哈爾濱工業大學
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Chapter 5: Reusability-Oriented Software Construction Approaches

5.3 Design Patterns for Reuse

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Outline

- **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.

Recall: Why reusable Designs?

A design…

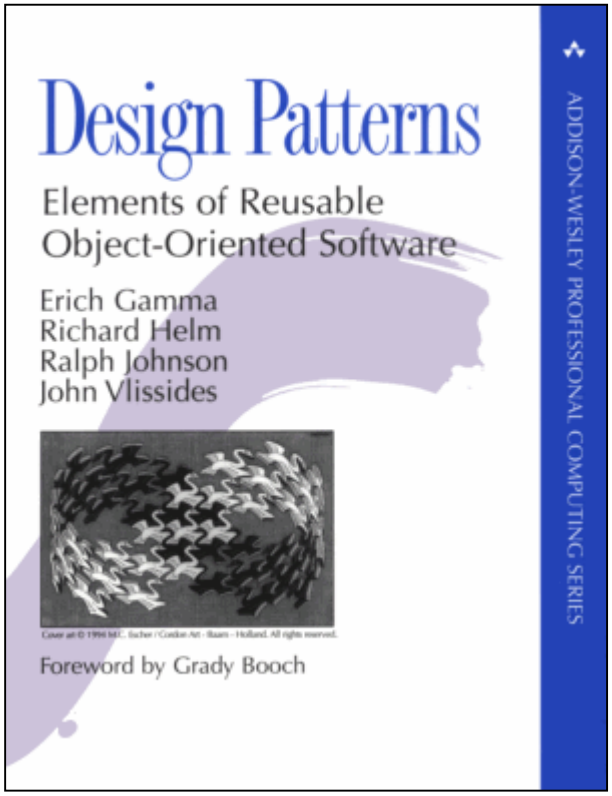
…enables flexibility to change (reusability) 柔性的改变

…minimizes the introduction of new problems when fixing old ones (maintainability) 易于修复

…allows the delivery of more functionality after an initial delivery (extensibility) 易于增加新功能

Gang of Four

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



《图解设计模式》
《Head First 设计模式》

Design patterns taxonomy

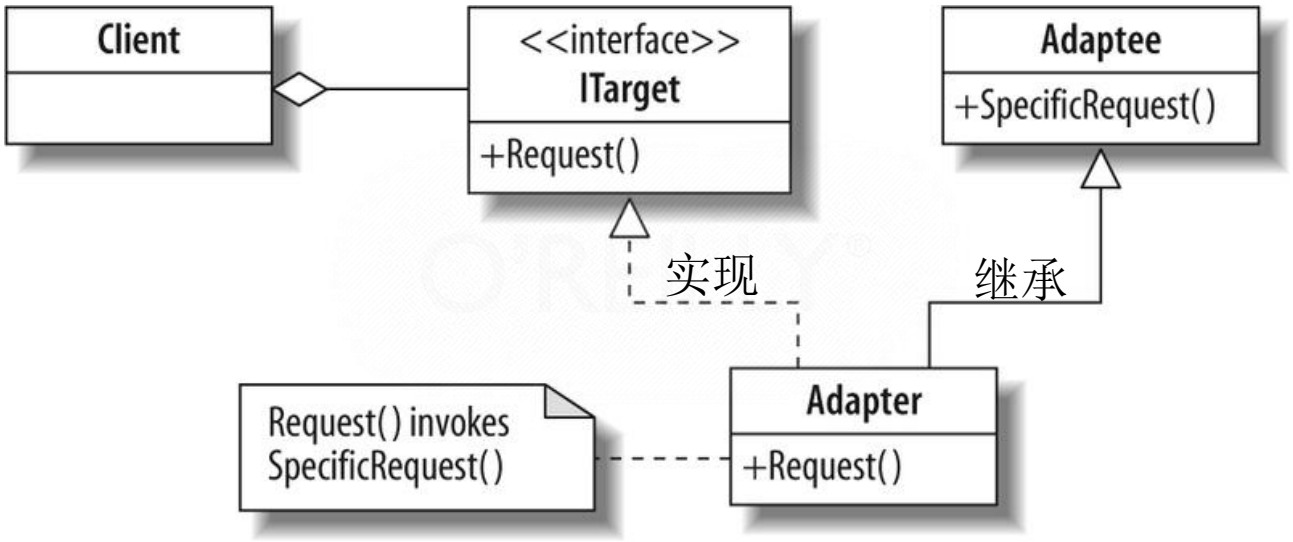
- **Creational patterns**
  - Concern the process of object creation 如何创建对象
- **Structural patterns**
  - Deal with the composition of classes or objects 如何组合类和对象
- **Behavioral patterns**
  - Characterize the ways in which classes or objects interact and distribute responsibility. 如何交互和分配责任

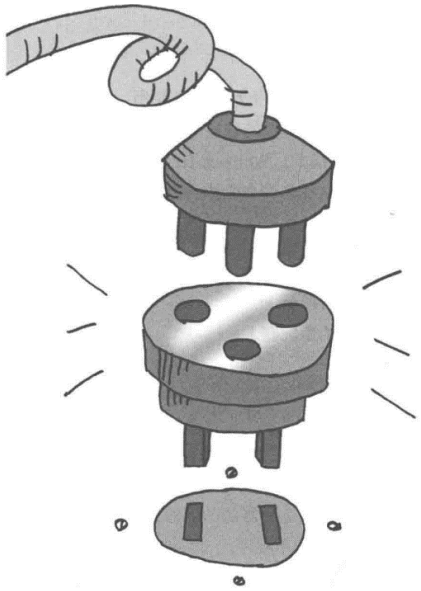
1 Structural patterns

(1) Adapter

Adapter Pattern 适配器模式

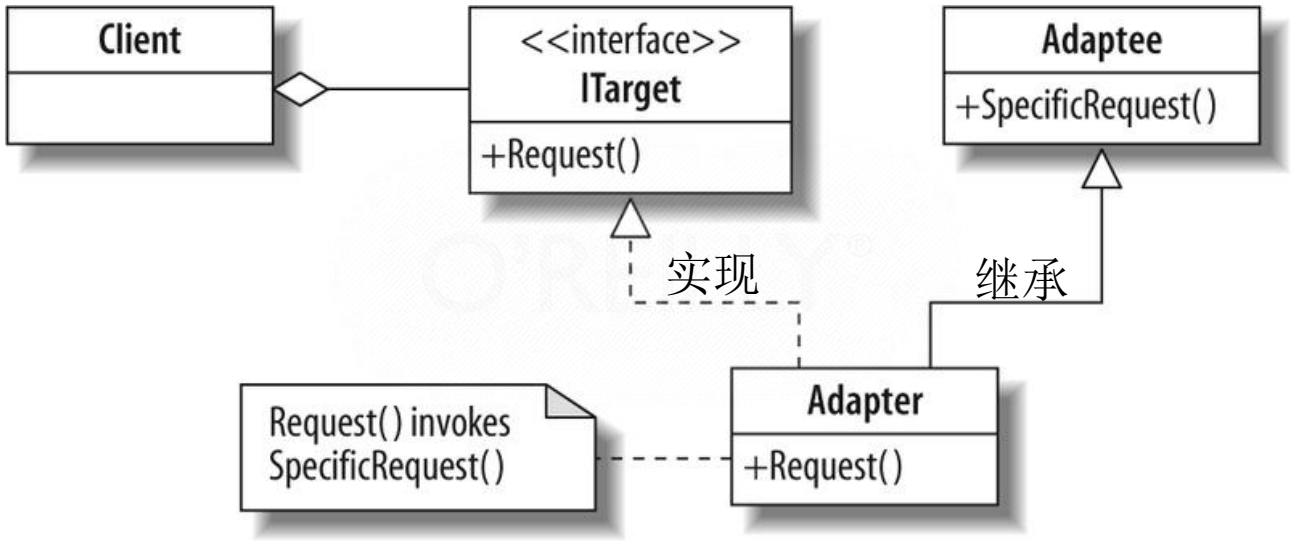
- **Intent: Convert the interface of a class into another interface clients expect.**
  - Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.
  - Wrap an existing class with a new interface.
- **Objective: to reuse an old component to a new system (also called "wrapper") 对旧的不兼容组件进行封装，使新系统中使用旧的组件**





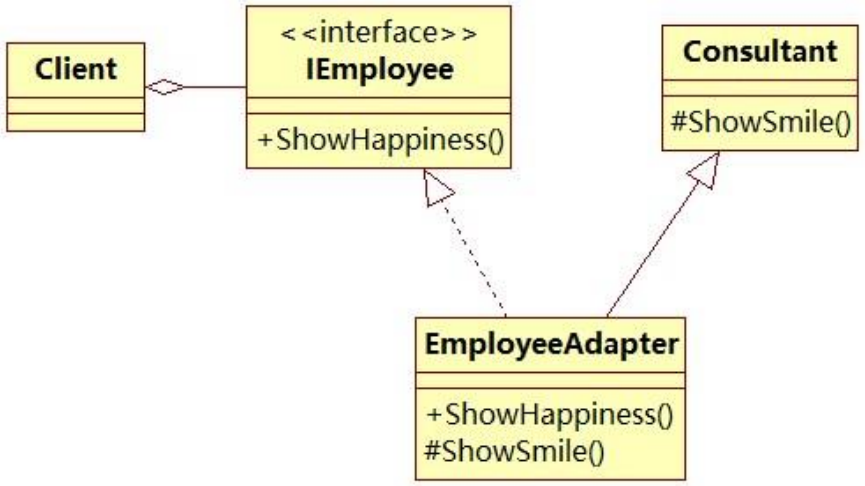
Example

- The ***Adaptee*** is the existing class.
- The ***ITarget*** is the interface defined in the existing library.
- The ***Adapter*** is the class that you create, it is inherited from the adaptee class and it implements the ITarget interface. Notice that it can call the SpecificRequest method(inherited from the adaptee) inside its request method(implemented by the ITarget).



Example

- An organization tree that is constructed where all the employees implements the *IEmployee* interface. The IEmployee interface has a method named ShowHappiness().
- We need to plug an existing *Consultant* class into the organization tree. The *Consultant* class is the adaptee which has a method named ShowSmile().
- **This incongruity can be reconciled by adding an additional level of indirection – i.e. an Adapter object.**



Example

```
public class Consultant { //已存在的类
    private String name;

    public Consultant(String name) {
        this.name = name;
    }

    protected void ShowSmile() {
        System.out.println("Consultant " + this.name + " showed
                           smile");
    }
}

public interface IEmployee {//目标接口
        void ShowHappiness();
}
```

Example

```
public class EmployeeAdapter extends Consultant implements
IEmployee {  //Adapter
        public EmployeeAdapter(String name){
                super(name);
        }

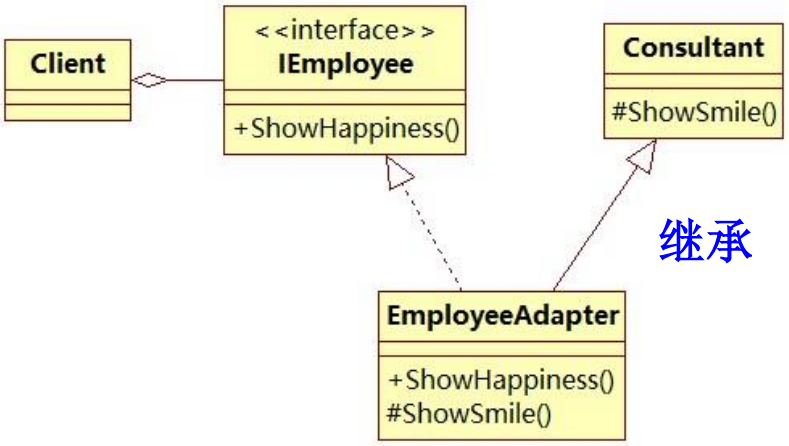
        @Override
        public void ShowHappiness() {
                ShowSmile(); // call the parent Consultant class
        }
}

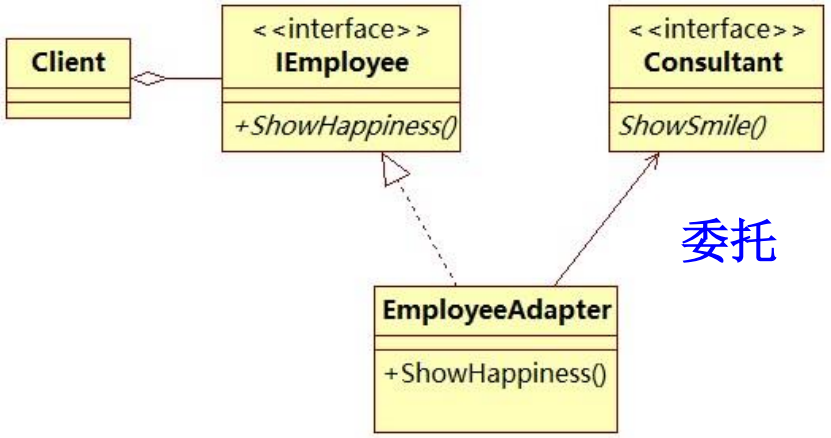
public class Client {
        public static void main(String[] args){
                IEmployee em = new EmployeeAdapter("Bruno");
                em.ShowHappiness();
        }
}
```

Result: Consultant Bruno showed smile

Adapter Pattern

- **Two types of Adapter Design Pattern**
  - Inheritance
  - Delegation





(2) Decorator

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

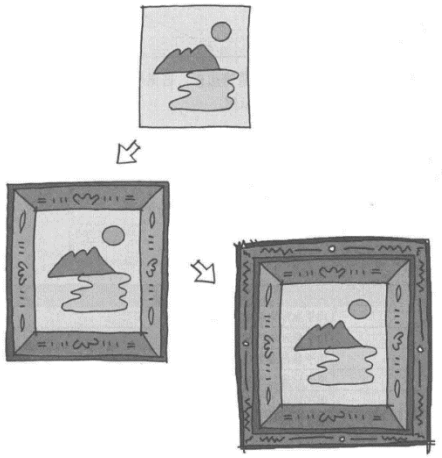
Inheritance

- **And arbitrarily composable extensions:**
  - `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 hierarchies? Multi-Inheritance?

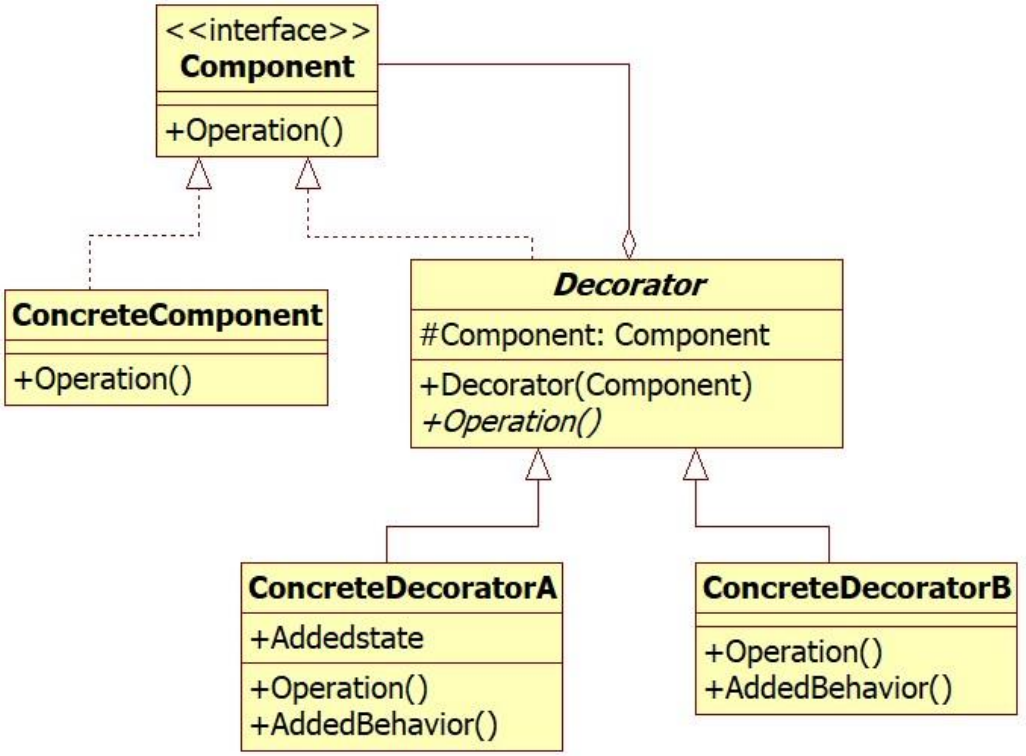
Decorator 装饰器模式

- **Problem: You need arbitrary or dynamically composable extensions to individual objects.**
- **Solution: Implement a common interface as the object you are extending, add functionality, but delegate primary responsibility to an underlying object.**
- **It works in a recursive way.**
- **Consequences:**
  - More flexible than static inheritance Customizable, cohesive extensions
- **Decorators use both subtyping and delegation**



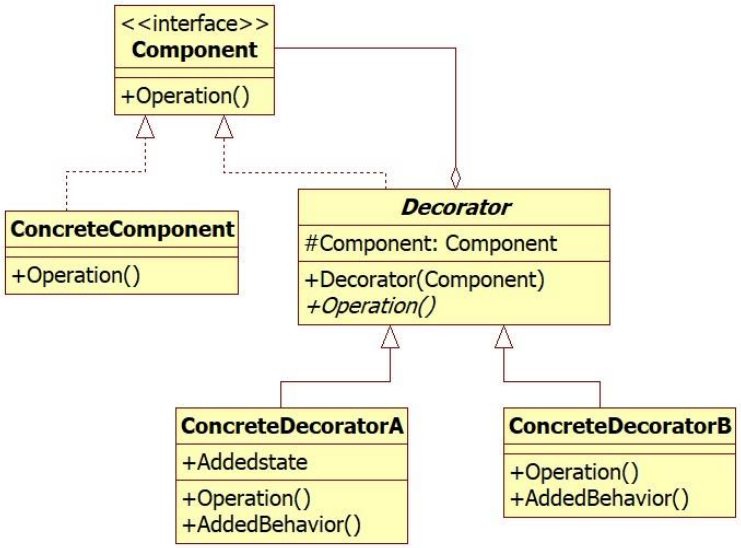
Decorator

- **The *Component* interface defines the operation, or the features that the decorators can perform.**
- **The *ConcreteComponent* class is the starting object that you can dynamically add features to. You will create this object first and add features to it.**



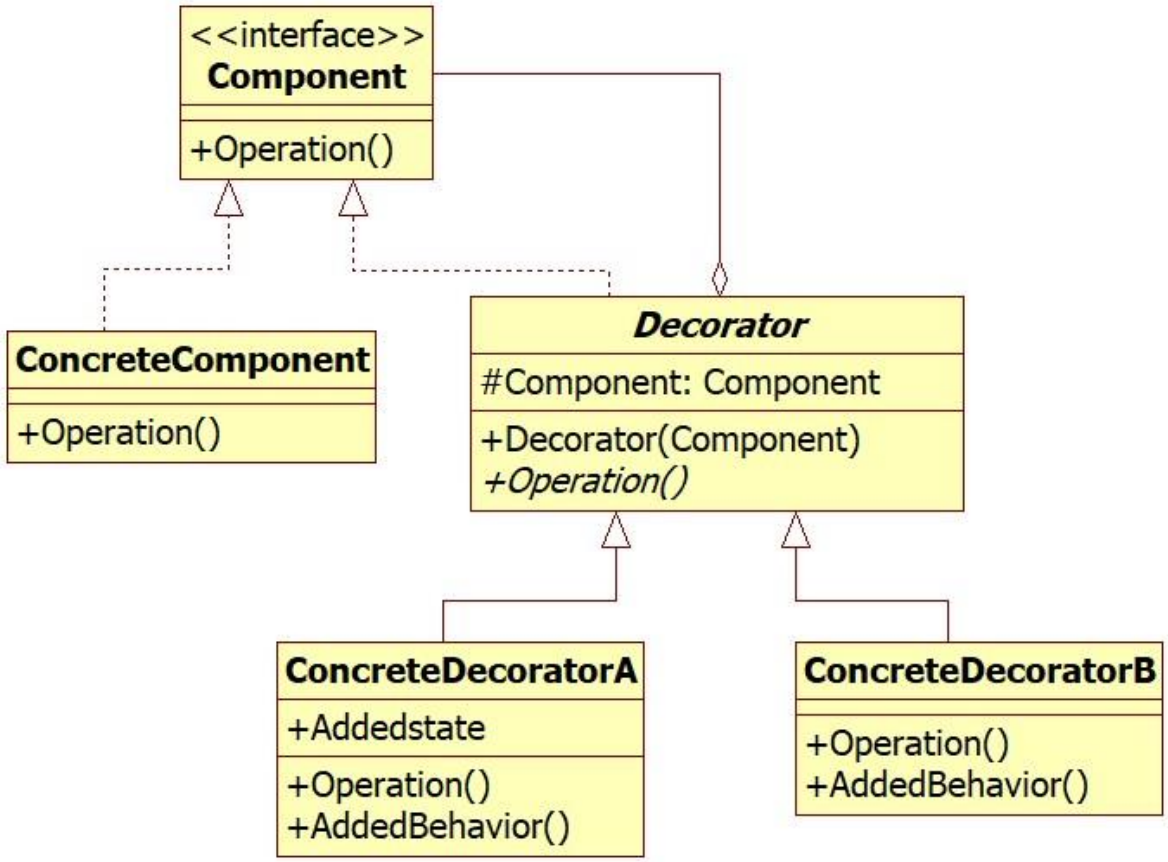
Decorator

- **The *Decorator* class is an abstract class and is the parent class of all the decorators. While it implements the Component interface to define the operations, it also contains a protected variable *component* that points to the object to be decorated. The *component* variable is simply assigned in the constructor.**
- **The constructor for the Decorator class is simply:**
- ```
  public Decorator(Component input)
  {
     component = input;
  }
  ```


  ```

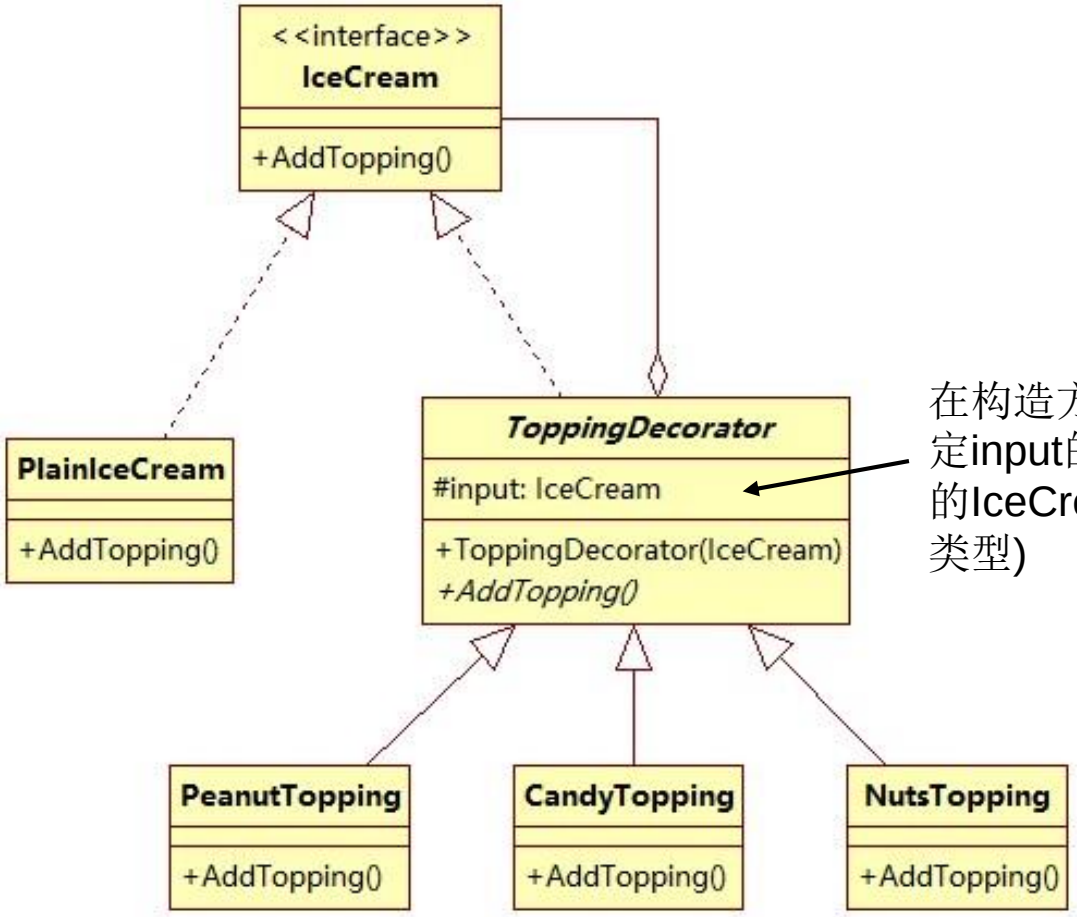
Decorator

- **The *ConcreteDecorator* class are the actual decorator classes that can add features. You can have as many ConcreteDecorator class as you like, and each will represent a feature that can be added.**



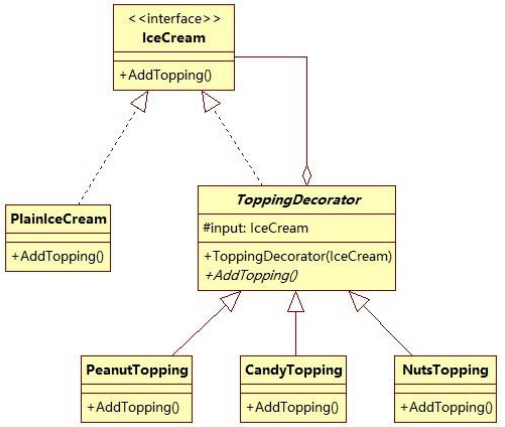
Example

- **In this example we have a plain ice cream where you can add different combination of toppings to it.**



在构造方法中，指定input的值(被装饰的IceCream的具体类型)

Example



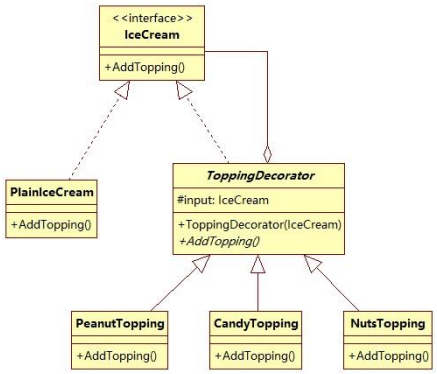

```
public interface IceCream { //顶层接口
    void AddTopping();
}

public class PlainIceCream implements IceCream{ //基础实现，无填加冰激凌
    @Override
    public void AddTopping() {
    System.out.println("Plain IceCream ready for some toppings!");
    }
}

/*装饰器基类*/
public abstract class ToppingDecorator implements IceCream{
    protected IceCream input;
    public ToppingDecorator(IceCream i){
        input = i;
    }

    public abstract void AddTopping();  //留给具体装饰器实现
}
```

Example




```
public class CandyTopping extends ToppingDecorator{
    public CandyTopping(IceCream i) {
        super(i);
    }

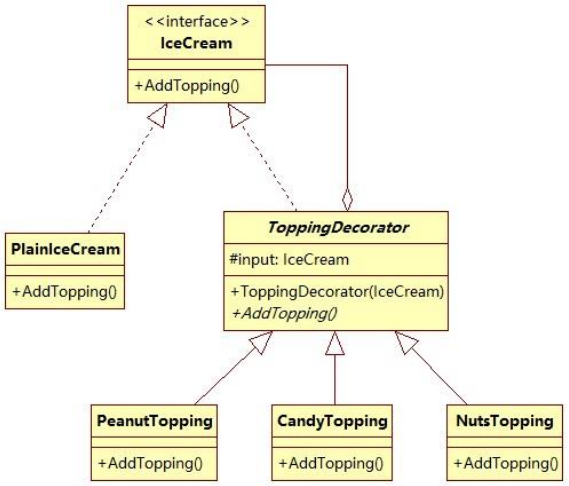
    public void AddTopping() {
        input.AddTopping();  //decorate others first
        System.out.println("Candy Topping added! ");
    }
}

public class NutsTopping extends ToppingDecorator{
    //similar to CandyTopping
}

public class PeanutTopping extends ToppingDecorator{
   //similar to CandyTopping

}
```

Another Example




```
public class Client {
    public static void main(String[] args) {
        IceCream a = new PlainIceCream();
        IceCream b = new CandyTopping(a);
        IceCream c = new PeanutTopping(b);
        IceCream d = new NutsTopping(c);
        d.AddTopping();

        //or
       IceCream toppingIceCream =
           new NutsTopping(
               new PeanutTopping(
                   new CandyTopping(
                        new PlainIceCream()
                       )
                   )
               );
        toppingIceCream.AddTopping();
}
```

The result:

```
Plain IceCream ready for some toppings!
Candy Topping added!
Peanut Topping added!
Nuts Topping added!
```

Example2

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

- **Flexibly Composible!**

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`

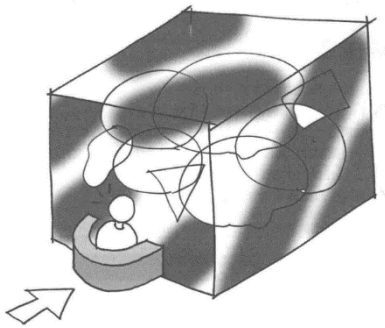
- **Turn a mutable list into an immutable list:**
  - `static List<T>  unmodifiableList(List<T> lst);`
  - `static Set<T>   unmodifiableSet( Set<T> set);`
  - `static Map<K,V> unmodifiableMap( Map<K,V> map);`
- **Similar for synchronization:**
  - `static List<T>  synchronizedList(List<T> lst);`
  - `static Set<T>   synchronizedSet( Set<T> set);`
  - `static Map<K,V> synchronizedMap( Map<K,V> map);`

(3) Façade

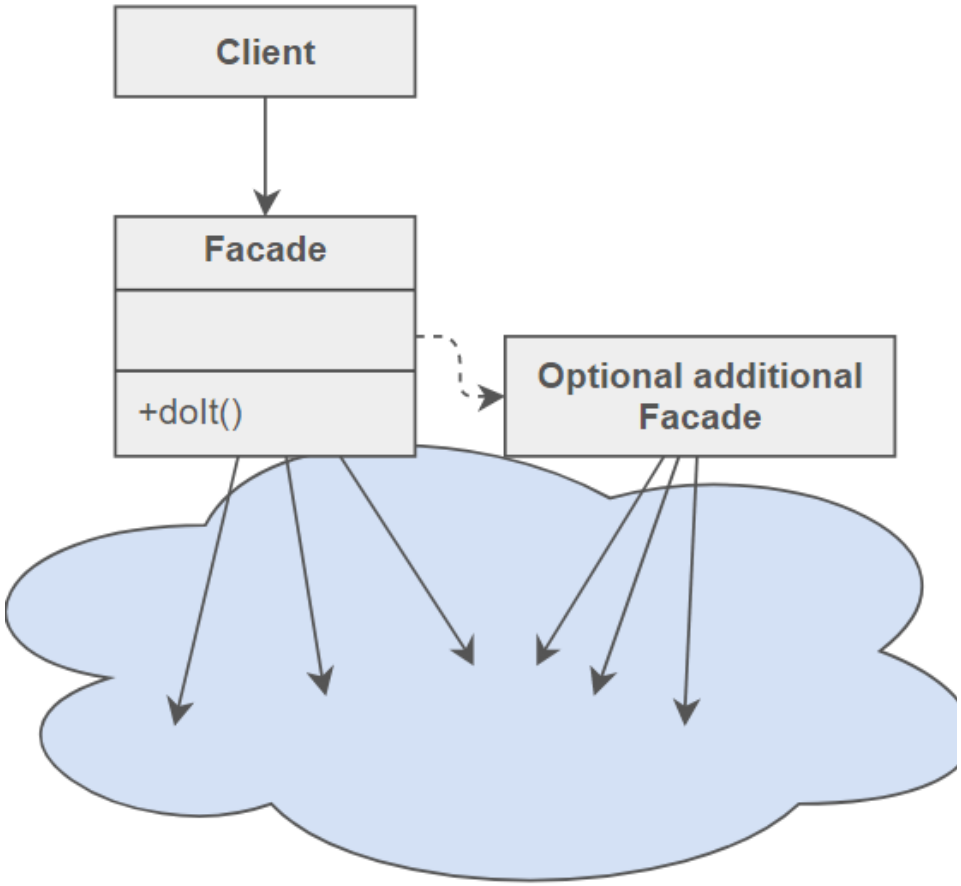
[fəˈsɑːd] 外观模式

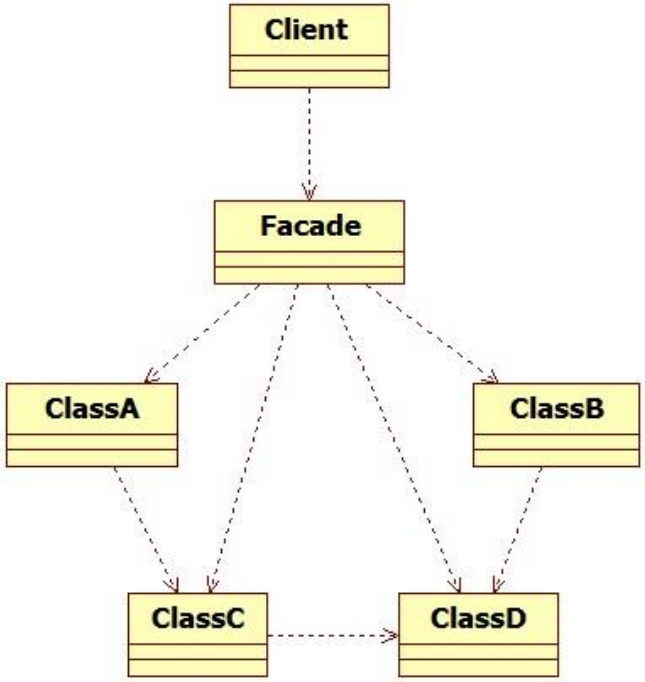
Facade

- **Problem**
  - A segment of the client community needs a simplified interface to the overall functionality of a complex subsystem.
- **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.
  - Wrap a complicated subsystem with a simpler interface.
- **This reduces the learning curve necessary to successfully leverage the subsystem.**
- **It also promotes decoupling the subsystem from its potentially many clients.**



Facade


Client
Facade
+dolt()
Optional additional Facade

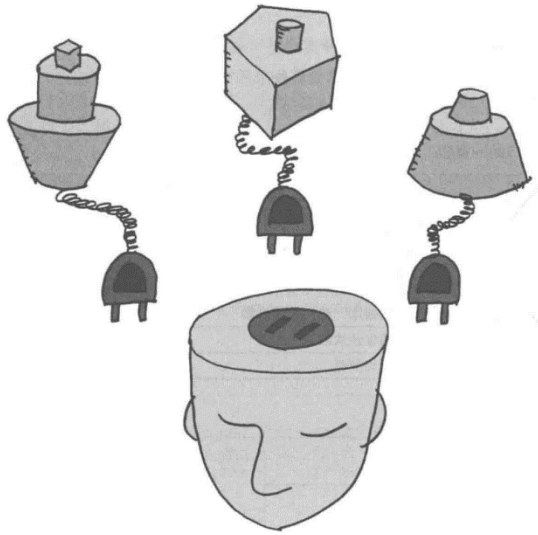

Client
Facade
ClassA
ClassB
ClassC
ClassD

2 Behavioral patterns

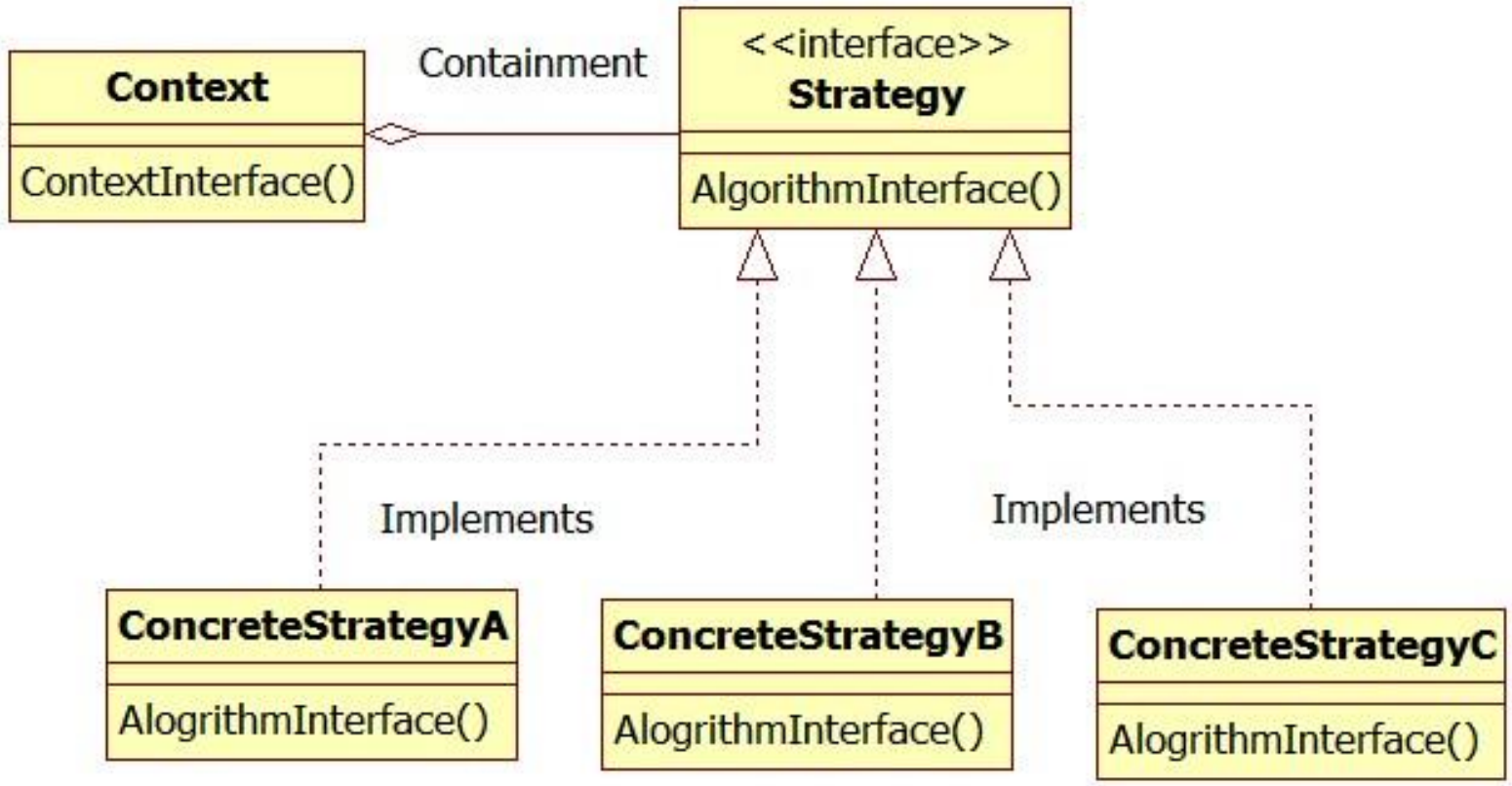
(1) Strategy

Strategy Pattern

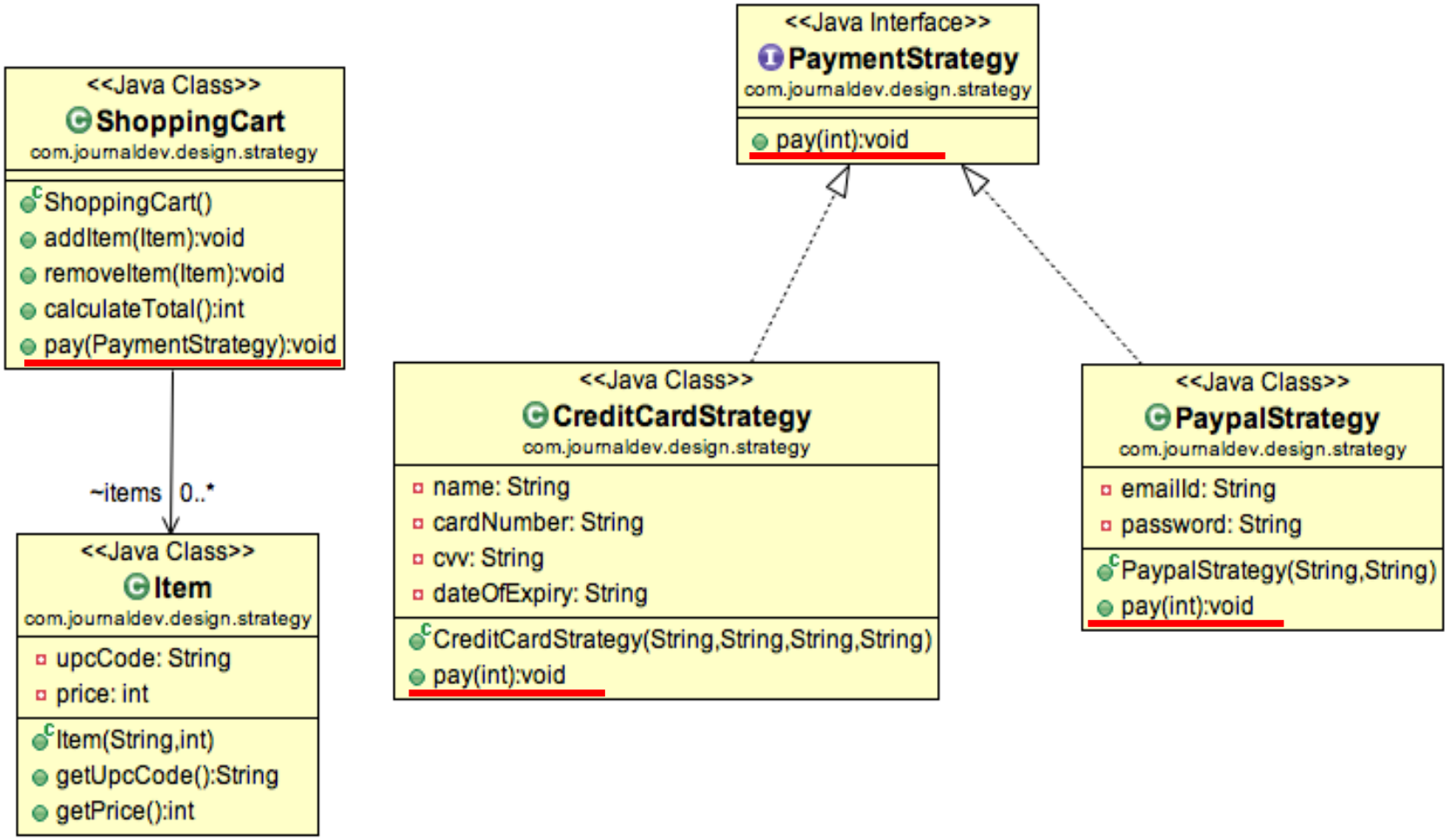
- **Problem:** Different algorithms exists for a specific task, but client can switch between the algorithms at run time in terms of dynamic context.
- **Example:** Sorting a list of customers (Bubble sort, mergesort, quicksort)
- **Solution:** Create an interface for the algorithm, with an implementing class for each variant of the algorithm.
- **Advantage:**
  - Easily extensible for new algorithm implementations
  - Separates algorithm from client context



Strategy Pattern

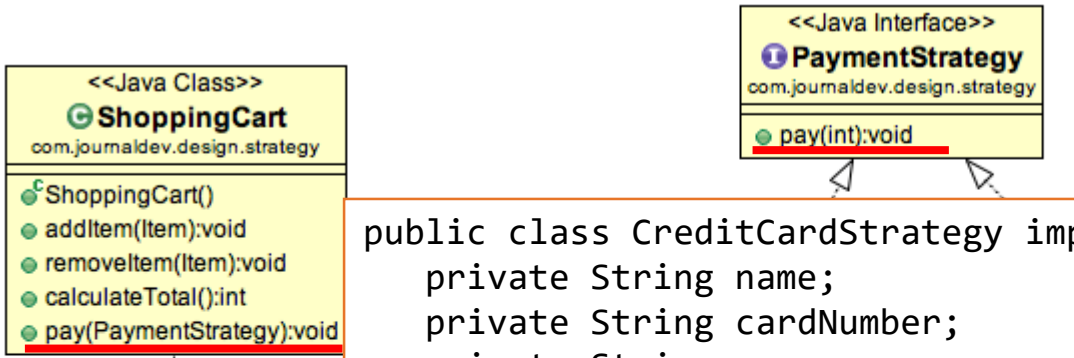


Code example



Code example

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

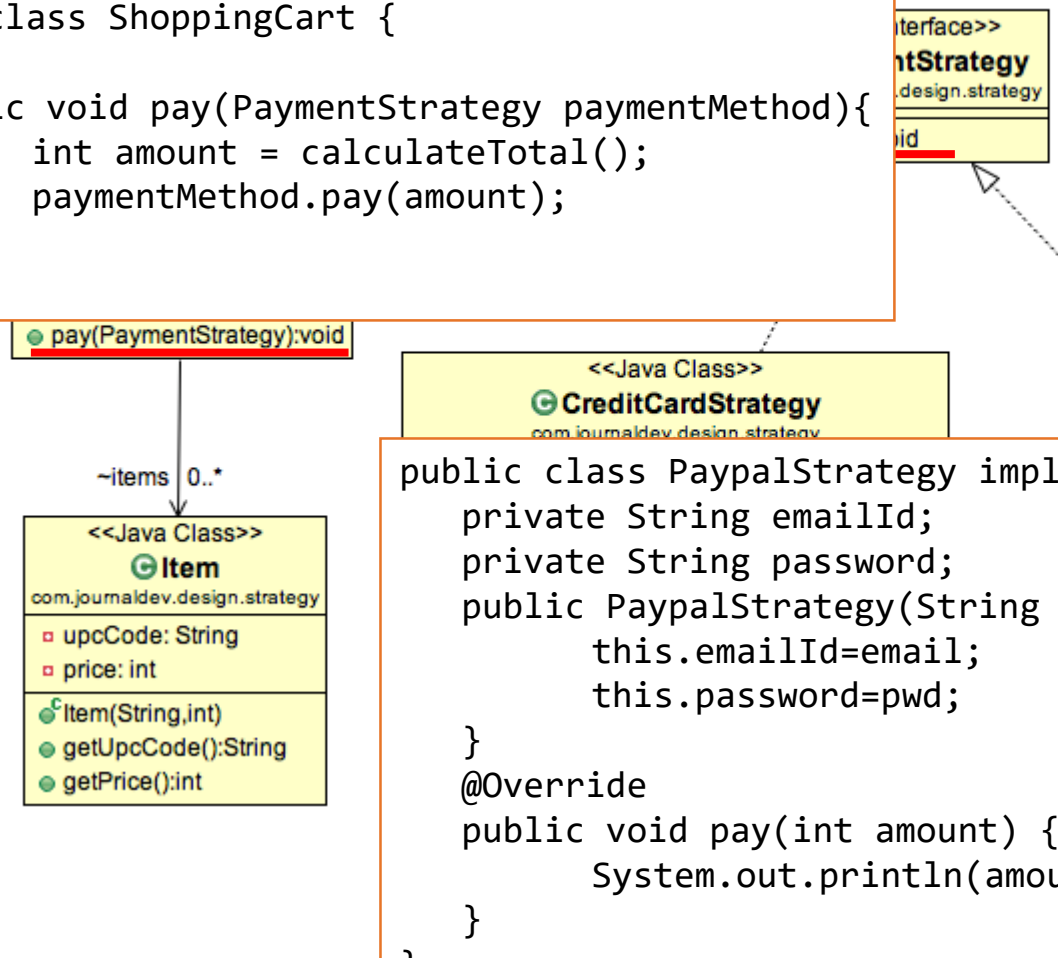



```
public class CreditCardStrategy implements PaymentStrategy {
   private String name;
   private String cardNumber;
   private String cvv;
   private String dateOfExpiry;
   public CreditCardStrategy(String nm, String ccNum,
               String cvv, String expiryDate){
         this.name=nm;
         this.cardNumber=ccNum;
         this.cvv=cvv;
         this.dateOfExpiry=expiryDate;
   }
   @Override
   public void pay(int amount) {
         System.out.println(amount +" paid with credit card");
   }
}
```

Code example

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

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

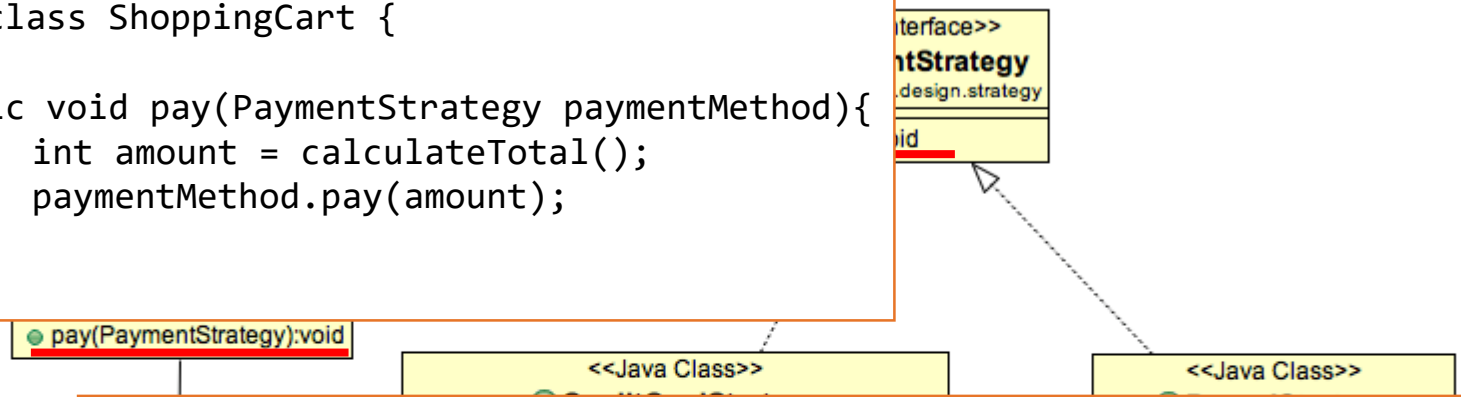



```
public class PaypalStrategy implements PaymentStrategy {
    private String emailId;
    private String password;
    public PaypalStrategy(String email, String pwd){
          this.emailId=email;
          this.password=pwd;
    }
    @Override
    public void pay(int amount) {
          System.out.println(amount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

Code example

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

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




```
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

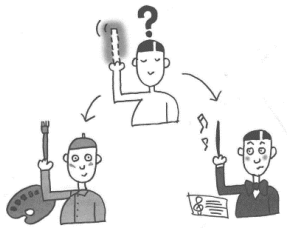
Template Method Motivation

- **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.** 不同的客户端具有相同的算法步骤，但是每个步骤的具体实现不同。

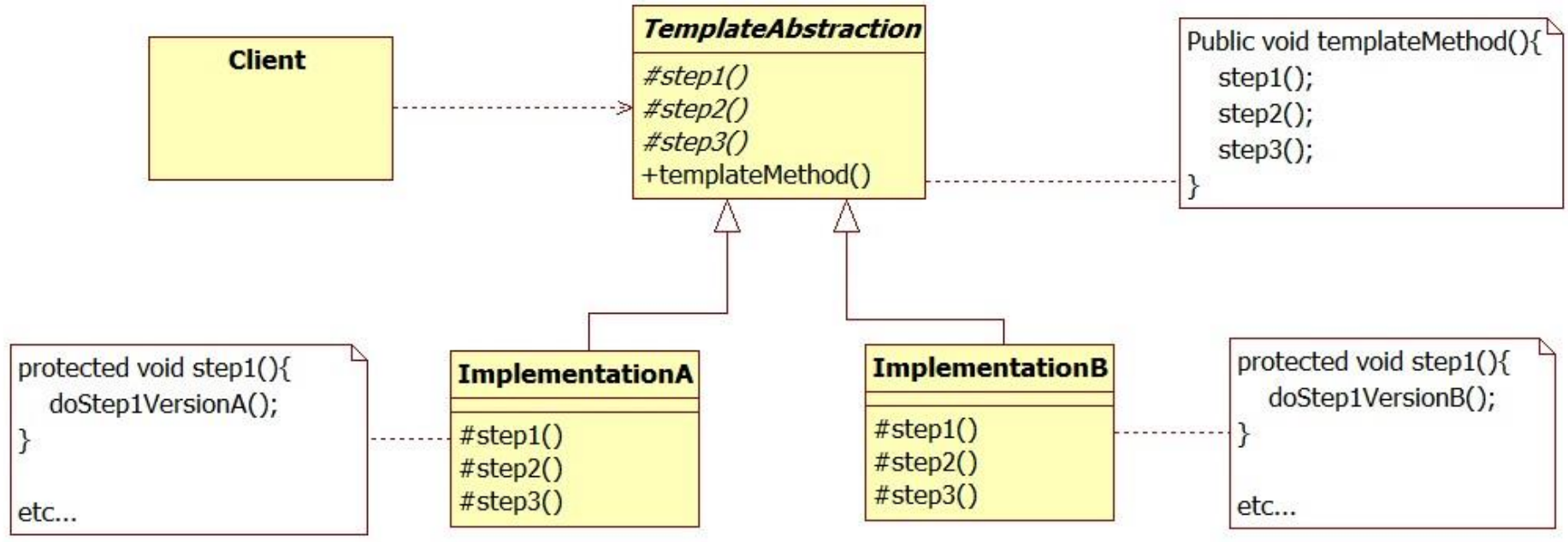
```
step1();
…
step2();
…
step3();
```

- **Examples:**
  - Executing a test suite of test cases
  - Opening, reading, writing documents of different types
- **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.在父类中定义通用逻辑和各步骤的抽象方法声明
  - Subclasses provide different realizations for each of these steps.

    子类中进行各步骤的具体实现

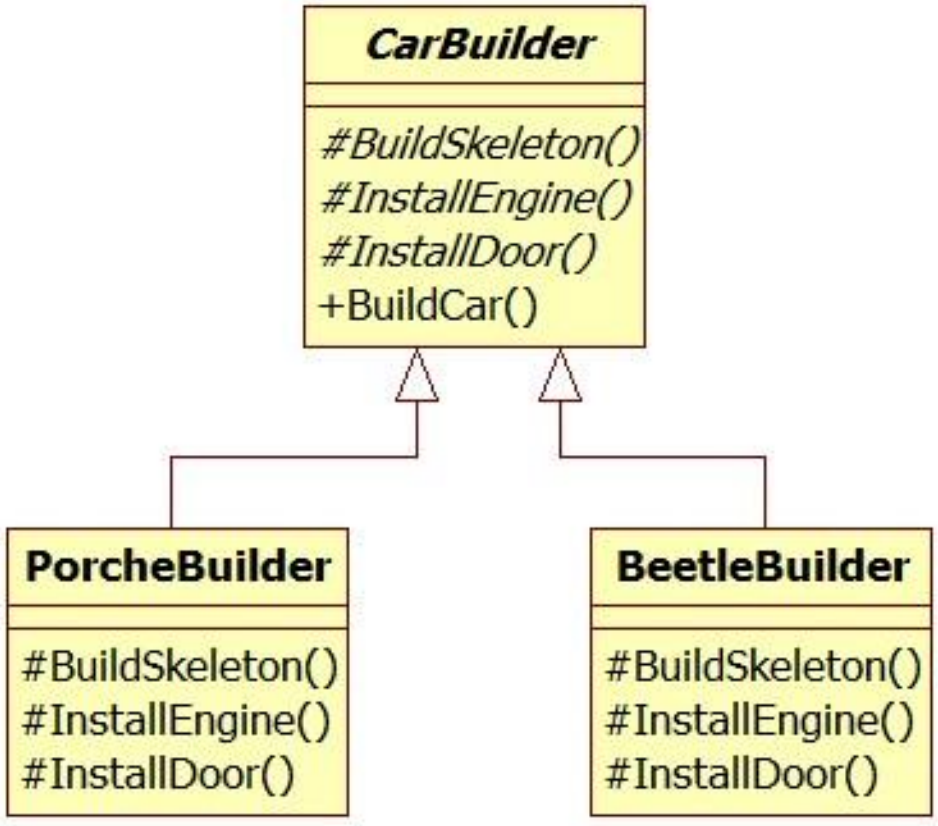


Template Method pattern



Example

- In the example, we will build 2 types of cars. One is a Porsche, the other is a VW Beetle.



Example

```
public abstract class CarBuilder {
        protected abstract void BuildSkeleton();
        protected abstract void InstallEngine();
        protected abstract void InstallDoor();

        // Template Method that specifies the general logic
        public void BuildCar() {  //通用逻辑
                BuildSkeleton();
                InstallEngine();
                InstallDoor();
        }
}
```

Example

```
public class PorcheBuilder extends CarBuilder {
        protected void BuildSkeleton() {
                System.out.println("Building Porche Skeleton");
        }
        protected void InstallEngine() {
                System.out.println("Installing Porche Engine");
        }
        protected void InstallDoor() {
                System.out.println("Installing Porche Door");
        }
}


public class BeetleBuilder extends CarBuilder {
        protected void BuildSkeleton() {
                System.out.println("Building Beetle Skeleton");
        }
        protected void InstallEngine() {
                System.out.println("Installing Beetle Engine");
        }
        protected void InstallDoor() {
                System.out.println("Installing Beetle Door");
        }
}
```

Example

```
public static void main(String[] args) {
        CarBuilder c = new PorcheBuilder();
        c.BuildCar();

        c = new BeetleBuilder();
        c.BuildCar();
        }
```

```
Building Porche Skeleton
Installing Porche Engine
Installing Porche Door
Building Beetle Skeleton
Installing Beetle Engine
Installing Beetle Door
```

Template Method Pattern Applicability

- Template Method Design Pattern allows you to declare a general logic at the parent class so that all the child classes can use the general logic. 在父类声明一个通用逻辑
- **Template method** pattern uses **inheritance + overridable** methods **to vary part of an algorithm**
  - 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”.

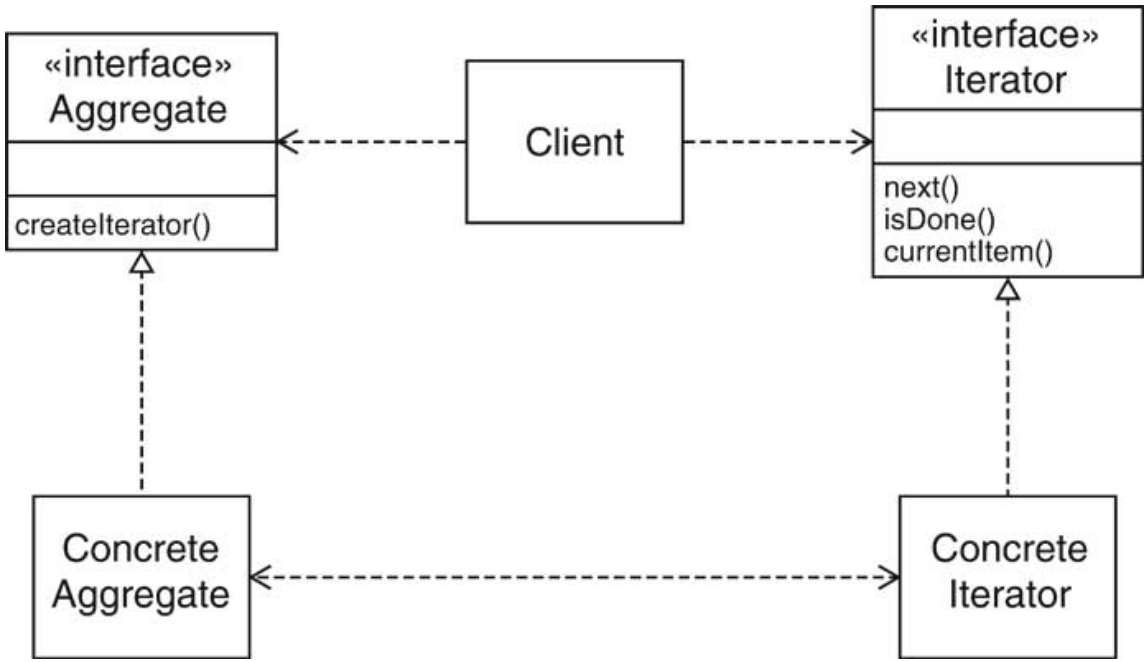
(3) Iterator

Iterator Pattern

- **Problem:** Clients need uniform strategy to access all elements in a container, independent of the container type
- **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



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

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The end

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