Object-Oriented Programming
Composite Pattern

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Catalog of Design patterns

- **Creational patterns**
  - Abstract Factory, Builder, Factory Method, Prototype, Singleton

- **Structural patterns (composition)**
  - Adaptor, Bridge, Composite, Decorator, Facade, Flyweight, Proxy

- **Behavioral patterns (interaction)**
  - Chain of Responsibility, Command, Interpreter, Iterator, Mediator, Memento, Observer, State, Strategy, Template Method, Visitor
Creational patterns

- **Abstract Factory**
  - Provide an interface for creating families of related or dependent objects without specifying their concrete classes.

- **Builder**
  - Separate the construction of a complex object from its representation so that same construction process can create different representations.

- **Factory Method**
  - Define an interface for creating an object, but let subclass decide which class to instantiate.

- **Singleton**
  - Ensure a class only has one instance, and provide a global point of access to it.
Structural patterns (1)

- **Adaptor**
  - Convert the interface of a class into another interface clients expect.

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

- **Composite**
  - Compose objects into tree structures to represent part-whole hierarchies. Composite lets clients treat individual objects and compositions of objects uniformly.

- **Decorator**
  - Attach additional responsibilities to an object dynamically.
Structural patterns (2)

- **Facade**
  - Provide a unified interface to a set of interfaces in subsystem. Facade defines a higher-level interface that makes the subsystem easier to use.

- **Flyweight**
  - Use sharing to support large numbers of fine-grained objects efficiently.

- **Proxy**
  - Provide a surrogate or placeholder for another object to control access to it.
Behavioral patterns (1)

- **Chain of Responsibility**
  - Avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request.

- **Command**
  - Encapsulate a request as an object, thereby letting you parameterize clients with different requests.

- **Interpreter**
  - Given a language, define a representation for its grammar along with an interpreter that uses the representation to interpret sentences in the language.

- **Iterator**
  - Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.
Behavioral patterns (2)

- **Mediator**
  - Define an object that encapsulates how a set of objects interact.

- **Memento**
  - Without violating encapsulation, capture and externalize an object’s internal state so that the object can be restored to this state later.

- **Observer**
  - Define a one-to-many dependency between objects so that when one object changes state, all its dependants are notified and updated automatically.

- **State**
  - Allow an object to alter its behavior when its internal state changes. The object all appear to change its class.
Behavioral patterns (3)

- **Strategy**
  - Define a family of algorithms, encapsulate each one, and make them interchangeable.

- **Template Method**
  - Define the skeleton of an algorithm in an operation, deferring some steps to subclass. Template Method lets subclasses redefine certain steps of an algorithm without changing the algorithm’s structure.

- **Visitor**
  - Represent an operation to be performed on the elements of an object structure. Visitor lets you define a new operation without changing the classes of the elements on which it operates.
Composite pattern
Composite pattern: Intent

Compose objects into tree structure to represent part-whole hierarchies.
- Composite lets clients treat individual objects and compositions of objects uniformly.
Composite pattern: Motivation (1)

Build a complex component out of some simple components.

- **Graphic**
  - Draw()
  - Add(Graphic)
  - Remove(Graphic)
  - GetChild(int)

- **Line**
  - Draw()

- **Rectangle**
  - Draw()

- **Text**
  - Draw()

- **Picture**
  - Draw()
  - Add(Graphic g)
  - Remove(Graphic)
  - GetChild(int)

- **Composite**

  For all g in graphics:
  - g.Draw()

  Add g to list of graphics.
Composite pattern: Motivation (2)

A typical Composite object structure

```
  aPicture
 /     \   
|       |   
| aPicture | aLine | aRectangle |
| aText    | aLine | aRectangle |
```

Composite pattern: Motivation (3)

Example: digital circuits

Composite
Composite pattern: Motivation (4)

A typical digital circuit structure

The entire circuit can also be thought of an IC

Half Adder IC

Half Adder

XOR can be an IC
Composite pattern: Applicability

- Use Composite pattern when
  - You want to represent part-whole hierarchies (tree) of objects.
  - You want clients to be able to ignore the difference between composite structure uniformly.
Composite pattern: Structure (1)

Client

Component

Operation()
Add(Component)
Remove(Component)
GetChild(int)

Leaf

Operation()

Composite

Operation()
Add(Component)
Remove(Component)
GetChild(int)

for all g in children
  g.Operation();
Composite pattern: Structure (2)

A typical Composite object structure

- aComposite
  - aLeaf
  - aLeaf
  - aComposite
    - aLeaf
    - aLeaf
    - aLeaf
Composite pattern: Participants

- **Component**
  - Interface for components (leaf, composite)
  - Implements default behavior
  - Interface for accessing & managing children
  - Interface for accessing parent component

- **Leaf**
  - Leaf objects (no children)
  - Defines behavior for primitive objects

- **Composite**
  - Defines behavior for components having children
  - Store child components
  - Implement child-related operations

- **Client**
  - Manipulate objects with component interface
Composite pattern: Collaboration

• Clients use the Component class interface to interact with objects in the composite structure.
  – If the recipient is a leaf, then the request is handled directly.
  – If the recipient is a composite, then it usually forwards requests to its child components, possibly performing additional operations before and/or after forwarding.
Composite pattern: Consequence

● Defines class hierarchies
  – consisting of primitive objects and composite objects.
    (Recursive composition)

● Makes the client simple
  – Clients usually do not care whether they are dealing
    with a leaf or a composite component.

● Easier to add new kinds of components
  – Clients don’t have to change for new components

● Can make your design overly general
  – You can’t rely on the type system to enforce
    constraints for components of a composite.
Composite pattern: Implementation (1)

- **Explicit parent references**
  - simplify traversal
  - best implemented in `Add()` and `Remove()` operations

- **Sharing components**
  - difficult when a component have only one parent

- **Maximizing the Component interface**
  - conflict with the principle that a class (component) should only defines operations that are meaningful to its subclass.

- **Declaring the child management operations**
  - root (transparency) ↔ leaf (safety)
Composite pattern: Implementation (2)

- **Should Component implement a list of Components?**
  - only if there are relatively few children in the structure

- **Child ordering**
  - example: front-to-back ordering for Graphics

- **Caching to improve performance**
  - Composite class can cache traversal or search information
  - best for components to know their parents (to update efficiently)

- **Who should delete component?**
  - make a Composite responsible for deleting its children

- **The best data structure for storing component?**
  - efficiency (array, vector, list, hash table)
Composite: Related patterns

- **Chain of Responsibility**
  - Component-parent link is often used for a Chain of Responsibility.
- **Decorator**
  - Decorator is often used with Composite.
- **Flyweight**
  - Flyweight lets you share components.
- **Iterator**
  - Iterator can be used to traverse composites.
- **Visitor**
  - Visitor localizes operations and behavior that would otherwise be distributed across Composite and Leaf classes.