A very dependent PizzaStore

Sharpen your pencil

Let's pretend you've never heard of an OO factory. Here's a version of the PizzaStore that doesn't use a factory; make a count of the number of concrete pizza objects this class is dependent on. If you added California style pizzas to this PizzaStore, how many objects would it be dependent on then?

```
public class DependentPizzaStore {

    public Pizza createPizza(String style, String type) {
        Pizza pizza = null;
        if (style.equals("NY")) {
            if (type.equals("cheese")) {
                pizza = new NYStyleCheesePizza();
            } else if (type.equals("veggie")) {
                pizza = new NYStyleVeggiePizza();
            } else if (type.equals("clam")) {
                pizza = new NYStyleClamPizza();
            } else if (type.equals("pepperoni")) {
                pizza = new NYStylePepperoniPizza();
            }
        } else if (style.equals("Chicago")) {
            if (type.equals("cheese")) {
                pizza = new ChicagoStyleCheesePizza();
            } else if (type.equals("veggie")) {
                pizza = new ChicagoStyleVeggiePizza();
            } else if (type.equals("clam")) {
                pizza = new ChicagoStyleClamPizza();
            } else if (type.equals("pepperoni")) {
                pizza = new ChicagoStylePepperoniPizza();
            }
        } else {
            System.out.println("Error: invalid type of pizza");
            return null;
        }
        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();
        return pizza;
    }
}
```

Handles all the NY style pizzas

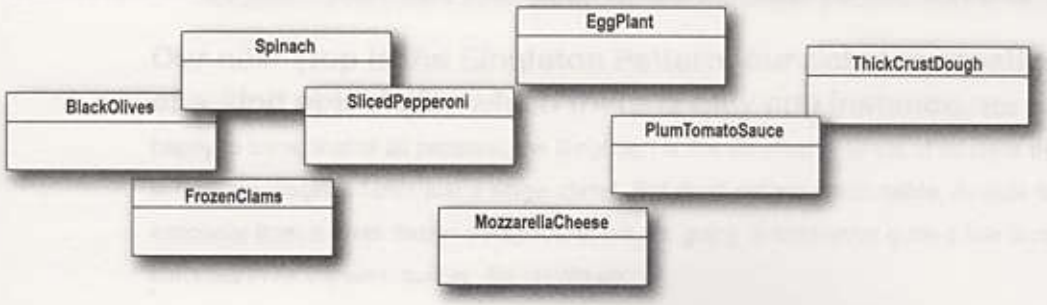
Handles all the Chicago style pizzas

You can write your answers here: 8 number 12 number with California too

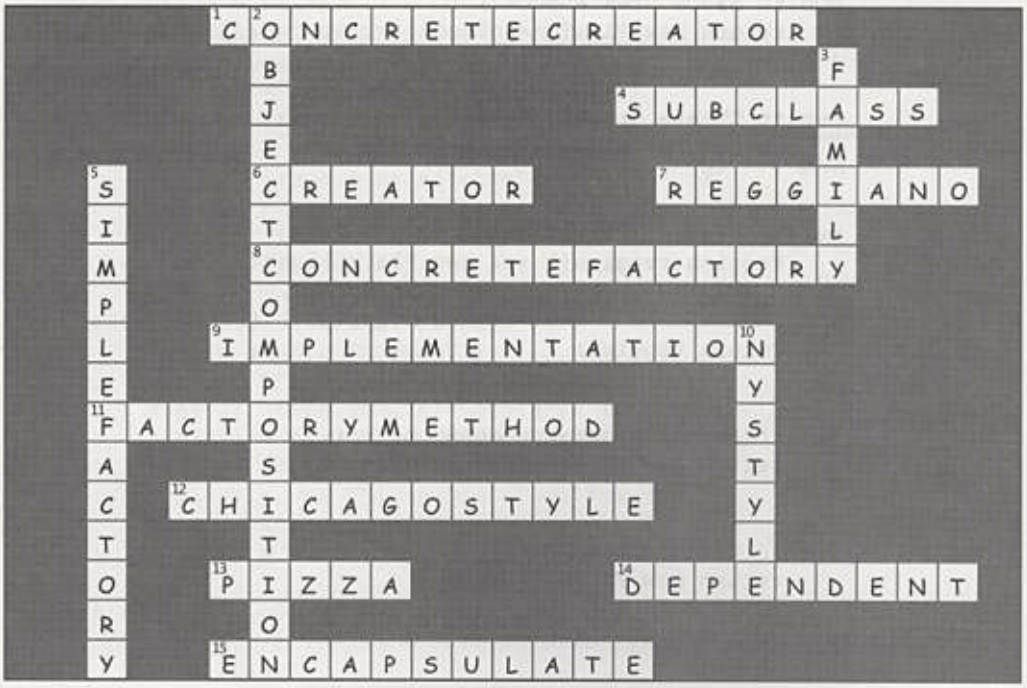
Sharpen your pencil

Go ahead and write the ChicagoPizzaIngredientFactory; you can reference the classes below in your implementation:

```
public class ChicagoPizzaIngredientFactory
    implements PizzaIngredientFactory
{
    public Dough createDough() {
        return new ThickCrustDough();
    }

    public Sauce createSauce() {
        return new PlumTomatoSauce();
    }

    public Cheese createCheese() {
        return new MozzarellaCheese();
    }

    public Veggies[] createVeggies() {
        Veggies veggies[] = { new BlackOlives(),
                              new Spinach(),
                              new Eggplant() };
        return veggies;
    }

    public Pepperoni createPepperoni() {
        return new SlicedPepperoni();
    }

    public Clams createClam() {
        return new FrozenClams();
    }
}
```



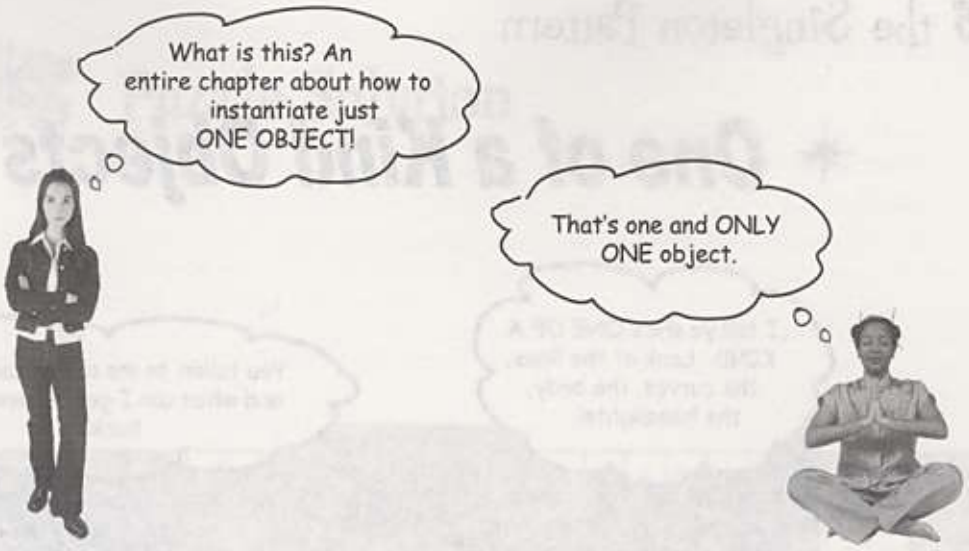
Puzzle Solution



5 the Singleton Pattern

One of a Kind Objects

Our next stop is the Singleton Pattern, our ticket to creating one-of-a-kind objects for which there is only one instance. You might be happy to know that of all patterns, the Singleton is the simplest in terms of its class diagram; in fact, the diagram holds just a single class! But don't get too comfortable; despite its simplicity from a class design perspective, we are going to encounter quite a few bumps and potholes in its implementation. So buckle up.



Developer: What use is that?

Guru: There are many objects we only need one of: thread pools, caches, dialog boxes, objects that handle preferences and registry settings, objects used for logging, and objects that act as device drivers to devices like printers and graphics cards. In fact, for many of these types of objects, if we were to instantiate more than one we'd run into all sorts of problems like incorrect program behavior, overuse of resources, or inconsistent results.

Developer: Okay, so maybe there are classes that should only be instantiated once, but do I need a whole chapter for this? Can't I just do this by convention or by global variables? You know, like in Java, I could do it with a static variable.

Guru: In many ways, the Singleton Pattern **is a convention** for ensuring one and only one object is instantiated for a given class. If you've got a better one, the world would like to hear about it; but remember, like all patterns, the Singleton Pattern is a time-tested method for ensuring only one object gets created. The Singleton Pattern also gives us a global point of access, just like a global variable, but without the downsides.

Developer: What downsides?

Guru: Well, here's one example: if you assign an object to a global variable, then you have to create that object when your application begins*. Right? What if this object is resource intensive and your application never ends up using it? As you will see, with the Singleton Pattern, we can create our objects only when they are needed.

Developer: This still doesn't seem like it should be so difficult.

Guru: If you've got a good handle on static class variables and methods as well as access modifiers, it's not. But, in either case, it is interesting to see how a Singleton works, and, as simple as it sounds, Singleton code is hard to get right. Just ask yourself: how do I prevent more than one object from being instantiated? It's not so obvious, is it?

*This is actually implementation dependent. Some JVM's will create these objects lazily.

The Little Singleton

A small Socratic exercise in the style of The Little Lisper

How would you create a single object?

```
new MyObject();
```

And, what if another object wanted to create a MyObject? Could it call new on MyObject again?

Yes, of course.

So as long as we have a class, can we always instantiate it one or more times?

Yes. Well, only if it's a public class.

And if not?

Well, if it's not a public class, only classes in the same package can instantiate it. But they can still instantiate it more than once.

Hmm, interesting.

Did you know you could do this?

No, I'd never thought of it, but I guess it makes sense because it is a legal definition.

```
public MyClass {

   private MyClass() {}

}
```

What does it mean?

I suppose it is a class that can't be instantiated because it has a private constructor.

Well, is there ANY object that could use the private constructor?

Hmm, I think the code in MyClass is the only code that could call it. But that doesn't make much sense.

Why not ?

Because I'd have to have an instance of the class to call it, but I can't have an instance because no other class can instantiate it. It's a chicken and egg problem: I can use the constructor from an object of type MyClass, but I can never instantiate that object because no other object can use "new MyClass()".

Okay. It was just a thought.

What does this mean?

MyClass is a class with a static method. We can call the static method like this:

```
MyClass.getInstance();
```

```
public MyClass {

    public static MyClass getInstance() {
    }
}
```

Why did you use MyClass, instead of some object name?

Well, getInstance() is a static method; in other words, it is a CLASS method. You need to use the class name to reference a static method.

Very interesting. What if we put things together.

Now can I instantiate a MyClass?

Wow, you sure can.

```
public MyClass {

    private MyClass() {}

    public static MyClass getInstance() {
        return new MyClass();
    }
}
```

So, now can you think of a second way to instantiate an object?

```
MyClass.getInstance();
```

Can you finish the code so that only ONE instance of MyClass is ever created?

Yes, I think so...

(You'll find the code on the next page.)

Dissecting the classic Singleton Pattern implementation

Watch it!

If you're just flipping through the book, don't blindly type in this code, you'll see a it has a few issues later in the chapter.

```
public class Singleton {
    private static Singleton uniqueInstance;

    // other useful instance variables here

    private Singleton() {}

    public static Singleton getInstance() {
        if (uniqueInstance == null) {
            uniqueInstance = new Singleton();
        }
        return uniqueInstance;
    }

    // other useful methods here
}
```

Let's rename MyClass to Singleton.

We have a static variable to hold our one instance of the class Singleton.

Our constructor is declared private; only Singleton can instantiate this class!

The getInstance() method gives us a way to instantiate the class and also to return an instance of it.

Of course, Singleton is a normal class; it has other useful instance variables and methods.

Code Up Close

```
if (uniqueInstance == null) {
    uniqueInstance = new MyClass();
}
return uniqueInstance;
```

uniqueInstance holds our ONE instance; remember, it is a static variable.

If uniqueInstance is null, then we haven't created the instance yet...

...and, if it doesn't exist, we instantiate Singleton through its private constructor and assign it to uniqueInstance. Note that if we never need the instance, it never gets created; this is lazy instantiation.

If uniqueInstance wasn't null, then it was previously created. We just fall through to the return statement.

By the time we hit this code, we have an instance and we return it.

Patterns Exposed

This week's interview:
Confessions of a Singleton

HeadFirst: Today we are pleased to bring you an interview with a Singleton object. Why don't you begin by telling us a bit about yourself.

Singleton: Well, I'm totally unique; there is just one of me!

HeadFirst: One?

Singleton: Yes, one. I'm based on the Singleton Pattern, which assures that at any one time there is only one instance of me.

HeadFirst: Isn't that sort of a waste? Someone took the time to develop a full-blown class and now all we can get is one object out of it?

Singleton: Not at all! There is power in ONE. Let's say you have an object that contains registry settings. You don't want multiple copies of that object and its values running around – that would lead to chaos. By using an object like me you can assure that every object in your application is making use of the same global resource.

HeadFirst: Tell us more…

Singleton: Oh, I'm good for all kinds of things. Being single sometimes has its advantages you know. I'm often used to manage pools of resources, like connection or thread pools.

HeadFirst: Still, only one of your kind? That sounds lonely.

Singleton: Because there's only one of me, I do keep busy, but it would be nice if more developers knew me – many developers run into bugs because they have multiple copies of objects floating around they're not even aware of.

HeadFirst: So, if we may ask, how do you know there is only one of you? Can't anyone with a new operator create a "new you"?

Singleton: Nope! I'm truly unique.

HeadFirst: Well, do developers swear an oath not to instantiate you more than once?

Singleton: Of course not. The truth be told… well, this is getting kind of personal but… I have no public constructor.

HeadFirst: NO PUBLIC CONSTRUCTOR! Oh, sorry, no public constructor?

Singleton: That's right. My constructor is declared private.

HeadFirst: How does that work? How do you EVER get instantiated?

Singleton: You see, to get a hold of a Singleton object, you don't instantiate one, you just ask for an instance. So my class has a static method called getInstance(). Call that, and I'll show up at once, ready to work. In fact, I may already be helping other objects when you request me.

HeadFirst: Well, Mr. Singleton, there seems to be a lot under your covers to make all this work. Thanks for revealing yourself and we hope to speak with you again soon!

The Chocolate Factory

Everyone knows that all modern chocolate factories have computer controlled chocolate boilers. The job of the boiler is to take in chocolate and milk, bring them to a boil, and then pass them on to the next phase of making chocolate bars.

Here's the controller class for Choc-O-Holic, Inc.'s industrial strength Chocolate Boiler. Check out the code; you'll notice they've tried to be very careful to ensure that bad things don't happen, like draining 500 gallons of unboiled mixture, or filling the boiler when it's already full, or boiling an empty boiler!

```
public class ChocolateBoiler {
    private boolean empty;
    private boolean boiled;

    public  ChocolateBoiler() {
        empty = true;
        boiled = false;
    }

    public void fill() {
        if (isEmpty()) {
            empty = false;
            boiled = false;
            // fill the boiler with a milk/chocolate mixture
        }
    }

    public void drain() {
        if (!isEmpty() && isBoiled()) {
            // drain the boiled milk and chocolate
            empty = true;
        }
    }

    public void boil() {
        if (!isEmpty() && !isBoiled()) {
            // bring the contents to a boil
            boiled = true;
        }
    }

    public boolean isEmpty() {
        return empty;
    }

    public boolean isBoiled() {
        return boiled;
    }
}
```

This code is only started when the boiler is empty!

To fill the boiler it must be empty, and, once it's full, we set the empty and boiled flags.

To drain the boiler, it must be full (non empty) and also boiled. Once it is drained we set empty back to true.

To boil the mixture, the boiler has to be full and not already boiled. Once it's boiled we set the boiled flag to true.

Choc-O-Holic has done a decent job of ensuring bad things don't happen, don't ya think? Then again, you probably suspect that if two ChocolateBoiler instances get loose, some very bad things can happen.

How might things go wrong if more than one instance of ChocolateBoiler is created in an application?

Can you help Choc-O-Holic improve their ChocolateBoiler class by turning it into a singleton?

```
public class ChocolateBoiler {
    private boolean empty;
    private boolean boiled;

    [                                        ]

    [          ] ChocolateBoiler() {
        empty = true;
        boiled = false;
    }

    [                                        ]
    [                                        ]
    [                                        ]

    public void fill() {
        if (isEmpty()) {
            empty = false;
            boiled = false;
            // fill the boiler with a milk/chocolate mixture
        }
    }
    // rest of ChocolateBoiler code...
}
```

Singleton Pattern defined

Now that you've got the classic implementation of Singleton in your head, it's time to sit back, enjoy a bar of chocolate, and check out the finer points of the Singleton Pattern.

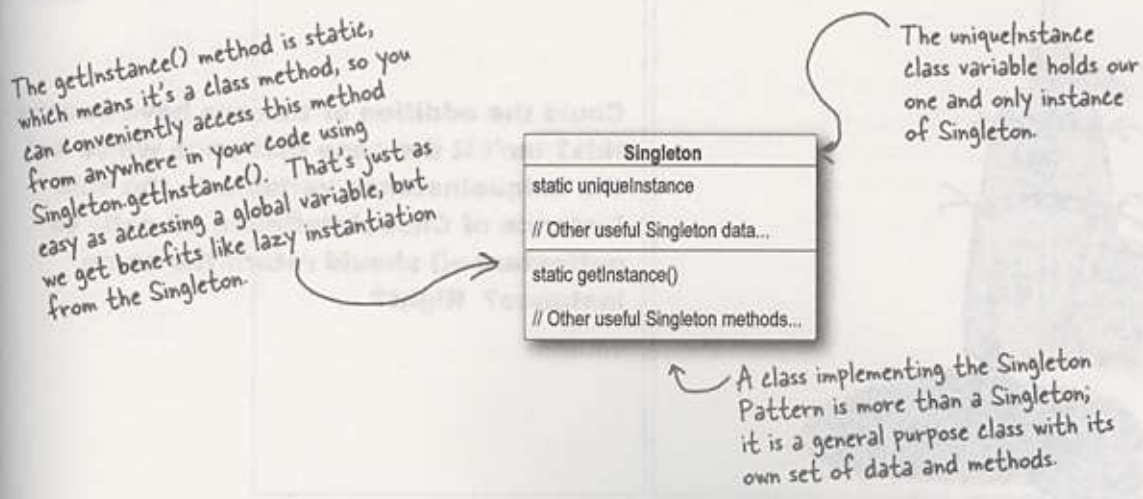
Let's start with the concise definition of the pattern:

> **The Singleton Pattern** ensures a class has only one instance, and provides a global point of access to it.

No big surprises there. But, let's break it down a bit more:

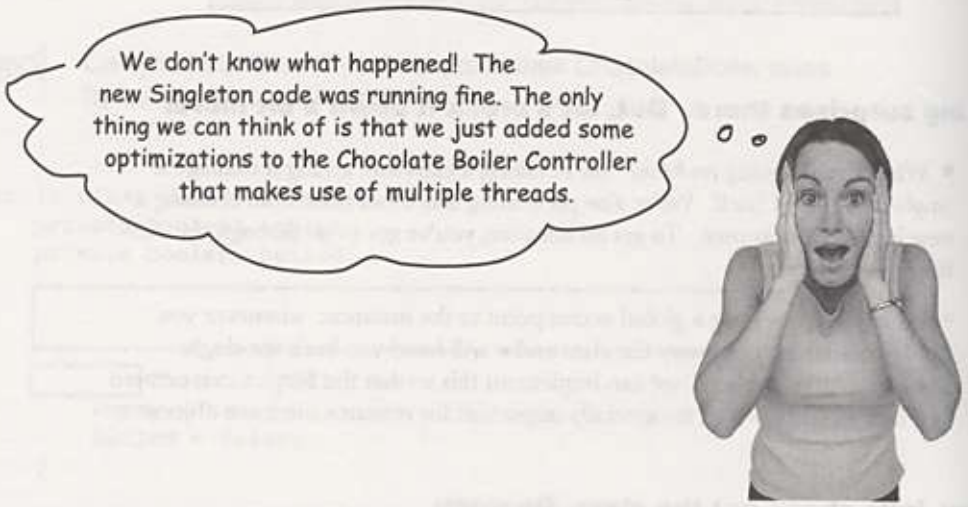
- What's really going on here? We're taking a class and letting it manage a single instance of itself. We're also preventing any other class from creating a new instance on its own. To get an instance, you've got to go through the class itself.
- We're also providing a global access point to the instance: whenever you need an instance, just query the class and it will hand you back the single instance. As you've seen, we can implement this so that the Singleton is created in a lazy manner, which is especially important for resource intensive objects.

Okay, let's check out the class diagram:



Hershey, PA ~~Houston,~~ we have a problem...

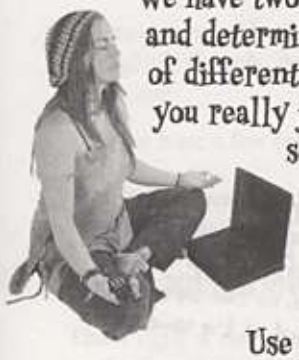
It looks like the Chocolate Boiler has let us down; despite the fact we improved the code using Classic Singleton, somehow the ChocolateBoiler's fill() method was able to start filling the boiler even though a batch of milk and chocolate was already boiling! That's 500 gallons of spilled milk (and chocolate)! What happened!?



Could the addition of threads have caused this? Isn't it the case that once we've set the uniqueInstance variable to the sole instance of ChocolateBoiler, all calls to getInstance() should return the same instance? Right?

BE the JVM

We have two threads, each executing this code. Your job is to play the JVM and determine whether there is a case in which two threads might get ahold of different boiler objects. Hint: you really just need to look at the sequence of operations in the getInstance() method and the value of uniqueInstance to see how they might overlap. Use the code Magnets to help you study how the code might interleave to create two boiler objects.



```
ChocolateBoiler boiler =
        ChocolateBoiler.getInstance();
fill();
boil();
drain();
```

```
public static ChocolateBoiler
    getInstance() {
  if (uniqueInstance == null) {
    uniqueInstance =
        new ChocolateBoiler();
  }
  return uniqueInstance;
}
```

Make sure you check your answer on page 188 before turning the page!

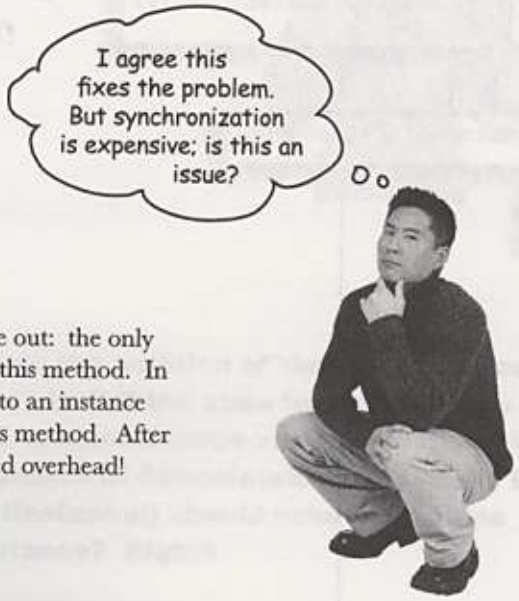
Thread One	Thread Two	Value of uniqueInstance

Dealing with multithreading

Our multithreading woes are almost trivially fixed by making getInstance() a synchronized method:

```
public class Singleton {
    private static Singleton uniqueInstance;

    // other useful instance variables here

    private Singleton() {}

    public static synchronized Singleton getInstance() {
        if (uniqueInstance == null) {
            uniqueInstance = new Singleton();
        }
        return uniqueInstance;
    }

    // other useful methods here
}
```

By adding the synchronized keyword to getInstance(), we force every thread to wait its turn before it can enter the method. That is, no two threads may enter the method at the same time.



Good point, and it's actually a little worse than you make out: the only time synchronization is relevant is the first time through this method. In other words, once we've set the uniqueInstance variable to an instance of Singleton, we have no further need to synchronize this method. After the first time through, synchronization is totally unneeded overhead!

Can we improve multithreading?

For most Java applications, we obviously need to ensure that the Singleton works in the presence of multiple threads. But, it looks fairly expensive to synchronize the getInstance() method, so what do we do?

Well, we have a few options...

1. Do nothing if the performance of getInstance() isn't critical to your application

That's right; if calling the getInstance() method isn't causing substantial overhead for your application, forget about it. Synchronizing getInstance() is straightforward and effective. Just keep in mind that synchronizing a method can decrease performance by a factor of 100, so if a high traffic part of your code begins using getInstance(), you may have to reconsider.

2. Move to an eagerly created instance rather than a lazily created one

If your application always creates and uses an instance of the Singleton or the overhead of creation and runtime aspects of the Singleton are not onerous, you may want to create your Singleton eagerly, like this:

```
public class Singleton {
    private static Singleton uniqueInstance = new Singleton();

    private Singleton() {}

    public static Singleton getInstance() {
        return uniqueInstance;
    }
}
```

Go ahead and create an instance of Singleton in a static initializer. This code is guaranteed to be thread safe!

We've already got an instance, so just return it.

Using this approach, we rely on the JVM to create the unique instance of the Singleton when the class is loaded. The JVM guarantees that the instance will be created before any thread accesses the static uniqueInstance variable.

3. Use "double-checked locking" to reduce the use of synchronization in getInstance()

With double-checked locking, we first check to see if an instance is created, and if not, THEN we synchronize. This way, we only synchronize the first time through, just what we want.

Let's check out the code:

```
public class Singleton {
    private volatile* static Singleton uniqueInstance;

    private Singleton() {}

    public static Singleton getInstance() {
        if (uniqueInstance == null) {
            synchronized (Singleton.class) {
                if (uniqueInstance == null) {
                    uniqueInstance = new Singleton();
                }
            }
        }
        return uniqueInstance;
    }
}
```

Check for an instance and if there isn't one, enter a synchronized block.

Note we only synchronize the first time through!

Once in the block, check again and if still null, create an instance.

* The volatile keyword ensures that multiple threads handle the uniqueInstance variable correctly when it is being initialized to the Singleton instance.

If performance is an issue in your use of the getInstance() method then this method of implementing the Singleton can drastically reduce the overhead.

Watch it!

Double-checked locking doesn't work in Java 1.4 or earlier!

Unfortunately, in Java version 1.4 and earlier, many JVMs contain implementations of the volatile keyword that allow improper synchronization for double-checked locking. If you must use a JVM other than Java 5, consider other methods of implementing your Singleton.

Meanwhile, back at the Chocolate Factory...

While we've been off diagnosing the multithreading problems, the chocolate boiler has been cleaned up and is ready to go. But first, we have to fix the multithreading problems. We have a few solutions at hand, each with different tradeoffs, so which solution are we going to employ?

Sharpen your pencil

For each solution, describe its applicability to the problem of fixing the Chocolate Boiler code:

Synchronize the getInstance() method:

_____

_____

Use eager instantiation:

_____

_____

Double-checked locking:

_____

_____

Congratulations!

At this point, the Chocolate Factory is a happy customer and Choc-O-Holic was glad to have some expertise applied to their boiler code. No matter which multithreading solution you applied, the boiler should be in good shape with no more mishaps. Congratulations. You've not only managed to escape 500lbs of hot chocolate in this chapter, but you've been through all the potential problems of the Singleton.

there are no Dumb Questions

Q: For such a simple pattern consisting of only one class, Singletons sure seem to have some problems.

A: Well, we warned you up front! But don't let the problems discourage you; while implementing Singletons *correctly* can be tricky, after reading this chapter you are now well informed on the techniques for creating Singletons and should use them wherever you need to control the number of instances you are creating.

Q: Can't I just create a class in which all methods and variables are defined as static? Wouldn't that be the same as a Singleton?

A: Yes, if your class is self-contained and doesn't depend on complex initialization. However, because of the way static initializations are handled in Java, this can get very messy, especially if multiple classes are involved. Often this scenario can result in subtle, hard to find bugs involving order of initialization. Unless there is a compelling need to implement your "singleton" this way, it is far better to stay in the object world.

Q: What about class loaders? I heard there is a chance that two class loaders could each end up with their own instance of Singleton.

A: Yes, that is true as each class loader defines a namespace. If you have two or more classloaders, you can load the same class multiple times (once in each classloader). Now, if that class happens to be a Singleton, then since we have more than one version of the class, we also have more than one instance of the Singleton. So, if you are using multiple classloaders and Singletons, be careful. One way around this problem is to specify the classloader yourself.

Rumors of Singletons being eaten by the garbage collectors are greatly exaggerated

Prior to Java 1.2, a bug in the garbage collector allowed Singletons to be prematurely collected if there was no global reference to them. In other words, you could create a Singleton and if the only reference to the Singleton was in the Singleton itself, it would be collected and destroyed by the garbage collector. This leads to confusing bugs because after the Singleton is "collected," the next call to getInstance() produced a shiny new Singleton. In many applications, this can cause confusing behavior as state is mysteriously reset to initial values or things like network connections are reset.

Since Java 1.2 this bug has been fixed and a global reference is no longer required. If you are, for some reason, still using a pre-Java 1.2 JVM, then be aware of this issue, otherwise, you can sleep well knowing your Singletons won't be prematurely collected.

Q: I've always been taught that a class should do one thing and one thing only. For a class to do two things is considered bad OO design. Isn't a Singleton violating this?

A: You would be referring to the "One Class, One Responsibility" principle, and yes, you are correct, the Singleton is not only responsible for managing its one instance (and providing global access), it is also responsible for whatever its main role is in your application. So, certainly it can be argued it is taking on two responsibilities. Nevertheless, it isn't hard to see that there is utility in a class managing its own instance; it certainly makes the overall design simpler. In addition, many developers are familiar with the Singleton pattern as it is in wide use. That said, some developers do feel the need to abstract out the Singleton functionality.

Q: I wanted to subclass my Singleton code, but I ran into problems. Is it okay to subclass a Singleton?

A: One problem with subclassing Singleton is that the constructor is private. You can't extend a class with a private constructor. So, the first thing you'll have to do is change your constructor so that it's public or protected. But then, it's not *really* a Singleton anymore, because other classes can instantiate it.

If you do change your constructor, there's another issue. The implementation of Singleton is based on a static variable, so if you do a straightforward subclass, all of your derived classes will share the same instance variable. This is probably not what you had in mind. So, for subclassing to work, implementing registry of sorts is required in the base class.

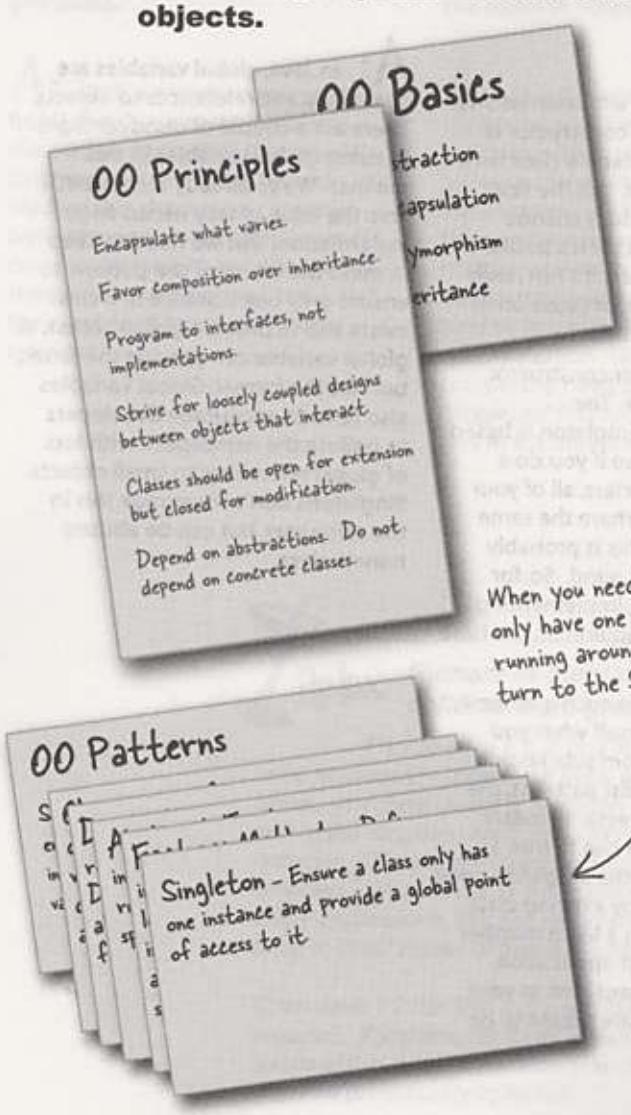
Before implementing such a scheme, you should ask yourself what you are really gaining from subclassing a Singleton. Like most patterns, the Singleton is not necessarily meant to be a solution that can fit into a library. In addition, the Singleton code is trivial to add to any existing class. Last, if you are using a large number of Singletons in your application, you should take a hard look at your design. Singletons are meant to be used sparingly.

Q: I still don't totally understand why global variables are worse than a Singleton.

A: In Java, global variables are basically static references to objects. There are a couple of disadvantages to using global variables in this manner. We've already mentioned one: the issue of lazy versus eager instantiation. But we need to keep in mind the intent of the pattern: to ensure only one instance of a class exists and to provide global access. A global variable can provide the latter, but not the former. Global variables also tend to encourage developers to pollute the namespace with lots of global references to small objects. Singletons don't encourage this in the same way, but can be abused nonetheless.

Tools for your Design Toolbox

You've now added another pattern to your toolbox. Singleton gives you another method of creating objects – in this case, unique objects.

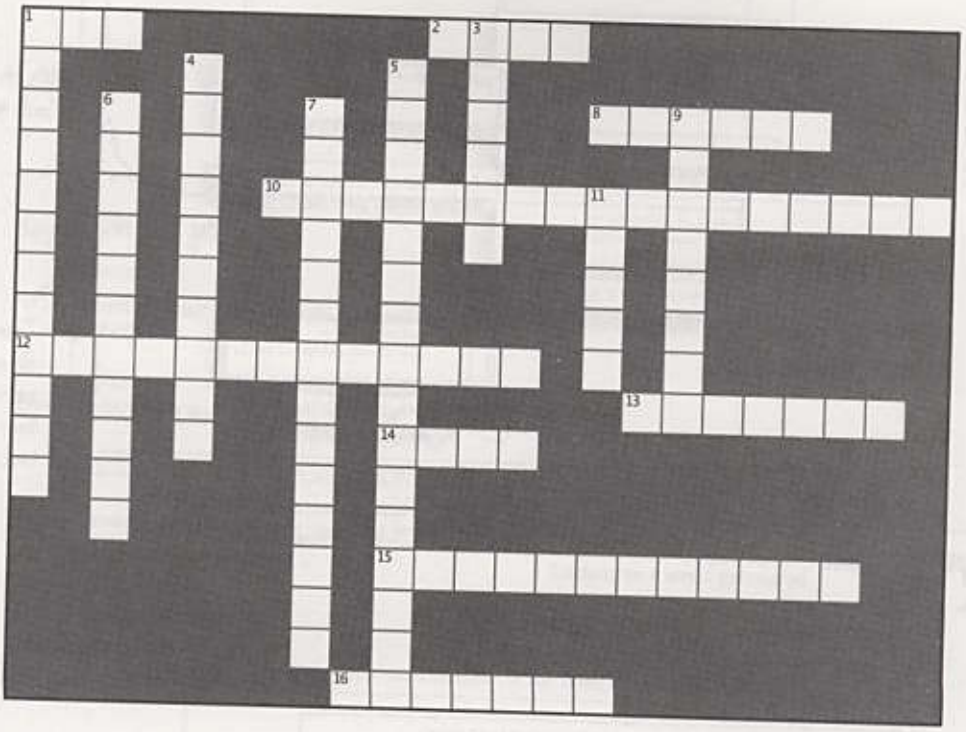


BULLET POINTS

- The Singleton Pattern ensures you have at most one instance of a class in your application.
- The Singleton Pattern also provides a global access point to that instance.
- Java's implementation of the Singleton Pattern makes use of a private constructor, a static method combined with a static variable.
- Examine your performance and resource constraints and carefully choose an appropriate Singleton implementation for multithreaded applications (and we should consider all applications multithreaded!).
- Beware of the double-checked locking implementation; it is not thread-safe in versions before Java 2, version 5.
- Be careful if you are using multiple class loaders; this could defeat the Singleton implementation and result in multiple instances.
- If you are using a JVM earlier than 1.2, you'll need to create a registry of Singletons to defeat the garbage collector.

As you've seen, despite its apparent simplicity, there are a lot of details involved in the Singleton's implementation. After reading this chapter, though, you are ready to go out and use Singleton in the wild.

Sit back, open that case of chocolate that you were sent for solving the multithreading problem, and have some downtime working on this little crossword puzzle; all of the solution words are from this chapter.



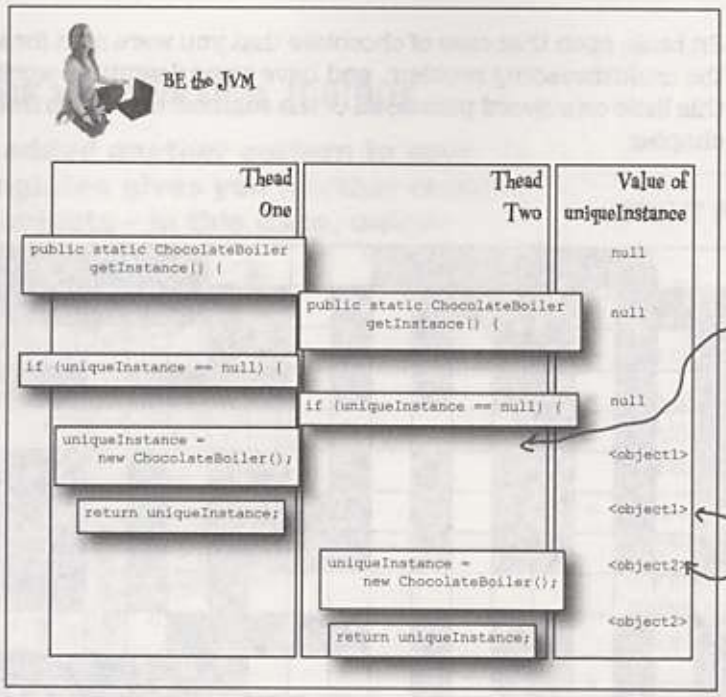
Across

1. It was "one of a kind"
2. Added to chocolate in the boiler
8. An incorrect implementation caused this to overflow
10. Singleton provides a single instance and (three words)
12. Flawed multithreading approach if not using Java 1.5
13. Chocolate capital of the US
14. One advantage over global variables: _____ creation
15. Company that produces boilers
16. To totally defeat the new constructor, we have to declare the constructor _____

Down

1. Multiple _____ can cause problems
3. A Singleton is a class that manages an instance of _____
4. If you don't need to worry about lazy instantiation, you can create your instance _____
5. Prior to 1.2, this can eat your Singletons (two words)
6. The Singleton was embarassed it had no public _____
7. The classic implementation doesn't handle this
9. Singleton ensures only one of these exist
11. The Singleton Pattern has one

Exercise solutions



Sharpen your pencil Can you help Choc-O-Holic improve their ChocolateBoiler class by turning it into a singleton?

```
public class ChocolateBoiler {
    private boolean empty;
    private boolean boiled;

    private static ChocolateBoiler uniqueInstance;

    private ChocolateBoiler() {
        empty = true;
        boiled = false;
    }

    public static ChocolateBoiler getInstance() {
        if (uniqueInstance == null) {
            uniqueInstance = new ChocolateBoiler();
        }
        return uniqueInstance;
    }

    public void fill() {
        if (isEmpty()) {
            empty = false;
            boiled = false;
            // fill the boiler with a milk/chocolate mixture
        }
    }
    // rest of ChocolateBoiler code...
}
```

Exercise solutions

Sharpen your pencil

For each solution, describe its applicability to the problem of fixing the Chocolate Boiler code:

Synchronize the getInstance() method:

A straightforward technique that is guaranteed to work. We don't seem to have any performance concerns with the chocolate boiler, so this would be a good choice.

Use eager instantiation:

We are always going to instantiate the chocolate boiler in our code, so statically inializing the instance would cause no concerns. This solution would work as well as the synchronized method, although perhaps be less obvious to a developer familar with the standard pattern.

Double checked locking:

Given we have no performance concerns, double-checked locking seems like overkill. In addition, we'd have to ensure that we are running at least Java 5.

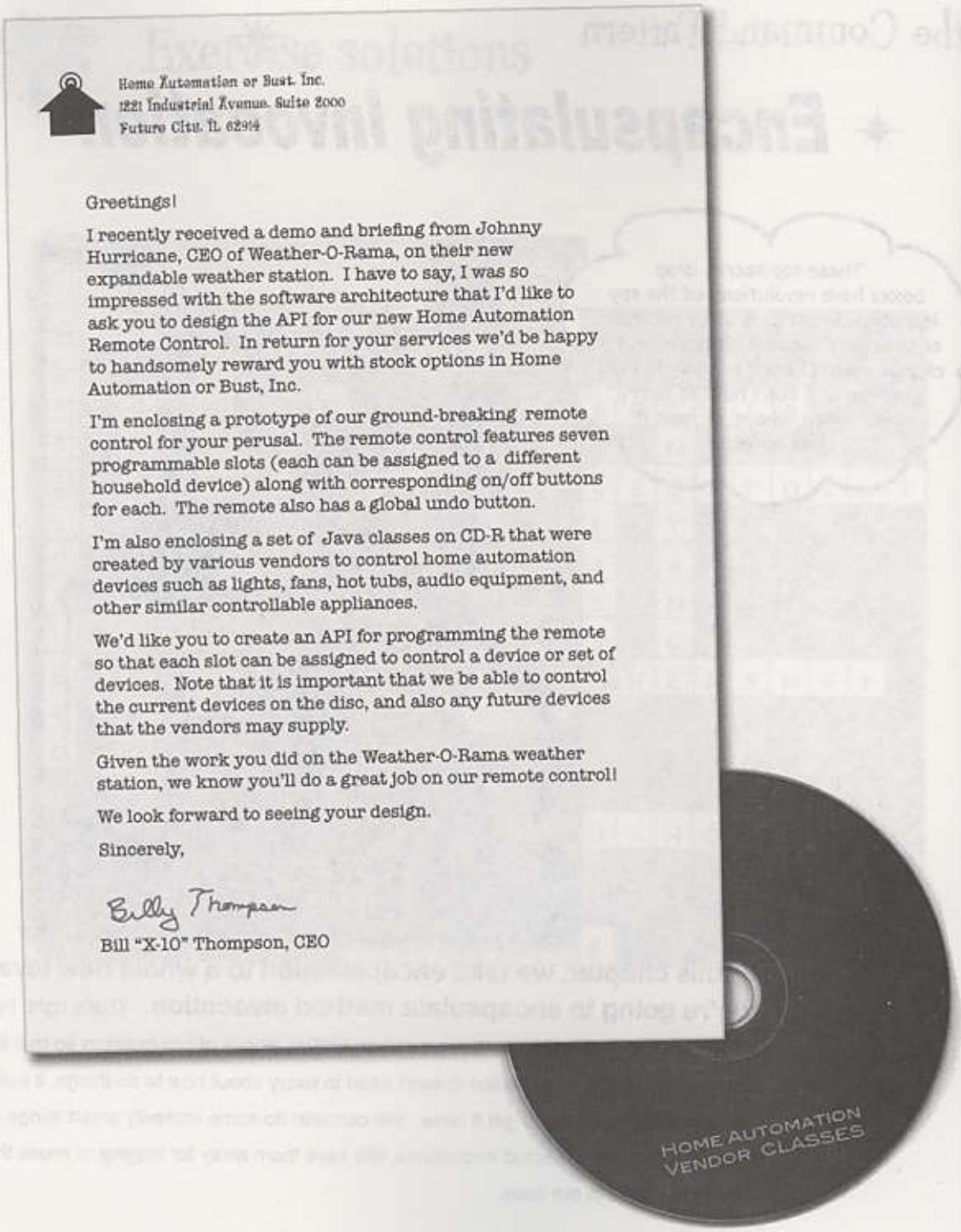
Exercise solutions

1 C	A	R							2 M	3 I	L	K							
L				4 S					5 G	T									
A		6 C		T		7 M			A	S			8 B	O	9 I	L	E	R	
S		O		A		U			R	E					N				
S		N		T	10 G	L	O	B	A	L	A	C	11 C	E	S	S	P	O	I	N	T
L		S		I		T		A		F			L		T				
O		T		C		I		G					A		A				
A		R		A		T		E					S		N				
12 D	O	U	B	L	E	C	H	E	C	K	E	D	S		C				
E		C		L		R		O						13 H	E	R	S	H	E	Y
R		T		Y		E		14 L	A	Z	Y								
S		O				A		L											
		R				D		E											
						I		15 C	H	O	C	-	O	-	H	O	L	I	C
						N		T											
						G		O											
							16 P	R	I	V	A	T	E						

6 the Command Pattern

Encapsulating Invocation

In this chapter, we take encapsulation to a whole new level: we're going to encapsulate method invocation. That's right, by encapsulating method invocation, we can crystallize pieces of computation so that the object invoking the computation doesn't need to worry about how to do things, it just uses our crystallized method to get it done. We can also do some wickedly smart things with these encapsulated method invocations, like save them away for logging or reuse them to implement undo in our code.



Home Automation or Bust, Inc.
1221 Industrial Avenue, Suite 2000
Future City, IL 62994

Greetings!

I recently received a demo and briefing from Johnny Hurricane, CEO of Weather-O-Rama, on their new expandable weather station. I have to say, I was so impressed with the software architecture that I'd like to ask you to design the API for our new Home Automation Remote Control. In return for your services we'd be happy to handsomely reward you with stock options in Home Automation or Bust, Inc.

I'm enclosing a prototype of our ground-breaking remote control for your perusal. The remote control features seven programmable slots (each can be assigned to a different household device) along with corresponding on/off buttons for each. The remote also has a global undo button.

I'm also enclosing a set of Java classes on CD-R that were created by various vendors to control home automation devices such as lights, fans, hot tubs, audio equipment, and other similar controllable appliances.

We'd like you to create an API for programming the remote so that each slot can be assigned to control a device or set of devices. Note that it is important that we be able to control the current devices on the disc, and also any future devices that the vendors may supply.

Given the work you did on the Weather-O-Rama weather station, we know you'll do a great job on our remote control!

We look forward to seeing your design.

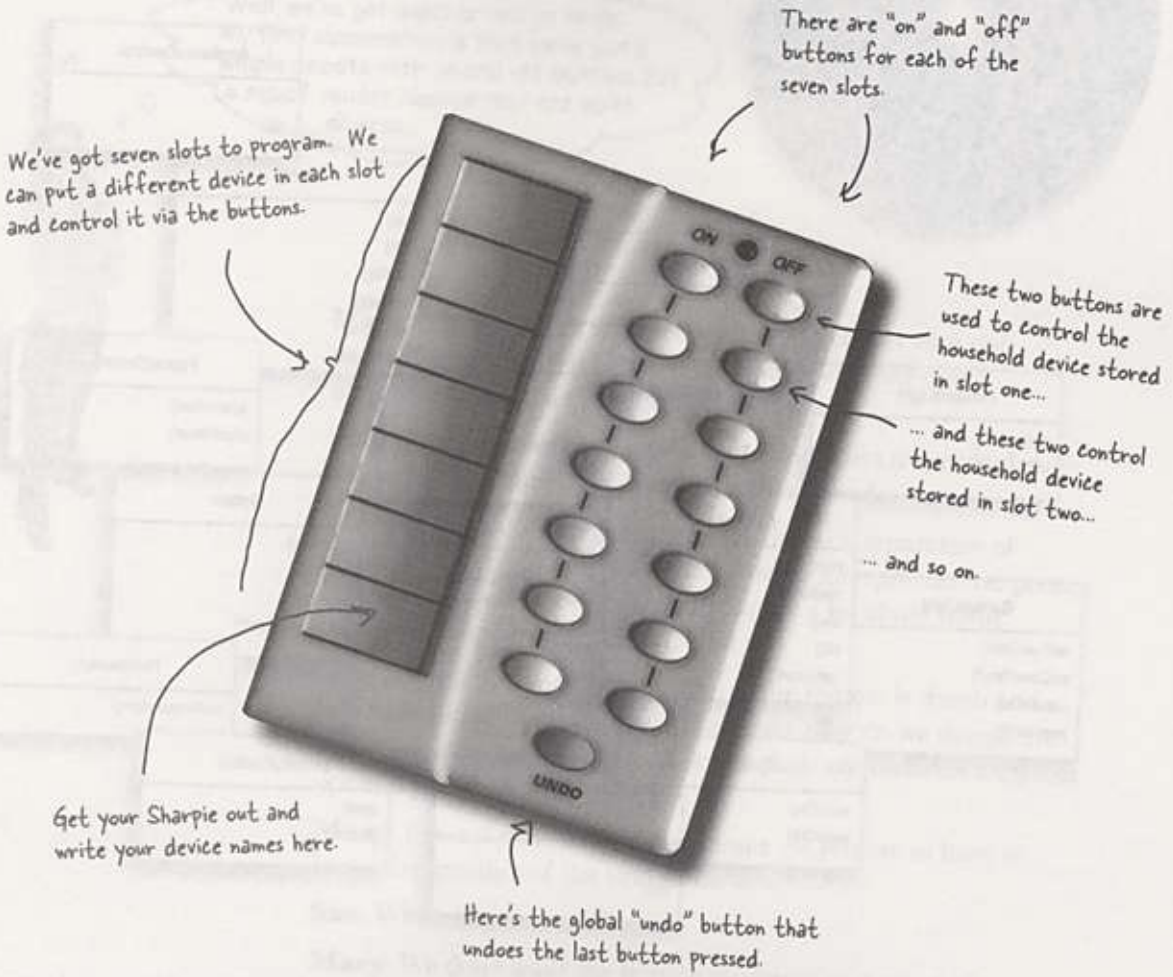
Sincerely,

Billy Thompson

Bill "X-10" Thompson, CEO

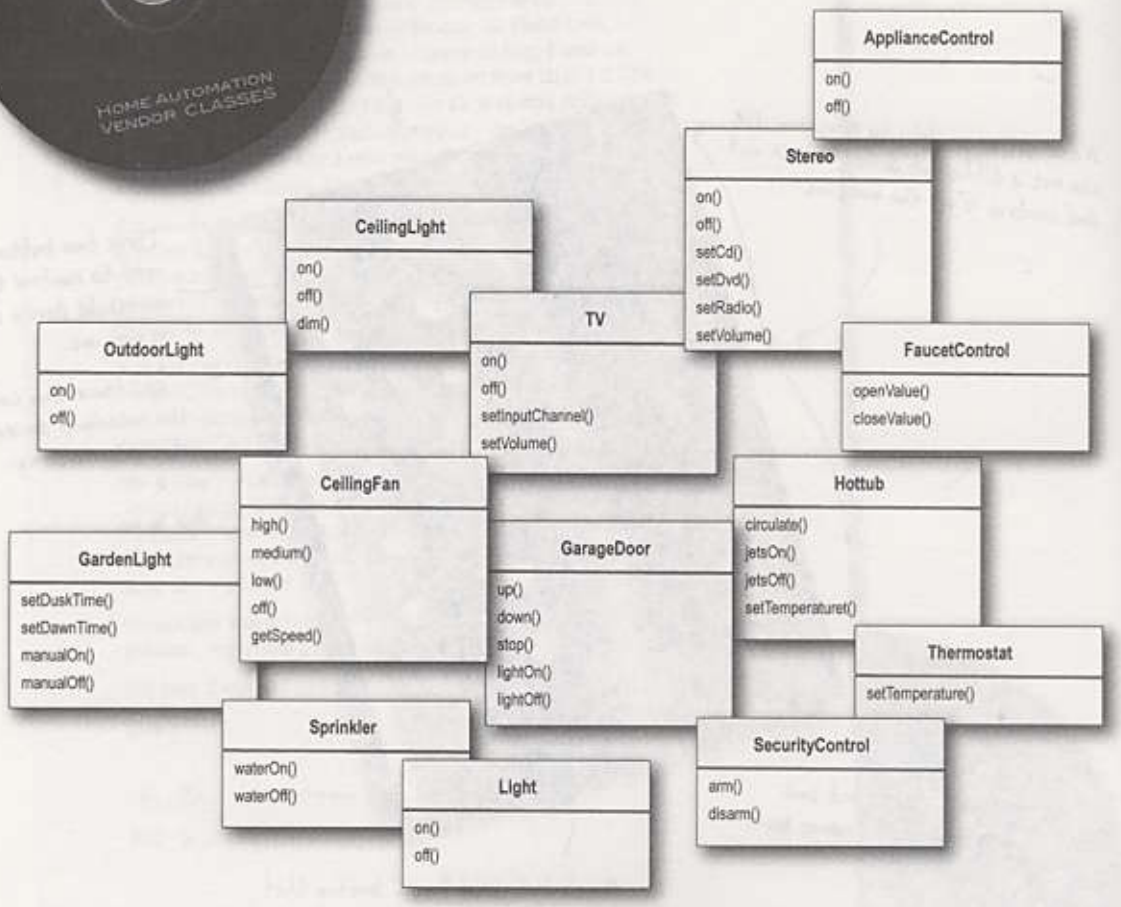
HOME AUTOMATION
VENDOR CLASSES

Free hardware! Let's check out the Remote Control...



Taking a look at the vendor classes

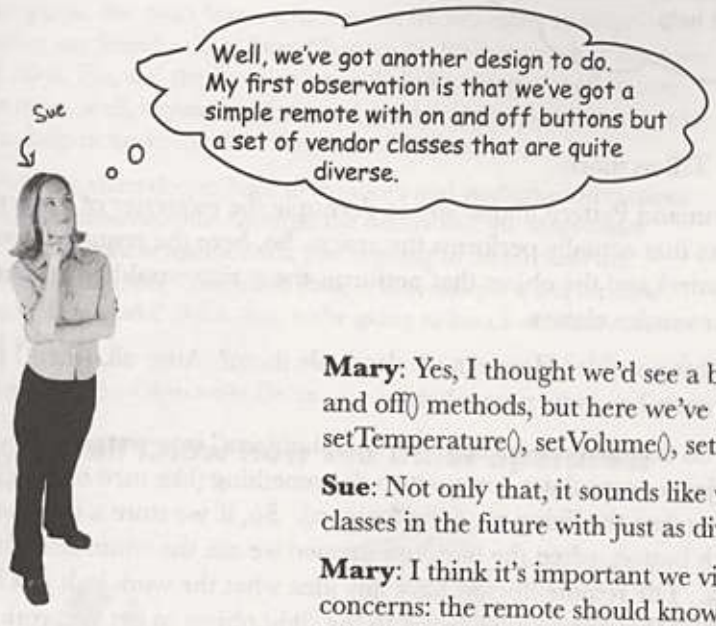
Check out the vendor classes on the CD-R. These should give you some idea of the interfaces of the objects we need to control from the remote.



It looks like we have quite a set of classes here, and not a lot of industry effort to come up with a set of common interfaces. Not only that, it sounds like we can expect more of these classes in the future. Designing a remote control API is going to be interesting. Let's get on to the design.

Cubicle Conversation

Your teammates are already discussing how to design the remote control API...



Mary: Yes, I thought we'd see a bunch of classes with on() and off() methods, but here we've got methods like dim(), setTemperature(), setVolume(), setDirection().

Sue: Not only that, it sounds like we can expect more vendor classes in the future with just as diverse methods.

Mary: I think it's important we view this as a separation of concerns: the remote should know how to interpret button presses and make requests, but it shouldn't know a lot about home automation or how to turn on a hot tub.

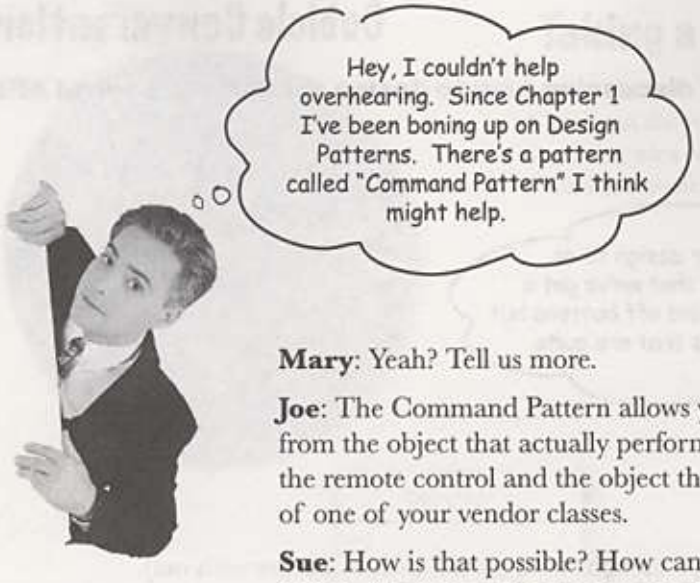
Sue: Sounds like good design. But if the remote is dumb and just knows how to make generic requests, how do we design the remote so that it can invoke an action that, say, turns on a light or opens a garage door?

Mary: I'm not sure, but we don't want the remote to have to know the specifics of the vendor classes.

Sue: What do you mean?

Mary: We don't want the remote to consist of a set of if statements, like "if slot1 == Light, then light.on(), else if slot1 = Hottub then hottub.jetsOn()". We know that is a bad design.

Sue: I agree. Whenever a new vendor class comes out, we'd have to go in and modify the code, potentially creating bugs and more work for ourselves!



Mary: Yeah? Tell us more.

Joe: The Command Pattern allows you to decouple the requester of an action from the object that actually performs the action. So, here the requester would be the remote control and the object that performs the action would be an instance of one of your vendor classes.

Sue: How is that possible? How can we decouple them? After all, when I press a button, the remote has to turn on a light.

Joe: You can do that by introducing "command objects" into your design. A command object encapsulates a request to do something (like turn on a light) on a specific object (say, the living room light object). So, if we store a command object for each button, when the button is pressed we ask the command object to do some work. The remote doesn't have any idea what the work is, it just has a command object that knows how to talk to the right object to get the work done. So, you see, the remote is decoupled from the light object!

Sue: This certainly sounds like it's going in the right direction.

Mary: Still, I'm having a hard time wrapping my head around the pattern.

Joe: Given that the objects are so decoupled, it's a little difficult to picture how the pattern actually works.

Mary: Let me see if I at least have the right idea: using this pattern we, could create an API in which these command objects can be loaded into button slots, allowing the remote code to stay very simple. And, the command objects encapsulate how to do a home automation task along with the object that needs to do it.

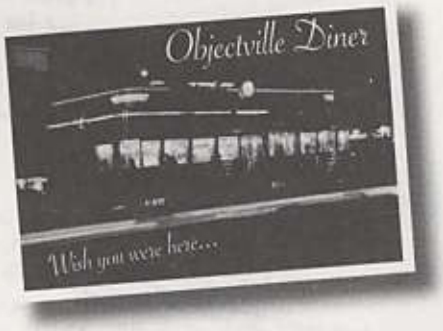
Joe: Yes, I think so. I also think this pattern can help you with that Undo button, but I haven't studied that part yet.

Mary: This sounds really encouraging, but I think I have a bit of work to do to really "get" the pattern.

Sue: Me too.

Meanwhile, back at the Diner..., or, A brief introduction to the Command Pattern

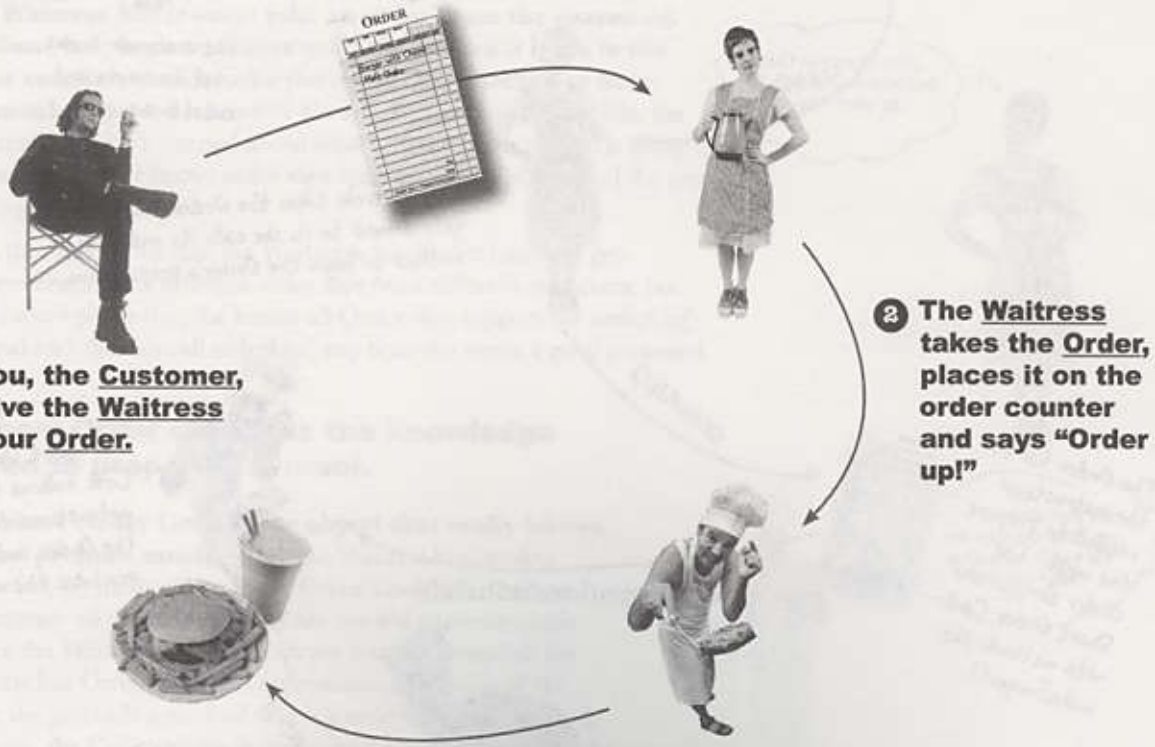
As Joe said, it is a little hard to understand the Command Pattern by just hearing its description. But don't fear, we have some friends ready to help: remember our friendly diner from Chapter 1? It's been a while since we visited Alice, Flo, and the short-order cook, but we've got good reason for returning (well, beyond the food and great conversation): the diner is going to help us understand the Command Pattern.



So, let's take a short detour back to the diner and study the interactions between the customers, the waitress, the orders and the short-order cook. Through these interactions, you're going to understand the objects involved in the Command Pattern and also get a feel for how the decoupling works. After that, we're going to knock out that remote control API.

Checking in at the Objectville Diner...

Okay, we all know how the Diner operates:



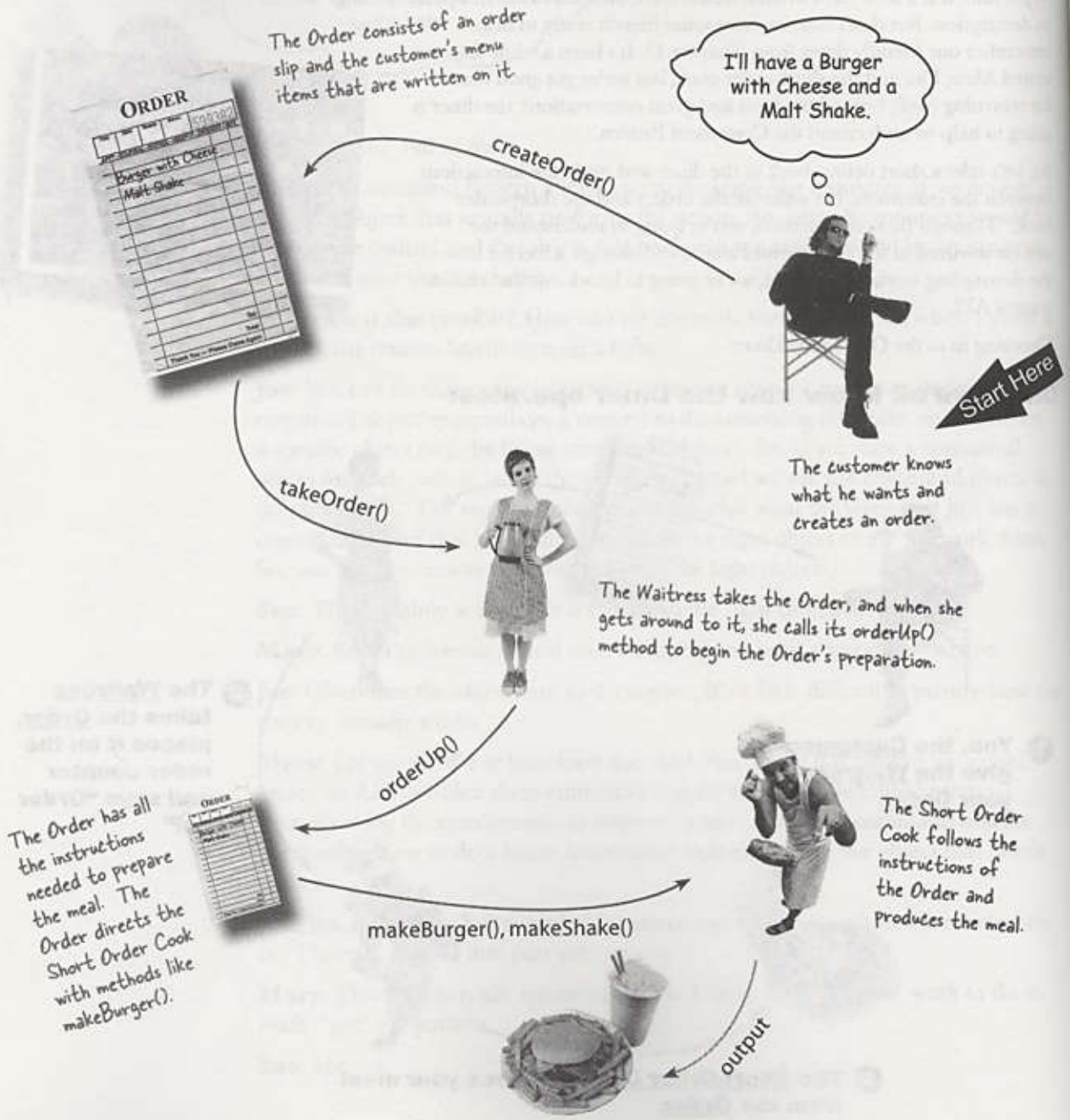
1 You, the Customer, give the Waitress your Order.

2 The Waitress takes the Order, places it on the order counter and says "Order up!"

3 The Short-Order Cook prepares your meal from the Order.

Let's study the interaction in a little more detail...

...and given this Diner is in Objectville, let's think about the object and method calls involved, too!



The Objectville Diner roles and responsibilities

An Order Slip encapsulates a request to prepare a meal.

Think of the Order Slip as an object, an object that acts as a request to prepare a meal. Like any object, it can be passed around – from the Waitress to the order counter, or to the next Waitress taking over her shift. It has an interface that consists of only one method, orderUp(), that encapsulates the actions needed to prepare the meal. It also has a reference to the object that needs to prepare it (in our case, the Cook). It's encapsulated in that the Waitress doesn't have to know what's in the order or even who prepares the meal; she only needs to pass the slip through the order window and call "Order up!"

Okay, in real life a waitress would probably care what is on the Order Slip and who cooks it, but this is Objectville... work with us here!

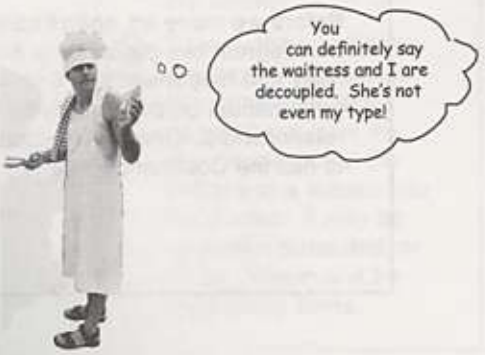
The Waitress's job is to take Order Slips and invoke the orderUp() method on them.

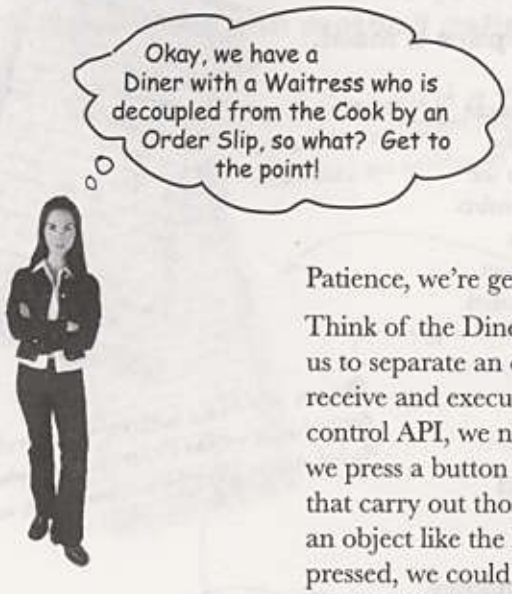
The Waitress has it easy: take an order from the customer, continue helping customers until she makes it back to the order counter, then invoke the orderUp() method to have the meal prepared. As we've already discussed, in Objectville, the Waitress really isn't worried about what's on the order or who is going to prepare it; she just knows order slips have an orderUp() method she can call to get the job done.

Now, throughout the day, the Waitress's takeOrder() method gets parameterized with different order slips from different customers, but that doesn't phase her; she knows all Order slips support the orderUp() method and she can call orderUp() any time she needs a meal prepared.

The Short Order Cook has the knowledge required to prepare the meal.

The Short Order Cook is the object that really knows how to prepare meals. Once the Waitress has invoked the orderUp() method; the Short Order Cook takes over and implements all the methods that are needed to create meals. Notice the Waitress and the Cook are totally decoupled: the Waitress has Order Slips that encapsulate the details of the meal; she just calls a method on each order to get it prepared. Likewise, the Cook gets his instructions from the Order Slip; he never needs to directly communicate with the Waitress.



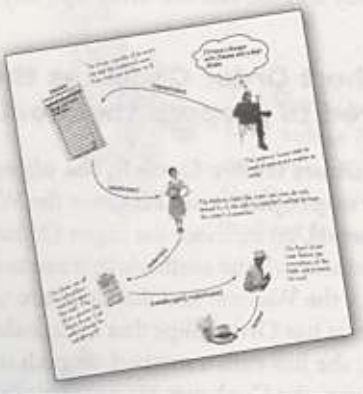


Patience, we're getting there...

Think of the Diner as a model for an OO design pattern that allows us to separate an object making a request from the objects that receive and execute those requests. For instance, in our remote control API, we need to separate the code that gets invoked when we press a button from the objects of the vendor-specific classes that carry out those requests. What if each slot of the remote held an object like the Diner's order slip object? Then, when a button is pressed, we could just call the equivalent of the "orderUp()" method on this object and have the lights turn on without the remote knowing the details of how to make those things happen or what objects are making them happen.

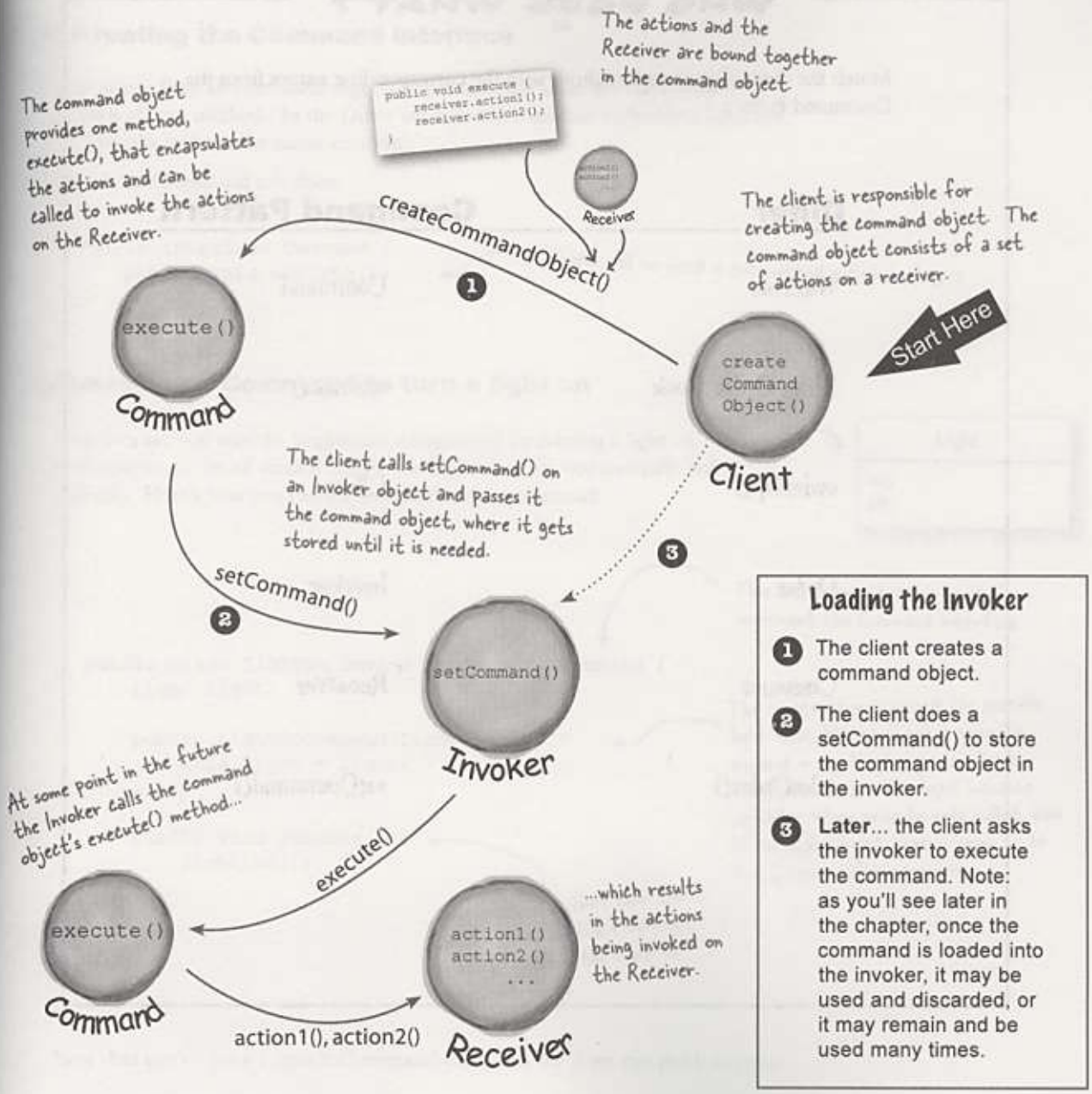
Now, let's switch gears a bit and map all this Diner talk to the Command Pattern...

Before we move on, spend some time studying the diagram two pages back along with Diner roles and responsibilities until you think you've got a handle on the Objectville Diner objects and relationships. Once you've done that, get ready to nail the Command Pattern!



From the Diner to the Command Pattern

Okay, we've spent enough time in the Objectville Diner that we know all the personalities and their responsibilities quite well. Now we're going rework the Diner diagram to reflect the Command Pattern. You'll see that all the players are the same; only the names have changed.



Loading the Invoker

1. The client creates a command object.
2. The client does a setCommand() to store the command object in the invoker.
3. **Later**... the client asks the invoker to execute the command. Note: as you'll see later in the chapter, once the command is loaded into the invoker, it may be used and discarded, or it may remain and be used many times.

WHO DOES WHAT?

Match the diner objects and methods with the corresponding names from the Command Pattern.

Diner	Command Pattern
Waitress	Command
Short Order Cook	execute()
orderUp()	Client
Order	Invoker
Customer	Receiver
takeOrder()	setCommand()

Our first command object

Isn't it about time we build our first command object? Let's go ahead and write some code for the remote control. While we haven't figured out how to design the remote control API yet, building a few things from the bottom up may help us...

Implementing the Command interface

First things first: all command objects implement the same interface, which consists of one method. In the Diner we called this method orderUp(); however, we typically just use the name execute().

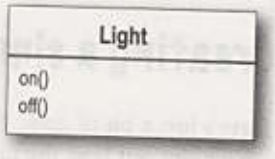
Here's the Command interface:

```
public interface Command {
    public void execute();
}
```

Simple. All we need is one method called execute().

Implementing a Command to turn a light on

Now, let's say you want to implement a command for turning a light on. Referring to our set of vendor classes, the Light class has two methods: on() and off(). Here's how you can implement this as a command:



This is a command, so we need to implement the Command interface.

```
public class LightOnCommand implements Command {
    Light light;

    public LightOnCommand(Light light) {
        this.light = light;
    }

    public void execute() {
        light.on();
    }
}
```

The constructor is passed the specific light that this command is going to control – say the living room light – and stashes it in the light instance variable. When execute gets called, this is the light object that is going to be the Receiver of the request.

The execute method calls the on() method on the receiving object, which is the light we are controlling.

Now that you've got a LightOnCommand class, let's see if we can put it to use...

Using the command object

Okay, let's make things simple: say we've got a remote control with only one button and corresponding slot to hold a device to control:

```
public class SimpleRemoteControl {
    Command slot;

    public SimpleRemoteControl() {}

    public void setCommand(Command command) {
        slot = command;
    }

    public void buttonWasPressed() {
        slot.execute();
    }
}
```

We have one slot to hold our command, which will control one device.

We have a method for setting the command the slot is going to control. This could be called multiple times if the client of this code wanted to change the behavior of the remote button.

This method is called when the button is pressed. All we do is take the current command bound to the slot and call its execute() method.

Creating a simple test to use the Remote Control

Here's just a bit of code to test out the simple remote control. Let's take a look and we'll point out how the pieces match the Command Pattern diagram:

```
public class RemoteControlTest {
    public static void main(String[] args) {
        SimpleRemoteControl remote = new SimpleRemoteControl();
        Light light = new Light();
        LightOnCommand lightOn = new LightOnCommand(light);

        remote.setCommand(lightOn);
        remote.buttonWasPressed();
    }
}
```

This is our Client in Command Pattern-speak.

The remote is our Invoker; it will be passed a command object that can be used to make requests.

Now we create a Light object, this will be the Receiver of the request.

Here, create a command and pass it to the Receiver.

Here, pass the command to the Invoker.

And then we simulate the button being pressed.

Here's the output of running this test code!

```
File Edit Window Help DinerFoodYum
%java RemoteControlTest
Light is On
%
```

Sharpen your pencil

Okay, it's time for you to implement the GarageDoorOpenCommand class. First, supply the code for the class below. You'll need the GarageDoor class diagram.


```
public class GarageDoorOpenCommand
        implements Command {

}
```

Your code here

Now that you've got your class, what is the output of the following code? (Hint: the GarageDoor up() method prints out "Garage Door is Open" when it is complete.)

```
public class RemoteControlTest {
    public static void main(String[] args) {
        SimpleRemoteControl remote = new SimpleRemoteControl();
        Light light = new Light();
        GarageDoor garageDoor = new GarageDoor();
        LightOnCommand lightOn = new LightOnCommand(light);
        GarageDoorOpenCommand garageOpen =
            new GarageDoorOpenCommand(garageDoor);


        remote.setCommand(lightOn);
        remote.buttonWasPressed();
        remote.setCommand(garageOpen);
        remote.buttonWasPressed();
    }
}
```

Your output here

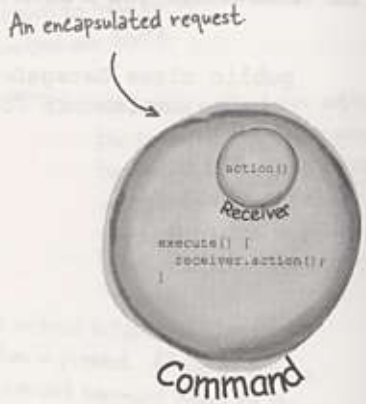
```
File Edit Window Help GreenEggs&Ham
%java RemoteControlTest
```

The Command Pattern defined

You've done your time in the Objectville Diner, you've partly implemented the remote control API, and in the process you've got a fairly good picture of how the classes and objects interact in the Command Pattern. Now we're going to define the Command Pattern and nail down all the details.

Let's start with its official definition:

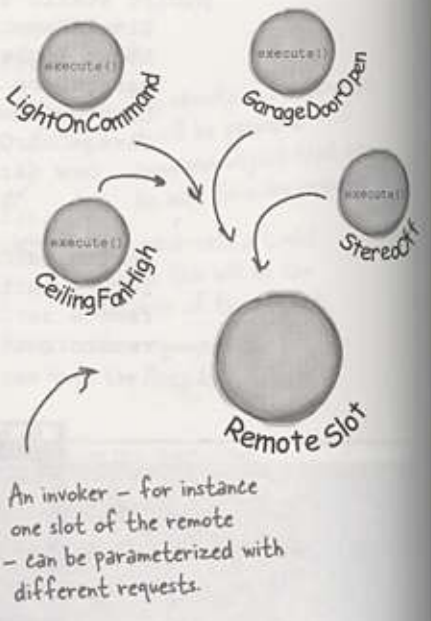
> **The Command Pattern** encapsulates a request as an object, thereby letting you parameterize other objects with different requests, queue or log requests, and support undoable operations.



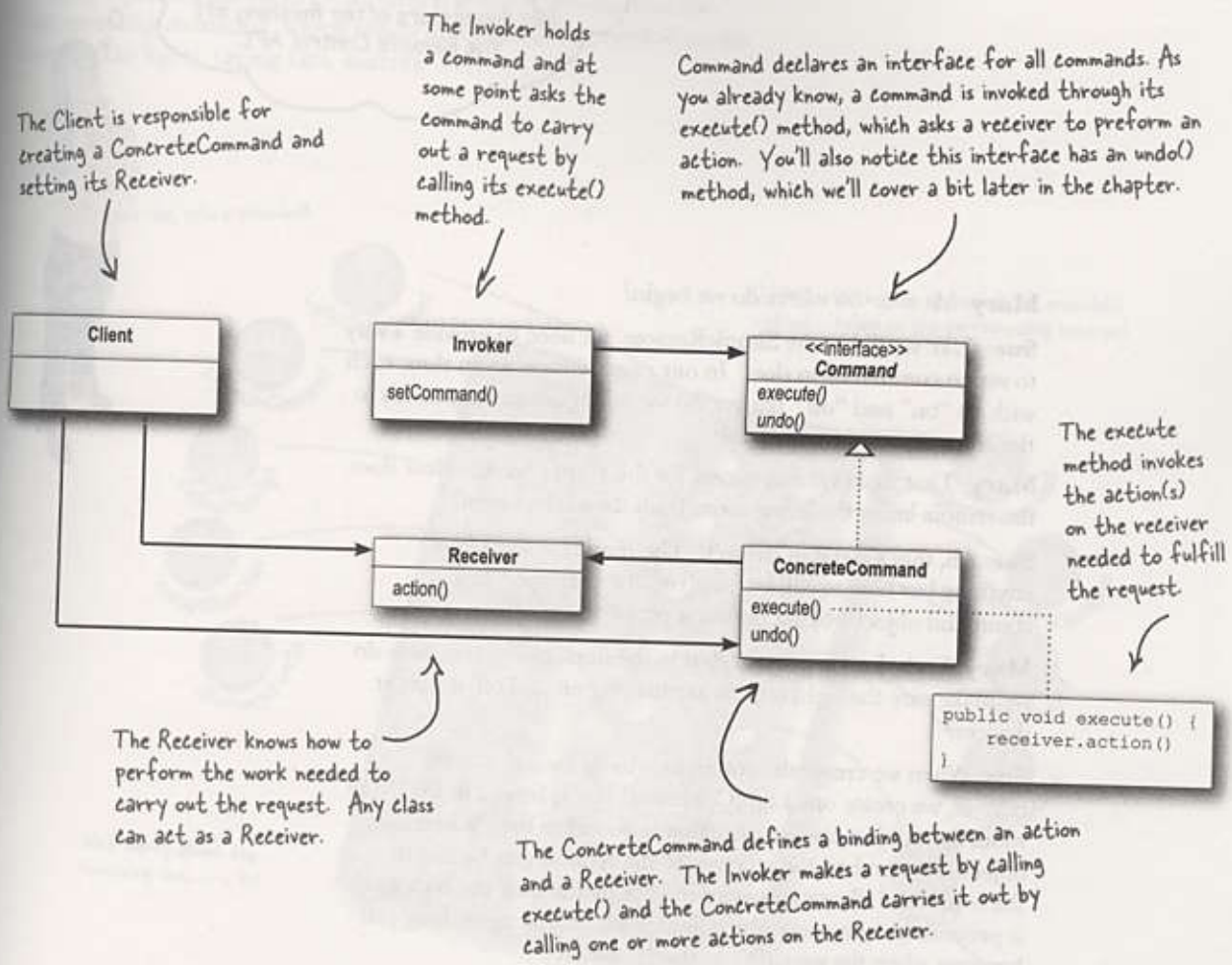
Let's step through this. We know that a command object *encapsulates a request* by binding together a set of actions on a specific receiver. To achieve this, it packages the actions and the receiver up into an object that exposes just one method, execute(). When called, execute() causes the actions to be invoked on the receiver. From the outside, no other objects really know what actions get performed on what receiver; they just know that if they call the execute() method, their request will be serviced.

We've also seen a couple examples of *parameterizing an object* with a command. Back at the diner, the Waitress was parameterized with multiple orders throughout the day. In the simple remote control, we first loaded the button slot with a "light on" command and then later replaced it with a "garage door open" command. Like the Waitress, your remote slot didn't care what command object it had, as long as it implemented the Command interface.

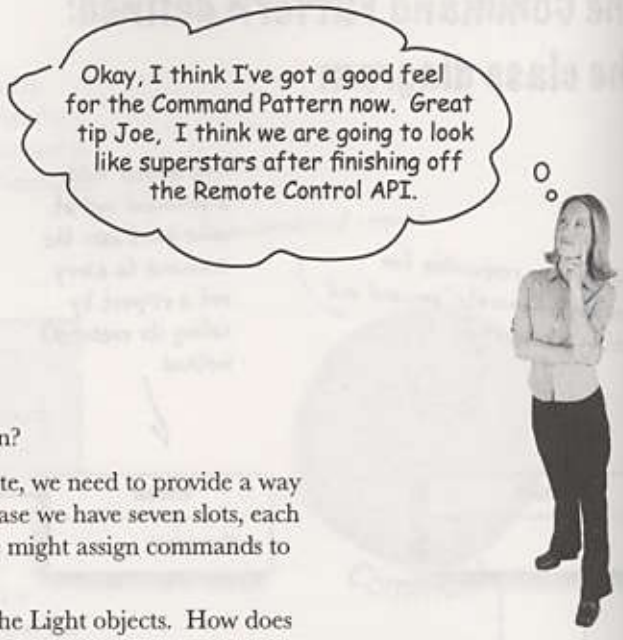
What we haven't encountered yet is using commands to implement *queues and logs and support undo operations*. Don't worry, those are pretty straightforward extensions of the basic Command Pattern and we will get to them soon. We can also easily support what's known as the Meta Command Pattern once we have the basics in place. The Meta Command Pattern allows you to create macros of commands so that you can execute multiple commands at once.



The Command Pattern defined: the class diagram



How does the design of the Command Pattern support the decoupling of the invoker of a request and the receiver of the request?



Mary: Me too. So where do we begin?

Sue: Like we did in the SimpleRemote, we need to provide a way to assign commands to slots. In our case we have seven slots, each with an "on" and "off" button. So we might assign commands to the remote something like this:

Mary: That makes sense, except for the Light objects. How does the remote know the living room from the kitchen light?

Sue: Ah, that's just it, it doesn't! The remote doesn't know anything but how to call execute() on the corresponding command object when a button is pressed.

Mary: Yeah, I sorta got that, but in the implementation, how do we make sure the right objects are turning on and off the right devices?

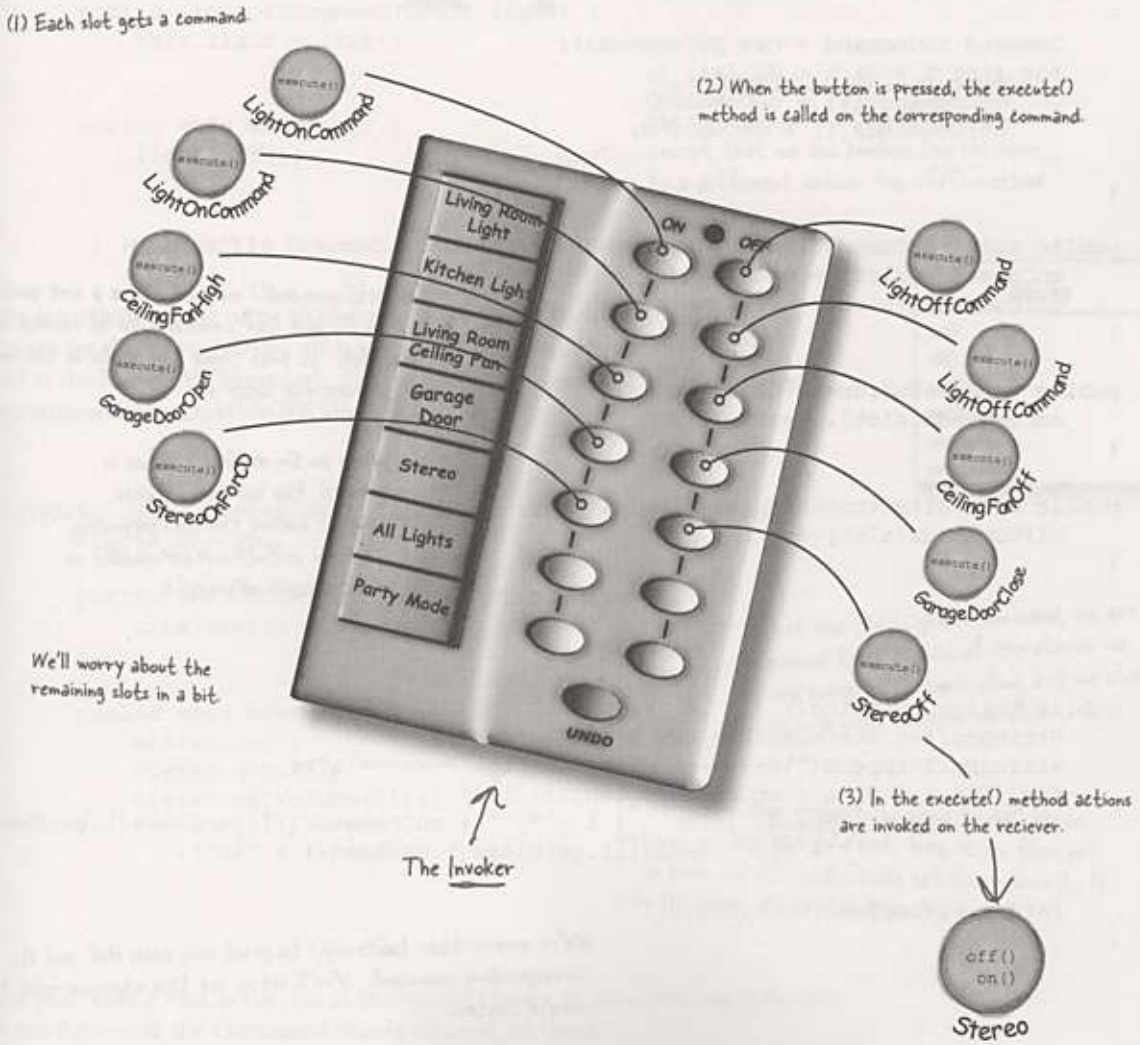
Sue: When we create the commands to be loaded into the remote, we create one LightCommand that is bound to the living room light object and another that is bound to the kitchen light object. Remember, the receiver of the request gets bound to the command it's encapsulated in. So, by the time the button is pressed, no one cares which light is which, the right thing just happens when the execute() method is called.

Mary: I think I've got it. Let's implement the remote and I think this will get clearer!

Sue: Sounds good. Let's give it a shot...

Assigning Commands to slots

So we have a plan: We're going to assign each slot to a command in the remote control. This makes the remote control our *invoker*. When a button is pressed the execute() method is going to be called on the corresponding command, which results in actions being invoked on the receiver (like lights, ceiling fans, stereos).



Implementing the Remote Control

```
public class RemoteControl {
    Command[] onCommands;
    Command[] offCommands;

    public RemoteControl() {
        onCommands = new Command[7];
        offCommands = new Command[7];

        Command noCommand = new NoCommand();
        for (int i = 0; i < 7; i++) {
            onCommands[i] = noCommand;
            offCommands[i] = noCommand;
        }
    }

    public void setCommand(int slot, Command onCommand, Command offCommand) {
        onCommands[slot] = onCommand;
        offCommands[slot] = offCommand;
    }

    public void onButtonWasPushed(int slot) {
        onCommands[slot].execute();
    }

    public void offButtonWasPushed(int slot) {
        offCommands[slot].execute();
    }

    public String toString() {
        StringBuffer stringBuff = new StringBuffer();
        stringBuff.append("\n------ Remote Control -------\n");
        for (int i = 0; i < onCommands.length; i++) {
            stringBuff.append("[slot " + i + "] " + onCommands[i].getClass().getName()
                + "    " + offCommands[i].getClass().getName() + "\n");
        }
        return stringBuff.toString();
    }
}
```

This time around the remote is going to handle seven On and Off commands, which we'll hold in corresponding arrays.

In the constructor all we need to do is instantiate and initialize the on and off arrays.

The setCommand() method takes a slot position and an On and Off command to be stored in that slot. It puts these commands in the on and off arrays for later use.

When an On or Off button is pressed, the hardware takes care of calling the corresponding methods onButtonWasPushed() or offButtonWasPushed().

We've overwritten toString() to print out each slot and its corresponding command. You'll see us use this when we test the remote control.

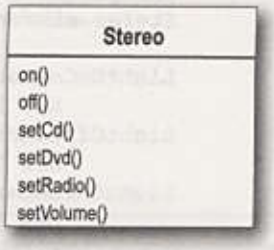
Implementing the Commands

Well, we've already gotten our feet wet implementing the LightOnCommand for the SimpleRemoteControl. We can plug that same code in here and everything works beautifully. Off commands are no different; in fact the LightOffCommand looks like this:

```
public class LightOffCommand implements Command {
    Light light;

    public LightOffCommand(Light light) {
        this.light = light;
    }

    public void execute() {
        light.off();
    }
}
```

The LightOffCommand works exactly the same way as the LightOnCommand, except that we are binding the receiver to a different action: the off() method.

Let's try something a little more challenging; how about writing on and off commands for the Stereo? Okay, off is easy, we just bind the Stereo to the off() method in the StereoOffCommand. On is a little more complicated; let's say we want to write a StereoOnWithCDCommand...




```
public class StereoOnWithCDCommand implements Command {
    Stereo stereo;

    public StereoOnWithCDCommand(Stereo stereo) {
        this.stereo = stereo;
    }

    public void execute() {
        stereo.on();
        stereo.setCD();
        stereo.setVolume(11);
    }
}
```

Just like the LightOnCommand, we get passed the instance of the stereo we are going to be controlling and we store it in a local instance variable.

To carry out this request, we need to call three methods on the stereo: first, turn it on, then set it to play the CD, and finally set the volume to 11. Why 11? Well, it's better than 10, right?

Not too bad. Take a look at the rest of the vendor classes; by now, you can definitely knock out the rest of the Command classes we need for those.

Putting the Remote Control through its paces

Our job with the remote is pretty much done; all we need to do is run some tests and get some documentation together to describe the API. Home Automation of Bust, Inc. sure is going to be impressed, don't ya think? We've managed to come up with a design that is going to allow them to produce a remote that is easy to maintain and they're going to have no trouble convincing the vendors to write some simple command classes in the future since they are so easy to write.

Let's get to testing this code!

```
public class RemoteLoader {

    public static void main(String[] args) {
        RemoteControl remoteControl = new RemoteControl();

        Light livingRoomLight = new Light("Living Room");
        Light kitchenLight = new Light("Kitchen");
        CeilingFan ceilingFan= new CeilingFan("Living Room");
        GarageDoor garageDoor = new GarageDoor("");
        Stereo stereo = new Stereo("Living Room");

        LightOnCommand livingRoomLightOn =
                new LightOnCommand(livingRoomLight);
        LightOffCommand livingRoomLightOff =
                new LightOffCommand(livingRoomLight);
        LightOnCommand kitchenLightOn =
                new LightOnCommand(kitchenLight);
        LightOffCommand kitchenLightOff =
                new LightOffCommand(kitchenLight);

        CeilingFanOnCommand ceilingFanOn =
                new CeilingFanOnCommand(ceilingFan);
        CeilingFanOffCommand ceilingFanOff =
                new CeilingFanOffCommand(ceilingFan);

        GarageDoorUpCommand garageDoorUp =
                new GarageDoorUpCommand(garageDoor);
        GarageDoorDownCommand garageDoorDown =
                new GarageDoorDownCommand(garageDoor);

        StereoOnWithCDCommand stereoOnWithCD =
                new StereoOnWithCDCommand(stereo);
        StereoOffCommand  stereoOff =
                new StereoOffCommand(stereo);
```

Create all the devices in their proper locations.

Create all the Light Command objects.

Create the On and Off for the ceiling fan.

Create the Up and Down commands for the Garage.

Create the stereo On and Off commands.

```
        remoteControl.setCommand(0, livingRoomLightOn, livingRoomLightOff);
        remoteControl.setCommand(1, kitchenLightOn, kitchenLightOff);
        remoteControl.setCommand(2, ceilingFanOn, ceilingFanOff);
        remoteControl.setCommand(3, stereoOnWithCD, stereoOff);

        System.out.println(remoteControl);

        remoteControl.onButtonWasPushed(0);
        remoteControl.offButtonWasPushed(0);
        remoteControl.onButtonWasPushed(1);
        remoteControl.offButtonWasPushed(1);
        remoteControl.onButtonWasPushed(2);
        remoteControl.offButtonWasPushed(2);
        remoteControl.onButtonWasPushed(3);
        remoteControl.offButtonWasPushed(3);
    }
}
```

Now that we've got all our commands, we can load them into the remote slots.

Here's where we use our toString() method to print each remote slot and the command that it is assigned to.

All right, we are ready to roll! Now, we step through each slot and push its On and Off button.

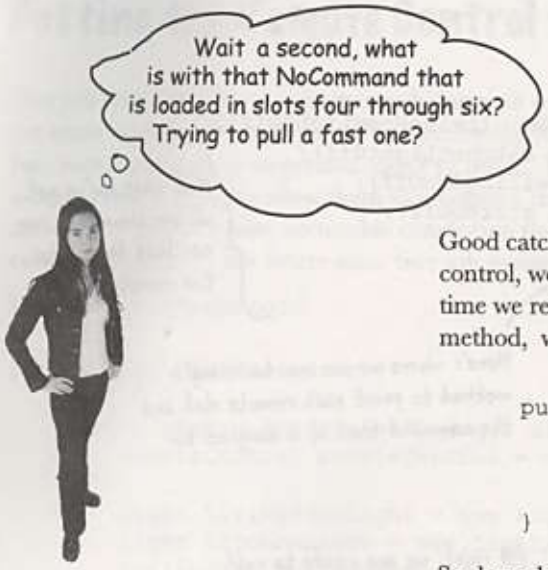
Now, let's check out the execution of our remote control test...

```
File Edit Window Help CommandsGetThingsDone

% java RemoteLoader
------ Remote Control -------
[slot 0] headfirst.command.remote.LightOnCommand       headfirst.command.remote.LightOffCommand
[slot 1] headfirst.command.remote.LightOnCommand       headfirst.command.remote.LightOffCommand
[slot 2] headfirst.command.remote.CeilingFanOnCommand  headfirst.command.remote.CeilingFanOffCommand
[slot 3] headfirst.command.remote.StereoOnWithCDCommand headfirst.command.remote.StereoOffCommand
[slot 4] headfirst.command.remote.NoCommand            headfirst.command.remote.NoCommand
[slot 5] headfirst.command.remote.NoCommand            headfirst.command.remote.NoCommand
[slot 6] headfirst.command.remote.NoCommand            headfirst.command.remote.NoCommand

Living Room light is on
Living Room light is off
Kitchen light is on
Kitchen light is off
Living Room ceiling fan is on high
Living Room ceiling fan is off
Living Room stereo is on
Living Room stereo is set for CD input
Living Room Stereo volume set to 11
Living Room stereo is off
%
```

On slots

Off Slots

Our commands in action! Remember, the output from each device comes from the vendor classes. For instance, when a light object is turned on it prints "Living Room light is on."



Good catch. We did sneak a little something in there. In the remote control, we didn't want to check to see if a command was loaded every time we referenced a slot. For instance, in the onButtonWasPushed() method, we would need code like this:

```
public void onButtonWasPushed(int slot) {
    if (onCommands[slot] != null) {
        onCommands[slot].execute();
    }
}
```

So, how do we get around that? Implement a command that does nothing!

```
public class NoCommand implements Command {
    public void execute() { }
}
```

Then, in our RemoteControl constructor, we assign every slot a NoCommand object by default and we know we'll always have some command to call in each slot.

```
Command noCommand = new NoCommand();
for (int i = 0; i < 7; i++) {
    onCommands[i] = noCommand;
    offCommands[i] = noCommand;
}
```

So in the output of our test run, you are seeing slots that haven't been assigned to a command, other than the default NoCommand object which we assigned when we created the RemoteControl.

Pattern Honorable Mention

The NoCommand object is an example of a *null object*. A null object is useful when you don't have a meaningful object to return, and yet you want to remove the responsibility for handling `null` from the client. For instance, in our remote control we didn't have a meaningful object to assign to each slot out of the box, so we provided a NoCommand object that acts as a surrogate and does nothing when its execute method is called.

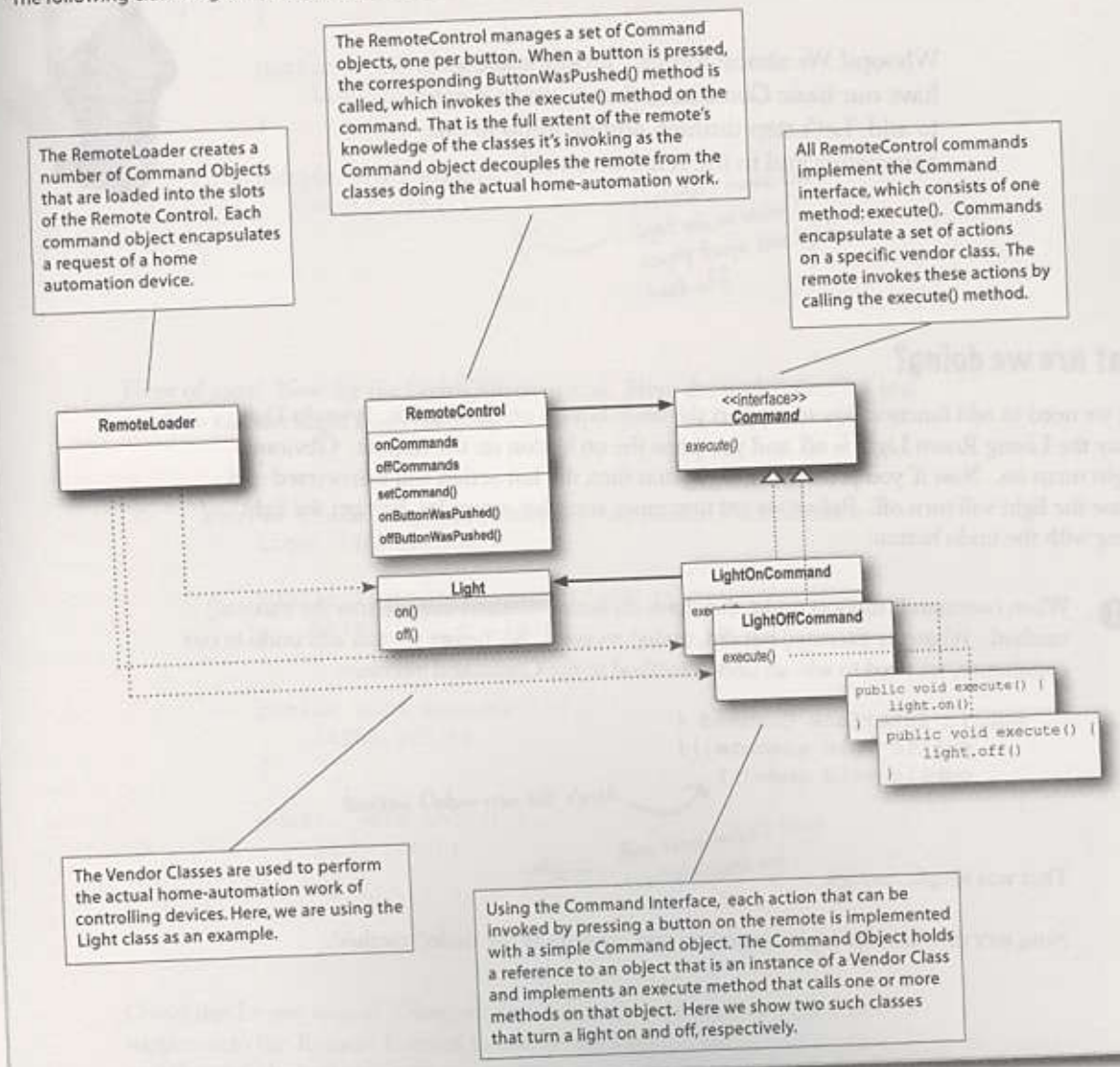
You'll find uses for Null Objects in conjunction with many Design Patterns and sometimes you'll even see Null Object listed as a Design Pattern.

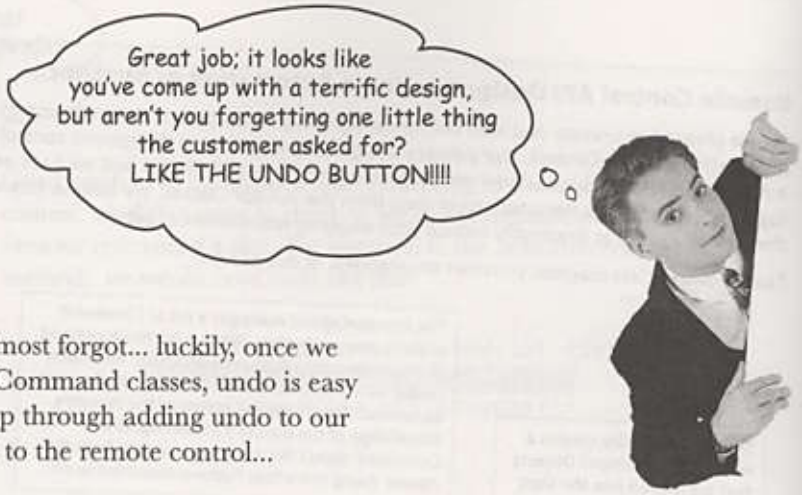
Time to write that documentation...

Remote Control API Design for Home Automation or Bust, Inc.,

We are pleased to present you with the following design and application programming interface for your Home Automation Remote Control. Our primary design goal was to keep the remote control code as simple as possible so that it doesn't require changes as new vendor classes are produced. To this end we have employed the Command Pattern to logically decouple the RemoteControl class from the Vendor Classes. We believe this will reduce the cost of producing the remote as well as drastically reduce your ongoing maintenance costs.

The following class diagram provides an overview of our design:





Whoops! We almost forgot... luckily, once we have our basic Command classes, undo is easy to add. Let's step through adding undo to our commands and to the remote control...

What are we doing?

Okay, we need to add functionality to support the undo button on the remote. It works like this: say the Living Room Light is off and you press the on button on the remote. Obviously the light turns on. Now if you press the undo button then the last action will be reversed – in this case the light will turn off. Before we get into more complex examples, let's get the light working with the undo button:

1. When commands support undo, they have an undo() method that mirrors the execute() method. Whatever execute() last did, undo() reverses. So, before we can add undo to our commands, we need to add an undo() method to the Command interface:

```
public interface Command {
    public void execute();
    public void undo();
}
```

Here's the new undo() method.

That was simple enough.

Now, let's dive into the Light command and implement the undo() method.

2 Let's start with the LightOnCommand: if the LightOnCommand's execute() method was called, then the on() method was last called. We know that undo() needs to do the opposite of this by calling the off() method.

```
public class LightOnCommand implements Command {
    Light light;

    public LightOnCommand(Light light) {
        this.light = light;
    }

    public void execute() {
        light.on();
    }

    public void undo() {
        light.off();
    }
}
```

execute() turns the light on, so undo() simply turns the light back off.

Piece of cake! Now for the LightOffCommand. Here the undo() method just needs to call the Light's on() method.

```
public class LightOffCommand implements Command {
    Light light;

    public LightOffCommand(Light light) {
        this.light = light;
    }

    public void execute() {
        light.off();
    }

    public void undo() {
        light.on();
    }
}
```

And here, undo() turns the light back on!

Could this be any easier? Okay, we aren't done yet; we need to work a little support into the Remote Control to handle tracking the last button pressed and the undo button press.

3 To add support for the undo button we only have to make a few small changes to the Remote Control class. Here's how we're going to do it: we'll add a new instance variable to track the last command invoked; then, whenever the undo button is pressed, we retrieve that command and invoke its undo() method.

```
public class RemoteControlWithUndo {
    Command[] onCommands;
    Command[] offCommands;
    Command undoCommand;

    public RemoteControlWithUndo() {
        onCommands = new Command[7];
        offCommands = new Command[7];

        Command noCommand = new NoCommand();
        for(int i=0;i<7;i++) {
            onCommands[i] = noCommand;
            offCommands[i] = noCommand;
        }
        undoCommand = noCommand;
    }

    public void setCommand(int slot, Command onCommand, Command offCommand) {
        onCommands[slot] = onCommand;
        offCommands[slot] = offCommand;
    }

    public void onButtonWasPushed(int slot) {
        onCommands[slot].execute();
        undoCommand = onCommands[slot];
    }

    public void offButtonWasPushed(int slot) {
        offCommands[slot].execute();
        undoCommand = offCommands[slot];
    }

    public void undoButtonWasPushed() {
        undoCommand.undo();
    }

    public String toString() {
        // toString code here...
    }
}
```

This is where we'll stash the last command executed for the undo button.

Just like the other slots, undo starts off with a NoCommand, so pressing undo before any other button won't do anything at all.

When a button is pressed, we take the command and first execute it; then we save a reference to it in the undoCommand instance variable. We do this for both "on" commands and "off" commands.

When the undo button is pressed, we invoke the undo() method of the command stored in undoCommand. This reverses the operation of the last command executed.

Time to QA that Undo button!

Okay, let's rework the test harness a bit to test the undo button:

```
public class RemoteLoader {

    public static void main(String[] args) {
        RemoteControlWithUndo remoteControl = new RemoteControlWithUndo();

        Light livingRoomLight = new Light("Living Room");

        LightOnCommand livingRoomLightOn =
                new LightOnCommand(livingRoomLight);
        LightOffCommand livingRoomLightOff =
                new LightOffCommand(livingRoomLight);

        remoteControl.setCommand(0, livingRoomLightOn, livingRoomLightOff);

        remoteControl.onButtonWasPushed(0);
        remoteControl.offButtonWasPushed(0);
        System.out.println(remoteControl);
        remoteControl.undoButtonWasPushed();
        remoteControl.offButtonWasPushed(0);
        remoteControl.onButtonWasPushed(0);
        System.out.println(remoteControl);
        remoteControl.undoButtonWasPushed();
    }
}
```

Create a Light, and our new undo() enabled Light On and Off Commands.

Add the light Commands to the remote in slot 0.

Turn the light on, then off and then undo.

Then, turn the light off, back on and undo.

And here's the test results...

```
File Edit Window Help UndoCommandsDefyEntropy
% java RemoteLoader
Light is on
Light is off

------ Remote Control -------
[slot 0] headfirst.command.undo.LightOnCommand    headfirst.command.undo.LightOffCommand
[slot 1] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 2] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 3] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 4] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 5] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 6] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[undo] headfirst.command.undo.LightOffCommand

Light is on
Light is off
Light is on

------ Remote Control -------
[slot 0] headfirst.command.undo.LightOnCommand    headfirst.command.undo.LightOffCommand
[slot 1] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 2] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 3] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 4] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 5] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[slot 6] headfirst.command.undo.NoCommand    headfirst.command.undo.NoCommand
[undo] headfirst.command.undo.LightOnCommand

Light is off
```

Turn the light on, then off.

Here's the Light commands.

Undo was pressed. the LightOffCommand undo() turns the light back on.

Now undo holds the LightOffCommand, the last command invoked.

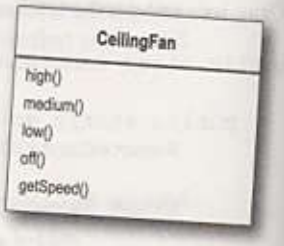
Then we turn the light off then back on.

Undo was pressed, the light is back off.

Now undo holds the LightOnCommand, the last command invoked.

Using state to implement Undo

Okay, implementing undo on the Light was instructive but a little too easy. Typically, we need to manage a bit of state to implement undo. Let's try something a little more interesting, like the CeilingFan from the vendor classes. The ceiling fan allows a number of speeds to be set along with an off method.



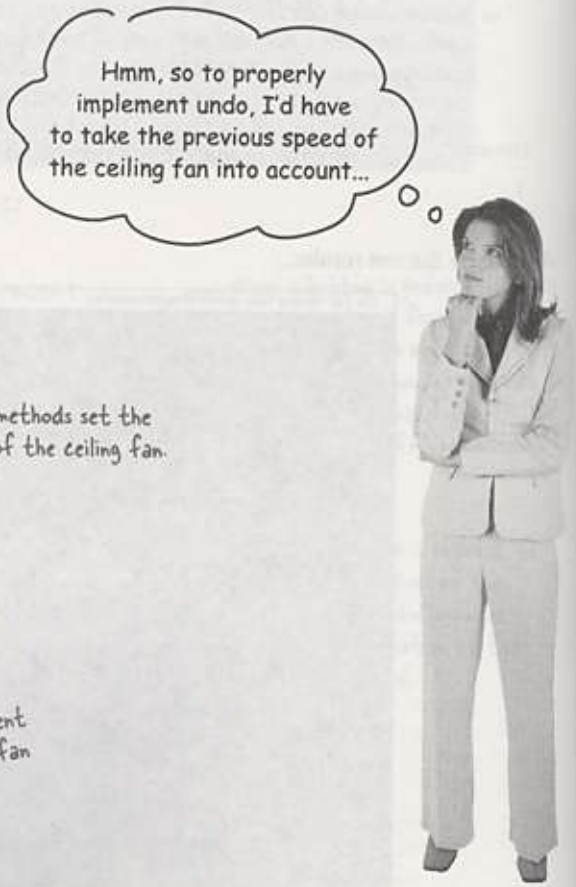
Here's the source code for the CeilingFan:

```
public class CeilingFan {
    public static final int HIGH = 3;
    public static final int MEDIUM = 2;
    public static final int LOW = 1;
    public static final int OFF = 0;
    String location;
    int speed;

    public CeilingFan(String location) {
        this.location = location;
        speed = OFF;
    }

    public void high() {
        speed = HIGH;
        // code to set fan to high
    }

    public void medium() {
        speed = MEDIUM;
        // code to set fan to medium
    }

    public void low() {
        speed = LOW;
        // code to set fan to low
    }

    public void off() {
        speed = OFF;
        // code to turn fan off
    }

    public int getSpeed() {
        return speed;
    }
}
```

Notice that the CeilingFan class holds local state representing the speed of the ceiling fan.

These methods set the speed of the ceiling fan.

We can get the current speed of the ceiling fan using getSpeed().



Adding Undo to the ceiling fan commands

Now let's tackle adding undo to the various CeilingFan commands. To do so, we need to track the last speed setting of the fan and, if the undo() method is called, restore the fan to its previous setting. Here's the code for the CeilingFanHighCommand:

```
public class CeilingFanHighCommand implements Command {
    CeilingFan ceilingFan;
    int prevSpeed;

    public CeilingFanHighCommand(CeilingFan ceilingFan) {
        this.ceilingFan = ceilingFan;
    }

    public void execute() {
        prevSpeed = ceilingFan.getSpeed();
        ceilingFan.high();
    }

    public void undo() {
        if (prevSpeed == CeilingFan.HIGH) {
            ceilingFan.high();
        } else if (prevSpeed == CeilingFan.MEDIUM) {
            ceilingFan.medium();
        } else if (prevSpeed == CeilingFan.LOW) {
            ceilingFan.low();
        } else if (prevSpeed == CeilingFan.OFF) {
            ceilingFan.off();
        }
    }
}
```

We've added local state to keep track of the previous speed of the fan.

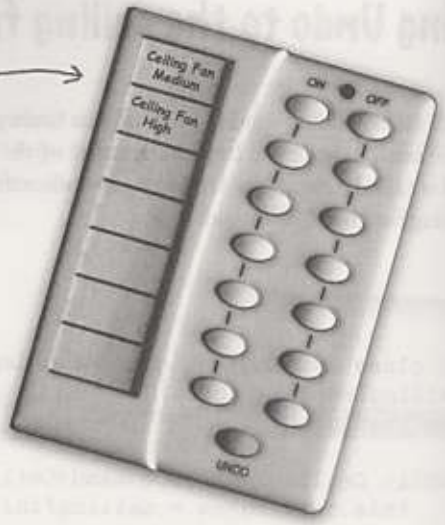
In execute, before we change the speed of the fan, we need to first record its previous state, just in case we need to undo our actions.

To undo, we set the speed of the fan back to its previous speed.

We've got three more ceiling fan commands to write: low, medium, and off. Can you see how these are implemented?

Get ready to test the ceiling fan

Time to load up our remote control with the ceiling fan commands. We're going to load slot zero's on button with the medium setting for the fan and slot one with the high setting. Both corresponding off buttons will hold the ceiling fan off command.



Here's our test script:

```
public class RemoteLoader {

    public static void main(String[] args) {
        RemoteControlWithUndo remoteControl = new RemoteControlWithUndo();

        CeilingFan ceilingFan = new CeilingFan("Living Room");

        CeilingFanMediumCommand ceilingFanMedium =
                new CeilingFanMediumCommand(ceilingFan);
        CeilingFanHighCommand ceilingFanHigh =
                new CeilingFanHighCommand(ceilingFan);
        CeilingFanOffCommand ceilingFanOff =
                new CeilingFanOffCommand(ceilingFan);

        remoteControl.setCommand(0, ceilingFanMedium, ceilingFanOff);
        remoteControl.setCommand(1, ceilingFanHigh, ceilingFanOff);

        remoteControl.onButtonWasPushed(0);
        remoteControl.offButtonWasPushed(0);
        System.out.println(remoteControl);
        remoteControl.undoButtonWasPushed();

        remoteControl.onButtonWasPushed(1);
        System.out.println(remoteControl);
        remoteControl.undoButtonWasPushed();
    }
}
```

Here we instantiate three commands: high, medium, and off.

Here we put medium in slot zero, and high in slot one. We also load up the off commands.

First, turn the fan on medium.

Then turn it off.

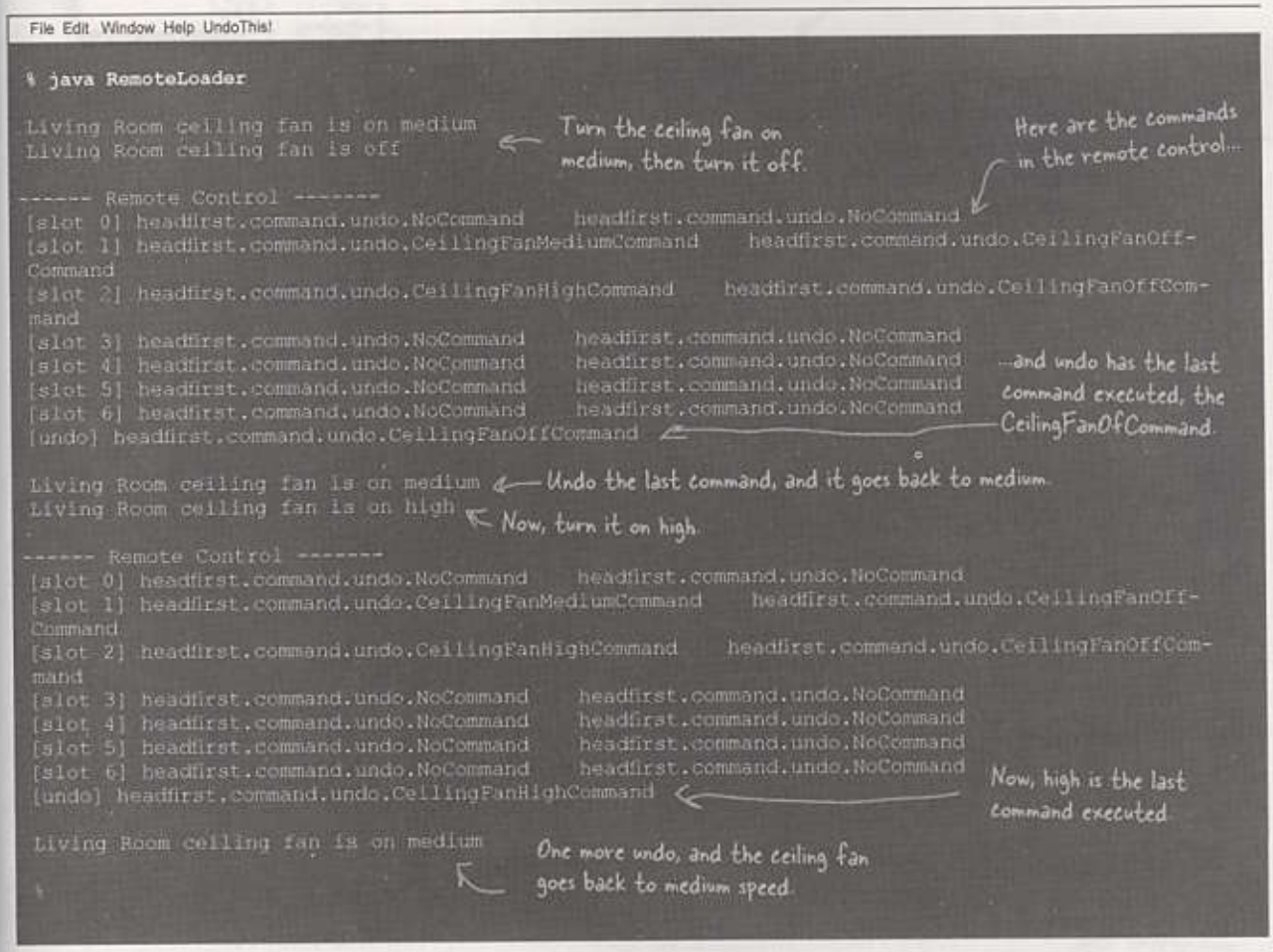
Undo! It should go back to medium...

Turn it on to high this time.

And, one more undo; it should go back to medium.

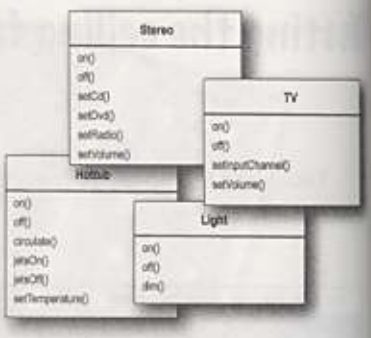
Testing the ceiling fan...

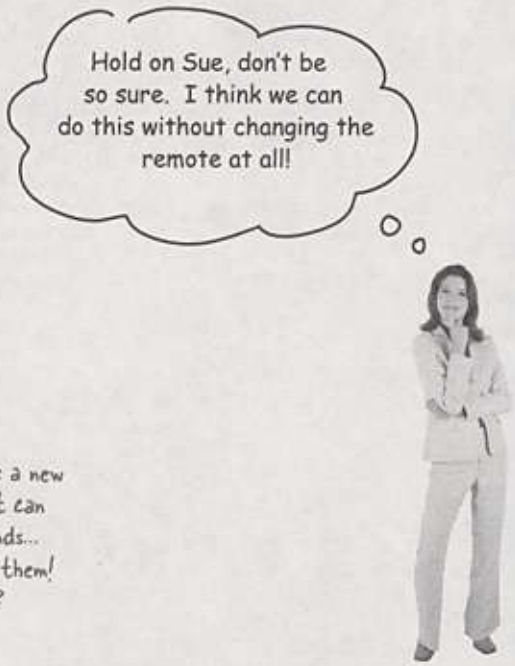
Okay, let's fire up the remote, load it with commands, and push some buttons!



Every remote needs a Party Mode!

What's the point of having a remote if you can't push one button and have the lights dimmed, the stereo and TV turned on and set to a DVD and the hot tub fired up?





Mary's idea is to make a new kind of Command that can execute other Commands... and more than one of them! Pretty good idea, huh?

```
public class MacroCommand implements Command {
    Command[] commands;

    public MacroCommand(Command[] commands) {
        this.commands = commands;
    }

    public void execute() {
        for (int i = 0; i < commands.length; i++) {
            commands[i].execute();
        }
    }
}
```

Take an array of Commands and store them in the MacroCommand.

When the macro gets executed by the remote, execute those commands one at a time.

Using a macro command

Let's step through how we use a macro command:

1. First we create the set of commands we want to go into the macro:

```
Light light = new Light("Living Room");
TV tv = new TV("Living Room");
Stereo stereo = new Stereo("Living Room");
Hottub hottub = new Hottub();

LightOnCommand lightOn = new LightOnCommand(light);
StereoOnCommand stereoOn = new StereoOnCommand(stereo);
TVOnCommand tvOn = new TVOnCommand(tv);
HottubOnCommand hottubOn = new HottubOnCommand(hottub);
```

Create all the devices, a light, tv, stereo, and hot tub.

Now create all the On commands to control them.

Sharpen your pencil

We will also need commands for the off buttons, write the code to create those here:

2. Next we create two arrays, one for the On commands and one for the Off commands, and load them with the corresponding commands:

```
Command[] partyOn = { lightOn, stereoOn, tvOn, hottubOn};
Command[] partyOff = { lightOff, stereoOff, tvOff, hottubOff};

MacroCommand partyOnMacro = new MacroCommand(partyOn);
MacroCommand partyOffMacro = new MacroCommand(partyOff);
```

Create an array for On and an array for Off commands...

...and create two corresponding macros to hold them.

3. Then we assign MacroCommand to a button like we always do:

```
remoteControl.setCommand(0, partyOnMacro, partyOffMacro);
```

Assign the macro command to a button as we would any command.

4 Finally, we just need to push some buttons and see if this works.

```
System.out.println(remoteControl);
System.out.println("--- Pushing Macro On---");
remoteControl.onButtonWasPushed(0);
System.out.println("--- Pushing Macro Off---");
remoteControl.offButtonWasPushed(0);
```

Here's the output.

File Edit Window Help You Can'tBeatABabka

```
% java RemoteLoader
------ Remote Control -------
[slot 0] headfirst.command.party.MacroCommand    headfirst.command.party.MacroCommand
[slot 1] headfirst.command.party.NoCommand    headfirst.command.party.NoCommand
[slot 2] headfirst.command.party.NoCommand    headfirst.command.party.NoCommand
[slot 3] headfirst.command.party.NoCommand    headfirst.command.party.NoCommand
[slot 4] headfirst.command.party.NoCommand    headfirst.command.party.NoCommand
[slot 5] headfirst.command.party.NoCommand    headfirst.command.party.NoCommand
[slot 6] headfirst.command.party.NoCommand    headfirst.command.party.NoCommand
[undo] headfirst.command.party.NoCommand

--- Pushing Macro On---
Light is on
Living Room stereo is on
Living Room TV is on
Living Room TV channel is set for DVD
Hottub is heating to a steaming 104 degrees
Hottub is bubbling!

--- Pushing Macro Off---
Light is off
Living Room stereo is off
Living Room TV is off
Hottub is cooling to 98 degrees

%
```

Here are the two macro commands.

All the Commands in the macro are executed when we invoke the on macro...

and when we invoke the off macro. Looks like it works.

The only thing our MacroCommand is missing its undo functionality. When the undo button is pressed after a macro command, all the commands that were invoked in the macro must undo their previous actions. Here's the code for MacroCommand; go ahead and implement the undo() method:

```
public class MacroCommand implements Command {
    Command[] commands;

    public MacroCommand(Command[] commands) {
        this.commands = commands;
    }

    public void execute() {
        for (int i = 0; i < commands.length; i++) {
            commands[i].execute();
        }
    }

    public void undo() {

        [                                    ]

    }
}
```

Q: Do I always need a receiver? Why can't the command object implement the details of the execute() method?

A: In general, we strive for "dumb" command objects that just invoke an action on a receiver; however, there are many examples of "smart" command objects that implement most, if not all, of the logic needed to carry out a request. Certainly you can do this; just keep in mind you'll no longer have the same level of decoupling between the invoker and receiver, nor will you be able to parameterize your commands with receivers.

there are no Dumb Questions

Q: How can I implement a history of undo operations? In other words, I want to be able to press the undo button multiple times.

A: Great question! It's pretty easy actually; instead of keeping just a reference to the last Command executed, you keep a stack of previous commands. Then, whenever undo is pressed, your invoker pops the first item off the stack and calls its undo() method.

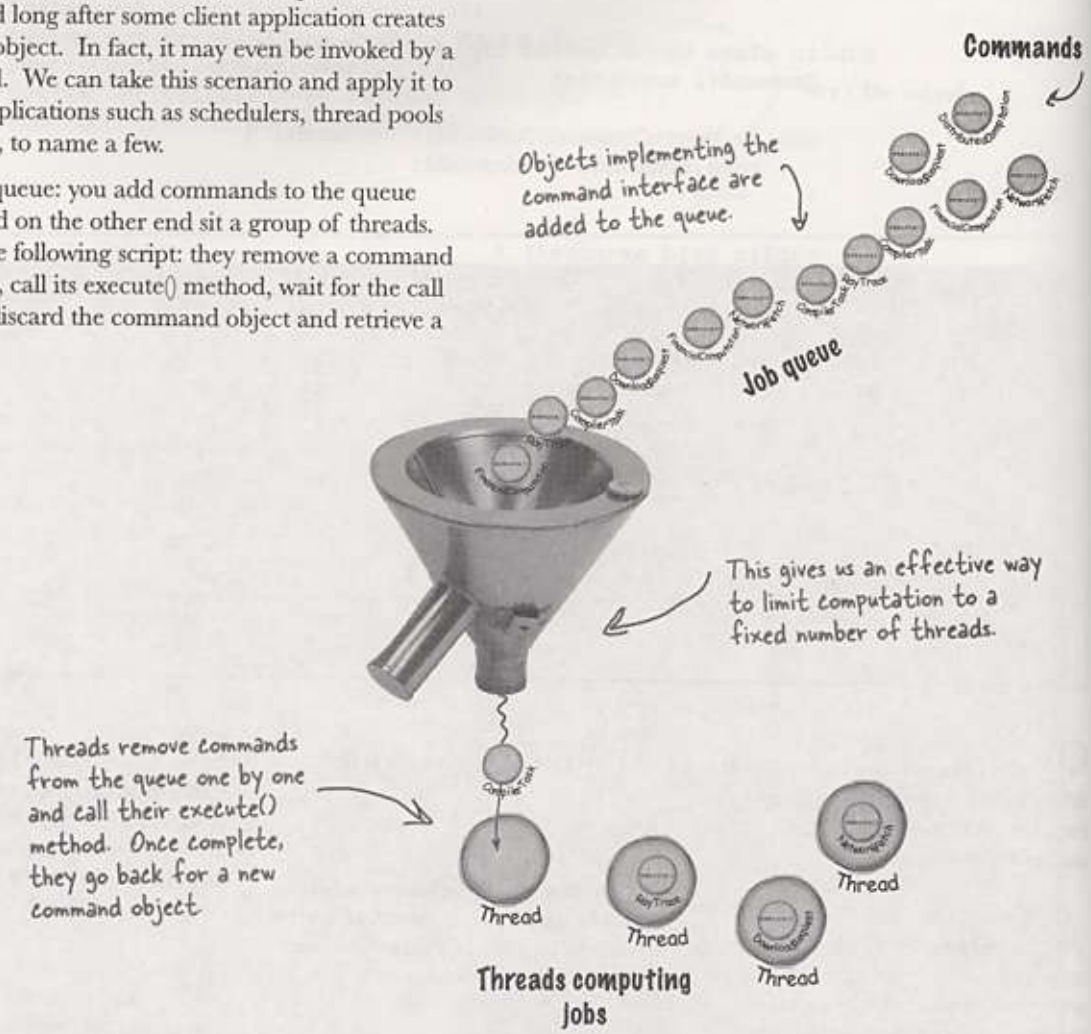
Q: Could I have just implemented Party Mode as a Command by creating a PartyCommand and putting the calls to execute the other Commands in the PartyCommand's execute() method?

A: You could; however, you'd essentially be "hardcoding" the party mode into the PartyCommand. Why go to the trouble? With the MacroCommand, you can decide dynamically which Commands you want to go into the PartyCommand, so you have more flexibility using MacroCommands. In general, the MacroCommand is a more elegant solution and requires less new code.

More uses of the Command Pattern: queuing requests

Commands give us a way to package a piece of computation (a receiver and a set of actions) and pass it around as a first-class object. Now, the computation itself may be invoked long after some client application creates the command object. In fact, it may even be invoked by a different thread. We can take this scenario and apply it to many useful applications such as schedulers, thread pools and job queues, to name a few.

Imagine a job queue: you add commands to the queue on one end, and on the other end sit a group of threads. Threads run the following script: they remove a command from the queue, call its execute() method, wait for the call to finish, then discard the command object and retrieve a new one.



Note that the job queue classes are totally decoupled from the objects that are doing the computation. One minute a thread may be computing a financial computation, and the next it may be retrieving something from the network. The job queue objects don't care; they just retrieve commands and call execute(). Likewise, as long as you put objects into the queue that implement the Command Pattern, your execute() method will be invoked when a thread is available.

How might a web server make use of such a queue? What other applications can you think of?

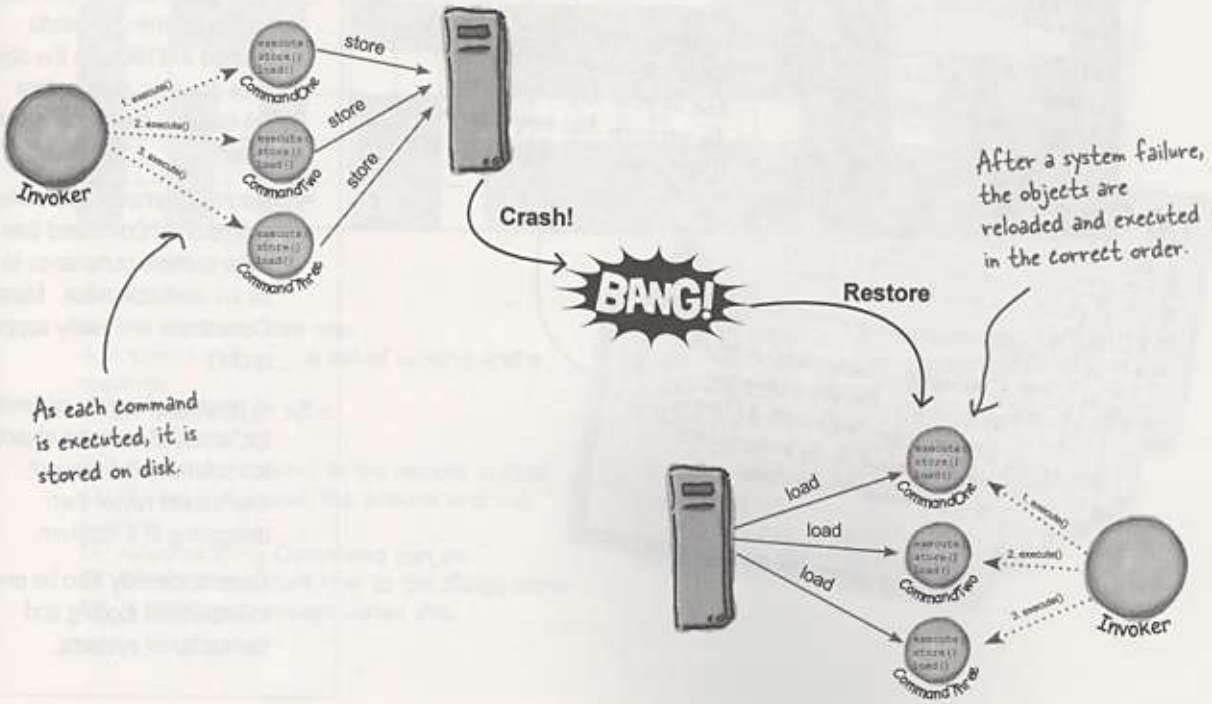
More uses of the Command Pattern: logging requests

The semantics of some applications require that we log all actions and be able to recover after a crash by reinvoking those actions. The Command Pattern can support these semantics with the addition of two methods: store() and load(). In Java we could use object serialization to implement these methods, but the normal caveats for using serialization for persistence apply.

How does this work? As we execute commands, we store a history of them on disk. When a crash occurs, we reload the command objects and invoke their execute() methods in batch and in order.

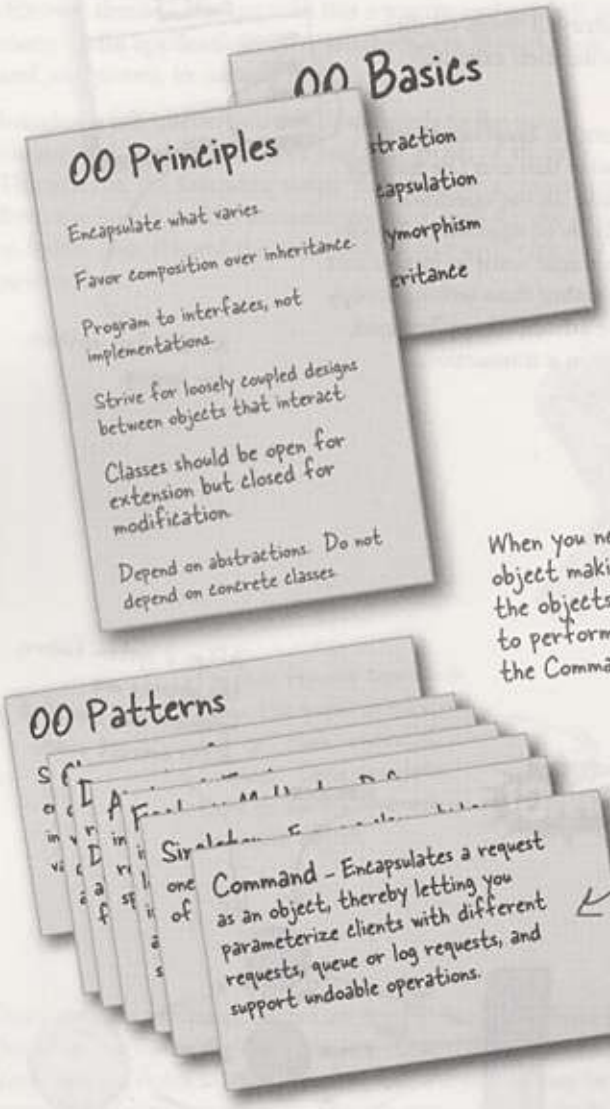
Now, this kind of logging wouldn't make sense for a remote control; however, there are many applications that invoke actions on large data structures that can't be quickly saved each time a change is made. By using logging, we can save all the operations since the last check point, and if there is a system failure, apply those operations to our checkpoint. Take, for example, a spreadsheet application: we might want to implement our failure recovery by logging the actions on the spreadsheet rather than writing a copy of the spreadsheet to disk every time a change occurs. In more advanced applications, these techniques can be extended to apply to sets of operations in a transactional manner so that all of the operations complete, or none of them do.

We add two methods for logging.



Tools for your Design Toolbox

Your toolbox is starting to get heavy! In this chapter we've added a pattern that allows us to encapsulate methods into Command objects: store them, pass them around, and invoke them when you need them.

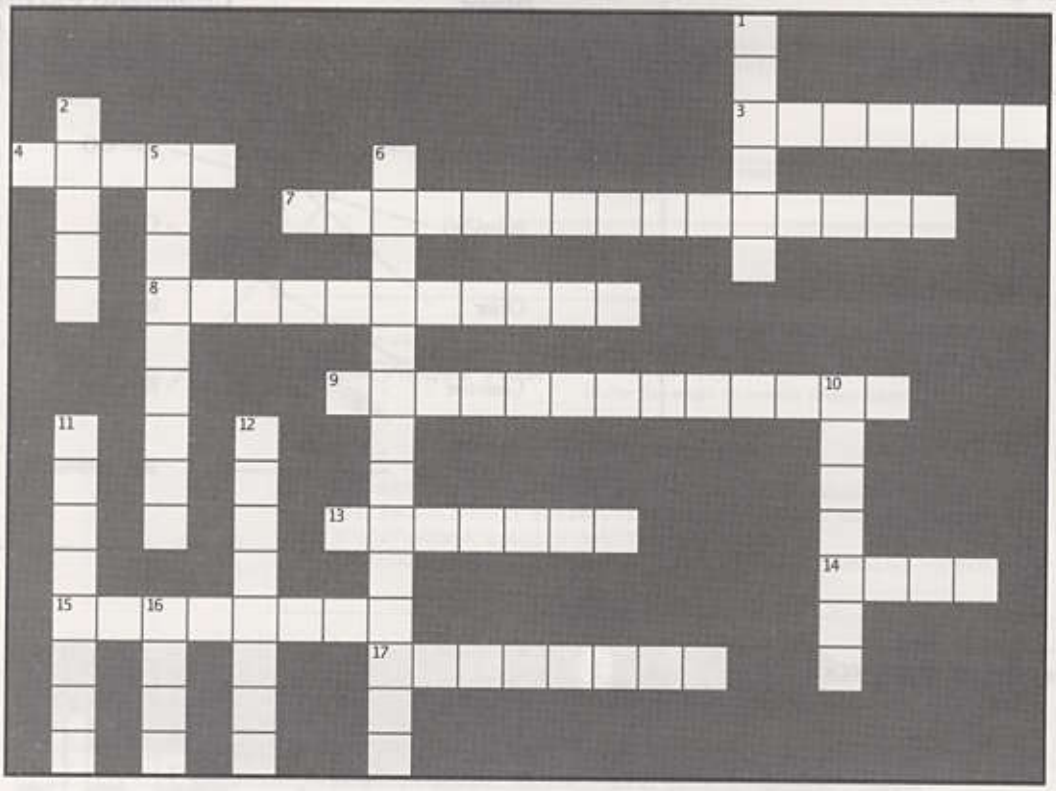


BULLET POINTS

- The Command Pattern decouples an object, making a request from the one that knows how to perform it.
- A Command object is at the center of this decoupling and encapsulates a receiver with an action (or set of actions).
- An invoker makes a request of a Command object by calling its execute() method, which invokes those actions on the receiver.
- Invokers can be parameterized with Commands, even dynamically at runtime.
- Commands may support undo by implementing an undo method that restores the object to its previous state before the excute() method was last called.
- Macro Commands are a simple extension of Command that allow multiple commands to be invoked. Likewise, Macro Commands can easily support undo().
- In practice, it is not uncommon for "smart" Command objects to implement the request themselves rather than delegating to a receiver.
- Commands may also be used to implement logging and transactional systems.

Time to take a breather and let it all sink in.

It's another crossword; all of the solution words are from this chapter.



Across

3. The Waitress was one
4. A command ____ a set of actions and a receiver
7. Dr. Seuss diner food
8. Our favorite city
9. Act as the receivers in the remote control
13. Object that knows the actions and the receiver
14. Another thing Command can do
15. Object that knows how to get things done
17. A command encapsulates this

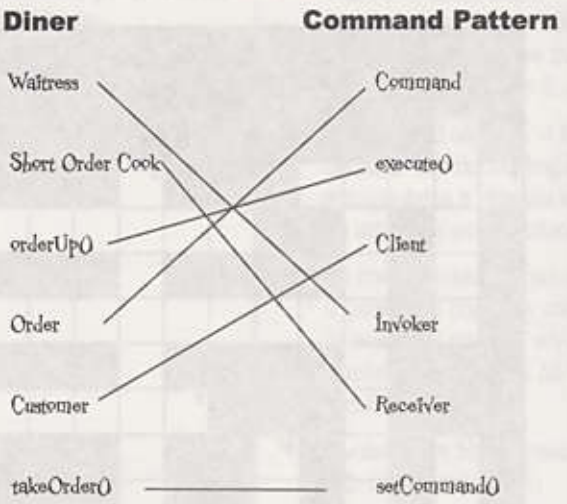
Down

1. Role of customer in the command pattern
2. Our first command object controlled this
5. Invoker and receiver are _____
6. Company that got us word of mouth business
10. All commands provide this
11. The cook and this person were definitely decoupled
12. Carries out a request
16. Waitress didn't do this

Exercise solutions

WHO DOES WHAT?

Match the diner objects and methods with the corresponding names from the Command Pattern



Sharpen your pencil

```
public class GarageDoorOpenCommand implements Command {
    GarageDoor garageDoor;
    public GarageDoorOpenCommand(GarageDoor garageDoor) {
        this.garageDoor = garageDoor;
    }

    public void execute() {
        garageDoor.up();
    }
}
```

```
File Edit Window Help GreenEggs&Ham
%java RemoteControlTest
Light is on
Garage Door is Open

%
```

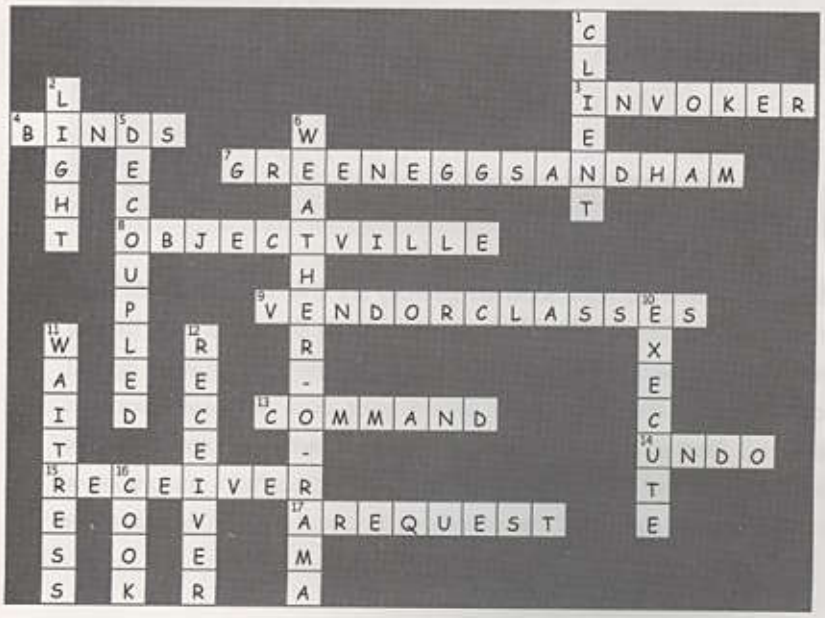
Exercise solutions

Write the undo() method for MacroCommand

```
public class MacroCommand implements Command {
    Command[] commands;
    public MacroCommand(Command[] commands) {
        this.commands = commands;
    }

    public void execute() {
        for (int i = 0; i < commands.length; i++) {
            commands[i].execute();
        }
    }

    public void undo() {
        for (int i = 0; i < commands.length; i++) {
            commands[i].undo();
        }
    }
}
```

We will also need commands for the off button. Write the code to create those here:

```
LightOffCommand lightOff = new LightOffCommand(light);
StereoOffCommand stereoOff = new StereoOffCommand(stereo);
TVOffCommand tvOff = new TVOffCommand(tv);
HottubOffCommand hottubOff = new HottubOffCommand(hottub);
```



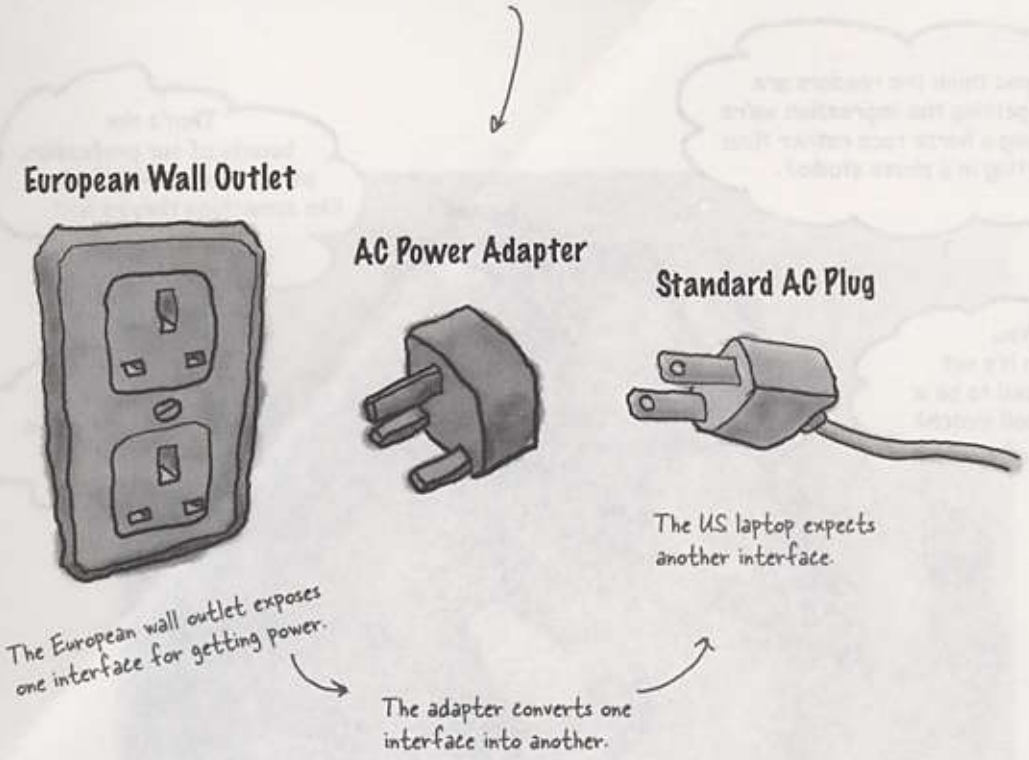
7 the Adapter and Facade Patterns

Being Adaptive

In this chapter we're going to attempt such impossible feats as putting a square peg in a round hole. Sound impossible? Not when we have Design Patterns. Remember the Decorator Pattern? We **wrapped objects** to give them new responsibilities. Now we're going to wrap some objects with a different purpose: to make their interfaces look like something they're not. Why would we do that? So we can adapt a design expecting one interface to a class that implements a different interface. That's not all; while we're at it, we're going to look at another pattern that wraps objects to simplify their interface.

Adapters all around us

You'll have no trouble understanding what an OO adapter is because the real world is full of them. How's this for an example: Have you ever needed to use a US-made laptop in a European country? Then you've probably needed an AC power adapter...



You know what the adapter does: it sits in between the plug of your laptop and the European AC outlet; its job is to adapt the European outlet so that you can plug your laptop into it and receive power. Or look at it this way: the adapter changes the interface of the outlet into one that your laptop expects.

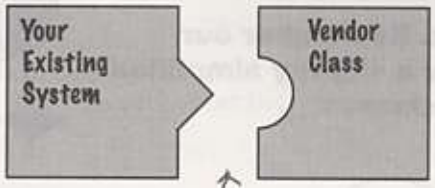
How many other real world adapters can you think of?

Some AC adapters are simple – they only change the shape of the outlet so that it matches your plug, and they pass the AC current straight through – but other adapters are more complex internally and may need to step the power up or down to match your devices' needs.

Okay, that's the real world, what about object oriented adapters? Well, our OO adapters play the same role as their real world counterparts: they take an interface and adapt it to one that a client is expecting.

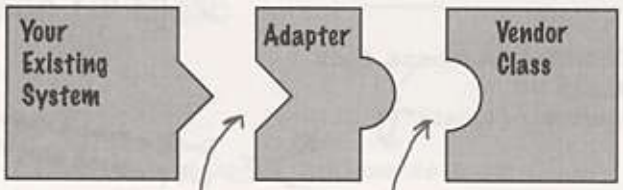
Object oriented adapters

Say you've got an existing software system that you need to work a new vendor class library into, but the new vendor designed their interfaces differently than the last vendor:



Their interface doesn't match the one you've written your code against. This isn't going to work!

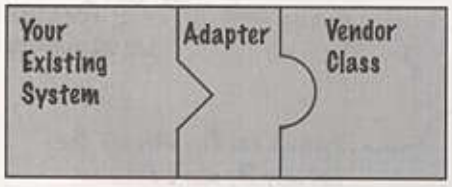
Okay, you don't want to solve the problem by changing your existing code (and you can't change the vendor's code). So what do you do? Well, you can write a class that adapts the new vendor interface into the one you're expecting.



The adapter implements the interface your classes expect.

And talks to the vendor interface to service your requests.

The adapter acts as the middleman by receiving requests from the client and converting them into requests that make sense on the vendor classes.



No code changes.

New code.

No code changes.

Can you think of a solution that doesn't require YOU to write ANY additional code to integrate the new vendor classes? How about making the vendor supply the adapter class.

If it walks like a duck and quacks like a duck, then it ~~must~~ might be a ~~duck~~ turkey wrapped with a duck adapter...

It's time to see an adapter in action. Remember our ducks from Chapter 1? Let's review a slightly simplified version of the Duck interfaces and classes:

```
public interface Duck {
    public void quack();
    public void fly();
}
```

This time around, our ducks implement a Duck interface that allows Ducks to quack and fly.

Here's a subclass of Duck, the MallardDuck.

```
public class MallardDuck implements Duck {
    public void quack() {
        System.out.println("Quack");
    }

    public void fly() {
        System.out.println("I'm flying");
    }
}
```

Simple implementations: the duck just prints out what it is doing.

Now it's time to meet the newest fowl on the block:

```
public interface Turkey {
    public void gobble();
    public void fly();
}
```

Turkeys don't quack, they gobble.

Turkeys can fly, although they can only fly short distances.

```
public class WildTurkey implements Turkey {
    public void gobble() {
        System.out.println("Gobble gobble");
    }

    public void fly() {
        System.out.println("I'm flying a short distance");
    }
}
```

Here's a concrete implementation of Turkey; like Duck, it just prints out its actions.

Now, let's say you're short on Duck objects and you'd like to use some Turkey objects in their place. Obviously we can't use the turkeys outright because they have a different interface.

So, let's write an Adapter:

Code Up Close

First, you need to implement the interface of the type you're adapting to. This is the interface your client expects to see.

```
public class TurkeyAdapter implements Duck {
    Turkey turkey;

    public TurkeyAdapter(Turkey turkey) {
        this.turkey = turkey;
    }

    public void quack() {
        turkey.gobble();
    }

    public void fly() {
        for(int i=0; i < 5; i++) {
            turkey.fly();
        }
    }
}
```

Next, we need to get a reference to the object that we are adapting; here we do that through the constructor.

Now we need to implement all the methods in the interface; the quack() translation between classes is easy: just call the gobble() method.

Even though both interfaces have a fly() method, Turkeys fly in short spurts – they can't do long-distance flying like ducks. To map between a Duck's fly() method and a Turkey's, we need to call the Turkey's fly() method five times to make up for it.

Test drive the adapter

Now we just need some code to test drive our adapter:

```
public class DuckTestDrive {
    public static void main(String[] args) {
        MallardDuck duck = new MallardDuck();

        WildTurkey turkey = new WildTurkey();
        Duck turkeyAdapter = new TurkeyAdapter(turkey);

        System.out.println("The Turkey says...");
        turkey.gobble();
        turkey.fly();

        System.out.println("\nThe Duck says...");
        testDuck(duck);

        System.out.println("\nThe TurkeyAdapter says...");
        testDuck(turkeyAdapter);
    }

    static void testDuck(Duck duck) {
        duck.quack();
        duck.fly();
    }
}
```

Let's create a Duck...

and a Turkey.

And then wrap the turkey in a TurkeyAdapter, which makes it look like a Duck.

Then, let's test the Turkey: make it gobble, make it fly.

Now let's test the duck by calling the testDuck() method, which expects a Duck object.

Now the big test: we try to pass off the turkey as a duck...

Here's our testDuck() method; it gets a duck and calls its quack() and fly() methods.

Test run

```
File Edit Window Help Don'tForgetToDuck
%java RemoteControlTest
The Turkey says...
Gobble gobble
I'm flying a short distance

The Duck says...
Quack
I'm flying

The TurkeyAdapter says...
Gobble gobble
I'm flying a short distance
I'm flying a short distance
I'm flying a short distance
I'm flying a short distance
I'm flying a short distance
```

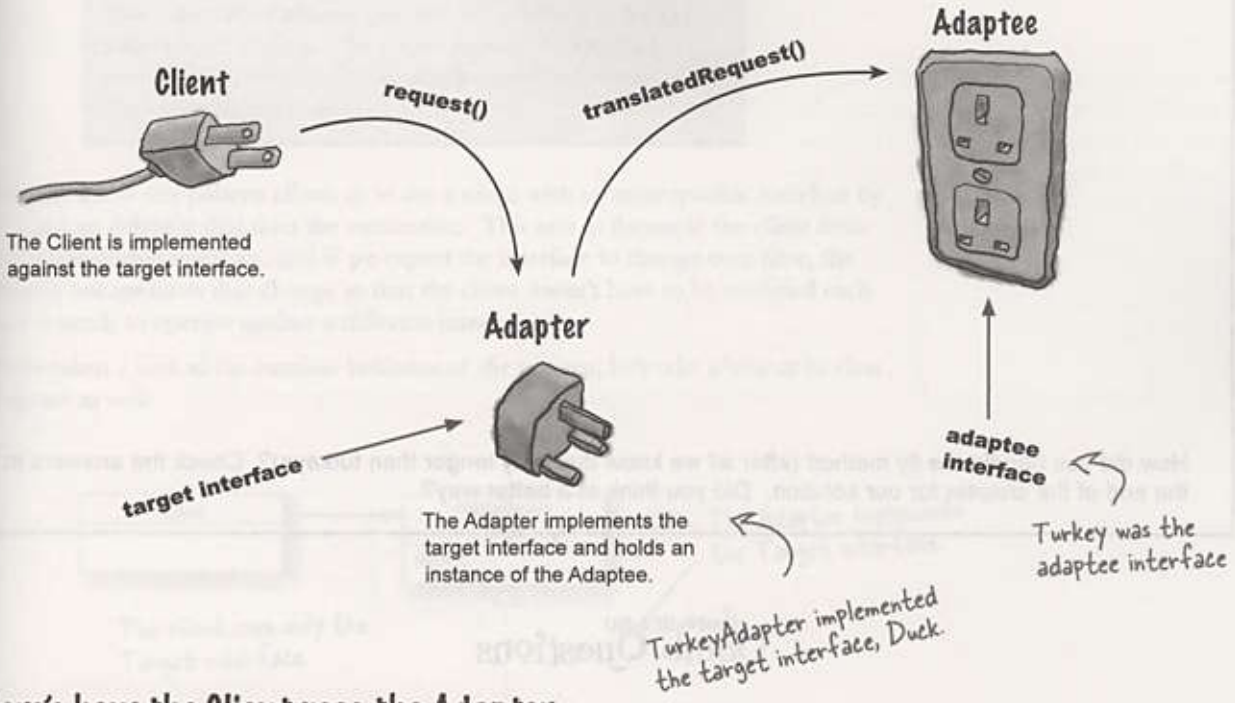
The Turkey gobbles and flies a short distance.

The Duck quacks and flies just like you'd expect.

And the adapter gobbles when quack() is called and flies a few times when fly() is called. The testDuck() method never knows it has a turkey disguised as a duck!

The Adapter Pattern explained

Now that we have an idea of what an Adapter is, let's step back and look at all the pieces again.



Here's how the Client uses the Adapter

1. **The client makes a request to the adapter by calling a method on it using the target interface.**
2. **The adapter translates that request into one or more calls on the adaptee using the adaptee interface.**
3. **The client receives the results of the call and never knows there is an adapter doing the translation.**

Note that the Client and Adaptee are decoupled – neither knows about the other.

Sharpen your pencil

Let's say we also need an Adapter that converts a Duck to a Turkey. Let's call it DuckAdapter. Write that class:

How did you handle the fly method (after all we know ducks fly longer than turkeys)? Check the answers at the end of the chapter for our solution. Did you think of a better way?

there are no Dumb Questions

Q: How much "adapting" does an adapter need to do? It seems like if I need to implement a large target interface, I could have a LOT of work on my hands.

A: You certainly could. The job of implementing an adapter really is proportional to the size of the interface you need to support as your target interface. Think about your options, however. You could rework all your client-side calls to the interface, which would result in a lot of investigative work and code changes. Or, you can cleanly provide one class that encapsulates all the changes in one class.

Q: Does an adapter always wrap one and only one class?

A: The Adapter Pattern's role is to convert one interface into another. While most examples of the adapter pattern show an adapter wrapping one adaptee, we both know the world is often a bit more messy. So, you may well have situations where an adapter holds two or more adaptees that are needed to implement the target interface.

This relates to another pattern called the Facade Pattern; people often confuse the two. Remind us to revisit this point when we talk about facades later in this chapter.

Q: What if I have old and new parts of my system, the old parts expect the old vendor interface, but we've already written the new parts to use the new vendor interface? It is going to get confusing using an adapter here and the unwrapped interface there. Wouldn't I be better off just writing my older code and forgetting the adapter?

A: Not necessarily. One thing you can do is create a Two Way Adapter that supports both interfaces. To create a Two Way Adapter, just implement both interfaces involved, so the adapter can act as an old interface or a new interface.

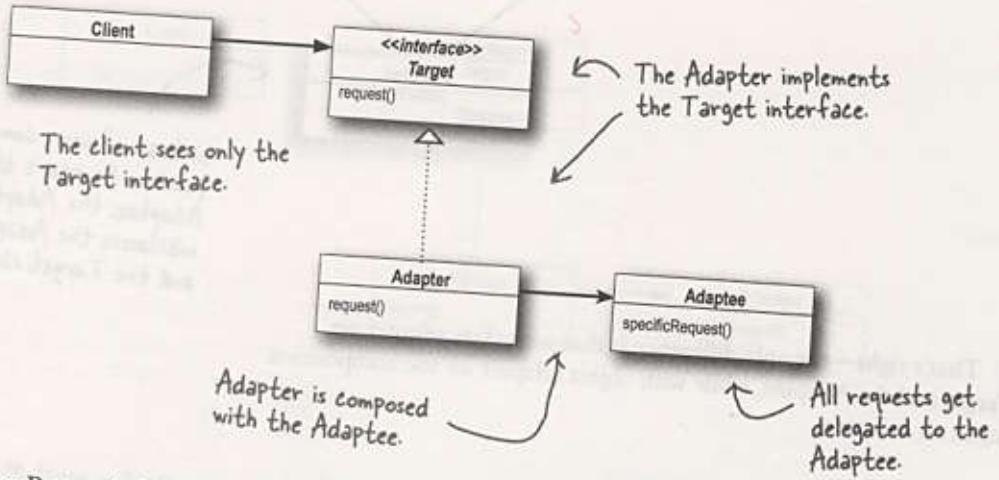
Adapter Pattern defined

Enough ducks, turkeys and AC power adapters; let's get real and look at the official definition of the Adapter Pattern:

> **The Adapter Pattern** converts the interface of a class into another interface the clients expect. Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.

Now, we know this pattern allows us to use a client with an incompatible interface by creating an Adapter that does the conversion. This acts to decouple the client from the implemented interface, and if we expect the interface to change over time, the adapter encapsulates that change so that the client doesn't have to be modified each time it needs to operate against a different interface.

We've taken a look at the runtime behavior of the pattern; let's take a look at its class diagram as well:



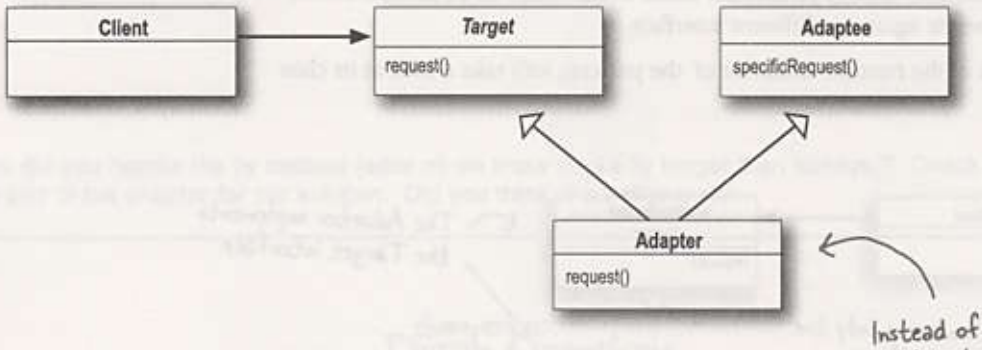
The Adapter Pattern is full of good OO design principles: check out the use of object composition to wrap the adaptee with an altered interface. This approach has the added advantage that we can use an adapter with any subclass of the adaptee.

Also check out how the pattern binds the client to an interface, not an implementation; we could use several adapters, each converting a different backend set of classes. Or, we could add new implementations after the fact, as long as they adhere to the Target interface.

Object and class adapters

Now despite having defined the pattern, we haven't told you the whole story yet. There are actually *two* kinds of adapters: *object* adapters and *class* adapters. This chapter has covered object adapters and the class diagram on the previous page is a diagram of an object adapter.

So what's a *class* adapter and why haven't we told you about it? Because you need multiple inheritance to implement it, which isn't possible in Java. But, that doesn't mean you might not encounter a need for class adapters down the road when using your favorite multiple inheritance language! Let's look at the class diagram for multiple inheritance.



Look familiar? That's right – the only difference is that with class adapter we subclass the Target and the Adaptee, while with object adapter we use composition to pass requests to an Adaptee.

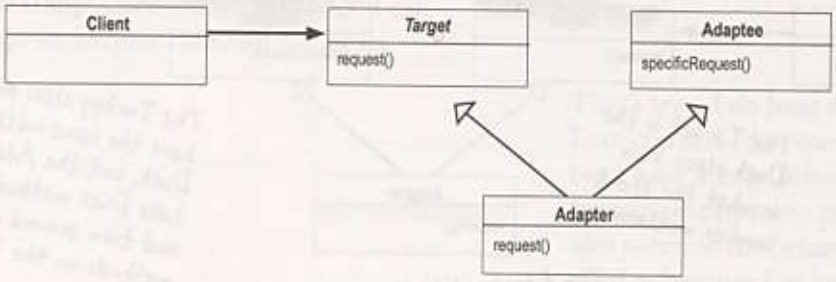
BRAIN POWER

Object adapters and class adapters use two different means of adapting the adaptee (composition versus inheritance). How do these implementation differences affect the flexibility of the adapter?

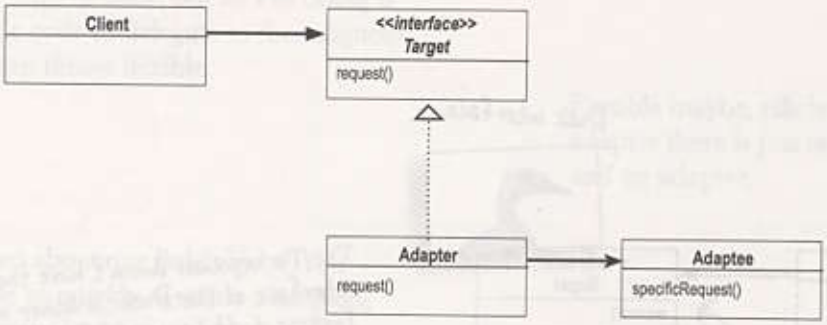
Duck Magnets

Your job is to take the duck and turkey magnets and drag them over the part of the diagram that describes the role played by that bird, in our earlier example. (Try not to flip back through the pages). Then add your own annotations to describe how it works.

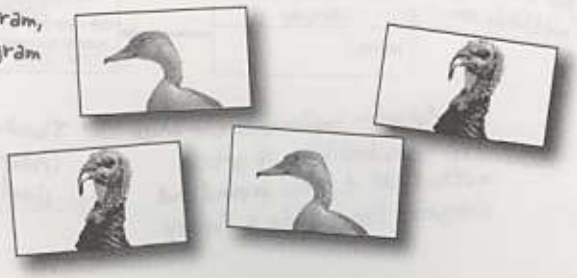
Class Adapter



Object Adapter



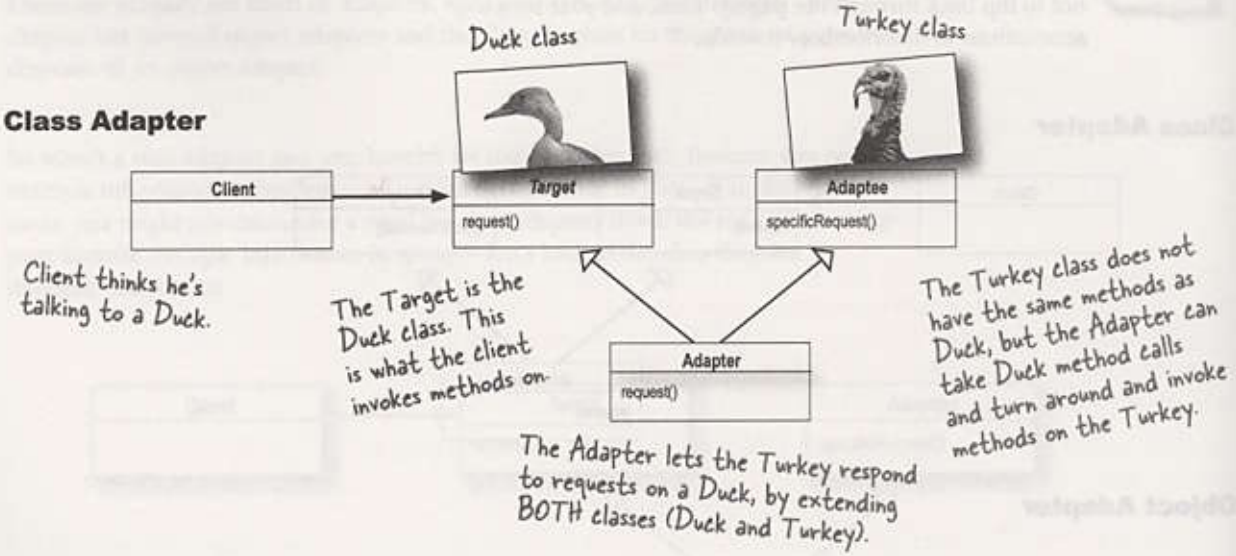
Drag these onto the class diagram, to show which part of the diagram represents the Duck and which represents the Turkey.



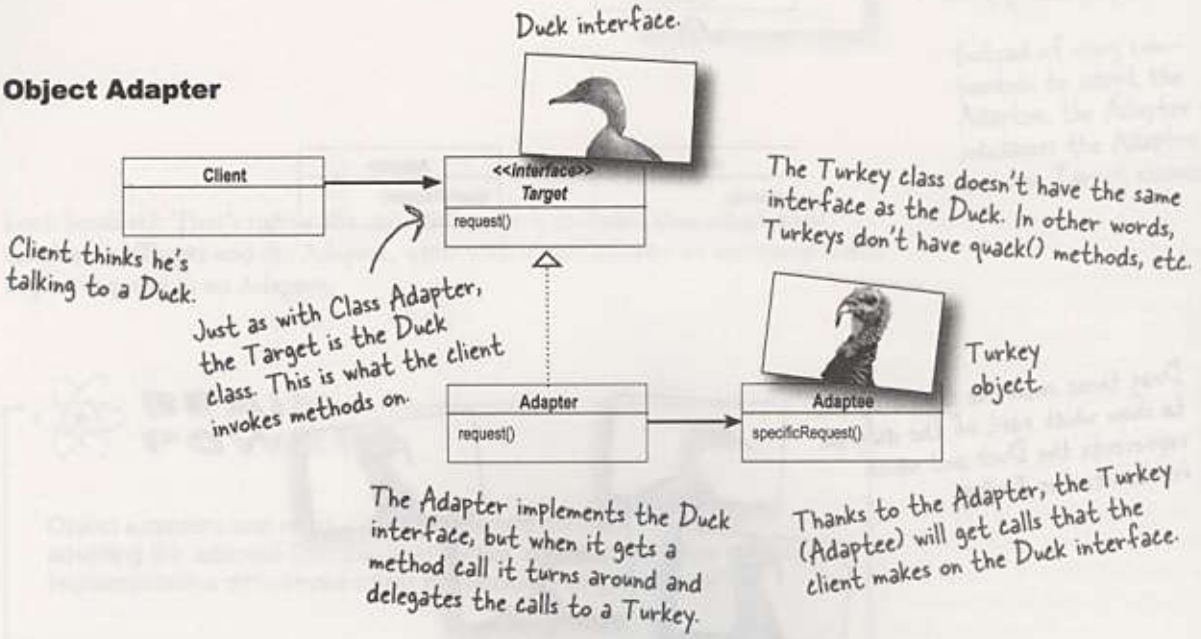
Duck Magnets Answer

Note: the class adapter uses multiple inheritance, so you can't do it in Java...

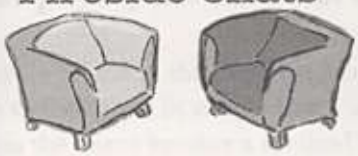
Class Adapter



Object Adapter



Fireside Chats



Tonight's talk: **The Object Adapter and Class Adapter meet face to face.**

Object Adapter

Because I use composition I've got a leg up. I can not only adapt an adaptee class, but any of its subclasses.

In my part of the world, we like to use composition over inheritance; you may be saving a few lines of code, but all I'm doing is writing a little code to delegate to the adaptee. We like to keep things flexible.

You're worried about one little object? You might be able to quickly override a method, but any behavior I add to my adapter code works with my adaptee class *and* all its subclasses.

Hey, come on, cut me a break, I just need to compose with the subclass to make that work.

You wanna see messy? Look in the mirror!

Class Adapter

That's true, I do have trouble with that because I am committed to one specific adaptee class, but I have a huge advantage because I don't have to reimplement my entire adaptee. I can also override the behavior of my adaptee if I need to because I'm just subclassing.

Flexible maybe, efficient? No. Using a class adapter there is just one of me, not an adapter and an adaptee.

Yeah, but what if a subclass of adaptee adds some new behavior. Then what?

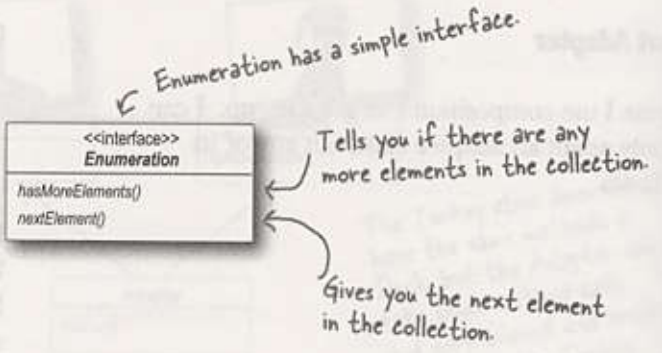
Sounds messy...

Real world adapters

Let's take a look at the use of a simple Adapter in the real world (something more serious than Ducks at least)...

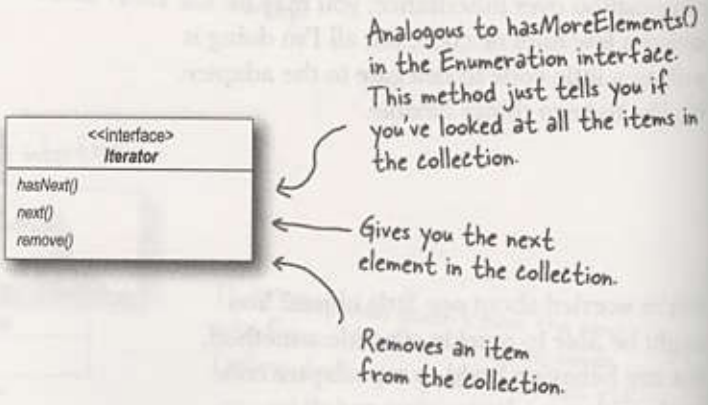
Old world Enumerators

If you've been around Java for a while you probably remember that the early collections types (Vector, Stack, Hashtable, and a few others) implement a method elements(), which returns an Enumeration. The Enumeration interface allows you to step through the elements of a collection without knowing the specifics of how they are managed in the collection.



New world Iterators

When Sun released their more recent Collections classes they began using an Iterator interface that, like Enumeration, allows you to iterate through a set of items in a collection, but also adds the ability to remove items.

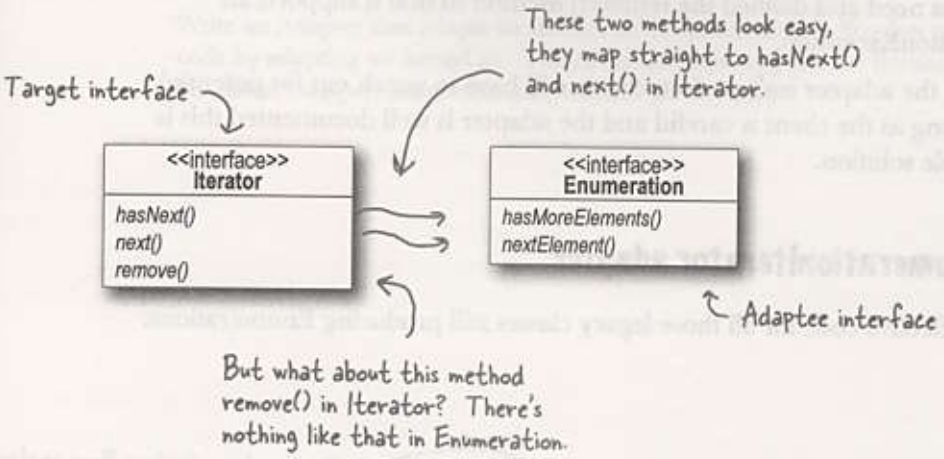


And today...

We are often faced with legacy code that exposes the Enumerator interface, yet we'd like for our new code to only use Iterators. It looks like we need to build an adapter.

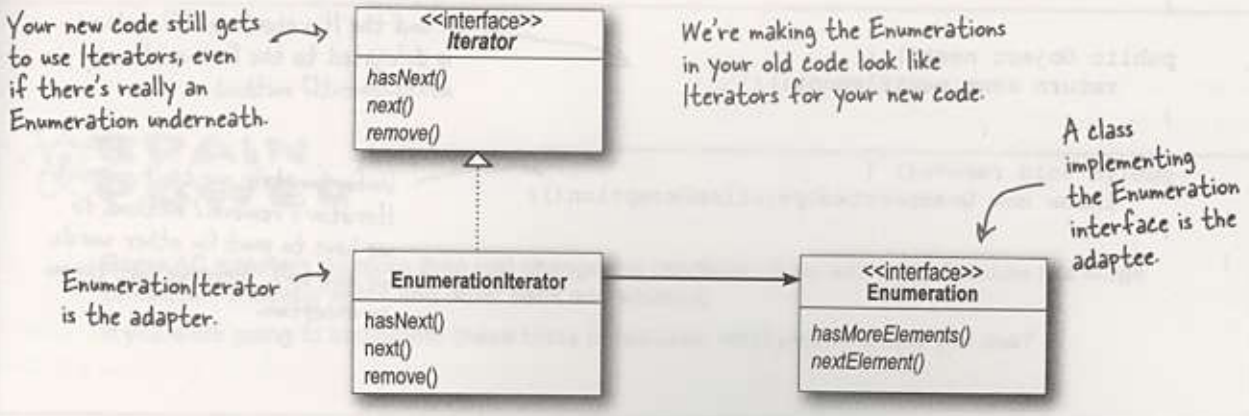
Adapting an Enumeration to an Iterator

First we'll look at the two interfaces to figure out how the methods map from one to the other. In other words, we'll figure out what to call on the adaptee when the client invokes a method on the target.



Designing the Adapter

Here's what the classes should look like: we need an adapter that implements the Target interface and that is composed with an adaptee. The hasNext() and next() methods are going to be straightforward to map from target to adaptee: we just pass them right through. But what do you do about remove()? Think about it for a moment (and we'll deal with it on the next page). For now, here's the class diagram:



Dealing with the remove() method

Well, we know Enumeration just doesn't support remove. It's a "read only" interface. There's no way to implement a fully functioning remove() method on the adapter. The best we can do is throw a runtime exception. Luckily, the designers of the Iterator interface foresaw this need and defined the remove() method so that it supports an UnsupportedOperationException.

This is a case where the adapter isn't perfect; clients will have to watch out for potential exceptions, but as long as the client is careful and the adapter is well documented this is a perfectly reasonable solution.

Writing the EnumerationIterator adapter

Here's simple but effective code for all those legacy classes still producing Enumerations:

```
public class EnumerationIterator implements Iterator
{
    Enumeration enum;

    public EnumerationIterator(Enumeration enum) {
        this.enum = enum;
    }

    public boolean hasNext() {
        return enum.hasMoreElements();
    }

    public Object next() {
        return enum.nextElement();
    }

    public void remove() {
        throw new UnsupportedOperationException();
    }
}
```

Since we're adapting Enumeration to Iterator, our Adapter implements the Iterator interface... it has to look like an Iterator.

The Enumeration we're adapting. We're using composition so we stash it in an instance variable.

The Iterator's hasNext() method is delegated to the Enumeration's hasMoreElements() method...

... and the Iterator's next() method is delegated to the Enumerations's nextElement() method.

Unfortunately, we can't support Iterator's remove() method, so we have to punt (in other words, we give up!). Here we just throw an exception.

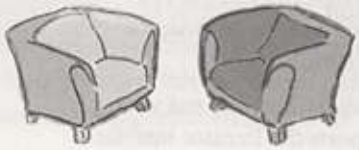
While Java has gone the direction of the Iterator, there is nevertheless a lot of legacy **client code** that depends on the Enumeration interface, so an Adapter that converts an Iterator to an Enumeration is also quite useful.

Write an Adapter that adapts an Iterator to an Enumeration. You can test your code by adapting an ArrayList. The ArrayList class supports the Iterator interface but doesn't support Enumerations (well, not yet anyway).

Some AC adapters do more than just change the interface – they add other features like surge protection, indicator lights and other bells and whistles.

If you were going to implement these kinds of features, what pattern would you use?

Fireside Chats



Tonight's talk: **The Decorator Pattern and the Adapter Pattern discuss their differences.**

Decorator

I'm important. My job is all about *responsibility* – you know that when a Decorator is involved there's going to be some new responsibilities or behaviors added to your design.

That may be true, but don't think we don't work hard. When we have to decorate a big interface, whoa, that can take a lot of code.

Cute. Don't think we get all the glory; sometimes I'm just one decorator that is being wrapped by who knows how many other decorators. When a method call gets delegated to you, you have no idea how many other decorators have already dealt with it and you don't know that you'll ever get noticed for your efforts servicing the request.

Adapter

You guys want all the glory while us adapters are down in the trenches doing the dirty work: converting interfaces. Our jobs may not be glamorous, but our clients sure do appreciate us making their lives simpler.

Try being an adapter when you've got to bring several classes together to provide the interface your client is expecting. Now that's tough. But we have a saying: "an uncoupled client is a happy client."

Hey, if adapters are doing their job, our clients never even know we're there. It can be a thankless job.

Decorator

Well us decorators do that as well, only we allow *new behavior* to be added to classes without altering existing code. I still say that adapters are just fancy decorators – I mean, just like us, you wrap an object.

Uh, no. Our job in life is to extend the behaviors or responsibilities of the objects we wrap, we aren't a *simple pass through*.

Maybe we should agree to disagree. We seem to look somewhat similar on paper, but clearly we are *miles* away in our *intent*.

Adapter

But, the great thing about us adapters is that we allow clients to make use of new libraries and subsets without changing *any* code, they just rely on us to do the conversion for them. Hey, it's a niche, but we're good at it.

No, no, no, not at all. We *always* convert the interface of what we wrap, you *never* do. I'd say a decorator is like an adapter; it is just that you don't change the interface!

Hey, who are you calling a simple pass through? Come on down and we'll see how long *you* last converting a few interfaces!

Oh yeah, I'm with you there.

And now for something different...

There's another pattern in this chapter.

You've seen how the Adapter Pattern converts the interface of a class into one that a client is expecting. You also know we achieve this in Java by wrapping the object that has an incompatible interface with an object that implements the correct one.

We're going to look at a pattern now that alters an interface, but for a different reason: to simplify the interface. It's aptly named the Facade Pattern because this pattern hides all the complexity of one or more classes behind a clean, well-lit facade.

Match each pattern with its intent:

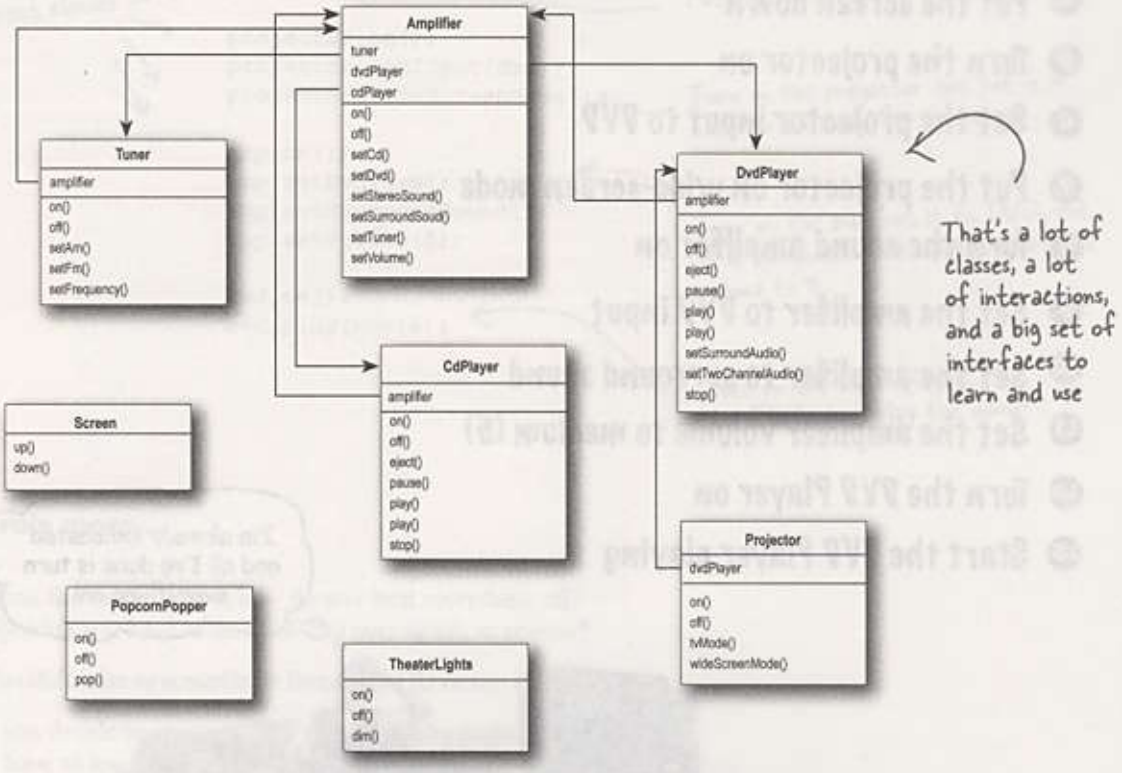
Pattern	Intent
Decorator	Converts one interface to another
Adapter	Doesn't alter the interface, but adds responsibility
Facade	Makes an interface simpler

Home Sweet Home Theater

Before we dive into the details of the Facade Pattern, let's take a look at a growing national obsession: building your own home theater.

You've done your research and you've assembled a killer system complete with a DVD player, a projection video system, an automated screen, surround sound and even a popcorn popper.

Check out all the components you've put together:



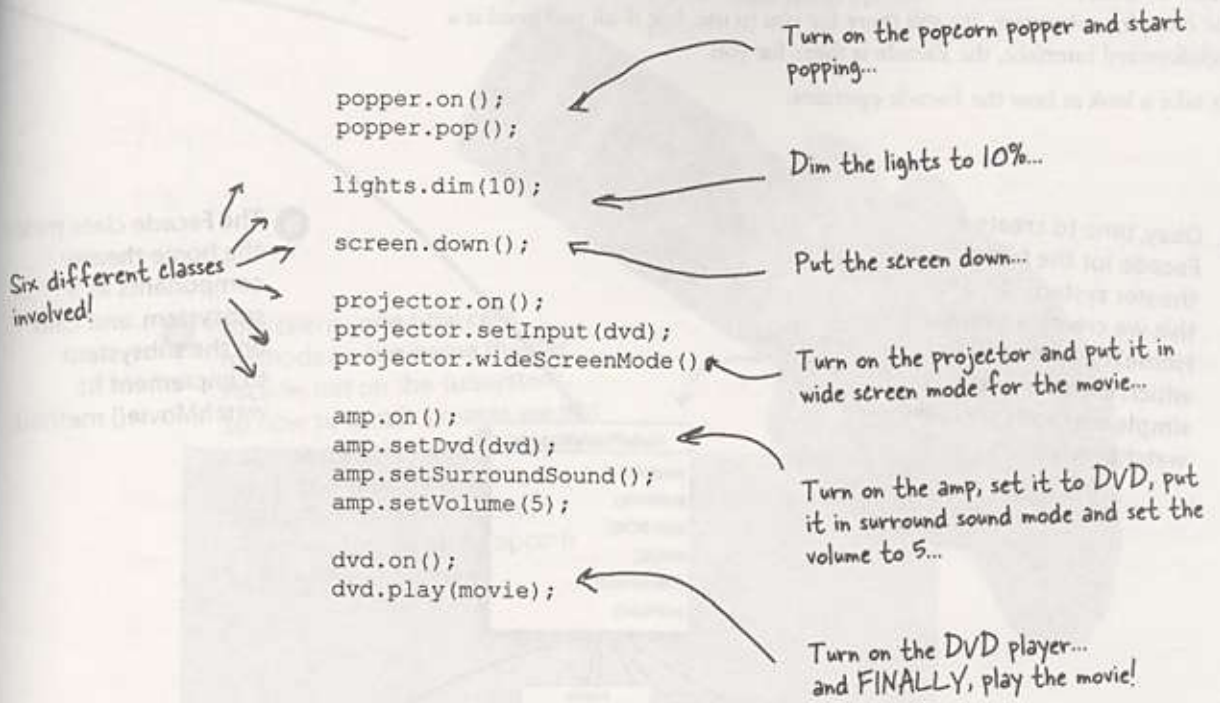
You've spent weeks running wire, mounting the projector, making all the connections and fine tuning. Now it's time to put it all in motion and enjoy a movie...

Watching a movie (the hard way)

Pick out a DVD, relax, and get ready for movie magic. Oh, there's just one thing – to watch the movie, you need to perform a few tasks:

1. Turn on the popcorn popper
2. Start the popper popping
3. Dim the lights
4. Put the screen down
5. Turn the projector on
6. Set the projector input to DVD
7. Put the projector on wide-screen mode
8. Turn the sound amplifier on
9. Set the amplifier to DVD input
10. Set the amplifier to surround sound
11. Set the amplifier volume to medium (5)
12. Turn the DVD Player on
13. Start the DVD Player playing

Let's check out those same tasks in terms of the classes and the method calls needed to perform them:



But there's more...

- When the movie is over, how do you turn everything off? Wouldn't you have to do all of this over again, in reverse?
- Wouldn't it be as complex to listen to a CD or the radio?
- If you decide to upgrade your system, you're probably going to have to learn a slightly different procedure.

So what to do? The complexity of using your home theater is becoming apparent!

Let's see how the Facade Pattern can get us out of this mess so we can enjoy the movie...

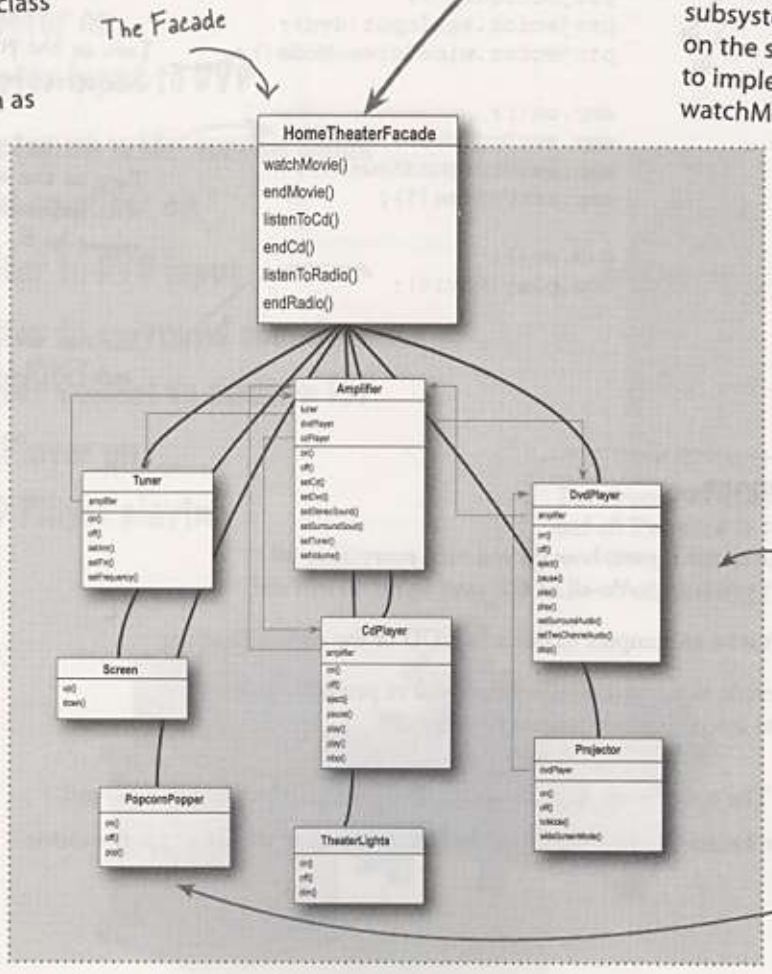
Lights, Camera, Facade!

A Facade is just what you need: with the Facade Pattern you can take a complex subsystem and make it easier to use by implementing a Facade class that provides one, more reasonable interface. Don't worry; if you need the power of the complex subsystem, it's still there for you to use, but if all you need is a straightforward interface, the Facade is there for you.

Let's take a look at how the Facade operates:

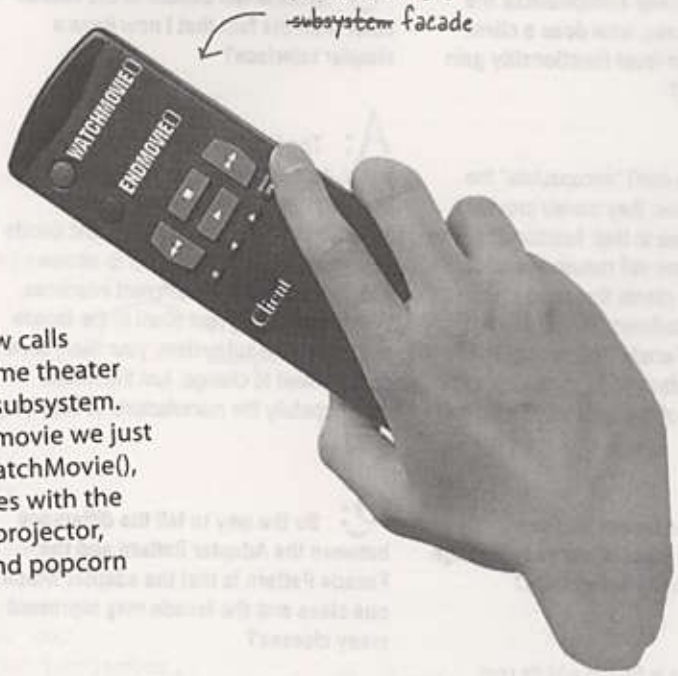
❶ Okay, time to create a Facade for the home theater system. To do this we create a new class HomeTheaterFacade, which exposes a few simple methods such as watchMovie().

❷ The Facade class treats the home theater components as a subsystem, and calls on the subsystem to implement its watchMovie() method.

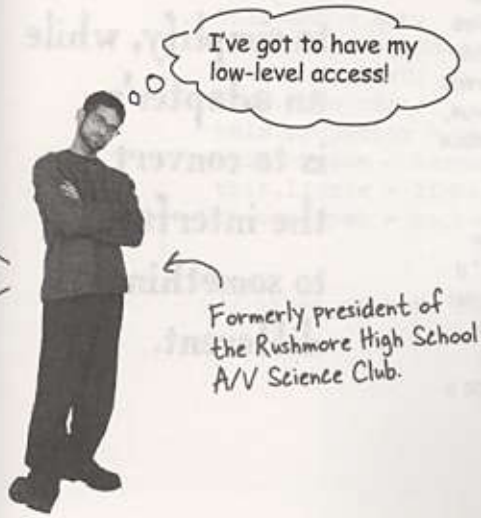


watchMovie()

A client of the ~~subsystem~~ facade



3 Your client code now calls methods on the home theater Facade, not on the subsystem. So now to watch a movie we just call one method, watchMovie(), and it communicates with the lights, DVD player, projector, amplifier, screen, and popcorn maker for us.



Formerly president of the Rushmore High School A/V Science Club.

4 The Facade still leaves the subsystem accessible to be used directly. If you need the advanced functionality of the subsystem classes, they are available for your use.

there are no Dumb Questions

Q: If the Facade encapsulates the subsystem classes, how does a client that needs lower-level functionality gain access to them?

A: Facades don't "encapsulate" the subsystem classes; they merely provide a simplified interface to their functionality. The subsystem classes still remain available for direct use by clients that need to use more specific interfaces. This is a nice property of the Facade Pattern: it provides a simplified interface while still exposing the full functionality of the system to those who may need it.

Q: Does the facade add any functionality or does it just pass through each request to the subsystem?

A: A facade is free to add its own "smarts" in addition to making use of the subsystem. For instance, while our home theater facade doesn't implement any new behavior, it is smart enough to know that the popcorn popper has to be turned on before it can pop (as well as the details of how to turn on and stage a movie showing).

Q: Does each subsystem have only one facade?

A: Not necessarily. The pattern certainly allows for any number of facades to be created for a given subsystem.

Q: What is the benefit of the facade other than the fact that I now have a simpler interface?

A: The Facade Pattern also allows you to decouple your client implementation from any one subsystem. Let's say for instance that you get a big raise and decide to upgrade your home theater to all new components that have different interfaces. Well, if you coded your client to the facade rather than the subsystem, your client code doesn't need to change, just the facade (and hopefully the manufacturer is supplying that!).

Q: So the way to tell the difference between the Adapter Pattern and the Facade Pattern is that the adapter wraps one class and the facade may represent many classes?

A: No! Remember, the Adapter Pattern changes the interface of one or more classes into one interface that a client is expecting. While most textbook examples show the adapter adapting one class, you may need to adapt many classes to provide the interface a client is coded to. Likewise, a Facade may provide a simplified interface to a single class with a very complex interface.

The difference between the two is not in terms of how many classes they "wrap," it is in their **intent**. The intent of the Adapter Pattern is to **alter** an interface so that it matches one a client is expecting. The intent of the Facade Pattern is to provide a **simplified** interface to a subsystem.

A facade not only simplifies an interface, it decouples a client from a subsystem of components.

Facades and adapters may wrap multiple classes, but a facade's intent is to simplify, while an adapter's is to convert the interface to something different.

Constructing your home theater facade

Let's step through the construction of the HomeTheaterFacade: The first step is to use composition so that the facade has access to all the components of the subsystem:

```
public class HomeTheaterFacade {
    Amplifier amp;
    Tuner tuner;
    DvdPlayer dvd;
    CdPlayer cd;
    Projector projector;
    TheaterLights lights;
    Screen screen;
    PopcornPopper popper;

    public HomeTheaterFacade(Amplifier amp,
                             Tuner tuner,
                             DvdPlayer dvd,
                             CdPlayer cd,
                             Projector projector,
                             Screen screen,
                             TheaterLights lights,
                             PopcornPopper popper) {

        this.amp = amp;
        this.tuner = tuner;
        this.dvd = dvd;
        this.cd = cd;
        this.projector = projector;
        this.screen = screen;
        this.lights = lights;
        this.popper = popper;
    }

    // other methods here

}
```

Here's the composition; these are all the components of the subsystem we are going to use.

The facade is passed a reference to each component of the subsystem in its constructor. The facade then assigns each to the corresponding instance variable.

We're just about to fill these in...

Implementing the simplified interface

Now it's time to bring the components of the subsystem together into a unified interface. Let's implement the watchMovie() and endMovie() methods:

```
public void watchMovie(String movie) {
    System.out.println("Get ready to watch a movie...");
    popper.on();
    popper.pop();
    lights.dim(10);
    screen.down();
    projector.on();
    projector.wideScreenMode();
    amp.on();
    amp.setDvd(dvd);
    amp.setSurroundSound();
    amp.setVolume(5);
    dvd.on();
    dvd.play(movie);
}

public void endMovie() {
    System.out.println("Shutting movie theater down...");
    popper.off();
    lights.on();
    screen.up();
    projector.off();
    amp.off();
    dvd.stop();
    dvd.eject();
    dvd.off();
}
```

watchMovie() follows the same sequence we had to do by hand before, but wraps it up in a handy method that does all the work. Notice that for each task we are delegating the responsibility to the corresponding component in the subsystem.

And endMovie() takes care of shutting everything down for us. Again, each task is delegated to the appropriate component in the subsystem.

Think about the facades you've encountered in the Java API. Where would you like to have a few new ones?

Time to watch a movie (the easy way)

It's SHOWTIME!

```
public class HomeTheaterTestDrive {
    public static void main(String[] args) {
        // instantiate components here

        HomeTheaterFacade homeTheater =
                new HomeTheaterFacade(amp, tuner, dvd, cd,
                        projector, screen, lights, popper);

        homeTheater.watchMovie("Raiders of the Lost Ark");
        homeTheater.endMovie();
    }
}
```

Here we're creating the components right in the test drive. Normally the client is given a facade, it doesn't have to construct one itself.

First you instantiate the Facade with all the components in the subsystem.

Use the simplified interface to first start the movie up, and then shut it down.

Here's the output.

Calling the Facade's watchMovie() does all this work for us...

...and here, we're done watching the movie, so calling endMovie() turns everything off.

```
File Edit Window Help SnakesWhy'dItHaveToBeSnakes?
%java HomeTheaterTestDrive
Get ready to watch a movie...
Popcorn Popper on
Popcorn Popper popping popcorn!
Theater Ceiling Lights dimming to 10%
Theater Screen going down
Top-O-Line Projector on
Top-O-Line Projector in widescreen mode (16x9 aspect ratio)
Top-O-Line Amplifier on
Top-O-Line Amplifier setting DVD player to Top-O-Line DVD Player
Top-O-Line Amplifier surround sound on (5 speakers, 1 subwoofer)
Top-O-Line Amplifier setting volume to 5
Top-O-Line DVD Player on
Top-O-Line DVD Player playing "Raiders of the Lost Ark"
Shutting movie theater down...
Popcorn Popper off
Theater Ceiling Lights on
Theater Screen going up
Top-O-Line Projector off
Top-O-Line Amplifier off
Top-O-Line DVD Player stopped "Raiders of the Lost Ark"
Top-O-Line DVD Player eject
Top-O-Line DVD Player off
%
```

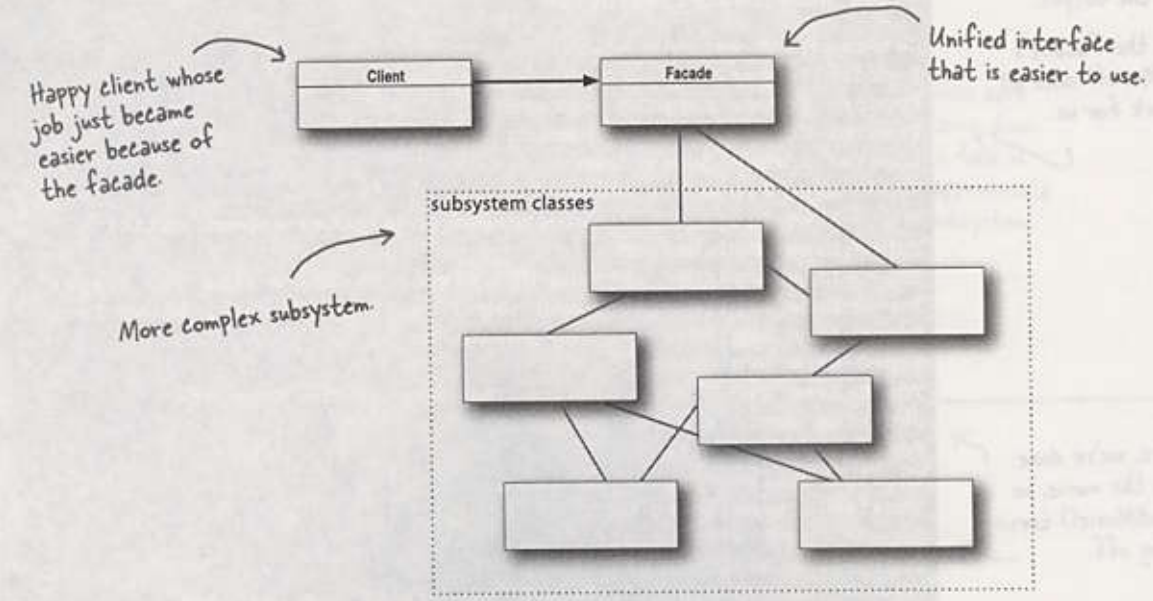
Facade Pattern defined

To use the Facade Pattern, we create a class that simplifies and unifies a set of more complex classes that belong to some subsystem. Unlike a lot of patterns, Facade is fairly straightforward; there are no mind bending abstractions to get your head around. But that doesn't make it any less powerful: the Facade Pattern allows us to avoid tight coupling between clients and subsystems, and, as you will see shortly, also helps us adhere to a new object oriented principle.

Before we introduce that new principle, let's take a look at the official definition of the pattern:

> **The Facade Pattern** provides a unified interface to a set of interfaces in a subsytem. Facade defines a higher-level interface that makes the subsystem easier to use.

There isn't a lot here that you don't already know, but one of the most important things to remember about a pattern is its intent. This definition tells us loud and clear that the purpose of the facade it to make a subsystem easier to use through a simplified interface. You can see this in the pattern's class diagram:



That's it; you've got another pattern under your belt! Now, it's time for that new OO principle. Watch out, this one can challenge some assumptions!

The Principle of Least Knowledge

The Principle of Least Knowledge guides us to reduce the interactions between objects to just a few close "friends." The principle is usually stated as:

Design Principle

Principle of Least Knowledge - talk only to your immediate friends.

But what does this mean in real terms? It means when you are designing a system, for any object, be careful of the number of classes it interacts with and also how it comes to interact with those classes.

This principle prevents us from creating designs that have a large number of classes coupled together so that changes in one part of the system cascade to other parts. When you build a lot of dependencies between many classes, you are building a fragile system that will be costly to maintain and complex for others to understand.

How many classes is this code coupled to?

```
public float getTemp() {
    return station.getThermometer().getTemperature();
}
```

How NOT to Win Friends and Influence Objects

Okay, but how do you keep from doing this? The principle provides some guidelines: take any object; now from any method in that object, the principle tells us that we should only invoke methods that belong to:

- The object itself
- Objects passed in as a parameter to the method
- Any object the method creates or instantiates
- Any components of the object

Notice that these guidelines tell us not to call methods on objects that were returned from calling other methods!!

Think of a "component" as any object that is referenced by an instance variable. In other words think of this as a HAS-A relationship.

This sounds kind of stringent doesn't it? What's the harm in calling the method of an object we get back from another call? Well, if we were to do that, then we'd be making a request of another object's subpart (and increasing the number of objects we directly know). In such cases, the principle forces us to ask the object to make the request for us; that way we don't have to know about its component objects (and we keep our circle of friends small). For example:

Without the Principle

```
public float getTemp() {
    Thermometer thermometer = station.getThermometer();
    return thermometer.getTemperature();
}
```

Here we get the thermometer object from the station and then call the getTemperature() method ourselves.

With the Principle

```
public float getTemp() {
    return station.getTemperature();
}
```

When we apply the principle, we add a method to the Station class that makes the request to the thermometer for us. This reduces the number of classes we're dependent on.