CS525
Advanced Software Development

Lesson 10 – The State Pattern

Design Patterns
Elements of Reusable Object-Oriented Software

Payman Salek, M.S.
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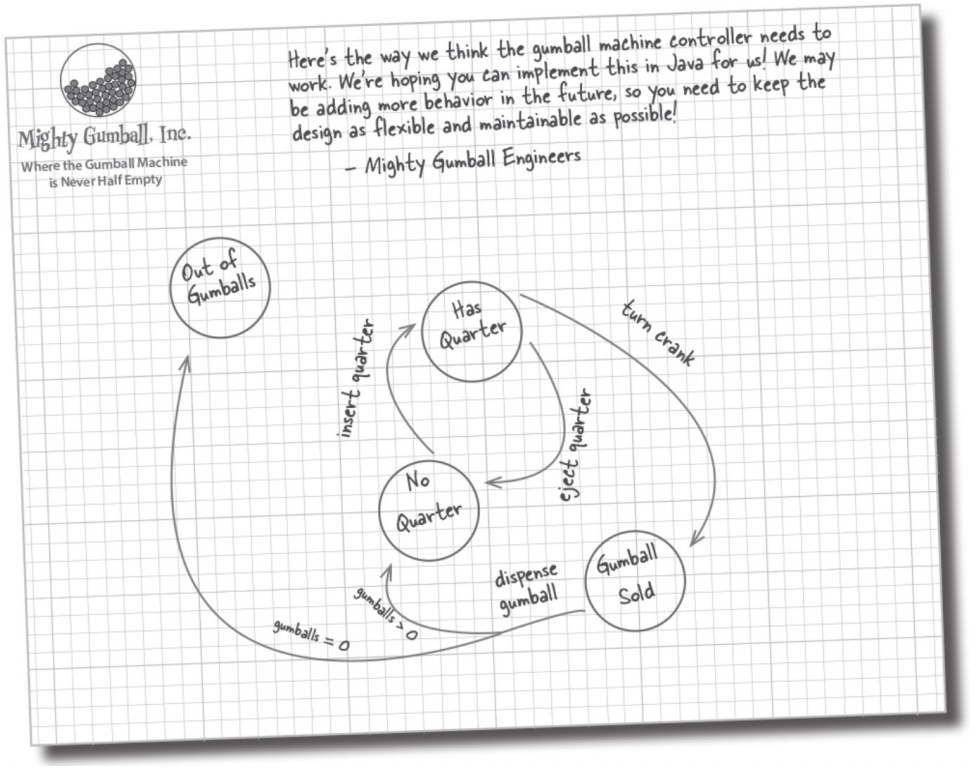
A little Known Fact

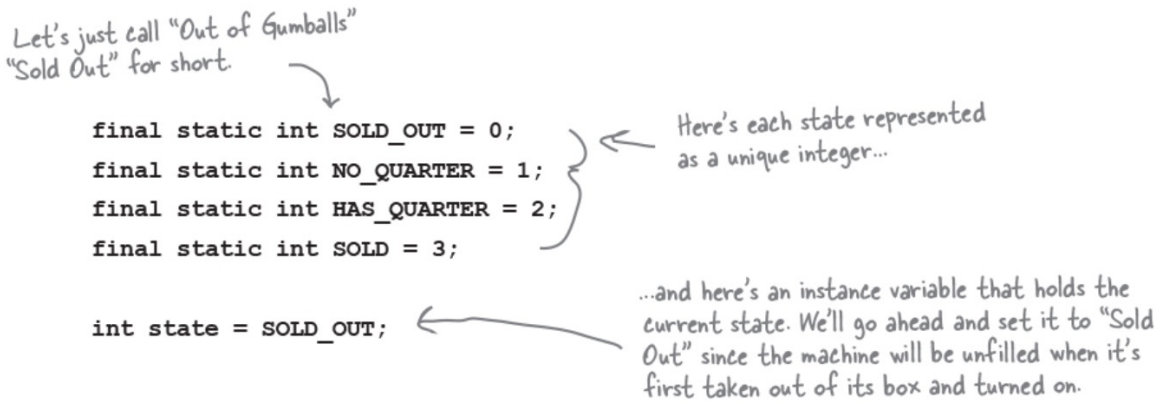
The Strategy and State Patterns are twins separated at birth. You'd think they'd live similar lives, but the Strategy Pattern went on to create a wildly successful business around interchangeable algorithms, while State took the perhaps more noble path of helping objects to control their behavior by changing their internal state.

Setting the stage (Java Breakers)

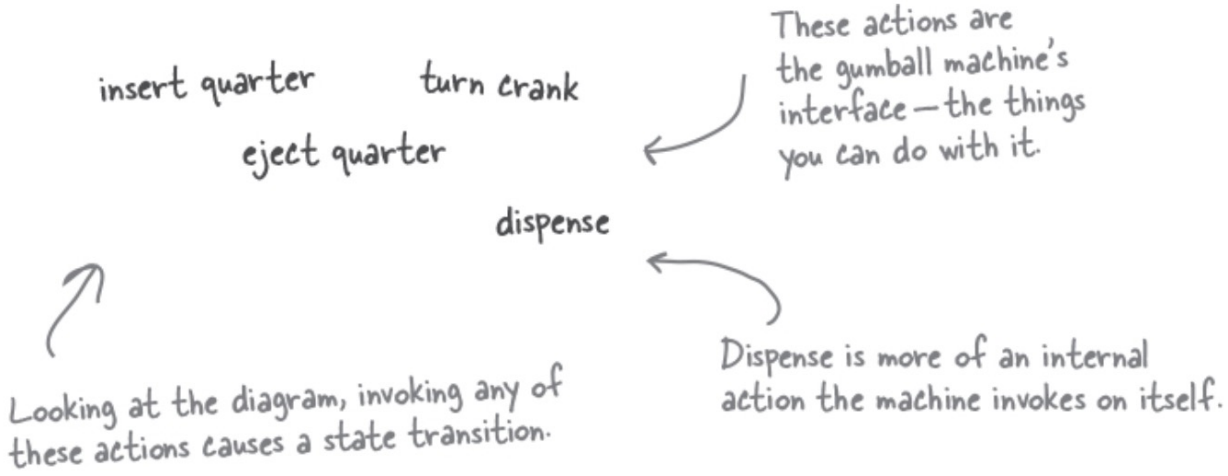


State Machine 101 (define states)

Instance Variable to Hold the State



Identify All Actions that Change State



Implement Each Action

```
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");

    }
}
```

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

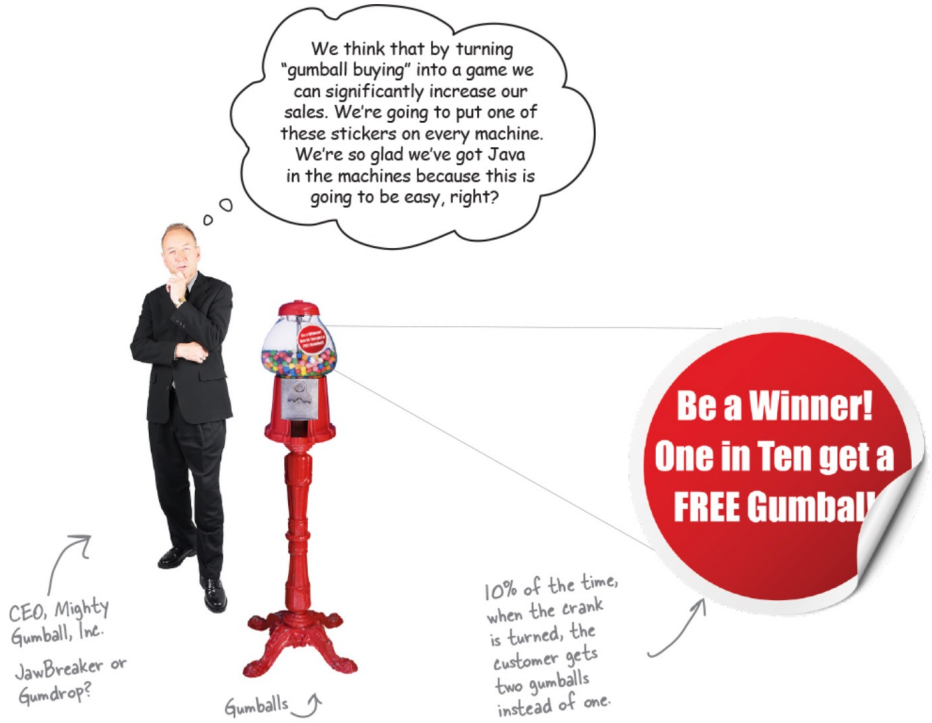
...and exhibits the appropriate behavior for each possible state...

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

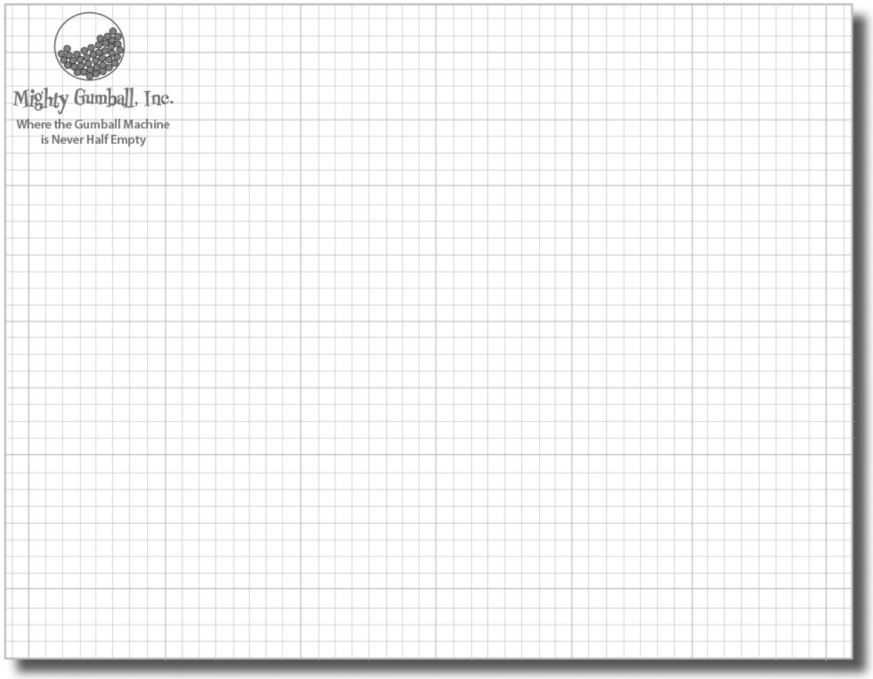
The Gumball Machine


```
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;
        }
    }

    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");
        }
    }
```

A Change Request

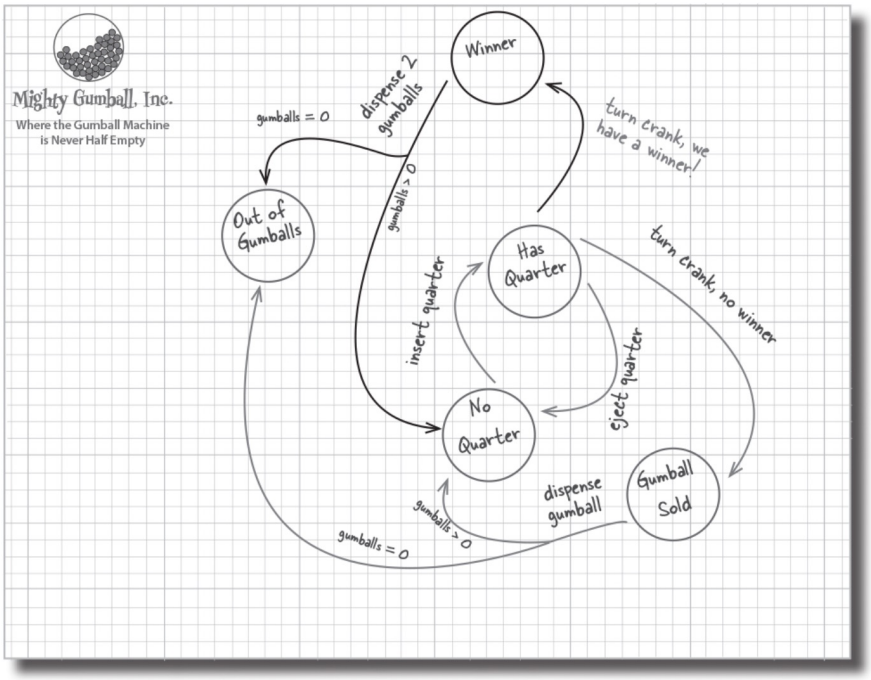


Add the New State



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

Solution


Mighty Gumball, Inc.
Where the Gumball Machine is Never Half Empty
Winner
dispense 2 gumballs
gumballs = 0
gumballs > 0
turn crank, we have a winner!
Out of Gumballs
Has Quarter
turn crank, no winner
insert quarter
eject quarter
No Quarter
dispense gumball
Gumball Sold
gumballs > 0
gumballs = 0

The Messy State of Things!

```
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.

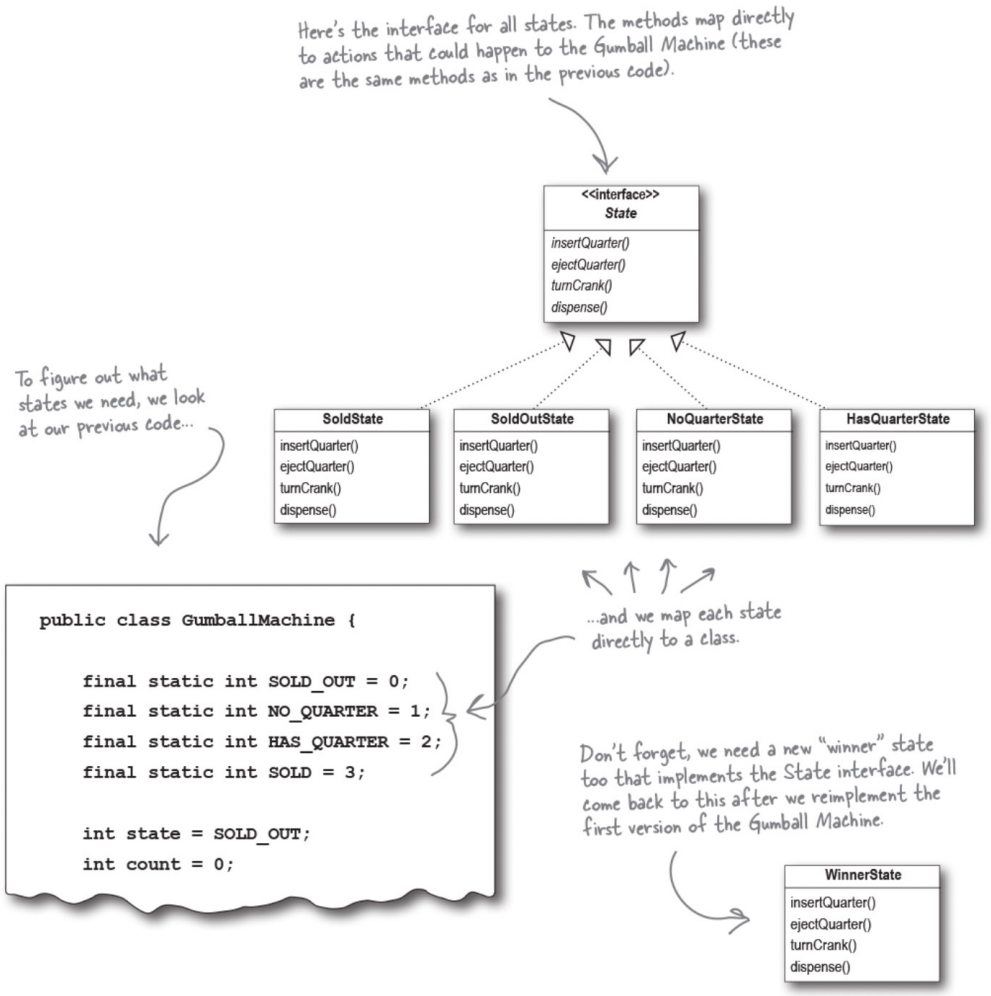
The New Design

- First, we're going to define a State interface that contains a method for every action in the Gumball Machine.

- 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.

- Finally, we're going to get rid of all of our conditional code and instead delegate the work to the State class.

Defining the State interface and classes



Implementing our State classes

```
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");
    }
}
```

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.

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

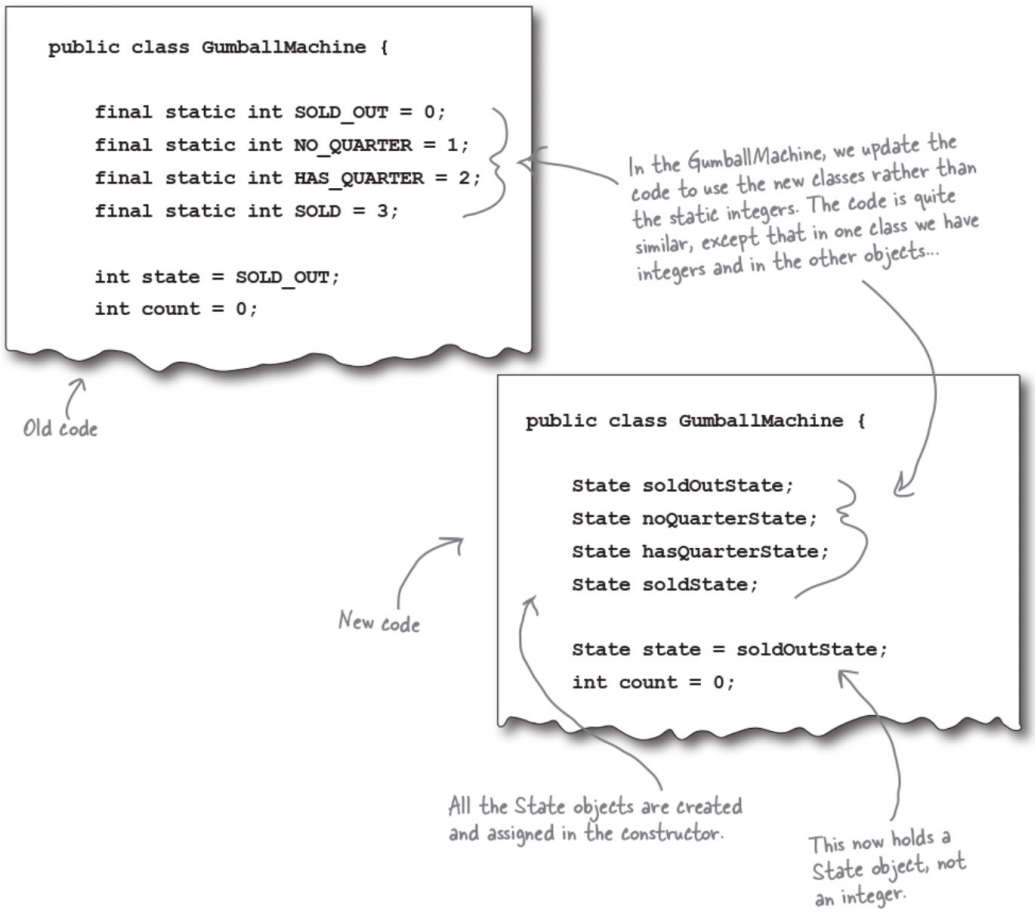
You'll see how these work in just a sec...

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



Reworking the Gumball Machine

Implementing More States

```
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.

Implementing More States

```
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.

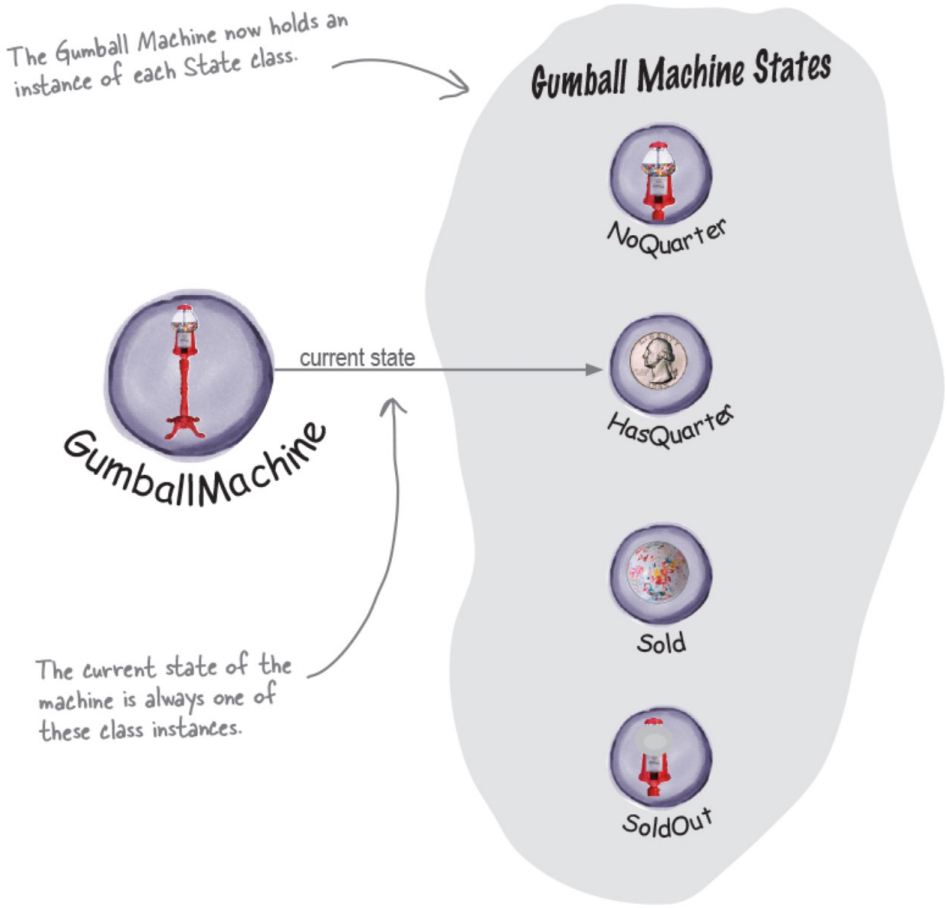
Can you write one of the States?


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

    public SoldOutState(GumballMachine gumballMachine) {

    }

    public void insertQuarter() {

    }

    public void ejectQuarter() {

    }

    public void turnCrank() {

    }

    public void dispense() {

    }
}
```

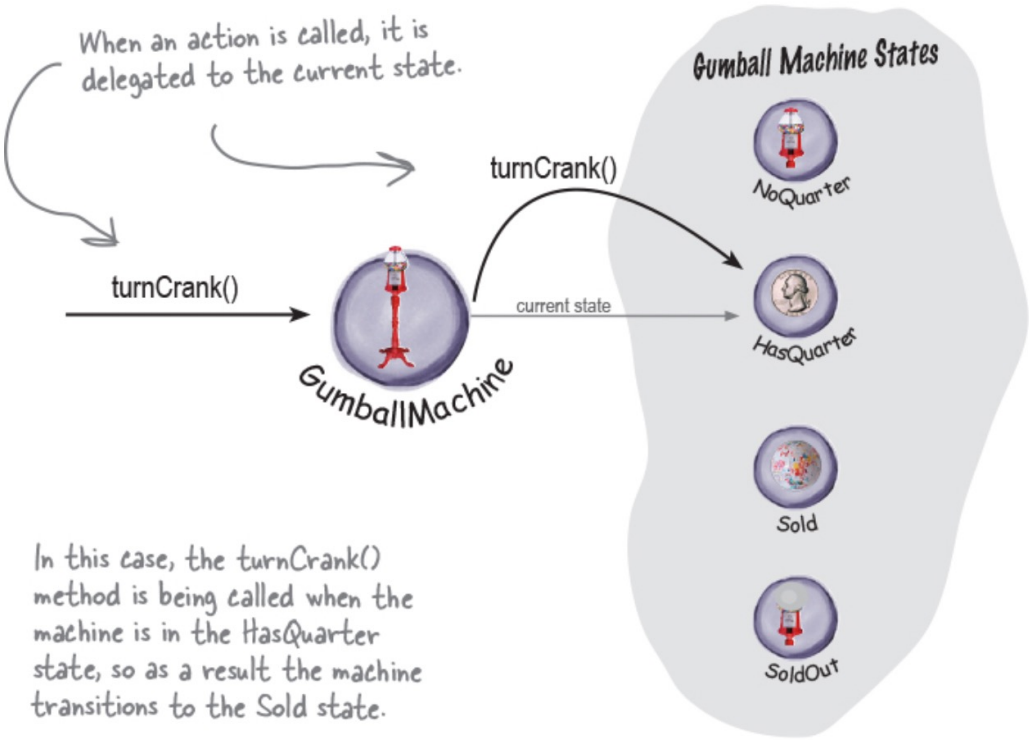
So far...

- 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.

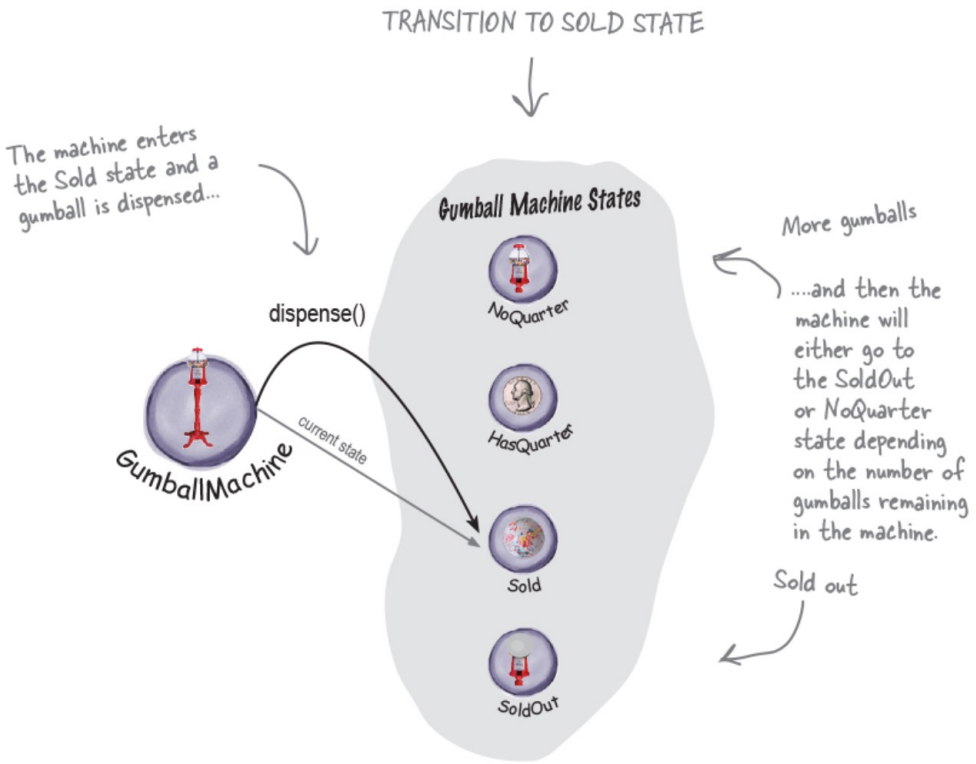
How does it work?



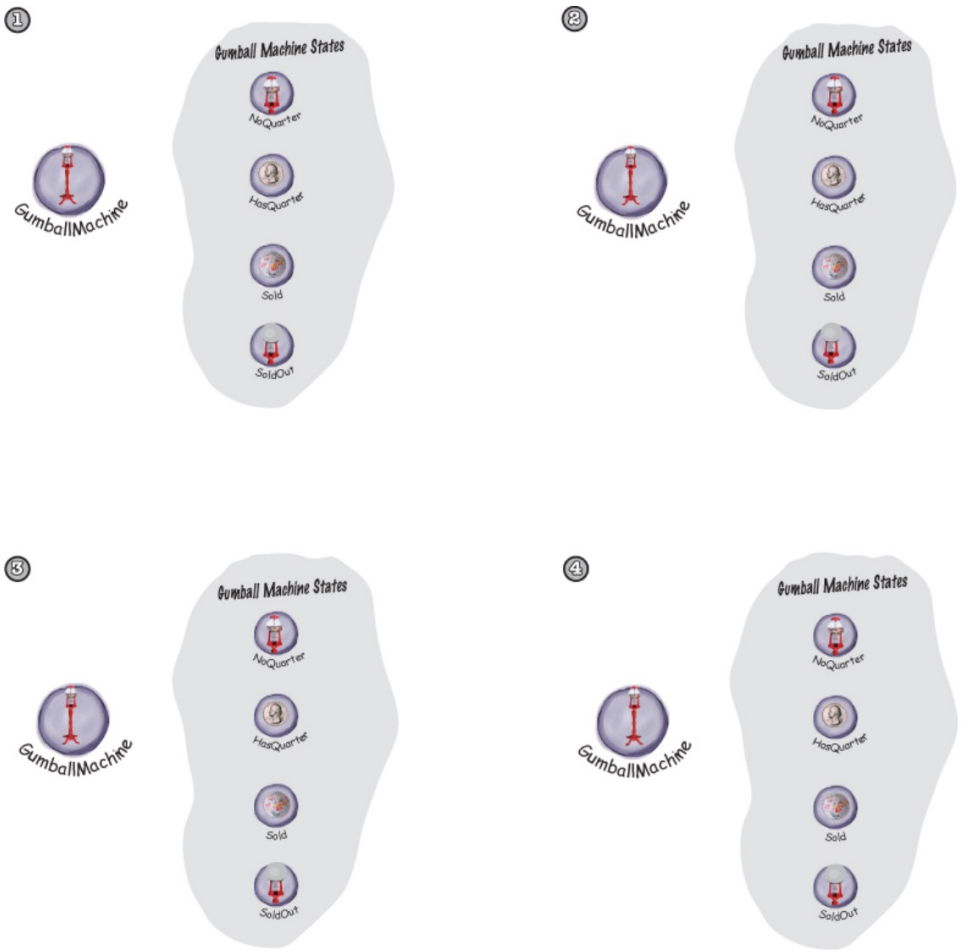
How does it work?



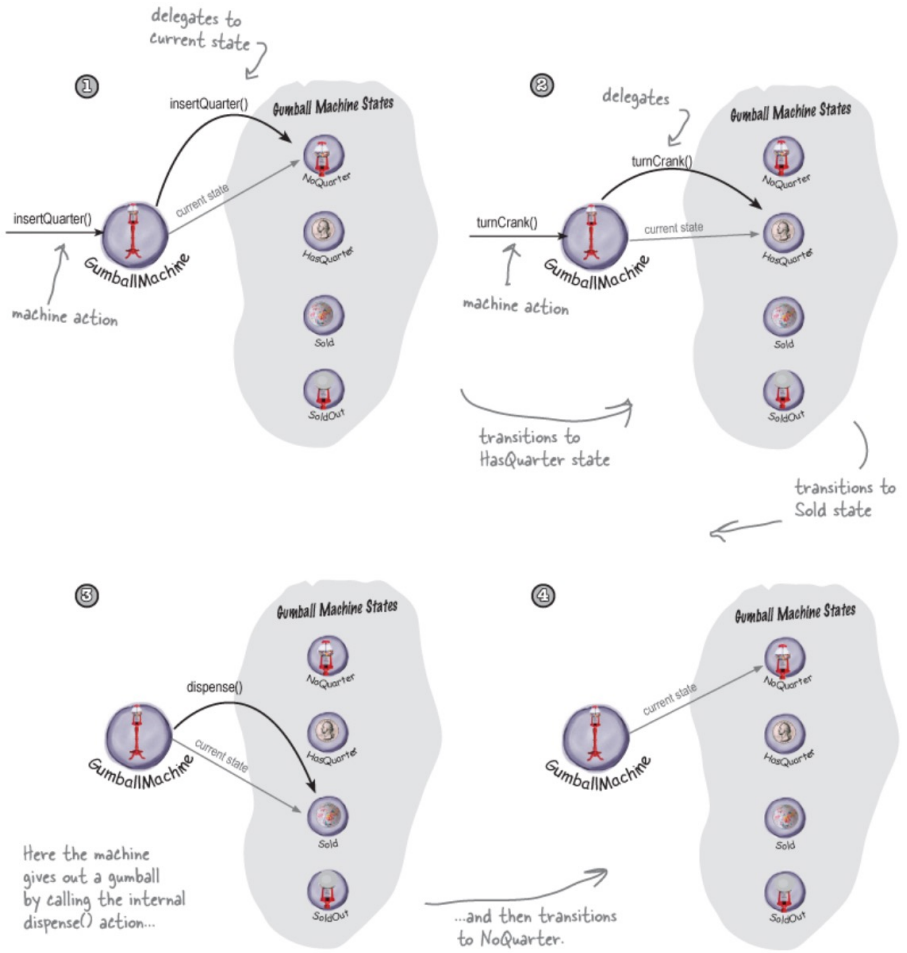
How does it work?



Trace the Steps of the Gumball Machine



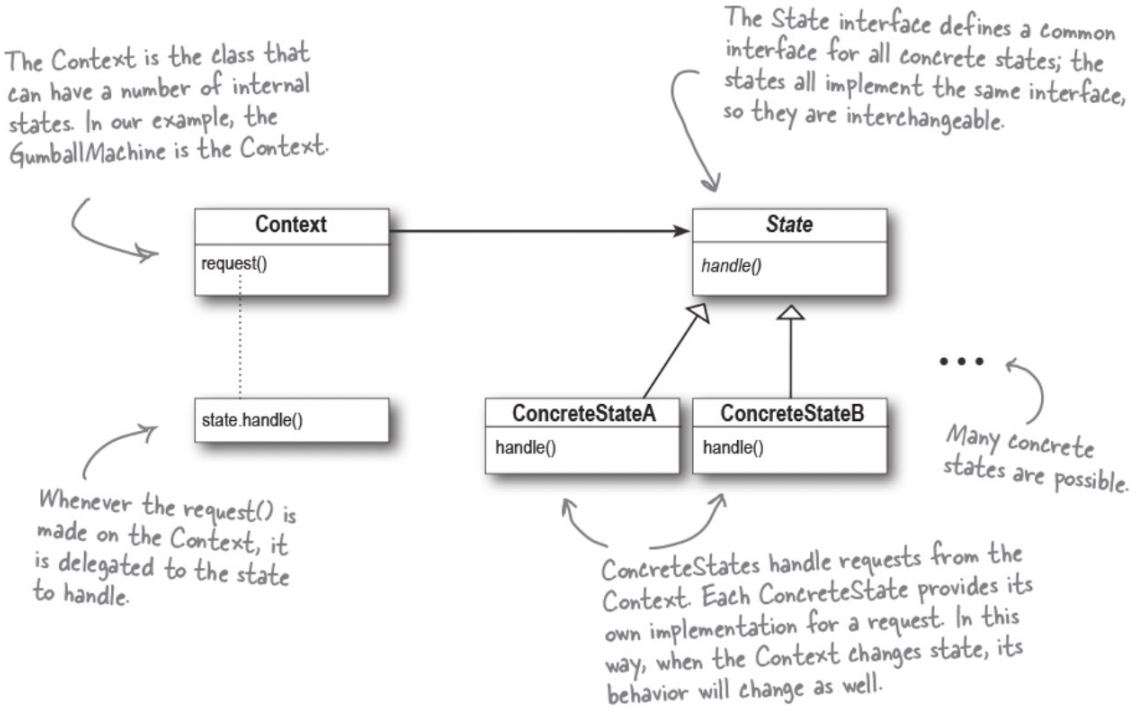
The Solution



The State Pattern Defined

Allows an object to alter its behavior when its internal state changes. The object will appear to change its class.

The State Pattern (UML)



The Gumball 1 in 10 Game

```
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.

The Gumball 1 in 10 Game

```
public class WinnerState implements State {

    // instance variables and constructor
    // insertQuarter error message
    // ejectQuarter error message
    // turnCrank error message

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

If we have a second gumball, we release it.

If we were able to release two gumballs, we let the user know he was a winner.

Finishing the Game...

```
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 WinnerState; otherwise, we go to SoldState (just like we always did).

The Demo

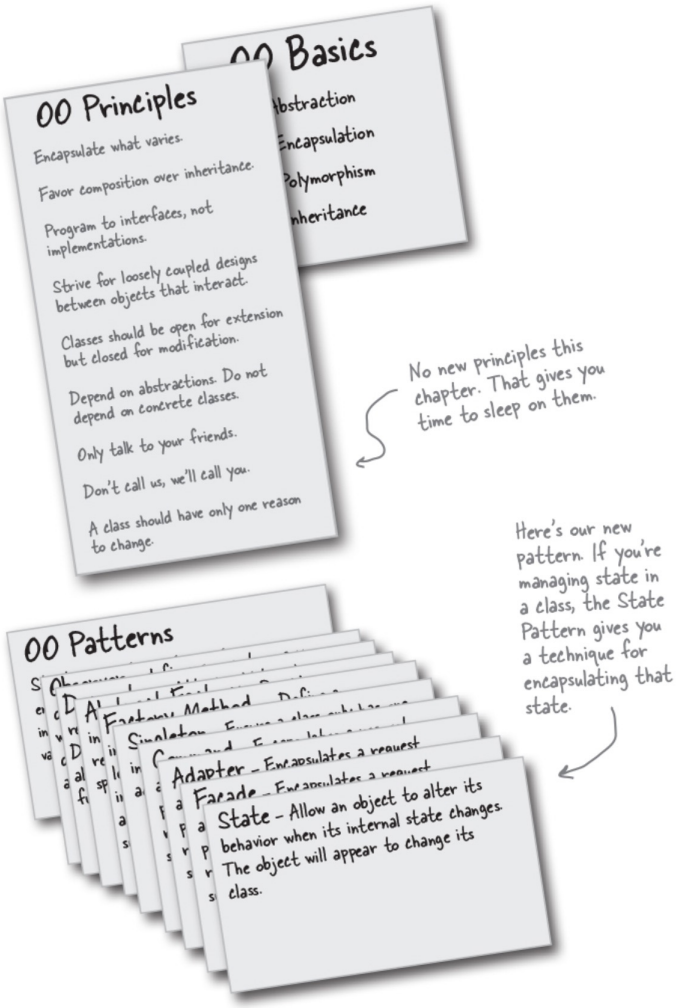
This code really hasn't changed at all; we just shortened it a bit.

```
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);
    }
}
```

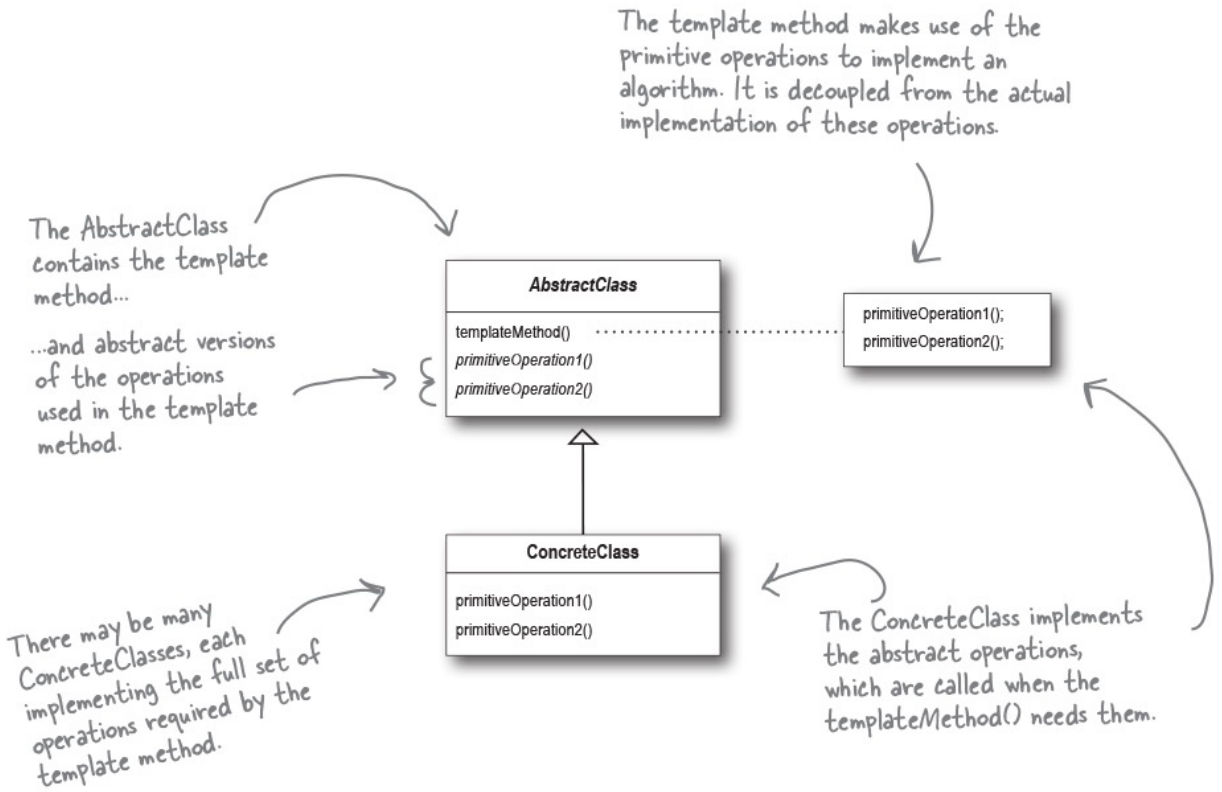
Once, again, start with a gumball machine with 5 gumballs.

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...

Summary


OO Basics
Abstraction
Encapsulation
Polymorphism
Inheritance
OO Principles
Encapsulate what varies.
Favor composition over inheritance.
Program to interfaces, not implementations.
Strive for loosely coupled designs between objects that interact.
Classes should be open for extension but closed for modification.
Depend on abstractions. Do not depend on concrete classes.
Only talk to your friends.
Don't call us, we'll call you.
A class should have only one reason to change.
No new principles this chapter. That gives you time to sleep on them.
OO Patterns
Adapter – Encapsulates a request
State – Allow an object to alter its behavior when its internal state changes. The object will appear to change its class.
Here's our new pattern. If you're managing state in a class, the State Pattern gives you a technique for encapsulating that state.

Class Diagram for the Pattern



Classical Implementation

```
abstract class AbstractClass {

    final void templateMethod() {
        primitiveOperation1();
        primitiveOperation2();
        concreteOperation();
    }

    abstract void primitiveOperation1();

    abstract void primitiveOperation2();

    void concreteOperation() {
        // implementation here
    }
}
```

The template method defines the sequence of steps, each represented by a method.

In this example, two of the primitive operations must be implemented by concrete subclasses.

Classical Implementation + Hook Method

We've changed the templateMethod() to include a new method call.

```
abstract class AbstractClass {

    final void templateMethod() {
        primitiveOperation1();
        primitiveOperation2();
        concreteOperation();
        hook();
    }

    abstract void primitiveOperation1();

    abstract void primitiveOperation2();

    final void concreteOperation() {
        // implementation here
    }

    void hook() {}

}
```

We still have our primitive operation methods; these are abstract and implemented by concrete subclasses.

A concrete operation is defined in the abstract class. This one is declared final so that subclasses can't override it. It may be used in the template method directly, or used by subclasses.

A concrete method, but it does nothing!

We can also have concrete methods that do nothing by default; we call these "hooks." Subclasses are free to override these but don't have to. We're going to see how these are useful on the next page.

The Hollywood Principle

Don’t call us, we’ll call you!

Template Method in Practice

```
public interface Iterator<E> {
    boolean hasNext();
    E next();
    default void forEachRemaining(Consumer<? super E> action) {
        Objects.requireNonNull(action);
        while (hasNext())
            action.accept(next());
    }
}
```

Summary

- A template method defines the steps of an algorithm, deferring to subclasses for the implementation of those steps.
- The Template Method Pattern gives us an important technique for code reuse.
- The template method's abstract class may define concrete methods, abstract methods, and hooks.
- Abstract methods are implemented by subclasses.
- Hooks are methods that do nothing or default behavior in the abstract class, but may be overridden in the subclass.

Summary - continued

- To prevent subclasses from changing the algorithm in the template method, declare the template method as final.
- The Hollywood Principle guides us to put decision making in high-level modules that can decide how and when to call low-level modules.
- You'll see lots of uses of the Template Method Pattern in real-world code, but (as with any pattern) don't expect it all to be designed "by the book."
- The Strategy and Template Method Patterns both encapsulate algorithms, the first by composition and the other by inheritance.
- Factory Method is a specialization of Template Method.

The Template Method Pattern