



Chapter 4: Reusability-Oriented Software Construction Approaches

4.3 Design Patterns for Reuse 面向复用的设计模式

April 11, 2020

Outline

除了Framework，4-2节所讨论的其他复用技术都过于“基础”和“细小”，有没有办法做更大规模的复用设计？

本节：几种典型的“面向复用”的设计模式

■ Structural patterns

- **Adapter** allows classes with incompatible interfaces to work together by wrapping its own interface around that of an already existing class.
- **Decorator** dynamically adds/overrides behavior in an existing method of an object.
- **Facade** provides a simplified interface to a large body of code.

■ Behavioral patterns

- **Strategy** allows one of a family of algorithms to be selected on-the-fly at runtime.
- **Template method** defines the skeleton of an algorithm as an abstract class, allowing its subclasses to provide concrete behavior.
- **Iterator** accesses the elements of an object sequentially without exposing its underlying representation.

Reading

- CMU 17-214: Sep 12、Sep 17
- 设计模式：第1、2章；第4.1、4.4、4.5、5.4、5.9、5.10节



Why reusable design patterns?



A design...

...enables flexibility to change (reusability)

...minimizes the introduction of new problems when fixing old ones (maintainability)

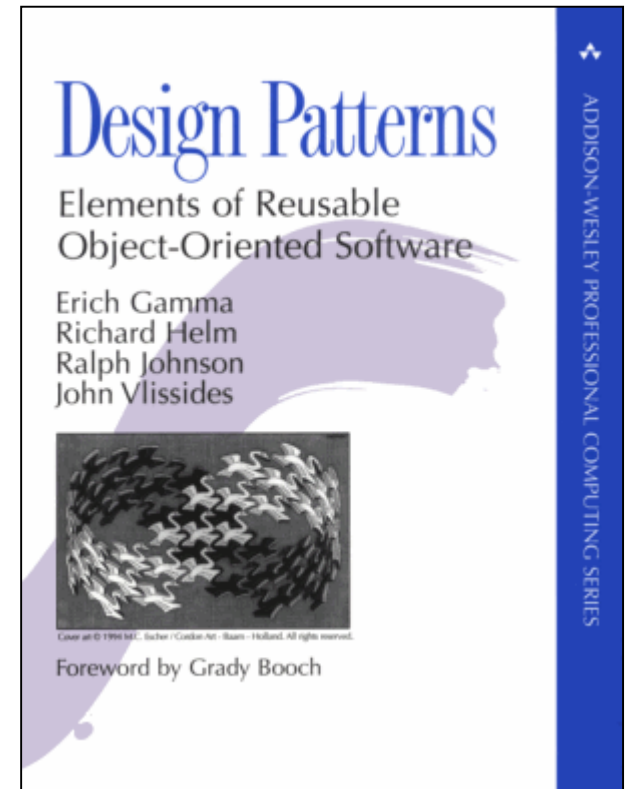
...allows the delivery of more functionality after an initial delivery (extensibility).

Design Patterns: a general, reusable solution to a commonly occurring problem within a given context in software design.

OO design patterns typically **show relationships and interactions between classes or objects**, without specifying the final application classes or objects that are involved. 除了类本身，设计模式更强调多个类/对象之间的关系和交互过程——比接口/类复用的粒度更大

Gang of Four

- **Design Patterns: Elements of Reusable Object-Oriented Software**
- **By GoF (Gang of Four)**
 - Erich Gamma
 - Richard Helm
 - Ralph Johnson
 - John Vlissides



Design patterns taxonomy

- **Creational patterns** 创建型模式
 - Concern the process of object creation
- **Structural patterns** 结构型模式
 - Deal with the composition of classes or objects
- **Behavioral patterns** 行为类模式
 - Characterize the ways in which classes or objects interact and distribute responsibility.



1 Structural patterns



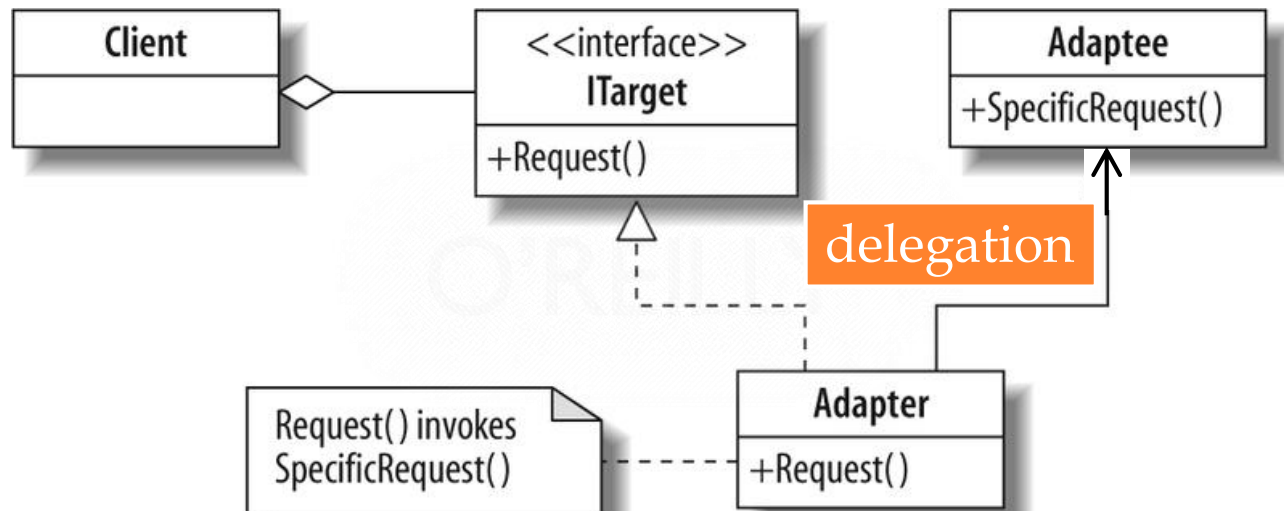


(1) Adapter

适配器模式

Adapter Pattern

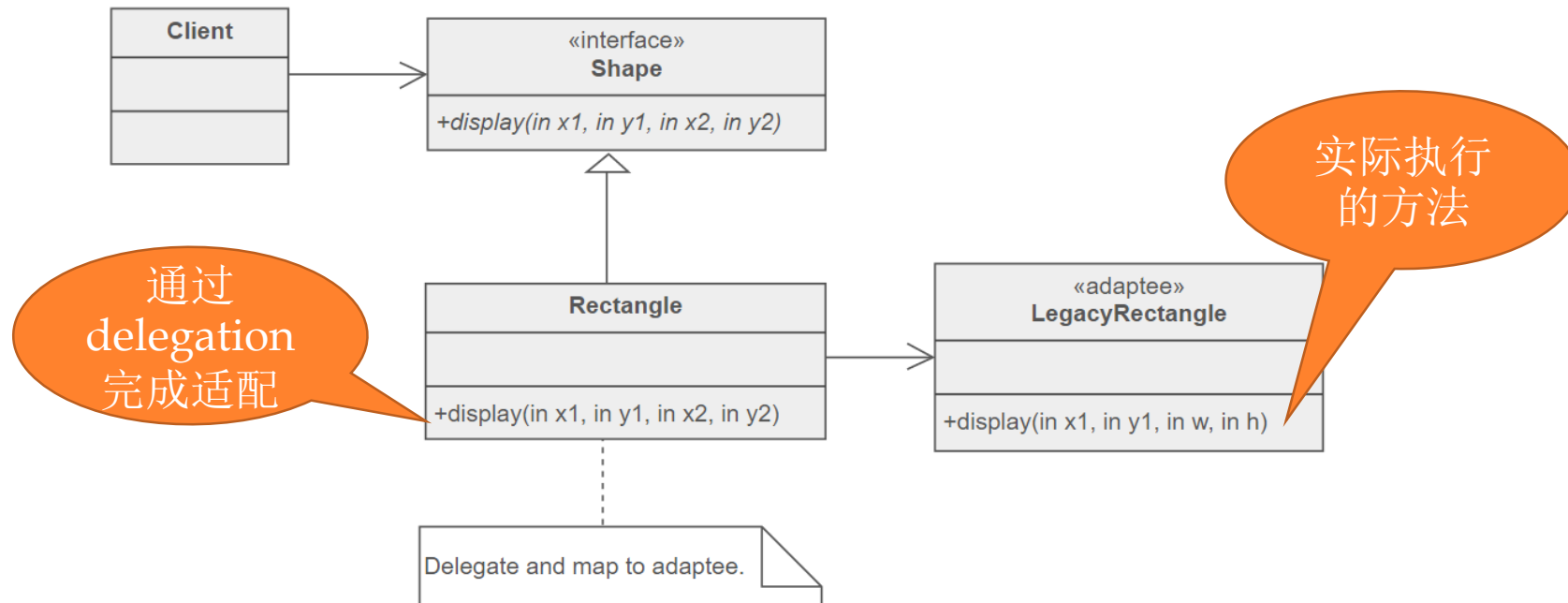
- **Intent:** Convert the interface of a class into another interface that clients expect to get. 将某个类/接口转换为client期望的其他形式
 - Adapter lets classes work together that couldn't otherwise because of **incompatible** interfaces.
 - Wrap an existing class with a new interface. 通过增加一个接口，将已存在的子类封装起来，client面向接口编程，从而隐藏了具体子类。
- **Object:** to reuse an old component to a new system (also called “**wrapper**”)



Example

Client里的调用代码怎么写？

- A LegacyRectangle component's display() method expects to receive "x, y, w, h" parameters.
- But the client wants to pass "upper left x and y" and "lower right x and y".
- This incongruity can be reconciled by adding an additional level of indirection – i.e. an Adapter object. ----Delegation



Example: without Adaptor pattern

```
class LegacyRectangle {  
    void display(int x1, int y1, int w, int h) {... }  
}
```

```
class Client {  
    public display() {  
        new LegacyRectangle().display(x1, y1, x2, y2);  
    }  
}
```



Delegation incompatible!

Example: with Adaptor pattern

```
interface Shape {  
    void display(int x1, int y1, int x2, int y2);  
}
```

Adaptor类实现抽象接口

```
class Rectangle implements Shape {  
    void display(int x1, int y1, int x2, int y2) {  
        new LegacyRectangle().display(x1, y1, x2-x1, y2-y1);  
    }  
}
```

具体实现方法的适配

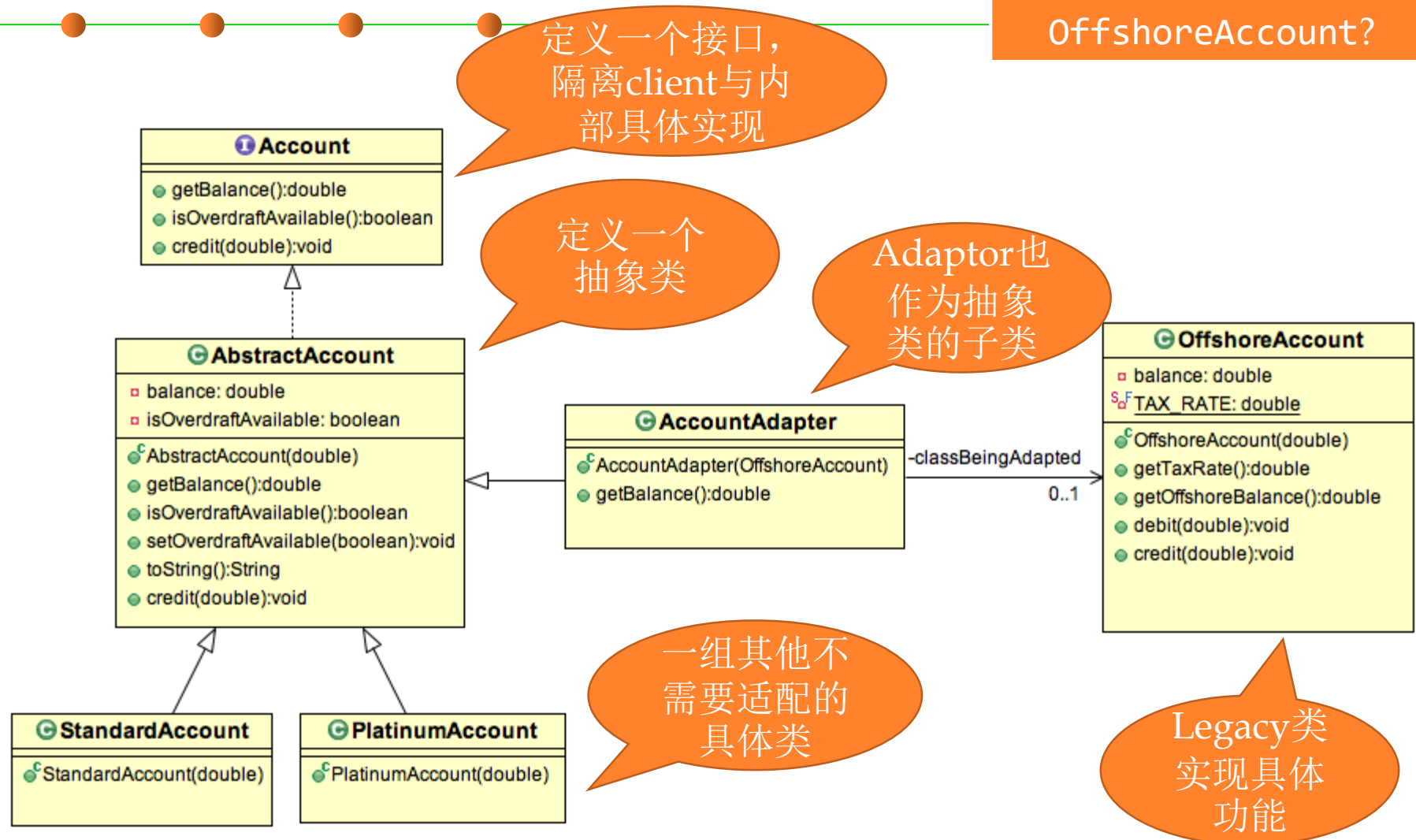
```
class LegacyRectangle {  
    void display(int x1, int y1, int w, int h) {...}  
}
```

```
class Client {  
    Shape shape = new Rectangle();  
    public display() {  
        shape.display(x1, y1, x2, y2);  
    }  
}
```

对抽象接口编程，与
LegacyRectangle隔离

Example

Question: How does a client use this OffshoreAccount?





(2) Decorator

装饰器模式

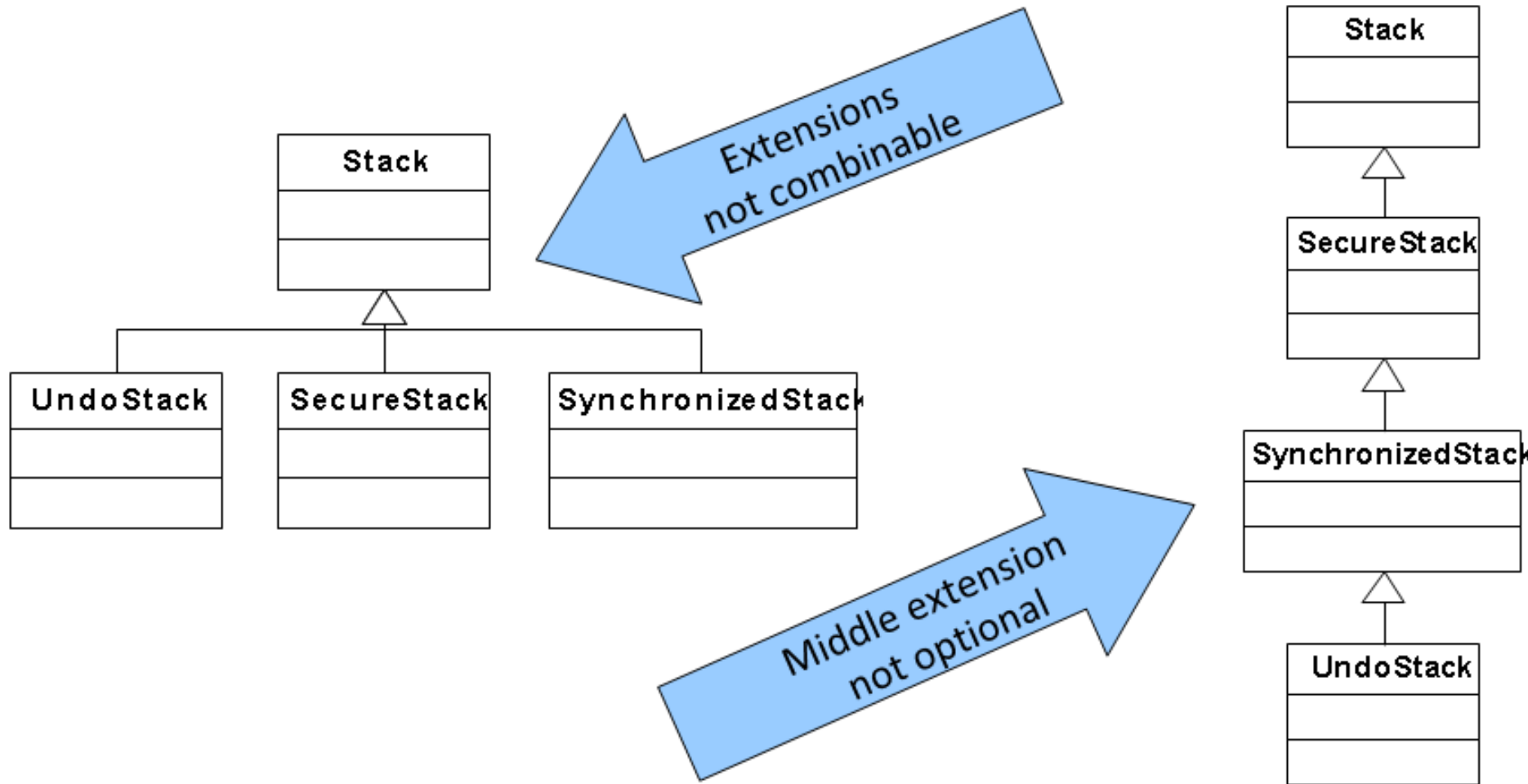
Motivating example of Decorator pattern

- **Suppose you want various extensions of a Stack data structure...**
 - UndoStack: A stack that lets you undo previous push or pop operations
 - SecureStack: A stack that requires a password
 - SynchronizedStack: A stack that serializes concurrent accesses
 - 用每个子类实现不同的特性
- **And *arbitrarily* composable extensions: 如果需要特性的任意组合呢?**
 - SecureUndoStack: A stack that requires a password, and also lets you undo previous operations
 - SynchronizedUndoStack: A stack that serializes concurrent accesses, and also lets you undo previous operations
 - SecureSynchronizedStack: ...
 - SecureSynchronizedUndoStack: ...

Inheritance

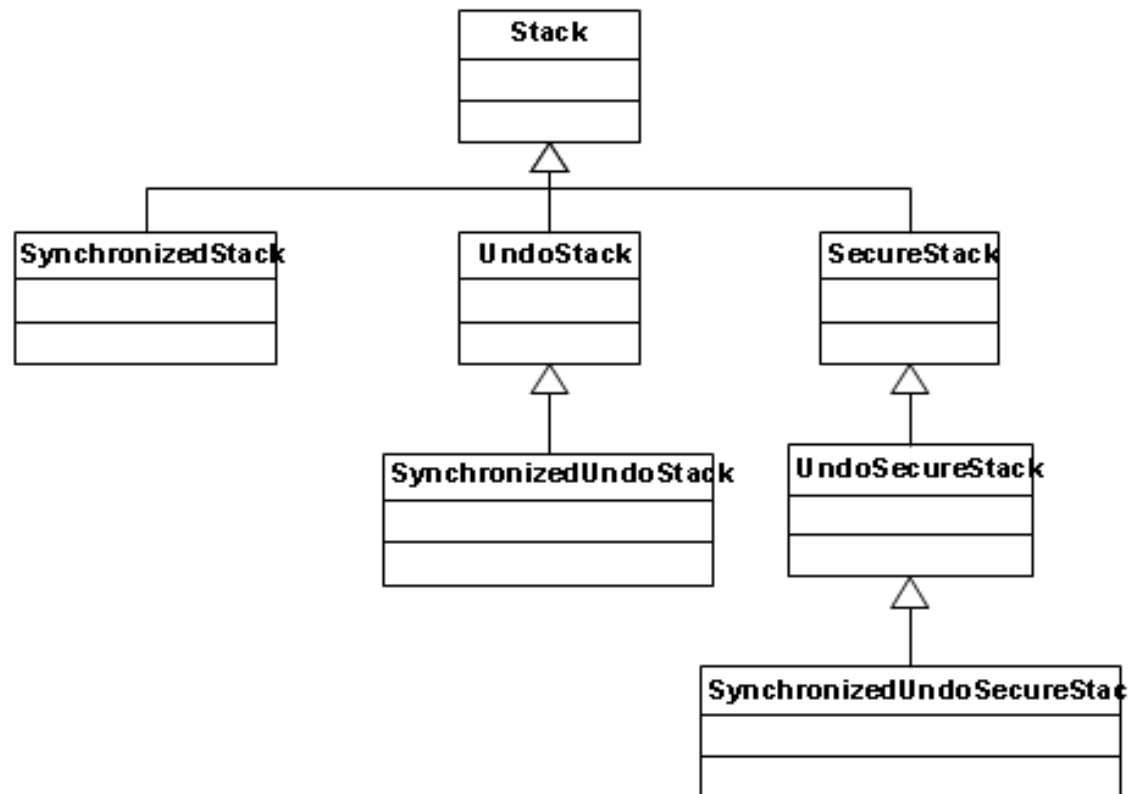
Inheritance
hierarchies?
Multi-Inheritance?

Limitations of inheritance



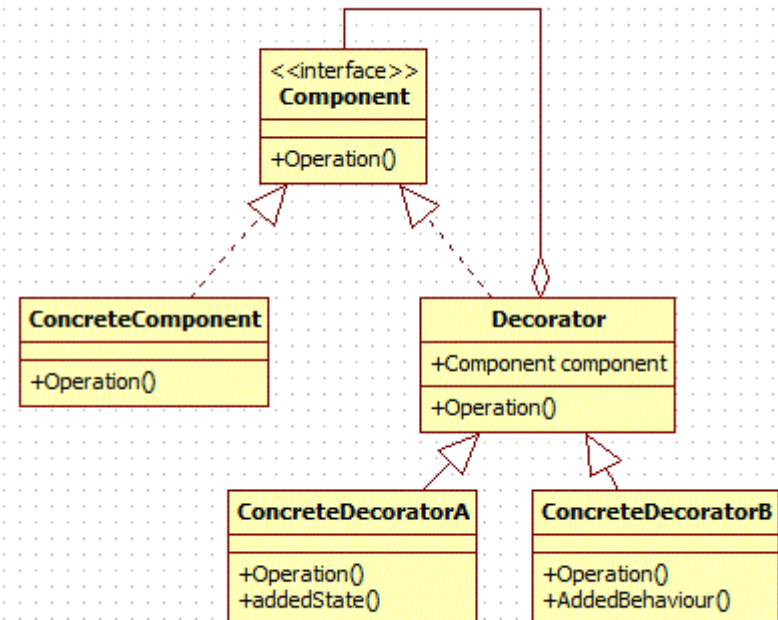
Limitations of inheritance

- **Combining inheritance hierarchies**
 - Combinatorial explosion 组合爆炸!
 - Massive code replication 大量的代码重复

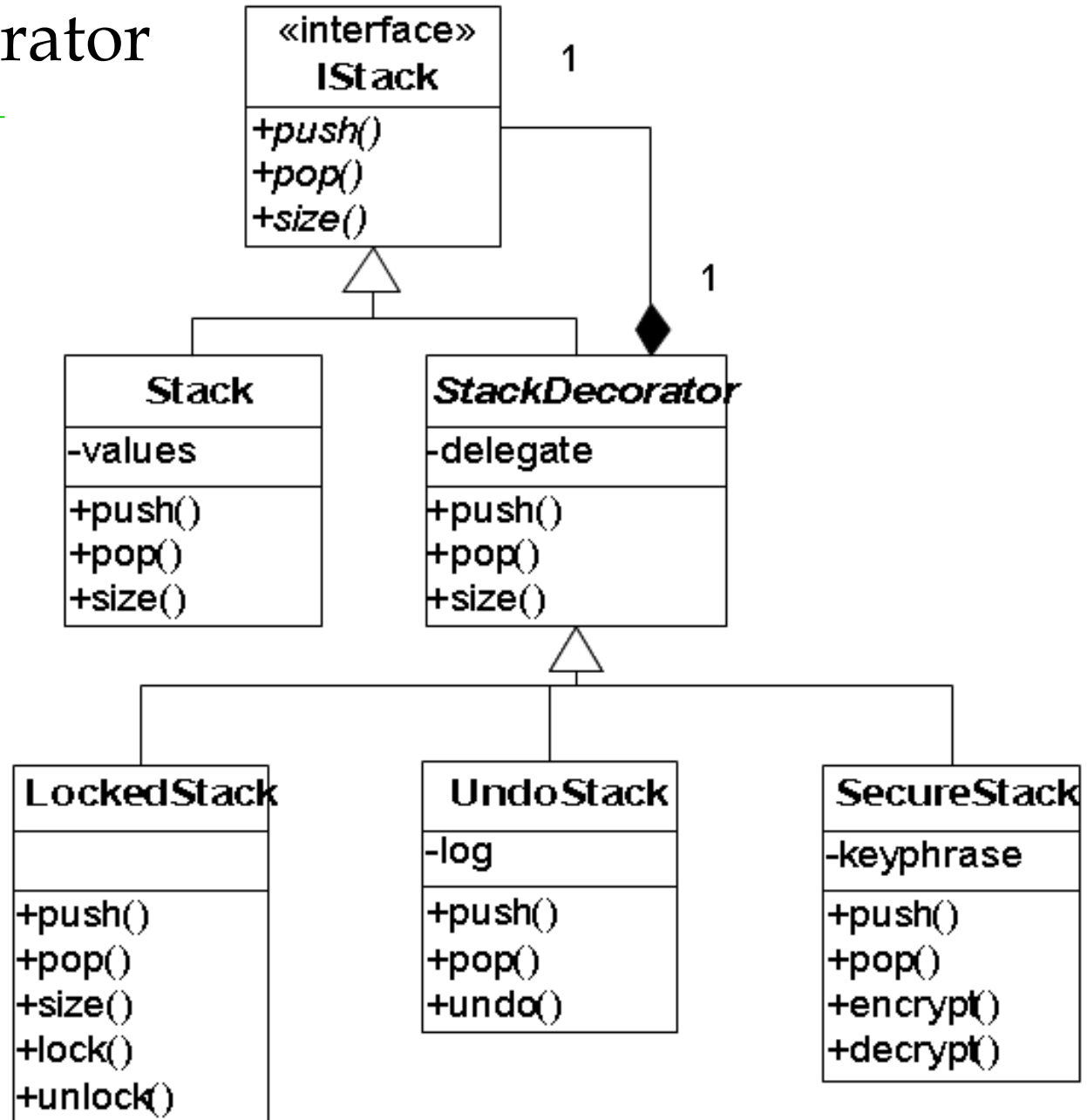


Decorator

- **Problem:** You need arbitrary or dynamically composable extensions to individual objects. 为对象增加不同侧面的特性
- **Solution:** Implement a common interface as the object you are extending, add functionality, but delegate primary responsibility to an underlying object. 对每一个特性构造子类，通过委派机制增加到对象上
- **Consequences:**
 - More flexible than static inheritance
 - Customizable, cohesive extensions
- Decorators use both **subtyping** and **delegation**



Example of Decorator



The ArrayStack Class

```
interface Stack {  
    void push(Item e);  
    Item pop();  
}  
  
public class ArrayStack implements Stack {  
    ... //rep  
  
    public ArrayStack() {...}  
    public void push(Item e) {  
        ...  
    }  
    public Item pop() {  
        ...  
    }  
    ...  
}
```



实现最基础的
Stack功能

The AbstractStackDecorator Class

```
interface Stack {  
    void push(Item e);  
    Item pop();  
}
```

给出一个用于
decorator的
基础类

```
public abstract class StackDecorator implements Stack {  
    protected final Stack stack;  
    public StackDecorator(Stack stack) {  
        this.stack = stack;  
    }  
    public void push(Item e) {  
        stack.push(e);  
    }  
    public Item pop() {  
        return stack.pop();  
    }  
    ...  
}
```

Delegation
(aggregation)

The concrete decorator classes

```
public class UndoStack
    extends StackDecorator
    implements Stack {

    private final UndoLog log = new UndoLog();
    public UndoStack(Stack stack) {
        super(stack);
    }
    public void push(Item e) {
        log.append(UndoLog.PUSH, e);
        super.push(e);
    }
    public void undo() {
        //implement decorator behaviors on stack
    }
    ...
}
```

增加了新特性

基础功能通过
delegation实现

增加了新特性

Using the decorator classes

- To construct a plain stack:
 - `Stack s = new ArrayStack();`
- To construct an undo stack:
 - `Stack t = new UndoStack(new ArrayStack());`
- To construct a **secure synchronized undo** stack:
 - `Stack t = new SecureStack(
 new SynchronizedStack(
 new UndoStack(s))`

- **Flexibly Composable!**

就像一层一层的穿衣服

...

客户端需要一个具有多种特性的object，通过一层一层的装饰来实现

Decorator vs. Inheritance

- Decorator composes features at **run time**
 - Inheritance composes features at **compile time**
- Decorator consists of **multiple** collaborating objects
 - Inheritance produces **a single, clearly-typed object**
- Can mix and match **multiple** decorations
 - Multiple inheritance is conceptually **difficult**

Decorators from java.util.Collections

■ Turn a mutable list into an immutable list:

- `static List<T> unmodifiableList(List<T> lst);`
- `static Set<T> unmodifiableSet(Set<T> set);`
- `static Map<K,V> unmodifiableMap(Map<K,V> map);`

See section 3-1

■ Similar for synchronization:

- `static List<T> synchronizedList(List<T> lst);`
- `static Set<T> synchronizedSet(Set<T> set);`
- `static Map<K,V> synchronizedMap(Map<K,V> map);`

See section 10-1

```
List<Trace> ts = new LinkedList<>();
List<Trace> ts2 =
    (List<Trace>) Collections.unmodifiableCollection(ts);

public static Stack UndoStackFactory(Stack stack) {
    return new UndoStack(stack);
}
```

如何使用
factory method
模式实现



(3) Facade

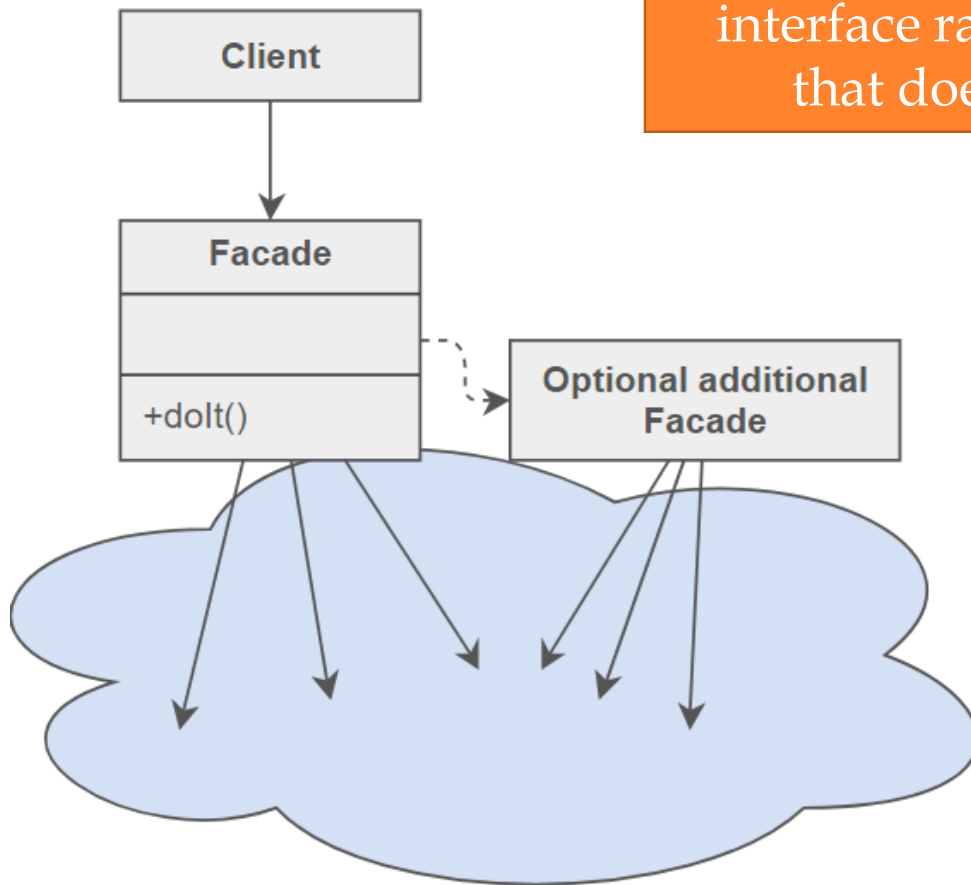
外观模式

Facade

- **Problem:** a segment of the client community needs a simplified interface to the overall functionality of a complex subsystem. 客户端需要通过一个简化的接口来访问复杂系统内的功能
- **Intent:** 提供一个统一的接口来取代一系列小接口调用，相当于对复杂系统做了一个封装，简化客户端使用
 - 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.
 - Wrap a complicated subsystem with a simpler interface.
- **This reduces the learning curve necessary to successfully leverage the subsystem.** 便于客户端学习使用，解耦
- **It also promotes decoupling the subsystem from its potentially many clients.**

Facade

Facade pattern is applied for similar kind of interfaces, its purpose is to provide a single interface rather than multiple interfaces that does the similar kind of jobs.



Façade Example

- Suppose we have an application with set of interfaces to use **MySQL/Oracle** database and to generate different types of reports, such as **HTML report**, **PDF report** etc.
- So we will have different set of interfaces to work with different types of database.
- Now a client application can use these interfaces to get the required database connection and generate reports.
- But when the complexity increases or the interface behavior names are confusing, client application will find it difficult to manage it.
- So we can apply **Facade pattern** here and provide a **wrapper interface** on top of the existing interface to help client application.

Two Helper Classes for MySQL and Oracle

分别封装了客户端所需的功能

```
public class MySqlHelper {  
  
    public static Connection getMySqlDBConnection() {...}  
    public void generateMySqlPDFReport  
        (String tableName, Connection con){...}  
    public void generateMySqlHTMLReport  
        (String tableName, Connection con){...}  
}  
  
public class OracleHelper {  
  
    public static Connection getOracleDBConnection() {...}  
    public void generateOraclePDFReport  
        (String tableName, Connection con){...}  
    public void generateOracleHTMLReport  
        (String tableName, Connection con){...}  
}
```

A façade class

```
public class HelperFacade {
    public static void generateReport
        (DBTypes dbType, ReportTypes reportType, String tableName){
        Connection con = null;
        switch (dbType){
        case MYSQL:
            con = MySqlHelper.getMySqlDBConnection();
            MySqlHelper mySqlHelper = new MySqlHelper();
            switch(reportType){
                case HTML:
                    mySqlHelper.generateMySqlHTMLReport(tableName, con);
                    break;
                case PDF:
                    mySqlHelper.generateMySqlPDFReport(tableName, con);
                    break;
            }
            break;
        case ORACLE: ...
        }
        public static enum DBTypes      { MYSQL,ORACLE; }
        public static enum ReportTypes { HTML,PDF;}
    }
```

Client code

Without
facade

```
String tableName="Employee";
```

```
Connection con = MySqlHelper.getMySqlDBConnection();  
MySqlHelper mySqlHelper = new MySqlHelper();  
mySqlHelper.generateMySqlHTMLReport(tableName, con);
```

```
Connection con1 = OracleHelper.getOracleDBConnection();  
OracleHelper oracleHelper = new OracleHelper();  
oracleHelper.generateOraclePDFReport(tableName,
```

With facade

```
HelperFacade.generateReport(HelperFacade.DBTypes.MYSQL,  
HelperFacade.ReportTypes.HTML, tableName);  
HelperFacade.generateReport(HelperFacade.DBTypes.ORACLE,  
HelperFacade.ReportTypes.PDF, tableName);
```




2 Behavioral patterns





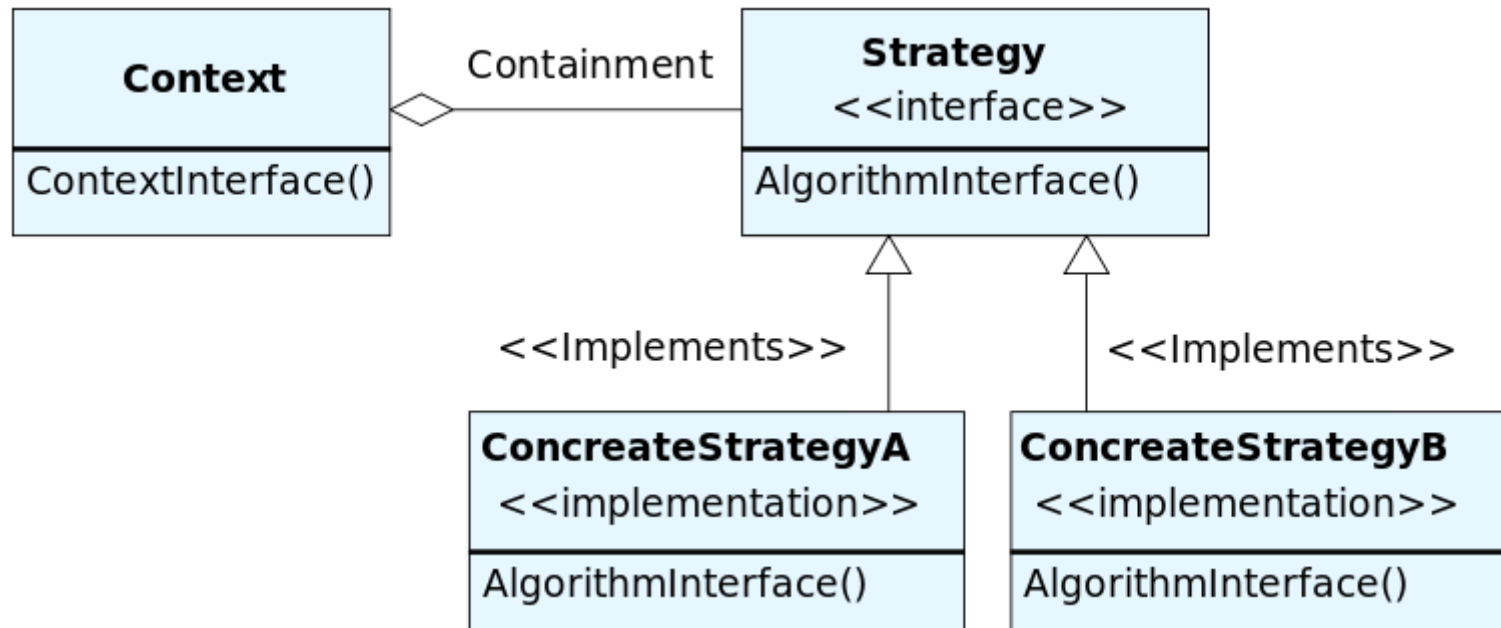
(1) Strategy

策略模式

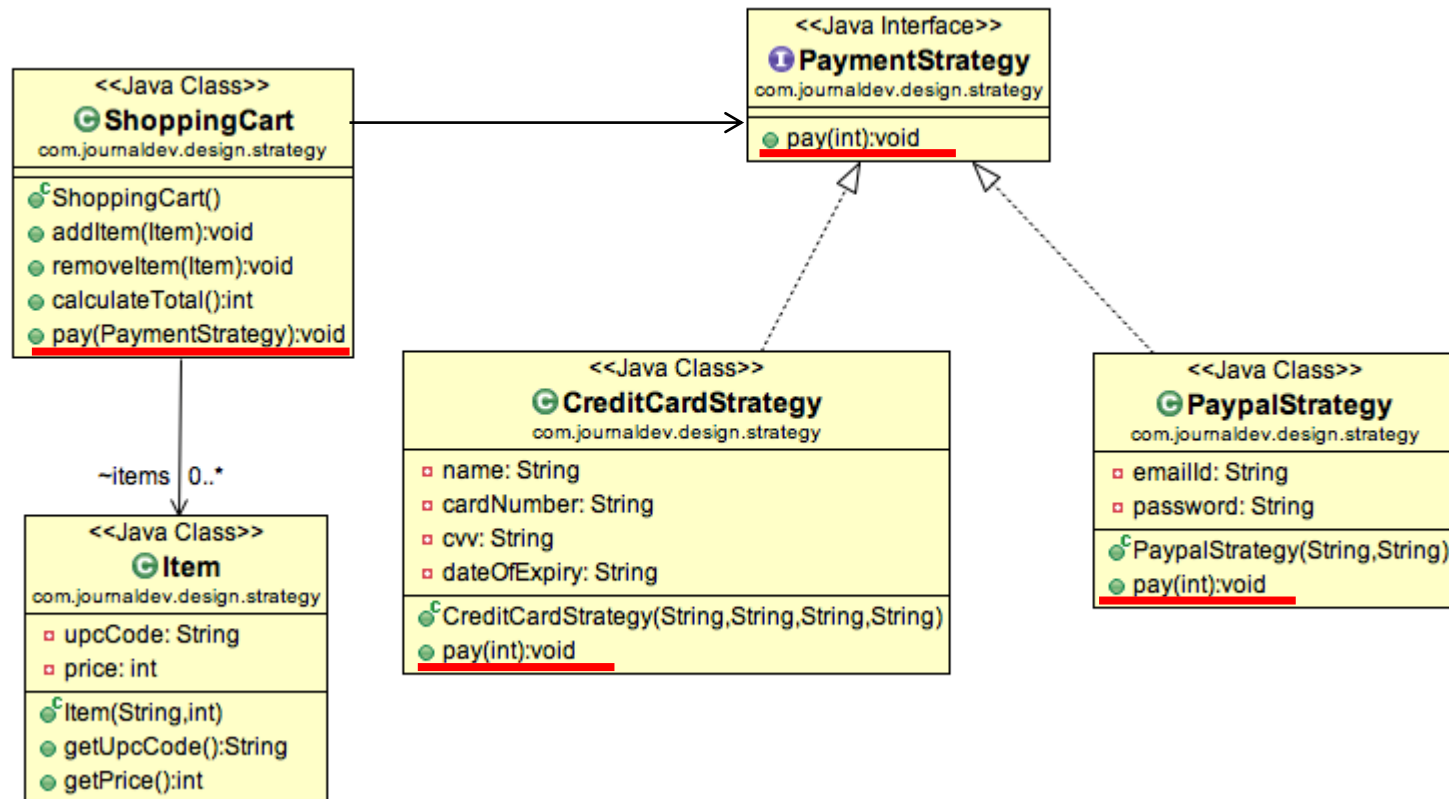
Strategy Pattern

- **Problem:** Different algorithms exist for a specific task, but client can switch between the algorithms at run time in terms of dynamic context. 有多种不同的算法来实现同一个任务，但需要client根据需求动态切换算法，而不是写死在代码里
- **Example:** **Sorting** a list of customers (bubble sort, mergesort, quicksort)
- **Solution:** Create an interface for the algorithm, with an implementing class for each variant of the algorithm. 为不同的实现算法构造抽象接口，利用delegation，运行时动态传入client倾向的算法类实例
- **Advantage:**
 - Easily extensible for new algorithm implementations
 - Separates algorithm from client context

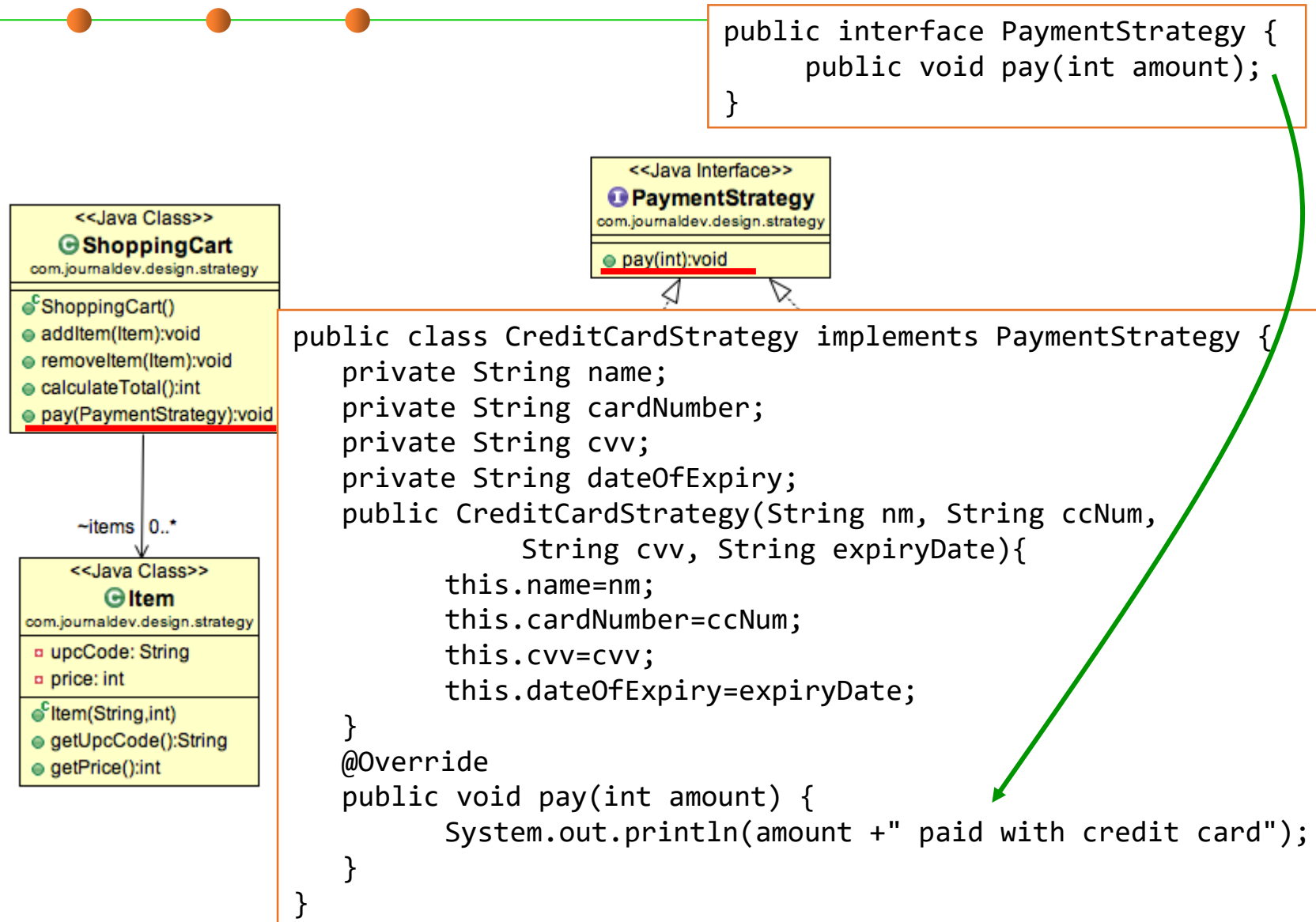
Strategy Pattern



Code example



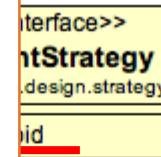
Code example



Code example

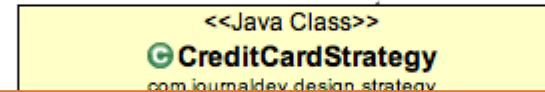
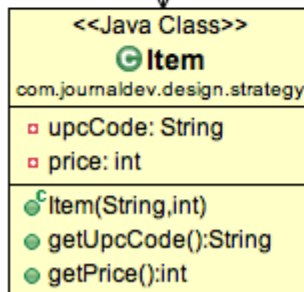
```
public class ShoppingCart {
    ...
    public void pay(PaymentStrategy paymentMethod){
        int amount = calculateTotal();
        paymentMethod.pay(amount);
    }
}
```

```
public interface PaymentStrategy {
    public void pay(int amount);
}
```



pay(PaymentStrategy):void

~items 0..*



```
public class PaypalStrategy implements PaymentStrategy {
    private String emailId;
    private String password;
    public PaypalStrategy(String email, String pwd){
        this.emailId=email;
        this.password=pwd;
    }
    @Override
    public void pay(int amount) {
        System.out.println(amount + " paid using Paypal.");
    }
}
```

Code example

```
public class ShoppingCart {
    ...
    public void pay(PaymentStrategy paymentMethod){
        int amount = calculateTotal();
        paymentMethod.pay(amount);
    }
}
```

delegation

```
public interface PaymentStrategy {
    public void pay(int amount);
}
```

```
interface >>
PaymentStrategy
design.strategy
void
```

```
pay(PaymentStrategy):void
```

```
<<Java Class>>
```

```
<<Java Class>>
```

```
public class ShoppingCartTest {
    public static void main(String[] args) {
        ShoppingCart cart = new ShoppingCart();
        Item item1 = new Item("1234",10);
        Item item2 = new Item("5678",40);
        cart.addItem(item1);
        cart.addItem(item2);
        //pay by paypal
        cart.pay(new PaypalStrategy("myemail@exp.com", "mypwd"));
        //pay by credit card
        cart.pay(new CreditCardStrategy("Alice", "1234", "786", "12/18"));
    }
}
```




(2) Template Method

模板模式

Template Method

- **Problem:** Several clients share the same algorithm but differ on the specifics, i.e., an algorithm consists of customizable parts and invariant parts. **Common steps should not be duplicated in the subclasses but need to be reused.**

- 做事情的步骤一样，但具体方法不同

- **Examples:**

- Executing a test suite of test cases
- Opening, reading, writing documents of different types

```
step1();  
...  
step2();  
...  
step3();
```

- **Solution:**

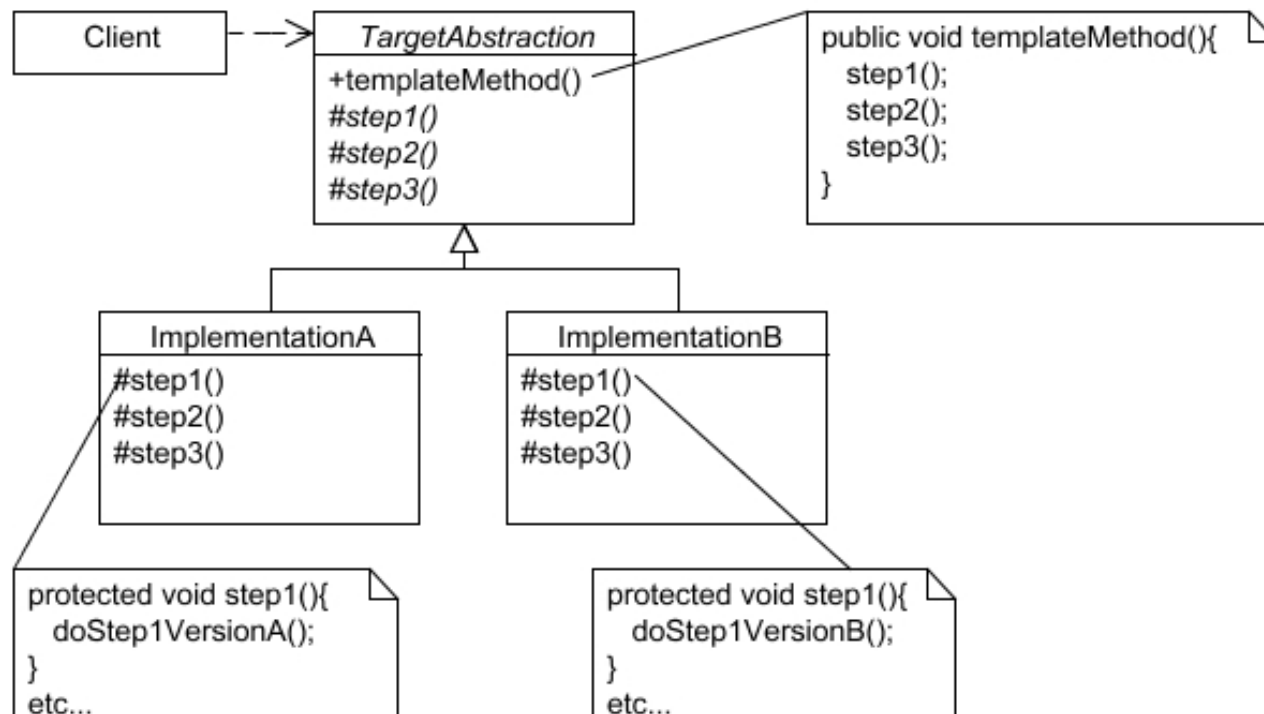
- The common steps of the algorithm are factored out into an abstract class, with abstract (unimplemented) primitive operations representing the customizable parts of the algorithm. 共性的步骤在抽象类内公共实现，差异化的步骤在各个子类中实现
- Subclasses provide different realizations for each of these steps.

Template Method Pattern

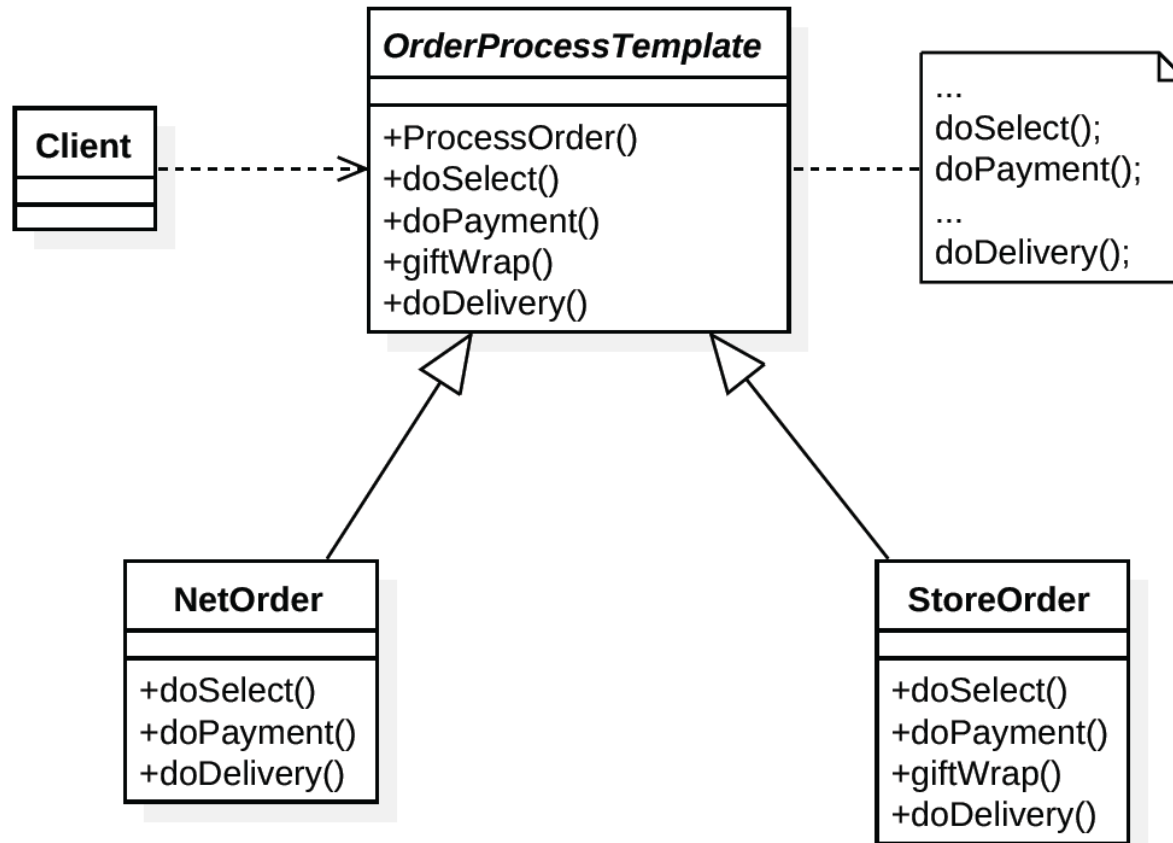
- **Template method** pattern uses **inheritance** + **overridable** methods to **vary part of an algorithm** 使用继承和重写实现模板模式
 - While strategy pattern uses **delegation** to vary the entire algorithm (interface and ad-hoc polymorphism).
- **Template Method is widely used in frameworks**
 - The framework implements the invariants of the algorithm
 - The client customizations provide specialized steps for the algorithm
 - Principle: “Don’t call us, we’ll call you”.

Whitebox or
Blackbox
framework?

Template Method pattern



Example

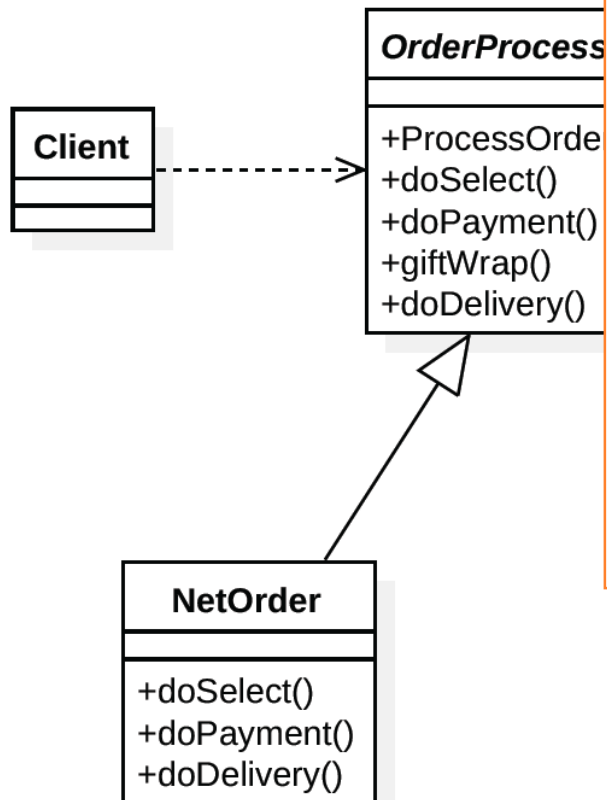


Example

```
public abstract class OrderProcessTemplate {
    public boolean isGift;

    public abstract void doSelect();
    public abstract void doPayment();
    public final void giftWrap() {
        System.out.println("Gift wrap done.");
    }

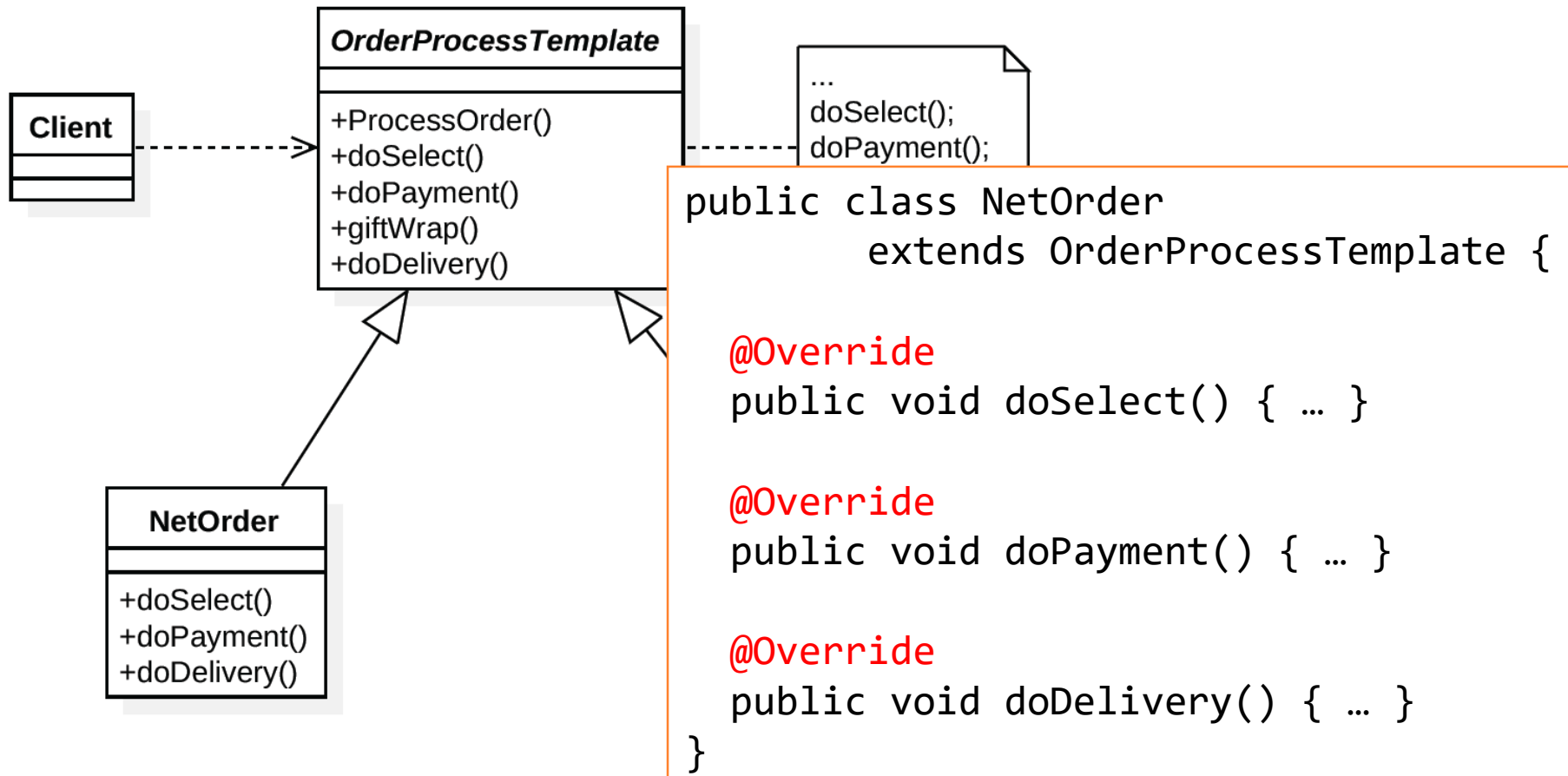
    public abstract void doDelivery();
    public final void processOrder() {
        doSelect();
        doPayment();
        if (isGift)
            giftWrap();
        doDelivery();
    }
}
```



Example

```
OrderProcessTemplate netOrder = new NetOrder();
netOrder.processOrder();
```

```
OrderProcessTemplate storeOrder = new StoreOrder();
storeOrder.processOrder();
```



See the whitebox framework

Overriding

```
public class Calculator extends Application {
    protected String getApplicationTitle() { return "My Great Calculator"; }
    protected String getButtonText() { return "calculate"; }
    protected String getInititalText() { return "(10 - 3) * 6"; }
    protected void buttonClicked() {
        JOptionPane.showMessageDialog(this, "The result of " + getInput() +
            " is " + calculate(getInput()));
    }
    private String calculate(String text) { ... }
}
```

Extension via subclassing and overriding methods
Subclass has main method but gives control to framework

```
public class Ping extends Application {
    protected String getApplicationTitle() { return "Ping"; }
    protected String getButtonText() { return "ping"; }
    protected String getInititalText() { return "127.0.0.1"; }
    protected void buttonClicked() { ... }
}
```

Overriding



(3) Iterator



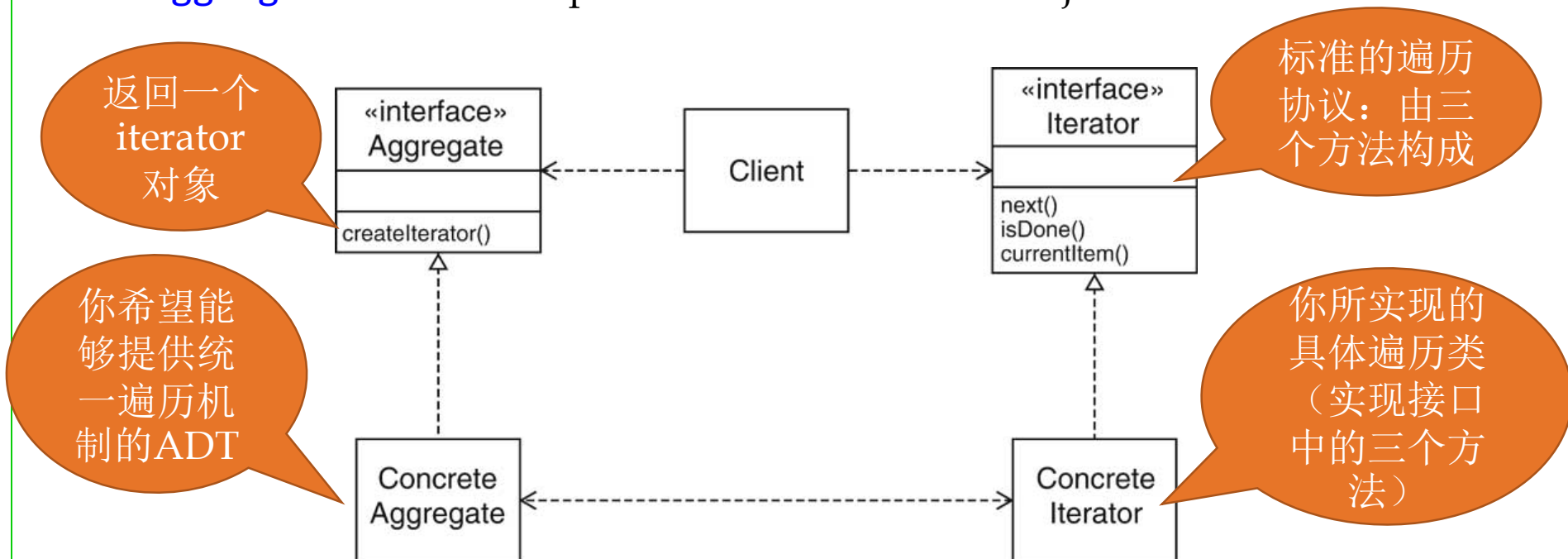
Iterator Pattern

- **Problem:** Clients need uniform strategy to access all elements in a container, independent of the container type 客户端希望遍历被放入容器/集合类的一组ADT对象，无需关心容器的具体类型
 - 也就是说，不管对象被放进哪里，都应该提供同样的遍历方式
- **Solution:** A strategy pattern for iteration
- **Consequences:**
 - Hides internal implementation of underlying container
 - Support multiple traversal strategies with uniform interface
 - Easy to change container type
 - Facilitates communication between parts of the program

Iterator Pattern

■ Pattern structure

- **Abstract Iterator** class defines traversal protocol
- **Concrete Iterator** subclasses for each aggregate class
- **Aggregate** instance creates instances of **Iterator** objects
- **Aggregate** instance keeps reference to **Iterator** object



Iterator pattern

- **Iterable**接口：实现该接口的集合对象是可迭代遍历的

```
public interface Iterable<T> {
    ...
    Iterator<T> iterator();
}
```

- **Iterator**接口：迭代器

```
public interface Iterator<E> {
    boolean hasNext();
    E next();
    void remove();
}
```

- **Iterator pattern**: 让自己的集合类实现**Iterable**接口，并实现自己的独特**Iterator**迭代器(hasNext, next, remove)，允许客户端利用这个迭代器进行显式或隐式的迭代遍历：

```
for (E e : collection) { ... }
```

```
Iterator<E> iter = collection.iterator();
while(iter.hasNext()) { ... }
```

Getting an Iterator

```
public interface Collection<E> extends Iterable<E> {  
    boolean add(E e);  
    boolean addAll(Collection<? extends E> c);  
    boolean remove(Object e);  
    boolean removeAll(Collection<?> c);  
    boolean retainAll(Collection<?> c);  
    boolean contains(Object e);  
    boolean containsAll(Collection<?> c);  
    void clear();  
    int size();  
    boolean isEmpty();  
    Iterator<E> iterator();  
    Object[] toArray()  
    <T> T[] toArray(T[] a);  
    ...  
}
```

Defines an interface for creating an Iterator, but allows Collection implementation to decide which Iterator to create.

An example of Iterator pattern

```
public class Pair<E> implements Iterable<E> {
    private final E first, second;
    public Pair(E f, E s) { first = f; second = s; }
    public Iterator<E> iterator() {
        return new PairIterator();
    }

    private class PairIterator implements Iterator<E> {
        private boolean seenFirst = false, seenSecond = false;
        public boolean hasNext() { return !seenSecond; }
        public E next() {
            if (!seenFirst) { seenFirst = true; return first; }
            if (!seenSecond) { seenSecond = true; return second; }
            throw new NoSuchElementException();
        }
        public void remove() {
            throw new UnsupportedOperationException();
        }
    }
}
```

Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { ... }



Summary



Summary

■ Structural patterns

- **Adapter** allows classes with incompatible interfaces to work together by wrapping its own interface around that of an already existing class.
- **Decorator** dynamically adds/overrides behavior in an existing method of an object.
- **Facade** provides a simplified interface to a large body of code.

■ Behavioral patterns

- **Strategy** allows one of a family of algorithms to be selected on-the-fly at runtime.
- **Template method** defines the skeleton of an algorithm as an abstract class, allowing its subclasses to provide concrete behavior.
- **Iterator** accesses the elements of an object sequentially without exposing its underlying representation.



The end

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