Intro to Software "Design Patterns"

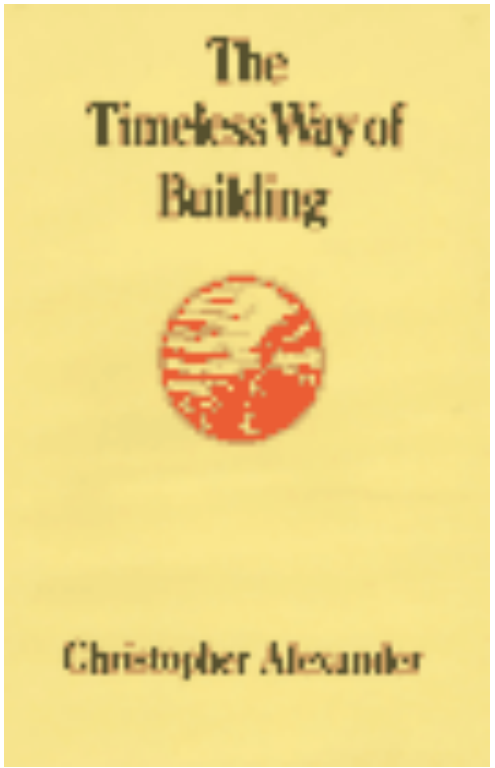
Design Patterns

- Focus of a great deal of current attention in software development research and practice

What started the idea

Two books on *architecture* (not software) by Christopher Alexander, et al.

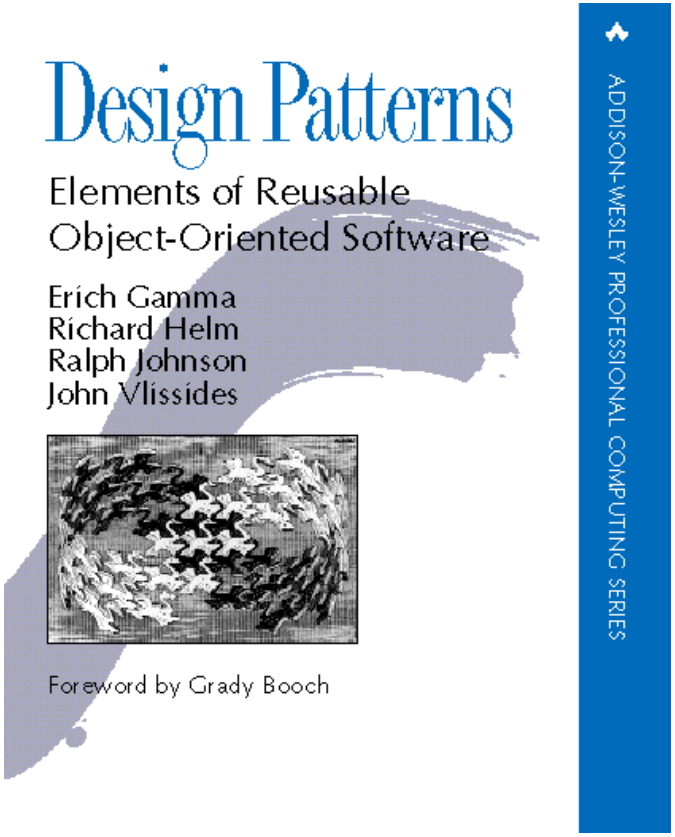
The Timeless Way of Building



A Pattern Language

and then came ...

(aka "Gang of four")



Uses earlier Booch Notation, rather than UML

Definition of a Pattern

- a solution to a recurrent problem
- not a "concrete" solution, but an abstract version of it
- four essential elements:
  - Name of the Pattern
  - The Problem
  - The Solution
  - Consequences, tradeoffs

Uses of Patterns

- Conversational "handle" on which to hang ideas and concepts
- To direct the developer to a known solution for a kind of problem
- To help focus a design
- As a vehicle for refining solution techniques

Patterns help to:

- solve specific design problems
- reduce the need for redesign
- provide reusable solutions
- act as templates
- pass on knowledge from experts to novices

slide lifted from: www.sis.port.ac.uk/%7Echandler/OOLectures/patterns/patterns.htm#Gang of Four

Patterns are not ...

- Classes
- Libraries
- Packages
- Macros
- Higher-order functions
- Template classes

  However, some of these could conceivably capture some design patterns.

UML

- We use UML diagrams to show possible designs of some patterns, for clarification.
- These diagrams should not be taken as *the definition* of the pattern, which remains informal.

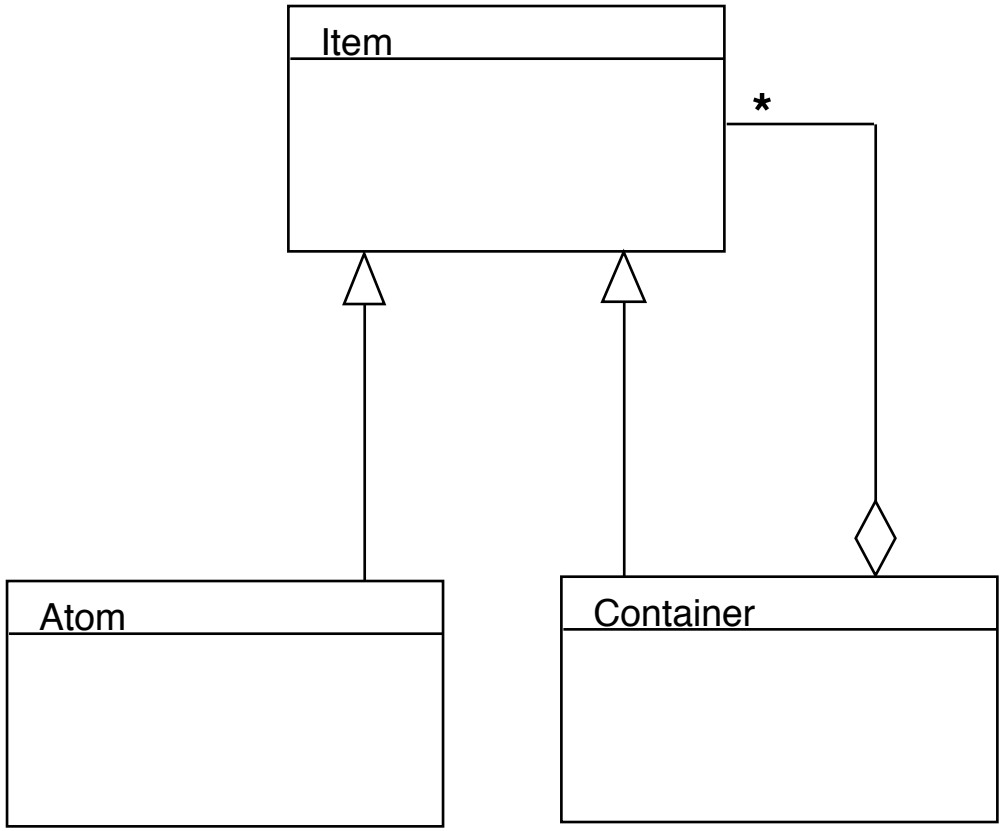
Examples of Patterns

- "Design Patterns" book lists 23 patterns, in several categories. These are sometimes annotated GoF ("Gang of Four").
- (Alexander's book lists 253)
- Larman: GRASPatterns
- Others have contributed many additional patterns (100's).

Example: Composite Pattern

- Name: Composite
- The Problem: Construct a class of objects wherein
  - Objects can be indivisible ***or*** have multiple components.
  - A collection of components can be treated as a ***single*** object by a client.
- The Solution: The one shown in the diagram
- Consequences, tradeoffs

UML for Composite



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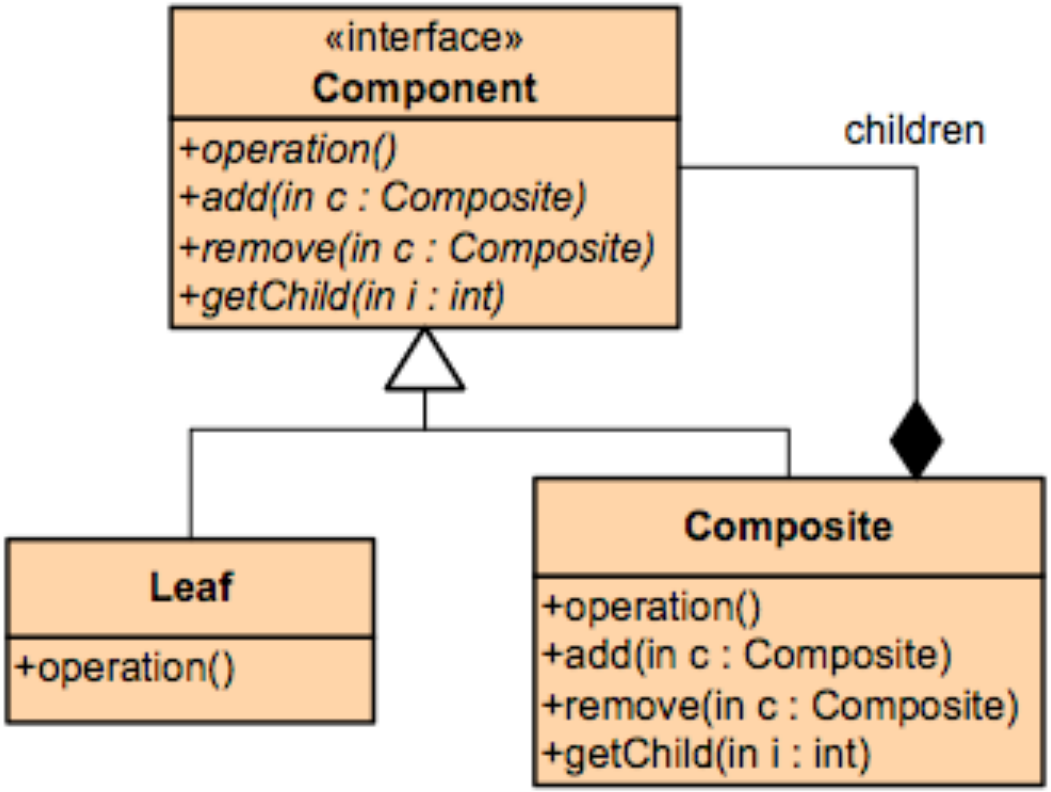


Composite

Type: Structural

What it is:
Compose objects into tree structures to represent part-whole hierarchies. Lets clients treat individual objects and compositions of objects uniformly.

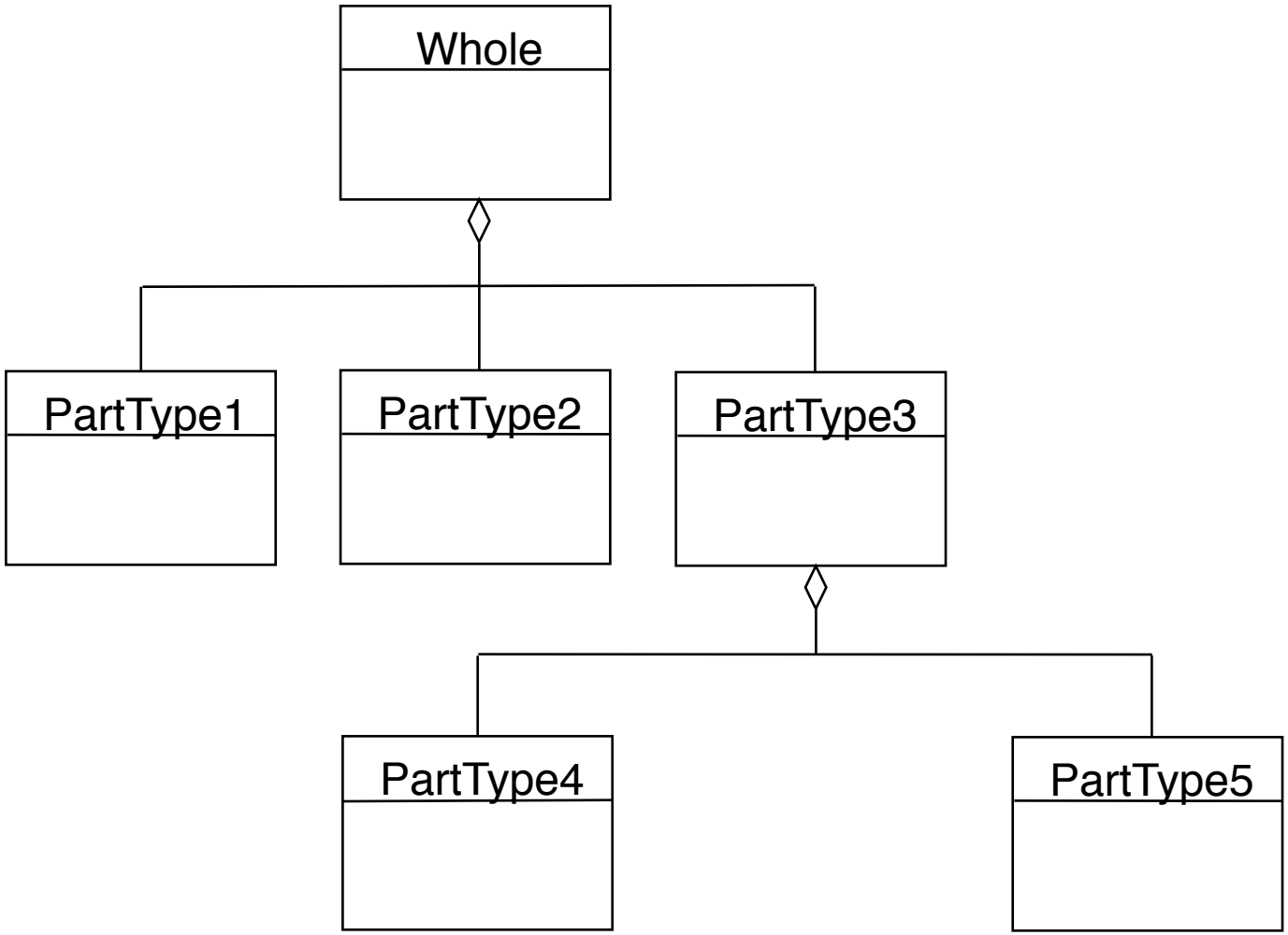
Examples of Composite Patterns

- Drawing program shape class:
  rectangle, oval, **group: set of shapes**
- File systems, files, directories, links
- Window system (e.g. Java awt/swing)
- S expressions
- XML

Tradeoffs in Composite Pattern

- Whether ***recursive*** structure is needed, or will "flat" structure suffice
- Whether ***ordering*** of components is significant
- Whether components refer to ***parents***
- Whether components can be **shared**
- Who should ***delete*** the *children*
- Whether children are represented as a ***list*** or simply enumerated
- Data structure issues (whether to use struct, array,linked list, etc.)

Non-Recursive Composite Pattern UML



Patterns to be Discussed (alphabetized)

- Adapter
- Cache
- Command
- Composite
- Decorator
- Delegation
- Façade
- Interface
- Iterator
- Memento
- Model-View-Controller
- Observer
- Proxy
- Singleton
- State
- Stream
- Visitor

Iterator Pattern

- (GoF, p 257) aka Cursor Pattern
- provides a way to enumerate the elements in a container **without exposing the internal structure of the implementation.**
- There can be multiple Iterators on a given container.
- Examples:
  - Java: **Enumeration** and **Iterator** interfaces
  - C++: Standard Library, there are for many iterator template classes.

C++ Iterator Concepts

- Trivial Iterator
- Input Iterator
- Output Iterator
- Forward Iterator
- Bidirectional Iterator
- Random Access Iterator

See www.sgi.com/tech/stl/Iterators.html

C++ Iterator Types

- istream_iterator
- ostream_iterator

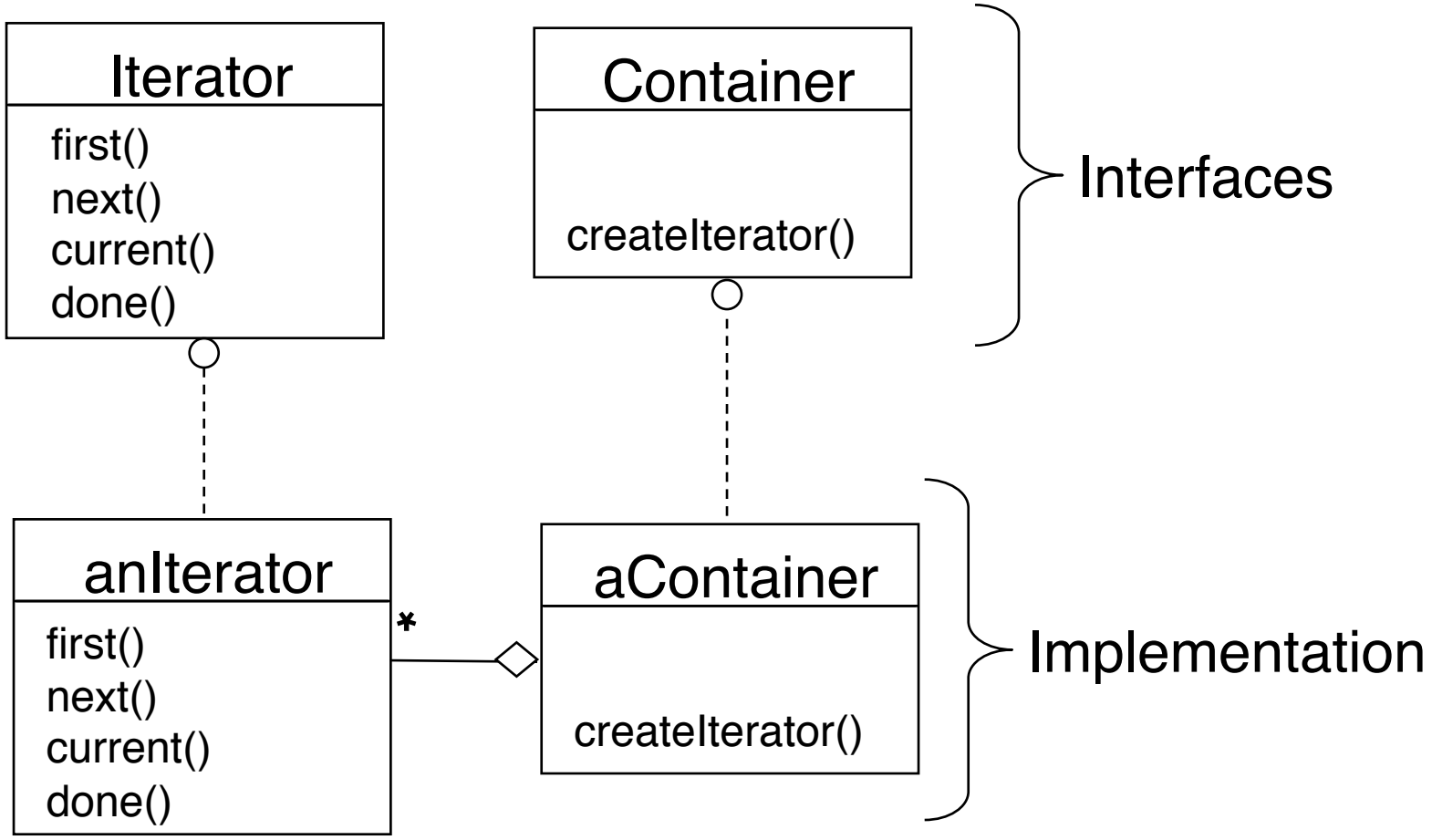
- reverse_iterator
- reverse_bidirectional_iterator
- insert_iterator
- front_insert_iterator
- back_insert_iterator

- input_iterator
- output_iterator
- forward_iterator
- bidirectional_iterator
- random_access_iterator

What Every Iterator Needs

- A way to establish a specific element, such as the "first" element
- A way to access the **current** element
- A way to move on to the "next" element
- A way to indicate that there are no more elements

Iterator Pattern UML, with Interfaces



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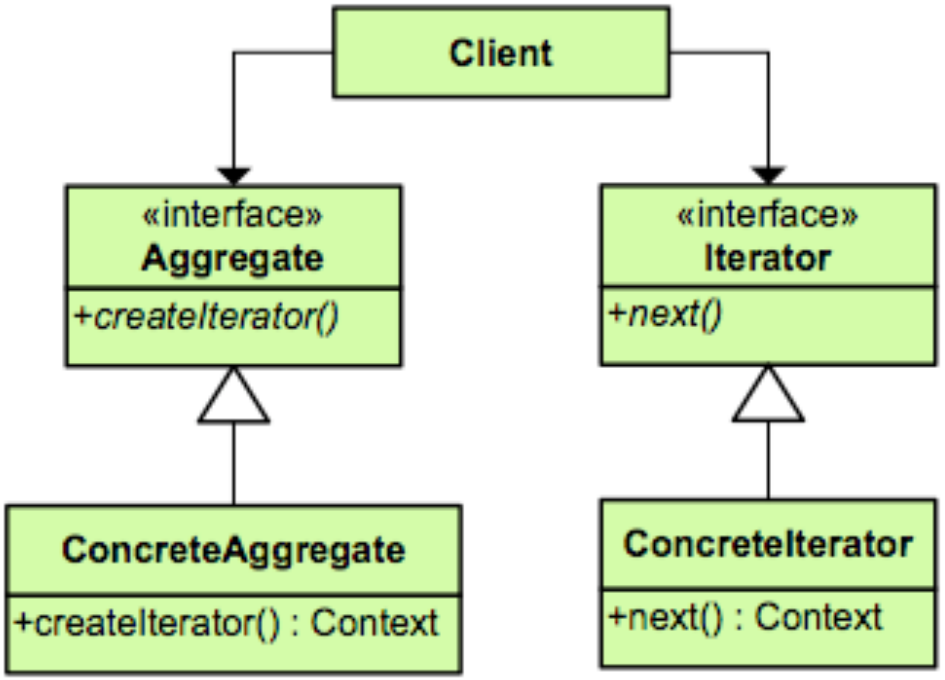


Iterator

Type: Behavioral

What it is:
Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.

Iterator Patterns in Java: Enumeration Interface

- Informal Methods:
  - `creator`
  - `first()`
  - `next()`
  - `!done()`
  - `currentItem()`
- Java realization:
  - `Enumeration e = container.elements();`
  - `(implied in initialization)`
  - `nextElement()`
  - `hasMoreElements()`
  - `none- use result of nextElement()`

Iterator Patterns in Java: **Iterator** Interface

- Informal Methods:
  - `creator`
  - `first()`
  - `next()`
  - `!done()`
  - `currentItem()`
- Java realization:
  - `Iterator e = linkedList.iterator();`
  - `(none, implicit)`
  - `next()`
  - `hasNext()`
  - `(none- save result of next ())`

Iterator Pattern in C++ STL

- General Methods:
  - first()
  - next()
  - done()
  - current()
- C++:
  Container<Type>::Iterator myIterator;
  - myIterator = container.begin();
  - myIterator++;
  - myIterator == container.end();
  - *myIterator
- **Syntax is that of a pointer**

Exercise

- Consider a composite that structures its elements as directed, ordered, **tree**.
- What kinds of iterators would you propose?
- What are the methods on each iterator?

Visitor Pattern

- (GoF, p 331)
- This is one of the more subtle patterns.
- Similar to the Iterator pattern, except that rather than passing objects outside during the enumeration, a Visitor object is passed **into** the Container.
- The Visitor works on the objects while *inside* the Container.
- **Purpose**: Can add **new operations** on a structure without the structure having to know details of the operation.

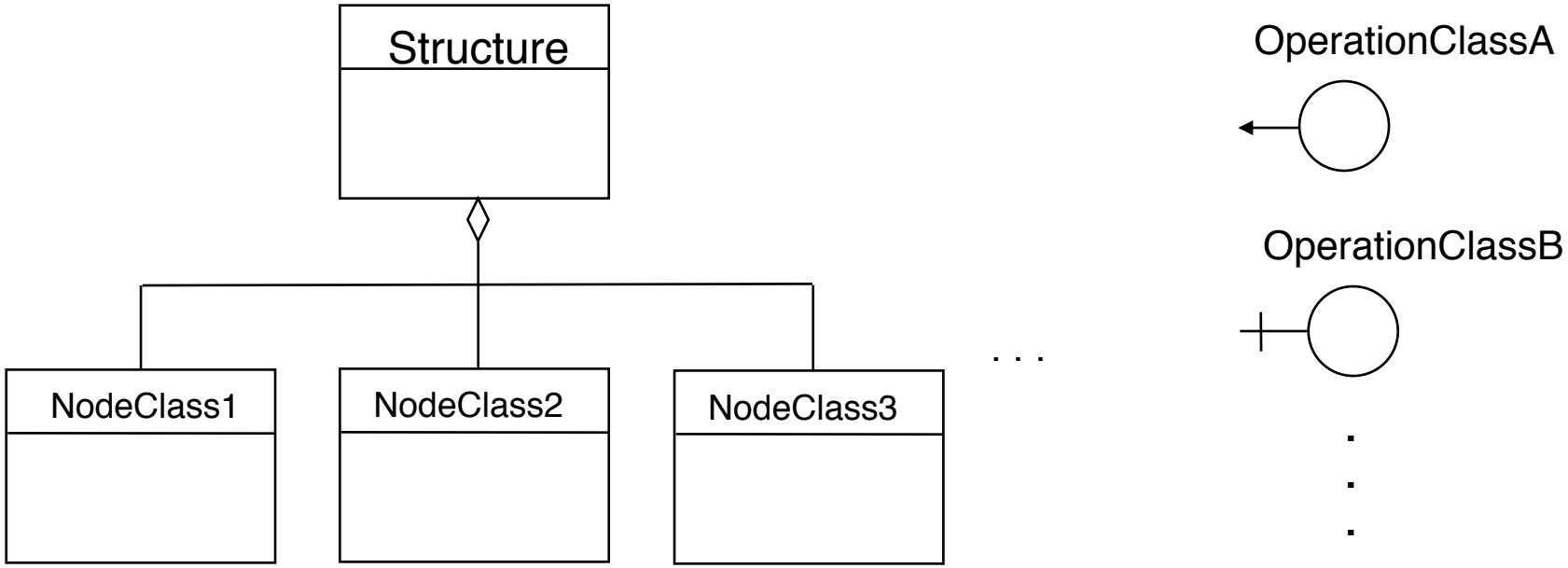
Similar to **map** in Functional Programming

- map(F, L) maps a function over a list.
- There is no explicit extraction of the list elements outside of the container.
- The function does not need to know how the list is structured; it just operates on single elements.

Visitor Details

- Suppose a structure of a given class contains sub-structures of various classes (call them "nodes").
- We plan to call a method on such structures, which will need to "visit" some or all of the nodes.
- We do *not* want to include in the definition of our structure the code for every type of operation that might be done on a node.
- We don't necessarily want to limit in advance the kinds of operations that are done with nodes.

Visitor Pattern Context



Setting Up for Visitor

- Each operation class is expected to have a method ***visit*** for each node class:
  - class OperationA
    {
    void visit(NodeClass1 n) …
    void visit(NodeClass2 n) …
    void visit(NodeClass3 n) …
    }
  - class OperationB
    {
    void visit(NodeClass1 n) …
    void visit(NodeClass2 n) …
    void visit(NodeClass3 n) …
    }

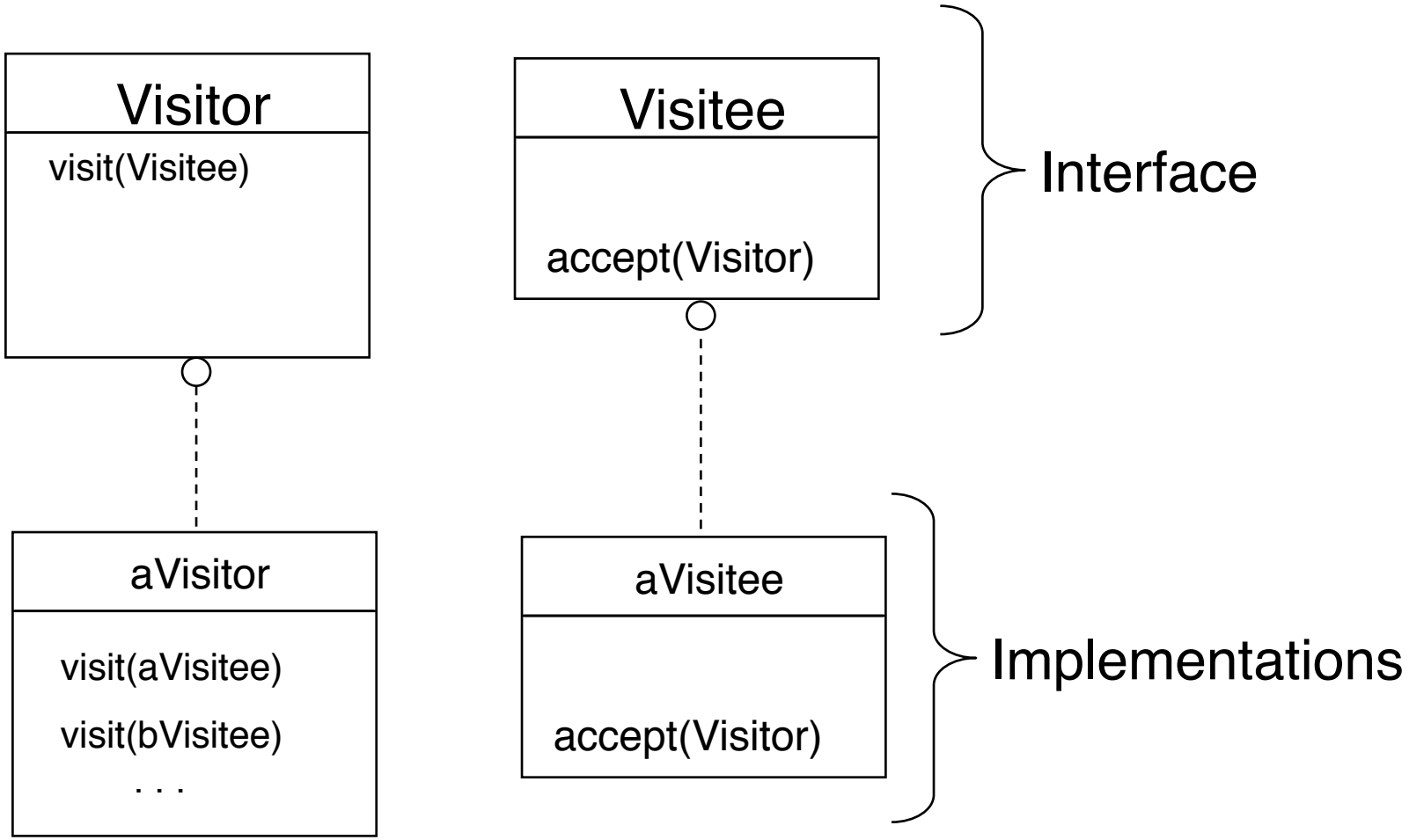
Setting Up for Visitor

- We characterize the preceding requirement by defining an interface, **Visitor**, that each operation class implements.
  - interface Visitor
    {
    void visit(NodeClass1 n);
    void visit(NodeClass2 n);
    void visit(NodeClass3 n);
    }
  - class OperationA implements Visit
    {
    void visit(NodeClass1 n) …
    void visit(NodeClass2 n) …
    void visit(NodeClass3 n) …
    }
  - class OperationB implements Visit
    etc.

Setting Up for Visitor

- Each node class provides a method ***accept*** with Visitor as argument which executes the corresponding aspect of the operation with the visitor.
  - class NodeClass1
    {
    void accept(Visitor v) { v.visit(this); }
    }
  - class NodeClass2
    {
    void accept(Visitor v) { v.visit(this); }
    }
- Generally, the meaning of visit will be distinct for each node class.
- This could be captured by having each node class implement an interface **Visitee**.

Visitor Pattern UML



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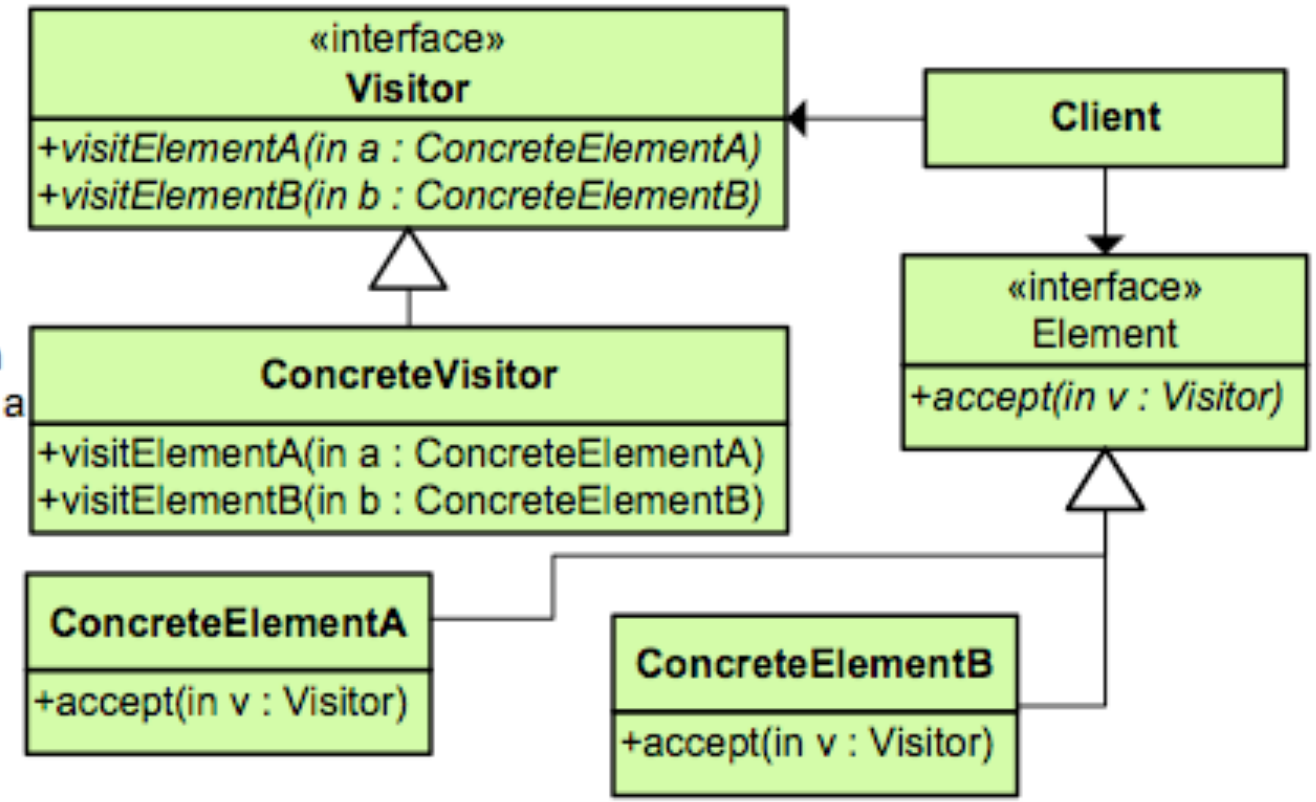
Visitor

Type: Behavioral

What it is:
Represent an operation to be performed on the elements of an object structure. Lets you define a new operation without changing the classes of the elements on which it operates.



Notes on Visitor

- The structure could be an instance of the Composite pattern.
- Thus visit() might be defined recursively.

Double Dispatch as Visitor

- Occasionally a need to dispatch not just on the object type by also on the type of argument to the object.
- It is preferable to have a compile-time, rather than run-time, implementation.
- In Visitor, both the choice of Visitor method and the choice of Visitor could be determined at compile time.
- [Some languages, not Java or C++, support general multiple dispatch syntax directly.]
- See http://en.wikipedia.org/wiki/Double_dispatch for example.

Visitor in C++

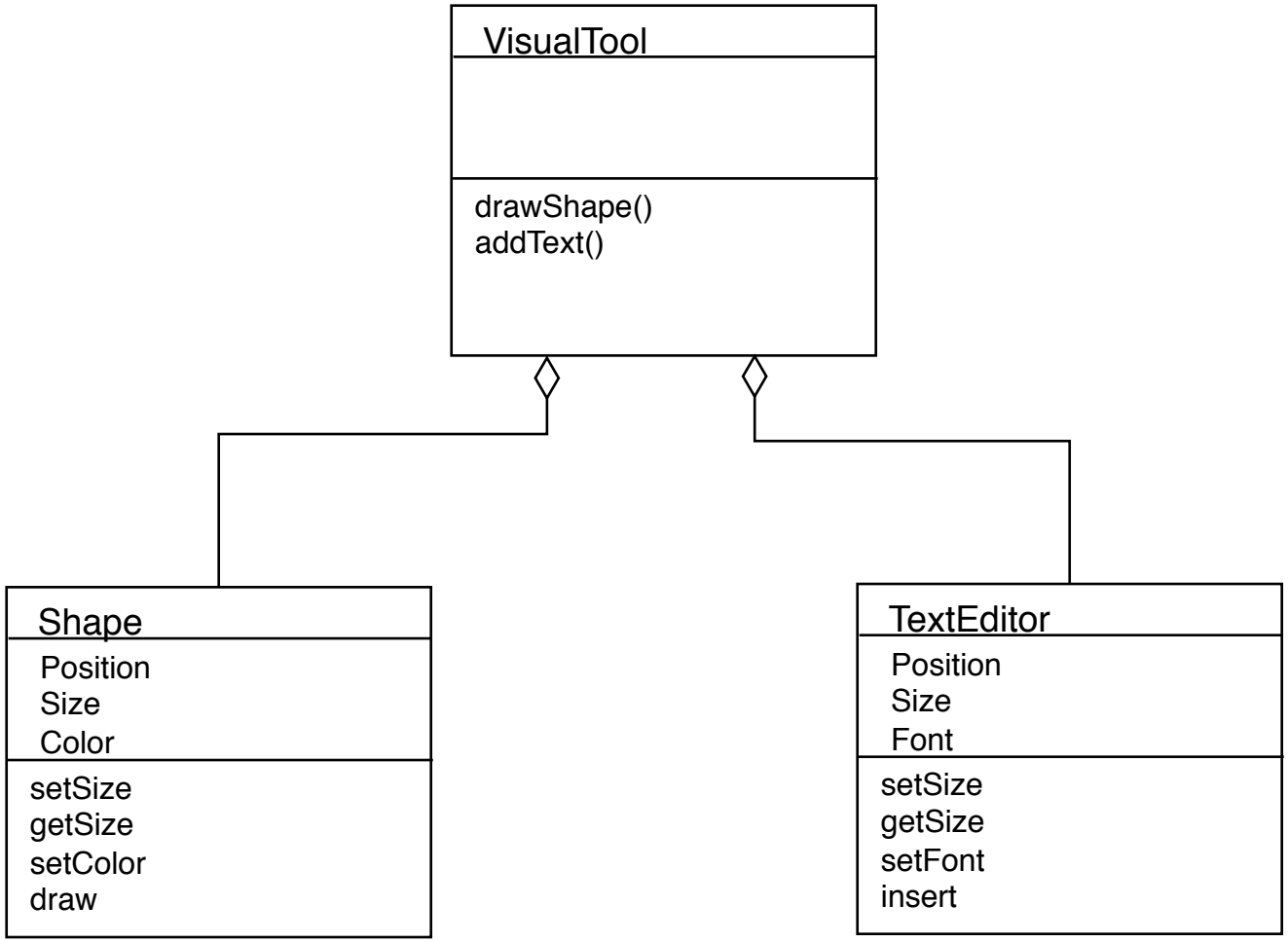
- ```
  class Visitee<VisiteeType>
  {
  accept(Visitor<VisitorType> v);
  ….
  }
  ```

- ```
  class Visitor<VisitorType>
  {
  visit(Visitee<VisiteeType> e);
  }
  ```

Façade Pattern

- (GoF, p 185)
- An entire sub-system or set of classes, etc. is given a **single simple interface** in order to
  - shield the user against the internal complexity of how the classes are used together
  - bundle together less-coupled components

Façade Pattern example



Façade Pattern

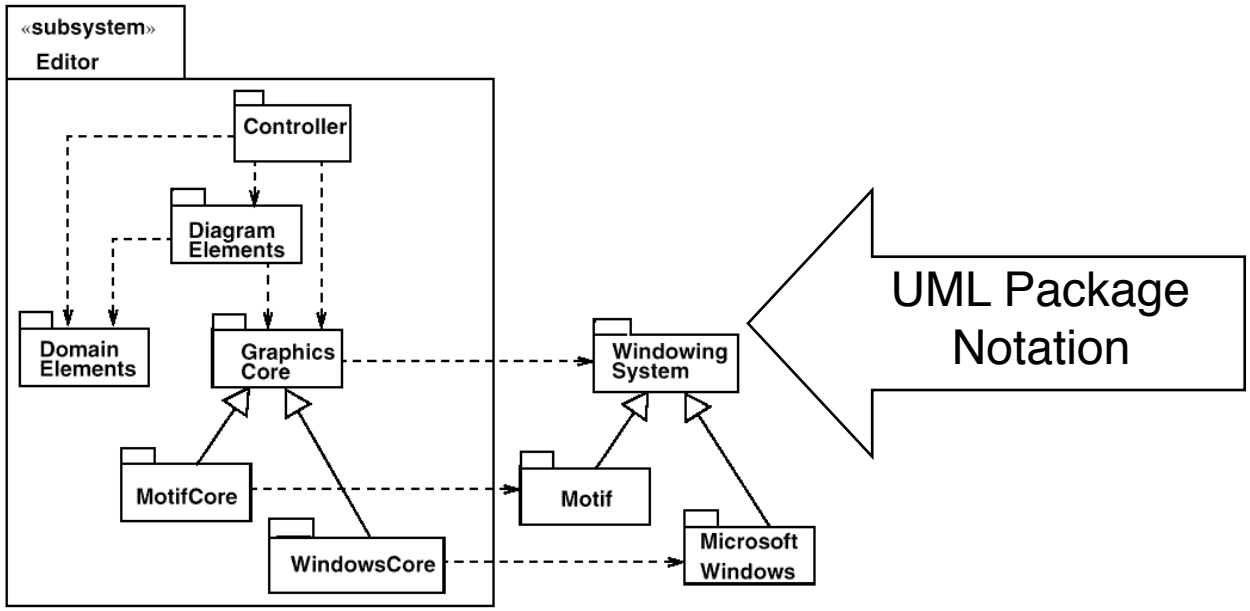
- In building using a façade pattern, it is important that the individual components not *depend* on the façade itself.
- This would introduce cross-coupling, which is undesirable.
- When the façade is "removed", the components should "fall apart" as their original, uncoupled or loosely-coupled, entities.

Question

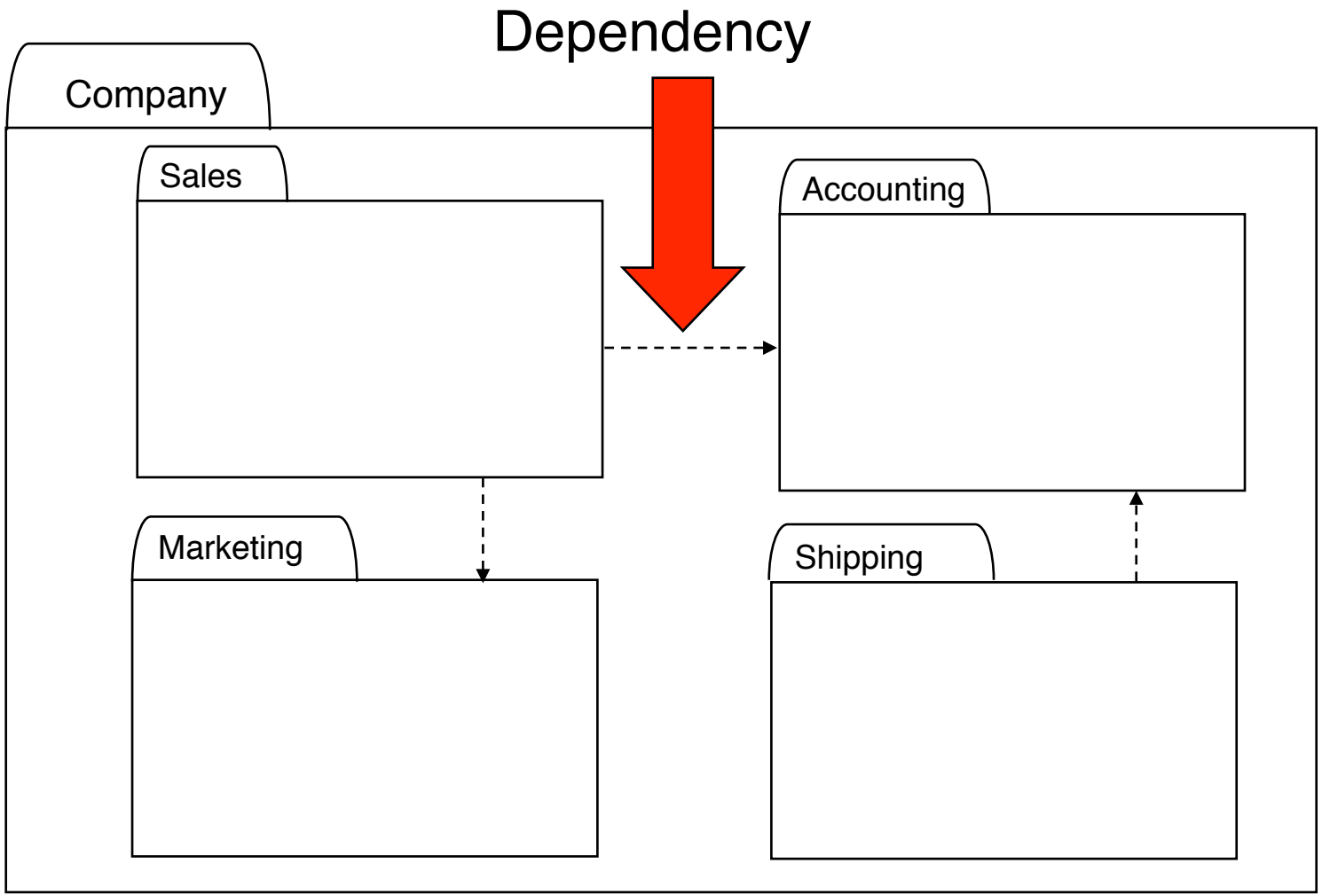
- Does the Façade pattern violate the SRP (Martin's Single-Responsibility Principle)?

Rather than Make the Façade a Single Class, A **Package** can also be used

- A package is a group of related classes.
- Packages can have sub-packages.
- Visibility can be controlled



Packages/Dependency notation in UML



Coupling / Cohesion Terminology

- Two packages (or classes, for that matter) between which there is a high-degree of inter-dependence are said to be **strongly-coupled**.

- Strong coupling is considered **undesirable**; **loosely-coupled** is better for packages and classes.

Coupling / Cohesion Terminology

- A set of methods for a class, or classes in a package, are said to be **cohesive** (or "coherent") if they provide aspects of a uniform model for dealing with objects.

- Cohesiveness is desirable; it is the mark of a careful design.

Coupling / Cohesion Summary

- Coupling is "bad".
- Cohesion (coherence) is "good".

- See also: GRASP (Larman):
  - Low-coupling pattern
  - High-cohesion pattern

About Packages

- **Innermost** packages contain classes
- **Cyclic dependencies** among packages should be avoided: break them, or combine into a single package.
- Packages can help delineate work-breakdown among teams, and can thus serve as a **management device**
- Consider **Java *package* construct.**
- Equivalent in C++ is **namespaces**

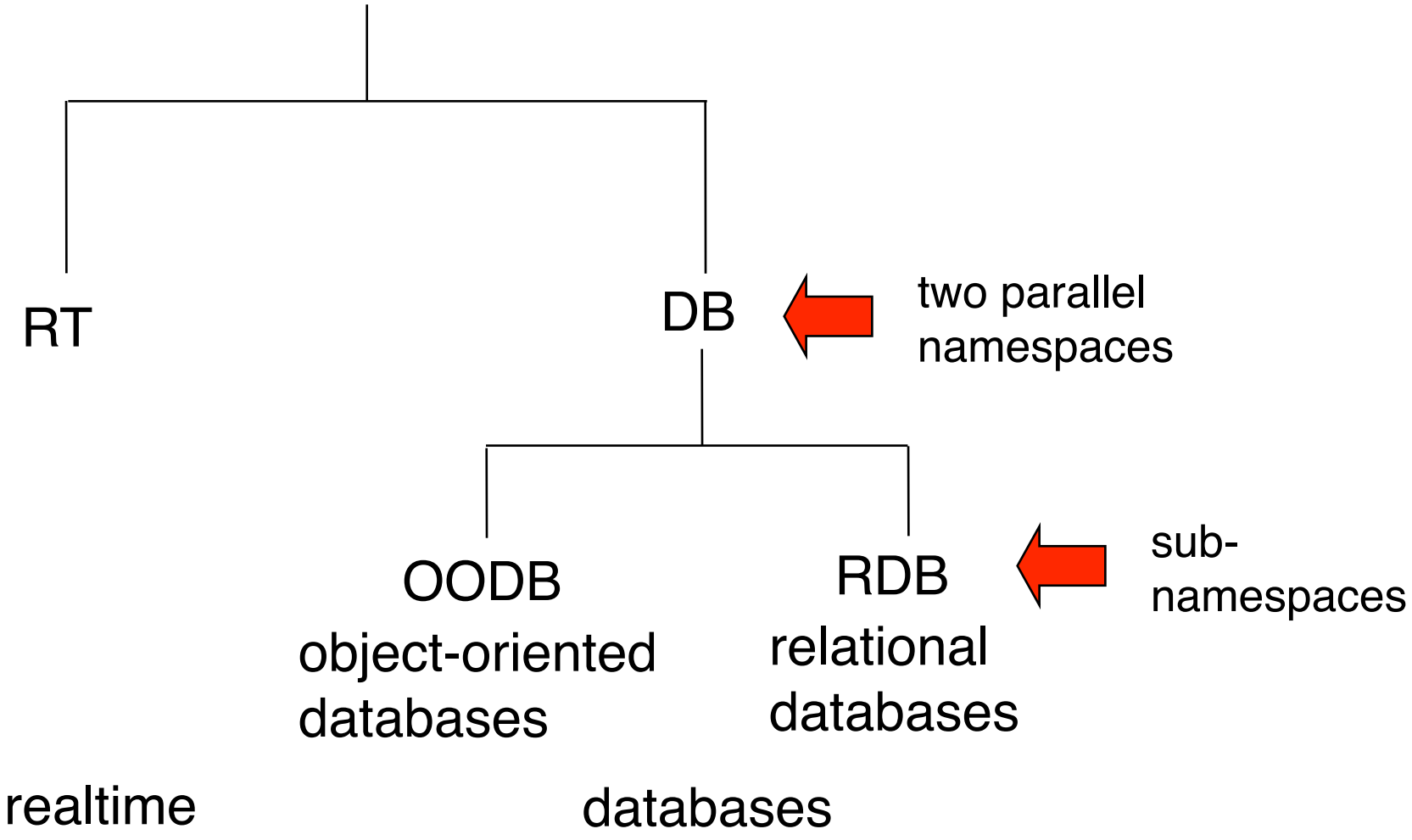
A Portion of a Java Package Hierarchy

```
java.net
java.rmi
     java.rmi.activation
     java.rmi.dgc
     java.rmi.registry
java.rmi.server
java.security
     java.security.acl
     java.security.cert
     java.security.interfaces
     java.security.spec
```

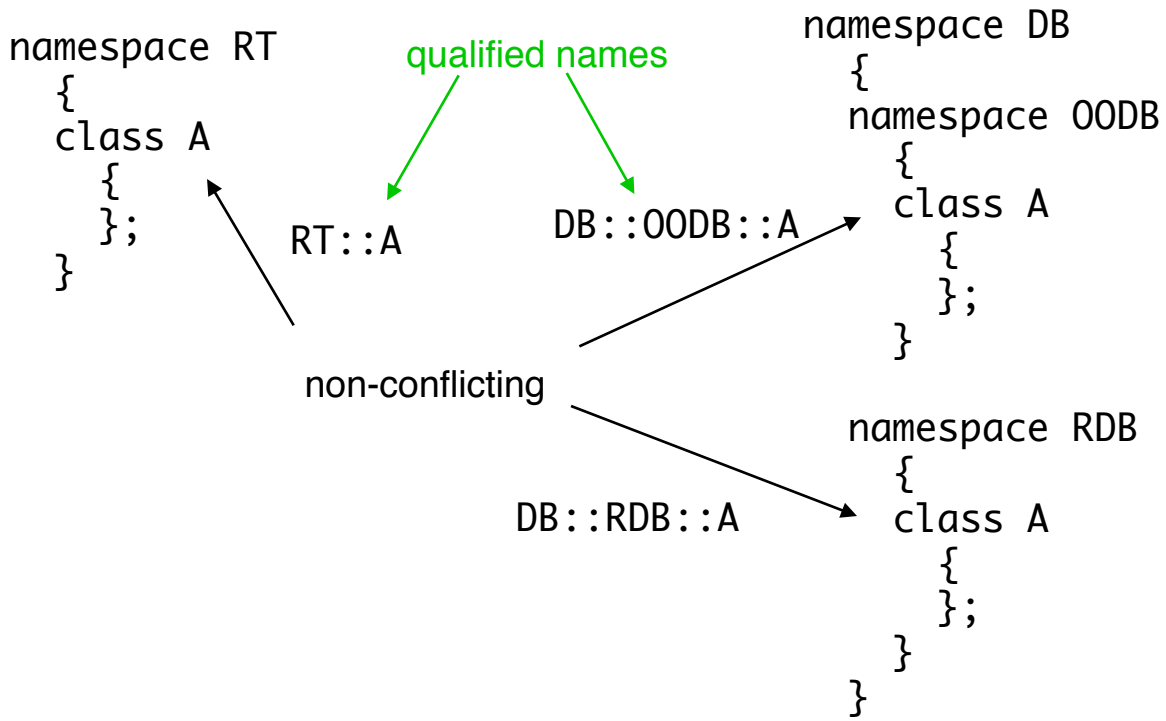
Namespaces in C++

- Without Namespaces, there is one big flat name space.
- The danger is conflicting names in different modules and name space "pollution" by modules with lots of names.
- Namespace construct allows structuring into an arbitrary number of hierarchical levels.

C++ Namespace Example



C++ Namespace Example



Short-cut rules can lead to confusion if used.

Decorator Pattern

- (GoF, p 175)
- aka Wrapper (one version)

- Enclose an object of one class in another class that "decorates" the original objects (e.g. scrollbars or a border around a window).

- Examples: streams of various types (OutputStream, **File**OutputStream, **Print**Stream, …)

Decorator Class Structure

- At least three possibilities:
  - The decorating class **inherits** from the decorated class ("direct" decoration).
  - The decorating class **aggregates** or **composes** a member of the decorated class ("decoration by **delegation**").
  - A third class aggregates or composes both the decorated class and the decorations (sometimes called "mix-ins", or "traits", which are not the same).

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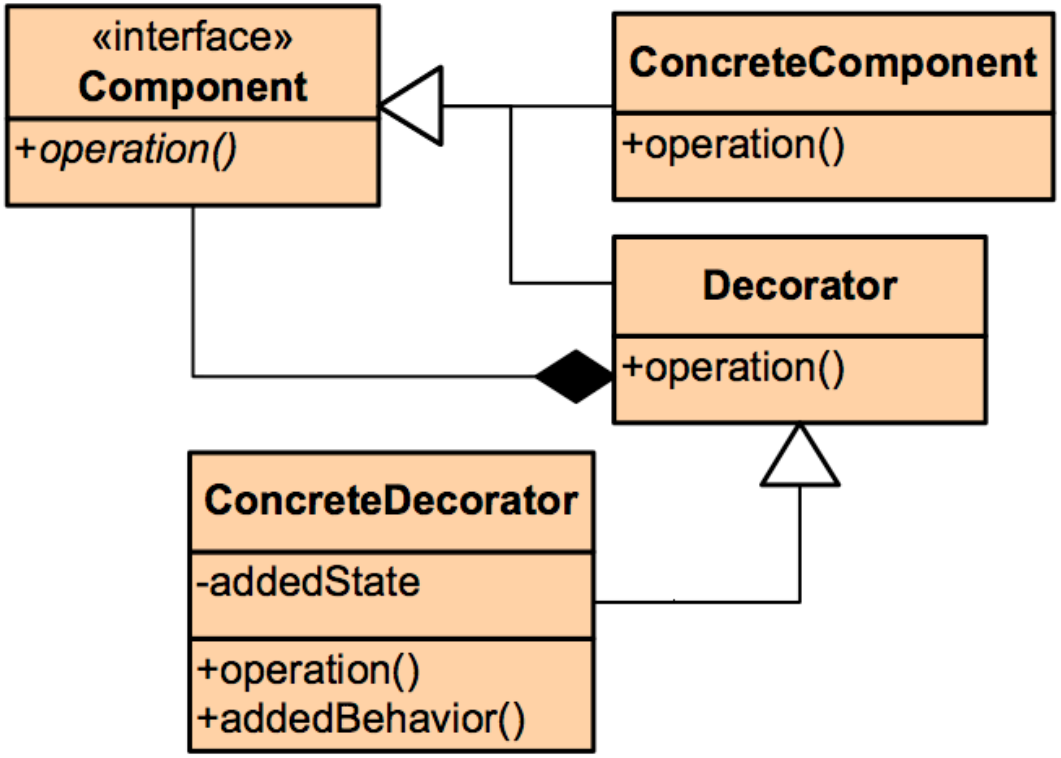


Decorator

Type: Structural

What it is:
Attach additional responsibilities to an object dynamically. Provide a flexible alternative to sub-classing for extending functionality.

Adapter Pattern

- (GoF, p 139)
- aka Binding, Wrapper (second version)

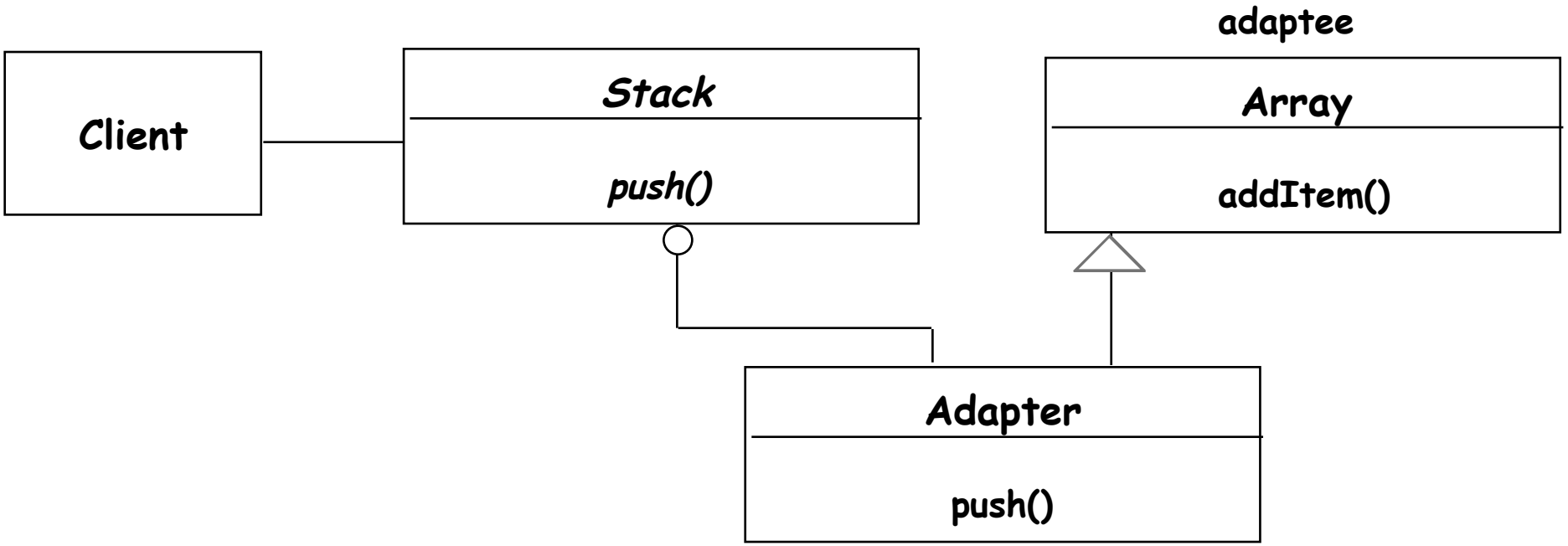
- Adapts one or more existing APIs to fit another API specification (one that clients expect).

- (API = Application Programming Interface)

Adapter Example

- An interface defines a **Stack**.
- A dynamic array implementation defines an **Array**.
- An adapter is an **ArrayStack**, i.e. a class satisfying the stack interface, implemented using an array.
- The roles of the Stack and Array classes are not symmetric.

Adapter Pattern Example (Brugge)



In C++, multiple inheritance would be used.

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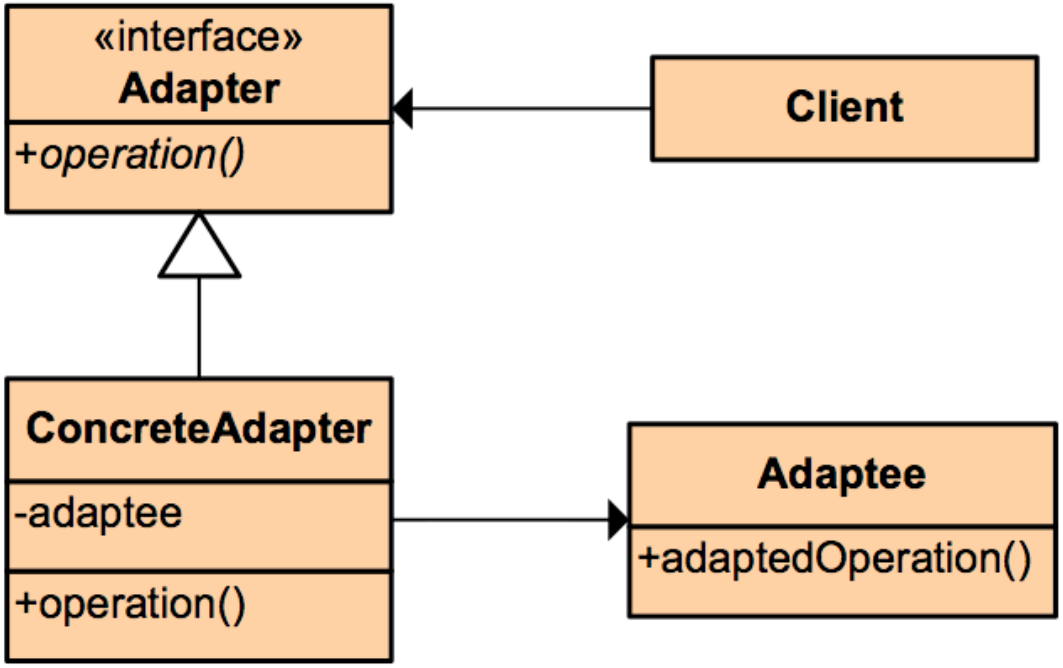


Adapter

Type: Structural

What it is:
Convert the interface of a class into another interface clients expect. Lets classes work together that couldn't otherwise because of incompatible interfaces.

Bridge Pattern

- (GoF, p 151)
- aka "Handle/Body" or "Interface" pattern

- Abstract an API by providing an interface class, with the **intention by design** of providing ***different implementations*** for the interface.

- Example: Java awt (abstract window toolkit) vs. M/S Windows or MacOS Windows (called "peer" classes)

Java Example

java.awt.peer

The java.awt.peer package is a subpackage of AWT that provides the (hidden) platform-specific AWT classes (for example, Motif, Macintosh, Windows 95) with platform-independent interfaces to implement. Thus, callers using these interfaces need not know which platform's window system these hidden AWT classes are currently implementing.

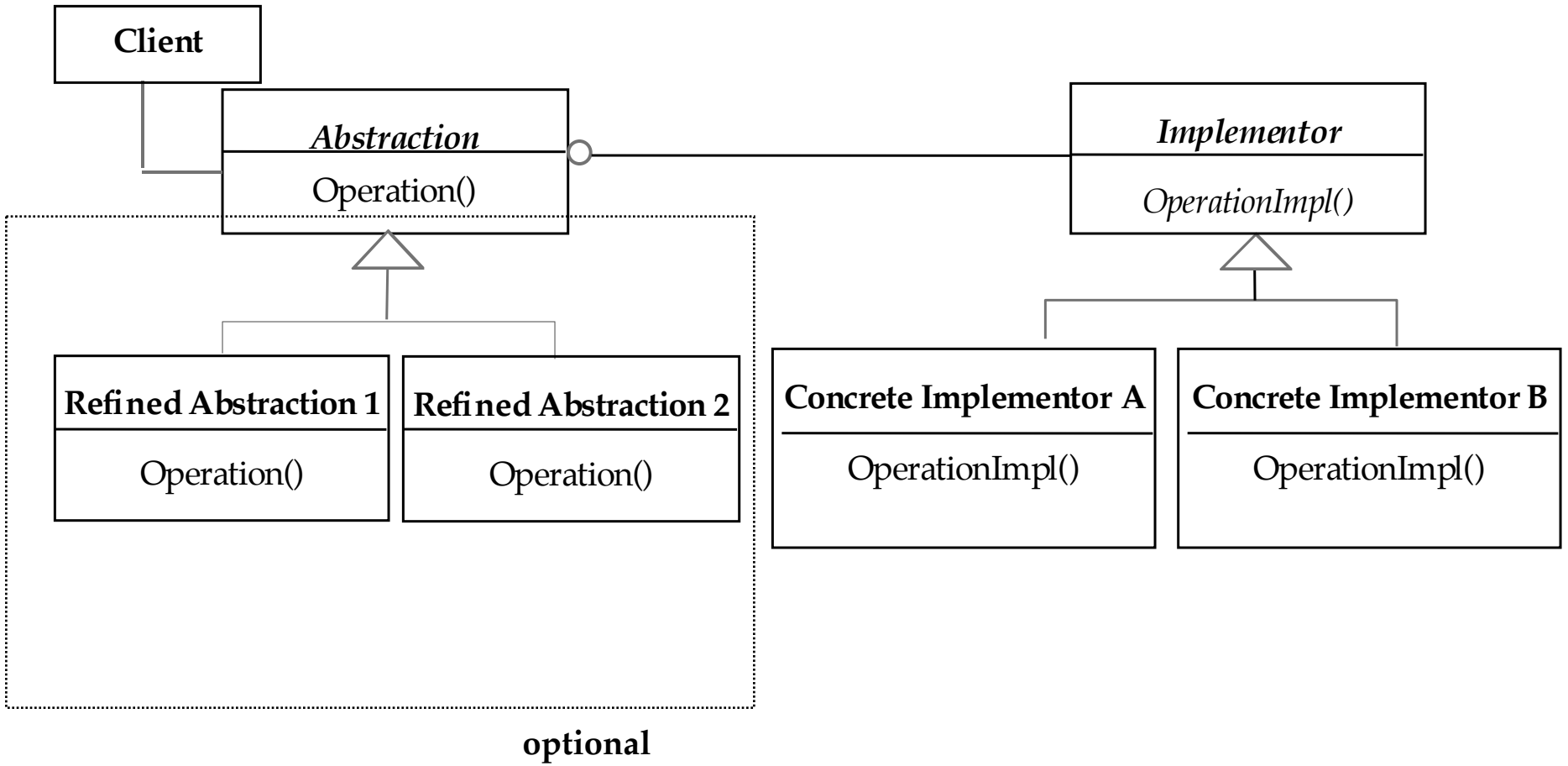
Each class in the AWT that inherits from either Component or MenuComponent has a corresponding peer class. Each of those classes is the name of the Component with -Peer added (for example, ButtonPeer, DialogPeer, and WindowPeer). Because each one provides similar behavior, they are not enumerated here.

§3.22 Interface WindowPeer

The window peer interface specifies the methods that all implementations of Abstract Window Toolkit windows must define.

```
public  interface  java.awt.peer.WindowPeer
    extends java.awt.peer.ContainerPeer  (II-§3.7)
{
        // Methods
    public abstract void toBack();       §3.22.1
    public abstract void toFront();      §3.22.2
}
```

Bridge Pattern UML (Brugge)



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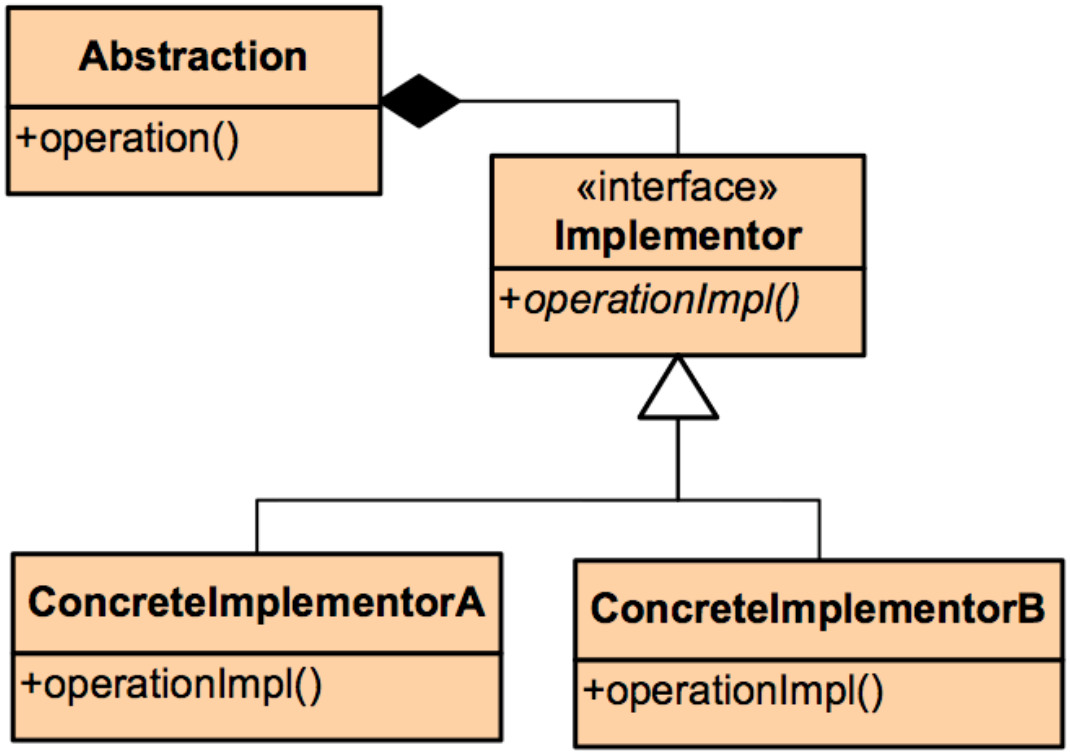


Bridge

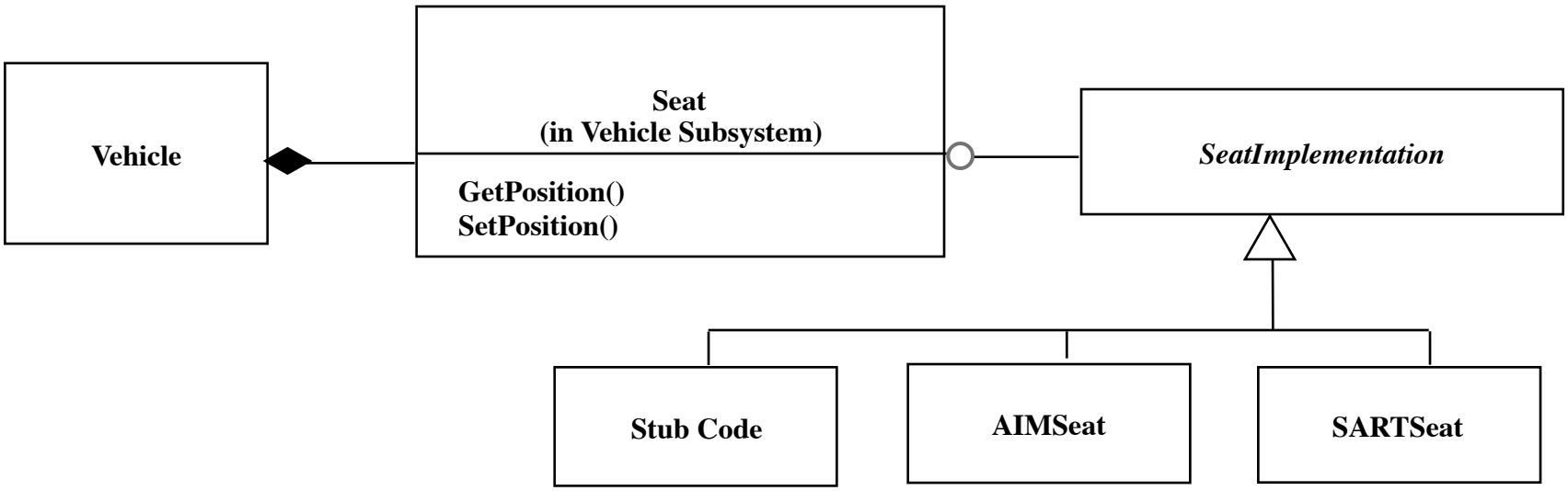
Type: Structural

What it is:
Decouple an abstraction from its implementation so that the two can vary independently.

Using a Bridge (Brugge)

- Example: Interface to a component that is incomplete, not yet known or unavailable during testing

- JAMES Project (CMU): if seat (for vehicle) data is required to be read, but the seat is not yet implemented, not yet known or only available by a simulation, provide a bridge:



JAMES Bridge Example in Java

```
public interface SeatImplementation {
  public int GetPosition();
  public void SetPosition(int newPosition);
}
public class AimSeat implements SeatImplementation {
  public int GetPosition() {
    // actual call to the AIM simulation system
  }
  ...
}
public class SARTSeat implements SeatImplementation {
  public int GetPosition() {
    // actual call to the SART seat simulator
 }
  ...
}
```

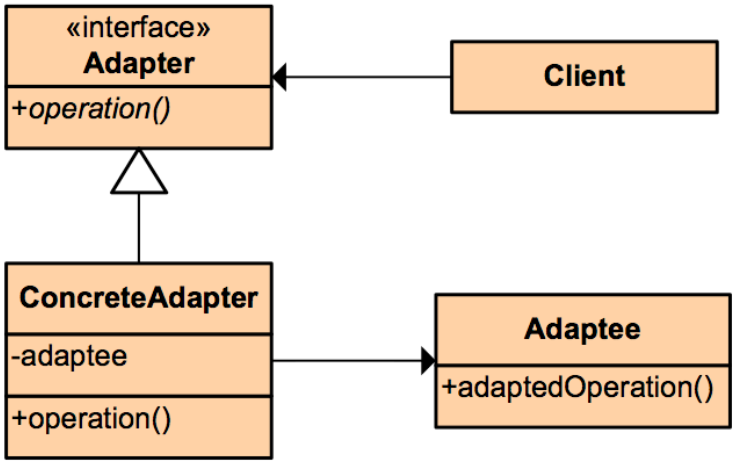
Adapter vs. Bridge

- Adapter and Bridge are similar:
  - **Adapter**: Adapts **existing** classes to an expected interface. The interface and classes exist; the new thing is the **adapter**, a go-between class.
  - **Bridge**: Creates an abstract Interface **to be** implemented by multiple classes; keeps the implementations separate from the interface. The new thing is the **interface**.

Adapter vs. Bridge

- The **adapter** pattern is geared towards making **unrelated** components work together
  - Applied to systems **after** they're designed (**reengineering**, interface engineering).
- A **bridge**, on the other hand, is used in a design to let abstractions and implementations vary independently.
  - **Ab initio engineering** of an "extensible system"
  - New "beasts" can be added to the "object zoo", even if these are not known at analysis or system design time.

Adapter vs. Bridge

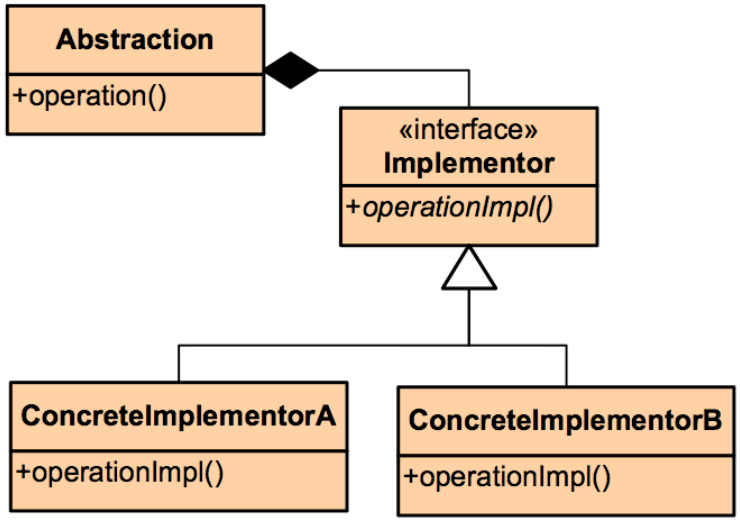


Adapter

Type: Structural

What it is:
Convert the interface of a class into another interface clients expect. Lets classes work together that couldn't otherwise because of incompatible interfaces.

Is this essential?



Bridge

Type: Structural

What it is:
Decouple an abstraction from its implementation so that the two can vary independently.

C++ Bridge Pattern (part 1)

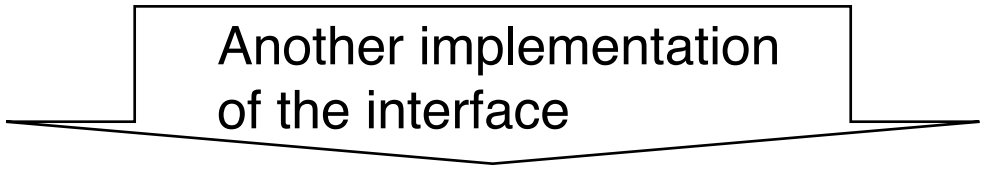
```
class Stack<Item>
{
virtual void push(Item item) = 0;
virtual Item pop() = 0;
}

class ArrayStack<Item> : public Stack<Item>
{
Item array[ ];
}
```

Interface definition

An implementation of the interface

C++ Bridge Pattern (cont'd)




- ```
  class ListStack<Item> : public Stack<Item>
  {
  list<item> List;
  }
  ```
  ```

Singleton Pattern

- (GoF, p 127)
- A class with exactly one instance (or a class, used only for its static members).
- Implements a **global access point**.
- Still use a class
  - Wired-in globals are still not a good idea.
  - May wish to use multiple instances **in the future**.

Flash Card Version

source: http://www.mcdonaldland.info/2007/11/28/40/

Singleton

Type: Creational

What it is:
Ensure a class only has one instance and provide a global point of access to it.