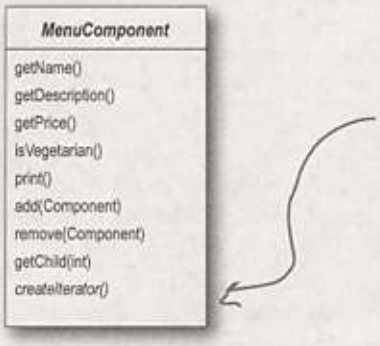
Flashback to Iterator

We promised you a few pages back that we'd show you how to use Iterator with a Composite. You know that we are already using Iterator in our internal implementation of the print() method, but we can also allow the Waitress to iterate over an entire composite if she needs to, for instance, if she wants to go through the entire menu and pull out vegetarian items.

To implement a Composite iterator, let's add a createIterator() method in every component. We'll start with the abstract MenuComponent class:



We've added a createIterator() method to the MenuComponent. This means that each Menu and MenuItem will need to implement this method. It also means that calling createIterator() on a composite should apply to all children of the composite.

Now we need to implement this method in the Menu and MenuItem classes:

```
public class Menu extends MenuComponent {

    // other code here doesn't change

    public Iterator createIterator() {
        return new CompositeIterator(menuComponents.iterator());
    }

}
```

Here we're using a new iterator called CompositeIterator. It knows how to iterate over any composite. We pass it the current composite's iterator.

```
public class MenuItem extends MenuComponent {

    // other code here doesn't change

    public Iterator createIterator() {
        return new NullIterator();
    }

}
```

Now for the MenuItem...

Whoa! What's this NullIterator? You'll see in two pages.

The Composite Iterator

The CompositeIterator is a SERIOUS iterator. It's got the job of iterating over the MenuItems in the component, and of making sure all the child Menus (and child child Menus, and so on) are included.

Here's the code. Watch out, this isn't a lot of code, but it can be a little mind bending. Just repeat to yourself as you go through it "recursion is my friend, recursion is my friend."

WATCH OUT: RECURSION ZONE AHEAD

Like all iterators, we're implementing the java.util.Iterator interface.

```
import java.util.*;

public class CompositeIterator implements Iterator {
    Stack stack = new Stack();

    public CompositeIterator(Iterator iterator) {
        stack.push(iterator);
    }

    public Object next() {
        if (hasNext()) {
            Iterator iterator = (Iterator) stack.peek();
            MenuComponent component = (MenuComponent) iterator.next();
            if (component instanceof Menu) {
                stack.push(component.createIterator());
            }
            return component;
        } else {
            return null;
        }
    }

    public boolean hasNext() {
        if (stack.empty()) {
            return false;
        } else {
            Iterator iterator = (Iterator) stack.peek();
            if (!iterator.hasNext()) {
                stack.pop();
                return hasNext();
            } else {
                return true;
            }
        }
    }

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

The iterator of the top level composite we're going to iterate over is passed in. We throw that in a stack data structure.

Okay, when the client wants to get the next element we first make sure there is one by calling hasNext()...

If there is a next element, we get the current iterator off the stack and get its next element.

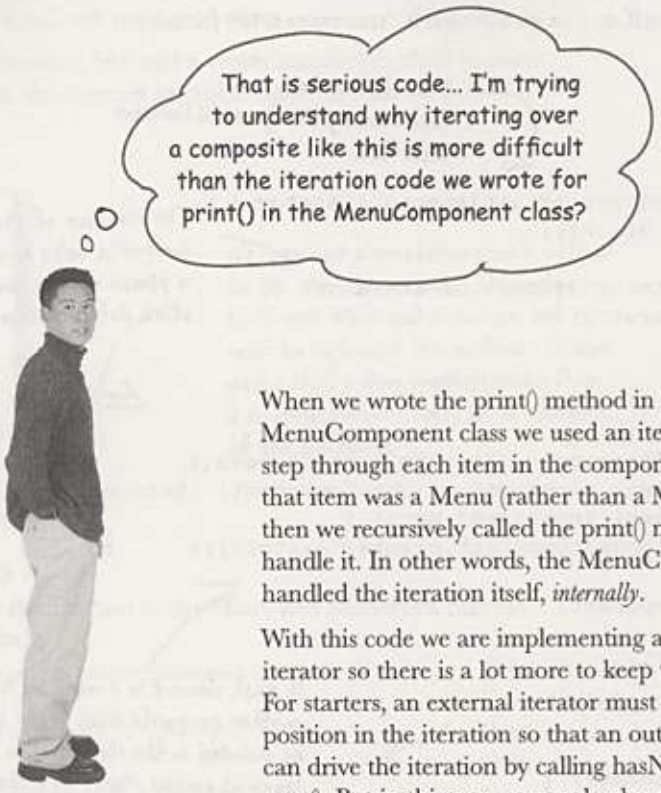
If that element is a menu, we have another composite that needs to be included in the iteration, so we throw it on the stack. In either case, we return the component.

To see if there is a next element, we check to see if the stack is empty; if so, there isn't.

Otherwise, we get the iterator off the top of the stack and see if it has a next element. If it doesn't we pop it off the stack and call hasNext() recursively.

Otherwise there is a next element and we return true.

We're not supporting remove, just traversal.



When we wrote the print() method in the MenuComponent class we used an iterator to step through each item in the component and if that item was a Menu (rather than a MenuItem), then we recursively called the print() method to handle it. In other words, the MenuComponent handled the iteration itself, *internally*.

With this code we are implementing an *external* iterator so there is a lot more to keep track of. For starters, an external iterator must maintain its position in the iteration so that an outside client can drive the iteration by calling hasNext() and next(). But in this case, our code also needs to maintain that position over a composite, recursive structure. That's why we use stacks to maintain our position as we move up and down the composite hierarchy.

Draw a diagram of the Menus and MenuItems. Then pretend you are the CompositeIterator, and your job is to handle calls to hasNext() and next(). Trace the way the CompositeIterator traverses the structure as this code is executed:

```
public void testCompositeIterator(MenuComponent component) {
      CompositeIterator iterator = new CompositeIterator(component.iterator);

      while(iterator.hasNext()) {
            MenuComponent component = iterator.next();
      }
}
```

The Null Iterator

Okay, now what is this Null Iterator all about? Think about it this way: a MenuItem has nothing to iterate over, right? So how do we handle the implementation of its createIterator() method? Well, we have two choices:

NOTE: Another example of the Null Object "Design Pattern."

Choice one:

Return null

We could return null from createIterator(), but then we'd need conditional code in the client to see if null was returned or not.

Choice two:

Return an iterator that always returns false when hasNext() is called

This seems like a better plan. We can still return an iterator, but the client doesn't have to worry about whether or not null is ever returned. In effect, we're creating an iterator that is a "no op".

The second choice certainly seems better. Let's call it NullIterator and implement it.

This is the laziest Iterator you've ever seen, at every step of the way it punts.

```
import java.util.Iterator;

public class NullIterator implements Iterator {

    public Object next() {
        return null;
    }

    public boolean hasNext() {
        return false;
    }

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

When next() is called, we return null.

Most importantly when hasNext() is called we always return false.

And the NullIterator wouldn't think of supporting remove.

Give me the vegetarian menu

Now we've got a way to iterate over every item of the Menu. Let's take that and give our Waitress a method that can tell us exactly which items are vegetarian.

```
public class Waitress {
    MenuComponent allMenus;

    public Waitress(MenuComponent allMenus) {
        this.allMenus = allMenus;
    }

    public void printMenu() {
        allMenus.print();
    }

    public void printVegetarianMenu() {
        Iterator iterator = allMenus.createIterator();
        System.out.println("\nVEGETARIAN MENU\n----");
        while (iterator.hasNext()) {
            MenuComponent menuComponent =
                    (MenuComponent)iterator.next();
            try {
                if (menuComponent.isVegetarian()) {
                    menuComponent.print();
                }
            } catch (UnsupportedOperationException e) {}
        }
    }
}
```

The printVegetarianMenu() method takes the allMenu's composite and gets its iterator. That will be our CompositeIterator.

Iterate through every element of the composite.

Call each element's isVegetarian() method and if true, we call its print() method.

print() is only called on MenuItems, never composites. Can you see why?

We implemented isVegetarian() on the Menus to always throw an exception. If that happens we catch the exception, but continue with our iteration.

The magic of Iterator & Composite together...

Whooo! It's been quite a development effort to get our code to this point. Now we've got a general menu structure that should last the growing Diner empire for some time. Now it's time to sit back and order up some veggie food:

```
File Edit Window Help HaveUhuggedYuriteratorToday?
% java MenuTestDrive
VEGETARIAN MENU
----
  K&B's Pancake Breakfast(v), 2.99
     -- Pancakes with scrambled eggs, and toast
  Blueberry Pancakes(v), 3.49
     -- Pancakes made with fresh blueberries, and blueberry syrup
  Waffles(v), 3.59
     -- Waffles, with your choice of blueberries or strawberries
  Vegetarian BLT(v), 2.99
     -- (Fakin') Bacon with lettuce & tomato on whole wheat
  Steamed Veggies and Brown Rice(v), 3.99
     -- Steamed vegetables over brown rice
  Pasta(v), 3.89
     -- Spaghetti with Marinara Sauce, and a slice of sourdough bread
  Apple Pie(v), 1.59
     -- Apple pie with a flakey crust, topped with vanilla icecream
  Cheesecake(v), 1.99
     -- Creamy New York cheesecake, with a chocolate graham crust
  Sorbet(v), 1.89
     -- A scoop of raspberry and a scoop of lime
  Apple Pie(v), 1.59
     -- Apple pie with a flakey crust, topped with vanilla icecream
  Cheesecake(v), 1.99
     -- Creamy New York cheesecake, with a chocolate graham crust
  Sorbet(v), 1.89
     -- A scoop of raspberry and a scoop of lime
  Veggie Burger and Air Fries(v), 3.99
     -- Veggie burger on a whole wheat bun, lettuce, tomato, and fries
  Burrito(v), 4.29
     -- A large burrito, with whole pinto beans, salsa, guacamole
%
```

The Vegetarian Menu consists of the vegetarian items from every menu.

I noticed in your printVegetarianMenu() method that you used the try/catch to handle the logic of the Menus not supporting the isVegetarian() method. I've always heard that isn't good programming form.

Let's take a look at what you're talking about:

```
try {
    if (menuComponent.isVegetarian()) {
        menuComponent.print();
    }
} catch (UnsupportedOperationException) {}
```

We call isVegetarian() on all MenuComponents, but Menus throw an exception because they don't support the operation.

If the menu component doesn't support the operation, we just throw away the exception and ignore it.

In general we agree; try/catch is meant for error handling, not program logic. What are our other options? We could have checked the runtime type of the menu component with instanceof to make sure it's a MenuItem before making the call to isVegetarian(). But in the process we'd lose *transparency* because we wouldn't be treating Menus and MenuItems uniformly.

We could also change isVegetarian() in the Menus so that it returns false. This provides a simple solution and we keep our transparency.

In our solution we are going for clarity: we really want to communicate that this is an unsupported operation on the Menu (which is different than saying isVegetarian() is false). It also allows for someone to come along and actually implement a reasonable isVegetarian() method for Menu and have it work with the existing code.

That's our story and we're stickin' to it.

Patterns Exposed

This week's interview:
The Composite Pattern, on Implementation issues

HeadFirst: We're here tonight speaking with the Composite Pattern. Why don't you tell us a little about yourself, Composite?

Composite: Sure... I'm the pattern to use when you have collections of objects with whole-part relationships and you want to be able to treat those objects uniformly.

HeadFirst: Okay, let's dive right in here... what do you mean by whole-part relationships?

Composite: Imagine a graphical user interface; there you'll often find a top level component like a Frame or a Panel, containing other components, like menus, text panes, scrollbars and buttons. So your GUI consists of several parts, but when you display it, you generally think of it as a whole. You tell the top level component to display, and count on that component to display all its parts. We call the components that contain other components, composite objects, and components that don't contain other components, leaf objects.

HeadFirst: Is that what you mean by treating the objects uniformly? Having common methods you can call on composites and leaves?

Composite: Right. I can tell a composite object to display or a leaf object to display and they will do the right thing. The composite object will display by telling all its components to display.

HeadFirst: That implies that every object has the same interface. What if you have objects in your composite that do different things?

Composite: Well, in order for the composite to work transparently to the client, you must implement the same interface for all objects in the composite, otherwise, the client has to worry about which interface each object is implementing, which kind of defeats the purpose. Obviously that means that at times you'll have objects for which some of the method calls don't make sense.

HeadFirst: So how do you handle that?

Composite: Well there's a couple of ways to handle it; sometimes you can just do nothing, or return null or false – whatever makes sense in your application. Other times you'll want to be more proactive and throw an exception. Of course, then the client has to be willing to do a little work and make sure that the method call didn't do something unexpected.

HeadFirst: But if the client doesn't know which kind of object they're dealing with, how would they ever know which calls to make without checking the type?

Composite: If you're a little creative you can structure your methods so that the default implementations do something that does make sense. For instance, if the client is calling getChild(), on the composite this makes sense. And it makes sense on a leaf too, if you think of the leaf as an object with no children.

HeadFirst: Ah... smart. But, I've heard some clients are so worried about this issue, that they require separate interfaces for different objects so they aren't allowed to make nonsensical method calls. Is that still the Composite Pattern?

Composite: Yes. It's a much safer version of the Composite Pattern, but it requires the client to check the type of every object before making a call so the object can be cast correctly.

HeadFirst: Tell us a little more about how these composite and leaf objects are structured.

Composite: Usually it's a tree structure, some kind of hierarchy. The root is the top level composite, and all its children are either composites or leaf nodes.

HeadFirst: Do children ever point back up to their parents?

Composite: Yes, a component can have a pointer to a parent to make traversal of the structure easier. And, if you have a reference to a child, and you need to delete it, you'll need to get the parent to remove the child. Having the parent reference makes that easier too.

HeadFirst: There's really quite a lot to consider in your implementation. Are there other issues we should think about when implementing the Composite Pattern?

Composite: Actually there are... one is the ordering of children. What if you have a composite that needs to keep its children in a particular order? Then you'll need a more sophisticated management scheme for adding and removing children, and you'll have to be careful about how you traverse the hierarchy.

HeadFirst: A good point I hadn't thought of.

Composite: And did you think about caching?

HeadFirst: Caching?

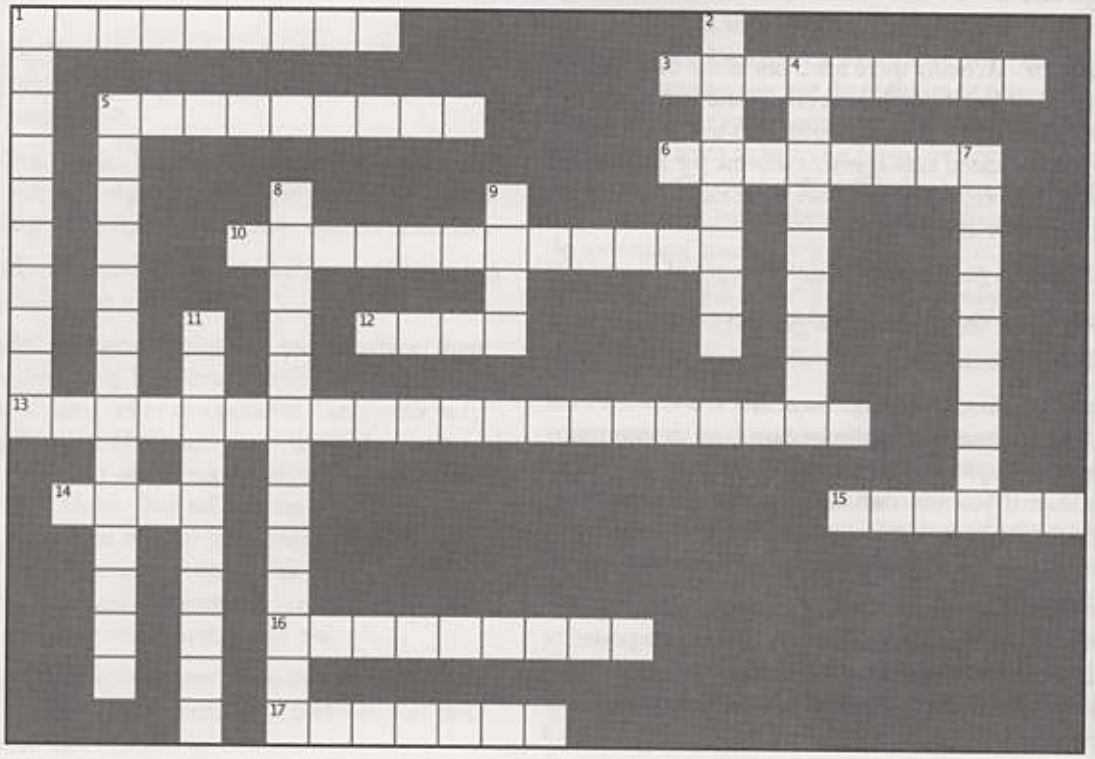
Composite: Yeah, caching. Sometimes, if the composite structure is complex or expensive to traverse, it's helpful to implement caching of the composite nodes. For instance, if you are constantly traversing a composite and all its children to compute some result, you could implement a cache that stores the result temporarily to save traversals.

HeadFirst: Well, there's a lot more to the Composite Patterns than I ever would have guessed. Before we wrap this up, one more question: What do you consider your greatest strength?

Composite: I think I'd definitely have to say simplifying life for my clients. My clients don't have to worry about whether they're dealing with a composite object or a leaf object, so they don't have to write if statements everywhere to make sure they're calling the right methods on the right objects. Often, they can make one method call and execute an operation over an entire structure.

HeadFirst: That does sound like an important benefit. There's no doubt you're a useful pattern to have around for collecting and managing objects. And, with that, we're out of time... Thanks so much for joining us and come back soon for another Patterns Exposed.

It's that time again....



Across

1. User interface packages often use this pattern for their components.
3. Collection and Iterator are in this package
5. We encapsulated this.
6. A separate object that can traverse a collection.
10. Merged with the Diner.
12. Has no children.
13. Name of principle that states only one responsibility per class.
14. Third company acquired.
15. A class should have only one reason to do this.
16. This class indirectly supports Iterator.
17. This menu caused us to change our entire implementation.

Down

1. A composite holds this.
2. We java-enabled her.
4. We deleted PancakeHouseMenuIterator because this class already provides an iterator.
5. The Iterator Pattern decouples the client from the aggregates _____.
7. CompositeIterator used a lot of this.
8. Iterators are usually created using this pattern.
9. A component can be a composite or this.
11. Hashtable and ArrayList both implement this interface.

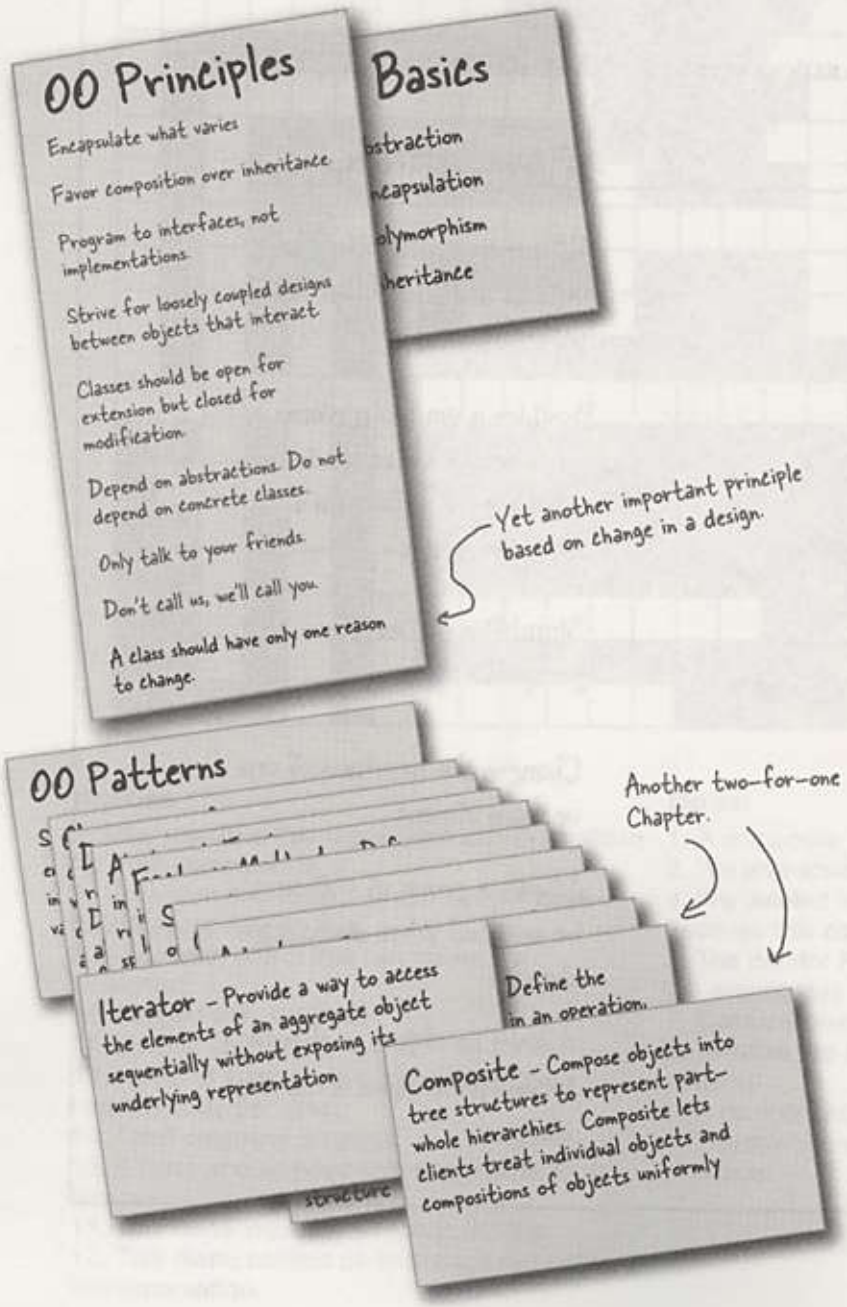
WHO DOES WHAT?

Match each pattern with its description:

Pattern	Description
State	Clients treat collections of objects and individual objects uniformly
Adapter	Provides a way to traverse a collection of objects without exposing the collection's implementation
Iterator	Simplifies the interface of a group of classes
Facade	Changes the interface of one or more classes
Composite	Allows a group of objects to be notified when some state changes
Observer	Allows an object to change its behavior when some state changes

Tools for your Design Toolbox

Two new patterns for your toolbox – two great ways to deal with collections of objects.



BULLET POINTS

- An Iterator allows access to an aggregate's elements without exposing its internal structure.
- An Iterator takes the job of iterating over an aggregate and encapsulates it in another object.
- When using an Iterator, we relieve the aggregate of the responsibility of supporting operations for traversing its data.
- An Iterator provides a common interface for traversing the items of an aggregate, allowing you to use polymorphism when writing code that makes use of the items of the aggregate.
- We should strive to assign only one responsibility to each class.
- The Composite Pattern provides a structure to hold both individual objects and composites.
- The Composite Pattern allows clients to treat composites and individual objects uniformly.
- A Component is any object in a Composite structure. Components may be other composites or leaf nodes.
- There are many design tradeoffs in implementing Composite. You need to balance transparency and safety with your needs.

Exercise solutions

Sharpen your pencil

Based on our implementation of printMenu(), which of the following apply?

- [x] A. We are coding to the PancakeHouseMenu and DinerMenu concrete implementations, not to an interface.
- [ ] B. The Waitress doesn't implement the Java Waitress API and so isn't adhering to a standard.
- [x] C. If we decided to switch from using DinerMenu to another type of menu that implemented its list of menu items with a Hashtable, we'd have to modify a lot of code in the Waitress.
- [x] C. The Waitress needs to know how each menu represents its internal collection of menu items is implemented, this violates encapsulation.
- [x] D. We have duplicate code: the printMenu() method needs two separate loop implementations to iterate over the two different kinds of menus. And if we added a third menu, we might have to add yet another loop.
- [ ] E. The implementation isn't based on MXML (Menu XML) and so isn't as interoperable as it should be.

Sharpen your pencil

Before turning the page, quickly jot down the three things we have to do to this code to fit it into our framework:

1. implement the Menu interface
2. get rid of getItems()
3. add createIterator() and return an Iterator that can step through the Hashtable values

Code Magnets Solution

The unscrambled "Alternating" DinerMenu Iterator

```
import java.util.Iterator;
import java.util.Calendar;

public class AlternatingDinerMenuIterator implements Iterator {

    MenuItem[] items;
    int position;

    public AlternatingDinerMenuIterator(MenuItem[] items) {

        this.items = items;
        Calendar rightNow = Calendar.getInstance();
        position = rightNow.DAY_OF_WEEK % 2;

    }

    public boolean hasNext() {

        if (position >= items.length || items[position] == null) {
            return false;
        } else {
            return true;
        }

    }

    public Object next() {

        MenuItem menuItem = items[position];
        position = position + 2;
        return menuItem;

    }

    public void remove() {

        throw new UnsupportedOperationException(
            "Alternating Diner Menu Iterator does not support remove()");

    }

}
```

Notice that this Iterator implementation does not support remove()

WHO DOES WHAT?

Match each pattern with its description:

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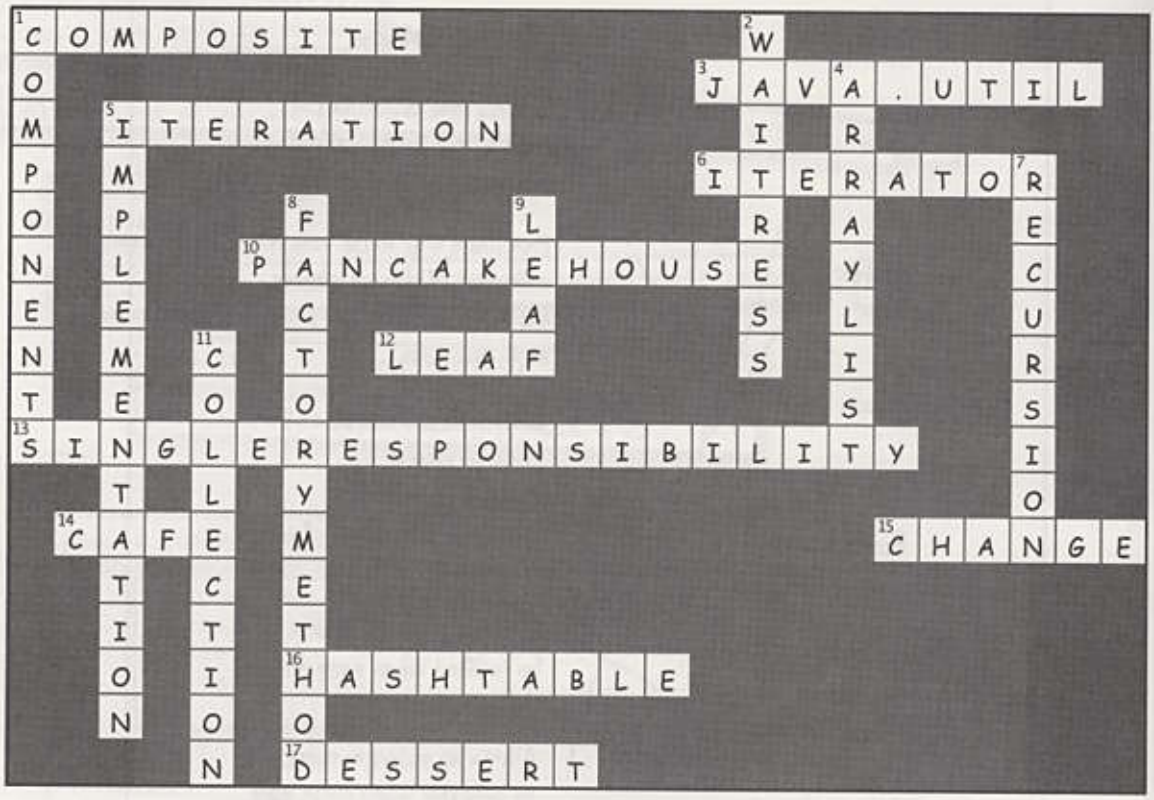
Exercise solutions



The State of Things

A little known fact: the Strategy and State Patterns were twins separated at birth. As you know, the Strategy Pattern went on to create a wildly successful business around interchangeable algorithms. State, however, took the perhaps more noble path of helping objects to control their behavior by changing their internal state. He's often overheard telling his object clients, "Just repeat after me: I'm good enough, I'm smart enough, and doggonit..."

Java Jaw Breakers

Java toasters are so '90s. Today people are building Java into *real* devices, like gumball machines. That's right, gumball machines have gone high tech; the major manufacturers have found that by putting CPUs into their machines, they can increase sales, monitor inventory over the network and measure customer satisfaction more accurately.

At least that's their story – we think they just got bored with the circa 1800's technology and needed to find a way to make their jobs more exciting.

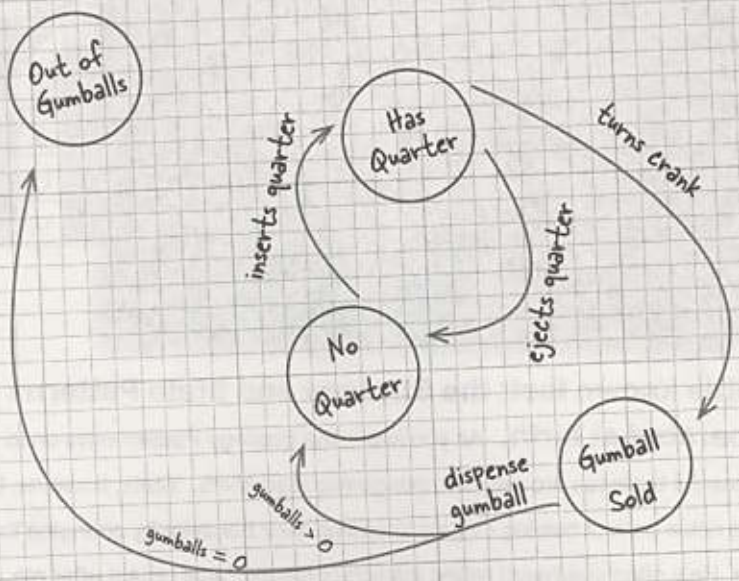
But these manufacturers are gumball machine experts, not software developers, and they've asked for your help:

Mighty Gumball, Inc.

Where the Gumball Machine is Never Half Empty

Here's the way we think the gumball machine controller needs to work. We're hoping you can implement this in Java for us! We may be adding more behavior in the future, so you need to keep the design as flexible and maintainable as possible!

– Mighty Gumball Engineers



Cubicle Conversation

Anne: This diagram looks like a state diagram.

Joe: Right, each of those circles is a state...

Anne: ... and each of the arrows is a state transition.

Frank: Slow down, you two, it's been too long since I studied state diagrams. Can you remind me what they're all about?

Anne: Sure, Frank. Look at the circles; those are states. "No Quarter" is probably the starting state for the gumball machine because it's just sitting there waiting for you to put your quarter in. All states are just different configurations of the machine that behave in a certain way and need some action to take them to another state.

Joe: Right. See, to go to another state, you need to do something like put a quarter in the machine. See the arrow from "No Quarter" to "Has Quarter?"

Frank: Yes...

Joe: That just means that if the gumball machine is in the "No Quarter" state and you put a quarter in, it will change to the "Has Quarter" state. That's the state transition.

Frank: Oh, I see! And if I'm in the "Has Quarter" state, I can turn the crank and change to the "Gumball Sold" state, or eject the quarter and change back to the "No Quarter" state.

Anne: You got it!

Frank: This doesn't look too bad then. We've obviously got four states, and I think we also have four actions: "inserts quarter," "ejects quarter," "turns crank" and "dispense." But... when we dispense, we test for zero or more gumballs in the "Gumball Sold" state, and then either go to the "Out of Gumballs" state or the "No Quarter" state. So we actually have five transitions from one state to another.

Anne: That test for zero or more gumballs also implies we've got to keep track of the number of gumballs too. Any time the machine gives you a gumball, it might be the last one, and if it is, we need to transition to the "Out of Gumballs" state.

Joe: Also, don't forget that you could do nonsensical things, like try to eject the quarter when the gumball machine is in the "No Quarter" state, or insert two quarters.

Frank: Oh, I didn't think of that; we'll have to take care of those too.

Joe: For every possible action we'll just have to check to see which state we're in and act appropriately. We can do this! Let's start mapping the state diagram to code...

State machines 101

How are we going to get from that state diagram to actual code? Here's a quick introduction to implementing state machines:

1. First, gather up your states:

Here are the states – four in total.

2. Next, create an instance variable to hold the current state, and define values for each of the states:

Let's just call "Out of Gumballs" "Sold Out" for short

```
final static int SOLD_OUT = 0;
final static int NO_QUARTER = 1;
final static int HAS_QUARTER = 2;
final static int SOLD = 3;

int state = SOLD_OUT;
```

Here's each state represented as a unique integer...

...and here's an instance variable that holds the current state. We'll go ahead and set it to "Sold Out" since the machine will be unfilled when it's first taken out of its box and turned on.

3. Now we gather up all the actions that can happen in the system:

inserts quarter turns crank ejects quarter dispense

These actions are the gumball machine's interface – the things you can do with it.

Dispense is more of an internal action the machine invokes on itself.

Looking at the diagram, invoking any of these actions causes a state transition.

4 Now we create a class that acts as the state machine. For each action, we create a method that uses conditional statements to determine what behavior is appropriate in each state. For instance, for the insert quarter action, we might write a method like this:

```
public void insertQuarter() {
    if (state == HAS_QUARTER) {
        System.out.println("You can't insert another quarter");
    } else if (state == SOLD_OUT) {
        System.out.println("You can't insert a quarter, the machine is sold out");
    } else if (state == SOLD) {
        System.out.println("Please wait, we're already giving you a gumball");
    } else if (state == NO_QUARTER) {
        state = HAS_QUARTER;
        System.out.println("You inserted a quarter");
    }
}
```

Each possible state is checked with a conditional statement...

...and exhibits the appropriate behavior for each possible state...

...but can also transition to other states, just as depicted in the diagram.

Here we're talking about a common technique: modeling state within an object by creating an instance variable to hold the state values and writing conditional code within our methods to handle the various states.

With that quick review, let's go implement the Gumball Machine!

Writing the code

It's time to implement the Gumball Machine. We know we're going to have an instance variable that holds the current state. From there, we just need to handle all the actions, behaviors and state transitions that can happen. For actions, we need to implement inserting a quarter, removing a quarter, turning the crank and dispensing a gumball; we also have the empty gumball condition to implement as well.

Here are the four states; they match the states in Mighty Gumball's state diagram.

Here's the instance variable that is going to keep track of the current state we're in. We start in the SOLD_OUT state.

We have a second instance variable that keeps track of the number of gumballs in the machine.

The constructor takes an initial inventory of gumballs. If the inventory isn't zero, the machine enters state NO_QUARTER, meaning it is waiting for someone to insert a quarter, otherwise it stays in the SOLD_OUT state.

```
public class GumballMachine {

    final static int SOLD_OUT = 0;
    final static int NO_QUARTER = 1;
    final static int HAS_QUARTER = 2;
    final static int SOLD = 3;

    int state = SOLD_OUT;
    int count = 0;

    public GumballMachine(int count) {
        this.count = count;
        if (count > 0) {
            state = NO_QUARTER;
        }
    }
```

Now we start implementing the actions as methods....

When a quarter is inserted, if....

a quarter is already inserted we tell the customer;

otherwise we accept the quarter and transition to the HAS_QUARTER state.

```
    public void insertQuarter() {
        if (state == HAS_QUARTER) {
            System.out.println("You can't insert another quarter");
        } else if (state == NO_QUARTER) {
            state = HAS_QUARTER;
            System.out.println("You inserted a quarter");
        } else if (state == SOLD_OUT) {
            System.out.println("You can't insert a quarter, the machine is sold out");
        } else if (state == SOLD) {
            System.out.println("Please wait, we're already giving you a gumball");
        }
    }
```

If the customer just bought a gumball he needs to wait until the transaction is complete before inserting another quarter.

and if the machine is sold out, we reject the quarter.

```
public void ejectQuarter() {
    if (state == HAS_QUARTER) {
        System.out.println("Quarter returned");
        state = NO_QUARTER;
    } else if (state == NO_QUARTER) {
        System.out.println("You haven't inserted a quarter");
    } else if (state == SOLD) {
        System.out.println("Sorry, you already turned the crank");
    } else if (state == SOLD_OUT) {
        System.out.println("You can't eject, you haven't inserted a quarter yet");
    }
}

public void turnCrank() {
    if (state == SOLD) {
        System.out.println("Turning twice doesn't get you another gumball!");
    } else if (state == NO_QUARTER) {
        System.out.println("You turned but there's no quarter");
    } else if (state == SOLD_OUT) {
        System.out.println("You turned, but there are no gumballs");
    } else if (state == HAS_QUARTER) {
        System.out.println("You turned...");
        state = SOLD;
        dispense();
    }
}

public void dispense() {
    if (state == SOLD) {
        System.out.println("A gumball comes rolling out the slot");
        count = count - 1;
        if (count == 0) {
            System.out.println("Oops, out of gumballs!");
            state = SOLD_OUT;
        } else {
            state = NO_QUARTER;
        }
    } else if (state == NO_QUARTER) {
        System.out.println("You need to pay first");
    } else if (state == SOLD_OUT) {
        System.out.println("No gumball dispensed");
    } else if (state == HAS_QUARTER) {
        System.out.println("No gumball dispensed");
    }
}

// other methods here like toString() and refill()
```

Now, if the customer tries to remove the quarter...

If there is a quarter, we return it and go back to the NO_QUARTER state.

Otherwise, if there isn't one we can't give it back.

You can't eject if the machine is sold out, it doesn't accept quarters!

If the customer just turned the crank, we can't give a refund; he already has the gumball!

The customer tries to turn the crank...

Someone's trying to cheat the machine.

We need a quarter first.

We can't deliver gumballs; there are none.

Success! They get a gumball. Change the state to SOLD and call the machine's dispense() method.

Called to dispense a gumball.

We're in the SOLD state; give 'em a gumball!

Here's where we handle the "out of gumballs" condition: If this was the last one, we set the machine's state to SOLD_OUT; otherwise, we're back to not having a quarter.

None of these should ever happen, but if they do, we give 'em an error, not a gumball.

In-house testing

That feels like a nice solid design using a well-thought out methodology doesn't it? Let's do a little in-house testing before we hand it off to Mighty Gumball to be loaded into their actual gumball machines. Here's our test harness:

```
public class GumballMachineTestDrive {
    public static void main(String[] args) {
        GumballMachine gumballMachine = new GumballMachine(5);

        System.out.println(gumballMachine);

        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();

        System.out.println(gumballMachine);

        gumballMachine.insertQuarter();
        gumballMachine.ejectQuarter();
        gumballMachine.turnCrank();

        System.out.println(gumballMachine);

        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();
        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();
        gumballMachine.ejectQuarter();

        System.out.println(gumballMachine);

        gumballMachine.insertQuarter();
        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();
        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();
        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();

        System.out.println(gumballMachine);
    }
}
```

Load it up with five gumballs total.

Print out the state of the machine.

Throw a quarter in...

Turn the crank; we should get our gumball.

Print out the state of the machine, again.

Throw a quarter in...

Ask for it back.

Turn the crank; we shouldn't get our gumball.

Print out the state of the machine, again.

Throw a quarter in...
Turn the crank; we should get our gumball
Throw a quarter in...
Turn the crank; we should get our gumball

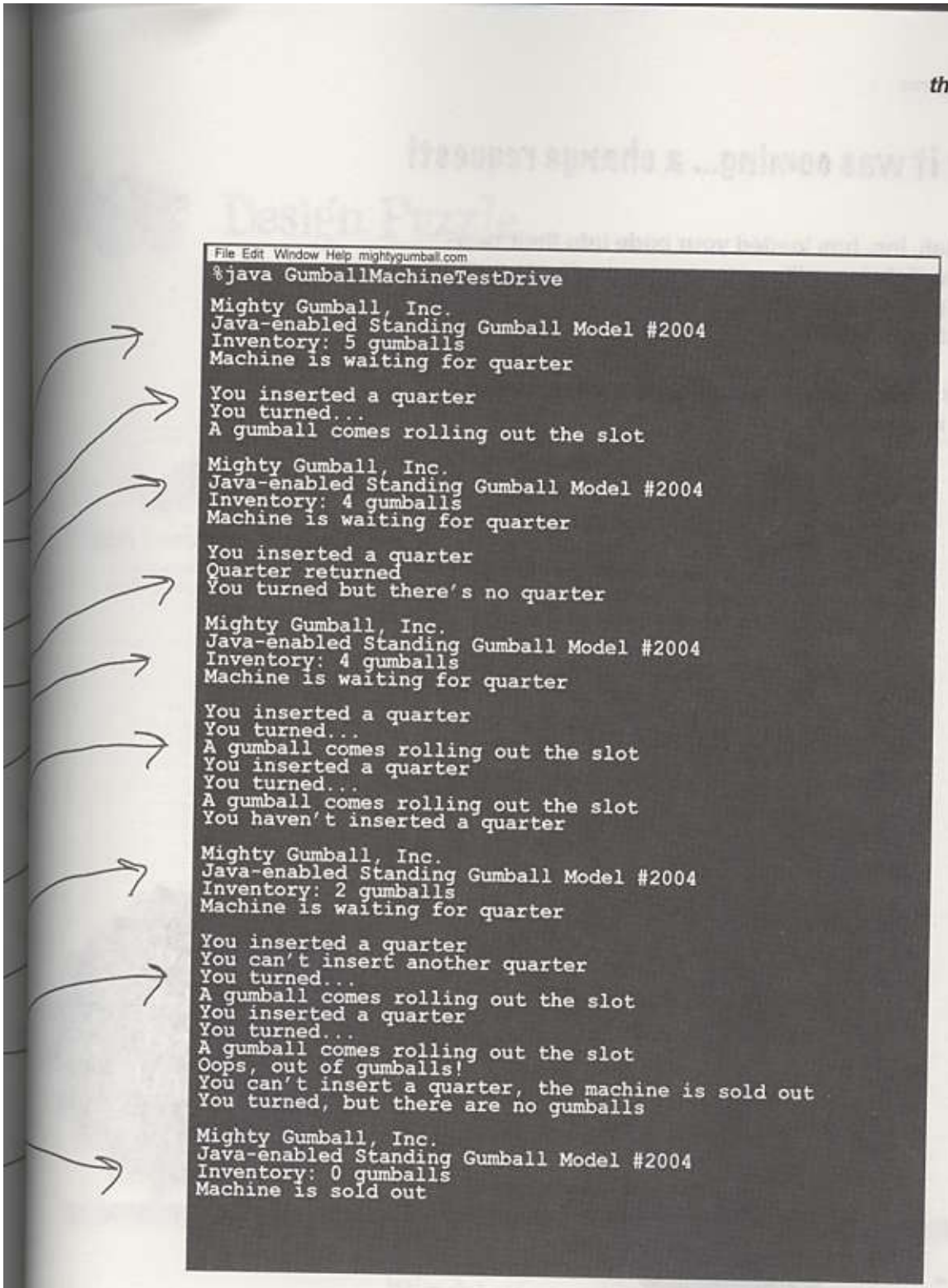
Ask for a quarter back we didn't put in.

Print out the state of the machine, again.

Throw TWO quarters in...
Turn the crank; we should get our gumball.

Now for the stress testing... ☺

Print that machine state one more time.


File Edit Window Help mightygumball.com
%java GumballMachineTestDrive
Mighty Gumball, Inc.
Java-enabled Standing Gumball Model #2004
Inventory: 5 gumballs
Machine is waiting for quarter
You inserted a quarter
You turned...
A gumball comes rolling out the slot
Mighty Gumball, Inc.
Java-enabled Standing Gumball Model #2004
Inventory: 4 gumballs
Machine is waiting for quarter
You inserted a quarter
Quarter returned
You turned but there's no quarter
Mighty Gumball, Inc.
Java-enabled Standing Gumball Model #2004
Inventory: 4 gumballs
Machine is waiting for quarter
You inserted a quarter
You turned...
A gumball comes rolling out the slot
You inserted a quarter
You turned...
A gumball comes rolling out the slot
You haven't inserted a quarter
Mighty Gumball, Inc.
Java-enabled Standing Gumball Model #2004
Inventory: 2 gumballs
Machine is waiting for quarter
You inserted a quarter
You can't insert another quarter
You turned...
A gumball comes rolling out the slot
You inserted a quarter
You turned...
A gumball comes rolling out the slot
Oops, out of gumballs!
You can't insert a quarter, the machine is sold out
You turned, but there are no gumballs
Mighty Gumball, Inc.
Java-enabled Standing Gumball Model #2004
Inventory: 0 gumballs
Machine is sold out

You knew it was coming... a change request!

Mighty Gumball, Inc. has loaded your code into their newest machine and their quality assurance experts are putting it through its paces. So far, everything's looking great from their perspective.

In fact, things have gone so smoothly they'd like to take things to the next level...

Design Puzzle

Draw a state diagram for a Gumball Machine that handles the 1 in 10 contest. In this contest, 10% of the time the Sold state leads to two balls being released, not one. Check your answer with ours (at the end of the chapter) to make sure we agree before you go further...

Mighty Gumball, Inc.

Where the Gumball Machine is Never Half Empty

Use Mighty Gumball's stationary to draw your state diagram.

The messy STATE of things...

Just because you've written your gumball machine using a well-thought out methodology doesn't mean it's going to be easy to extend. In fact, when you go back and look at your code and think about what you'll have to do to modify it, well...

```
final static int SOLD_OUT = 0;
final static int NO_QUARTER = 1;
final static int HAS_QUARTER = 2;
final static int SOLD = 3;


public void insertQuarter() {
    // insert quarter code here
}

public void ejectQuarter() {
    // eject quarter code here
}

public void turnCrank() {
    // turn crank code here
}

public void dispense() {
    // dispense code here
}
```

First, you'd have to add a new WINNER state here. That isn't too bad...

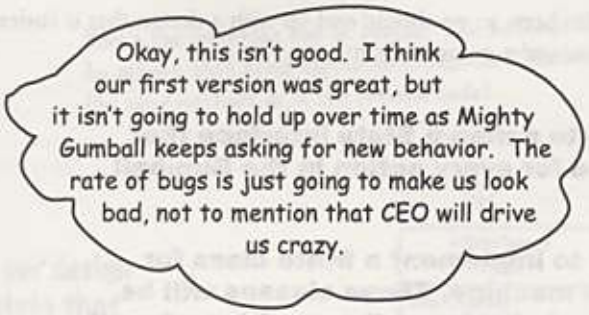
... but then, you'd have to add a new conditional in every single method to handle the WINNER state; that's a lot of code to modify.

turnCrank() will get especially messy, because you'd have to add code to check to see whether you've got a WINNER and then switch to either the WINNER state or the SOLD state.

Sharpen your pencil

Which of the following describe the state of our implementation? (Choose all that apply.)

- ❑ A. This code certainly isn't adhering to the Open Closed Principle.
- ❑ B. This code would make a FORTRAN programmer proud.
- ❑ C. This design isn't even very object oriented.
- ❑ C. State transitions aren't explicit; they are buried in the middle of a bunch of conditional statements.
- ❑ D. We haven't encapsulated anything that varies here.
- ❑ E. Further additions are likely to cause bugs in working code.



Joe: You're right about that! We need to refactor this code so that it's easy to maintain and modify.

Anne: We really should try to localize the behavior for each state so that if we make changes to one state, we don't run the risk of messing up the other code.

Joe: Right; in other words, follow that ol' "encapsulate what varies" principle.

Anne: Exactly.

Joe: If we put each state's behavior in its own class, then every state just implements its own actions.

Anne: Right. And maybe the Gumball Machine can just delegate to the state object that represents the current state.

Joe: Ah, you're good: favor composition... more principles at work.

Anne: Cute. Well, I'm not 100% sure how this is going to work, but I think we're on to something.

Joe: I wonder if this will this make it easier to add new states?

Anne: I think so... We'll still have to change code, but the changes will be much more limited in scope because adding a new state will mean we just have to add a new class and maybe change a few transitions here and there.

Joe: I like the sound of that. Let's start hashing out this new design!

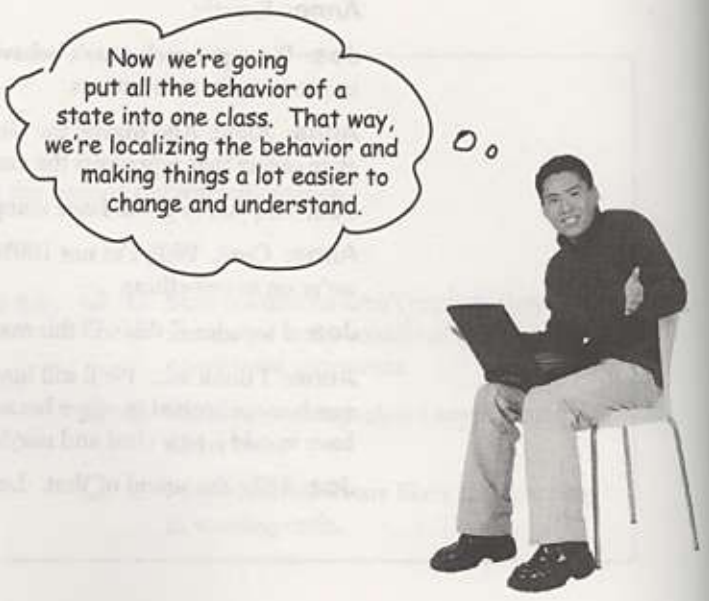
The new design

It looks like we've got a new plan: instead of maintaining our existing code, we're going to rework it to encapsulate state objects in their own classes and then delegate to the current state when an action occurs.

We're following our design principles here, so we should end up with a design that is easier to maintain down the road. Here's how we're going to do it:

1. **First, we're going to define a State interface that contains a method for every action in the Gumball Machine.**
2. **Then we're going to implement a State class for every state of the machine. These classes will be responsible for the behavior of the machine when it is in the corresponding state.**
3. **Finally, we're going to get rid of all of our conditional code and instead delegate to the state class to do the work for us.**

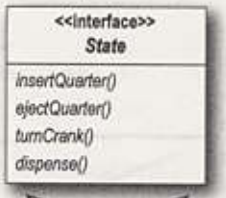
Not only are we following design principles, as you'll see, we're actually implementing the State Pattern. But we'll get to all the official State Pattern stuff after we rework our code...



Defining the State interfaces and classes

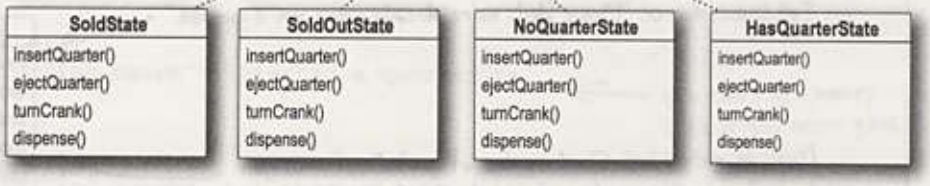
First let's create an interface for State, which all our states implement:

Here's the interface for all states. The methods map directly to actions that could happen to the Gumball Machine (these are the same methods as in the previous code).



Then take each state in our design and encapsulate it in a class that implements the State interface.

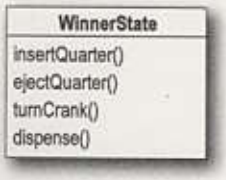
To figure out what states we need, we look at our previous code...



... and we map each state directly to a class.

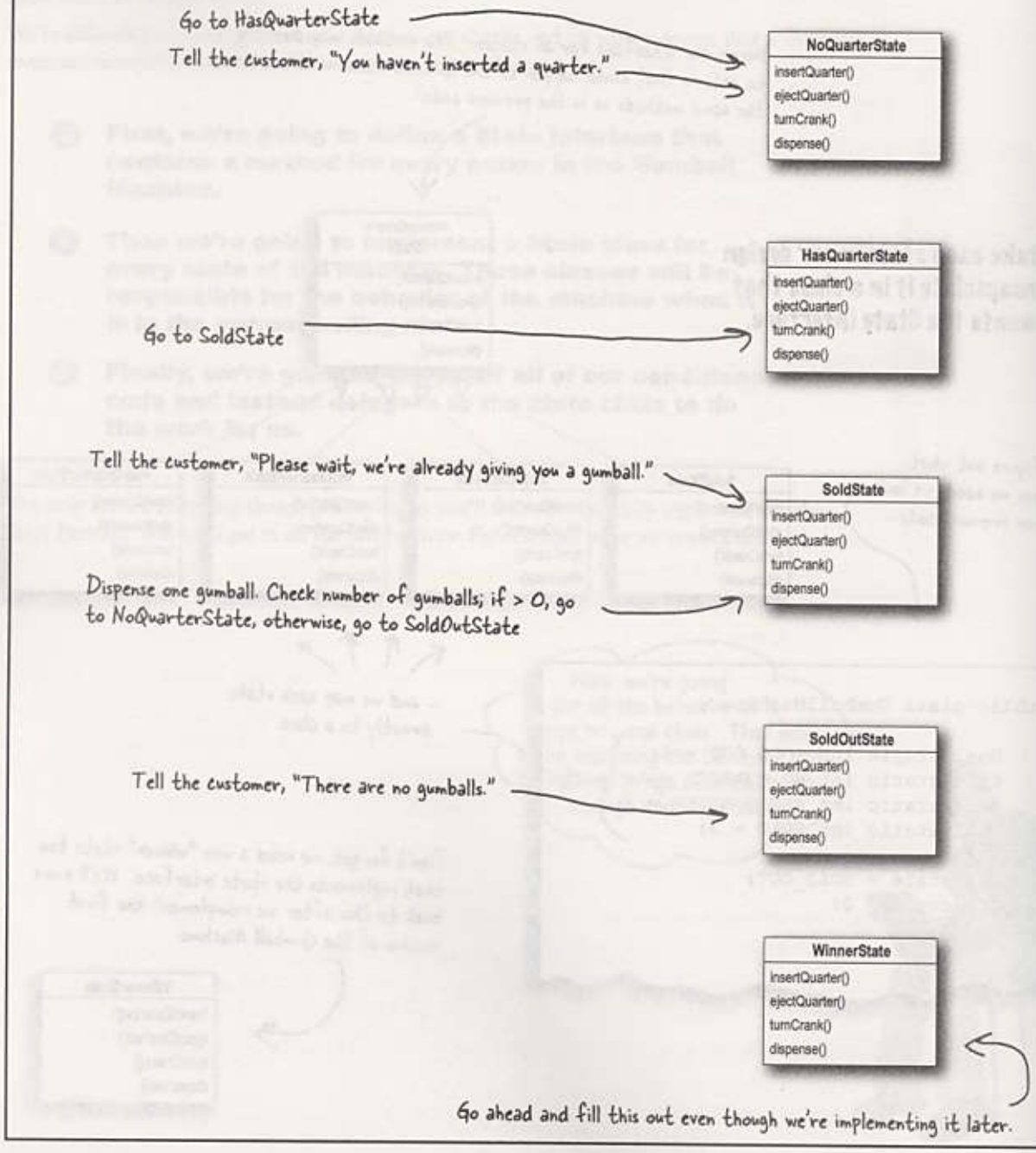
```
public class GumballMachine {

    final static int SOLD_OUT = 0;
    final static int NO_QUARTER = 1;
    final static int HAS_QUARTER = 2;
    final static int SOLD = 3;

    int state = SOLD_OUT;
    int count = 0;
```

Don't forget, we need a new "winner" state too that implements the state interface. We'll come back to this after we reimplement the first version of the Gumball Machine.



Sharpen your pencil

To implement our states, we first need to specify the behavior of the classes when each action is called. Annotate the diagram below with the behavior of each action in each class; we've already filled in a few for you.



Implementing our State classes

Time to implement a state: we know what behaviors we want; we just need to get it down in code. We're going to closely follow the state machine code we wrote, but this time everything is broken out into different classes.

Let's start with the NoQuarterState:

First we need to implement the State interface.

We get passed a reference to the Gumball Machine through the constructor. We're just going to stash this in an instance variable.

```
public class NoQuarterState implements State {
    GumballMachine gumballMachine;

    public NoQuarterState(GumballMachine gumballMachine) {
        this.gumballMachine = gumballMachine;
    }

    public void insertQuarter() {
        System.out.println("You inserted a quarter");
        gumballMachine.setState(gumballMachine.getHasQuarterState());
    }

    public void ejectQuarter() {
        System.out.println("You haven't inserted a quarter");
    }

    public void turnCrank() {
        System.out.println("You turned, but there's no quarter");
    }

    public void dispense() {
        System.out.println("You need to pay first");
    }
}
```

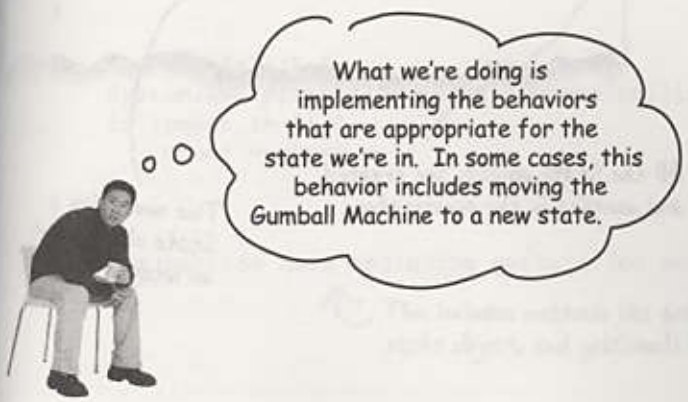
If someone inserts a quarter, we print a message saying the quarter was accepted and then change the machine's state to the HasQuarterState.

You'll see how these work in just a sec...

You can't get money back if you never gave it to us!

And, you can't get a gumball if you don't pay us.

We can't be dispensing gumballs without payment.



Reworking the Gumball Machine

Before we finish the State classes, we're going to rework the Gumball Machine – that way you can see how it all fits together. We'll start with the state-related instance variables and switch the code from using integers to using state objects:

```
public class GumballMachine {

    final static int SOLD_OUT = 0;
    final static int NO_QUARTER = 1;
    final static int HAS_QUARTER = 2;
    final static int SOLD = 3;

    int state = SOLD_OUT;
    int count = 0;
```

Old code

In the GumballMachine, we update the code to use the new classes rather than the static integers. The code is quite similar, except that in one class we have integers and in the other objects...

```
public class GumballMachine {

    State soldOutState;
    State noQuarterState;
    State hasQuarterState;
    State soldState;

    State state = soldOutState;
    int count = 0;
```

New code

All the State objects are created and assigned in the constructor.

This now holds a State object, not an integer.

Now, let's look at the complete GumballMachine class...

```
public class GumballMachine {

    State soldOutState;
    State noQuarterState;
    State hasQuarterState;
    State soldState;

    State state = soldOutState;
    int count = 0;

    public GumballMachine(int numberGumballs) {
        soldOutState = new SoldOutState(this);
        noQuarterState = new NoQuarterState(this);
        hasQuarterState = new HasQuarterState(this);
        soldState = new SoldState(this);
        this.count = numberGumballs;
        if (numberGumballs > 0) {
            state = noQuarterState;
        }
    }

    public void insertQuarter() {
        state.insertQuarter();
    }

    public void ejectQuarter() {
        state.ejectQuarter();
    }

    public void turnCrank() {
        state.turnCrank();
        state.dispense();
    }

    void setState(State state) {
        this.state = state;
    }

    void releaseBall() {
        System.out.println("A gumball comes rolling out the slot...");
        if (count != 0) {
            count = count - 1;
        }
    }

    // More methods here including getters for each State...
}
```

Here are all the States again...

...and the State instance variable.

The count instance variable holds the count of gumballs – initially the machine is empty.

Our constructor takes the initial number of gumballs and stores it in an instance variable.

It also creates the State instances, one of each.

If there are more than 0 gumballs we set the state to the NoQuarterState.

Now for the actions. These are VERY EASY to implement now. We just delegate to the current state.

Note that we don't need an action method for dispense() in GumballMachine because it's just an internal action; a user can't ask the machine to dispense directly. But we do call dispense() on the State object from the turnCrank() method.

This method allows other objects (like our State objects) to transition the machine to a different state.

The machine supports a releaseBall() helper method that releases the ball and decrements the count instance variable.

This includes methods like getNoQuarterState() for getting each state object, and getCount() for getting the gumball count.

Implementing more states

Now that you're starting to get a feel for how the Gumball Machine and the states fit together, let's implement the HasQuarterState and the SoldState classes...

```
public class HasQuarterState implements State {
    GumballMachine gumballMachine;

    public HasQuarterState(GumballMachine gumballMachine) {
        this.gumballMachine = gumballMachine;
    }

    public void insertQuarter() {
        System.out.println("You can't insert another quarter");
    }

    public void ejectQuarter() {
        System.out.println("Quarter returned");
        gumballMachine.setState(gumballMachine.getNoQuarterState());
    }

    public void turnCrank() {
        System.out.println("You turned...");
        gumballMachine.setState(gumballMachine.getSoldState());
    }
    public void dispense() {
        System.out.println("No gumball dispensed");
    }
}
```

When the state is instantiated we pass it a reference to the GumballMachine. This is used to transition the machine to a different state.

An inappropriate action for this state.

Return the customer's quarter and transition back to the NoQuarterState.

When the crank is turned we transition the machine to the SoldState state by calling its setState() method and passing it the SoldState object. The SoldState object is retrieved by the getSoldState() getter method (there is one of these getter methods for each state).

Another inappropriate action for this state.

Now, let's check out the SoldState class...

```
public class SoldState implements State {
   //constructor and instance variables here

   public void insertQuarter() {
      System.out.println("Please wait, we're already giving you a gumball");
   }

   public void ejectQuarter() {
      System.out.println("Sorry, you already turned the crank");
   }

   public void turnCrank() {
      System.out.println("Turning twice doesn't get you another gumball!");
   }

   public void dispense() {
      gumballMachine.releaseBall();
      if (gumballMachine.getCount() > 0) {
         gumballMachine.setState(gumballMachine.getNoQuarterState());
      } else {
         System.out.println("Oops, out of gumballs!");
         gumballMachine.setState(gumballMachine.getSoldOutState());
      }
   }
}
```

Here are all the inappropriate actions for this state

And here's where the real work begins...

We're in the SoldState, which means the customer paid. So, we first need to ask the machine to release a gumball.

Then we ask the machine what the gumball count is, and either transition to the NoQuarterState or the SoldOutState.

Look back at the GumballMachine implementation. If the crank is turned and not successful (say the customer didn't insert a quarter first), we call dispense anyway, even though it's unnecessary. How might you fix this?

Sharpen your pencil

We have one remaining class we haven't implemented: SoldOutState. Why don't you implement it? To do this, carefully think through how the Gumball Machine should behave in each situation. Check your answer before moving on...

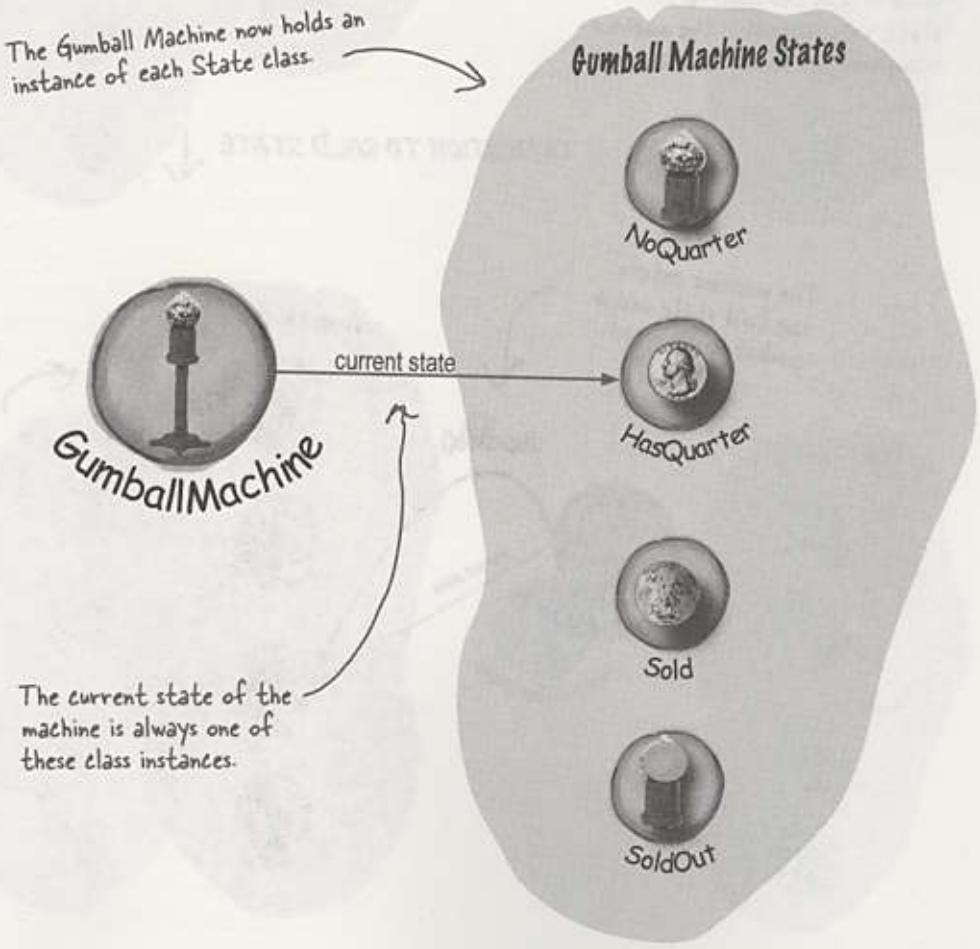
```
public class SoldOutState implements [          ] {
    GumballMachine gumballMachine;

    public SoldOutState(GumballMachine gumballMachine) {


    }

    public void insertQuarter() {



    }

    public void ejectQuarter() {



    }

    public void turnCrank() {



    }

    public void dispense() {



    }
}
```

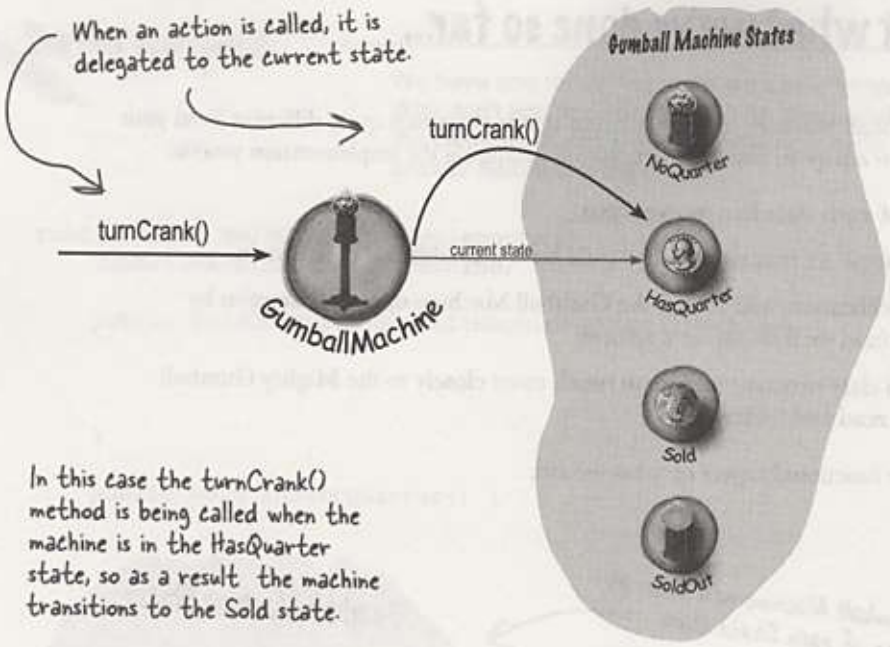
Let's take a look at what we've done so far...

For starters, you now have a Gumball Machine implementation that is *structurally* quite different from your first version, and yet *functionally it is exactly the same.* By structurally changing the implemention you've:

- Localized the behavior of each state into its own class.
- Removed all the troublesome `if` statements that would have been difficult to maintain.
- Closed each state for modification, and yet left the Gumball Machine open to extension by adding new state classes (and we'll do this in a second).
- Created a code base and class structure that maps much more closely to the Mighty Gumball diagram and is easier to read and understand.

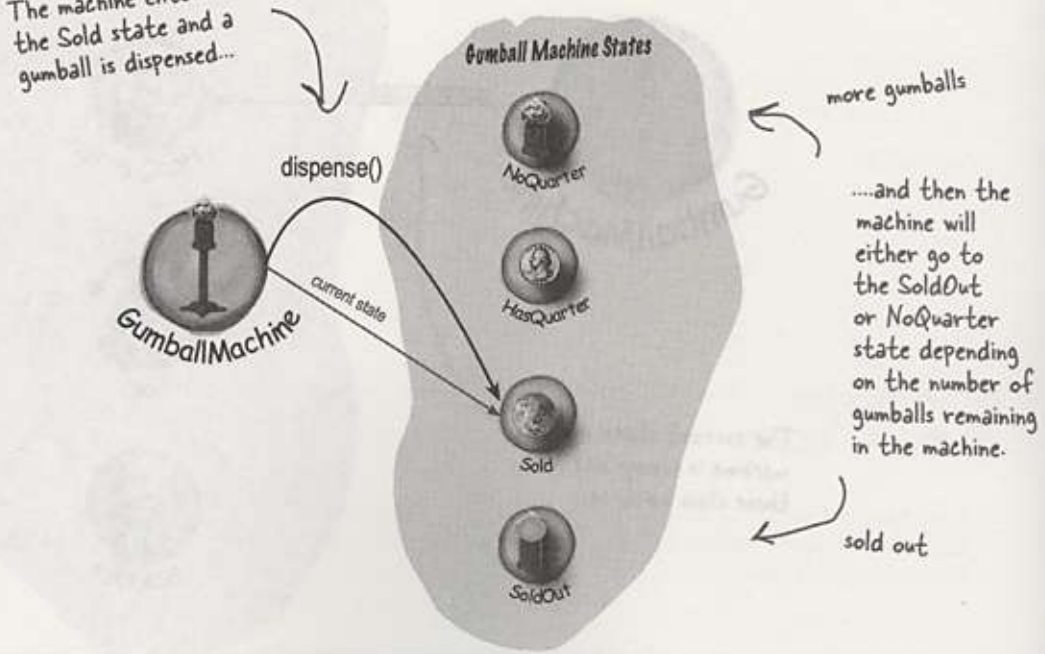
Now let's look a little more at the functional aspect of what we did:





In this case the turnCrank() method is being called when the machine is in the HasQuarter state, so as a result the machine transitions to the Sold state.

TRANSITION TO SOLD STATE

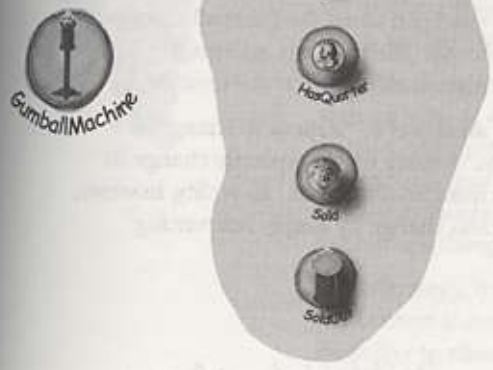


Sharpen your pencil

Behind the Scenes: Self-Guided Tour

Trace the steps of the Gumball Machine starting with the NoQuarter state. Also annotate the diagram with actions and output of the machine. For this exercise you can assume there are plenty of gumballs in the machine.

1



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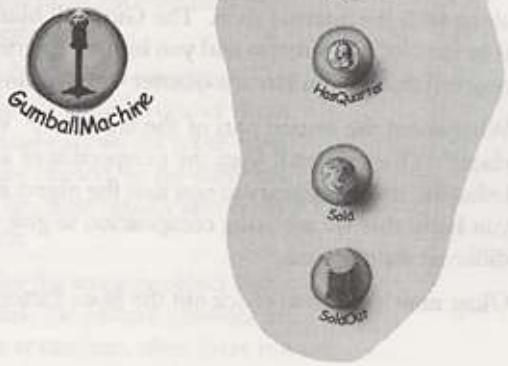

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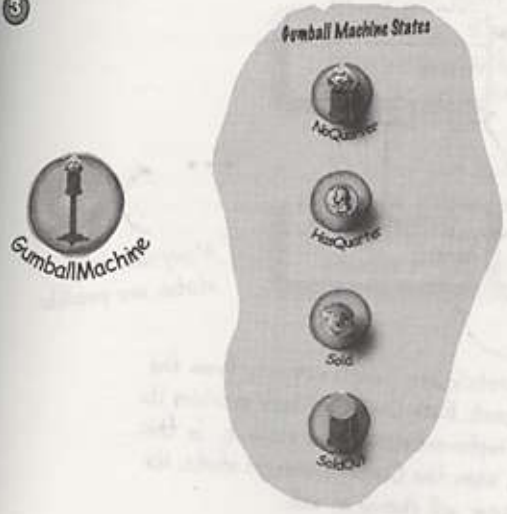

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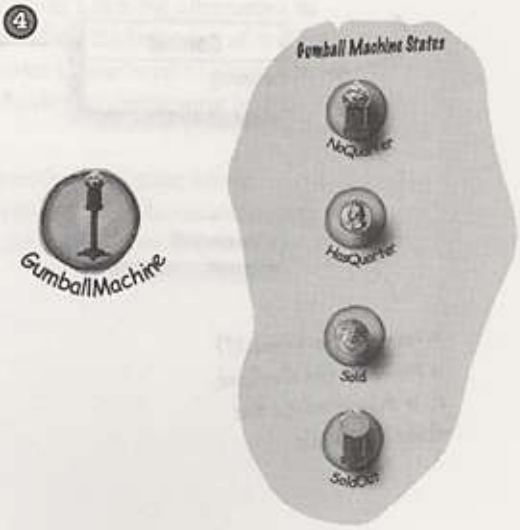


The State Pattern defined

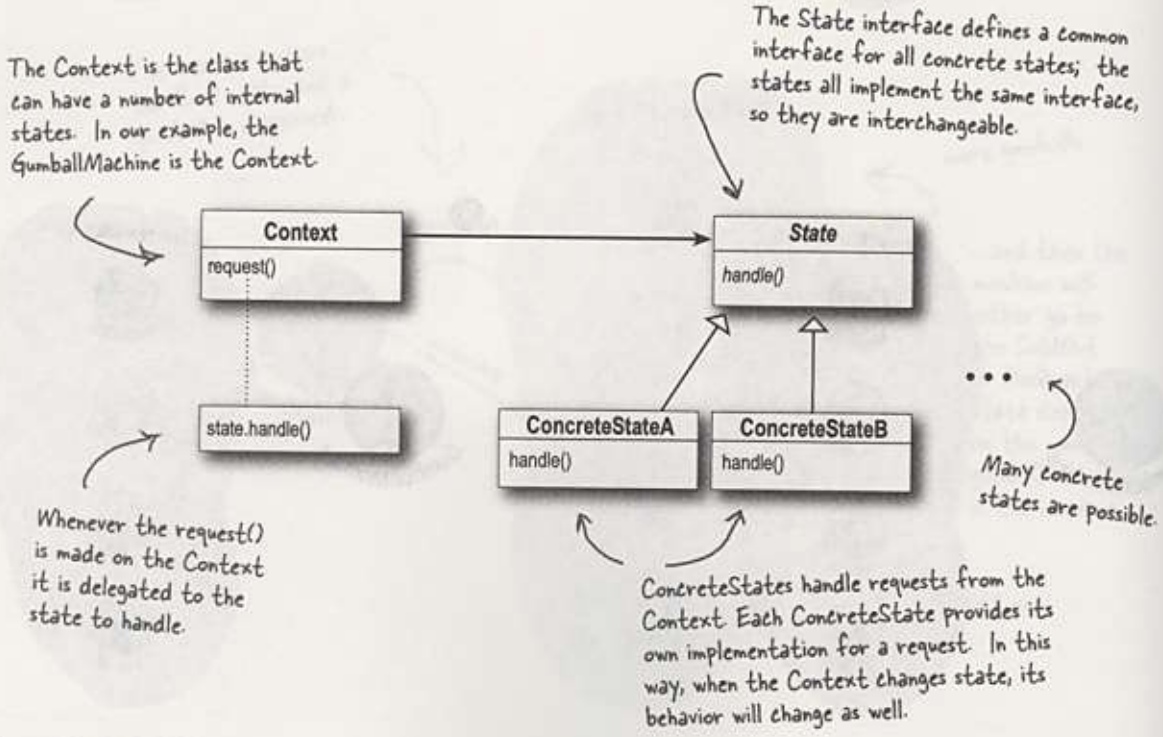
Yes, it's true, we just implemented the State Pattern! So now, let's take a look at what it's all about:

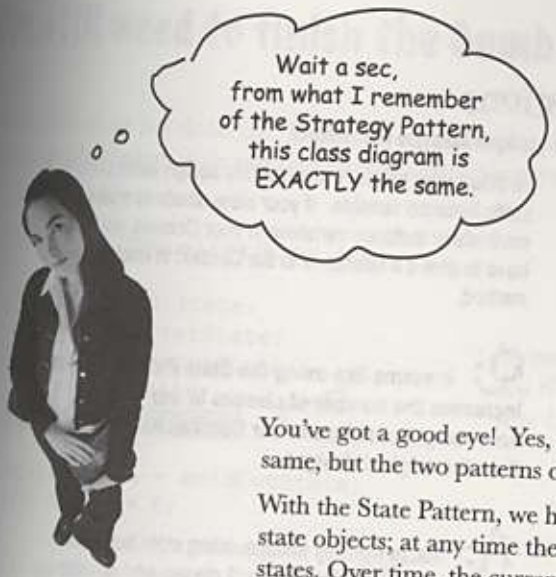
> **The State Pattern** allows an object to alter its behavior when its internal state changes. The object will appear to change its class.

The first part of this description makes a lot of sense, right? Because the pattern encapsulates state into separate classes and delegates to the object representing the current state, we know that behavior changes along with the internal state. The Gumball Machine provides a good example: when the gumball machine is in the NoQuarterState and you insert a quarter, you get different behavior (the machine accepts the quarter) than if you insert a quarter when it's in the HasQuarterState (the machine rejects the quarter).

What about the second part of the definition? What does it mean for an object to "appear to change its class?" Think about it from the perspective of a client: if an object you're using can completely change its behavior, then it appears to you that the object is actually instantiated from another class. In reality, however, you know that we are using composition to give the appearance of a class change by simply referencing different state objects.

Okay, now it's time to check out the State Pattern class diagram:





You've got a good eye! Yes, the class diagrams are essentially the same, but the two patterns differ in their *intent*.

With the State Pattern, we have a set of behaviors encapsulated in state objects; at any time the context is delegating to one of those states. Over time, the current state changes across the set of state objects to reflect the internal state of the context, so the context's behavior changes over time as well. The client usually knows very little, if anything, about the state objects.

With Strategy, the client usually specifies the strategy object that the context is composed with. Now, while the pattern provides the flexibility to change the strategy object at runtime, often there is a strategy object that is most appropriate for a context object. For instance, in Chapter 1, some of our ducks were configured to fly with typical flying behavior (like mallard ducks), while others were configured with a fly behavior that kept them grounded (like rubber ducks and decoy ducks).

In general, think of the Strategy Pattern as a flexible alternative to subclassing; if you use inheritance to define the behavior of a class, then you're stuck with that behavior even if you need to change it. With Strategy you can change the behavior by composing with a different object.

Think of the State Pattern as an alternative to putting lots of conditionals in your context; by encapsulating the behaviors within state objects, you can simply change the state object in context to change its behavior.

there are no Dumb Questions

Q: In the GumballMachine, the states decide what the next state should be. Do the ConcreteStates always decide what state to go to next?

A: No, not always. The alternative is to let the Context decide on the flow of state transitions.

As a general guideline, when the state transitions are fixed they are appropriate for putting in the Context; however, when the transitions are more dynamic, they are typically placed in the state classes themselves (for instance, in the GumballMachine the choice of the transition to NoQuarter or SoldOut depended on the runtime count of gumballs).

The disadvantage of having state transitions in the state classes is that we create dependencies between the state classes. In our implementation of the GumballMachine we tried to minimize this by using getter methods on the Context, rather than hardcoding explicit concrete state classes.

Notice that by making this decision, you are making a decision as to which classes are closed for modification – the Context or the state classes – as the system evolves.

Q: Do clients ever interact directly with the states?

A: No. The states are used by the Context to represent its internal state and behavior, so all requests to the states come from the Context. Clients don't directly change the state of the Context. It is the Context's job to oversee its state, and you don't usually want a client changing the state of a Context without that Context's knowledge.

Q: If I have lots of instances of the Context in my application, is it possible to share the state objects across them?

A: Yes, absolutely, and in fact this is a very common scenario. The only requirement is that your state objects do not keep their own internal state; otherwise, you'd need a unique instance per context.

To share your states, you'll typically assign each state to a static instance variable. If your state needs to make use of methods or instance variables in your Context, you'll also have to give it a reference to the Context in each handler() method.

Q: It seems like using the State Pattern always increases the number of classes in our designs. Look how many more classes our GumballMachine had than the original design!

A: You're right, by encapsulating state behavior into separate state classes, you'll always end up with more classes in your design. That's often the price you pay for flexibility. Unless your code is some "one off" implementation you're going to throw away (yeah, right), consider building it with the additional classes and you'll probably thank yourself down the road. Note that often what is important is the number of classes that you expose to your clients, and there are ways to hide these extra classes from your clients (say, by declaring them package visible).

Also, consider the alternative: if you have an application that has a lot of state and you decide not to use separate objects, you'll instead end up with very large, monolithic conditional statements. This makes your code hard to maintain and understand. By using objects, you make states explicit and reduce the effort needed to understand and maintain your code.

Q: The State Pattern class diagram shows that State is an abstract class. But didn't you use an interface in the implementation of the gumball machine's state?

A: Yes. Given we had no common functionality to put into an abstract class, we went with an interface. In your own implementation, you might want to consider an abstract class. Doing so has the benefit of allowing you to add methods to the abstract class later, without breaking the concrete state implementations.

We still need to finish the Gumball 1 in 10 game

Remember, we're not done yet. We've got a game to implement; but now that we've got the State Pattern implemented, it should be a breeze. First, we need to add a state to the GumballMachine class:

```
public class GumballMachine {

    State soldOutState;
    State noQuarterState;
    State hasQuarterState;
    State soldState;
    State winnerState;

    State state = soldOutState;
    int count = 0;

    // methods here
}
```

All you need to add here is the new WinnerState and initialize it in the constructor.

Don't forget you also have to add a getter method for WinnerState too.

Now let's implement the WinnerState class itself, it's remarkably similar to the SoldState class:

```
public class WinnerState implements State {

    // instance variables and constructor

    // insertQuarter error message

    // ejectQuarter error message

    // turnCrank error message

    public void dispense() {
        System.out.println("YOU'RE A WINNER! You get two gumballs for your quarter");
        gumballMachine.releaseBall();
        if (gumballMachine.getCount() == 0) {
            gumballMachine.setState(gumballMachine.getSoldOutState());
        } else {
            gumballMachine.releaseBall();
            if (gumballMachine.getCount() > 0) {
                gumballMachine.setState(gumballMachine.getNoQuarterState());
            } else {
                System.out.println("Oops, out of gumballs!");
                gumballMachine.setState(gumballMachine.getSoldOutState());
            }
        }
    }
}
```

Just like SoldState.

Here we release two gumballs and then either go to the NoQuarterState or the SoldOutState.

As long as we have a second gumball we release it.

Finishing the game

We've just got one more change to make: we need to implement the random chance game and add a transition to the WinnerState. We're going to add both to the HasQuarterState since that is where the customer turns the crank:

```
public class HasQuarterState implements State {
    Random randomWinner = new Random(System.currentTimeMillis());
    GumballMachine gumballMachine;

    public HasQuarterState(GumballMachine gumballMachine) {
        this.gumballMachine = gumballMachine;
    }

    public void insertQuarter() {
        System.out.println("You can't insert another quarter");
    }

    public void ejectQuarter() {
        System.out.println("Quarter returned");
        gumballMachine.setState(gumballMachine.getNoQuarterState());
    }

    public void turnCrank() {
        System.out.println("You turned...");
        int winner = randomWinner.nextInt(10);
        if ((winner == 0) && (gumballMachine.getCount() > 1)) {
            gumballMachine.setState(gumballMachine.getWinnerState());
        } else {
            gumballMachine.setState(gumballMachine.getSoldState());
        }
    }
    public void dispense() {
        System.out.println("No gumball dispensed");
    }
}
```

First we add a random number generator to generate the 10% chance of winning...

...then we determine if this customer won.

If they won, and there's enough gumballs left for them to get two, we go to the WinnerState; otherwise, we go to the SoldState (just like we always did).

Wow, that was pretty simple to implement! We just added a new state to the GumballMachine and then implemented it. All we had to do from there was to implement our chance game and transition to the correct state. It looks like our new code strategy is paying off...

Demo for the CEO of Mighty Gumball, Inc.

The CEO of Mighty Gumball has dropped by for a demo of your new gumball game code. Let's hope those states are all in order! We'll keep the demo short and sweet (the short attention span of CEOs is well documented), but hopefully long enough so that we'll win at least once.

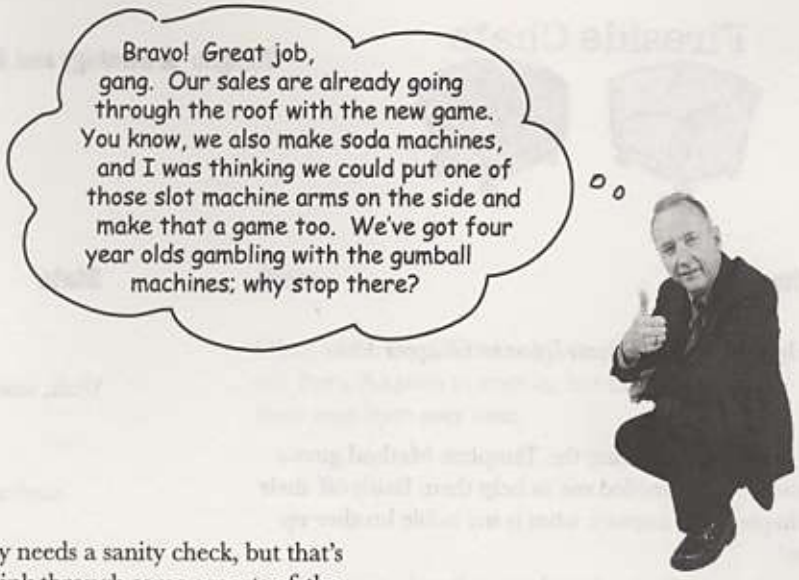
This code really hasn't changed at all; we just shortened it a bit.

Once, again, start with a gumball machine with 5 gumballs.

```
public class GumballMachineTestDrive {
    public static void main(String[] args) {
        GumballMachine gumballMachine = new GumballMachine(5);

        System.out.println(gumballMachine);

        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();

        System.out.println(gumballMachine);

        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();
        gumballMachine.insertQuarter();
        gumballMachine.turnCrank();

        System.out.println(gumballMachine);
    }
}
```

We want to get a winning state, so we just keep pumping in those quarters and turning the crank. We print out the state of the gumball machine every so often...

The whole engineering team is waiting outside the conference room to see if the new State Pattern–based design is going to work!!



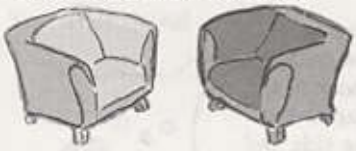
Sanity check...

Yes, the CEO of Mighty Gumball probably needs a sanity check, but that's not what we're talking about here. Let's think through some aspects of the GumballMachine that we might want to shore up before we ship the gold version:

- We've got a lot of duplicate code in the Sold and Winning states and we might want to clean those up. How would we do it? We could make State into an abstract class and build in some default behavior for the methods; after all, error messages like, "You already inserted a quarter," aren't going to be seen by the customer. So all "error response" behavior could be generic and inherited from the abstract State class.
- The dispense() method always gets called, even if the crank is turned when there is no quarter. While the machine operates correctly and doesn't dispense unless it's in the right state, we could easily fix this by having turnCrank() return a boolean, or by introducing exceptions. Which do you think is a better solution?
- All of the intelligence for the state transitions is in the State classes. What problems might this cause? Would we want to move that logic into the Gumball Machine? What would be the advantages and disadvantages of that?
- Will you be instantiating a lot of GumballMachine objects? If so, you may want to move the state instances into static instance variables and share them. What changes would this require to the GumballMachine and the States?

Dammit Jim, I'm a gumball machine, not a computer!

Fireside Chats



Tonight: **A Strategy and State Pattern Reunion.**

Strategy

Hey bro. Did you hear I was in Chapter 1?

I was just over giving the Template Method guys a hand – they needed me to help them finish off their chapter. So, anyway, what is my noble brother up to?

I don't know, you always sound like you've just copied what I do and you're using different words to describe it. Think about it: I allow objects to incorporate different behaviors or algorithms through composition and delegation. You're just copying me.

Oh yeah? How so? I don't get it.

Yeah, that was some *fine* work... and I'm sure you can see how that's more powerful than inheriting your behavior, right?

Sorry, you're going to have to explain that.

State

Yeah, word is definitely getting around.

Same as always – helping classes to exhibit different behaviors in different states.

I admit that what we do is definitely related, but my intent is totally different than yours. And, the way I teach my clients to use composition and delegation is totally different.

Well if you spent a little more time thinking about something other than *yourself*, you might. Anyway, think about how you work: you have a class you're instantiating and you usually give it a strategy object that implements some behavior. Like, in Chapter 1 you were handing out quack behaviors, right? Real ducks got a real quack, rubber ducks got a quack that squeaked.

Yes, of course. Now, think about how I work; it's totally different.

Strategy

Hey, come on, I can change behavior at runtime too; that's what composition is all about!

Well, I admit, I don't encourage my objects to have a well-defined set of transitions between states. In fact, I typically like to control what strategy my objects are using.

Yeah, yeah, keep living your pipe dreams brother. You act like you're a big pattern like me, but check it out: I'm in Chapter 1; they stuck you way out in Chapter 10. I mean, how many people are actually going to read this far?

That's my brother, always the dreamer.

State

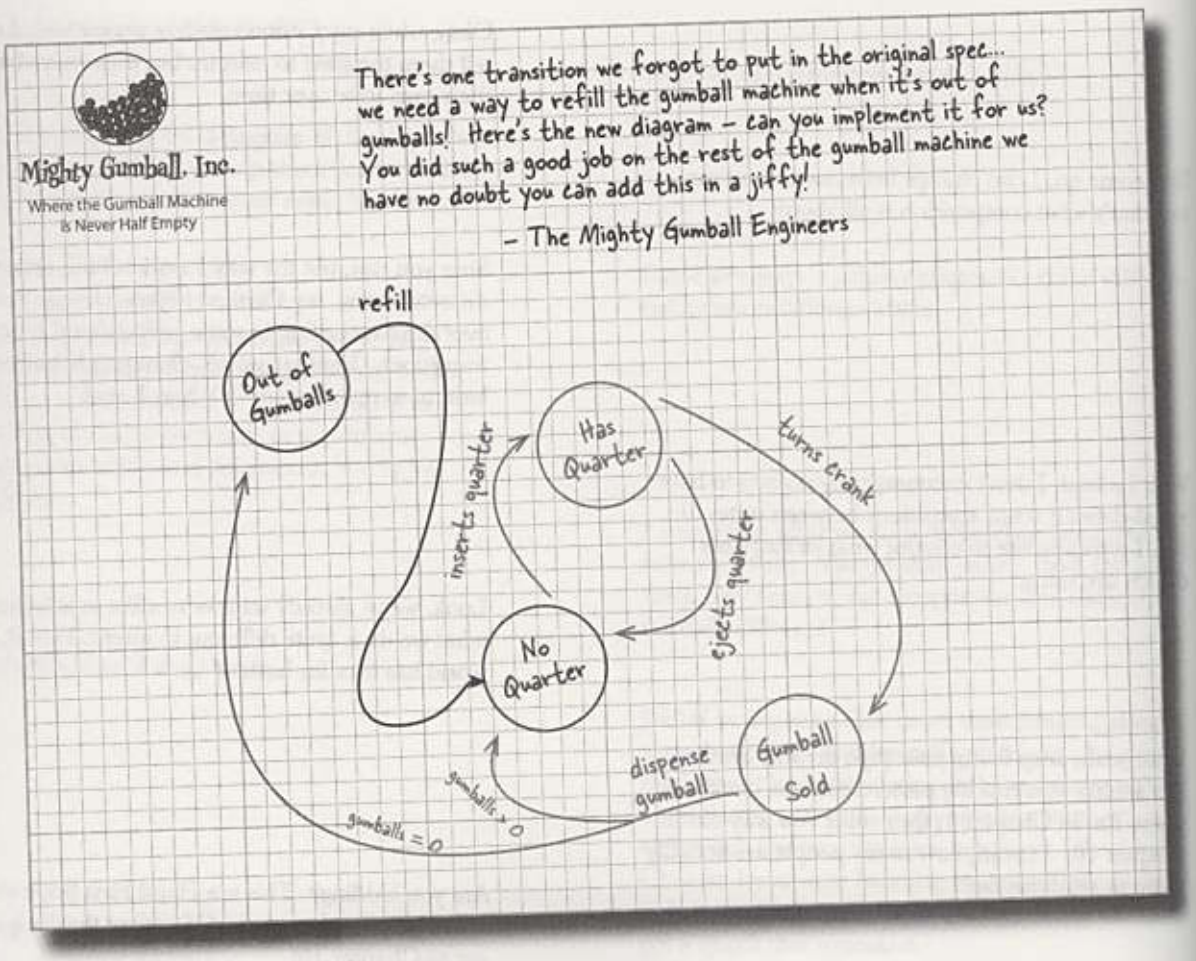
Okay, when my Context objects get created, I may tell them the state to start in, but then they change their own state over time.

Sure you can, but the way I work is built around discrete states; my Context objects change state over time according to some well defined state transitions. In other words, changing behavior is built in to my scheme – it's how I work!

Look, we've already said we're alike in structure, but what we do is quite different in intent. Face it, the world has uses for both of us.

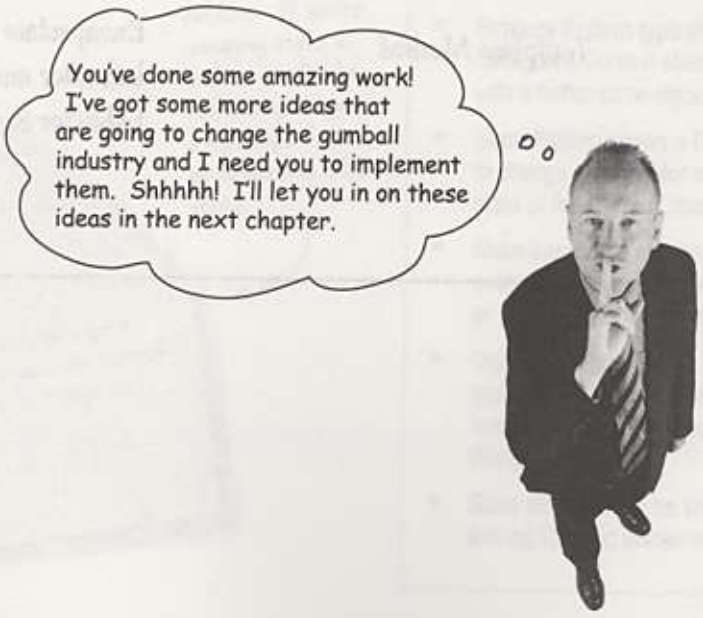
Are you kidding? This is a Head First book and Head First readers rock. Of course they're going to get to Chapter 10!

We almost forgot!



Sharpen your pencil

We need you to write the refill() method for the Gumball machine. It has one argument – the number of gumballs you're adding to the machine – and should update the gumball machine count and reset the machine's state.



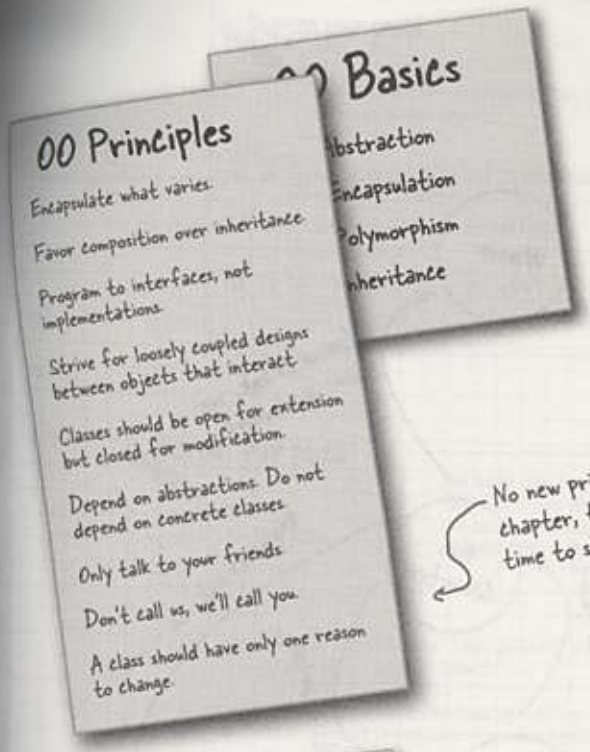
WHO DOES WHAT?

Match each pattern with its description:

Pattern	Description
State	Encapsulate interchangeable behaviors and use delegation to decide which behavior to use
Strategy	Subclasses decide how to implement steps in an algorithm
Template Method	Encapsulate state-based behavior and delegate behavior to the current state

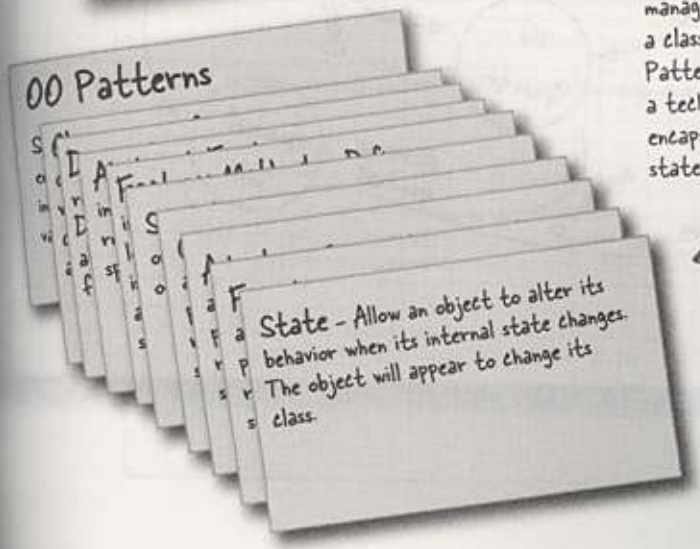
Tools for your Design Toolbox

It's the end of another chapter; you've got enough patterns here to breeze through any job interview!



No new principles this chapter, that gives you time to sleep on them.

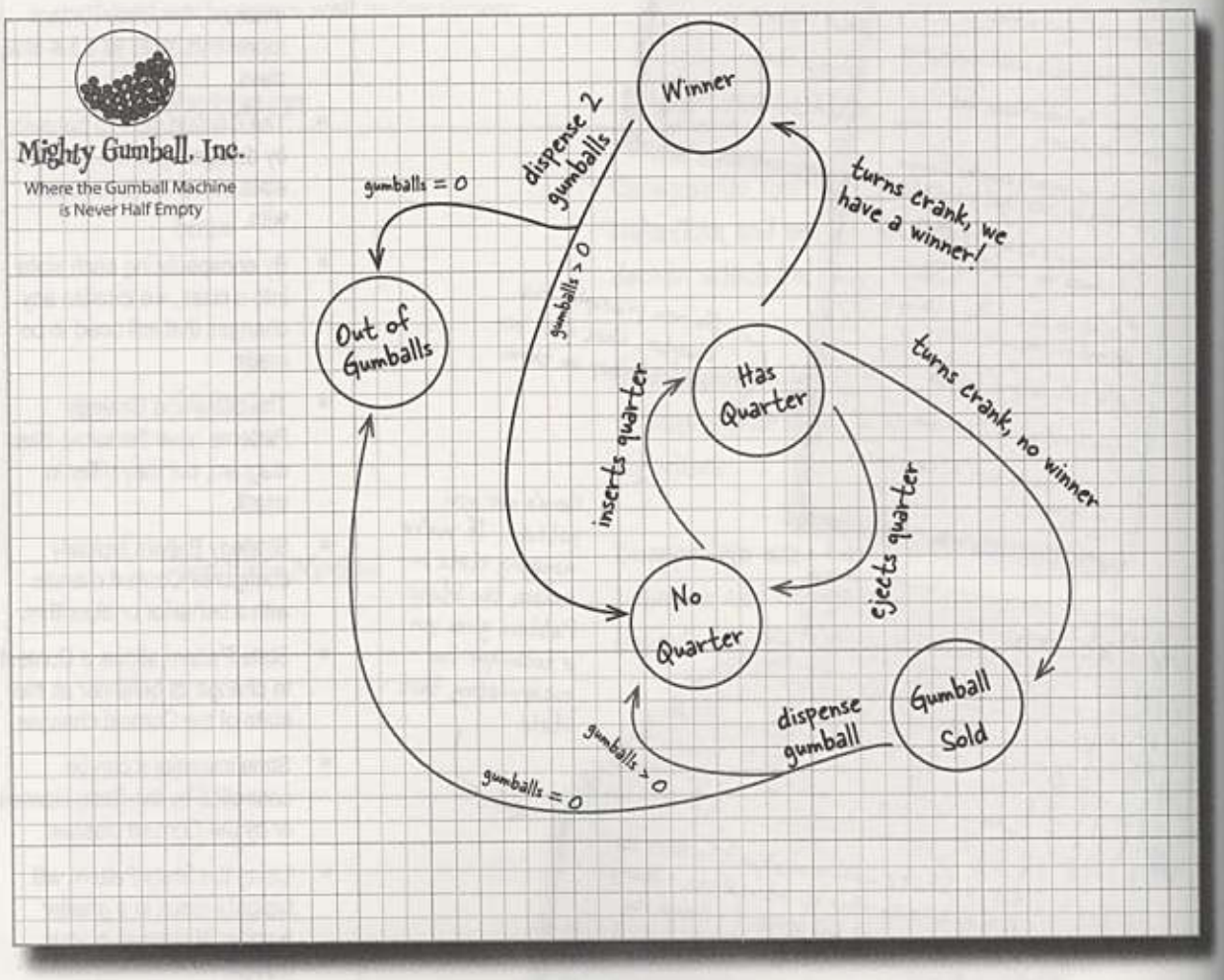
Here's our new pattern. If you're managing state in a class, the State Pattern gives you a technique for encapsulating that state.



BULLET POINTS

- The State Pattern allows an object to have many different behaviors that are based on its internal state.
- Unlike a procedural state machine, the State Pattern represents state as a full-blown class.
- The Context gets its behavior by delegating to the current state object it is composed with.
- By encapsulating each state into a class, we localize any changes that will need to be made.
- The State and Strategy Patterns have the same class diagram, but they differ in intent.
- Strategy Pattern typically configures Context classes with a behavior or algorithm.
- State Pattern allows a Context to change its behavior as the state of the Context changes.
- State transitions can be controlled by the State classes or by the Context classes.
- Using the State Pattern will typically result in a greater number of classes in your design.
- State classes may be shared among Context instances.

Exercise solutions



Exercise solutions

Sharpen your pencil

Based on our first implementation, which of the following apply? (Choose all that apply.)

- [x] A. This code certainly isn't adhering to the Open Closed Principle!
- [x] B. This code would make a FORTRAN programmer proud.
- [x] C. This design isn't even very object oriented.
- [x] C. State transitions aren't explicit; they are buried in the middle of a bunch of conditional code.
- [x] D. We haven't encapsulated anything that varies here.
- [x] E. Further additions are likely to cause bugs in working code.

Sharpen your pencil

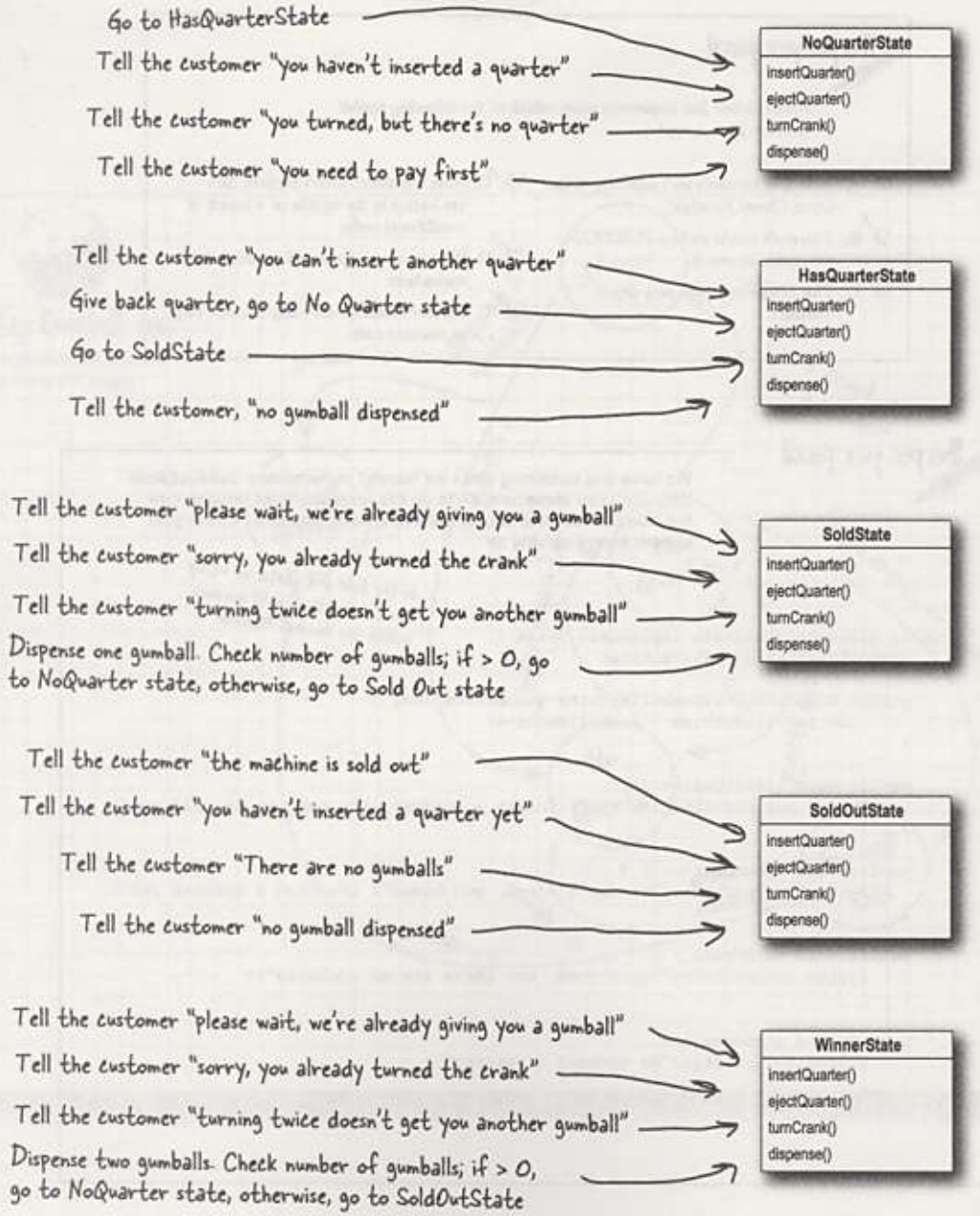
We have one remaining class we haven't implemented: SoldOutState. Why don't you implement it? To do this, carefully think through how the Gumball Machine should behave in each situation. Check your answer before moving on...

In the Sold Out state, we really can't do anything until someone refills the Gumball Machine.

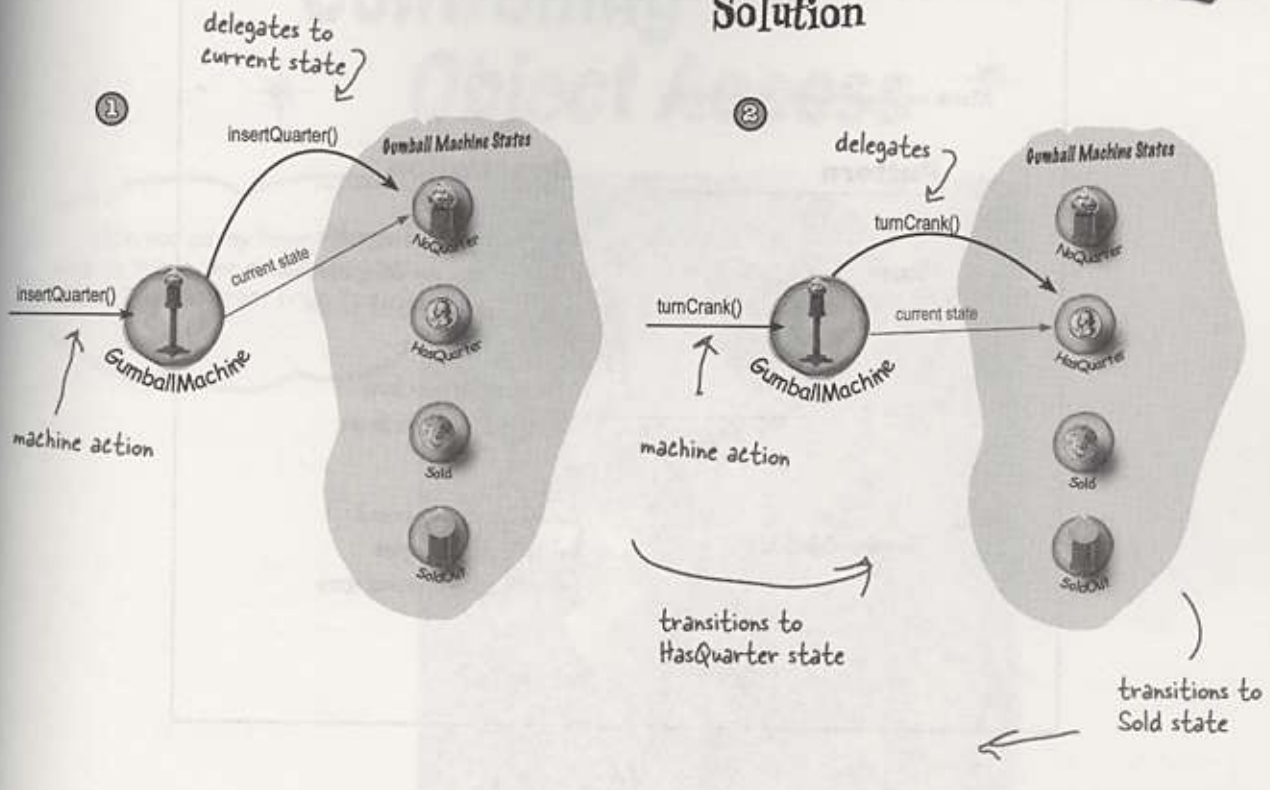
```
public class SoldOutState implements State {
    GumballMachine gumballMachine;

    public SoldOutState(GumballMachine gumballMachine) {
        this.gumballMachine = gumballMachine;
    }

    public void insertQuarter() {
        System.out.println("You can't insert a quarter, the machine is sold out");
    }

    public void ejectQuarter() {
        System.out.println("You can't eject, you haven't inserted a quarter yet");
    }

    public void turnCrank() {
        System.out.println("You turned, but there are no gumballs");
    }

    public void dispense() {
        System.out.println("No gumball dispensed");
    }
}
```

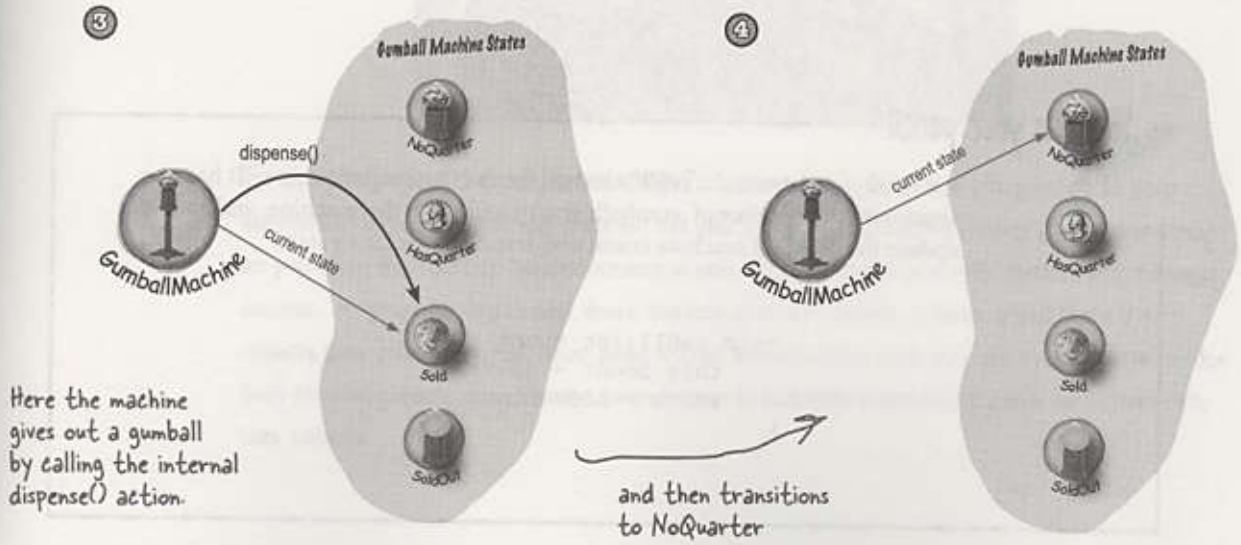
Sharpen your pencil

To implement the states, we first need to define what the behavior will be when the corresponding action is called. Annotate the diagram below with the behavior of each action in each class; we've already filled in a few for you.



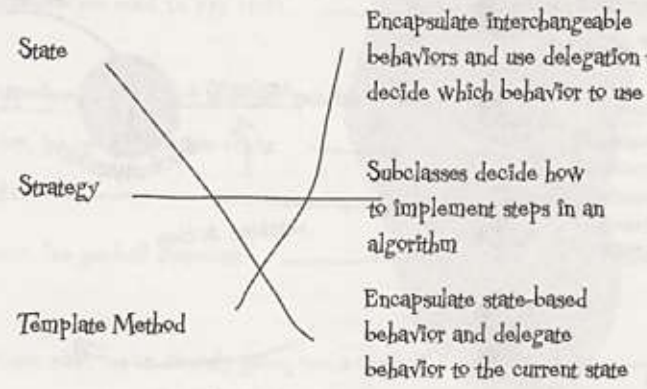
Behind the Scenes: Self-Guided Tour Solution





Who does what?

Match each pattern with its description:



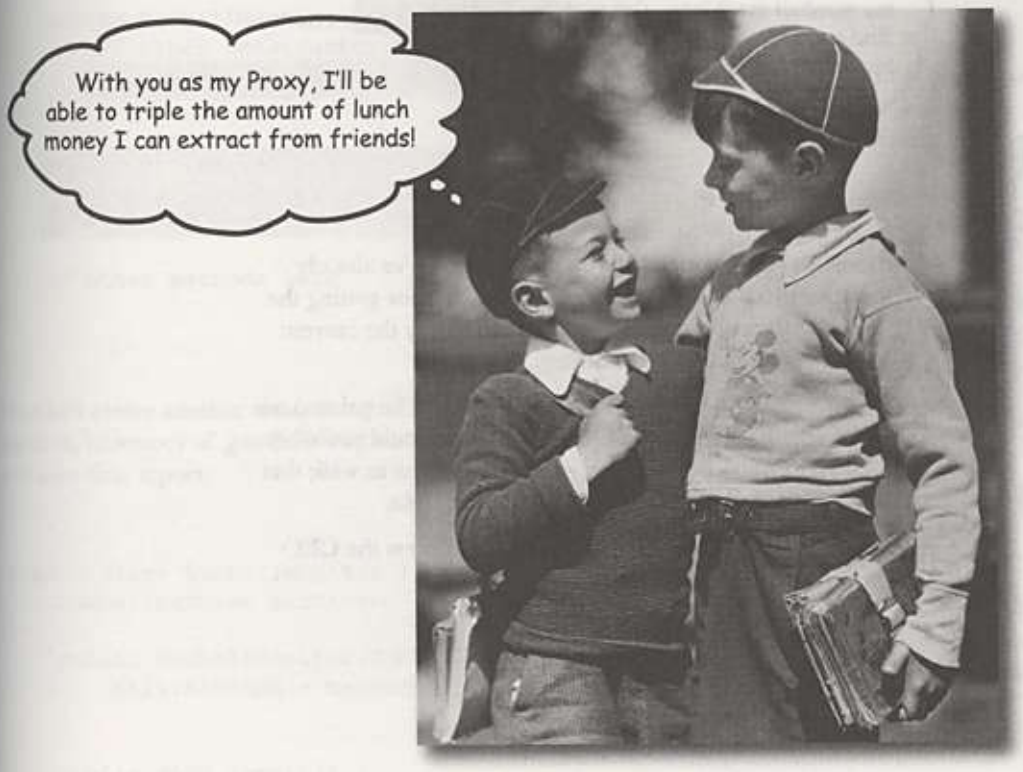
Sharpen your pencil

We need you to write the refill() method for the Gumball machine. It has one argument, the number of gumballs you're adding to the machine, and should update the gumball machine count and reset the machine's state.

```
void refill(int count) {
    this.count = count;
    state = noQuarterState;
}
```

11 the Proxy Pattern

Controlling Object Access



Ever play good cop, bad cop? You're the good cop and you provide all your services in a nice and friendly manner, but you don't want *everyone* asking you for services, so you have the bad cop *control access* to you. That's what proxies do: control and manage access. As you're going to see, there are *lots* of ways in which proxies stand in for the objects they proxy. Proxies have been known to haul entire method calls over the Internet for their proxied objects; they've also been known to patiently stand in the place for some pretty lazy objects.

Sounds easy enough. If you remember, we've already got methods in the gumball machine code for getting the count of gumballs (getCount()), and getting the current state of the machine (getState()).

All we need to do is create a report that can be printed out and sent back to the CEO. Hmmm, we should probably add a location field to each gumball machine as well; that way the CEO can keep the machines straight.

Let's just jump in and code this. We'll impress the CEO with a very fast turnaround.

Coding the Monitor

Let's start by adding support to the GumballMachine class so that it can handle locations:

```
public class GumballMachine {
    // other instance variables
    String location;

    public GumballMachine(String location, int count) {
        // other constructor code here
        this.location = location;
    }

    public String getLocation() {
        return location;
    }

    // other methods here
}
```

A location is just a String.

The location is passed into the constructor and stored in the instance variable.

Let's also add a getter method to grab the location when we need it

Now let's create another class, GumballMonitor, that retrieves the machine's location, inventory of gumballs and the current machine state and prints them in a nice little report:

```
public class GumballMonitor {
    GumballMachine machine;

    public GumballMonitor(GumballMachine machine) {
        this.machine = machine;
    }

    public void report() {
        System.out.println("Gumball Machine: " + machine.getLocation());
        System.out.println("Current inventory: " + machine.getCount() + " gumballs");
        System.out.println("Current state: " + machine.getState());
    }
}
```

The monitor takes the machine in its constructor and assigns it to the machine instance variable.

Our report method just prints a report with location, inventory and the machine's state.

Testing the Monitor

We implemented that in no time. The CEO is going to be thrilled and amazed by our development skills.

Now we just need to instantiate a GumballMonitor and give it a machine to monitor:

```
public class GumballMachineTestDrive {
    public static void main(String[] args) {
        int count = 0;

        if (args.length < 2) {
            System.out.println("GumballMachine <name> <inventory>");
            System.exit(1);
        }

        count = Integer.parseInt(args[1]);
        GumballMachine gumballMachine = new GumballMachine(args[0], count);

        GumballMonitor monitor = new GumballMonitor(gumballMachine);


        // rest of test code here

        monitor.report();
    }
}
```

Pass in a location and initial # of gumballs on the command line.

Don't forget to give the constructor a location and count...

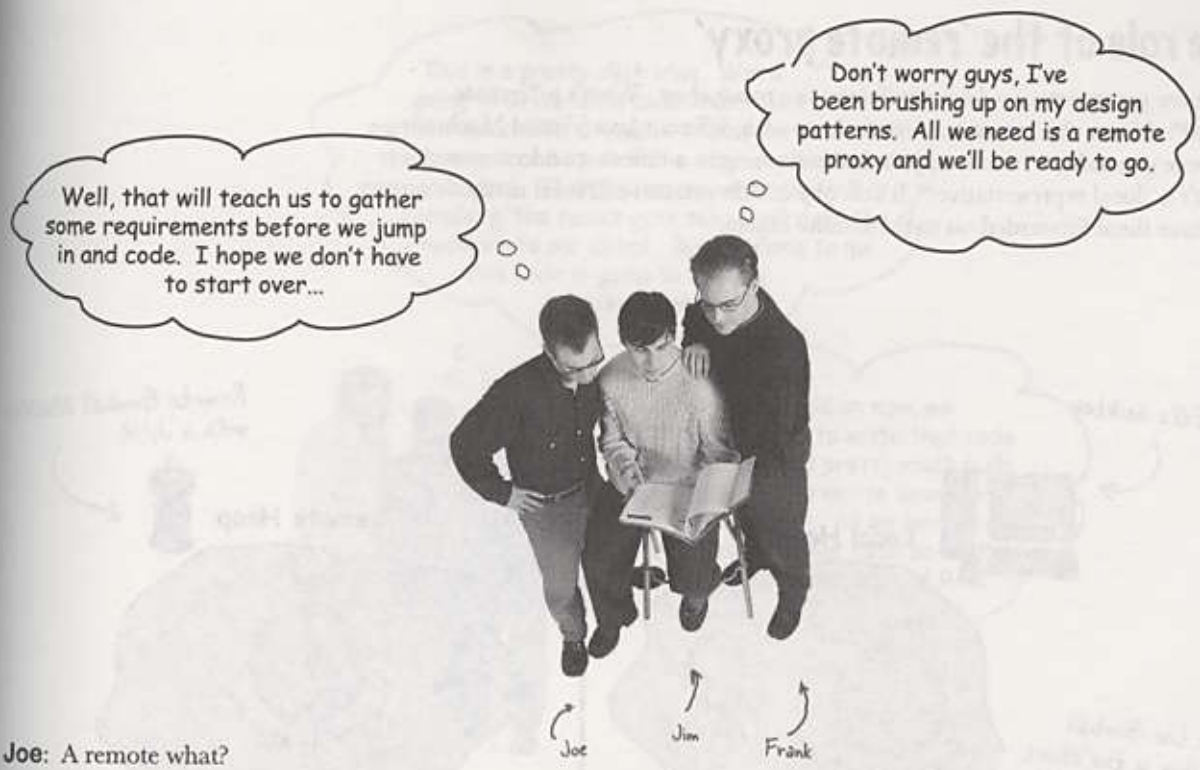
...and instantiate a monitor and pass it a machine to provide a report on.

When we need a report on the machine, we call the report() method.

```
File Edit Window Help FlyingFish
%java GumballMachineTestDrive Seattle 112
Gumball Machine: Seattle
Current Inventory: 112 gumballs
Current State: waiting for quarter
```

And here's the output!

The monitor output looks great, but I guess I wasn't clear. I need to monitor gumball machines REMOTELY! In fact, we already have the networks in place for monitoring. Come on guys, you're supposed to be the Internet generation!



Joe: A remote what?

Frank: *Remote proxy*. Think about it: we've already got the monitor code written, right? We give the GumballMonitor a reference to a machine and it gives us a report. The problem is that monitor runs in the same JVM as the gumball machine and the CEO wants to sit at his desk and *remotely* monitor the machines! So what if we left our GumballMonitor class as is, but handed it a proxy to a *remote* object?

Joe: I'm not sure I get it.

Jim: Me neither.

Frank: Let's start at the beginning... a proxy is a stand in for a *real* object. In this case, the proxy acts just like it is a Gumball Machine object, but behind the scenes it is communicating over the network to talk to the real, remote GumballMachine.

Jim: So you're saying we keep our code as it is, and we give the monitor a reference to a proxy version of the GumballMachine...

Joe: And this proxy pretends it's the real object, but it's really just communicating over the net to the real object.

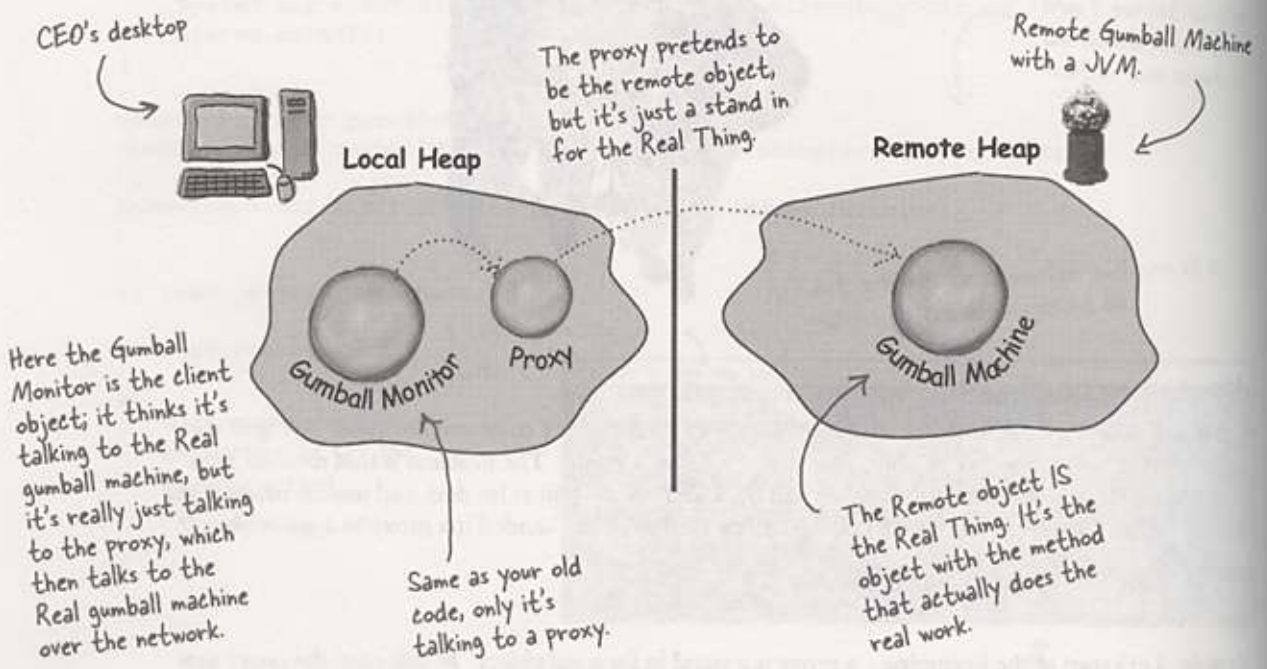
Frank: Yeah, that's pretty much the story.

Joe: It sounds like something that is easier said than done.

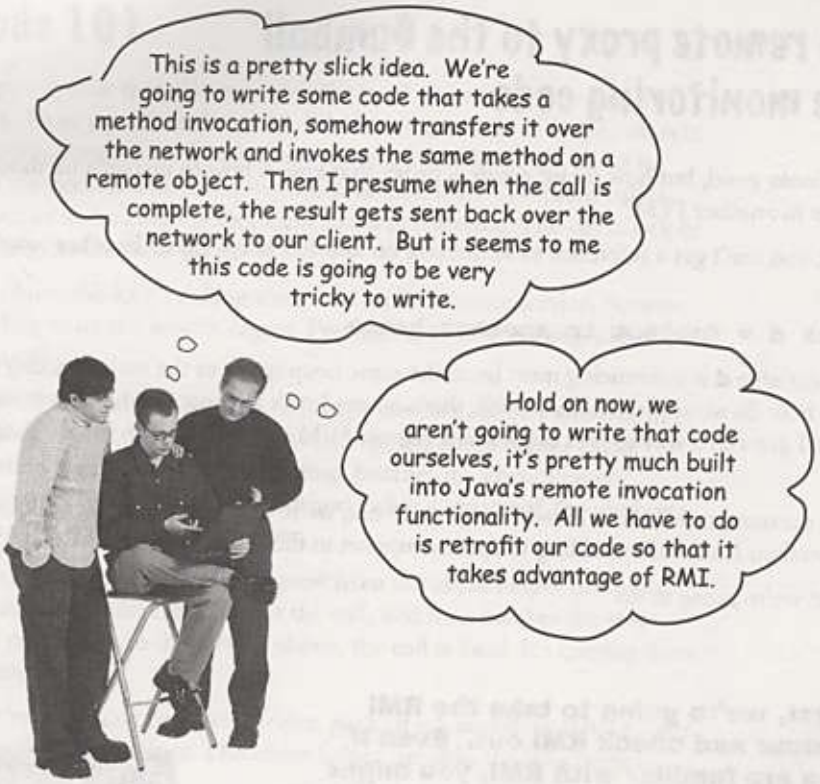
Frank: Perhaps, but I don't think it'll be that bad. We have to make sure that the gumball machine can act as a service and accept requests over the network; we also need to give our monitor a way to get a reference to a proxy object, but we've got some great tools already built into Java to help us. Let's talk a little more about remote proxies first...

The role of the 'remote proxy'

A remote proxy acts as a *local representative to a remote object*. What's a "remote object?" It's an object that lives in the heap of a different Java Virtual Machine (or more generally, a remote object that is running in a different address space). What's a "local representative?" It's an object that you can call local methods on and have them forwarded on to the remote object.



Your client object acts like it's making remote method calls. But what it's really doing is calling methods on a heap-local 'proxy' object that handles all the low-level details of network communication.



BRAIN POWER

Before going further, think about how you'd design a system to enable remote method invocation. How would you make it easy on the developer so that she has to write as little code as possible? How would you make the remote invocation look seamless?

BRAIN² POWER

Should making remote calls be totally transparent? Is that a good idea? What might be a problem with that approach?

Adding a remote proxy to the Gumball Machine monitoring code

On paper this looks good, but how do we create a proxy that knows how to invoke a method on an object that lives in another JVM?

Hmmm. Well, you can't get a reference to something on another heap, right? In other words, you can't say:

```
Duck d = <object in another heap>
```

Whatever the variable **d** is referencing must be in the same heap space as the code running the statement. So how do we approach this? Well, that's where Java's Remote Method Invocation comes in... RMI gives us a way to find objects in a remote JVM and allows us to invoke their methods.

You may have encountered RMI in Head First Java; if not, we're going to take a slight detour and come up to speed on RMI before adding the proxy support to the Gumball Machine code.

So, here's what we're going to do:

1. **First, we're going to take the RMI Detour and check RMI out. Even if you are familiar with RMI, you might want to follow along and check out the scenery.**

2. **Then we're going to take our GumballMachine and make it a remote service that provides a set of methods calls that can be invoked remotely.**

3. **Then, we going to create a proxy that can talk to a remote GumballMachine, again using RMI, and put the monitoring system back together so that the CEO can monitor any number of remote machines.**

If you're new to RMI, take the detour that runs over the next few pages; otherwise, you might want to just quickly thumb through the detour as a review.

Remote methods 101

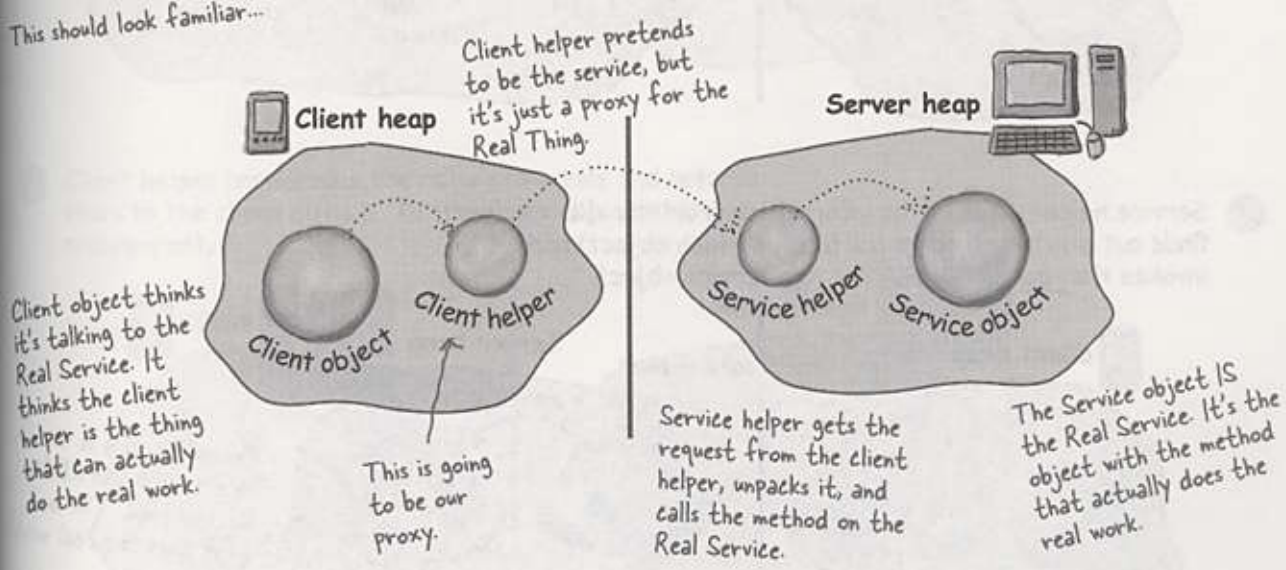
Let's say we want to design a system that allows us to call a local object that forwards each request to a remote object. How would we design it? We'd need a couple of helper objects that actually do the communicating for us. The helpers make it possible for the client to act as though it's calling a method on a local object (which in fact, it is). The client calls a method on the client helper, as if the client helper were the actual service. The client helper then takes care of forwarding that request for us.

In other words, the client object thinks it's calling a method on the remote service, because the client helper is pretending to be the service object. Pretending to be the thing with the method the client wants to call.

But the client helper isn't really the remote service. Although the client helper acts like it (because it has the same method that the service is advertising), the client helper doesn't have any of the actual method logic the client is expecting. Instead, the client helper contacts the server, transfers information about the method call (e.g., name of the method, arguments, etc.), and waits for a return from the server.

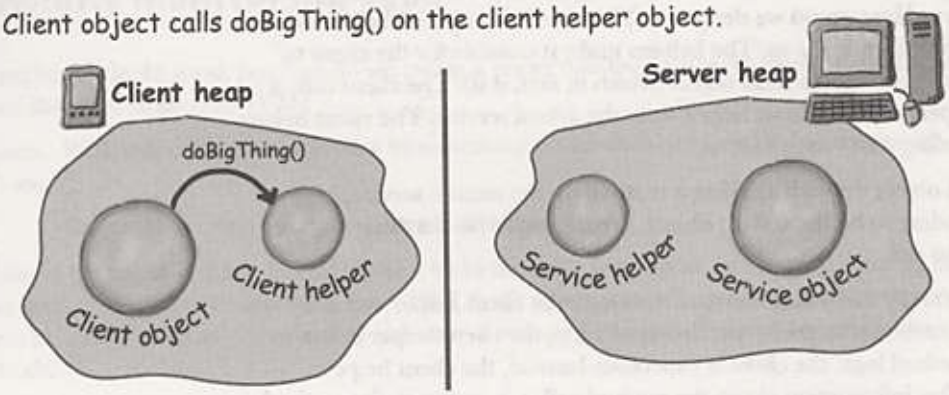
On the server side, the service helper receives the request from the client helper (through a Socket connection), unpacks the information about the call, and then invokes the real method on the real service object. So, to the service object, the call is local. It's coming from the service helper, not a remote client.

The service helper gets the return value from the service, packs it up, and ships it back (over a Socket's output stream) to the client helper. The client helper unpacks the information and returns the value to the client object.

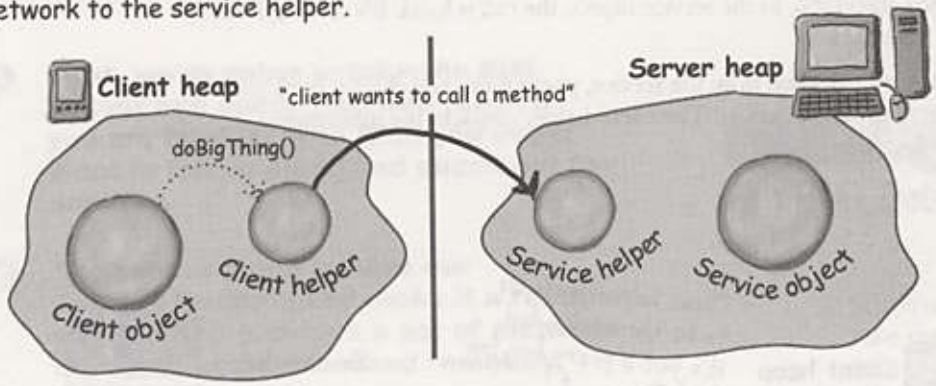


How the method call happens

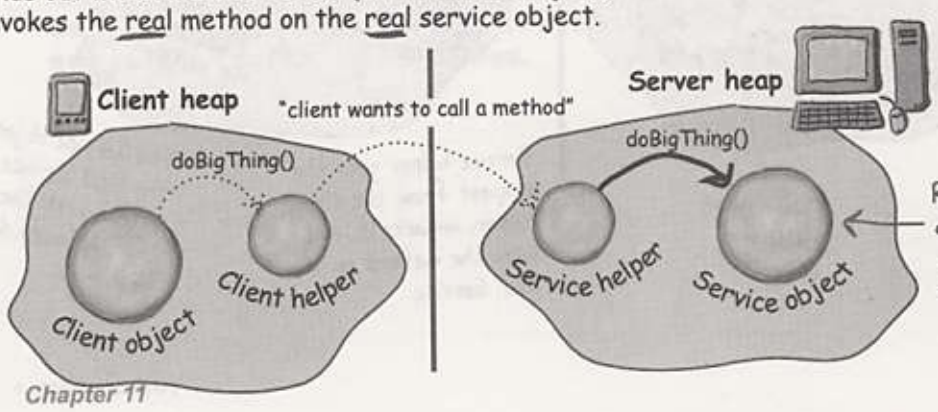
1. Client object calls doBigThing() on the client helper object.



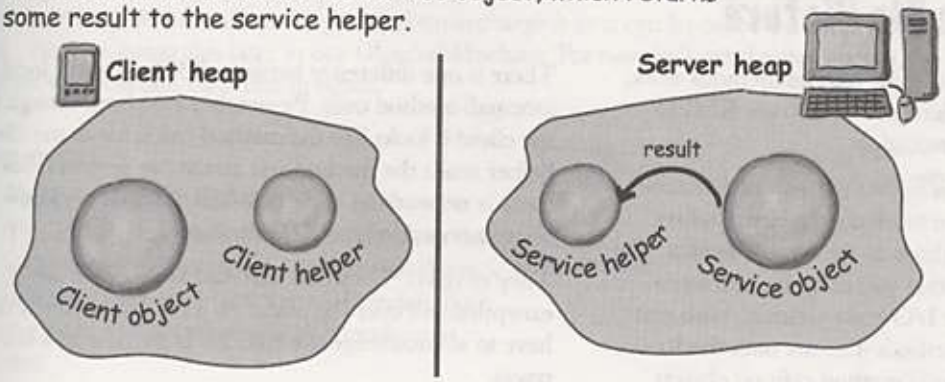
2. Client helper packages up information about the call (arguments, method name, etc.) and ships it over the network to the service helper.



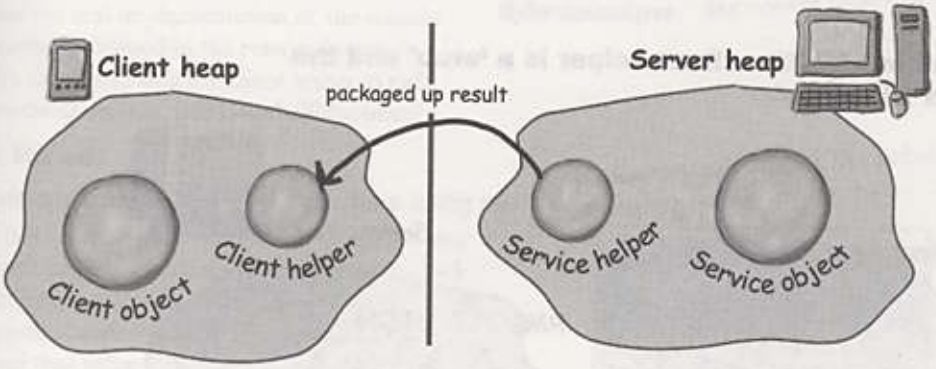
3. Service helper unpacks the information from the client helper, finds out which method to call (and on which object) and invokes the real method on the real service object.



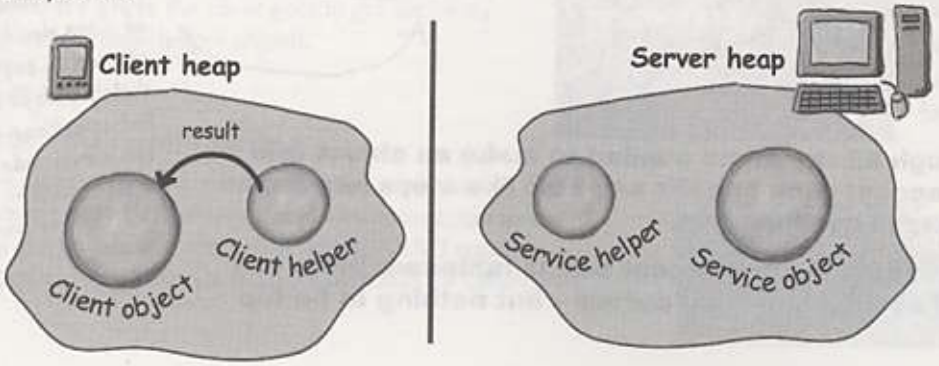
④ The method is invoked on the service object, which returns some result to the service helper.



⑤ Service helper packages up information returned from the call and ships it back over the network to the client helper.



⑥ Client helper unpackages the returned values and returns them to the client object. To the client object, this was all transparent.



Java RMI, the Big Picture

Okay, you've got the gist of how remote methods work; now you just need to understand how to use RMI to enable remote method invocation.

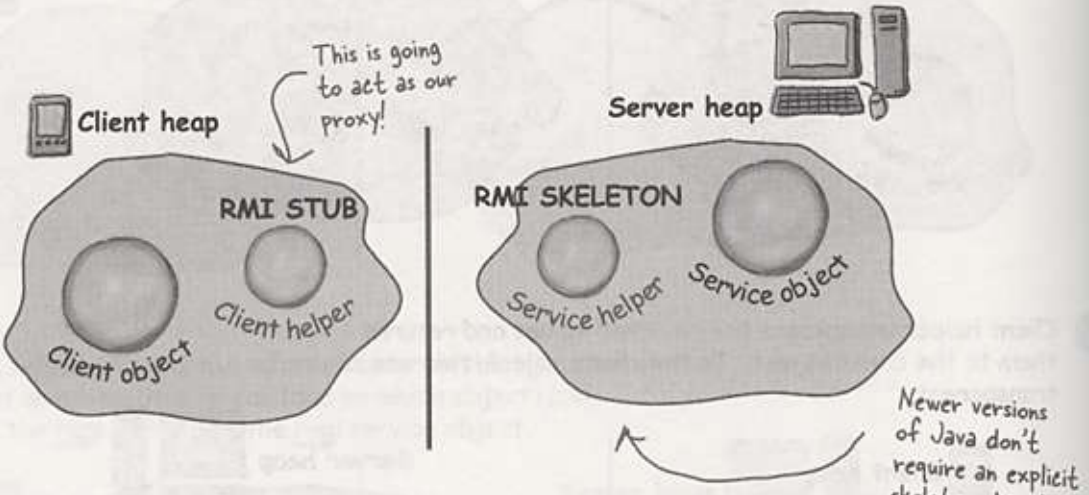
What RMI does for you is build the client and service helper objects, right down to creating a client helper object with the same methods as the remote service. The nice thing about RMI is that you don't have to write any of the networking or I/O code yourself. With your client, you call remote methods (i.e., the ones the Real Service has) just like normal method calls on objects running in the client's own local JVM.

RMI also provides all the runtime infrastructure to make it all work, including a lookup service that the client can use to find and access the remote objects.

There is one difference between RMI calls and local (normal) method calls. Remember that even though to the client it looks like the method call is local, the client helper sends the method call across the network. So there is networking and I/O. And what do we know about networking and I/O methods?

They're risky! They can fail! And so, they throw exceptions all over the place. As a result, the client does have to acknowledge the risk. We'll see how in a few pages.

RMI Nomenclature: in RMI, the client helper is a 'stub' and the service helper is a 'skeleton'.



Now let's go through all the steps needed to make an object into a service that can accept remote calls and also the steps needed to allow a client to make remote calls.

You might want to make sure your seat belt is fastened; there are a lot of steps and a few bumps and curves – but nothing to be too worried about.

Making the Remote service

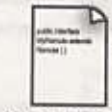

An RMI Detour

This is an **overview** of the five steps for making the remote service. In other words, the steps needed to take an ordinary object and supercharge it so it can be called by a remote client. We'll be doing this later to our GumballMachine. For now, let's get the steps down and then we'll explain each one in detail.

Step one:

Make a Remote Interface

The remote interface defines the methods that a client can call remotely. It's what the client will use as the class type for your service. Both the Stub and actual service will implement this!


MyService.java

This interface defines the remote methods that you want clients to call.

Step two:

Make a Remote Implementation

This is the class that does the Real Work. It has the real implementation of the remote methods defined in the remote interface. It's the object that the client wants to call methods on (e.g., our GumballMachine!).


MyServiceImpl.java

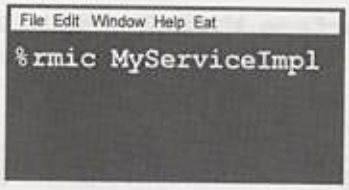
The Real Service; the class with the methods that do the real work. It implements the remote interface.

Step three:

Generate the stubs and skeletons using rmic

These are the client and server 'helpers'. You don't have to create these classes or ever look at the source code that generates them. It's all handled automatically when you run the rmic tool that ships with your Java development kit.

Running rmic against the actual service implementation class...



...spits out two new classes for the helper objects.

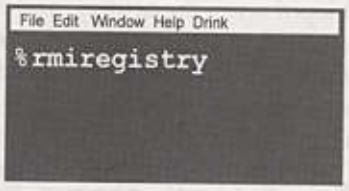

MyServiceImpl_Stub.class


MyServiceImpl_Skel.class

Step four:

Start the RMI registry (rmiregistry)

The *rmiregistry* is like the white pages of a phone book. It's where the client goes to get the proxy (the client stub/helper object).

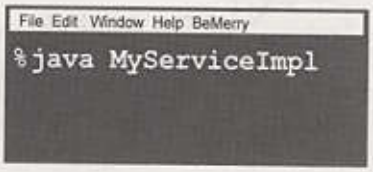


Run this in a separate terminal.

Step five:

Start the remote service

You have to get the service object up and running. Your service implementation class instantiates an instance of the service and registers it with the RMI registry. Registering it makes the service available for clients.



Step one: make a Remote interface

① Extend java.rmi.Remote

Remote is a 'marker' interface, which means it has no methods. It has special meaning for RMI, though, so you must follow this rule. Notice that we say 'extends' here. One interface is allowed to *extend* another interface.

```
public interface MyRemote extends Remote {
```

This tells us that the interface is going to be used to support remote calls.

② Declare that all methods throw a RemoteException

The remote interface is the one the client uses as the type for the service. In other words, the client invokes methods on something that implements the remote interface. That something is the stub, of course, and since the stub is doing networking and I/O, all kinds of Bad Things can happen. The client has to acknowledge the risks by handling or declaring the remote exceptions. If the methods in an interface declare exceptions, any code calling methods on a reference of that type (the interface type) must handle or declare the exceptions.

```
import java.rmi.*;
```

Remote interface is in java.rmi

```
public interface MyRemote extends Remote {
    public String sayHello() throws RemoteException;
}
```

Every remote method call is considered 'risky'. Declaring RemoteException on every method forces the client to pay attention and acknowledge that things might not work.

③ Be sure arguments and return values are primitives or Serializable

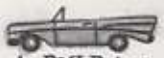
Arguments and return values of a remote method must be either primitive or Serializable. Think about it. Any argument to a remote method has to be packaged up and shipped across the network, and that's done through Serialization. Same thing with return values. If you use primitives, Strings, and the majority of types in the API (including arrays and collections), you'll be fine. If you are passing around your own types, just be sure that you make your classes implement Serializable.

Check out Head First Java if you need to refresh your memory on Serializable.

```
public String sayHello() throws RemoteException;
```

This return value is gonna be shipped over the wire from the server back to the client, so it must be Serializable. That's how args and return values get packaged up and sent.

Step two: make a Remote implementation



① Implement the Remote interface

Your service has to implement the remote interface—the one with the methods your client is going to call.

```
public class MyRemoteImpl extends UnicastRemoteObject implements MyRemote {
    public String sayHello() {
        return "Server says, 'Hey'";
    }
    // more code in class
}
```

The compiler will make sure that you've implemented all the methods from the interface you implement. In this case, there's only one.

② Extend UnicastRemoteObject

In order to work as a remote service object, your object needs some functionality related to 'being remote'. The simplest way is to extend UnicastRemoteObject (from the java.rmi.server package) and let that class (your superclass) do the work for you.

```
public class MyRemoteImpl extends UnicastRemoteObject implements MyRemote {
```

③ Write a no-arg constructor that declares a RemoteException

Your new superclass, UnicastRemoteObject, has one little problem—its constructor throws a RemoteException. The only way to deal with this is to declare a constructor for your remote implementation, just so that you have a place to declare the RemoteException. Remember, when a class is instantiated, its superclass constructor is always called. If your superclass constructor throws an exception, you have no choice but to declare that your constructor also throws an exception.

```
public MyRemoteImpl() throws RemoteException { }
```

You don't have to put anything in the constructor. You just need a way to declare that your superclass constructor throws an exception.

④ Register the service with the RMI registry

Now that you've got a remote service, you have to make it available to remote clients. You do this by instantiating it and putting it into the RMI registry (which must be running or this line of code fails). When you register the implementation object, the RMI system actually puts the *stub* in the registry, since that's what the client really needs. Register your service using the static rebind() method of the java.rmi.Naming class.

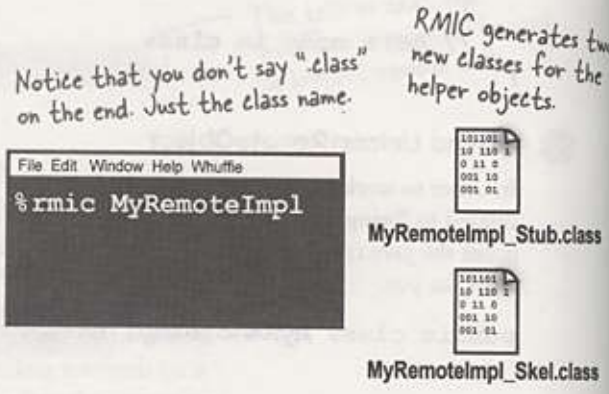
```
try {
    MyRemote service = new MyRemoteImpl();
    Naming.rebind("RemoteHello", service);
} catch(Exception ex) {...}
```

Give your service a name (that clients can use to look it up in the registry) and register it with the RMI registry. When you bind the service object, RMI swaps the service for the stub and puts the stub in the registry.

Step three: generate stubs and skeletons

1 Run rmic on the remote implementation class (not the remote interface)

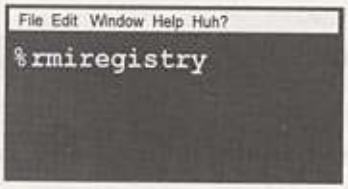
The rmic tool, which comes with the Java software development kit, takes a service implementation and creates two new classes, the stub and the skeleton. It uses a naming convention that is the name of your remote implementation, with either _Stub or _Skel added to the end. There are other options with rmic, including not generating skeletons, seeing what the source code for these classes looked like, and even using IIOP as the protocol. The way we're doing it here is the way you'll usually do it. The classes will land in the current directory (i.e. whatever you did a `cd` to). Remember, rmic must be able to see your implementation class, so you'll probably run rmic from the directory where your remote implementation is located. (We're deliberately not using packages here, to make it simpler. In the Real World, you'll need to account for package directory structures and fully-qualified names).



Step four: run rmiregistry

1 Bring up a terminal and start the rmiregistry.

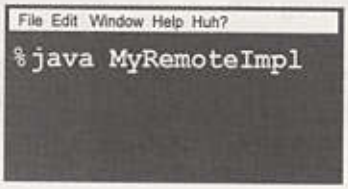
Be sure you start it from a directory that has access to your classes. The simplest way is to start it from your 'classes' directory.



Step five: start the service

1 Bring up another terminal and start your service

This might be from a main() method in your remote implementation class, or from a separate launcher class. In this simple example, we put the starter code in the implementation class, in a main method that instantiates the object and registers it with RMI registry.



Complete code for the server side

The Remote interface:

```
import java.rmi.*;

public interface MyRemote extends Remote {

   public String sayHello() throws RemoteException;
}
```

RemoteException and Remote interface are in java.rmi package.

Your interface MUST extend java.rmi.Remote

All of your remote methods must declare a RemoteException.

The Remote service (the implementation):

```
import java.rmi.*;
import java.rmi.server.*;

public class MyRemoteImpl extends UnicastRemoteObject implements MyRemote {

  public String sayHello() {
      return "Server says, 'Hey'";
  }

  public MyRemoteImpl() throws RemoteException { }

  public static void main (String[] args) {

      try {
          MyRemote service = new MyRemoteImpl();
          Naming.rebind("RemoteHello", service);
      } catch(Exception ex) {
          ex.printStackTrace();
      }
  }
}
```

UnicastRemoteObject is in the java.rmi.server package.

Extending UnicastRemoteObject is the easiest way to make a remote object

You MUST implement your remote interface!!

You have to implement all the interface methods, of course. But notice that you do NOT have to declare the RemoteException.

Your superclass constructor (for UnicastRemoteObject) declares an exception, so YOU must write a constructor, because it means that your constructor is calling risky code (its super constructor).

Make the remote object, then 'bind' it to the rmiregistery using the static Naming.rebind(). The name you register it under is the name clients will use to look it up in the RMI registry.

How does the client get the stub object?

The client has to get the stub object (our proxy), since that's the thing the client will call methods on. And that's where the RMI registry comes in. The client does a 'lookup', like going to the white pages of a phone book, and essentially says, "Here's a name, and I'd like the stub that goes with that name."

Let's take a look at the code we need to lookup and retrieve a stub object.

Here's how it works.

Code Up Close

The client always uses the remote implementation as the type of the service. In fact, the client never needs to know the actual class name of your remote service.

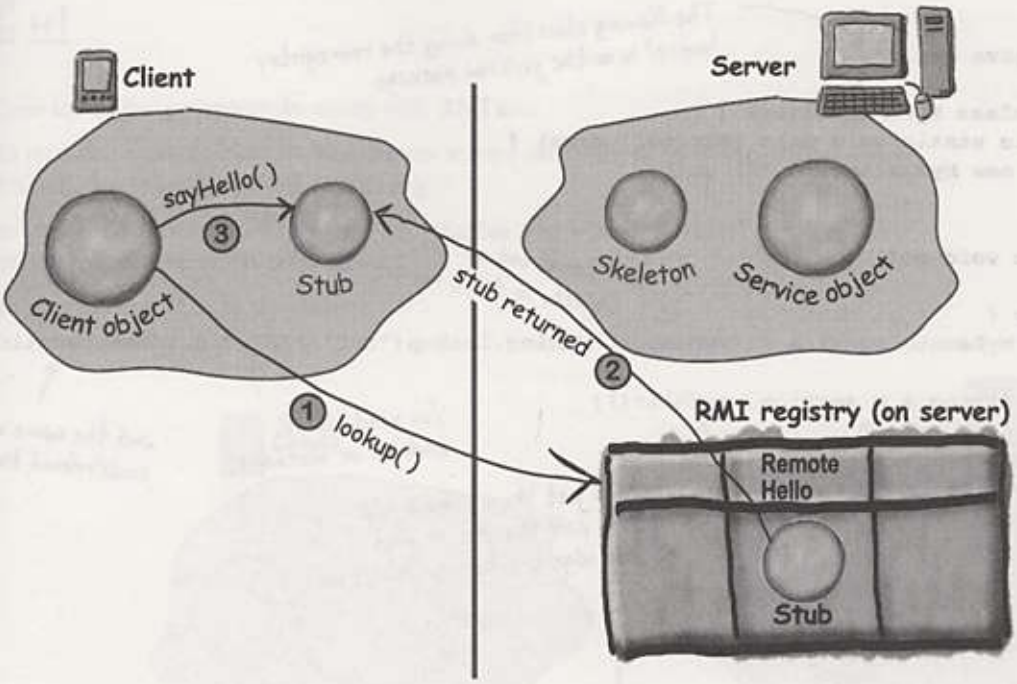
lookup() is a static method of the Naming class.

This must be the name that the service was registered under.

```
MyRemote service =
    (MyRemote) Naming.lookup("rmi://127.0.0.1/RemoteHello");
```

You have to cast it to the interface, since the lookup method returns type Object.

The host name or IP address where the service is running.



How it works...

1 Client does a lookup on the RMI registry

```
Naming.lookup("rmi://127.0.0.1/RemoteHello");
```

2 RMI registry returns the stub object

(as the return value of the lookup method) and RMI deserializes the stub automatically. You MUST have the stub class (that rmic generated for you) on the client or the stub won't be deserialized.

3 Client invokes a method on the stub, as if the stub IS the real service

Complete client code

```
import java.rmi.*;

public class MyRemoteClient {
   public static void main (String[] args) {
        new MyRemoteClient().go();
   }

   public void go() {

      try {
         MyRemote service = (MyRemote) Naming.lookup("rmi://127.0.0.1/RemoteHello");

         String s = service.sayHello();

         System.out.println(s);
      } catch(Exception ex) {
         ex.printStackTrace();
      }
   }
}
```

The Naming class (for doing the rmiregistry lookup) is in the java.rmi package.

It comes out of the registry as type Object, so don't forget the cast.

You need the IP address or hostname.

and the name used to bind/rebind the service.

It looks just like a regular old method call! (Except it must acknowledge the RemoteException.)

Geek Bits

How does the client get the stub class?

Now we get to the interesting question. Somehow, some way, the client must have the stub class (that you generated earlier using rmic) at the time the client does the lookup, or else the stub won't be deserialized on the client and the whole thing blows up. The client also needs classes for any serialized objects returned by method calls to the remote object. In a simple system, you can simply hand-deliver the these classes to the client.

There's a much cooler way, although it's beyond the scope of this book. But just in case you're interested, the cooler way is called "dynamic class downloading". With dynamic class downloading, Serialized objects (like the stub) are "stamped" with a URL that tells the RMI system on the client where to find the class file for that object. Then, in the process of deserializing an object, if RMI can't find the class locally, it uses that URL to do an HTTP Get to retrieve the class file. So you'd need a simple web server to serve up class files, and you'd also need to change some security parameters on the client. There are a few other tricky issues with dynamic class downloading, but that's the overview.

For the stub object specifically, there's *another* way the client can get the class. This is only available in Java 5, though. We'll briefly talk about this near the end of the chapter.

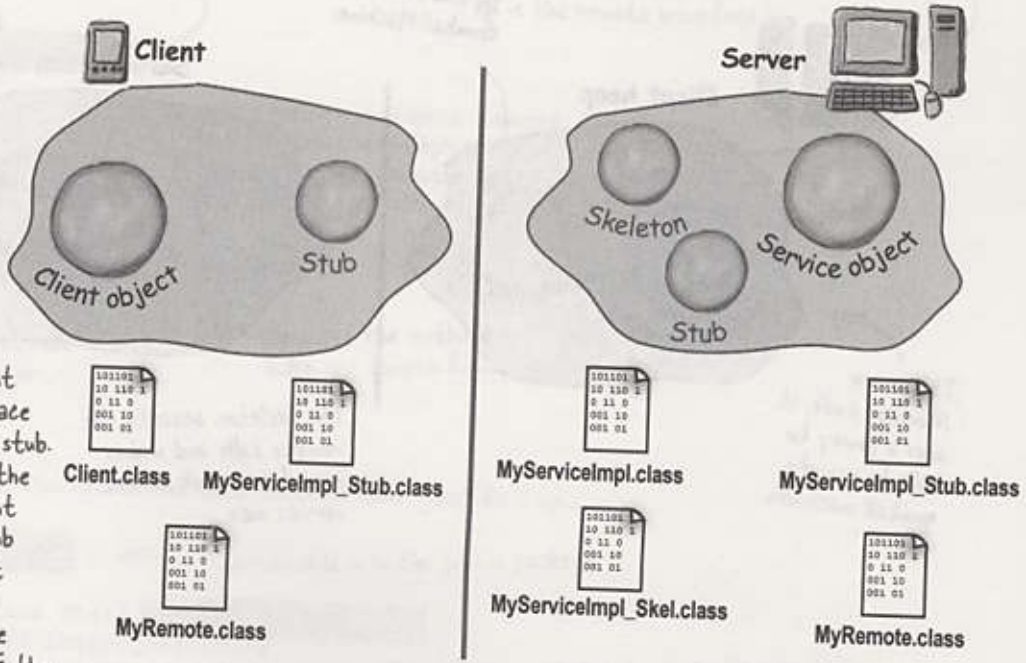
Watch it!

The top three things programmers do wrong with RMI are:

1) Forget to start rmiregistry before starting remote service (when the service is registered using Naming.rebind(), the rmiregistry must be running!)

2) Forget to make arguments and return types serializable (you won't know until runtime; this is not something the compiler will detect.)

3) Forget to give the stub class to the client.

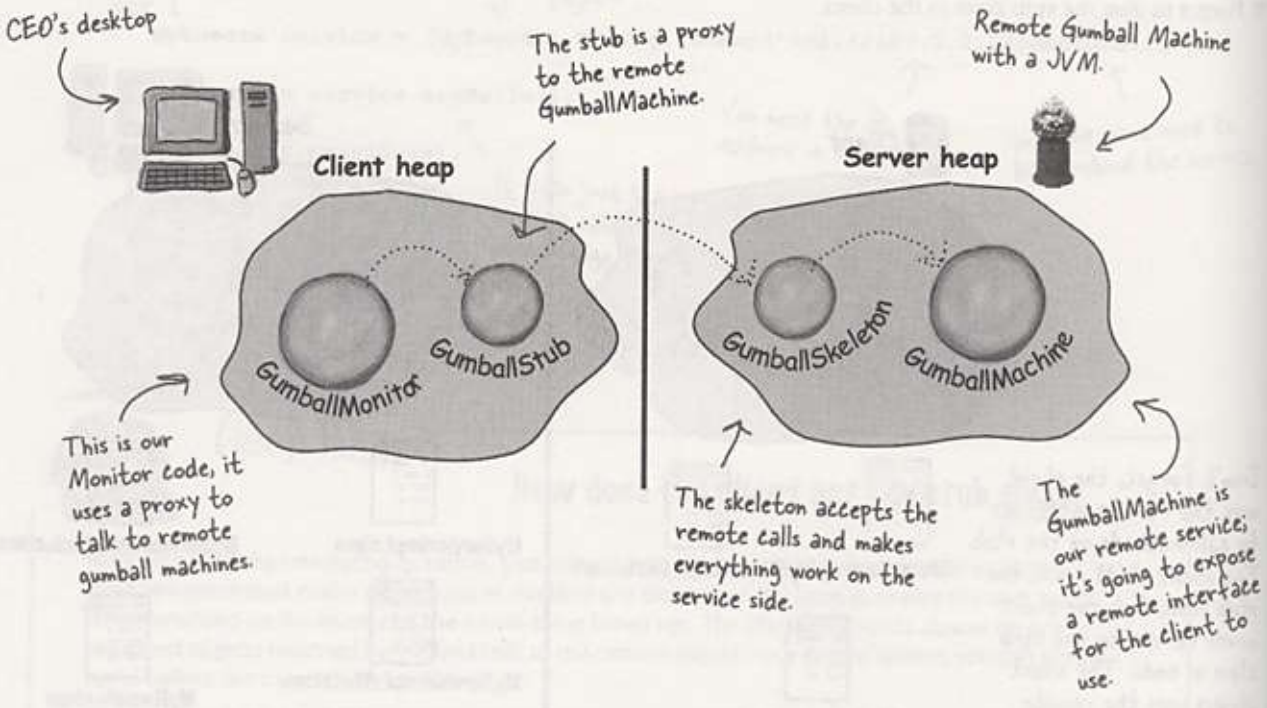


Don't forget, the client uses the remote interface to call methods on the stub. The client JVM needs the stub class, but the client never refers to the stub class in code. The client always uses the remote interface, as though the remote interface WERE the actual remote object.

Server needs both the Stub and Skeleton classes, as well as the service and the remote interface. It needs the stub class because remember, the stub is substituted for the real service when the real service is bound to the RMI registry.

Back to our GumballMachine remote proxy

Okay, now that you have the RMI basics down, you've got the tools you need to implement the gumball machine remote proxy. Let's take a look at how the GumballMachine fits into this framework:



Getting the GumballMachine ready to be a remote service

The first step in converting our code to use the remote proxy is to enable the GumballMachine to service remote requests from clients. In other words, we're going to make it into a service. To do that, we need to:

1) Create a remote interface for the GumballMachine. This will provide a set of methods that can be called remotely.

2) Make sure all the return types in the interface are serializable.

3) Implement the interface in a concrete class.

We'll start with the remote interface:

Don't forget to import java.rmi.*

This is the remote interface.

```
import java.rmi.*;

public interface GumballMachineRemote extends Remote {
    public int getCount() throws RemoteException;
    public String getLocation() throws RemoteException;
    public State getState() throws RemoteException;
}
```

All return types need to be primitive or Serializable...

Here are the methods were going to support. Each one throws RemoteException.

We have one return type that isn't Serializable: the State class. Let's fix it up...

```
import java.io.*;

public interface State extends Serializable {
    public void insertQuarter();
    public void ejectQuarter();
    public void turnCrank();
    public void dispense();
}
```

Serializable is in the java.io package.

Then we just extend the Serializable interface (which has no methods in it). And now State in all the subclasses can be transferred over the network.

Actually, we're not done with Serializable yet; we have one problem with State. As you may remember, each State object maintains a reference to a gumball machine so that it can call the gumball machine's methods and change its state. We don't want the entire gumball machine serialized and transferred with the State object. There is an easy way to fix this:

```
public class NoQuarterState implements State {
    transient GumballMachine gumballMachine;

    // all other methods here
}
```

In each implementation of State, we add the transient keyword to the GumballMachine instance variable. This tells the JVM not to serialize this field.

We've already implemented our GumballMachine, but we need to make sure it can act as a service and handle requests coming from over the network. To do that, we have to make sure the GumballMachine is doing everything it needs to implement the GumballMachineRemote interface.

As you've already seen in the RMI detour, this is quite simple, all we need to do is add a couple of things...

First, we need to import the rmi packages.

GumballMachine is going to subclass the UnicastRemoteObject; this gives it the ability to act as a remote service.

GumballMachine also needs to implement the remote interface...

```
import java.rmi.*;
import java.rmi.server.*;

public class GumballMachine
        extends UnicastRemoteObject implements GumballMachineRemote
{
    // instance variables here

    public GumballMachine(String location, int numberGumballs) throws RemoteException {
        // code here
    }

    public int getCount() {
        return count;
    }

    public State getState() {
        return state;
    }

    public String getLocation() {
        return location;
    }

    // other methods here
}
```

...and the constructor needs to throw a remote exception, because the superclass does.

That's it! Nothing changes here at all!

Registering with the RMI registry...

That completes the gumball machine service. Now we just need to fire it up so it can receive requests. First, we need to make sure we register it with the RMI registry so that clients can locate it.

We're going to add a little code to the test drive that will take care of this for us:

```
public class GumballMachineTestDrive {

    public static void main(String[] args) {
        GumballMachineRemote gumballMachine = null;
        int count;
        if (args.length < 2) {
            System.out.println("GumballMachine <name> <inventory>");
            System.exit(1);
        }

        try {
            count = Integer.parseInt(args[1]);

            gumballMachine =
                new GumballMachine(args[0], count);
            Naming.rebind("//" + args[0] + "/gumballmachine", gumballMachine);
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
}
```

First we need to add a try/catch block around the gumball instantiation because our constructor can now throw exceptions.

We also add the call to Naming.rebind, which publishes the GumballMachine stub under the name gumballmachine.

Let's go ahead and get this running...

Run this first.

This gets the RMI registry service up and running.

```
File Edit Window Help Huh?
% rmiregistry
```

```
File Edit Window Help Huh?
% java GumballMachine "Seattle" 100
```

Run this second.

This gets the GumballMachine up and running and registers it with the RMI registry.

Now for the GumballMonitor client...

Remember the GumballMonitor? We wanted to reuse it without having to rewrite it to work over a network. Well, we're pretty much going to do that, but we do need to make a few changes.

We need to import the RMI package because we are using the RemoteException class below...

```
import java.rmi.*;

public class GumballMonitor {
    GumballMachineRemote machine;

    public GumballMonitor(GumballMachineRemote machine) {
        this.machine = machine;
    }

    public void report() {
        try {
            System.out.println("Gumball Machine: " + machine.getLocation());
            System.out.println("Current inventory: " + machine.getCount() + " gumballs");
            System.out.println("Current state: " + machine.getState());
        } catch (RemoteException e) {
            e.printStackTrace();
        }
    }
}
```

Now we're going to rely on the remote interface rather than the concrete GumballMachine class.

We also need to catch any remote exceptions that might happen as we try to invoke methods that are ultimately happening over the network.

Writing the Monitor test drive

Now we've got all the pieces we need. We just need to write some code so the CEO can monitor a bunch of gumball machines:

Here's the monitor test drive. The CEO is going to run this!

```
import java.rmi.*;

public class GumballMonitorTestDrive {

    public static void main(String[] args) {
        String[] location = {"rmi://santafe.mightygumball.com/gumballmachine",
                             "rmi://boulder.mightygumball.com/gumballmachine",
                             "rmi://seattle.mightygumball.com/gumballmachine"};

        GumballMonitor[] monitor = new GumballMonitor[location.length];

        for (int i=0;i < location.length; i++) {
            try {
                GumballMachineRemote machine =
                        (GumballMachineRemote) Naming.lookup(location[i]);
                monitor[i] = new GumballMonitor(machine);
                System.out.println(monitor[i]);
            } catch (Exception e) {
                e.printStackTrace();
            }
        }

        for(int i=0; i < monitor.length; i++) {
            monitor[i].report();
        }
    }
}
```

Here's all the locations were going to monitor.

We create an array of locations, one for each machine.

We also create an array of monitors.

Now we need to get a proxy to each remote machine.

Then we iterate through each machine and print out its report.

Code Up Close

This returns a proxy to the remote Gumball Machine (or throws an exception if one can't be located).

Remember, Naming.lookup() is a static method in the RMI package that takes a location and service name and looks it up in the rmiregistry at that location.

```
try {
    GumballMachineRemote machine =
                (GumballMachineRemote) Naming.lookup(location[i]);

    monitor[i] = new GumballMonitor(machine);

} catch (Exception e) {
    e.printStackTrace();
}
```

Once we get a proxy to the remote machine, we create a new GumballMonitor and pass it the machine to monitor.

Another demo for the CEO of Mighty Gumball...

Okay, it's time to put all this work together and give another demo. First let's make sure a few gumball machines are running the new code:

On each machine, run rmiregistry in the background or from a separate terminal window...

...and then run the GumballMachine, giving it a location and an initial gumball count.

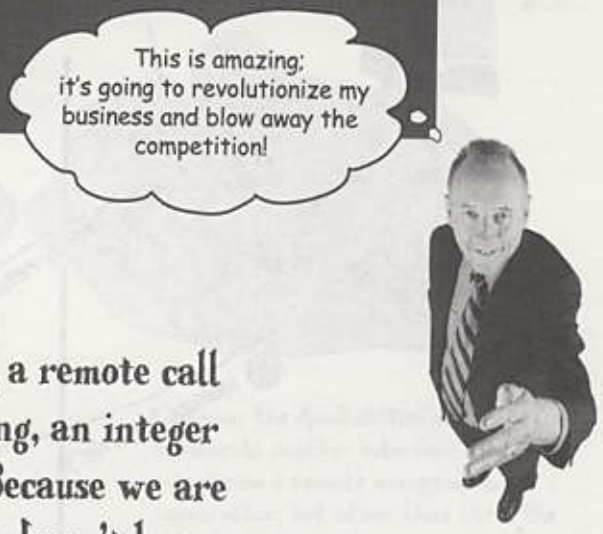
```
File Edit Window Help Huh?
% rmiregistry &
% java GumballMachine santafe.mightygumball.com 100

File Edit Window Help Huh?
% rmiregistry &
% java GumballMachine boulder.mightygumball.com 100

File Edit Window Help Huh?
% rmiregistry &
% java GumballMachine seattle.mightygumball.com 250
```

popular machine!

And now let's put the monitor in the hands of the CEO. Hopefully this time he'll love it:

```
File Edit Window Help GumballsAndBeyond
% java GumballMonitor
Gumball Machine: santafe.mightygumball.com
Current inventory: 99 gumballs
Current state: waiting for quarter

Gumball Machine: boulder.mightygumball.com
Current inventory: 44 gumballs
Current state: waiting for turn of crank

Gumball Machine: seattle.mightygumball.com
Current inventory: 187 gumballs
Current state: waiting for quarter
%
```

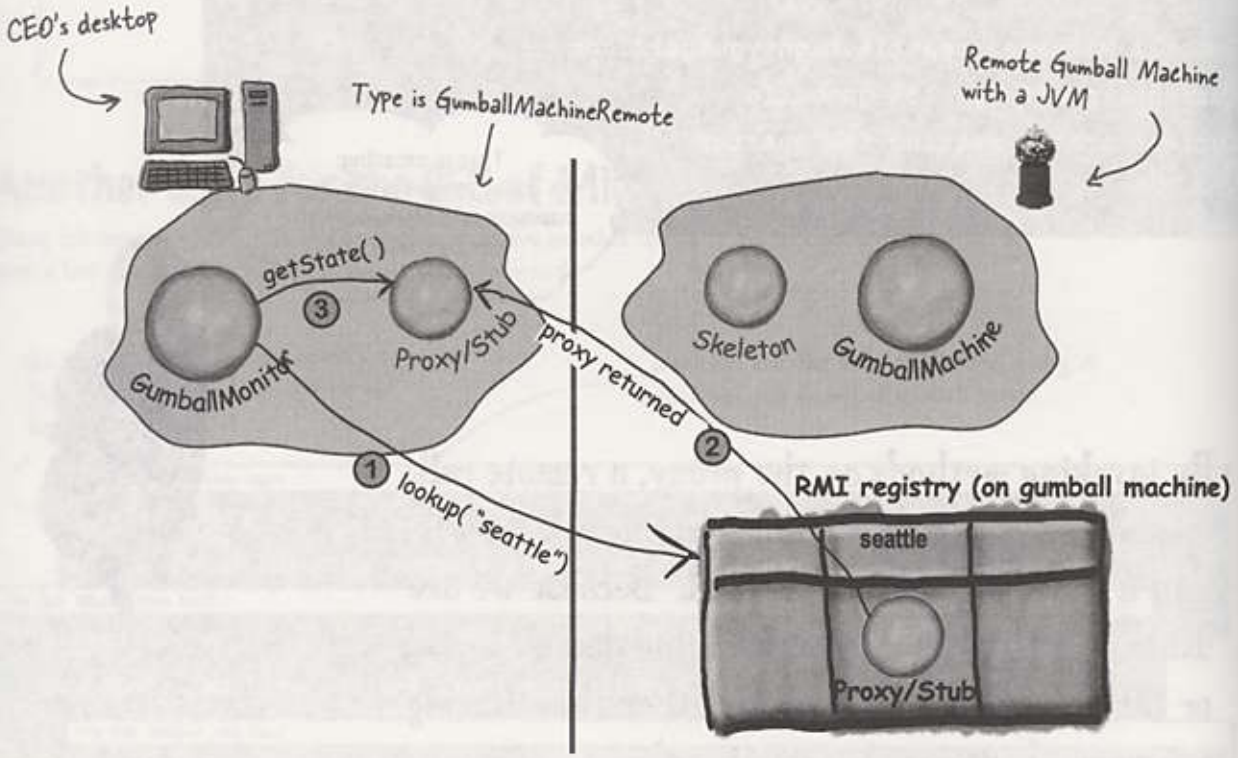
The monitor iterates over each remote machine and calls its getLocation(), getCount() and getState() methods.



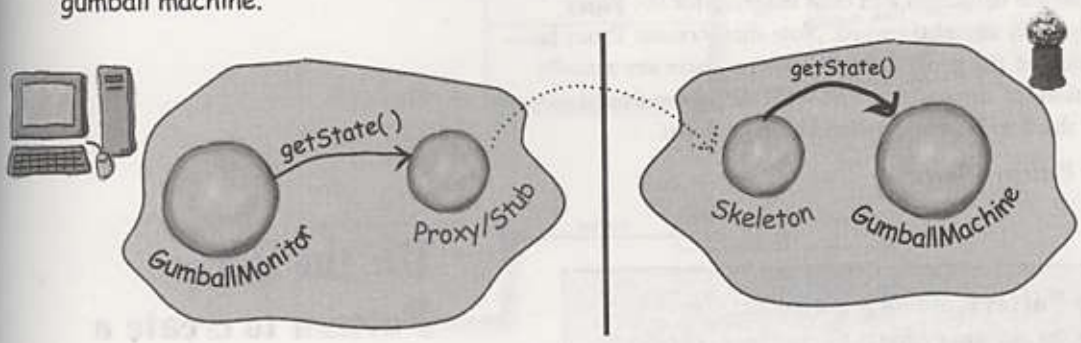
By invoking methods on the proxy, a remote call is made across the wire and a String, an integer and a State object are returned. Because we are using a proxy, the GumballMonitor doesn't know, or care, that calls are remote (other than having to worry about remote exceptions).

Behind the Scenes

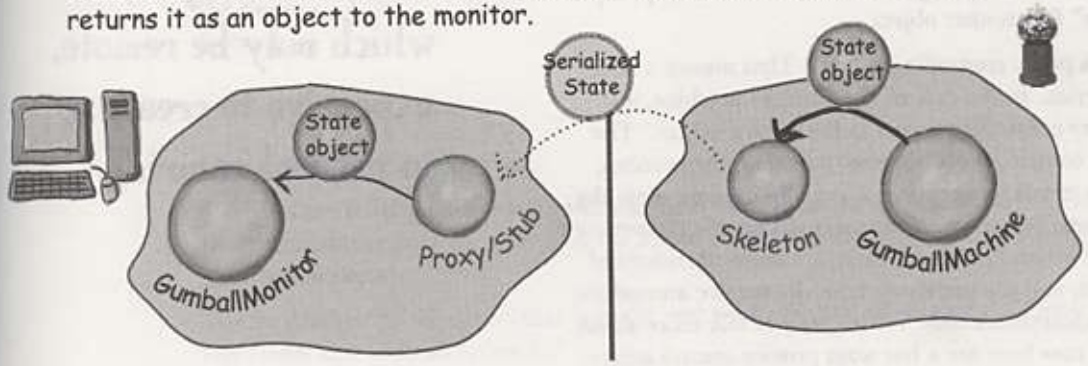
1. The CEO runs the monitor, which first grabs the proxies to the remote gumball machines and then calls getState() on each one (along with getCount() and getLocation()).



2 getState() is called on the proxy, which forwards the call to the remote service. The skeleton receives the request and then forwards it to the gumball machine.



3 GumballMachine returns the state to the skeleton, which serializes it and transfers it back over the wire to the proxy. The proxy deserializes it and returns it as an object to the monitor.



The monitor hasn't changed at all, except it knows it may encounter remote exceptions. It also uses the GumballMachineRemote interface rather than a concrete implementation.

Likewise, the GumballMachine implements another interface and may throw a remote exception in its constructor, but other than that, the code hasn't changed.

We also have a small bit of code to register and locate stubs using the RMI registry. But no matter what, if we were writing something to work over the Internet, we'd need some kind of locator service.

The Proxy Pattern defined

We've already put a lot of pages behind us in this chapter; as you can see, explaining the Remote Proxy is quite involved. Despite that, you'll see that the definition and class diagram for the Proxy Pattern is actually fairly straightforward. Note that Remote Proxy is one implementation of the general Proxy Pattern; there are actually quite a few variations of the pattern, and we'll talk about them later. For now, let's get the details of the general pattern down.

Here's the Proxy Pattern definition:

> **The Proxy Pattern** provides a surrogate or placeholder for another object to control access to it.

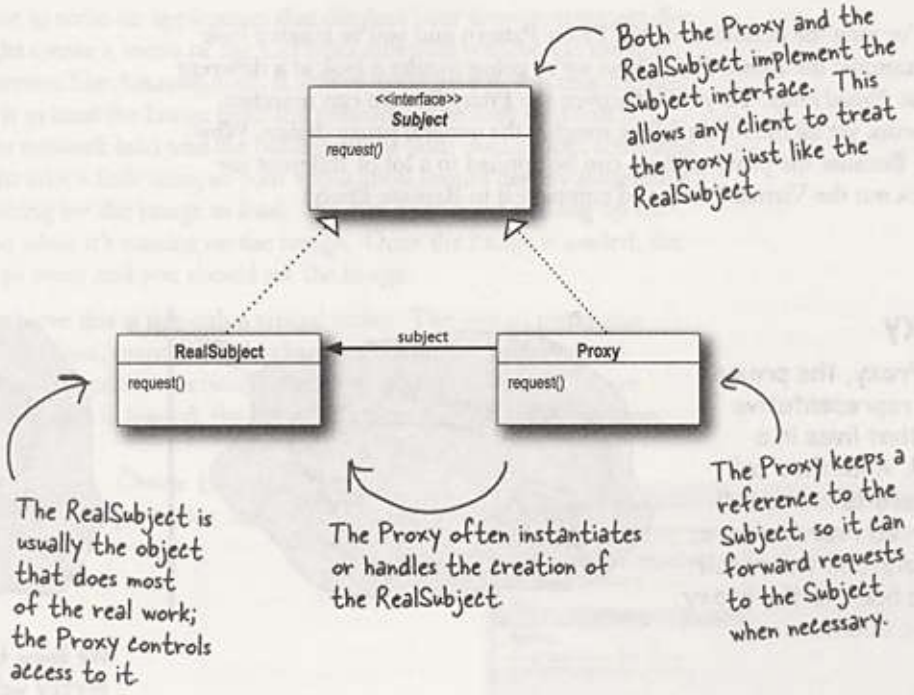
Use the Proxy Pattern to create a representative object that controls access to another object, which may be remote, expensive to create or in need of securing.

Well, we've seen how the Proxy Pattern provides a surrogate or placeholder for another object. We've also described the proxy as a "representative" for another object.

But what about a proxy controlling access? That sounds a little strange. No worries. In the case of the gumball machine, just think of the proxy controlling access to the remote object. The proxy needed to control access because our client, the monitor, didn't know how to talk to a remote object. So in some sense the remote proxy controlled access so that it could handle the network details for us. As we just discussed, there are many variations of the Proxy Pattern, and the variations typically revolve around the way the proxy "controls access." We're going to talk more about this later, but for now here are a few ways proxies control access:

- As we know, a remote proxy controls access to a remote object.
- A virtual proxy controls access to a resource that is expensive to create.
- A protection proxy controls access to a resource based on access rights.

Now that you've got the gist of the general pattern, check out the class diagram...



Let's step through the diagram...

First we have a Subject, which provides an interface for the RealSubject and the Proxy. By implementing the same interface, the Proxy can be substituted for the RealSubject anywhere it occurs.

The RealSubject is the object that does the real work. It's the object that the Proxy represents and controls access to.

The Proxy holds a reference to the RealSubject. In some cases, the Proxy may be responsible for creating and destroying the RealSubject. Clients interact with the RealSubject through the Proxy. Because the Proxy and RealSubject implement the same interface (Subject), the Proxy can be substituted anywhere the subject can be used. The Proxy also controls access to the RealSubject; this control may be needed if the Subject is running on a remote machine, if the Subject is expensive to create in some way or if access to the subject needs to be protected in some way.

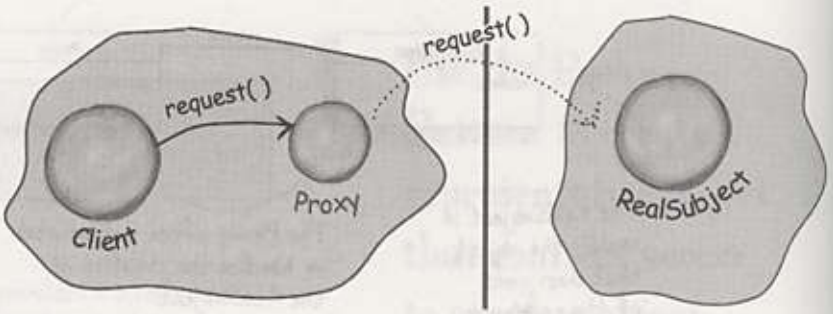
Now that you understand the general pattern, let's look at some other ways of using proxy beyond the Remote Proxy...

Get ready for Virtual Proxy

Okay, so far you've seen the definition of the Proxy Pattern and you've taken a look at one specific example: the *Remote Proxy*. Now we're going to take a look at a different type of proxy, the *Virtual Proxy*. As you'll discover, the Proxy Pattern can manifest itself in many forms, yet all the forms follow roughly the general proxy design. Why so many forms? Because the proxy pattern can be applied to a lot of different use cases. Let's check out the Virtual Proxy and compare it to Remote Proxy:

Remote Proxy

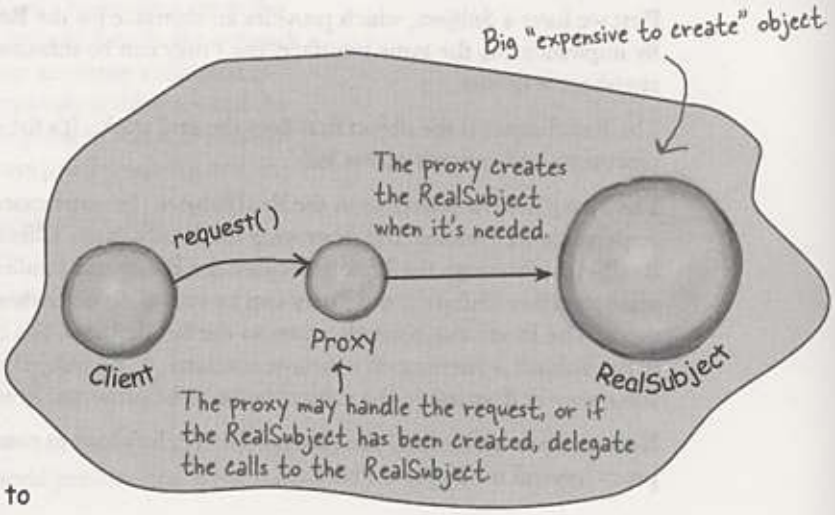
With Remote Proxy, the proxy acts as a local representative for an object that lives in a different JVM. A method call on the proxy results in the call being transferred over the wire, invoked remotely, and the result being returned back to the proxy and then to the Client.



We know this diagram pretty well by now...

Virtual Proxy

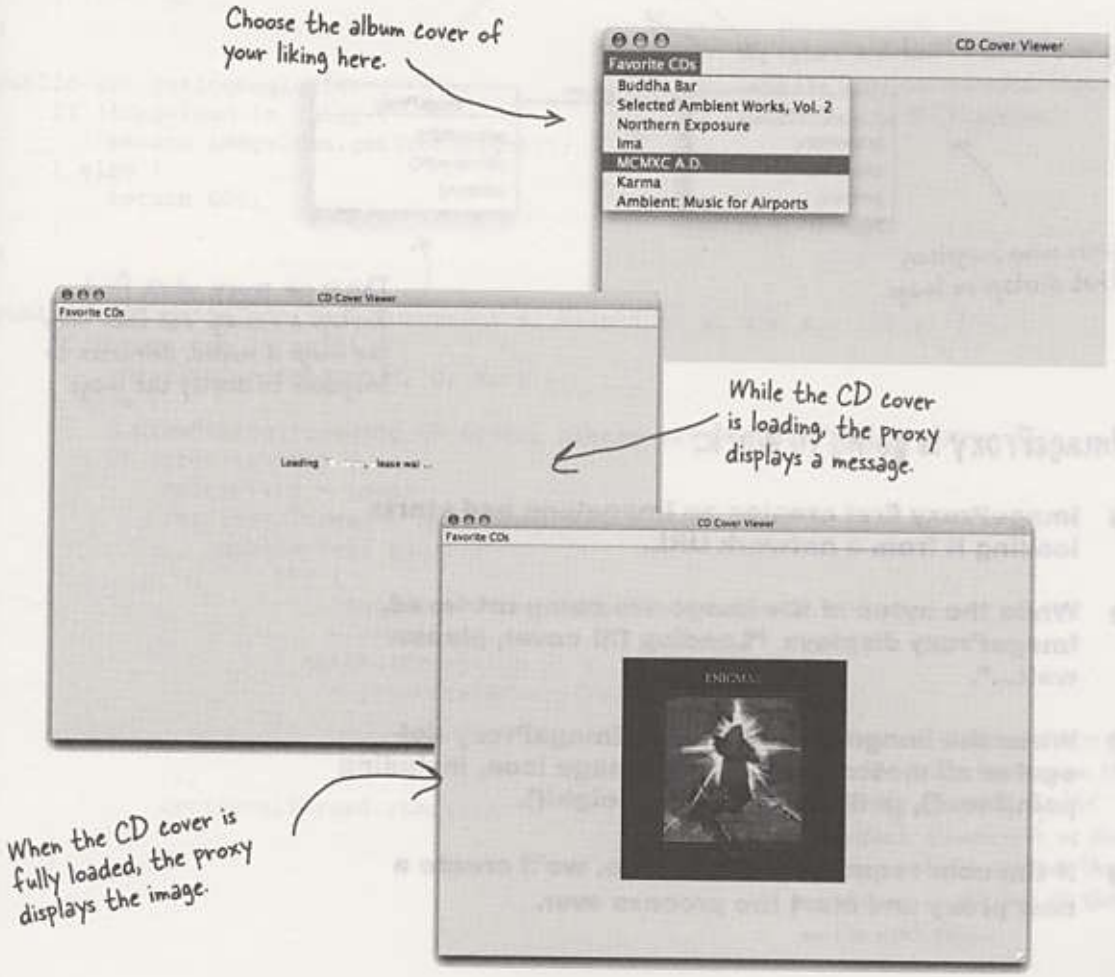
Virtual Proxy acts as a representative for an object that may be expensive to create. The Virtual Proxy often defers the creation of the object until it is needed; the Virtual Proxy also acts as a surrogate for the object before and while it is being created. After that, the proxy delegates requests directly to the RealSubject.



Displaying CD covers

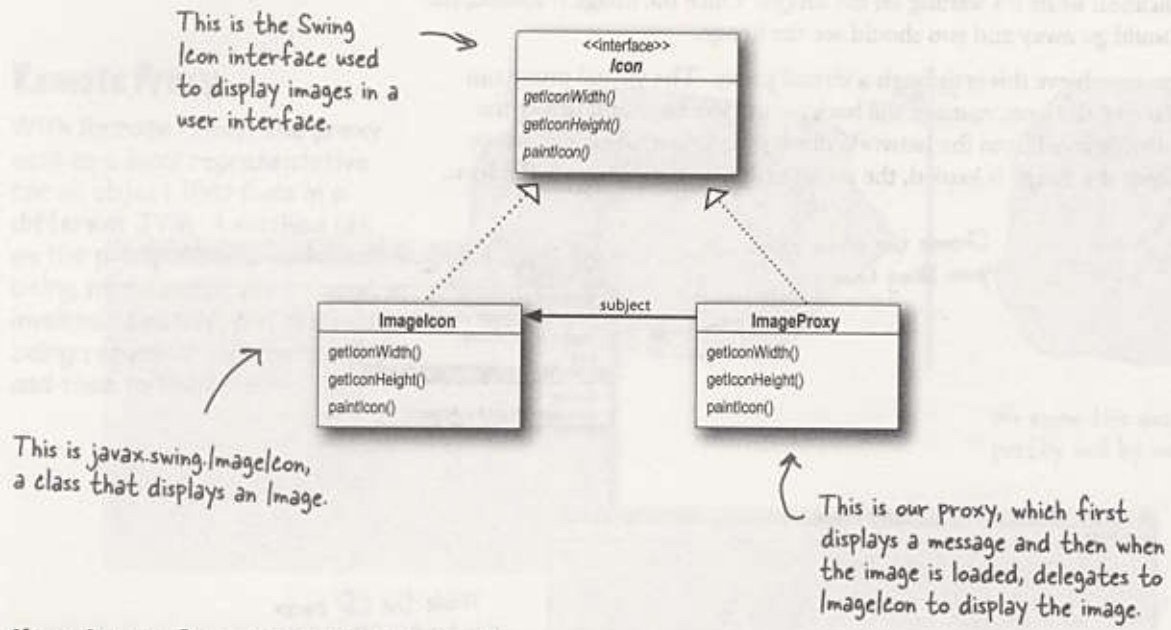
Let's say you want to write an application that displays your favorite compact disc covers. You might create a menu of the CD titles and then retrieve the images from an online service like Amazon.com. If you're using Swing, you might create an Icon and ask it to load the image from the network. The only problem is, depending on the network load and the bandwidth of your connection, retrieving a CD cover might take a little time, so your application should display something while you are waiting for the image to load. We also don't want to hang up the entire application while it's waiting on the image. Once the image is loaded, the message should go away and you should see the image.

An easy way to achieve this is through a virtual proxy. The virtual proxy can stand in place of the icon, manage the background loading, and before the image is fully retrieved from the network, display "Loading CD cover, please wait...". Once the image is loaded, the proxy delegates the display to the Icon.



Designing the CD cover Virtual Proxy

Before writing the code for the CD Cover Viewer, let's look at the class diagram. You'll see this looks just like our Remote Proxy class diagram, but here the proxy is used to hide an object that is expensive to create (because we need to retrieve the data for the Icon over the network) as opposed to an object that actually lives somewhere else on the network.

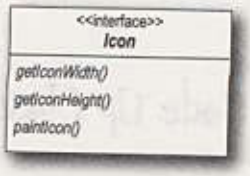


How ImageProxy is going to work:

1. **ImageProxy first creates an ImageIcon and starts loading it from a network URL.**
2. **While the bytes of the image are being retrieved, ImageProxy displays "Loading CD cover, please wait...".**
3. **When the image is fully loaded, ImageProxy delegates all method calls to the image icon, including paintIcon(), getWidth() and getHeight().**
4. **If the user requests a new image, we'll create a new proxy and start the process over.**

Writing the Image Proxy

The ImageProxy implements the Icon interface.




```
class ImageProxy implements Icon {
    ImageIcon imageIcon;
    URL imageURL;
    Thread retrievalThread;
    boolean retrieving = false;

    public ImageProxy(URL url) { imageURL = url; }

    public int getIconWidth() {
        if (imageIcon != null) {
            return imageIcon.getIconWidth();
        } else {
            return 800;
        }
    }

    public int getIconHeight() {
        if (imageIcon != null) {
            return imageIcon.getIconHeight();
        } else {
            return 600;
        }
    }

    public void paintIcon(final Component c, Graphics  g, int x,  int y) {
        if (imageIcon != null) {
            imageIcon.paintIcon(c, g, x, y);
        } else {
            g.drawString("Loading CD cover, please wait...", x+300, y+190);
            if (!retrieving) {
                retrieving = true;
                retrievalThread = new Thread(new Runnable() {
                    public void run() {
                        try {
                            imageIcon = new ImageIcon(imageURL, "CD Cover");
                            c.repaint();
                        } catch (Exception e) {
                            e.printStackTrace();
                        }
                    }
                });
                retrievalThread.start();
            }
        }
    }
}
```

The imageIcon is the REAL icon that we eventually want to display when it's loaded.

We pass the URL of the image into the constructor. This is the image we need to display once it's loaded!

We return a default width and height until the imageIcon is loaded; then we turn it over to the imageIcon.

Here's where things get interesting. This code paints the icon on the screen (by delegating to the imageIcon). However, if we don't have a fully created ImageIcon, then we create one. Let's look at this closer on the next page...

Code Up Close

This method is called when it's time to paint the icon on the screen.

```
public void paintIcon(final Component c, Graphics  g, int x,  int y) {
    if (imageIcon != null) {

        imageIcon.paintIcon(c, g, x, y);

    } else {

        g.drawString("Loading CD cover, please wait...", x+300, y+190);
        if (!retrieving) {

            retrieving = true;
            retrievalThread = new Thread(new Runnable() {
                public void run() {
                    try {
                        imageIcon = new ImageIcon(imageURL, "CD Cover");
                        c.repaint();
                    } catch (Exception e) {
                        e.printStackTrace();
                    }
                }
            });

            retrievalThread.start();
        }
    }
}
```

If we've got an icon already, we go ahead and tell it to paint itself.

Otherwise we display the "loading" message.

Here's where we load the REAL icon image. Note that the image loading with IconImage is synchronous: the ImageIcon constructor doesn't return until the image is loaded. That doesn't give us much of a chance to do screen updates and have our message displayed, so we're going to do this asynchronously. See the "Code Way Up Close" on the next page for more...

Code Way Up Close

If we aren't already trying to retrieve the image...

...then it's time to start retrieving it (in case you were wondering, only one thread calls paint, so we should be okay here in terms of thread safety).

We don't want to hang up the entire user interface, so we're going to use another thread to retrieve the image.

```
if (!retrieving) {
    retrieving = true;

    retrievalThread = new Thread(new Runnable() {
        public void run() {
            try {
                imageIcon = new ImageIcon(imageURL, "CD Cover");
                c.repaint();
            } catch (Exception e) {
                e.printStackTrace();
            }
        }
    });
    retrievalThread.start();
}
```

In our thread we instantiate the Icon object. Its constructor will not return until the image is loaded.

When we have the image, we tell Swing that we need to be repainted.

So, the next time the display is painted after the ImageIcon is instantiated, the paintIcon method will paint the image, not the loading message.

Design Puzzle

The ImageProxy class appears to have two states that are controlled by conditional statements. Can you think of another pattern that might clean up this code? How would you redesign ImageProxy?

```
class ImageProxy implements Icon {
    // instance variables & constructor here

    public int getIconWidth() {
        if (imageIcon != null) {
            return imageIcon.getIconWidth();
        } else {
            return 800;
        }
    }

    public int getIconHeight() {
        if (imageIcon != null) {
            return imageIcon.getIconHeight();
        } else {
            return 600;
        }
    }

    public void paintIcon(final Component c, Graphics  g, int x,  int y) {
        if (imageIcon != null) {
            imageIcon.paintIcon(c, g, x, y);
        } else {
            g.drawString("Loading CD cover, please wait...", x+300, y+190);
            // more code here
        }
    }
}
```

Two states

Two states

Two states