Lecture 17: Design Patterns (part 2)

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Object-Oriented Analysis and Design

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Last Lecture

- Design Patterns
  - Background and Core Concepts
  - Examples
    - Singleton, Factory Method, and Adapter

Goals of Lecture

- Cover Additional Design Patterns
  - State
  - Iterator
  - Flyweight
  - Decorator
  - Observer
  - Composite

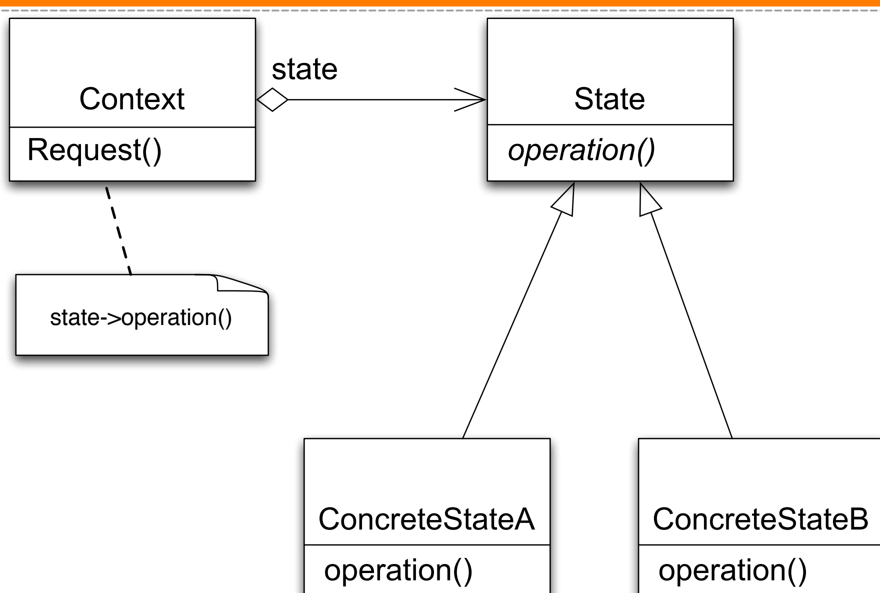
State

- Intent
  - Allow an object to alter its behavior when its internal state changes
- Motivation
  - TCPConnection example
  - A TCPConnection class must respond to an open operation differently based on its current state: established, closed, listening, etc.
- Previous Example
  - In lecture 12, we saw the State pattern being used in our MessageBuilder example
    - the MessageBuilder would respond differently to timeout events and selection events based on its current state

State, continued

- Applicability
  - Use State when
    - an object's behavior depends on its state
    - operations have large, multipart conditional statements that depend on the object's state
- Participants
  - Context
    - defines the interface of interest to clients
    - maintains an instance of a ConcreteState subclass
  - State
    - defines an interface for encapsulating the behavior associated with a particular state of the Context
  - ConcreteState
    - each subclass of State implements a different behavior that implements the correct behavior for a particular state

State's Structure and Roles



State, continued

- Collaborations
  - Context delegates state-specific requests to the current ConcreteState object
  - A context may pass itself as an argument to the State object handling the request
  - Context is the primary interface for clients
  - Either Context or ConcreteState subclasses can decide which state succeeds another and under what circumstances
    - In the MessageBuilder example of Lecture 12, each ConcreteState object returned a pointer to the next state

State, continued

- Consequences
  - State localizes state-specific behavior and partitions behavior for different states
  - State makes state transitions explicit
  - State objects can be shared
- Example
  - See the code distributed with Lecture 12 for an example of the State Pattern

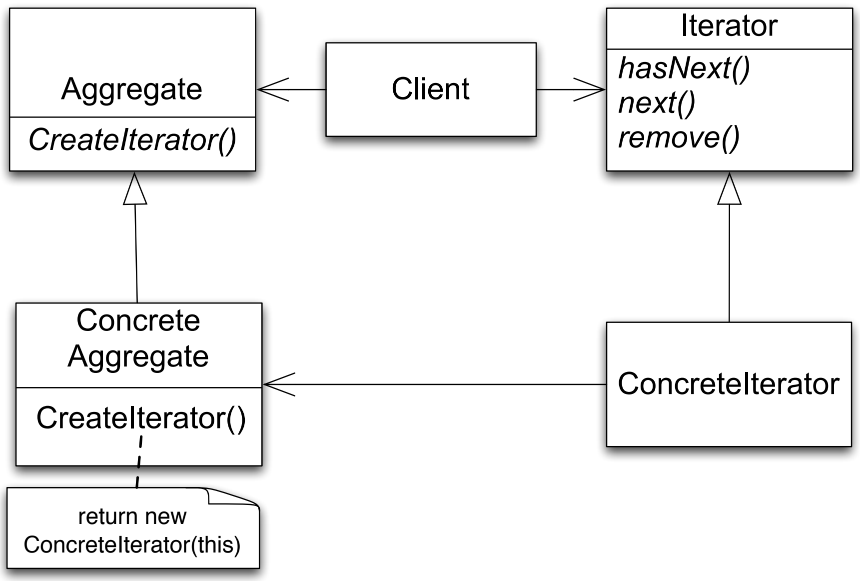
Iterator

- Intent
  - Provide a way to access the elements of an aggregate object (e.g. a collection class) sequentially without exposing its underlying representation
- Also Known As
  - Cursor
- Motivation
  - A collection may have multiple ways of being "traversed"; Iterator lets you keep traversal operations out of the core collection interface

Iterator, continued

- Applicability
  - Use the Iterator pattern
    - to access the contents of a collection without exposing its internals
    - to support multiple traversals of collections
    - to provide a uniform interface for traversing different collections
- Participants
  - Iterator
    - defines an interface for accessing and traversing elements
  - ConcreteIterator
    - implements Iterator interface and keeps track of current position within collection
  - Aggregate (Collection Class Interface)
    - defines an interface for creating an Iterator (factory method)
  - ConcreteAggregate (Collection Class)
    - implements the factory method

Iterator’s Structure and Roles



Iterator, continued

- Collaborations
  - A ConcreteIterator keeps track of the current object in the aggregate and can compute the next object in the traversal
- Consequences
  - The Iterator pattern supports multiple traversals for each collection (e.g. inorder, preorder, postorder for trees)
  - Iterators simplify Aggregate interface
  - More than one traversal can occur on a single collection at once; as long as the traversal is read-only

Iterator, continued

- Implementation
  - The Iterator interface in the Java Collection classes
    - java.util.Iterator (interface)
    - java.util.List (interface)
    - java.util.LinkedList (class)
    - java.util.ListIterator (interface)
      - implementing subclass is private within List class

Flyweight

- Intent
  - Use sharing to support large numbers of fine-grained objects efficiently
- Motivation
  - Imagine a text editor that creates one object per character in a document
  - For large documents, that is a lot of objects!
    - but for simple text documents, there are only 26 letters, 10 digits, and a handful of punctuation marks being referenced by all of the individual character objects

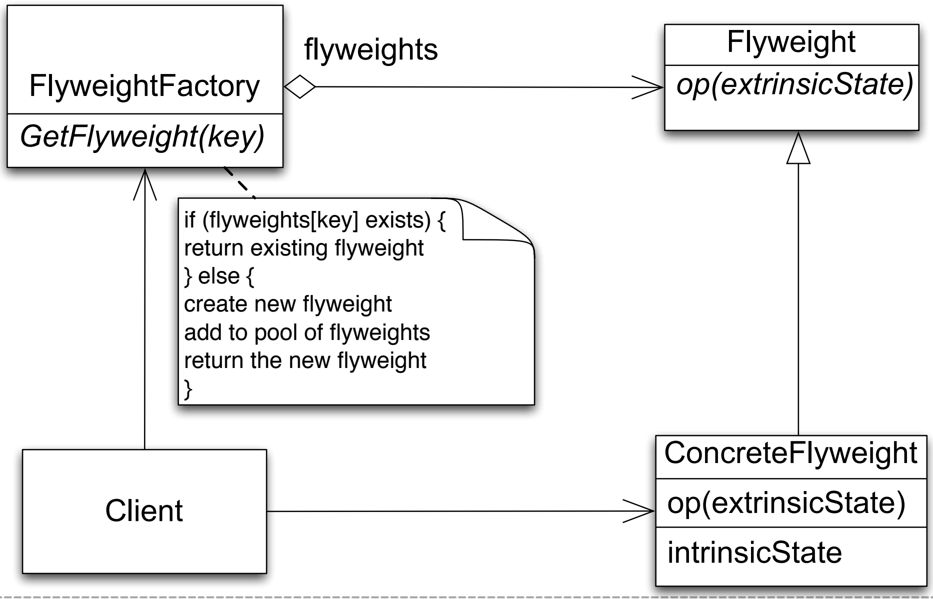
Flyweight, continued

- Applicability
  - Use flyweight when all of the following are true
    - An application uses a large number of objects
    - Storage costs are high because of the sheer quantity of objects
    - Most object state can be made extrinsic
    - Many groups of objects may be replaced by relatively few shared objects once extrinsic state is removed
    - The application does not depend on object identity. Since flyweight objects may be shared, identity tests will return true for conceptually distinct objects

Flyweight, continued

- Participants
  - Flyweight
    - declares an interface through which flyweights can receive and act on extrinsic state
  - ConcreteFlyweight
    - implements Flyweight interface and adds storage for intrinsic state
  - UnsharedConcreteFlyweight
    - not all flyweights need to be shared; unshared flyweights typically have children which are flyweights
  - FlyweightFactory
    - creates and manages flyweight objects
  - Client
    - maintains extrinsic state and stores references to flyweights

Flyweight's Structure and Roles



Flyweight, continued

- Collaborations
  - Data that a flyweight needs to process must be classified as intrinsic or extrinsic
    - Intrinsic is stored with client; Extrinsic is stored with client
  - Clients should not instantiate ConcreteFlyweights directly
- Consequences
  - Storage savings is a tradeoff between total reduction in number of objects verses the amount of intrinsic state per flyweight and whether or not extrinsic state is computed or stored
    - greatest savings occur when extrinsic state is computed

Flyweight, continued

- See code example (released with lecture 13)
- Simple implementation of flyweight pattern
  - Focus is on factory and flyweight rather than on client
  - Demonstrates how to do simple sharing of characters

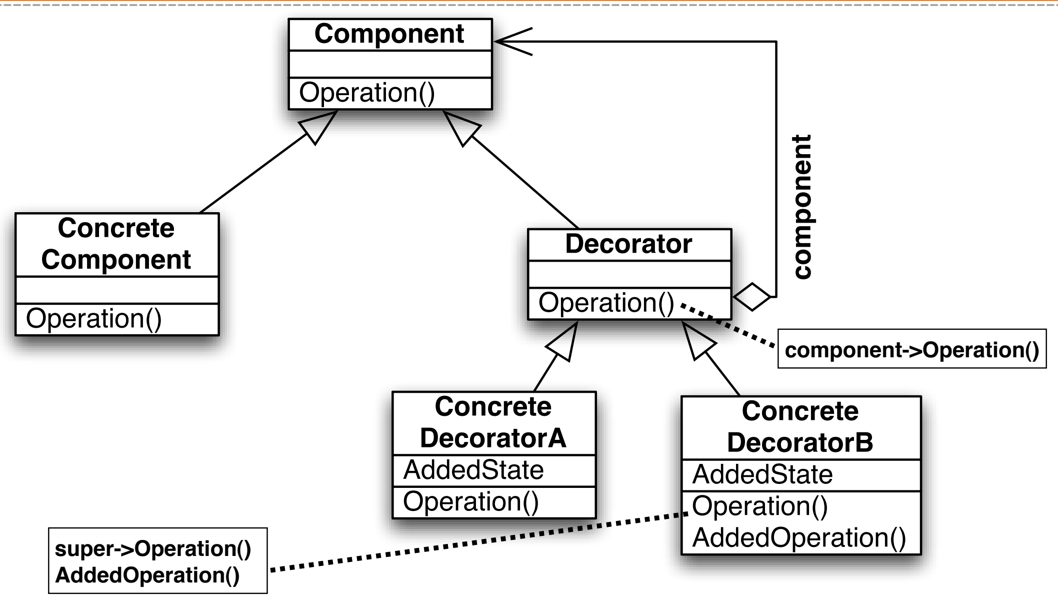
Decorator

- Intent
  - Attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality
- Also Known As
  - Wrapper
- Motivation
  - Sometimes we want to add responsibilities to individual objects, not to an entire class (like adding scrollbars to windows in GUI toolkits)

Decorator, continued

- Applicability
  - Use Decorator
    - to add responsibilities to individual objects dynamically
    - for responsibilities that can be withdrawn
    - when extension by subclassing is impractical
- Participants
  - Component
    - defines interface of objects to decorate
  - ConcreteComponent
    - defines an object to decorate
  - Decorator and ConcreteDecorator
    - Decorator maintains a reference to component and defines an interface that conforms to Component's interface; ConcreteDecorator adds responsibilities to the component

Decorator's Structure and Roles



Decorator, continued

- Collaborations
  - Decorator forwards requests to its Component object. It may optionally perform additional operations before and after forwarding the request
- Consequences
  - More flexibility than static inheritance
  - Avoids feature-laden classes high up in the hierarchy
  - A decorator and its component are not identical
  - Lots of little objects

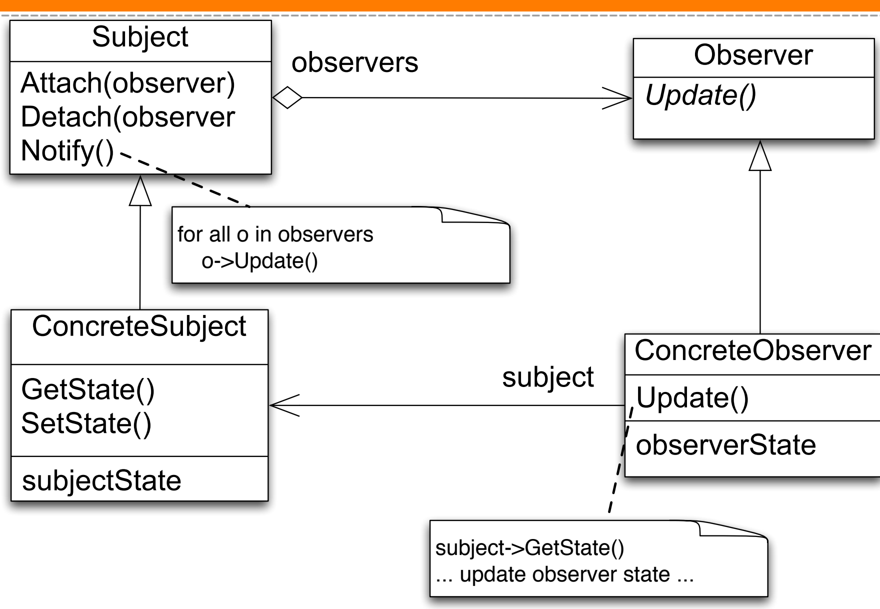
Observer

- Intent
  - Define a one-to-many dependency between objects so that when one object changes states, all its dependents are notified and updated automatically
- Also Known As
  - Dependants, Publish-Subscribe
- Motivation
  - Need a way to update dependant objects while avoiding tight coupling
    - User Interface Example

Observer, continued

- Applicability
  - Use Observer
    - when an abstraction has two aspects, one dependent on the other
    - when a change to one object requires changing others
    - when an object should notify objects but should not make assumptions about which objects need to be notified
- Participants
  - Subject
    - provides interface to add and delete observers
  - Observer
    - defines an updating interface for dependants
  - ConcreteSubject
    - stores the state being observed
  - ConcreteObserver
    - stores state that must be consistent with observed state

Observer's Structure and Roles



Observer, continued

- Collaborations
  - ConcreteSubject notifies observers whenever it changes its observed state
  - After receiving a notification, ConcreteObserver gets state from ConcreteSubject
    - see sequence diagram on page 295 of Design Patterns

Observer, continued

- Consequences
  - Abstract coupling between Subject and Observer
    - Subjects do not know the concrete subclasses of their observers
  - Support for broadcast communication
    - Subject does not know who is listening
  - Unexpected updates
    - Change in state may update an unintended object, one we didn't suspect was an observer, or should only be observing at well-defined times

Composite

- Intent
  - Compose objects into tree structures to represent part-whole hierarchies
  - Composite lets clients treat individual objects and compositions of objects uniformly
- Motivation
  - Image programs that allow graphic primitives to be grouped into collections of objects
    - Many operations are shared, such as move(), copy(), paste(), draw(), etc.

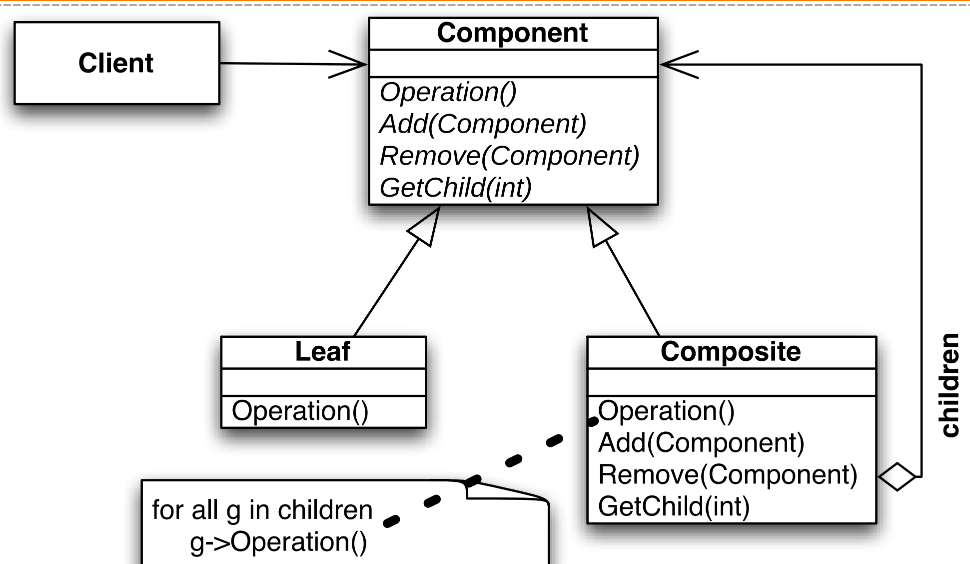
Composite, continued

- Applicability
  - Use Composite when
    - you want to represent part-whole hierarchies
    - you want clients to be able to ignore the difference between compositions of objects and individual objects

Composite, continued

- Participants
  - Component
    - declares the shared interface
    - declares child management operations
      - empty methods for leaves
    - defines an interface to retrieve parent
  - Leaf
    - implements shared interface
  - Composite
    - stores children
    - implements shared interface by delegating to children
    - implements child management operations
  - Client
    - Manipulates objects using the Component interface

Composite's Structure and Roles



Composite, continued

- Collaborations
  - Client uses the Component interface to interact with all objects
  - If the recipient is a leaf, then the request is handled directly
  - If the recipient is a composite, then the request is delegated to its children

Composite, continued

- Consequences
  - Composite allows primitive objects and composite objects to be treated transparently
    - especially since the child management functions are defined in the Component interface
  - Composite simplifies code in the client
  - It makes it easy to add new types of "leaves"
    - nothing needs to change to add a new type of component (not even the client)
  - Disadvantage: Difficult to create composites that have only certain types of leaves; you need to subclass the Composite class and use run-time checks to make sure that only "legal" children are added to it

Summary

- Patterns are a design technique that can help you create more flexible software designs
  - They describe generic solutions that can be applied to many different software systems
- We have now seen a number of patterns
  - Adapter, Blackboard, Composite, Decorator, Double Dispatch, Factory Method, Flyweight, Iterator, Observable, Singleton, State
- Note: some patterns built on previous ones
  - Factory Method appeared in Iterator
  - A variation of Singleton appeared in Flyweight

What's Next?

- Refactoring
  - How to improve the structure of a software system without changing its functionality
- Test-Driven Design
  - How to evolve software systems by writing test cases FIRST!
- Spring Break!
- Design Patterns, part 3
  - Command, Facade, and more...
- Refactoring to Design Patterns
- Domain-Driven Design
  - Information from the second textbook...