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

**Drawing**

**Object-Diagram**

- **Suitcase**
  - **Group**
    - **Group**
      - **Handle**: Line
      - **Case**: Rectangle
      - **Name**: Text
    - **Tag**: Rectangle
    - **Price**: Text

**Corresponding Object Diagram**
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Example

Object-Diagram:
- Group
  - tag: Rectangle
  - price: Text
- handle: Line
- case: Rectangle
- name: Text

Suitcase
- 9.99€

Element
- draw()

Rectangle
- draw()

Line
- draw()

Text
- draw()

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

| Object diagram for the context.  
<table>
<thead>
<tr>
<th>Which roles are involved?</th>
</tr>
</thead>
</table>
| Sequence diagram for interactions  
| (Interaction diagram for context & interaction.)  
| What is the order of method calls? |
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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”.)

...(next page)
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Structure

### Issue - General Design Principle:

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

```
«method»
{
    forall g in children
    g.operation()
}
```

Sometimes some “creativity” is needed!
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

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;
    }
}
```
public class HardDisk extends Equipment {

    public int price() {
        return 50;
    }

    ...

}
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Example - Composite Class

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{
    // Implementation...
}

public class Bus extends CompositeEquipment{
    // Implementation...
}

public class Card extends Equipment{
    // Implementation...
}

public class Mainboard extends CompositeEquipment{
    // Implementation...
}

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

chassis.add(new HardDisk("Personal 1Tb Drive");
chases.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() );
```
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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, Files)
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
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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.