

Tecniche di Progettazione: Design Patterns

GoF: Decorator

An example

Welcome to Starbuzz Coffee

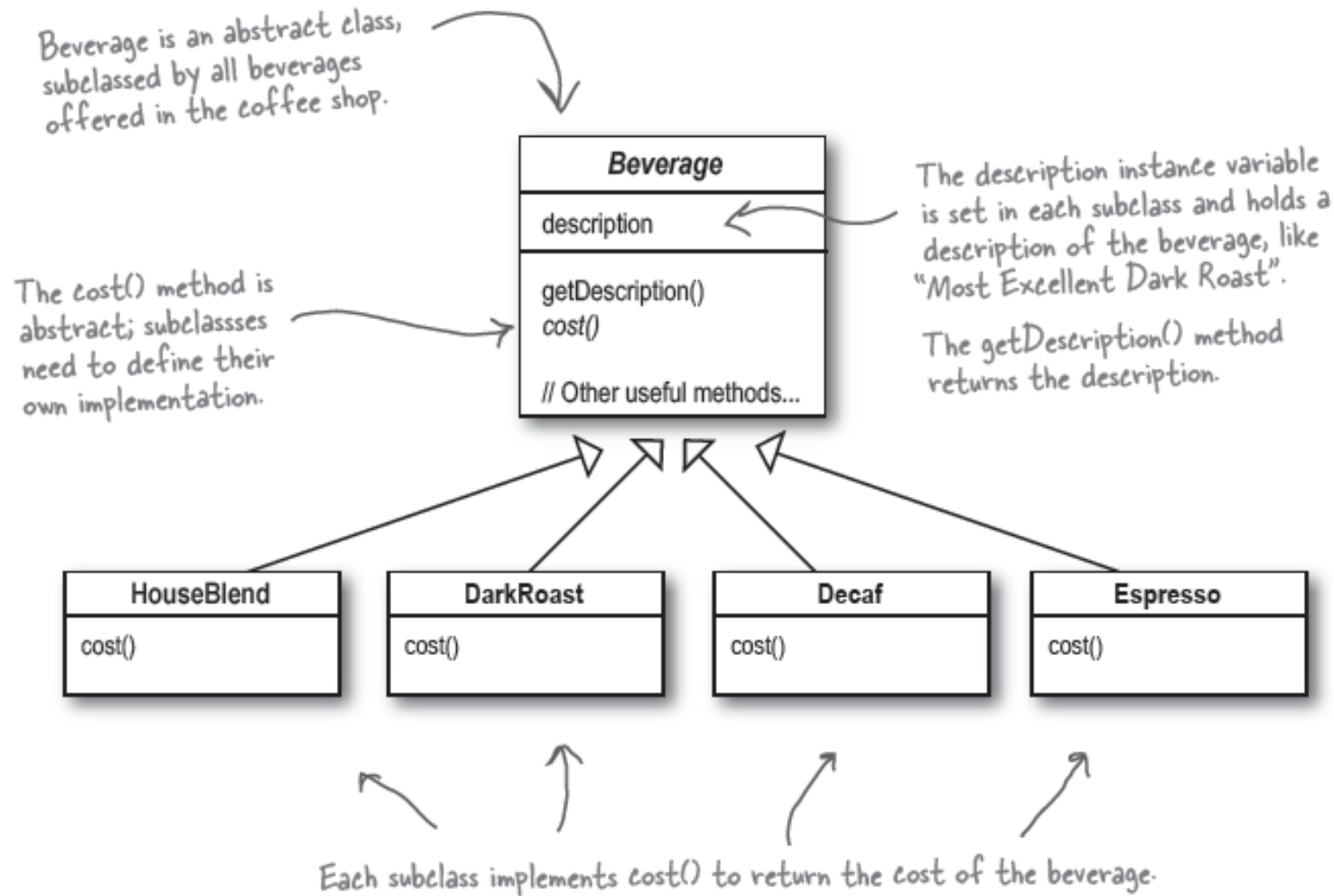
Starbuzz Coffee has made a name for itself as the fastest growing coffee shop around. If you've seen one on your local corner, look across the street; you'll see another one.

Because they've grown so quickly, they're scrambling to update their ordering systems to match their beverage offerings.

When they first went into business they designed their classes like this...



Your first idea of implementation

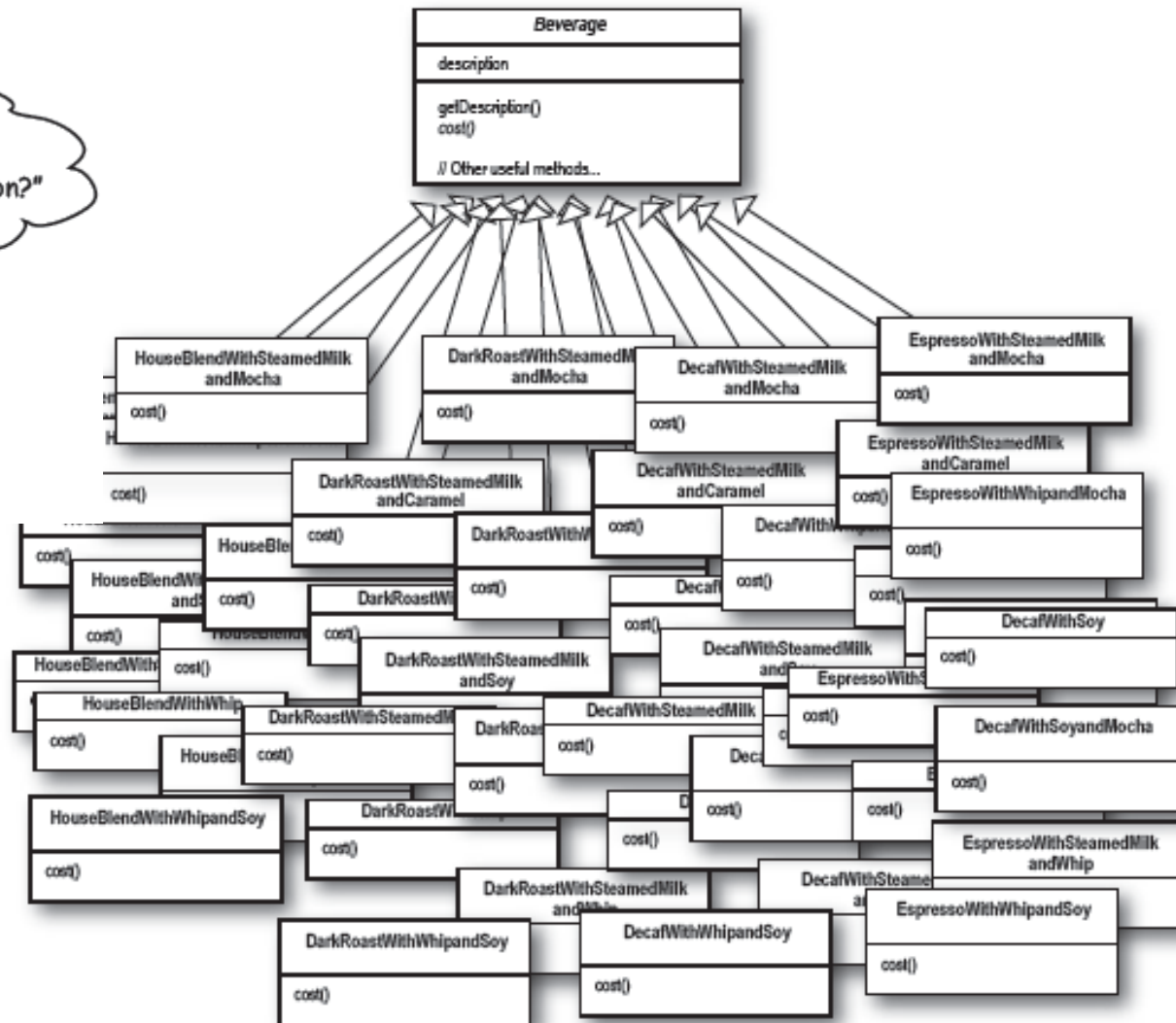


In reality

In addition to your coffee, you can also ask for several condiments like steamed milk, soy, and mocha (otherwise known as chocolate), and have it all topped off with whipped milk. Starbuzz charges a bit for each of these, so they really need to get them built into their order system.

Here's their first attempt...

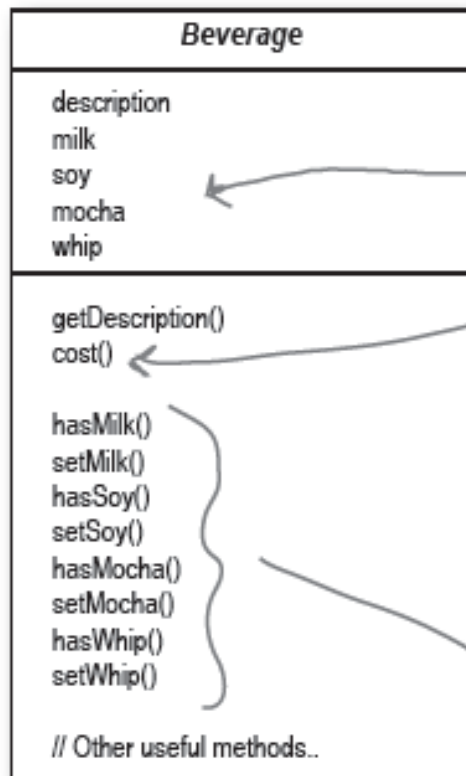
Now a beverage can be mixed from different condiment to form a new beverage





This is stupid; why do we need all these classes? Can't we just use instance variables and inheritance in the superclass to keep track of the condiments?

Well, let's give it a try. Let's start with the Beverage base class and add instance variables to represent whether or not each beverage has milk, soy, mocha and whip...



New boolean values for each condiment.

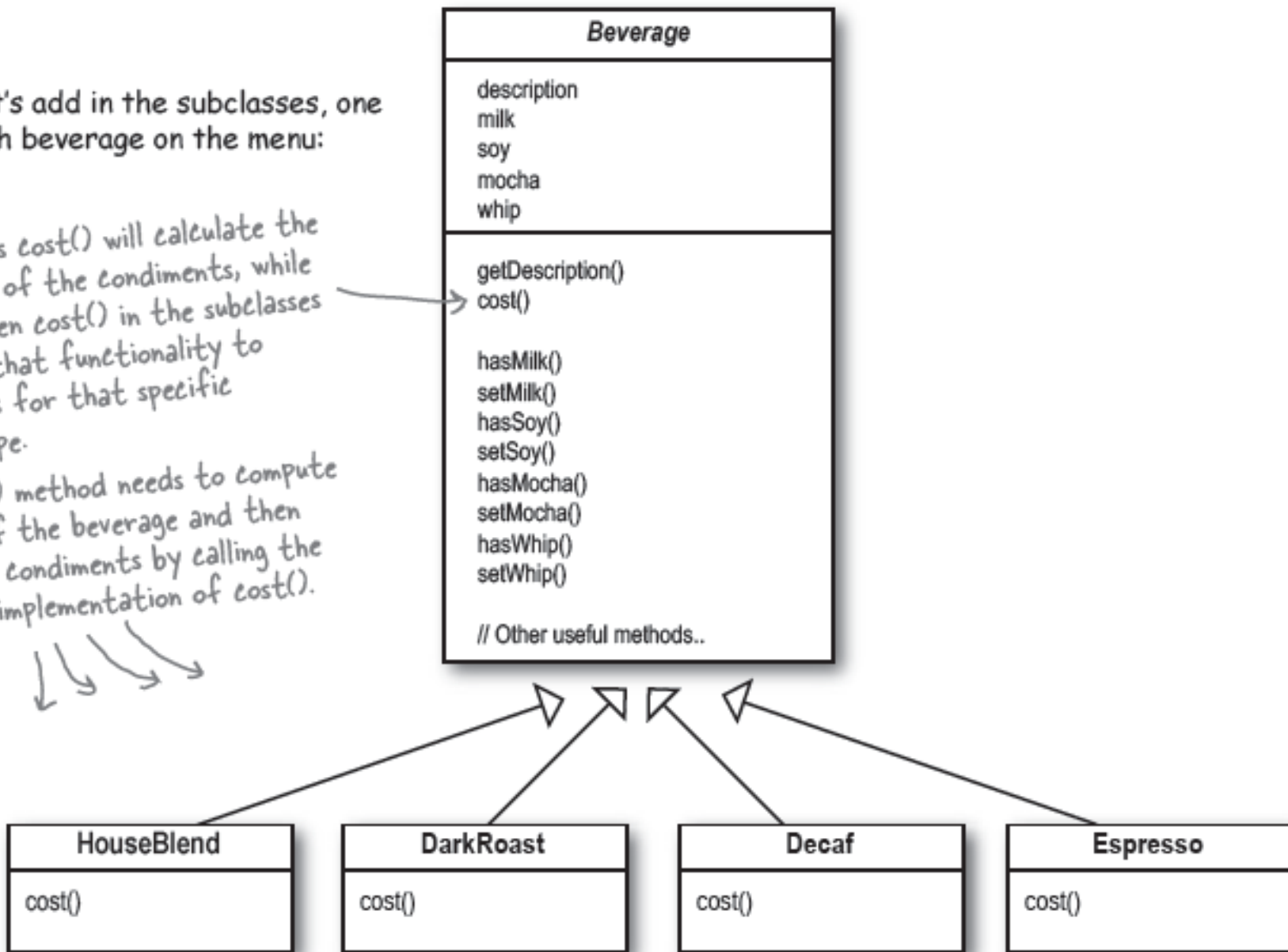
Now we'll implement `cost()` in Beverage (instead of keeping it abstract), so that it can calculate the costs associated with the condiments for a particular beverage instance. Subclasses will still override `cost()`, but they will also invoke the super version so that they can calculate the total cost of the basic beverage plus the costs of the added condiments.

These get and set the boolean values for the condiments.

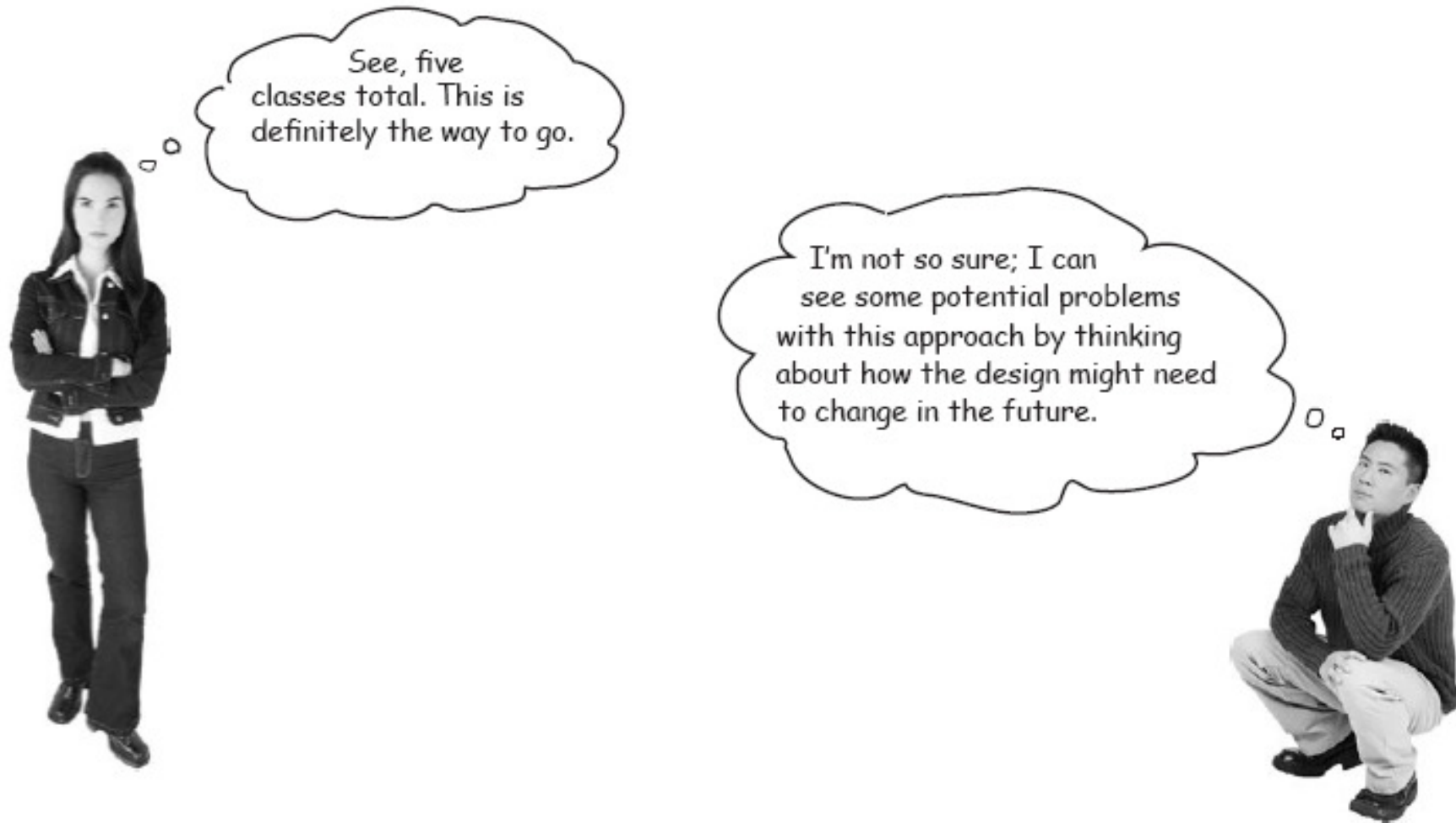
Now let's add in the subclasses, one for each beverage on the menu:

The superclass `cost()` will calculate the costs for all of the condiments, while the overridden `cost()` in the subclasses will extend that functionality to include costs for that specific beverage type.

Each `cost()` method needs to compute the cost of the beverage and then add in the condiments by calling the superclass implementation of `cost()`.



Now, your turns. It is a good solution?





Sharpen your pencil

What requirements or other factors might change that will impact this design?

Price changes for condiments will force us to alter existing code.

New condiments will force us to add new methods and alter the cost method in the superclass.

We may have new beverages. For some of these beverages (iced tea?), the condiments may not be appropriate, yet the Tea subclass will still inherit methods like `hasWhip()`.

As we saw in Chapter 1, this is a very bad idea!

What if a customer wants a double mocha?

Your turn:



Design Principle

Classes should be open for extension, but closed for modification.

- ▶ **SOLID 2: Open Closed Principle :**
 - ▶ Extending a class shouldn't require modification of that class.
 - ▶ Software entities like classes, modules and functions should be open for extension but closed for modifications.
 - ▶ OPC is a generic principle. You can consider it when writing your classes to make sure that when you need to extend their behavior you don't have to change the class but to extend it. The same principle can be applied for modules, packages, libraries.

Q: How can I make every part of my design follow the Open-Closed Principle?

A: Usually, you can't. Making OO design flexible and open to extension without the modification of existing code takes time and effort. In general, we don't have the luxury of tying down every part of our designs (and it would probably be wasteful). Following the Open-Closed Principle usually introduces new levels of abstraction, which adds complexity to our code. You want to concentrate on those areas that are most likely to change in your designs and apply the principles there.

Q: How do I know which areas of change are more important?

A: That is partly a matter of experience in designing OO systems and also a matter of the knowing the domain you are working in. Looking at other examples will help you learn to identify areas of change in your own designs.

Decorator Pattern

- ▶ **The problems of two previous designs**
 - ▶ we get class explosions, rigid designs,
 - ▶ or we add functionality to the base class that isn't appropriate for some of the subclasses.

Revisit the problem again

- ▶ If a customer wants a Dark Roast with Mocha and Whip
 - ▶ Take a DarkRoast object
 - ▶ Decorate it with a Mocha object
 - ▶ Decorate it with a Whip object
 - ▶ Call the cost() method and rely on delegation to add on the condiment costs

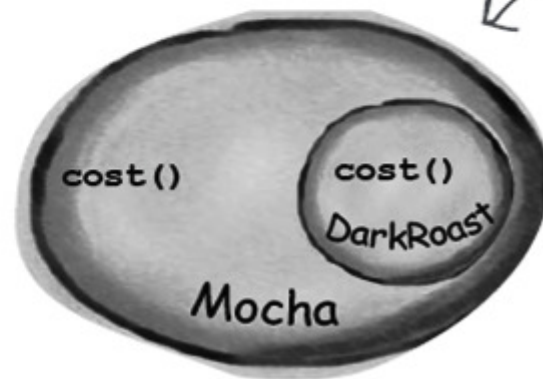
Constructing a drink order with Decorators

- 1 We start with our DarkRoast object.



Remember that DarkRoast inherits from Beverage and has a cost() method that computes the cost of the drink.

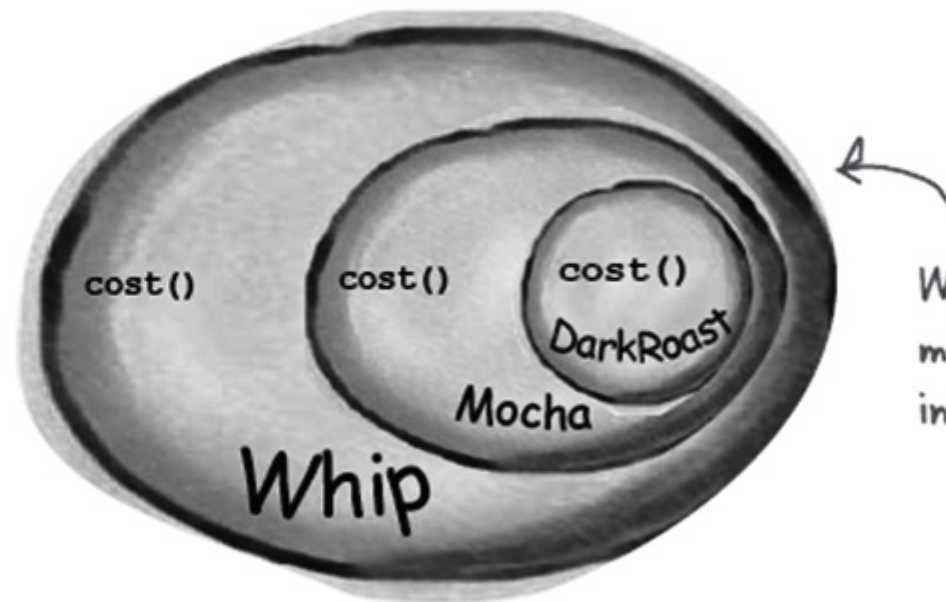
- 2 The customer wants Mocha, so we create a Mocha object and wrap it around the DarkRoast.



The Mocha object is a decorator. Its type mirrors the object it is decorating, in this case, a Beverage. (By "mirror", we mean it is the same type..)

So, Mocha has a cost() method too, and through polymorphism we can treat any Beverage wrapped in Mocha as a Beverage, too (because Mocha is a subtype of Beverage).

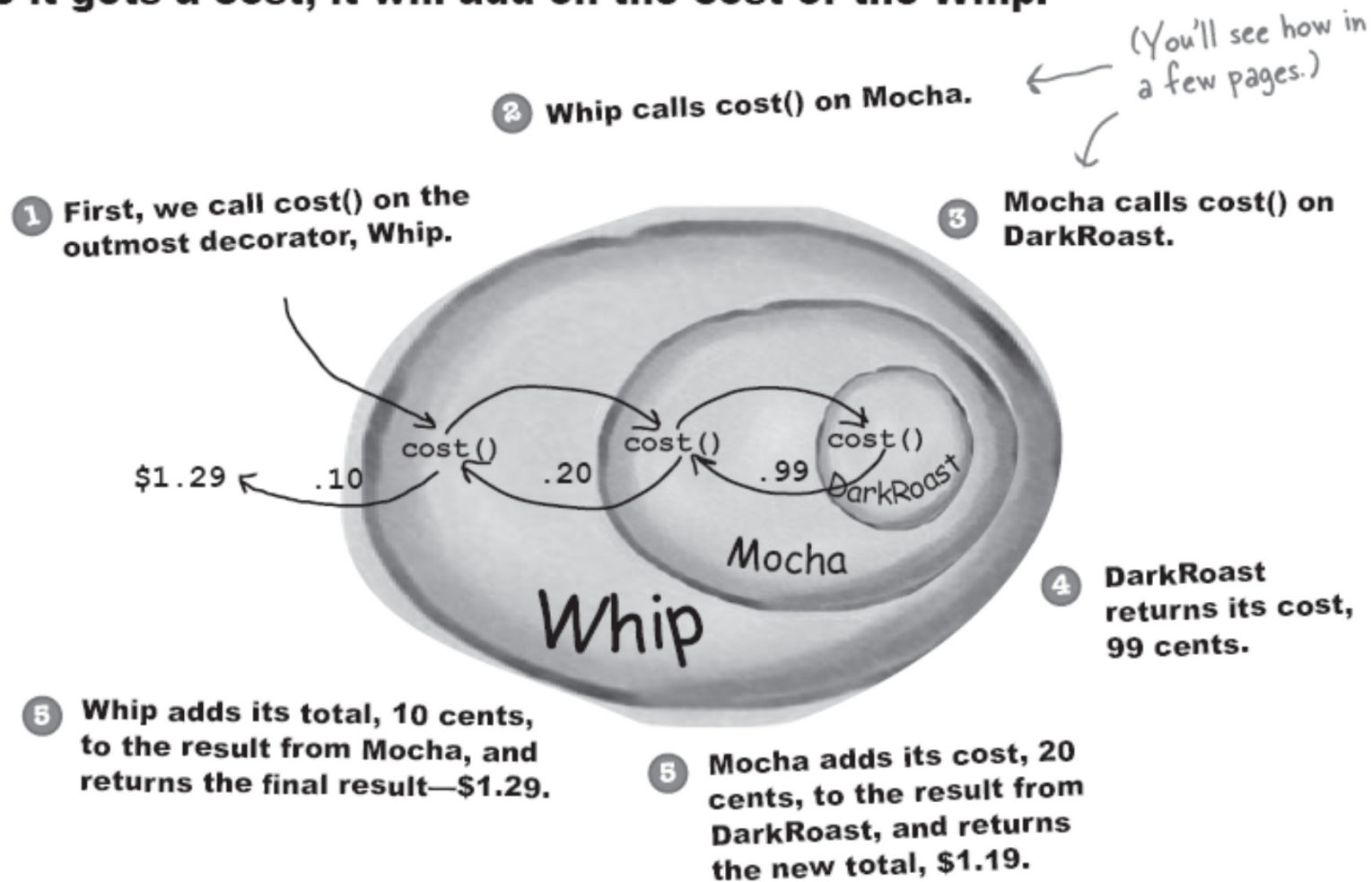
The customer also wants Whip, so we create a Whip decorator and wrap Mocha with it.



Whip is a decorator, so it also mirrors DarkRoast's type and includes a `cost()` method.

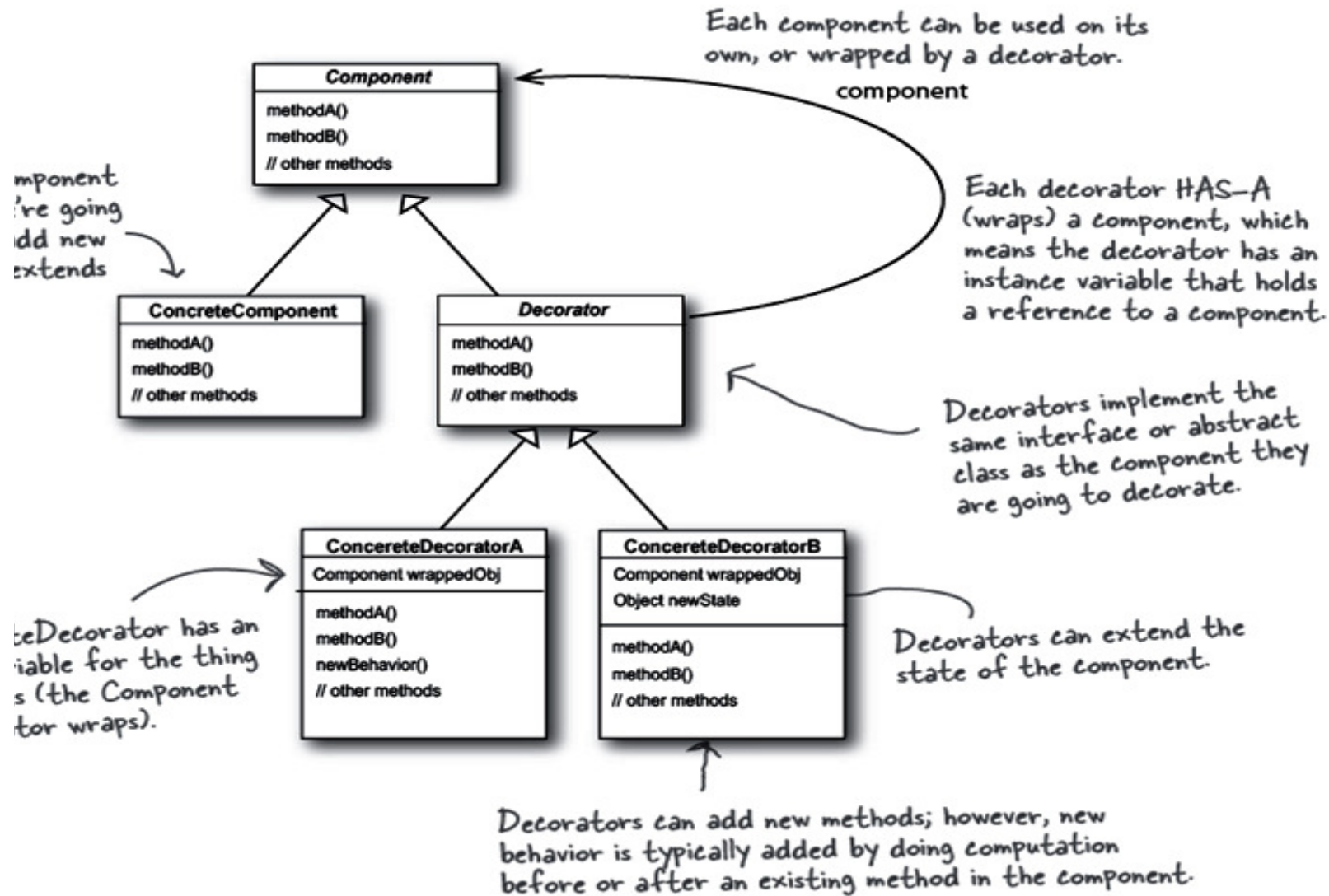
So, a DarkRoast wrapped in Mocha and Whip is still a Beverage and we can do anything with it we can do with a DarkRoast, including call its `cost()` method.

- ④ Now it's time to compute the cost for the customer. We do this by calling `cost()` on the outermost decorator, Whip, and Whip is going to delegate computing the cost to the objects it decorates. Once it gets a cost, it will add on the cost of the Whip.

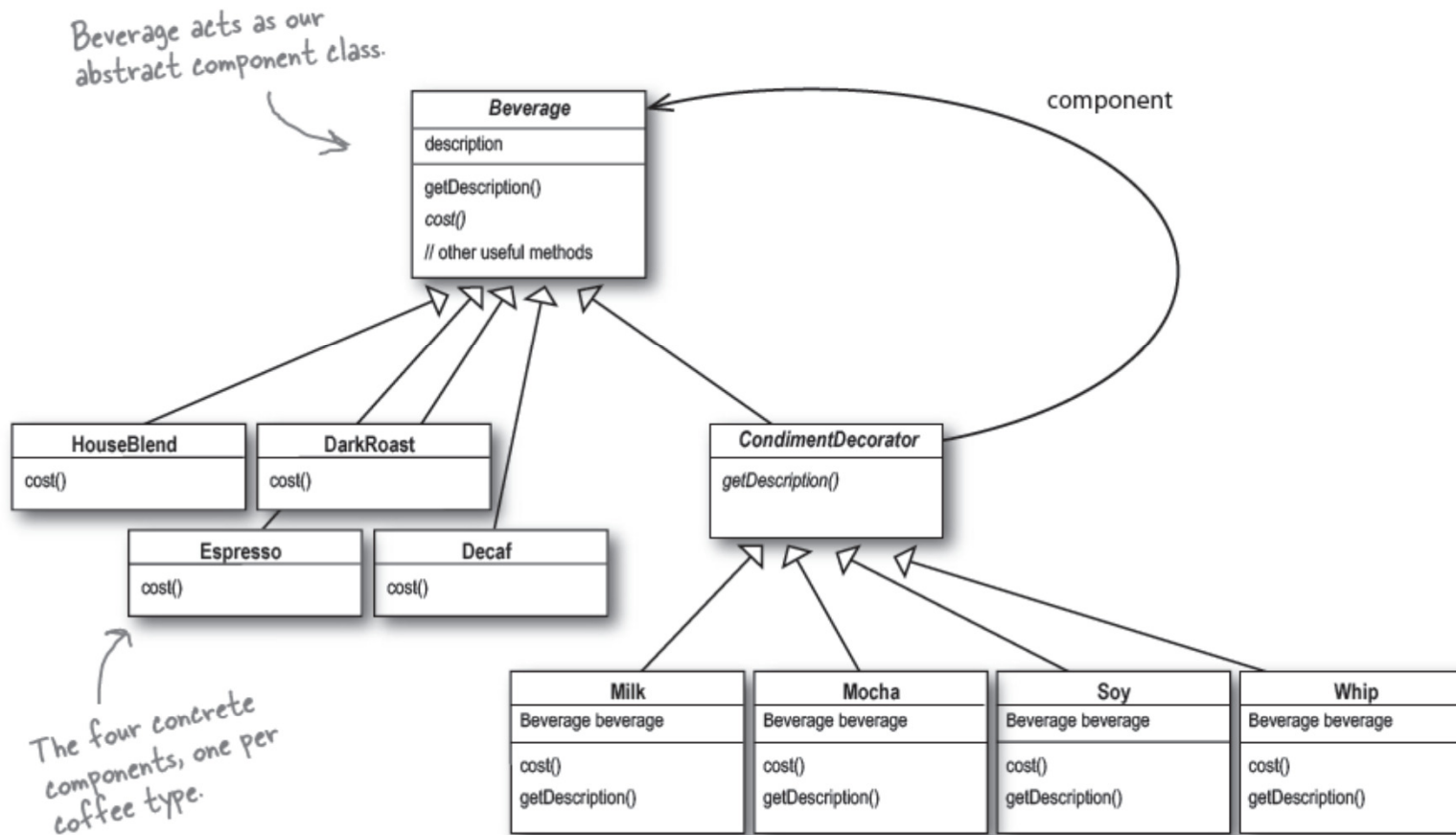


The Decorator Pattern attaches additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality.

Decorator Pattern defined



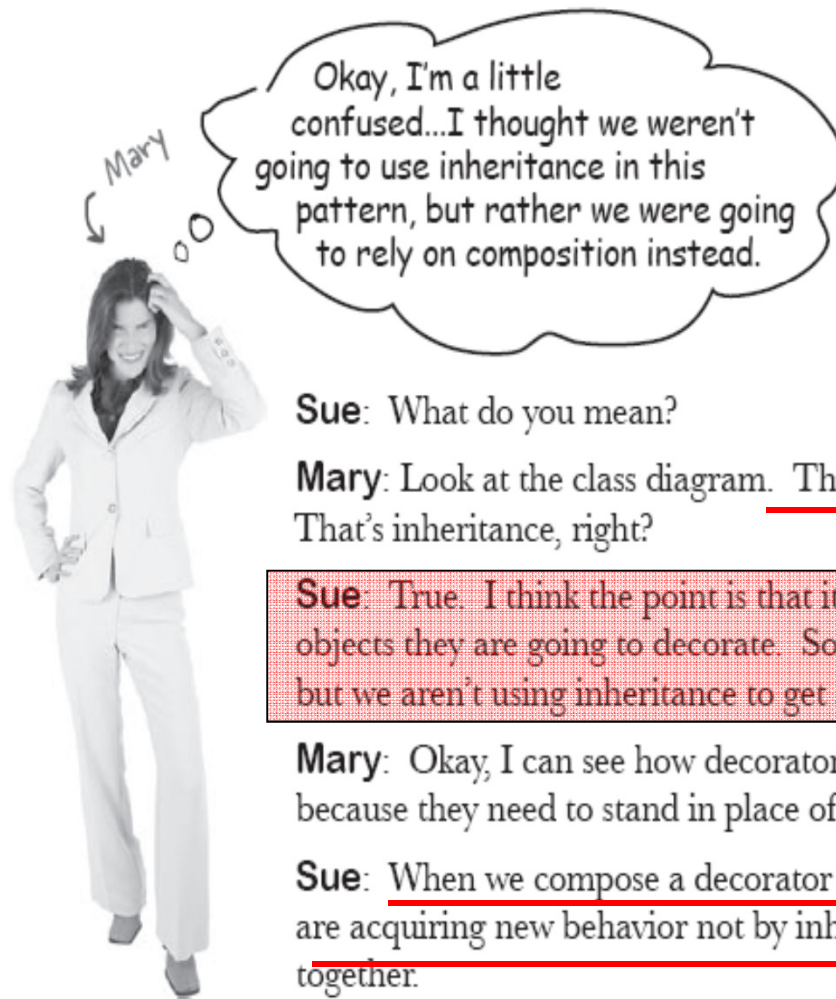
The decorator pattern for Starbucks beverages



The four concrete components, one per coffee type.

And here are our condiment decorators; notice they need to implement not only `cost()` but also `getDescription()`. We'll see why in a moment...

Some confusion over Inheritance versus Composition



Sue: What do you mean?

Mary: Look at the class diagram. The CondimentDecorator is extending the Beverage class. That's inheritance, right?

Sue: True. I think the point is that it's vital that the decorators have the same type as the objects they are going to decorate. So here we're using inheritance to achieve the *type matching*, but we aren't using inheritance to get *behavior*.

Mary: Okay, I can see how decorators need the same "interface" as the components they wrap because they need to stand in place of the component. But where does the behavior come in?

Sue: When we compose a decorator with a component, we are adding new behavior. We are acquiring new behavior not by inheriting it from a superclass, but by composing objects together.

Mary: Okay, so we're subclassing the abstract class Beverage in order to have the correct type, not to inherit its behavior. The behavior comes in through the composition of decorators with the base components as well as other decorators.

Sue: That's right.

Mary: Ooooh, I see. And because we are using object composition, we get a whole lot more flexibility about how to mix and match condiments and beverages. Very smooth.

Sue: Yes, if we rely on inheritance, then our behavior can only be determined statically at compile time. In other words, we get only whatever behavior the superclass gives us or that we override. With composition, we can mix and match decorators any way we like... *at runtime.*

Mary: And as I understand it, we can implement new decorators at any time to add new behavior. If we relied on inheritance, we'd have to go in and change existing code any time we wanted new behavior.

Sue: Exactly.

Mary: I just have one more question. If all we need to inherit is the type of the component, how come we didn't use an interface instead of an abstract class for the Beverage class?

Sue: Well, remember, when we got this code, Starbuzz already *had* an abstract Beverage class. Traditionally the Decorator Pattern does specify an abstract component, but in Java, obviously, we could use an interface. But we always try to avoid altering existing code, so don't "fix" it if the abstract class will work just fine.

Let's see the code


```
public abstract class Beverage {  
    String description = "Unknown Beverage";  
  
    public String getDescription() {  
        return description;  
    }  
  
    public abstract double cost();  
}
```

Beverage is an abstract class with the two methods `getDescription()` and `cost()`.

`getDescription` is already implemented for us, but we need to implement `cost()` in the subclasses.


The abstract class of condiments

First, we need to be interchangeable with a Beverage so we extend the Beverage class



```
public abstract class CondimentDecorator extends Beverage {  
    public abstract String getDescription();  
}
```

We're also going to require that the condiment decorators all reimplement the `getDescription()` method. Again, we'll see why in a sec...



Starbuzz Coffee	
<u>Coffees</u>	
House Blend	.89
Dark Roast	.99
Decaf	1.05
Espresso	1.99
<u>Condiments</u>	
Steamed Milk	.10
Mocha	.20
Soy	.15
Whip	.10

Concrete Base Classes of Beverages



First we extend the Beverage class, since this is a beverage.

```
public class Espresso extends Beverage {
```

```
    public Espresso() {
        description = "Espresso";
    }
```

← To take care of the description, we set this in the constructor for the class. Remember the description instance variable is inherited from Beverage.

```
    public double cost() {
        return 1.99;
    }
}
```

↖ Finally, we need to compute the cost of an Espresso. We don't need to worry about adding in condiments in this class, we just need to return the price of an Espresso: \$1.99.

A concrete Condiment class

```
public class Mocha extends CondimentDecorator {
    Beverage beverage;

    public Mocha(Beverage beverage) {
        this.beverage = beverage;
    }

    public String getDescription() {
        return beverage.getDescription() + ", Mocha";
    }

    public double cost() {
        return .20 + beverage.cost();
    }
}
```

Mocha is a decorator, so we extend CondimentDecorator.

Remember, CondimentDecorator extends Beverage.

We're going to instantiate Mocha with a reference to a Beverage using:

- (1) An instance variable to hold the beverage we are wrapping.

- (2) A way to set this instance variable to the object we are wrapping. Here, we're going to pass the beverage we're wrapping to the decorator's constructor.

We want our description to not only include the beverage – say “Dark Roast” – but also to include each item decorating the beverage, for instance, “Dark Roast, Mocha”. So we first delegate to the object we are decorating to get its description, then append “, Mocha” to that description.

When Mocha price changed, we only need to change this

Now we need to compute the cost of our beverage with Mocha. First, we delegate the call to the object we're decorating, so that it can compute the cost; then, we add the cost of Mocha to the result.

Constructing new beverages from decorator classes dynamically

```
public class StarbuzzCoffee {
```

```
    public static void main(String args[]) {  
        Beverage beverage = new Espresso();  
        System.out.println(beverage.getDescription()  
            + " $" + beverage.cost());
```

Order up an espresso, no condiments and print its description and cost.

```
        Beverage beverage2 = new DarkRoast();  
        beverage2 = new Mocha(beverage2);  
        beverage2 = new Mocha(beverage2);  
        beverage2 = new Whip(beverage2);  
        System.out.println(beverage2.getDescription()  
            + " $" + beverage2.cost());
```

Make a DarkRoast object.
Wrap it with a Mocha.

Wrap it in a second Mocha.

Wrap it in a Whip.

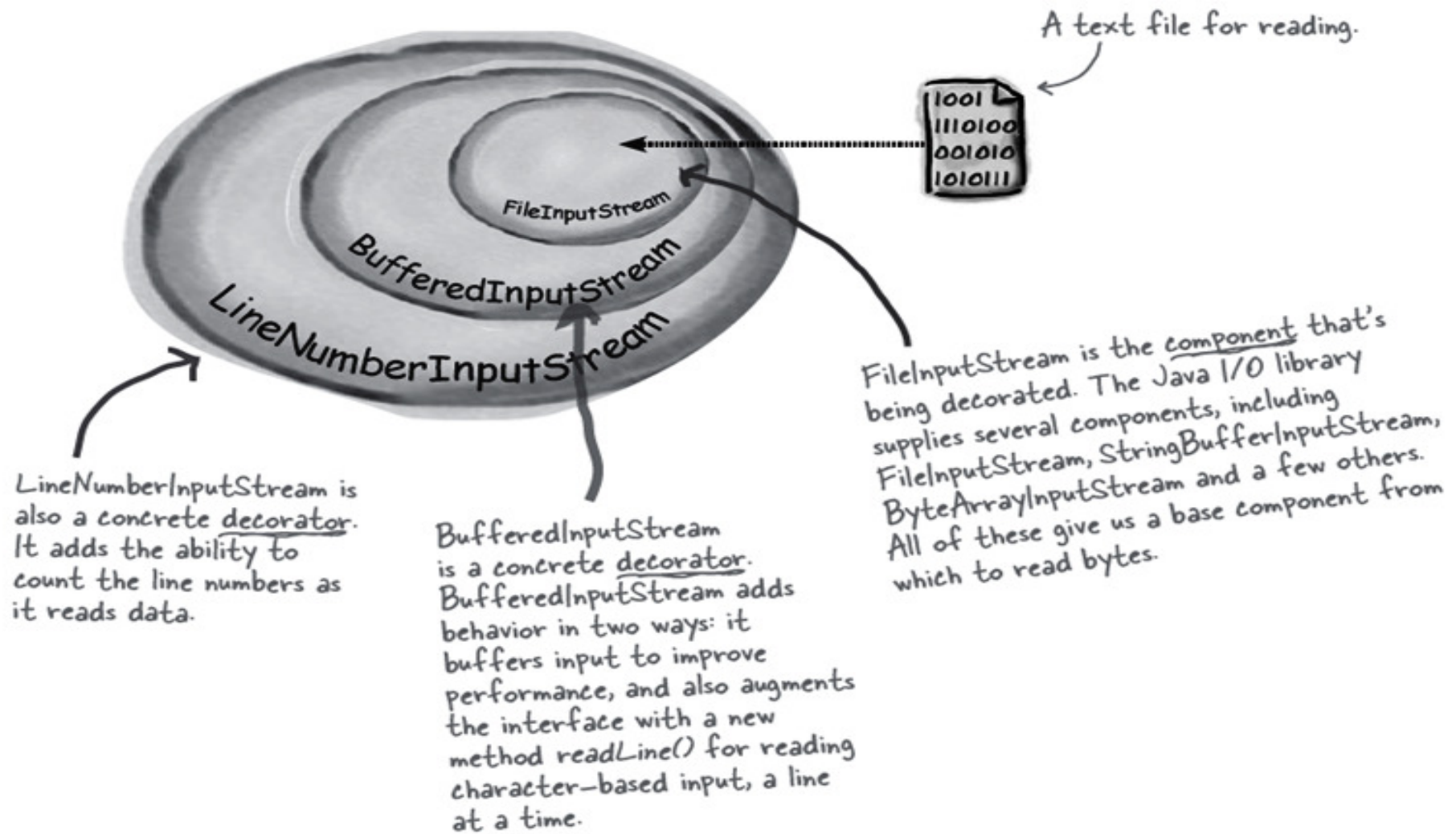
```
        Beverage beverage3 = new HouseBlend();  
        beverage3 = new Soy(beverage3);  
        beverage3 = new Mocha(beverage3);  
        beverage3 = new Whip(beverage3);  
        System.out.println(beverage3.getDescription()  
            + " $" + beverage3.cost());
```

Finally, give us a HouseBlend with Soy, Mocha, and Whip.

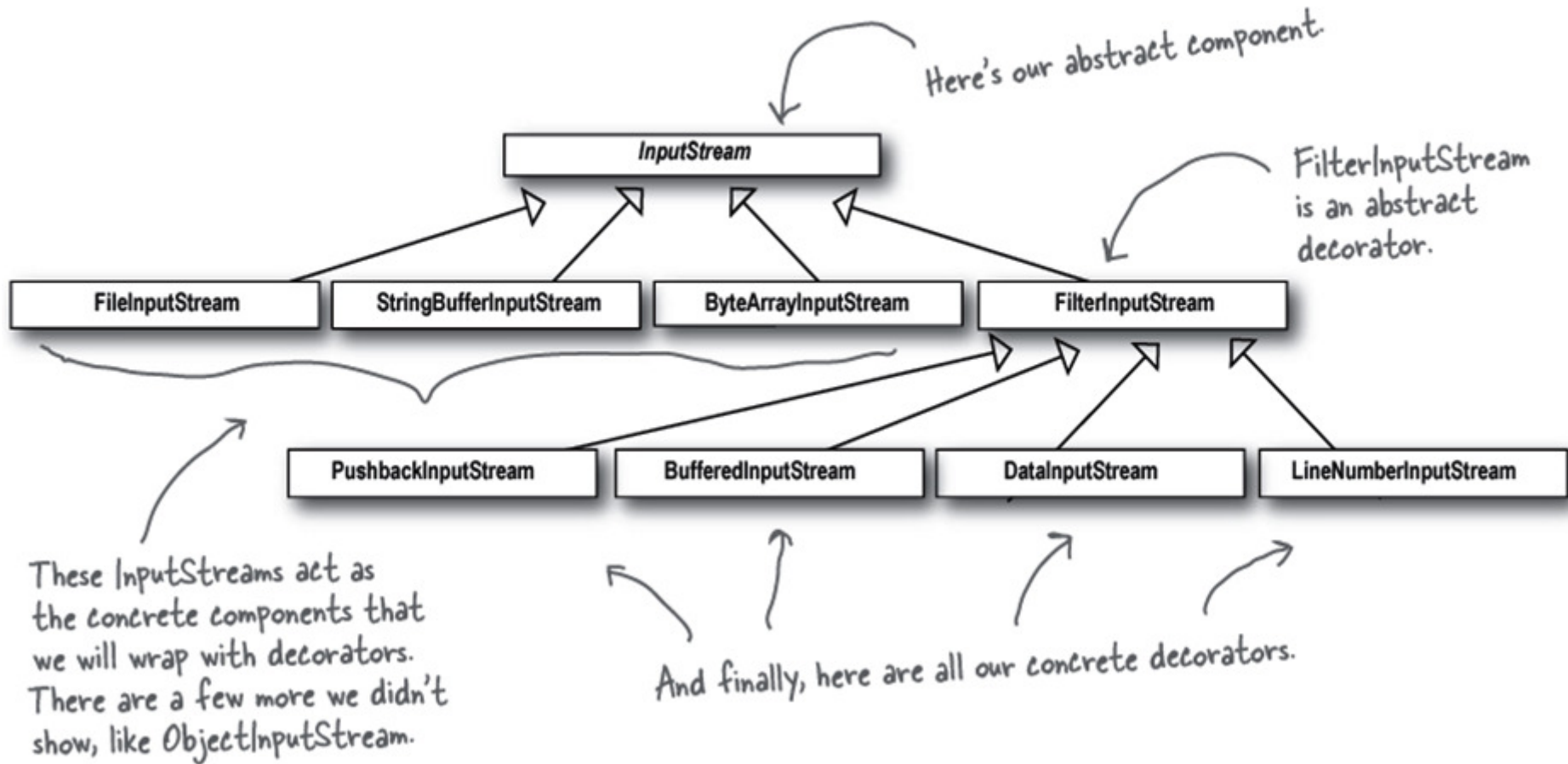
```
    }
```

```
}
```

Real world decorator – Java I/O



Decorating the java.io classes



Comments

- ▶ You can see that this isn't so different from the Starbuzz design. You should now be in a good position to look over the java.io API docs and compose decorators on the various input streams.
- ▶ You'll see that the output streams have the same design. And you've probably already found that the reader/Writer streams (for character-based data) closely mirror the design of the streams classes (with a few differences and inconsistencies, but close enough to figure out what's going on).

Let's write a new decorator

Don't forget to import
java.io... (not shown)

First, extend the FilterInputStream, the
abstract decorator for all InputStreams.

```
public class LowerCaseInputStream extends FilterInputStream {
    public LowerCaseInputStream(InputStream in) {
        super(in);
    }

    public int read() throws IOException {
        int c = super.read();
        return (c == -1 ? c : Character.toLowerCase((char)c));
    }

    public int read(byte[] b, int offset, int len) throws IOException {
        int result = super.read(b, offset, len);
        for (int i = offset; i < offset+result; i++) {
            b[i] = (byte)Character.toLowerCase((char)b[i]);
        }
        return result;
    }
}
```

Now we need to implement two
read methods. They take a
byte (or an array of bytes)
and convert each byte (that
represents a character) to
lowercase if it's an uppercase
character.

Test out your new Java I/O decorator

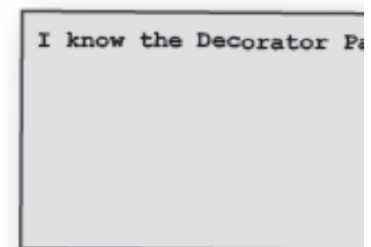
```
public class InputTest {
    public static void main(String[] args) throws IOException {
        int c;
        try {
            InputStream in =
                new LowerCaseInputStream(
                    new BufferedInputStream(
                        new FileInputStream("test.txt")));

            while((c = in.read()) >= 0) {
                System.out.print((char)c);
            }

            in.close();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

Just use the stream to read characters until the end of file and print as we go.

Set up the stream and decorator and then use the LowerCaseInputStream



test.txt

Dark Side

- ▶ You can usually insert decorators transparently and the client never has to know it's dealing with a decorator
- ▶ However, if you write some code is dependent on specific types -> Bad things happen
- ▶ Java library is notorious to be used badly by people who do not know decorator pattern

```
Beverage beverage2 = new DarkRoast();  
beverage2 = new Mocha(beverage2);  
beverage2 = new Mocha(beverage2);  
beverage2 = new Whip(beverage2);  
System.out.println(beverage2.getDescription()  
+ " $" + beverage2.cost());
```

The right way

```
Beverage beverage2 = new DarkRoast();  
beverage2 = new Mocha(beverage2);  
beverage2 = new Mocha(beverage2);  
Whip beverage3 = new Whip(beverage2);  
System.out.println(beverage3.getDescription()  
+ " $" + beverage2.cost());
```

The poor way

Exercise solutions

```
public class Beverage {  
  
    // declare instance variables for milkCost,  
    // soyCost, mochaCost, and whipCost, and  
    // getters and setters for milk, soy, mocha  
    // and whip.  
  
    public float cost() {  
        float condimentCost = 0.0;  
        if (hasMilk()) {  
            condimentCost += milkCost;  
        }  
        if (hasSoy()) {  
            condimentCost += soyCost;  
        }  
        if (hasMocha()) {  
            condimentCost += mochaCost;  
        }  
        if (hasWhip()) {  
            condimentCost += whipCost;  
        }  
        return condimentCost;  
    }  
}
```

```
public class DarkRoast extends Beverage {  
  
    public DarkRoast() {  
        description = "Most Excellent Dark Roast";  
    }  
  
    public float cost() {  
        return 1.99 + super.cost();  
    }  
}
```

Decorator: Consequences

▶ Good

- ▶ More Flexibility than static inheritance
 - ▶ Much easier to use than multiple inheritance
 - ▶ Can be used to mix and match features
 - ▶ Can add the same property twice
 - ▶ Allows to easily add new features incrementally

Decorator: Consequences

- ▶ **Bad**
 - ▶ If Decorator is complex, it becomes costly to use in quantity
 - ▶ A decorator and its component aren't identical
 - ▶ From an object identity point of view, a decorated component is not identical to the component itself
 - ▶ Don't rely on object identity when using decorators
 - ▶ Lots of little objects
 - ▶ Often end up with systems composed of lots of little objects
 - ▶ Can be hard to learn and debug

Implementation Issues

- ▶ Several issues should be considered when applying the Decorator pattern:

1. Interface conformance:

A decorator object's interface must conform to the interface of the component it decorates.

2. Omitting the abstract Decorator class:

If only one responsibility is needed, don't define abstract Decorator. Merge Decorator's responsibility into the ConcreteDecorator.

Implementation Issues

3. Keeping Component classes light weight:

The Component class is inherited by components and decorators. Component class should be dedicated to defining an interface, no other functions. E.g. The Component class should not be used for storing data, and defining data. That should be done in subclasses. If the Component class becomes complex, it might make the decorators too heavyweight to use in quantities. Keep it light and simple. A complex Component class might make Decorator too costly to use in quantity.

4. Changing the skin of an object versus its guts:

Decorator classes should act as a layer of skin over an object. If there's a need to change the object's guts, use Strategy pattern.

Decorator

- ▶ **Intent**

- ▶ Attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality.

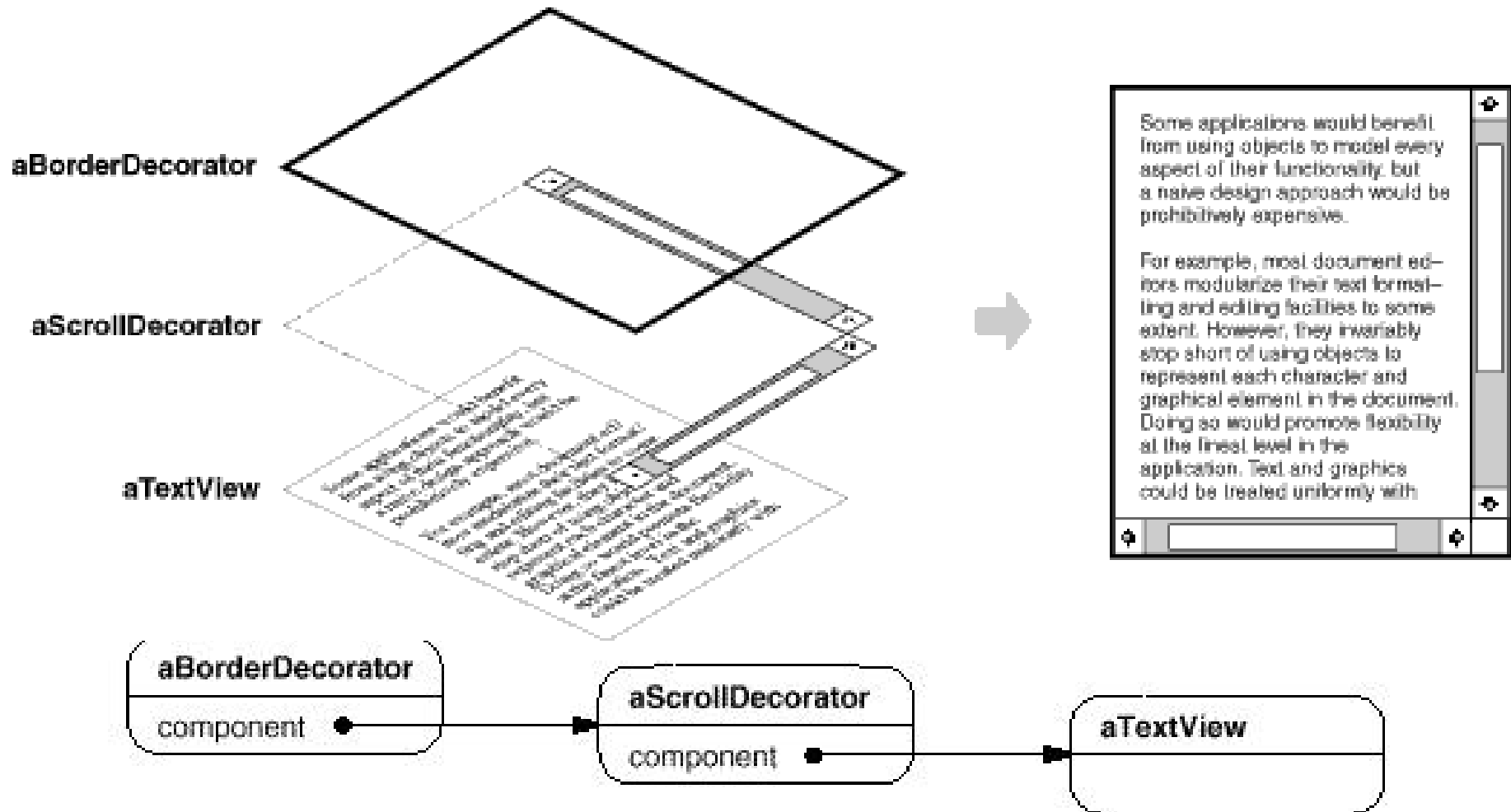
- ▶ **Also Known As**

- ▶ Wrapper

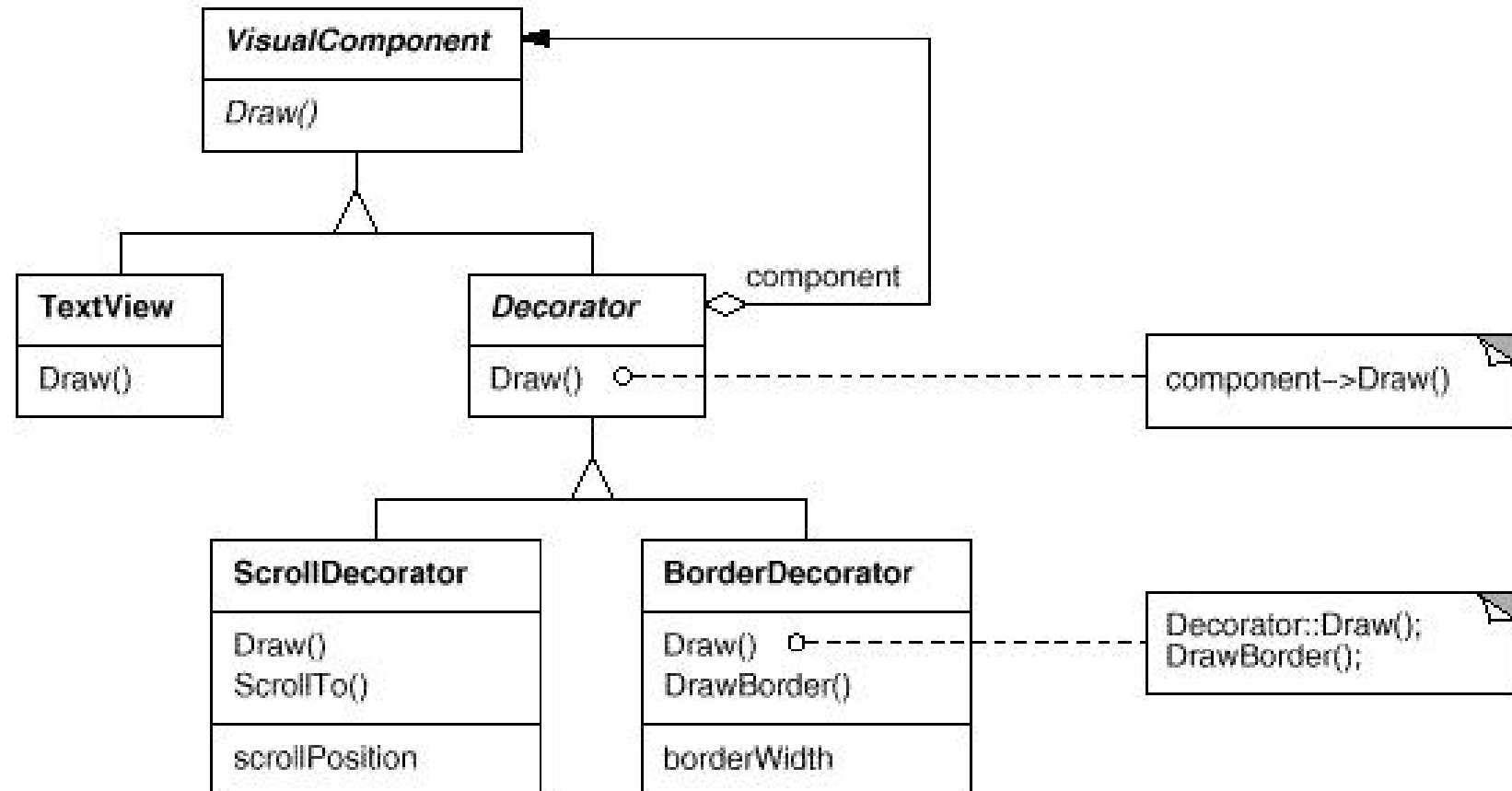
- ▶ **Motivation**

- ▶ We want to add properties, such as borders or scrollbars to a GUI component. We can do this with inheritance (subclassing), but this limits our flexibility. A better way is to use composition!

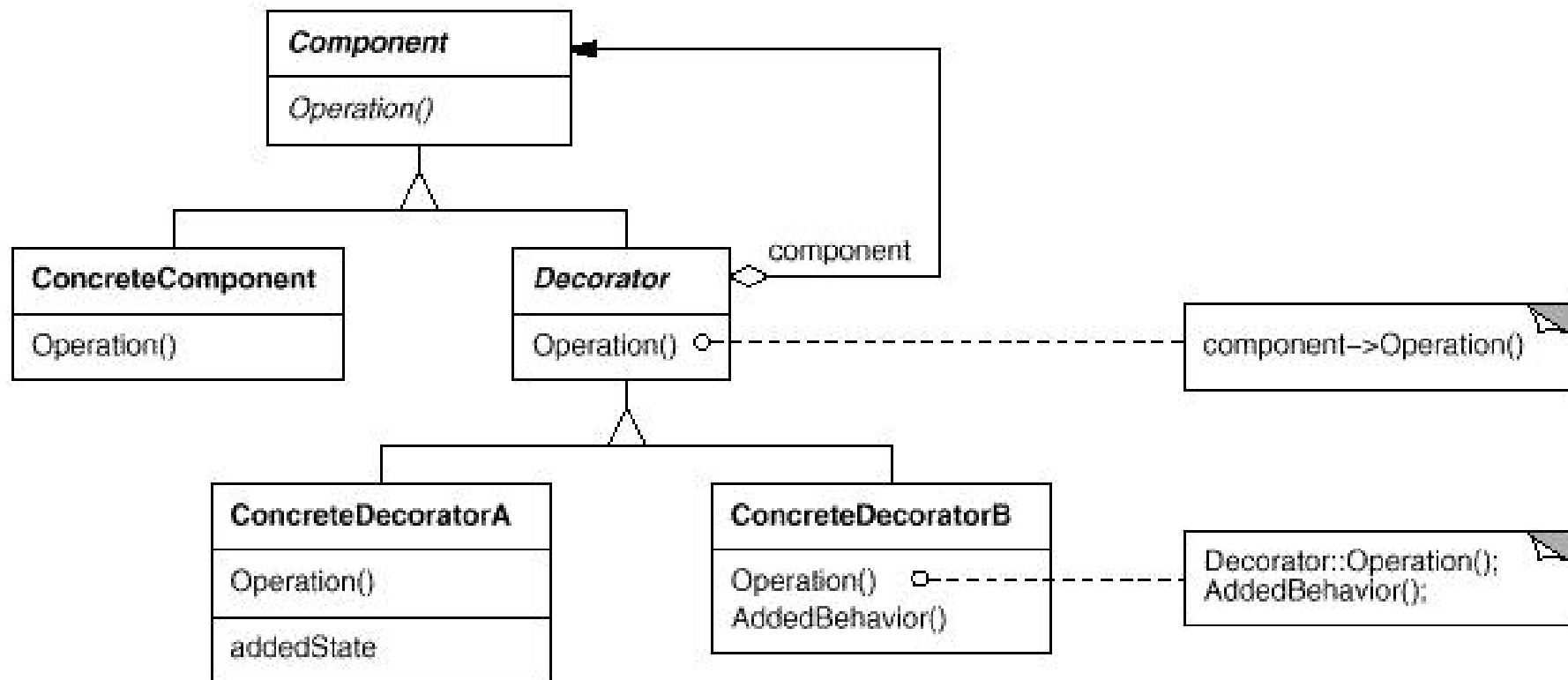
Motivation



Structure: the TextView example



Structure



Decorator in Lexi

- ▶ **Il problema**
 - ▶ Attaccare al glifo altri elementi, quali scrollbar e bordi
 - ▶ Nel contempo si vogliono tenere questi elementi separati, visto che sono necessari o meno a seconda della situazione
- ▶ **La soluzione: applicare Decorator**

Decorator pattern (Wrapper)

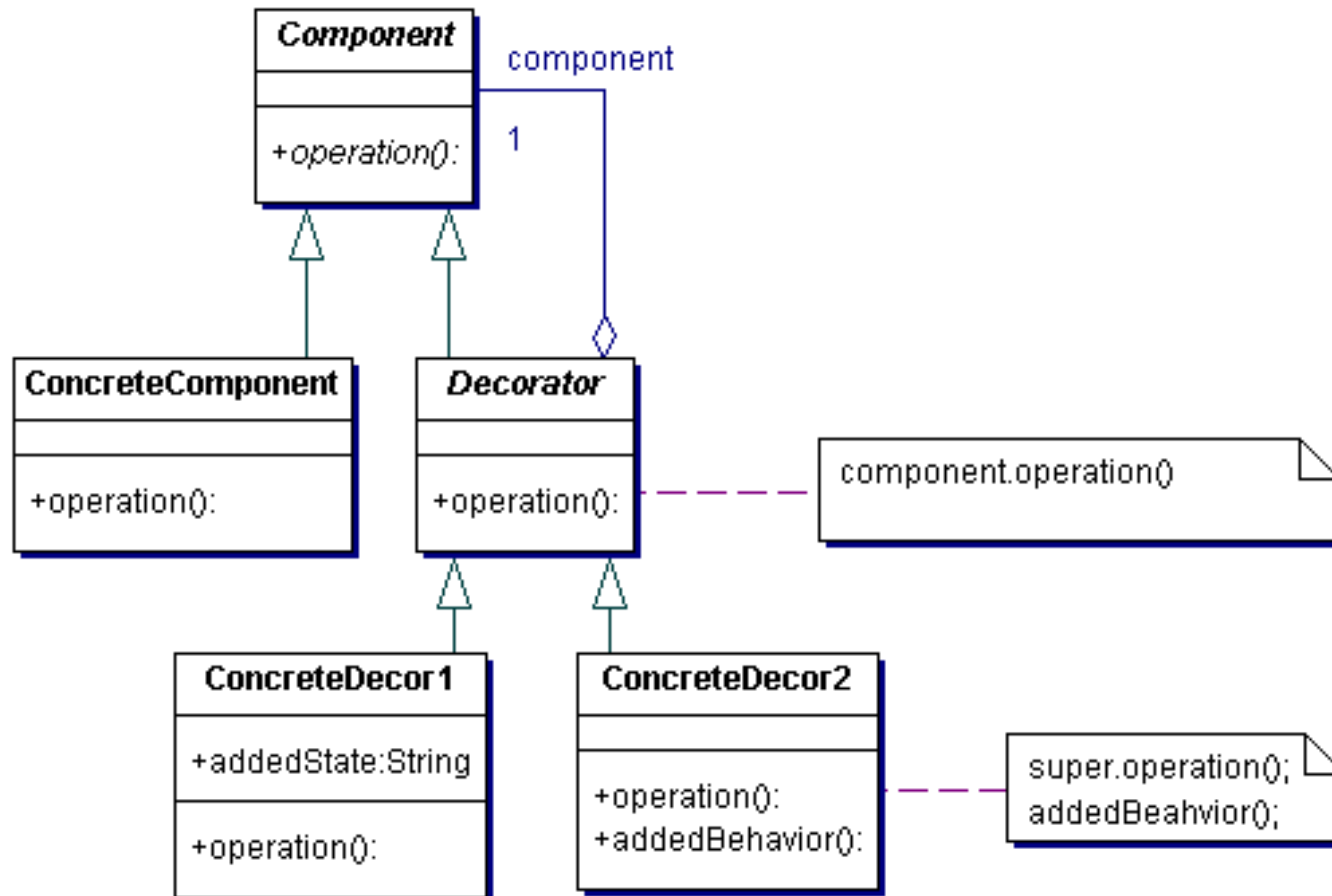
▶ Scopo

- ▶ Aggiungere dinamicamente responsabilità a un oggetto

▶ Motivazioni

- ▶ Spesso può essere necessario aggiungere responsabilità a un oggetto di una classe e magari successivamente toglierle: ad esempio le barre di scorrimento al testo contenuto in una finestra
- ▶ Se si usano le sottoclassi ci può essere un problema di proliferazione, se si vogliono combinare diverse responsabilità: con decorator si aggiunge una classe per ogni responsabilità e si combinano a piacere le responsabilità, dinamicamente

Decorator: struttura



```

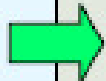
public class AdministrativeManager extends ResponsibleWorker {

    public AdministrativeManager( Employee empl ) {
        super( empl );
    }

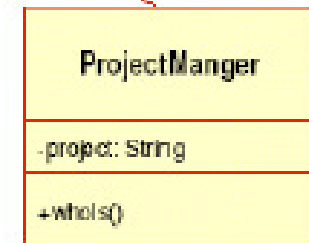
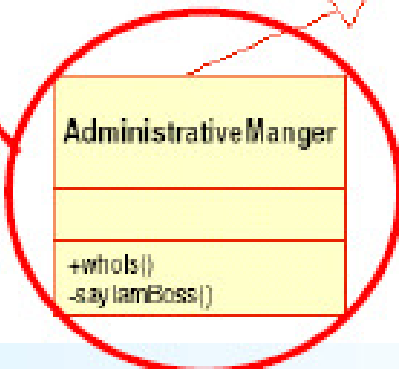
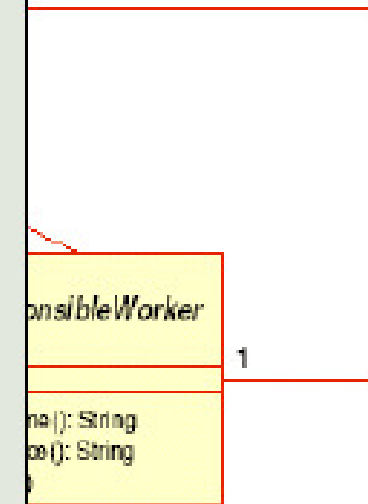
    public void whoIs() {
        sayIamBoss();
        super.whoIs();
    }

    private void sayIamBoss() {
        System.out.print( "I am a boss. " );
    }
}

```



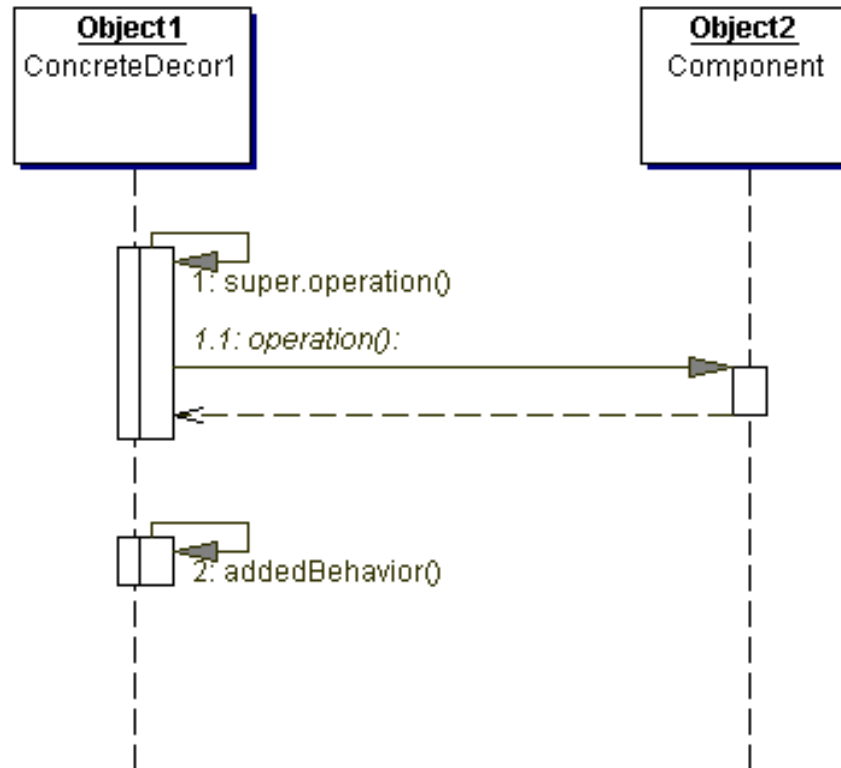
<- Extends



Decorator: partecipanti

- ▶ **Component**
 - ▶ L'interfaccia comune degli oggetti da decorare
- ▶ **ConcreteComponent**
 - ▶ La classe degli oggetti base che possono ricevere nuove responsabilità
- ▶ **Decorator**
 - ▶ Definisce un'interfaccia conforme a quella comune e mantiene un riferimento a un solo oggetto Component (eventualmente già decorato)
- ▶ **ConcreteDecorator**
 - ▶ Definisce una nuova responsabilità

Decorator: collaborazione



Motivation for the Decorator pattern in a little more detail.

- ▶ Suppose we have a `TextView` GUI component and we want to add different kinds of borders and scrollbars to it.
- ▶ Suppose we have three types of borders:
 - ▶ Plain, 3D, Fancy
- ▶ And two types of scrollbars:
 - ▶ Horizontal, Vertical
- ▶ **Solution I: Let's use inheritance first. We'll generate subclasses of `TextView` for all the required cases. We'll need the 15**

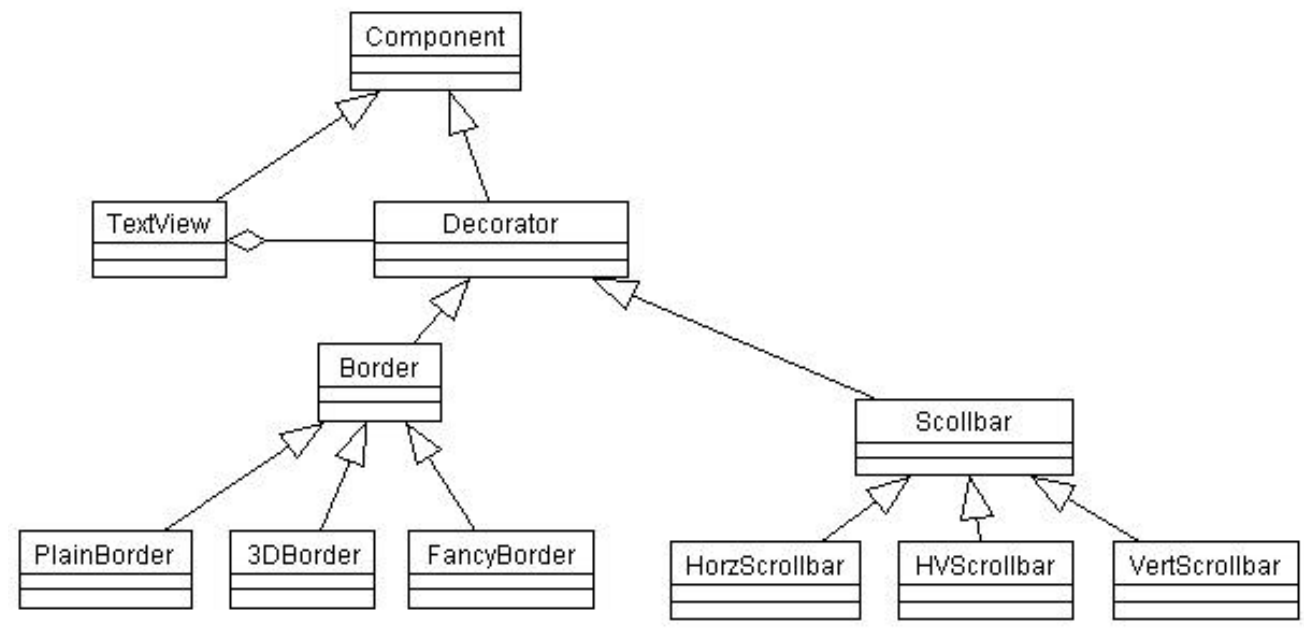
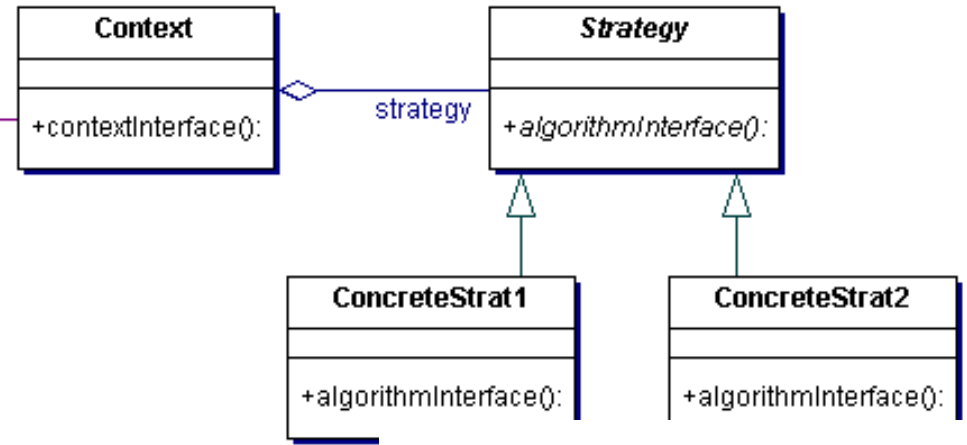
subclasses:

<code>TextView-Plain</code>	<code>TextView-Plain-Horizontal-Vertical</code>
<code>TextView-Fancy</code>	<code>TextView-3D-Horizontal</code>
<code>TextView-3D</code>	<code>TextView-3D-Vertical</code>
<code>TextView-Horizontal</code>	<code>TextView-3D-Horizontal-Vertical</code>
<code>TextView-Vertical</code>	<code>TextView-Fancy-Horizontal</code>
<code>TextView-Horizontal-Vertical</code>	<code>TextView-Fancy-Vertical</code>
<code>TextView-Plain-Horizontal</code>	<code>TextView-Fancy-Horizontal-Vertical</code>
<code>TextView-Plain-Vertical</code>	

Bad solution

- ▶ We already have an explosion of subclasses. What if we add another type of border? Or an entirely different property?
 - ▶ We have to instantiate a specific subclass to get the behavior we want.
- ▶ This choice is made statically and a client can't control how and when to decorate the component.

at some point , strategy.algorithmInterface()



Using Strategy

- ▶ Now the TextView Class looks like this:

```
public class TextView extends Component {
    private Border border;
    private Scrollbar sb;
    public TextView(Border border, Scrollbar sb) {
        this.border = border;
        this.sb = sb;
    }
    public void draw() {
        border.draw();
        sb.draw();
        // Code to draw the TextView object itself.
    }
}
```

Using Strategy: pro and cons

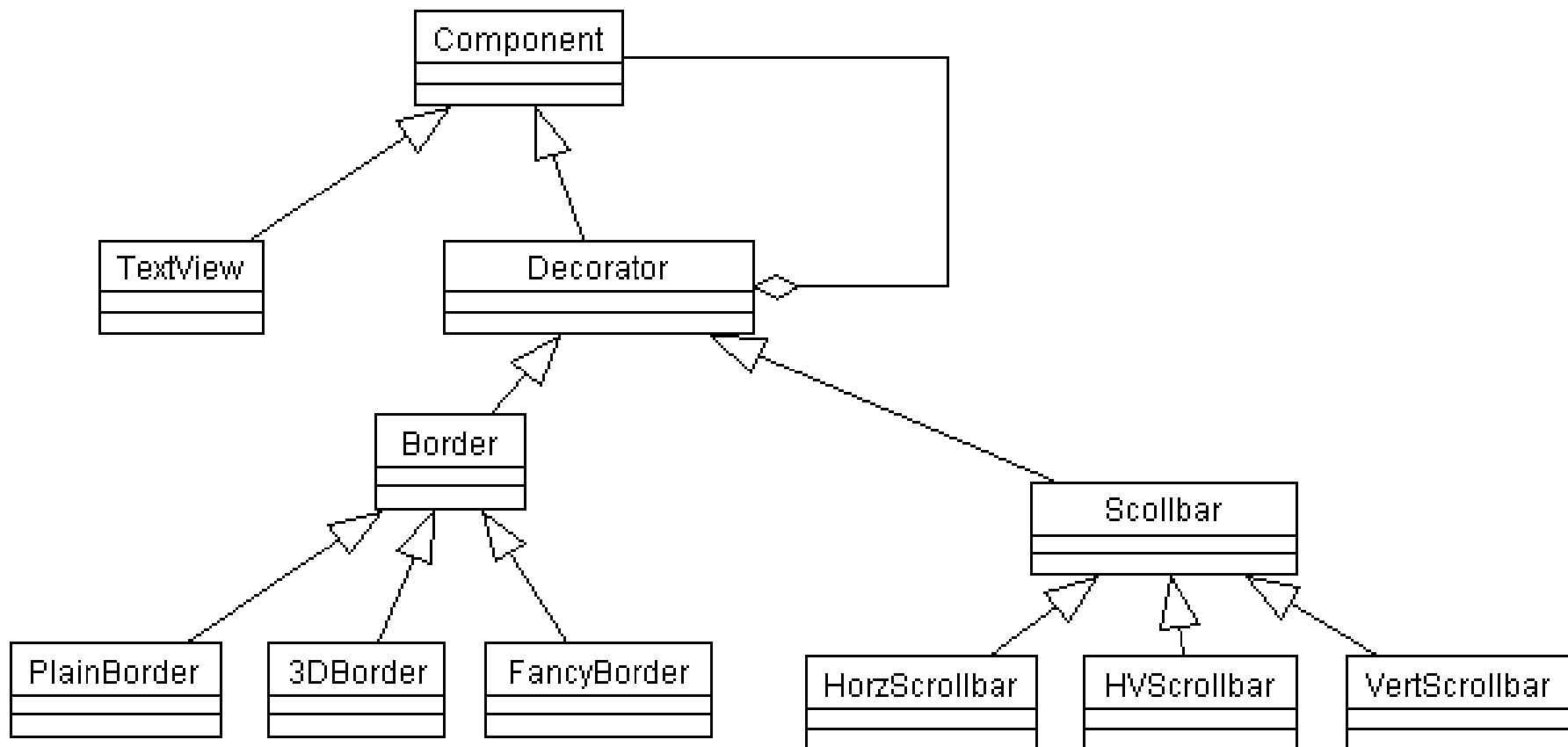
▶ Pro:

- ▶ we can add or change properties to the `TextView` component dynamically. For example, we could have mutators for the border and sb attributes and we could change them at run-time.

▶ Cons:

- ▶ But note that the `TextView` object itself had to be modified and it has knowledge of borders and scrollbars! If we wanted to add another kind of property or behavior, we would have to again modify `TextView`.

Let's turn Strategy inside out to get the Decorator pattern



Implementing the Decorator solution

- ▶ Now the TextView class knows nothing about borders and scrollbars:

```
public class TextView extends Component {  
    public void draw() {  
        // Code to draw the TextView object itself.  
    }  
}
```

Implementing the Decorator solution (cont'd)

- ▶ But the decorators need to know about components:

```
public class FancyBorder extends Decorator {  
    private Component component;  
    public FancyBorder(Component component) {  
        this.component = component;  
    }  
    public void draw() {  
        component.draw();  
        // Code to draw the FancyBorder object itself.  
    }  
}
```

Implementing the Decorator solution (cont'd)

- ▶ Now a client can add borders as follows:

```
public class Client {  
    public static void main(String[] args) {  
        TextView data = new TextView();  
        Component borderData = new FancyBorder(data);  
        Component scrolledData = new VertScrollbar(borderData);  
        Component borderAndScrolledData = new  
            HorzScrollbar(scrolledData);  
    }  
}
```

- ▶ Decorator: Changing the skin of an object
- ▶ Strategy: Changing the guts (viscere) of an object



References

- ▶ [GoF95]: Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides. Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley Professional Computing Series, Addison-Wesley, Reading Mass. 1995.
- ▶ [AGCS]: AG Communication Systems, <http://www.agcs.com/>
- ▶ SDSU & Roger Whitney (2001) CS 635 Advanced Object-Oriented Design & Programming, Decorator, Chain of Responsibility, OO Recursion, San Diego State University, <http://www.eli.sdsu.edu/courses/spring01/cs635/notes/decorator/decorator.html>
- ▶ Bob Tarr, [Computer Science and Electrical Engineering Department, University of Maryland Baltimore County](http://www.research.umbc.edu/~tarr/dp/lectures/Decorator-2pp.pdf), <http://www.research.umbc.edu/~tarr/dp/lectures/Decorator-2pp.pdf>