Software design†

Topics in Object-Oriented Design Patterns

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† Material mainly from the book *Design Patterns* by Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides; slides originally by Spiros Mancoridis; modified by Ian Davis and Grant Weddell.

Outline

- Terminology and motivation.
- Reusable object-oriented *design patterns*.
  - *creational patterns*
  - *structural patterns*
  - *behavior patterns*

Design patterns

- Good designers know not to solve every problem from first principles. They reuse solutions.
- Practitioners do not do a good job of recording experience in software design for others to use.

Design patterns (cont'd)

- A *design pattern* systematically names, explains, and evaluates an important and recurring design.
- We describe a set of well-engineered design patterns that practitioners can apply when crafting their applications.

Becoming a skilled designer

We first learn the basics.

- algorithms
- data structures
- languages

Then, “programming in the medium.”

- structured programming
- modular programming
- object-oriented programming

Becoming a skilled designer (cont'd)

Ultimately, a designer needs to become familiar with the good designs and design ideas of others.

- Design *patterns* must be understood, memorized, and applied.
- There are thousands of existing design patterns.

Reusable object-oriented design patterns

Creational patterns

- Factory
- Abstract factory
- Builder
- Prototype
- Singleton

Factory: intent

- Introduces a layer of software which allows run time creation of objects that are identified by parametric value rather than by compile time name.

- May use polymorphism to create different objects in distinct subclasses sharing common factory method.

Factory: motivation

- May wish to restrict conditions under which objects returned by factory may be created.
- The classes employed within software may not be known until run-time; e.g., OLE pictures etc. may be inserted into documents.
- May wish to identify classes by GUID's, and to register them.

Abstract factory: intent

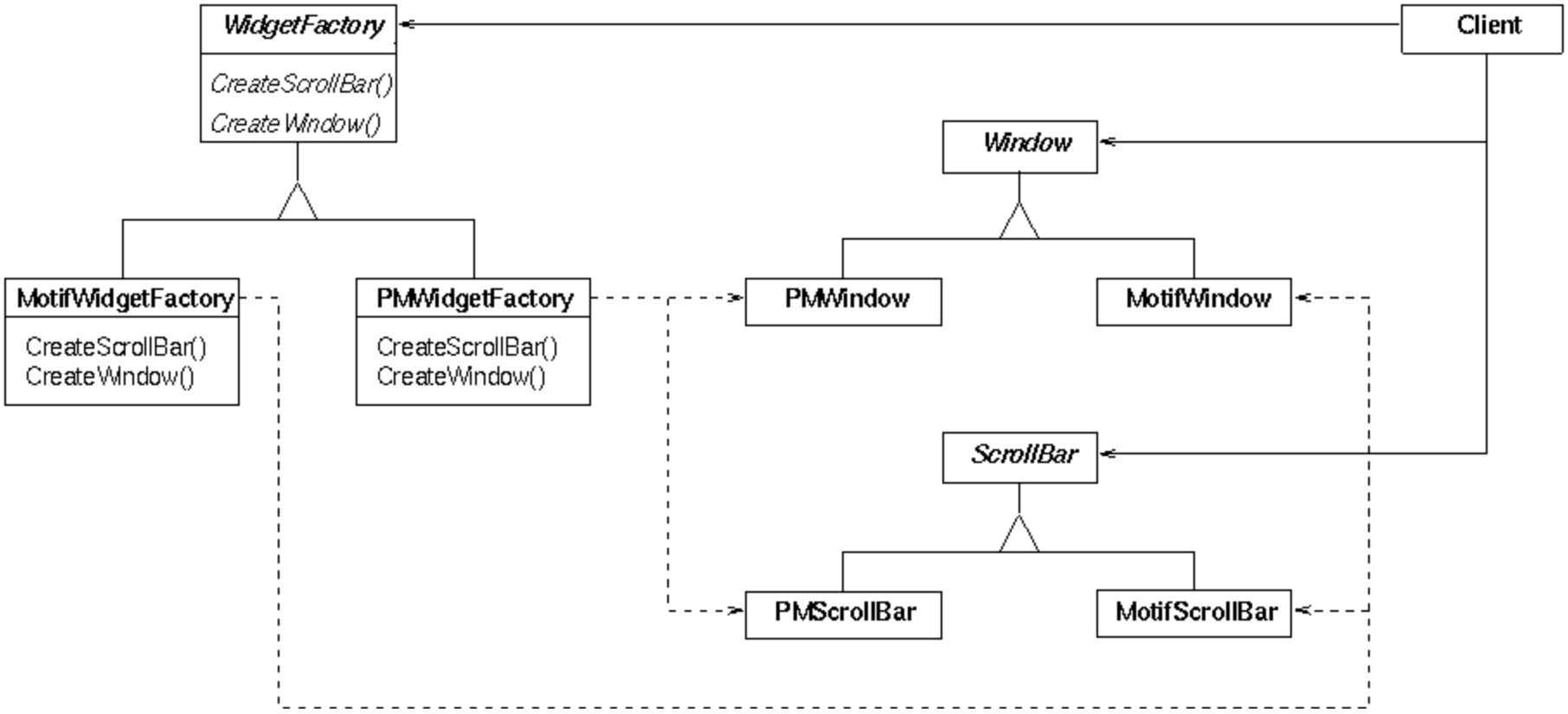
- Provides an interface for creating families of related or dependent objects without specifying their concrete classes.
- Allows entire suites of classes to optionally be interchanged easily at run time.

Abstract factory: behavior

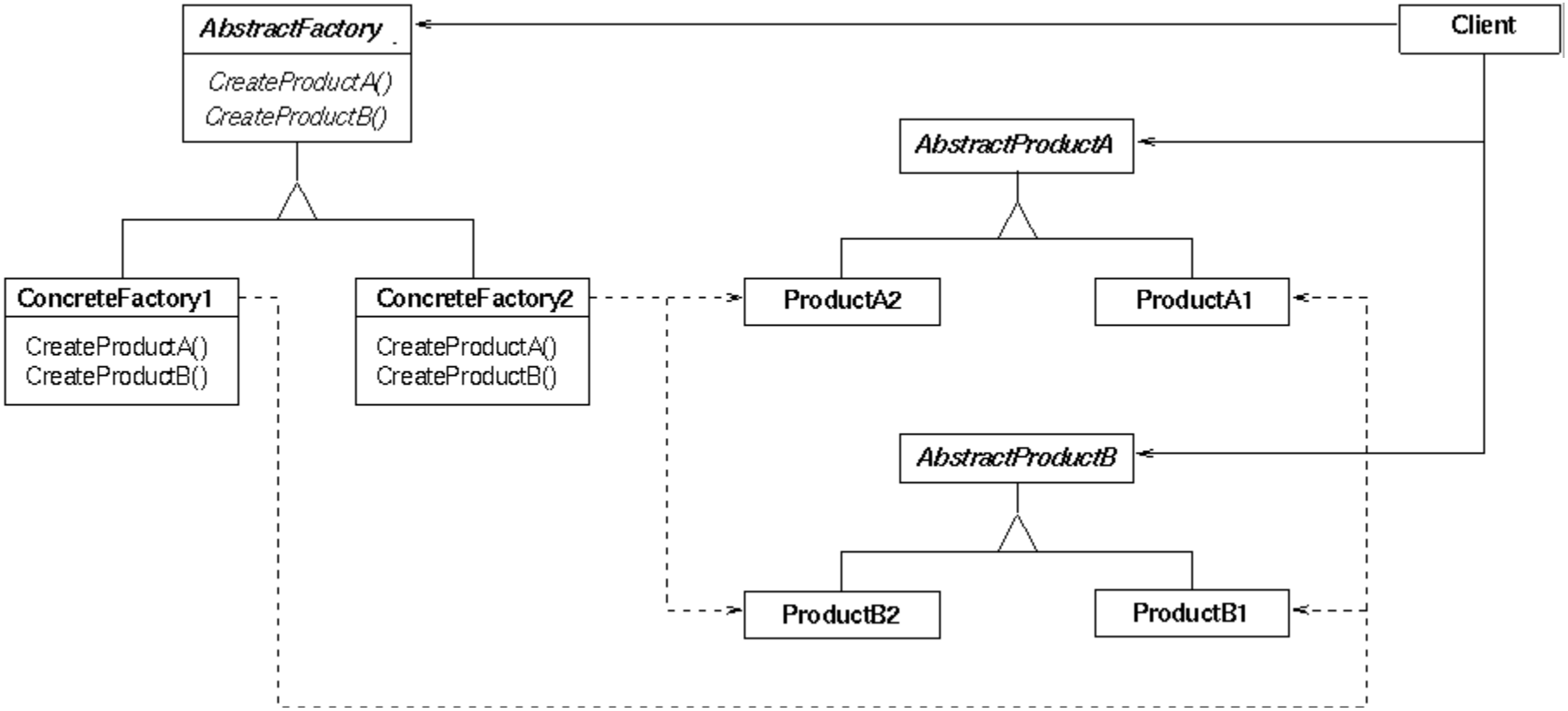
- Sometimes we have systems that support different representations depending on external factors.

- There is an *abstract factory* that provides an interface for the client. In this way the client can obtain a specific object through this abstract interface.

Abstract factory: example



Abstract factory: structure



Abstract factory: participants

Abstract Factory:

- Declares an interface for operations that create abstract product objects.

Concrete Factory:

- Implements the operations to create concrete product objects.

Abstract factory: participants (cont'd)

Abstract Product:

- Declares an interface for a type of product object.

Concrete Product:

- Defines a product object to be declared by the corresponding concrete factory. (Implements the Abstract Product interface).

Client:

- Uses only interfaces declared by Abstract Factory and Abstract Product classes.

Builder

- Methods of a builder class provide an interface which allows the builder class to receive in a pre-determined manner the material from which something is to be built, produced or used.
- The builder also provides a method to return the result of construction if appropriate.

Builder: motivation

- Want to divorce the issue of what is used to build a result from how the result is built.
- May want to build many different things from the same input.
- Easy to create and introduce into system new builder classes, if they all have the same external behaviour.
- Essentially, the builder pattern reinforces the importance of polymorphism.

Builder: example

- SGML parser identifies types of data token traversed within document.
- Want to tell application what has been seen while traversing document.
- Don't want to tell application what to do with this data. Application may format this data, build electronic indices from it, etc.
- May want to view document in many concurrent windows and styles.

Prototype

- Don't want to explicitly remember the knowledge of exactly what class, and with what parameters a class should be created when requested.
- Instead encapsulate this information by holding a dummy instance of the class to be created following a given request.
- Clone copies of this dummy instance as needed.

Prototype: examples

- Visio has vast numbers of visual symbols stored in template sheets.
- The symbols can be identified by GUID.
- The GUID allows the class supporting the representation of that symbol to be loaded.
- Once loaded the visual symbol can be cloned multiple times.
- It may appear multiple times in a drawing.

Singleton

- Provides global access to single instances of a class transparently.
- Centralizes access to this single instance.
- Embeds appropriate concurrency control within the singleton pattern.
- Avoids potential misuse of global objects.

Singleton: example

- Threads may wish to emit error messages.
- How error messages are handled is not the threads problem.
- May want to direct error messages to a single shared error message area.
- Need to avoid conflict when multiple threads concurrently report errors.
- Easy to change so that each thread has their own error message area if desired.

Structural patterns

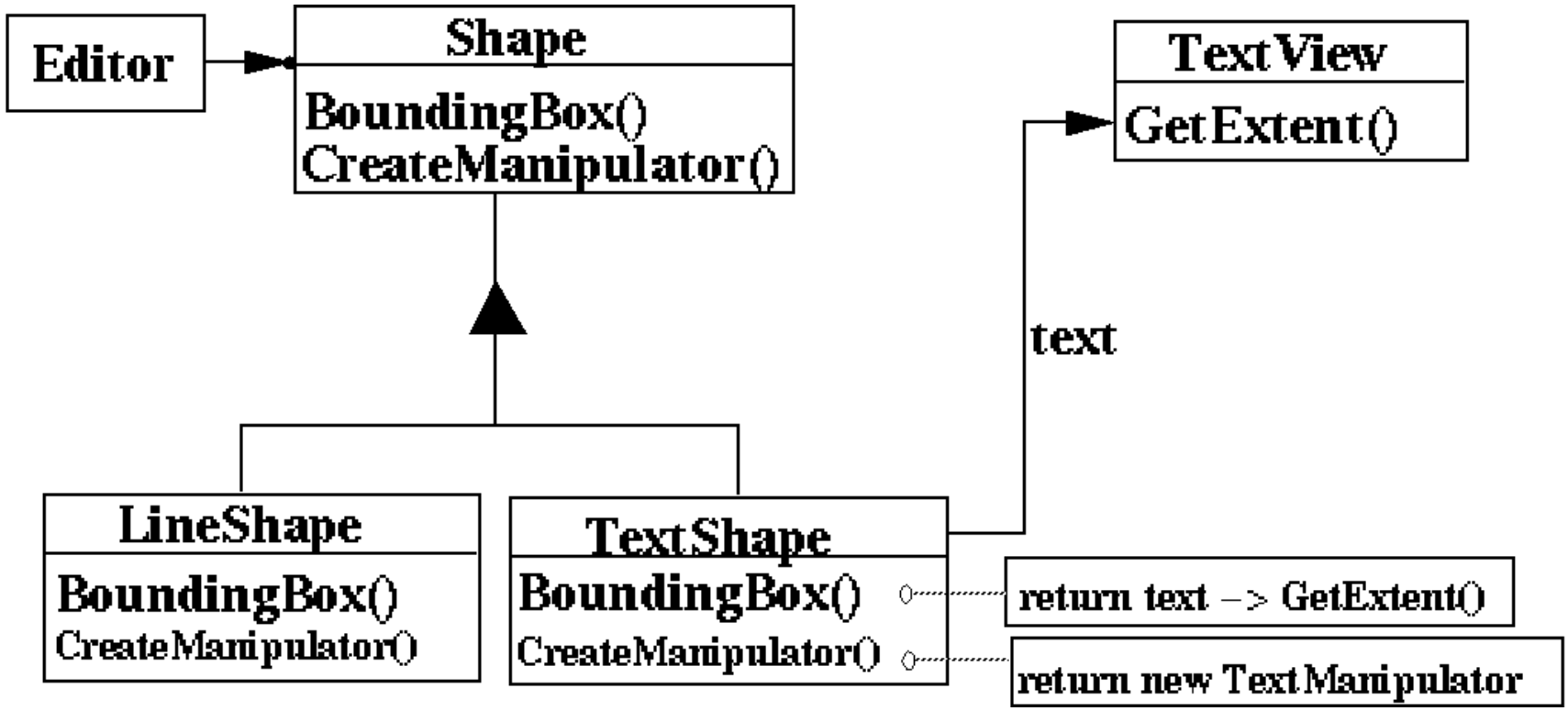
- Adapter
- Facade
- Composite

Adapter

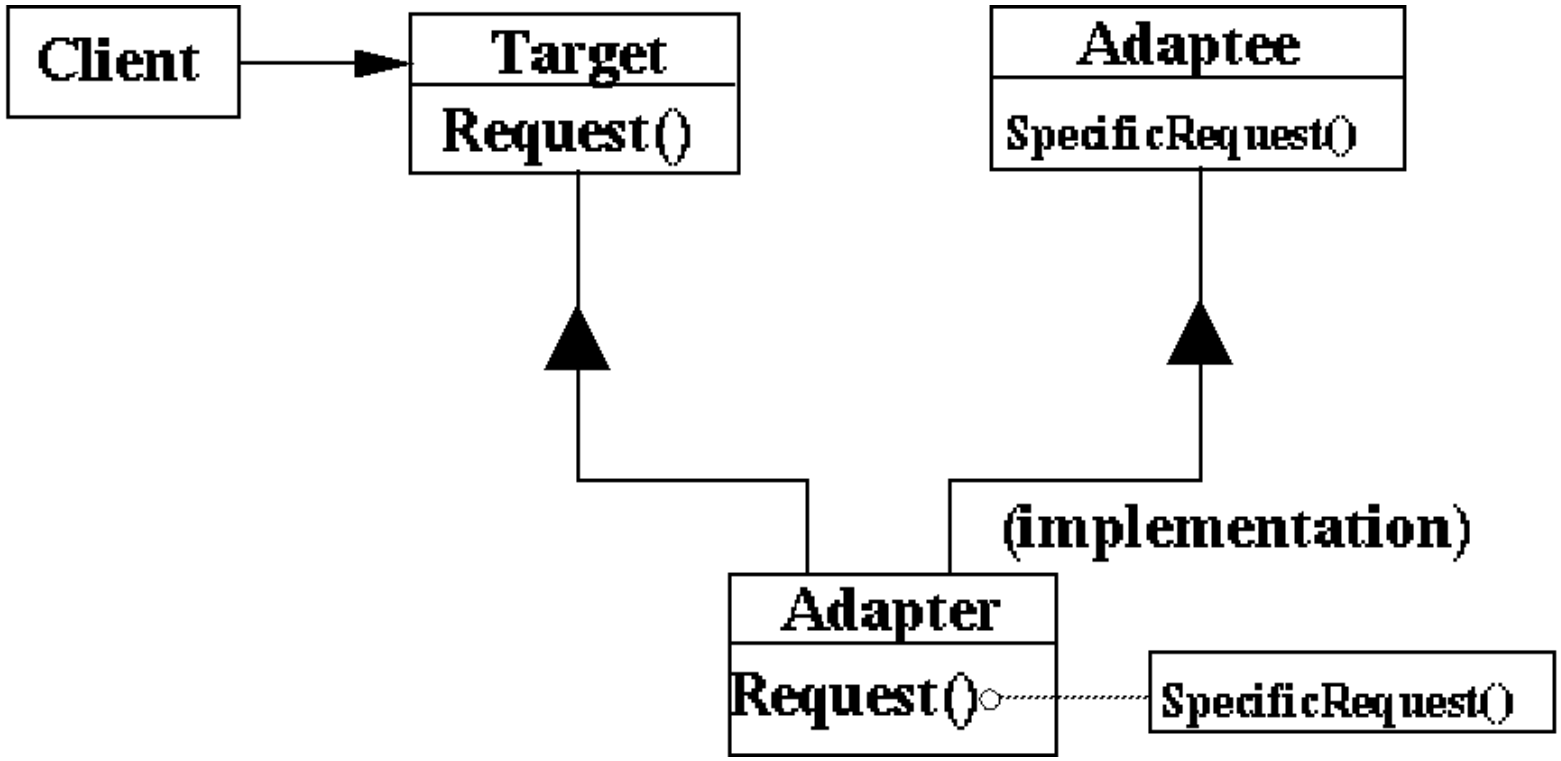
Intent: Convert the interface of a class into another interface clients expect. Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.

Motivation: When we want to reuse classes in an application that expects a different interface, we do not want to (and often cannot) change the reusable classes to suit our application.

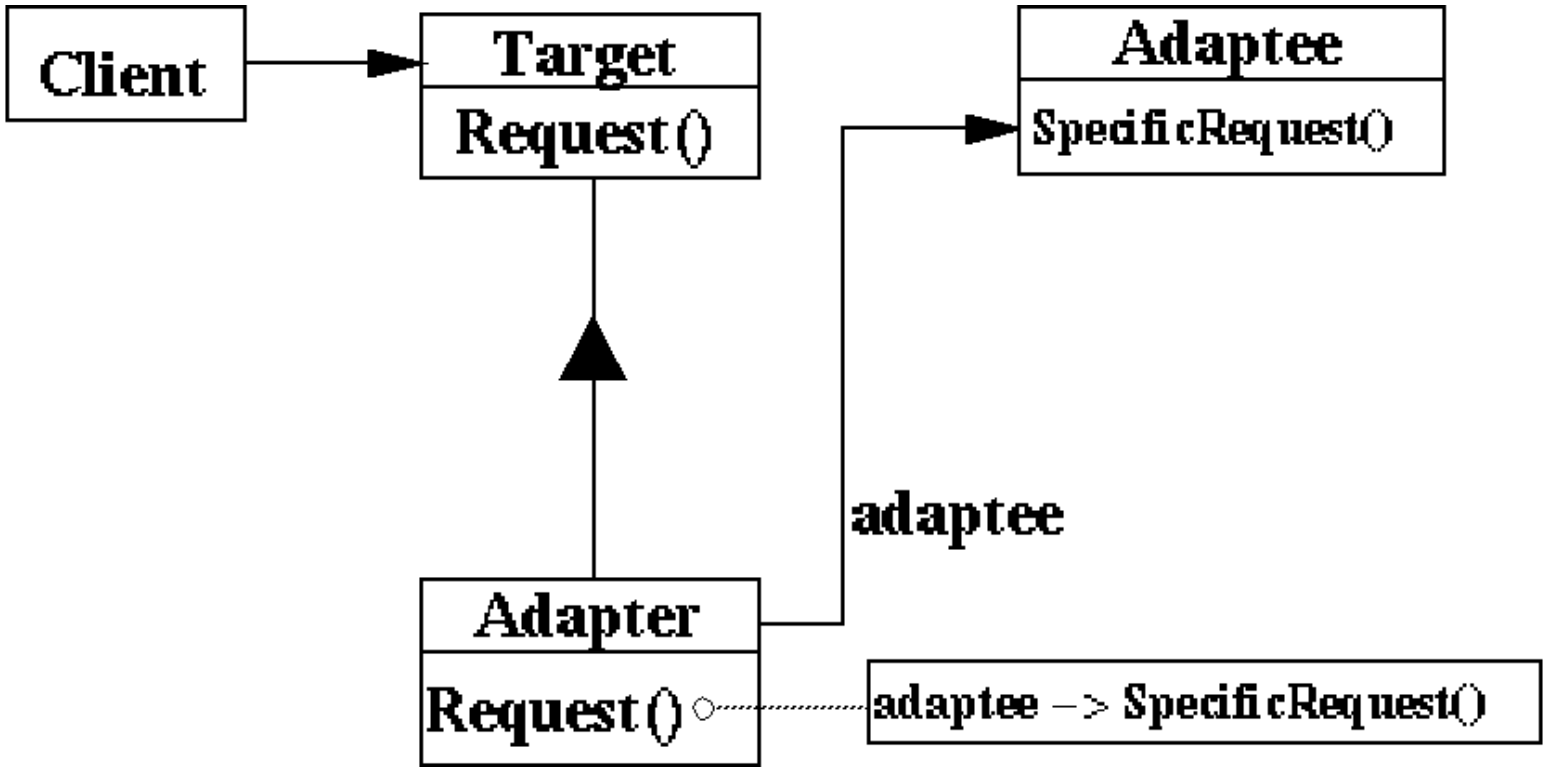
Adapter: example



Adapter: structure with multiple inheritance



Adapter: structure using object composition



Adapter: participants

Target: Defines the application-specific interface that clients use.

Client: Collaborates with objects conforming to the target interface.

Adaptee: Defines an existing interface that needs adapting.

Adapter: Adapts the interface of the adaptee to the target interface.

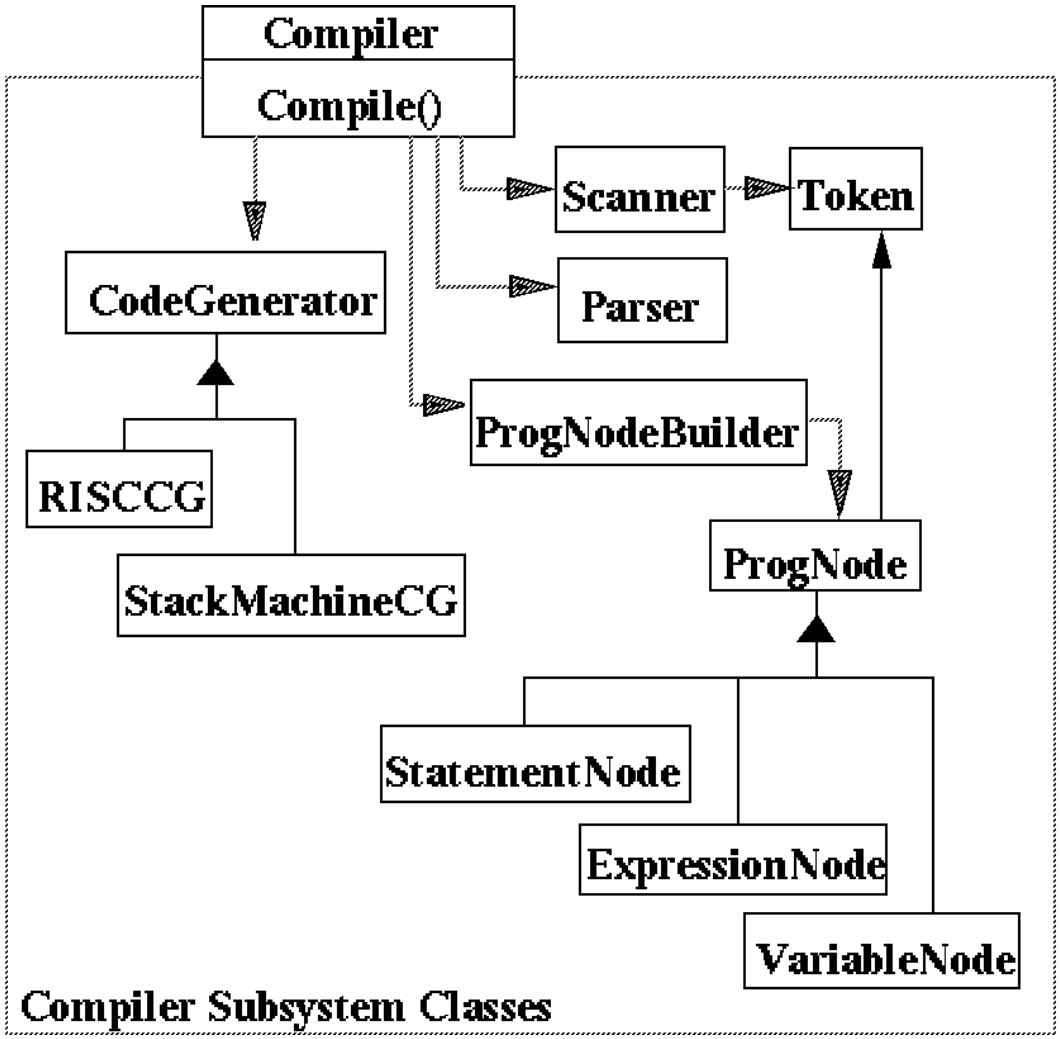
Facade: intent

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

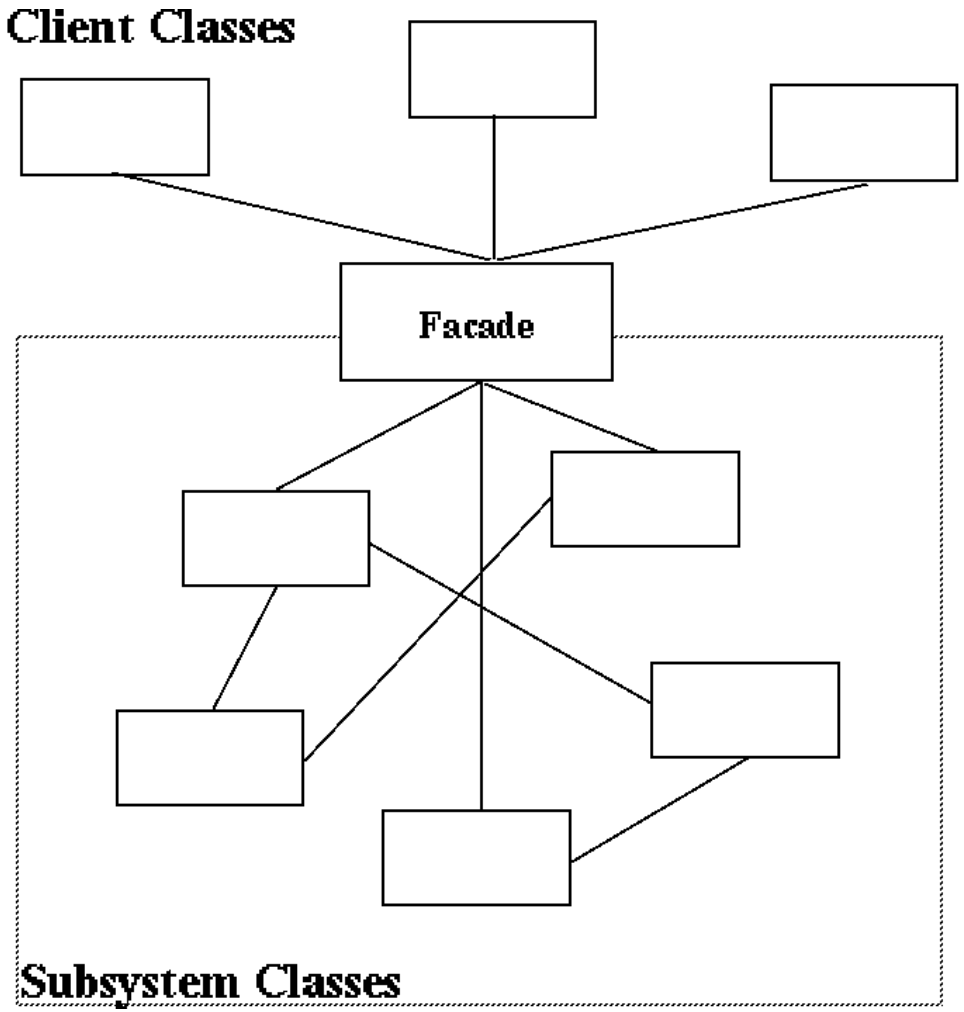
Facade: motivation

- Structuring a system into subsystems helps reduce complexity.
- A common design goal is to minimize the communication and dependencies between subsystems.
- Use a facade object to provide a single simplified interface to the more general facilities of a subsystem.

Facade: example



Facade: structure



Facade: participants

Facade:

- Knows which subsystem classes are responsible for a request.
- Delegates client requests to appropriate subsystem objects.

Subsystem Classes:

- Implement subsystem functionality.
- Handle work assigned by the facade object.
- Have no knowledge of the facade; that is, they keep no references to it.

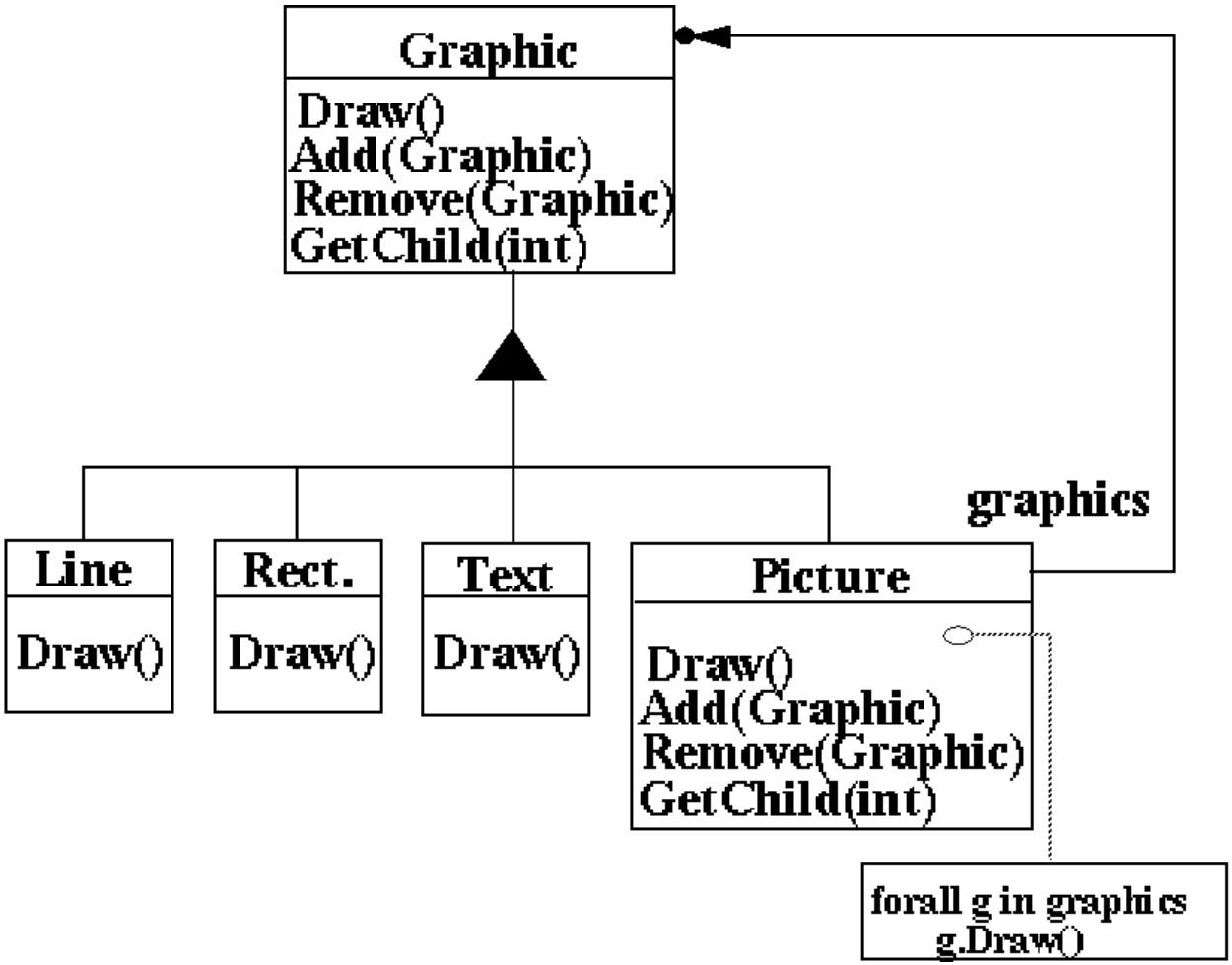
Composite: intent

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

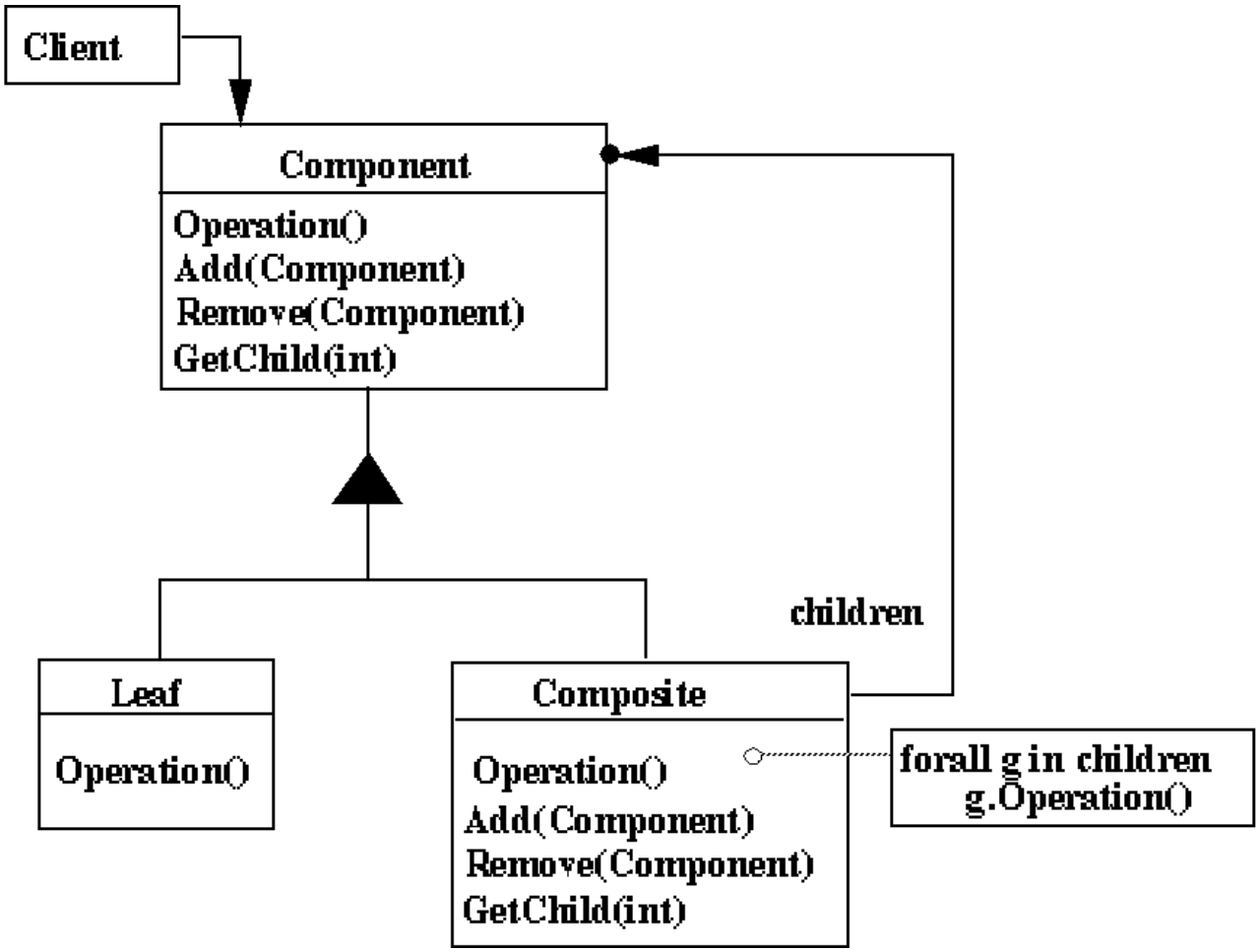
Composite: motivation

- If the composite pattern is not used, client code must treat primitive and container classes differently, making the application more complex than is necessary.

Composite: example



Composite: structure



Composite: participants

Component:

- Declares the interface for objects in the composition.
- Implements default behavior for the interface common to all classes.
- Declares an interface for accessing and managing its child components.
- Defines an interface for accessing a component's parent in the recursive structure (optional).

Composite: participants (cont'd)

Leaf:

- Represents leaf objects in the composition. A leaf has no children.
- Defines behavior for primitive objects in the composition.

Composite:

- Defines behavior for components having children.
- Stores child components.
- Implements child-related operations in the component interface.

Composite: participants (cont'd)

Client:

- Manipulates objects in the composition through the component interface.

Behavioral patterns

- Command
- Interpreter
- Iterator
- Template
- Observer
- Master-slave

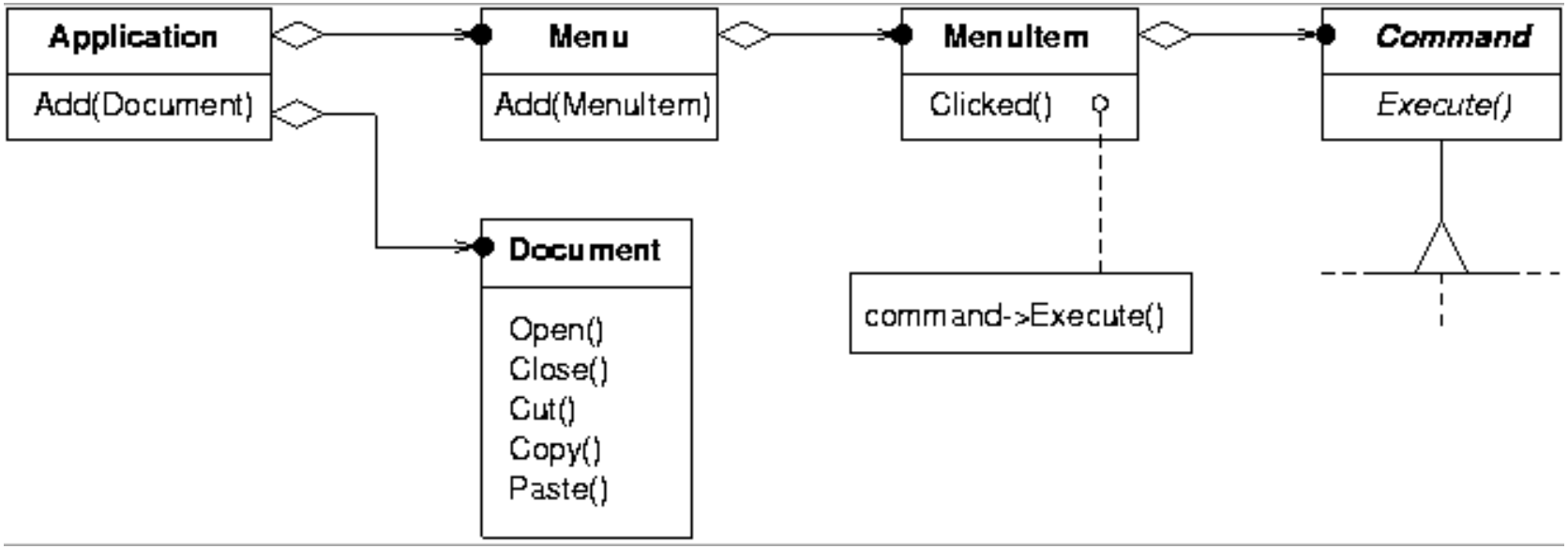
Command: intent

- Encapsulate a request as an object, thereby letting one parameterize clients with different requests, queue or log requests, and support undoable operations.

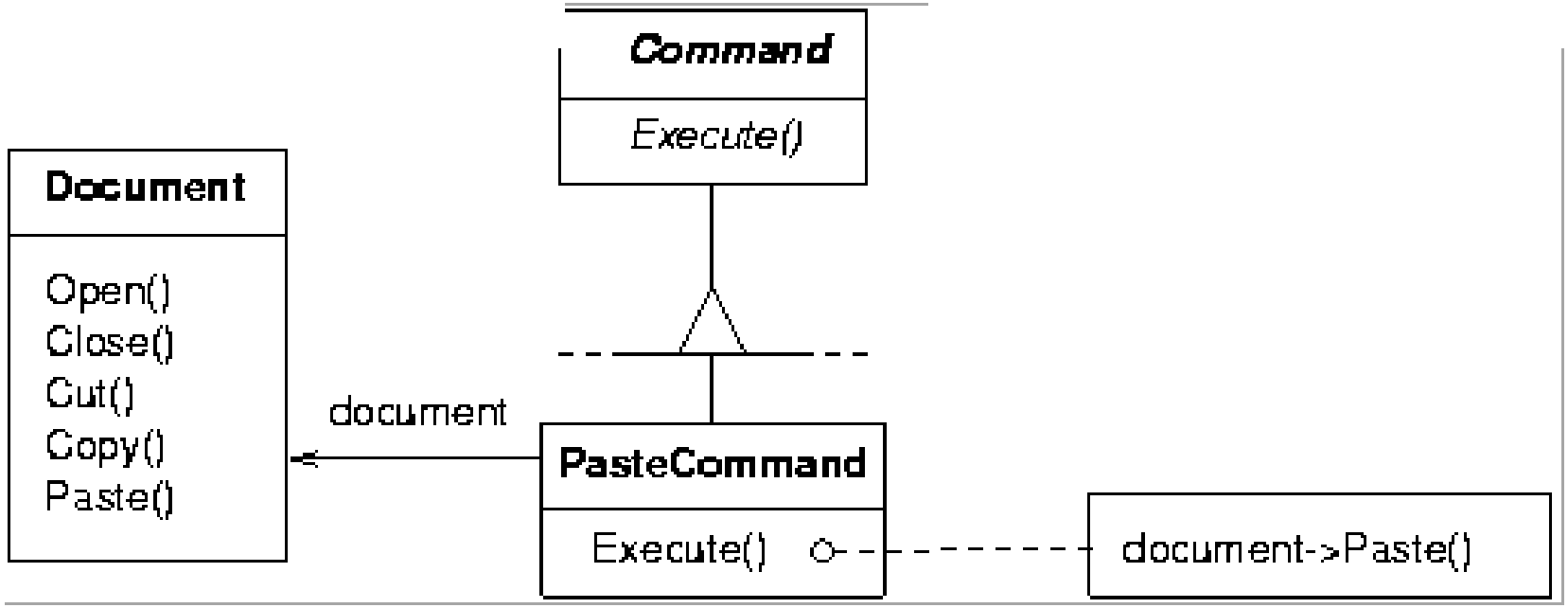
Command: motivation

- Sometimes it's necessary to issue requests to objects without knowing anything about the operation being requested or the receiver of the request.

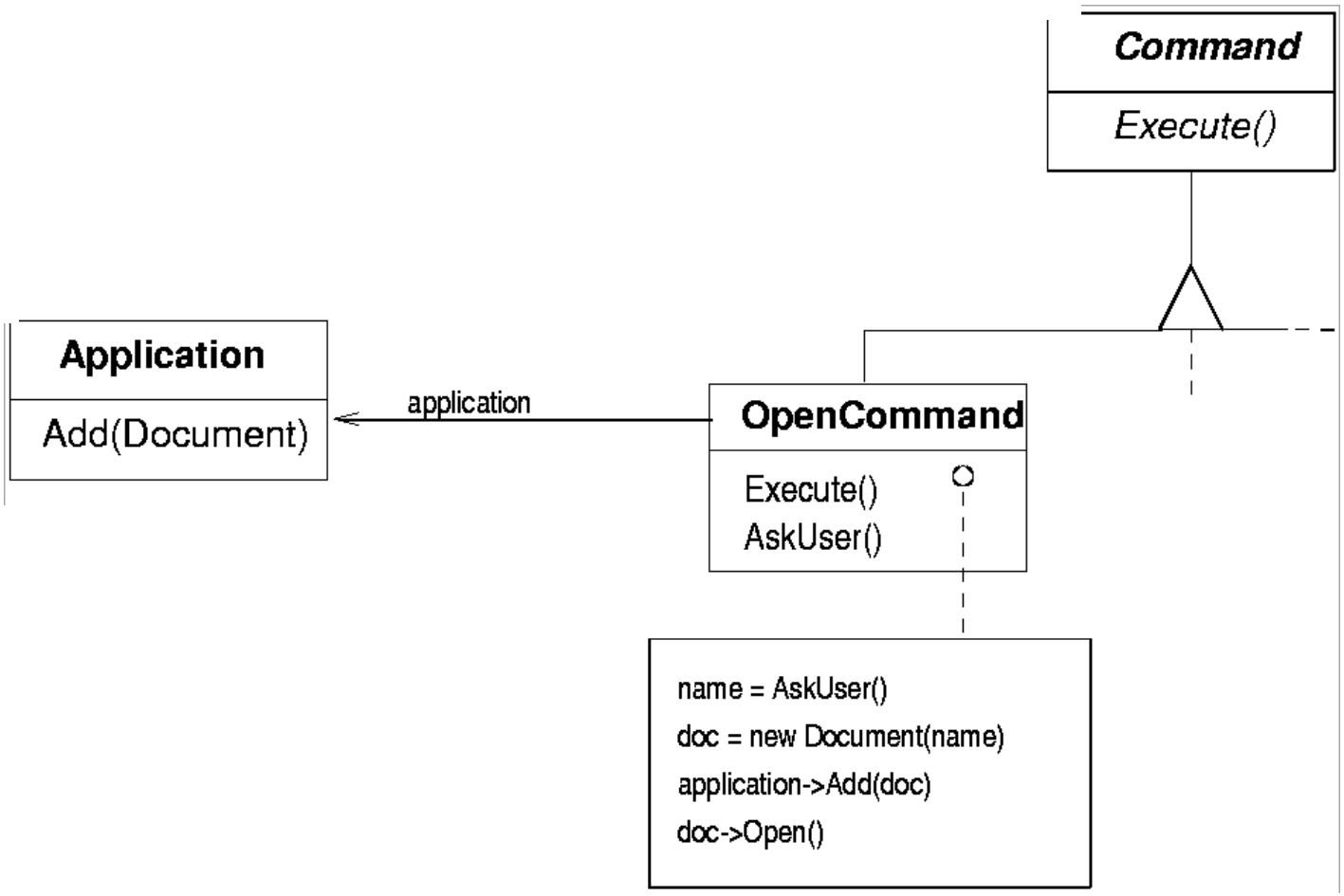
Command: example



Command: structure



Command: structure (cont'd)



Command: participants

Command:

- Declares an interface for executing an operation.

Concrete Command:

- Defines a binding between a *Receiver* object and an action.
- Implements *Execute* by invoking the corresponding operations(s) on *Receiver*.

Command: participants (cont'd)

Client:

- Creates a *Concrete Command* object and sets its receiver.

Invoker:

- Asks the command to carry out the request.

Receiver:

- Knows how to perform the operations associated with carrying out a request. Any class may serve as a *Receiver*.

Interpreter: intent and motivation

- Want to compute something capable of being expressed in a language.
- The computation is performed on structural representation of the language operations to be performed.
- Structural objects representing operations have built in knowledge of how to perform their own operation.

Interpreter: example

- A language statement may be converted to an expression tree of operations to be performed.
- Each operation takes as its input the results returned by it's child expression trees.
- Such an expression tree is often called a plan.

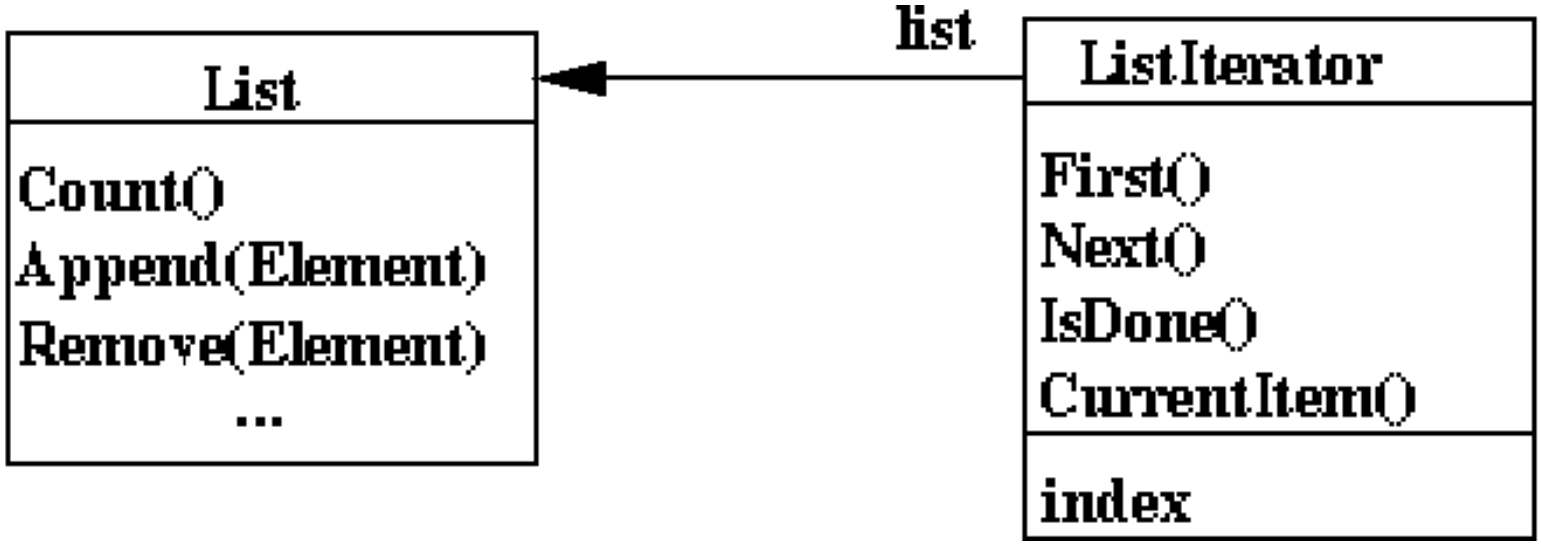
Iterator: intent

- Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.
- Move the responsibility for access and traversal from the aggregate object to the iterator object.
- Potentially preserves state information which speeds traversal.

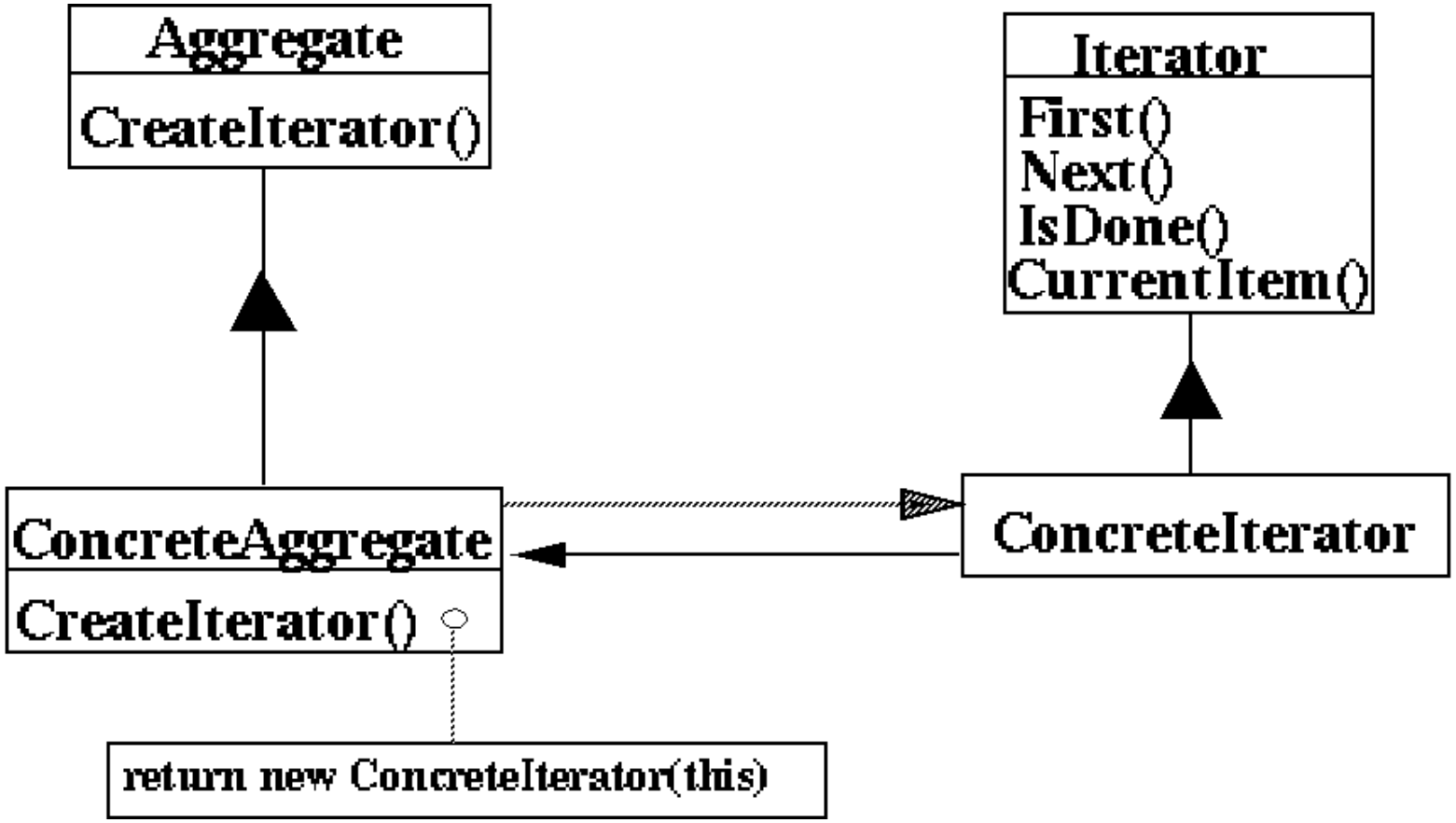
Iterator: motivation

- One might want to traverse an aggregate object in different ways.
- One might want to have more than one traversal pending on the same aggregate object.
- Not all types of traversals can be anticipated a priori.
- One should not bloat the interface of the aggregate object with all these traversals.

Iterator: example



Iterator: structure



Iterator: participants

- **Iterator:** Defines an interface for accessing and traversing elements.
- **Concrete Iterator:** Implements an iterator interface and keeps track of the current position in the traversal of the aggregate.
- **Aggregate:** Defines an interface for creating an iterator object.
- **Concrete Aggregate:** Implements the iterator creation interface to return an instance of the proper concrete iterator.

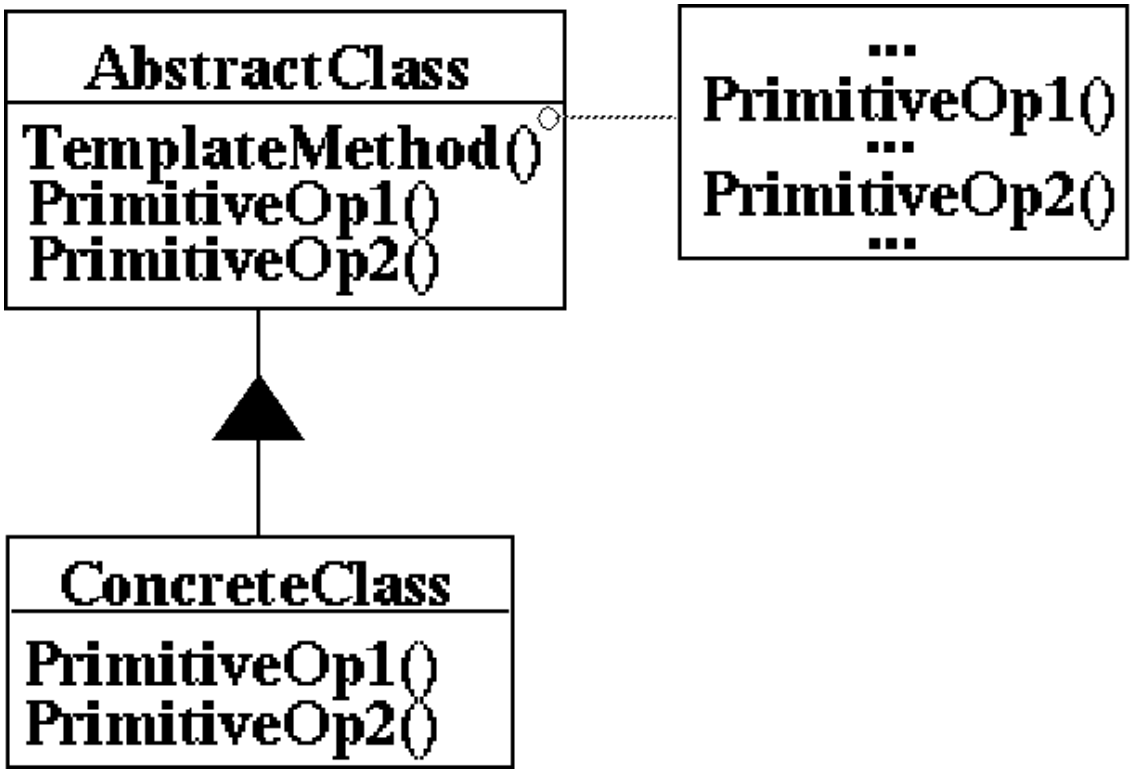
Template: intent

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

Template: motivation

- By defining some of the steps of an algorithm using abstract operations, the template method fixes their ordering.

Template: structure



Template: participants

Abstract Class:

- Defines abstract primitive operations that concrete subclasses define to implement steps of an algorithm.
- Implements a template method defining the skeleton of an algorithm. The template method calls primitive operations as well as operations defined in *Abstract Class* or those of other objects.

Template: participants (cont'd)

Concrete Class:

- Implements the primitive operations to carry out subclass-specific steps to the algorithm.

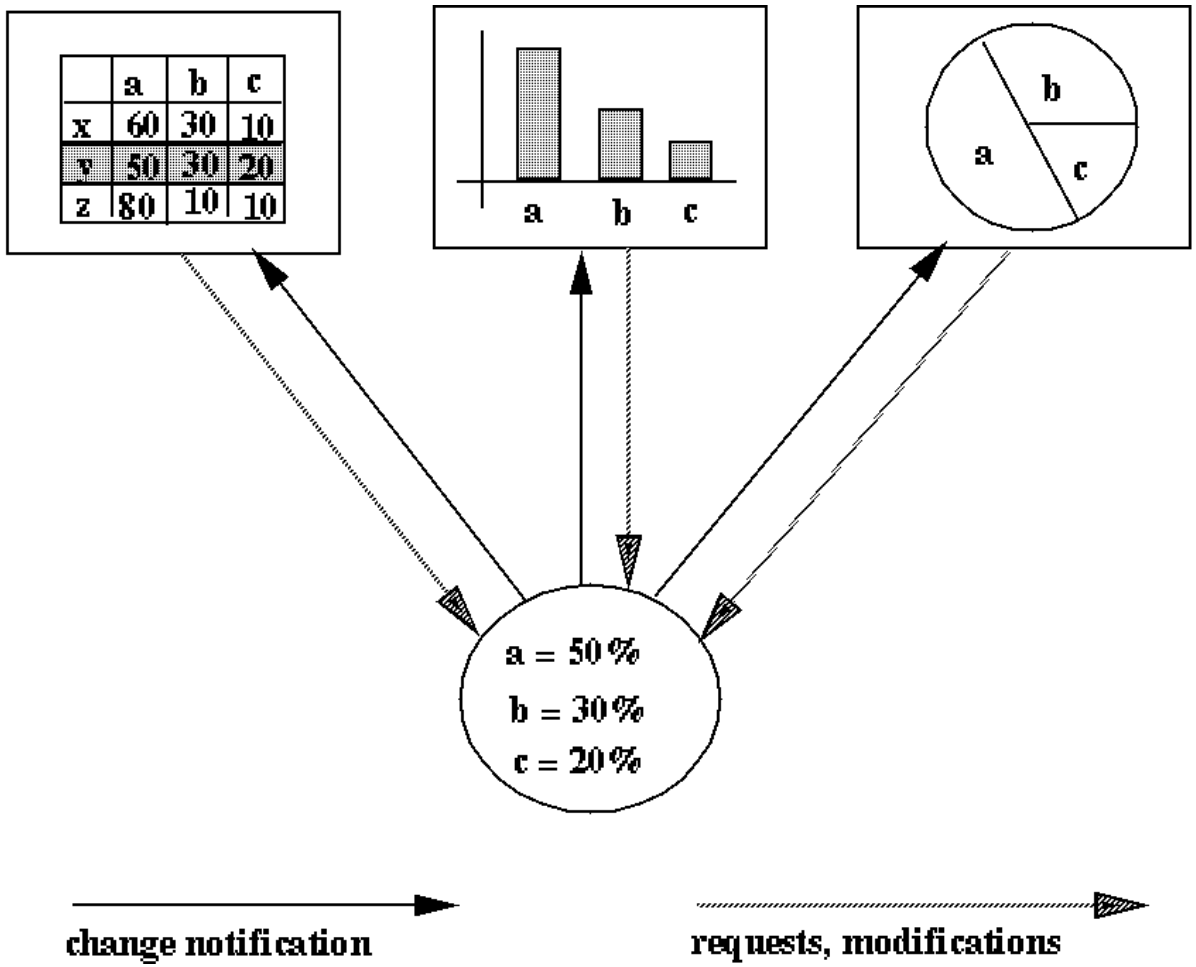
Observer: intent

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

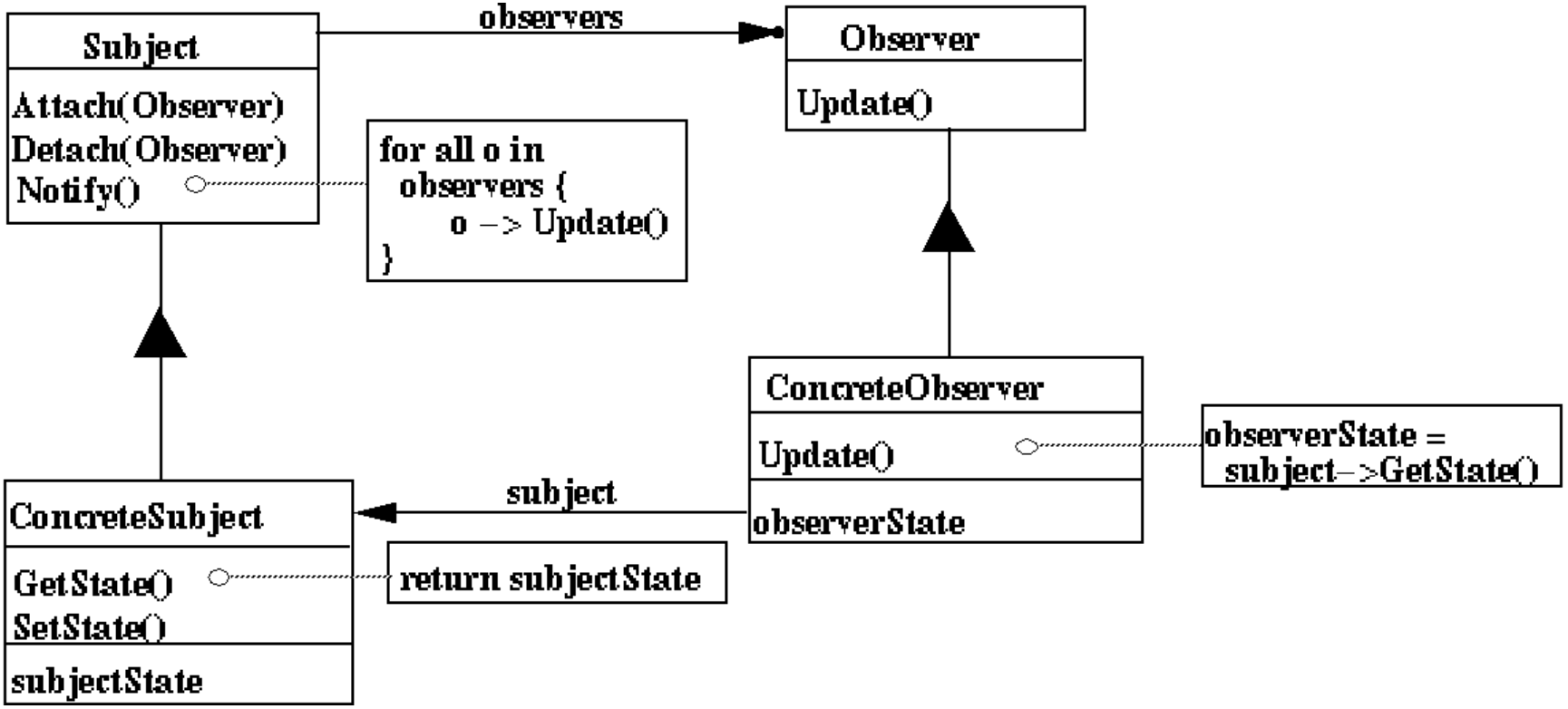
Observer: motivation

- A common side-effect of partitioning a system into a collection of cooperating classes is the need to maintain consistency between related objects.
- You don't want to achieve consistency by making the classes tightly coupled because that reduces their reusability.

Observer: example



Observer: structure



Observer: structure (cont'd)

The key objects in this pattern are **subject** and **observer**.

- A subject may have any number of dependent observers.
- All observers are notified whenever the subject undergoes a change in state.

Observer: participants

Subject:

- Knows its numerous observers.
- Provides an interface for attaching and detaching observer objects.
- Sends a notification to its observers when its state changes.

Observer:

- Defines an updating interface for concrete observers.

Observer: participants (cont'd)

Concrete Subject:

- Stores state of interest to concrete observers.

Concrete Observer:

- Maintains a reference to a concrete subject object.
- Stores state that should stay consistent with the subject's.
- Implements the updating interface.

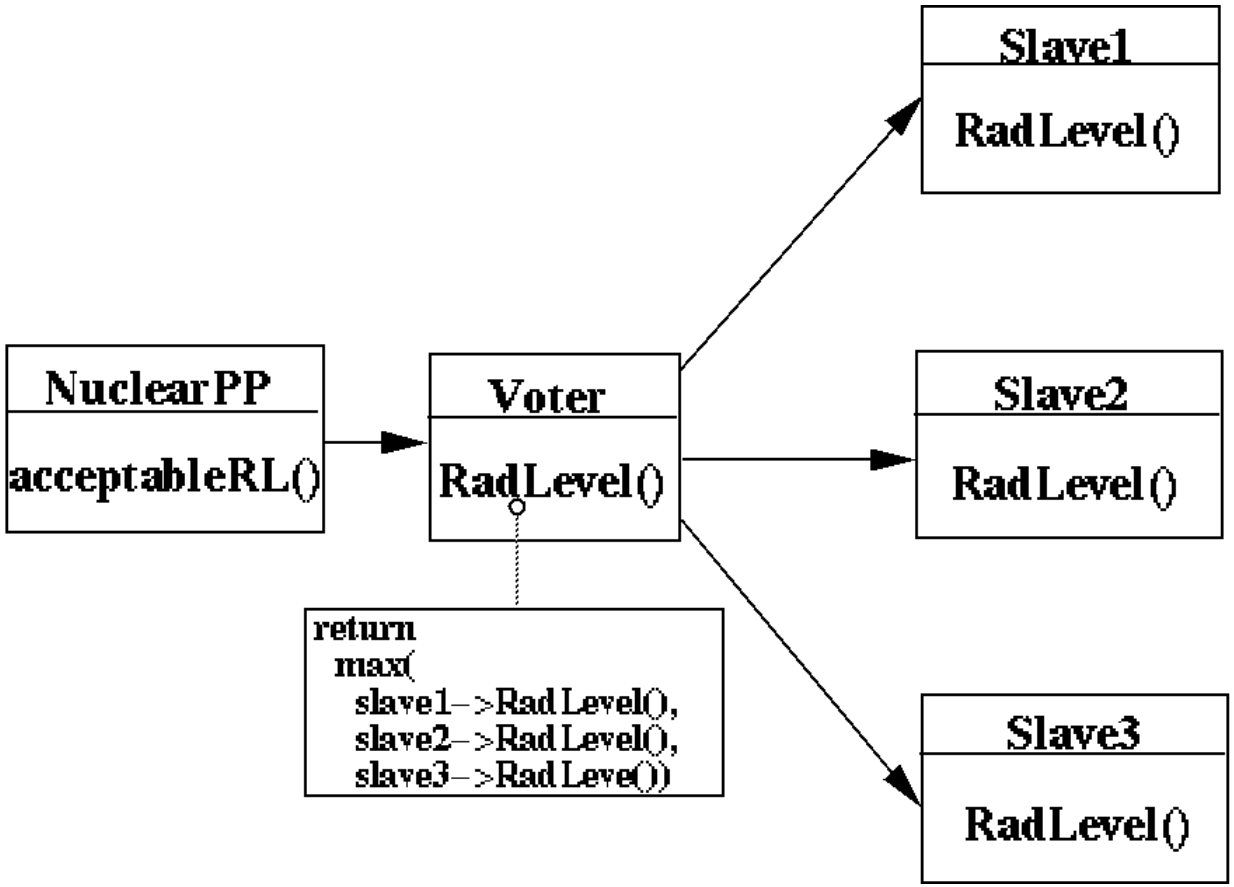
Master-slave: intent

- Handles the computation of replicated services within a software system to achieve fault tolerance and robustness.
- Independent components providing the same service; *slaves* are separated from a component *master* responsible for invoking them and for selecting a particular result from the results returned by the slaves.

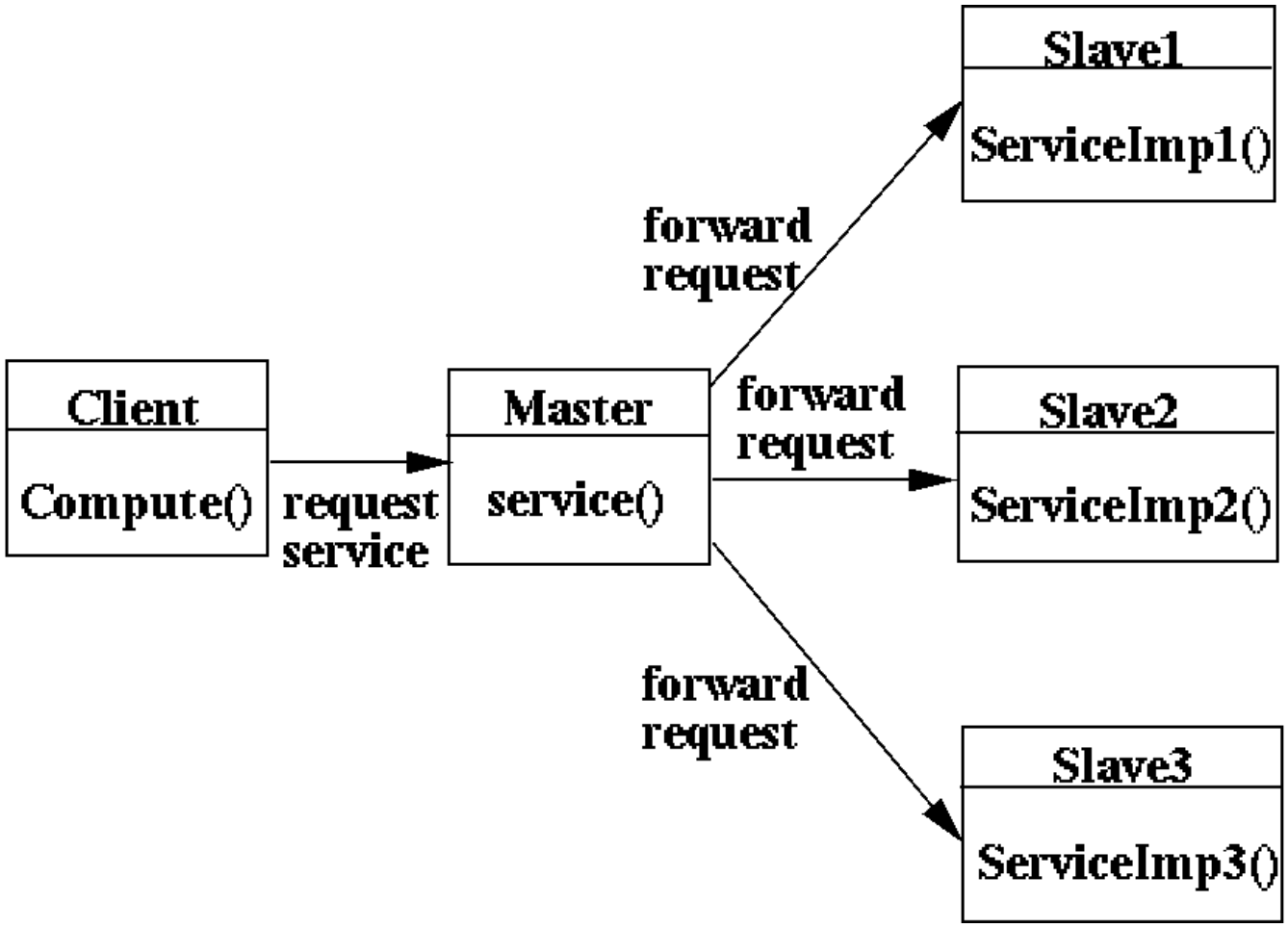
Master-slave: motivation

- Fault tolerance is a critical factor in many systems.
- Replication of services and delegation of the same task to several independent suppliers is a common strategy to handle such cases.

Master-slave: example



Master-slave: structure



Master-slave: participants

Slave:

- Implements a service.

Master:

- Organizes the invocation of replicated services.
- Decides which of the results returned by its slaves is to be passed to its clients.

Client:

- Requires a certain service in order to solve its own task.