpleTask2);

        // Nested task list
        TaskList phase1Tasks = new TaskList("Phase 1 Tasks");
        phase1Tasks.addTask(new SimpleTask("Design"));
        phase1Tasks.addTask(new SimpleTask("Implementation")

        projectTasks.addTask(phase1Tasks);

        // Displaying tasks
        projectTasks.display();
    }
}
```

Complete code for the above example:

This code includes the `Task`, `SimpleTask`, `TaskList`, and `TaskManagementApp` classes. It demonstrates the Composite Design Pattern for organizing tasks in a project management system.

```java
import java.util.ArrayList;
import java.util.List;

// Component
interface Task {
    String getTitle();
    void setTitle(String title);
    void display();
}

// Leaf
class SimpleTask implements Task {
    private String title;

    public SimpleTask(String title) {
        this.title = title;
    }

    @Override
    public String getTitle() {
        return title;
    }

    @Override
    public void setTitle(String title) {
        this.title = title;
    }

    @Override
    public void display() {
        System.out.println("Simple Task: " + title);
    }
}

// Composite
class TaskList implements Task {
    private String title;
    private List<Task> tasks;

    public TaskList(String title) {
        this.title = title;
        this.tasks = new ArrayList<>();
    }

    @Override
    public String getTitle() {
        return title;
    }

    @Override
    public void setTitle(String title) {
        this.title = title;
    }

    public void addTask(Task task) {
        tasks.add(task);
    }

    public void removeTask(Task task) {
        tasks.remove(task);
    }

    @Override
    public void display() {
        System.out.println("Task List: " + title);
        for (Task task : tasks) {
            task.display();
        }
    }
}

// Client
```

```java
public class TaskManagementApp {
    public static void main(String[] args) {
        // Creating simple tasks
        Task simpleTask1 = new SimpleTask("Complete Coding");
        Task simpleTask2 = new SimpleTask("Write Documentation");

        // Creating a task list
        TaskList projectTasks = new TaskList("Project Tasks")
        projectTasks.addTask(simpleTask1);
        projectTasks.addTask(simpleTask2);

        // Nested task list
        TaskList phase1Tasks = new TaskList("Phase 1 Tasks");
        phase1Tasks.addTask(new SimpleTask("Design"));
        phase1Tasks.addTask(new SimpleTask("Implementation"))

        projectTasks.addTask(phase1Tasks);

        // Displaying tasks
        projectTasks.display();
    }
}
```

Output

```
Task List: Project Tasks
Simple Task: Complete Coding
Simple Task: Write Documentation
Task List: Phase 1 Tasks
Simple Task: Design
Simple Task: Implementation
```

Why do we need Composite Design Pattern?

The Composite Design Pattern was created to address specific challenges related to the representation and manipulation of hierarchical structures in a uniform way. Here are some points that highlight the need for the Composite Design Pattern:

1. **Uniform Interface:**

- The Composite Pattern provides a uniform interface for both individual objects and compositions.
- This uniformity simplifies client code, making it more intuitive and reducing the need for conditional statements to differentiate between different types of objects.
- Other design patterns may not offer the same level of consistency in handling individual and composite objects.

2. **Hierarchical Structures:**
    - The primary focus of the Composite Pattern is to deal with hierarchical structures where objects can be composed of other objects.
    - While other patterns address different types of problems, the Composite Pattern specifically targets scenarios involving tree-like structures.

3. **Flexibility and Scalability:**
    - The Composite Pattern allows for dynamic composition of objects, enabling the creation of complex structures.
    - It promotes flexibility and scalability, making it easier to add or remove elements from the hierarchy without modifying the client code.

4. **Common Operations:**
    - By defining common operations at the component level, the Composite Pattern reduces code duplication and promotes a consistent approach to handling both leaf and composite objects.
    - Other design patterns may not provide the same level of support for common operations within hierarchical structures.

5. **Client Simplification:**
    - The Composite Pattern simplifies client code by providing a unified way to interact with individual and composite objects. This simplification is particularly valuable when working with complex structures, such as graphical user interfaces or organizational hierarchies.

When to use Composite Design Pattern?

Composite Pattern should be used when clients need to ignore the difference between compositions of objects and individual objects. If programmers find that they are using multiple objects in the same way, and often have nearly identical code to handle each of them, then composite is a good choice, it is less complex in this situation to treat primitives and composites as homogeneous.

- Less number of objects reduces the memory usage, and it manages to keep us away from errors related to memory like java.lang.OutOfMemoryError.
- Although creating an object in Java is really fast, we can still reduce the execution time of our program by sharing objects.

When not to use Composite Design Pattern?

Composite Design Pattern makes it harder to restrict the type of components of a composite. So it should not be used when you don't want to represent a full or partial hierarchy of objects.

- Composite Design Pattern can make the design overly general.
- It makes harder to restrict the components of a composite.
- Sometimes you want a composite to have only certain components. With Composite, you can't rely on the type system to enforce those constraints for you.
- Instead you'll have to use run-time checks.

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