The Composite Design Pattern

For details see Gamma et al. in “Design Patterns”
The Composite Design Pattern

Motivation

• Imagine a drawing editor where complex diagrams are build out of simple components and where the user wants to treat classes uniformly most of the time whether they represent primitives or components

• Example
  • Picture contains elements
  • Elements can be grouped
  • Groups can contain other groups
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Intent

• Compose objects into tree structures to represent part-whole hierarchies

• The composite design pattern lets clients treat individual objects and compositions of objects uniformly
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Example
The Composite Design Pattern

Example

Object-Diagram:
- Group
- Suitcase
- Case: Rectangle
- Name: Text
- Price: Text
- Handle: Line

class Group:
- draw()
- add(Element)
- remove(Element)
- getChild(int)

class Element:
- draw()

class Rectangle:
- draw()

class Line:
- draw()

class Text:
- draw()
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Applicability

Use composite when...

- you want to represent part-whole hierarchies of objects
- you want clients to be able to ignore the difference between individual and composed objects

(Clients will treat all objects in the composite structure uniformly.)
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Structure

Client

Leaf

Composite

Component

operation()

add(Composite)

remove(Composite)

getchild(int)

forall g in children

g.operation()
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Participants

• **Component**
  • Declares the interface for objects in the composition
  • Implements the default behavior as appropriate
  • (Often) declares an interface for accessing and managing child components

• **Leaf**
  Represents leaf objects in the composition; defines the primitive behavior

• **Composite**
  Stores children / composite behavior

• **Client**
  Accesses objects in the composition via Component interface
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Collaborations

• Clients interact with objects through the Component interface
• Leaf recipients react directly
• Composites forward requests to their children, possibly adding before/after operations

Excursion: A pattern is a collaboration

<table>
<thead>
<tr>
<th>Object diagram for the context.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which roles are involved?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence diagram for interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Interaction diagram for context &amp; interaction.)</td>
</tr>
<tr>
<td>What is the order of method calls?</td>
</tr>
</tbody>
</table>
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Consequences

• Primitive objects can be recursively composed ✓

• Clients can treat composites and primitives uniformly ✓
  (Clients do not have to write tag-and-case statement-style functions.)

• New components can easily be added ✓

• Design may become overly general ✗
  (You can’t always rely on the type system to enforce certain constraints; e.g. that a composite has only certain components.)
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Implementation

• **Explicit parent references**
  May facilitate traversal and management of a composite structure; often defined in the component class. Need to be maintained.

• **Sharing components**
  E.g. to reduce storage requirements it is often useful to share components. (→Flyweight Pattern)

• **Size of the component interface**
  To make clients unaware of the specific Leaf or Composite classes the Component class should define as many operations for Composite and Leaf as possible.
  (May require a little “creativity”…)
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Structure

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Component

{abstract}

operation()

add(Composite)
remove(Composite)
getChild(int)

Issue - General Design Principle:

“A class should only define methods meaningful to its subclasses.”

Leaf

operation()

Composite

operation()

add(Composite)
remove(Composite)
getChild(int)

Sometimes some “creativity” is needed!
The Composite Design Pattern - **Implementation**

**The GoF Design Patterns - Composite Pattern**

- **Placing child management operations - who declares them?**
  - at the root (Component) is convenient, but less safe because clients may try to do meaningless things
  - in Composite is safe

```
Component {abstract}
operation()

Component {abstract}
operation()
add(Component)
remove(Component)
getChild(int)

Composite
operation()
add(Component)
remove(Component)
getChild(int)

Composite
```

Trade-off between safety and transparency.
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Example - Component Class

• Computer equipment contains:
  • drives,
  • graphic cards in the PCIe slots,
  • memory,
  • and more.

• Such a part-whole structure can be modeled naturally with the Composite pattern.
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Example - Component Class

```java
public abstract class Equipment {
    private String name;
    public String name() { return name; }

    public abstract int price();
    // more methods, e.g., for power consumption etc.

    // Child management
    public abstract void add(Equipment eq);
    public abstract void remove(Equipment eq);
    public Iterator<Equipment> iterator(){
        return NULL_ITERATOR;
    }
}
```
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Example - Leaf Class

```java
public class HardDisk extends Equipment {

    public int price() {
        return 50;
    }

    ...
}
```
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Example - Composite Class

```java
public class CompositeEquipment extends Equipment {

    ...

    public int price() {
        int total = 0;
        for (int i=0; i < equipment.length; i++)
            total += equipment[i].price();
        return total;
    }

    public void add(Equipment eq) {...};
    public void remove(Equipment eq) {...};

    public Iterator<Equipment> iterator() {...};
}
```
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Example - Demo Usage

```java
public class Chassis extends CompositeEquipment {...}
public class Bus extends CompositeEquipment {...}
public class Card extends Equipment {...}
public class Mainboard extends CompositeEquipment {...}

Chassis chassis = new Chassis();
Mainboard mainboard = new Mainboard("Hypermulticore");
Bus bus = new Bus("PCiE Bus");

chassis.add(new HardDisk("Personal 2Tb Drive");
chassis.add(new HardDisk("512GB PCiE - SSD");
chasses.add(mainboard);
mainboard.add(bus);
bus.add(new Card("Graphics Card");
bus.add(new HardDisk("YetAnotherDisk"); // checks required...
System.out.println("Total price: " + chassis.price());
```

Further Definitions
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Known Uses

• View class of Model/View/Controller
• Application frameworks & toolkits
  • ET++, 1988
  • Graphics, 1988
  • Glyphs, 1990
  • InterViews, 1992
  • Java (AWT, Swing, SWT, JavaFX, Files, …)
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Related Patterns

- **Iterator**
  Traverse composite

- **Visitor**
  To localize operations that are otherwise distributed across Composite and Leaf classes

- **Chain of Responsibility**
  Use components hierarchy for task solving

- **Flyweight**
  For sharing components

Will be discussed later (as part of more advanced lectures.)
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Summary

The Composite Design Pattern facilitates to compose objects into tree structures to represent part-whole hierarchies.

Apply the composite pattern if clients can treat individual objects and compositions of objects uniformly.