



Software Engineering and Architecture

Deriving Strategy Pattern
From the principles...

Last – Alphatown county

- Customer – *Alphatown* county:
- The pay station must:
 - accept coins for payment
 - show time bought
 - print parking time receipts
 - US: 2 minutes cost 5 cent
 - handle buy and cancel
 - maintenance (empty it)



- Where did we end with the PayStation?
- On the Backlog
 - Cancel not implemented
 - No validation of correct coin
 - No clearing after a buy
- But we did
 - Adding payment
 - Buying a receipt

Testlist for PayStation

- [OK] accept legal 5 cent coin
- [OK] 5c entered => 2 min displayed
- [OK] 10c enter => 4 min display
- [OK] 5+10 cent => 6 min display
- reject 17c
- [OK] 25c buy => receipt of 10 min
- [OK] 50c buy => receipt of 20 min
- cancel => 0 in display

- We got to a code base like

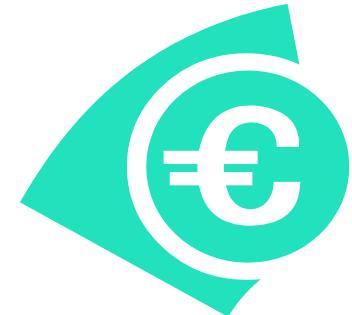
```
💡 @Override
public void addPayment(int coinValue) throws IllegalCoinException {
    insertedSoFar += coinValue;
    timeBought = insertedSoFar / 5 * 2;
}
```

- But would soon be at

```
@Override
public void addPayment(int coinValue) throws IllegalCoinException {
    if (coinValue != 5 && coinValue != 10 && coinValue != 25)
        throw new IllegalCoinException("Error adding payment: Illegal coin: " + coinValue);
    insertedSoFar += coinValue;
    timeBought = insertedSoFar / 5 * 2;
}
```

The nightmare: Success!

- The Alphatown county is very satisfied!
- Success is terrible!
- It means:
- New requirements, add-ons, special cases and “wouldn’t it be nice if...”
- So – our parking machine software is now required by the Betatown county – but with a twist ☹



New requirement

- Betatown: “New **progressive** price model”

1. First hour: \$1.50 (5 cent gives 2 minutes)
2. Second hour: \$2.00 (5 cent gives 1.5 minutes)
3. Third and following hours: \$3.00 per hour (5 cent gives 1 minute)

- Maybe we will see future changes in pricing models ???

- *How can we handle these two products?*



The present code

- This is the spot where things may change:
variability point

```
@Override
public void addPayment(int coinValue) throws IllegalCoinException {
    if (coinValue != 5 && coinValue != 10 && coinValue != 25)
        throw new IllegalCoinException("Error adding payment: Illegal coin: " + coinValue);
    insertedSoFar += coinValue;
    timeBought = insertedSoFar / 5 * 2;
}
```

Exercise !

- Propose some models to handle this issue



- Consider:
 - Most of the code is the same in the two products
 - What about real success? 20 product variants?
- Focus:
 - Sketch *several models*, not just an “optimal” one.
 - Read the book? Find a fifth model!

- Model 1:
 - Source code copy proposal: Make a copy of the source tree
- Model 2:
 - Parameterization proposal: Throw in some ‘if’-statements
- Model 3:
 - Polymorphic proposal: Variation through inheritance
- Model 4:
 - Compositional proposal: Factor out rate model responsibility

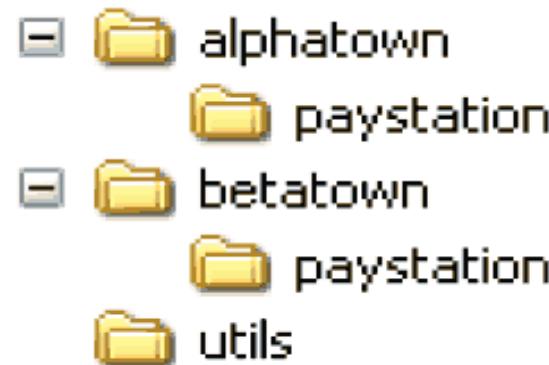
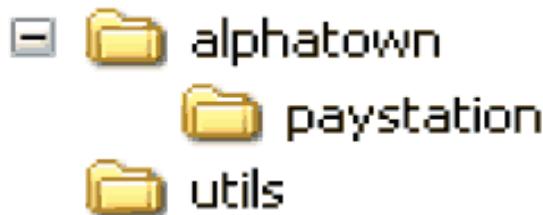


Model 1: Source Code Copy

Widely used: Next generation software

Model 1: Source tree copying

- Idea: Deep copy production code source tree



- Code the new variant by replacing the code at the variability point.

```
@Override
public void addPayment(int coinValue) throws IllegalCoinException {
    if (coinValue != 5 && coinValue != 10 && coinValue != 25)
        throw new IllegalCoinException("Error adding payment: Illegal coin: " + coinValue);
    insertedSoFar += coinValue;
    timeBought = insertedSoFar / 5 * 2;
```

- Benefits:
 - It is simple!
 - no special skill set required in developer team
 - easy to explain idea to new developers
 - It is fast!
 - < 5 minutes?
 - It provides perfect variant decoupling
 - defects introduced in variant 2 does **not** reduce reliability of variant 1
 - easy to distinguish variants (consult folder hierarchy)

- Liabilities:
- **Multiple maintenance problem** ⚡
 - Changes in common code must be propagated to all copies
 - Usually manual process (or tedious SCM operation)

```
@Override
public void addPayment(int coinValue) throws IllegalCoinException {
    if (coinValue != 5 && coinValue != 10 && coinValue != 25)
        throw new IllegalCoinException("Error adding payment: Illegal coin: " + coinValue);
    insertedSoFar += coinValue;
    timeBought = insertedSoFar / 5 * 2;
}
```

Identical code copies!
Bugs here must be fixed in
N different places!!!

```
@Override
public void addPayment(int coinValue) throws IllegalCoinException {
    if (coinValue != 5 && coinValue != 10 && coinValue != 25)
        throw new IllegalCoinException("Error adding payment: Illegal coin: " + coinValue);
    insertedSoFar += coinValue;
}
```

New code here ...

- Liabilities:
- **Multiple maintenance problem** 🔥
 - Changes in common code must be propagated to all copies
 - Usually manual process (or tedious SCM operation)
- Example:
 - 8 pay station variants (different rate policies)
 - request: pay station keeps track of earning ☹
- Experience: Variants drift apart, becoming different products instead of variants...

- If you have many copies you easily get mixed up
 - thus the benefit of easily identifying which variant you are working on is actually not true
- Example:
 - Fixing the same bug in 5 nearly identical SAVOS production code bases at the same time ☹



Model 2: Parametric Solution

Perhaps the most Common in the book

- Idea:
 - It is only a single “behavioural unit” in the addPayment method that varies
 - I can simply make a *conditional statement* there
- A) Introduce a parameter (Which town are we in?)
- B) Switch on that parameter, each time town specific behaviour is needed.

```
@Override
public void addPayment(int coinValue) throws IllegalCoinException {
    if (coinValue != 5 && coinValue != 10 && coinValue != 25)
        throw new IllegalCoinException("Error adding payment: Illegal coin: " + coinValue);
    insertedSoFar += coinValue;
    timeBought = insertedSoFar / 5 * 2;
}
```

```
public class PayStationImpl implements PayStation {  
    [...]  
    public enum Town { ALPHATOWN, BETATOWN }  
    private Town town;  
  
    public PayStationImpl(Town town) {  
        this.town = town;  
    }  
    [...]  
    public void addPayment(int coinValue)  
        throws IllegalCoinException {  
        switch (coinValue) {  
            case 5:  
            case 10:  
            case 25: break;  
            default:  
                throw new IllegalCoinException("Invalid coin: "+coinValue);  
            }  
            insertedSoFar += coinValue;  
            if (town == Town.ALPHATOWN) {  
                timeBought = insertedSoFar * 2 / 5;  
            } else if (town == Town.BETATOWN) {  
                [the progressive rate policy code]  
            }  
    }  
}
```

Instantiation

- Of course – we now have to specify *which* variant of the pay station to use
 - Either AlphaTown or BetaTown
- Defined by the constructor parameters:
 - Here for ‘AlphaTown’

```
public void setUp() {  
    ps = new PayStationImpl(PayStationImpl.Town.ALPHATOWN);  
}
```

- Benefits:
 - Simple
 - A conditional statement is one of the first aspects learned by programmers, used widely, and thus easy to understand for any skill level developer team
 - Avoid multiple maintenance problem
 - Yeah!!! Common defects/requirements are handled once and for all.



```
public void addPayment(int coinValue)
    throws IllegalCoinException {
    switch (coinValue) {
        case 5:
        case 10:
        case 25: break;
        default:
            throw new IllegalCoinException("Invalid coin: "+coinValue);
    }
    insertedSoFar += coinValue;
    if (town == Town.ALPHATOWN) {
        timeBought = insertedSoFar * 2 / 5;
    } else if (town == Town.BETATOWN) {
        [the progressive rate policy code]
    }
}
```

- Liabilities:
 - Reliability concerns
 - Readability concerns
 - Responsibility erosion
 - Composition problem

- **Reliability/quality problem**

- Each time we must add a new rate model (sell in a new town) we must *add code* to the existing PayStationImpl class.

```
[...]
if (town == Town.ALPHATOWN) {
    timeBought = insertedSoFar * 2 / 5;
} else if (town == Town.BETATOWN) {
    [BetaTown implementation]
} else if (town == Town.GAMMATOWN) {
    [GammaTown implementation]
}
```

- This means potential of introducing errors in old code.
- This means complete regression testing (and test case review) of all product variants!
- *Change by modification* is costly !!!

- **Reliability/quality problem**

- Actually our pay station case is the easiest one: *only one ‘switch’!*
- Consider a big system in which there are 83 places where we switch on the town parameter
 - Or – was it **84** places ???

```
[...]
if (town == Town.ALPHATOWN) {
    timeBought = insertedSoFar * 2 / 5;
} else if (town == Town.BETATOWN) {
    [BetaTown implementation]
} else if (town == Town.GAMMATOWN) {
    [GammaTown implementation]
}
```

- *Change by modification* is costly !!!

I did a count on release 4.1.1 of GCC and there are a total of 4079 lines with an #ifdef in the source code. The HAVE_cc0 alone is switched upon in 83 places in 22 different source files.

- **Readability: Code bloat**

- If we must handle 43 different price models, then the switching code becomes long and winding, and the original algorithm almost drowns...

- **Switch creep**

- Throwing in “if” often leads to more “if”

```
if ( Town == ALPHATOWN ) {  
    if ( databaseServer == ORACLE && optimizingOn ) {  
        if ( DEBUG ) { System.out.println( "...." ); }  
        ...  
    } else { if ( isMobilePayment() ) {  
        discountFactor = 0.9;  
        XXX  
    } else { ... }  
}
```

Tell me what options are set in the XXX code ? Difficult, huh?

- **Responsibility erosion (“feature creep”)**
 - Let us review what the responsibilities of the pay station really are now:

```
<<interface>>  
PayStation
```

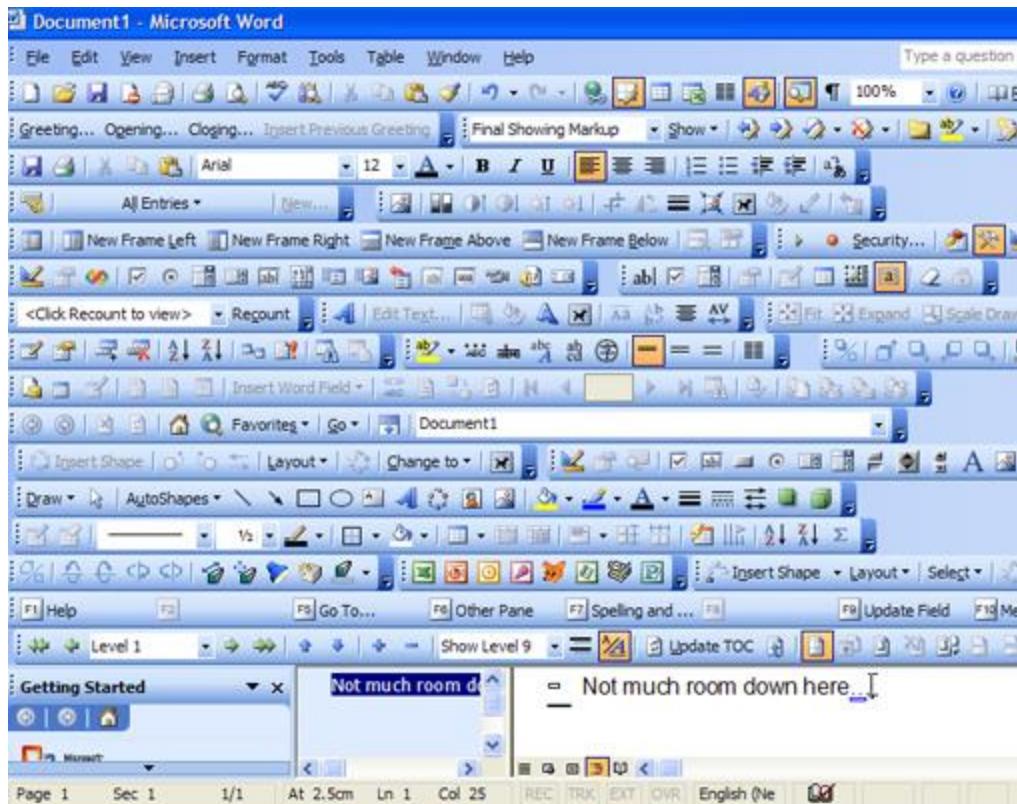
Responsibility

1. **Accept payment**
2. **Handle transactions**
3. **Know time bought**
4. **Print receipt**
5. **Handle variations for Alphatown and Betatown**

Wait a few month and the machine is also responsible for parsing JSON files, printing debug statements in the console, updating a database, and handle transactions over MobilePay and EasyPark!

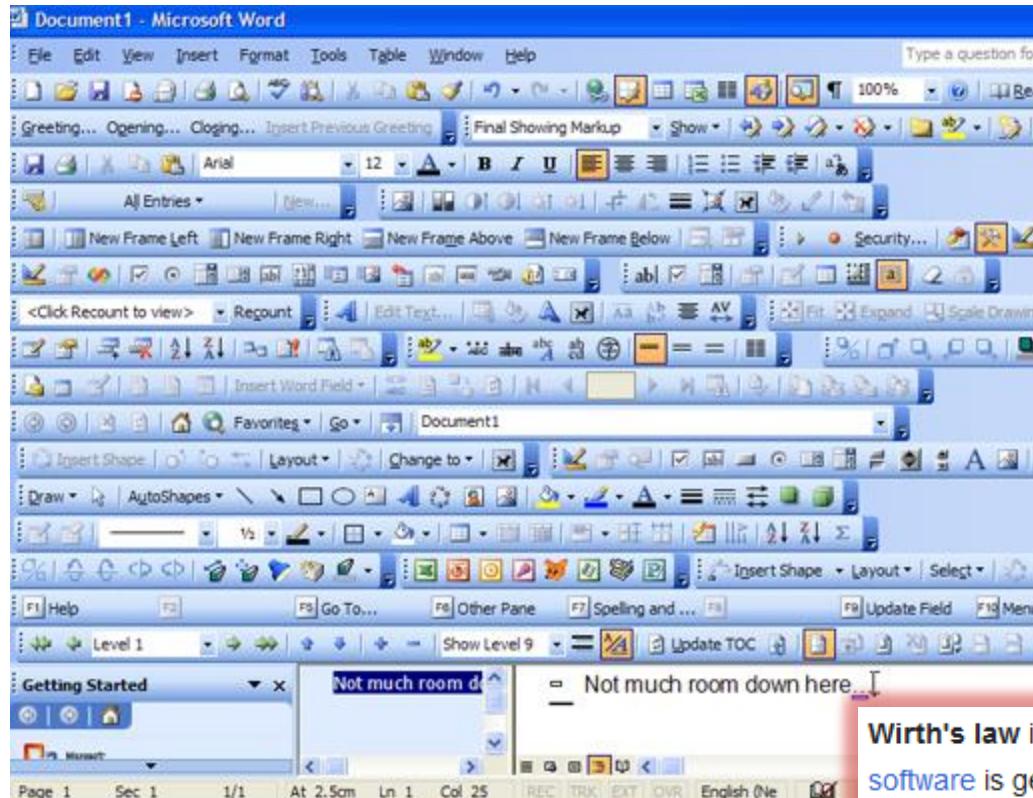
AntiPattern: The Blob

Feature Creep Visually ☺



Feature Creep Visually ☺

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Wirth's law is an adage on computer performance which states that software is getting slower more rapidly than hardware is becoming faster.

The adage is named after [Niklaus Wirth](#), a computer scientist who discussed it in his 1995 article "A Plea for Lean Software".^{[1][2]}

- **Composition problem**

- A rate model that is a *combination* of existing ones leads to code duplication [can be avoided by making private methods in the class]
- Example of much worse situation will be dealt with later...



Conditional compilation

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- In C and C++ you may alternatively use #ifdef's
- The analysis is basically the same as for parameterization, except that there is no performance penalty --- but choice of which model to be used cannot be made at run-time.
- ***Note: Embedded software where memory footprint of code is important this may be the solution far superior to a pattern based solution!***

Example

```
/* Main.cpp */
#include "BasicFunctionality.hpp"
#ifndef HAS_ADVANCED_FEATURE
#include "AdvancedFunctionality.hpp"
#endif
Void main (void)
{
    BasicFunctionality::doSomething();
#ifndef HAS_ADVANCED_FEATURE
    AdvancedFunctionality::doSomething();
#endif
    If (BasicFunctionality::getCondition() ||
#ifndef HAS_ADVANCED_FEATURE
    AdvancedFunctionality::getCondition() ||
#endif
    false)
    {
        Printf("Condition present");
    }
}
```

Include-niveau

Funktions-niveau

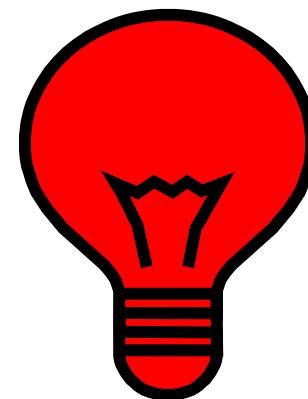
Kode-niveau

Example

- Data from "reality"
 - 600.000 lines of C++
 - 1.300 classes
 - 2.400 files
 - 60.000 staff-days for development
 - 3 sites of development
- 432 parameters ("compile-flags") must be set to determine the specific variant of the product
 - All defined in a make-file (~ build.gradle)

Model 2: Summary

- It is tempting!
 - it is easy - $\frac{1}{2}$ minute in the editor, compile, done!
 - the first 'if' is easy to overview, understand, and get correct
 - but it should turn on the **alarm bell** !





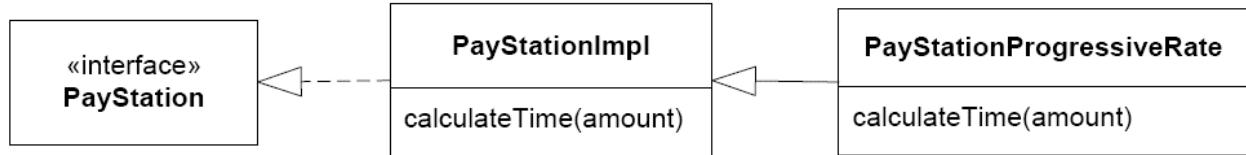
Model 3: Polymorphic Solution

Still widely used, but...

*Give a man a hammer and the world
will seem to consist purely of nails...*

Model 3: Polymorphic proposal

- Subclass and override!



```
public void addPayment( int coinValue )
    throws IllegalCoinException {
    switch ( coinValue ) {
        case 5:
        case 10:
        case 25: break;
        default:
            throw new IllegalCoinException("Invalid coin: "+coinValue);
    }
    insertedSoFar += coinValue;
    timeBought = calculateTime(insertedSoFar);
}
/** calculate the parking time equivalent to the amount of
 * cents paid so far
 * @param paidSoFar the amount of cents paid so far
 * @return the parking time this amount qualifies for
 */
protected int calculateTime(int paidSoFar) {
    return paidSoFar * 2 / 5;
}
```

A red arrow points from the underlined text "timeBought = calculateTime(insertedSoFar);" in the code to the "calculateTime(amount)" method in the "PayStationProgressiveRate" class in the UML diagram.



Proposal 3: Polymorphic

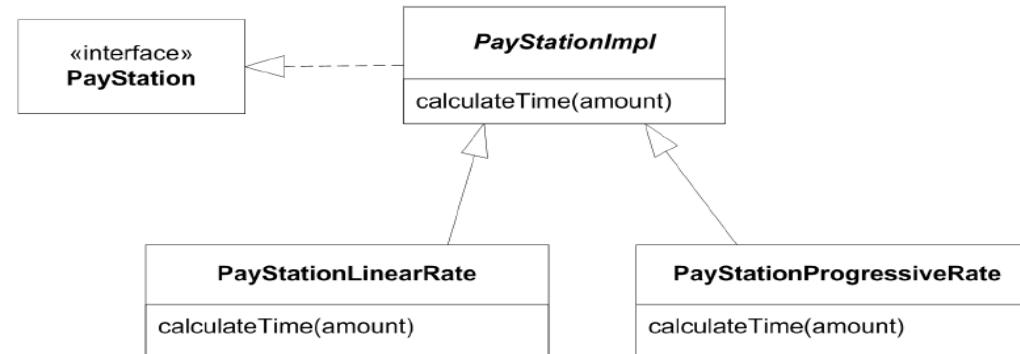
```
public class PayStationProgressiveRate extends PayStationImpl {  
    @Override  
    protected int calculateTime(int paidSoFar) {  
        int time = 0;  
        if ( paidSoFar >= 150+200 ) { // from 2nd hour onwards  
            paidSoFar -= 350;  
            time = 120 /*min*/ + paidSoFar / 5;  
        } else if ( paidSoFar >= 150 ) { // from 1st to 2nd hour  
            paidSoFar -= 150;  
            time = 60 /*min*/ + paidSoFar * 3 / 10;  
        } else { // up to 1st hour  
            time = paidSoFar * 2 / 5;  
        }  
        return time;  
    }  
}
```

Made by TDD – Triangulation,
of course ☺

Instantiation:
PayStation ps =
 new PayStationProgressiveRate();

Formulation using *abstract*

- In OO languages like Java, you can make a ‘template’ superclass, an *abstract class*, deferring method implementations to the subclasses



```
public abstract class PayStationAbstract implements PayStation {  
    private int insertedSoFar;  
    private int timeBought;  
  
    @Override  
    public void addPayment(int coinValue) throws IllegalCoinException {  
        if (coinValue != 5 && coinValue != 10 && coinValue != 25) {  
            throw new IllegalCoinException("The entered coin is not valid");  
        }  
        insertedSoFar += coinValue;  
        timeBought = calculateTime(insertedSoFar);  
    }  
  
    abstract int calculateTime(int paidSoFar);  
  
    @Override  
    public int readDisplay() {  
        return timeBought;  
    }  
}
```

abstract tells us that some methods needs to be defined in the subclass.
You cannot make an instance of an abstract class!

```
public class PayStationLinear extends PayStationAbstract {  
    @Override  
    int calculateTime(int paidSoFar) {  
        return paidSoFar / 5 * 2;  
    }  
}
```

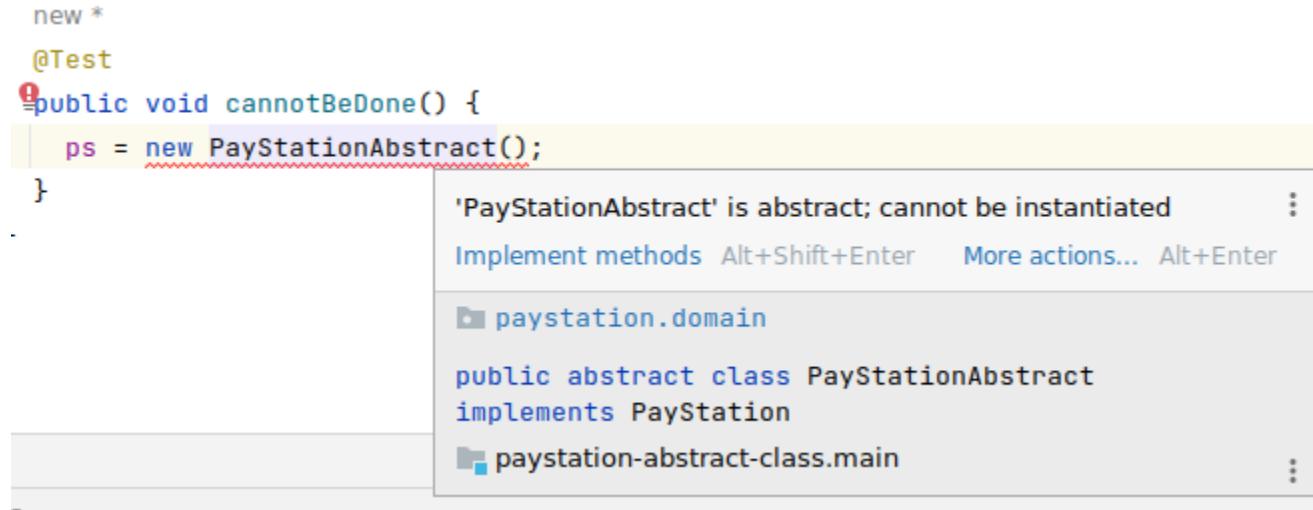
AlphaTown = Linear

BetaTown =
Progressive

```
public class PayStationProgressiveRate extends PayStationAbstract {  
    @Override  
    protected int calculateTime(int paidSoFar) {  
        int time = 0;  
        if (paidSoFar >= 150+200) { // from 2nd hour onwards  
            paidSoFar -= 350;  
            time = 120 + paidSoFar / 5;  
        } else if (paidSoFar >= 150) { // from 1st to 2nd hour  
            paidSoFar -= 150;  
            time = 60 + paidSoFar *3 / 10;  
        } else { // up to first hour  
            time = paidSoFar / 2 * 5;  
        }  
        return time;  
    }  
}
```

Exercise

- Why is it not possible to make an instance of an abstract class?



```
new *  
@Test  
public void cannotBeDone() {  
    ps = new PayStationAbstract();  
}  
  
'PayStationAbstract' is abstract; cannot be instantiated  
Implement methods Alt+Shift+Enter More actions... Alt+Enter  
paystation.domain  
public abstract class PayStationAbstract  
implements PayStation  
paystation-abstract-class.main
```



Analysis

Pros and Cons of
inheritance based design of
our variable pricing

- Benefits
 - Avoid multiple maintenance
 - Reliability concern
 - Code readability
- Liabilities
 - Increased number of classes
 - Inheritance relation spent on single variation type
 - Reuse across variants difficult
 - Compile-time binding

- ☺ Reliability concern
 - The first time I add a new rate policy I *change by modification!*
 - I have to refactor the code to introduce the new private method `calculateTime`
- **But**
 - All following new requirements regarding rate policies can be handled by **adding** new subclasses, not by **modifying** existing classes.
 - Thus, no fear of introducing defects in existing software; no regression testing, no reviews.

- ***Change by addition, not by modification***



- 😊 Readability
 - There is no code bloating from introduction conditional statements
 - I simply add new classes instead

- 😞 Increased number of classes
 - I have to add one new class for each rate policy variant
 - thus instead of 43 if statements in one class I get 43 subclasses to overview

- ☹ Spent inheritance on single variation type
 - You have “wasted” your single implementation-inheritance capability on *one type* of variation!

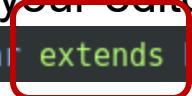
```
public class PayStationProgressiveRate extends PayStationImpl {
```

- The name is odd – isn’t it? The *parameter* is part of the name “PayStationProgressiveRate”
- What is next:
- “PayStationProgressiveRateButLiniarInWeekendsWithOracleDataBaseAccessDebuggingVersionAndBothCoinAndMobilePayPaymentAndEasyParkOptions” ???
- We will discuss this problem in detail later...

⌚ Inheritance is a *compile time binding*

- Inheritance is a compile time binding !!!
 - you literally write “extends / :” in your editor !!!

```
public class PayStationLinear extends PayStationAbstract {
```


- Thus you cannot change rate model except by rewriting code!
 - Sorts of similar to “change by modification ☺”
- And it is completely impossible to dynamically change rate policy at run-time or at start-up time.

- 😞 Reuse across variants is difficult
 - Gammatown
 - “We want a rate policy similar to Alphatown during weekdays but similar to Betatown during weekends.”
 - but some code is in one superclass and some in another subclass...
 - combining them will lead to a pretty odd design
 - or I have to refactor into an abstract superclass that contains the rate policies... But what do they do there?



Model 5: Generative Solution

The masked ‘source code copy’
approach

- Source code divided into
 - Template code with “holes”
 - Code fragments that fit the holes
 - A set defined by the fragments that define a variant
- Weaving
 - $\text{Merge}(\text{template}, \text{fragment set}) \Rightarrow \text{source}$
- Now you can compile the variant source code.
- *Example: FMPP used in generating source code for the book in two variants: download or in-book listings*

Example: PayStation.java

```
/** ${paystationClassHeadline}
<if type == "code">
<#include "/data/paystation/class-responsibilities.txt">
<#include "/data/author.txt">
<if>
</
public interface PayStation {

    /**
<#include "/data/paystation/addPayment-specification.txt">
    *
    public void addPayment( int coinValue ) throws IllegalCoinException;

    /**
<#include "/data/paystation/readDisplay-specification.txt">
    *
    public int readDisplay();

    /**
<#include "/data/paystation/buy-specification.txt">
    *
    public Receipt buy();

    /**
<#include "/data/paystation/cancel-specification.txt">
    *
    public void cancel();
}
```

A "hole"

```
/** The business logic of a Parking Pay Station.

Responsibilities:
1) Accept payment;
2) Calculate parking time based on payment;
3) Know earning, parking time bought;
4) Issue receipts;
5) Handle buy and cancel events.

This source code is from the book
"Flexible, Reliable Software:
Using Patterns and Agile Development"
published 2010 by CRC Press.
Author:
Henrik B Christensen
Computer Science Department
Aarhus University

This source code is provided WITHOUT ANY WARRANTY either
expressed or implied. You may study, use, modify, and
distribute it for non-commercial purposes. For any
commercial use, see http://www.baerbak.com/
*/
public interface PayStation {

    /**
     * Insert coin into the pay station and adjust state accordingly.
     * @param coinValue is an integer value representing the coin in
     * cent. That is, a quarter is coinValue=25, etc.
     * @throws IllegalCoinException in case coinValue is not
     * a valid coin value
     */
    public void addPayment( int coinValue ) throws IllegalCoinException;

    /**
     * Read the machine's display. The display shows a numerical
     * description of the amount of parking time accumulated so far
     * based on inserted payment.
     * @return the number to display on the pay station display
     */
    public int readDisplay();

    /**
     * Buy parking time. Terminate the ongoing transaction and
     * return a parking receipt. A non-null object is always returned.
     * @return a valid parking receipt object.
     */
}
```

- Examples
 - Maven archetype
 - AspectJ – aspect oriented programming
 - FMPP that handles aspects of my book's code
 - SpecFlow: BDD framework



My experience

- This type systems pops up again and again
 - Maven archetype is the newest I know of...
- It is basically *source-code-copy* over again
 - But with some tooling support to avoid multiple maintenance problem
- However
 - It **stinks!** Why?
 - **Because the executing code differs from what I see in my editor!**
 - **We short-circuit our power of reasoning => BUGS!**
 - Morale: Avoid it if possible...
 - But it is not always possible.
 - I use it for my book's code – I have no other option (except *manual* source code copy – yikes...)



Exercise Break

Before we go into model 4

- Which variability technique is used here?

```
/** calculate a formatted 10 minute mean string to insert into a
 * specific meterological report and calculated according to
 * national algorithms. */
public String calculateFormatted10MinWind( int[] datavalues,
                                             int algorithmType ) {
    int meanSpeed = 7, meanDirection = 234; // fake-it
    boolean vrb = false; // fake-it
    switch ( algorithmType ) {
        case DANISH:
            /* calculate means speed, direction, and vrb condition according
               to Danish regulations (omitted) */
            break;
        case FRENCH: /* French algorithm (omitted) */ break;
        case GERMAN: /* German algorithm (omitted) */ break;
    }
    return format( meanSpeed, meanDirection, vrb );
}
```

Polymorphic?
Parametric?
Both?

```

public abstract class CoolingFanControlB {
    public static void main(String args[]) {
        CoolingFanControlB ctrl = new CoolingFanControl_LED_Phillips();
        ctrl.controlTemperature();
    }
    /** The main controller loop: read sensor and control fan.
     */
    public void controlTemperature() {
        while (true) {
            double reading = readTemperature();
            double fanFrequency = controlAlgorithm( reading );
            displayFrequency( fanFrequency );
            // [control the cooling fan]
        }
    }
    abstract void displayFrequency( double f );
    abstract double readTemperature();

    double controlAlgorithm( double T ) {
        /* [calculate frequency based on T] */
        return 250.0; // Fake it
    }
}

class CoolingFanControl_LED_Phillips extends CoolingFanControlB {
    void displayFrequency( double f ) {
        /* [Turn off all LEDs] */
        if ( f < 100 ) { /* [LowSpeedLED.turnOn()] */ }
        if ( f >= 100 && f < 500 ) { /* [MediumSpeedLED.turnOn()] */ }
        if ( f >= 500 ) { /* [HighSpeedLED.turnOn()] */ }
    }
    double readTemperature() {
        double reading; // the temperature measured, assigned in code below
        /* [measure temperature using PHILIPS sensor] */;
        return reading;
    }
}

```

Exercise 2

- A fridge *reads temperature* and *displays frequency of fan*
- Variability
 - Temp sensor type
 - Display type

Parametric? Polymorphic?
Both?



Model 4: Compositional Solution

A fresh and new look at the problem



Proposal 4: Composition

PayStation

- Accept payment
- Calculate parking time based on payment
- Know earning, parking time bought
- Print receipts
- Handle buy and cancel transactions

Golden rule: No abstraction should have too many responsibilities. Max three is a good rule of thumb...

(Facade objects are an exception)



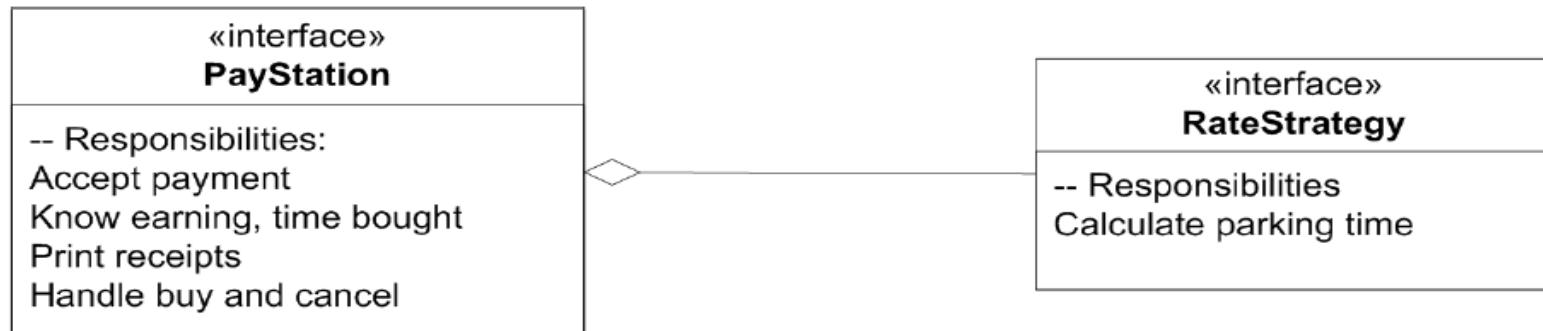
Serving too many responsibilities

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- The reason that we have to *modify* code to handle the new requirement instead of *adding* code is because:
 - *The change revolves around a responsibility (calculate parking time) that is buried within an abstraction and mixed up with many other responsibilities (print receipt, handle buy, etc.) !!!*
- So: What do we do???

- A proposal is simply to

Put the responsibility in its own abstraction / object



Delegation

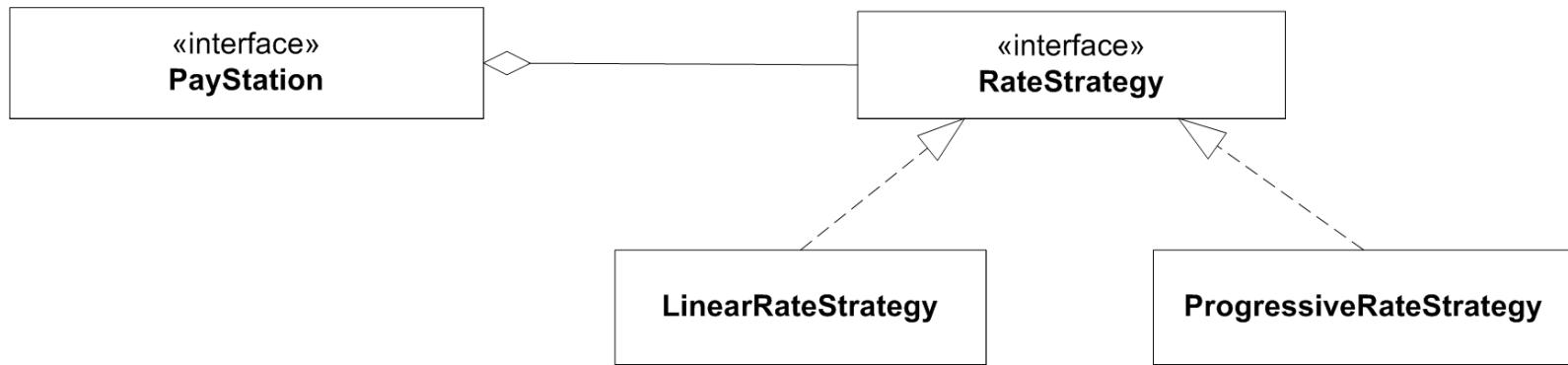
- The basic principle is simple but powerful:
 - Instead of *one* object doing it all by itself, it *asks* another object to help out. Some of the job is handled by another “actor” – the *delegate*
- This principle has a name:

Definition: Delegation

In delegation, two objects collaborate to satisfy a request or fulfill a responsibility. The behavior of the receiving object is partially handled by a subordinate object, called the **delegate**.

Concrete behaviours

- Responsibilities must be served by concrete behaviour in objects...

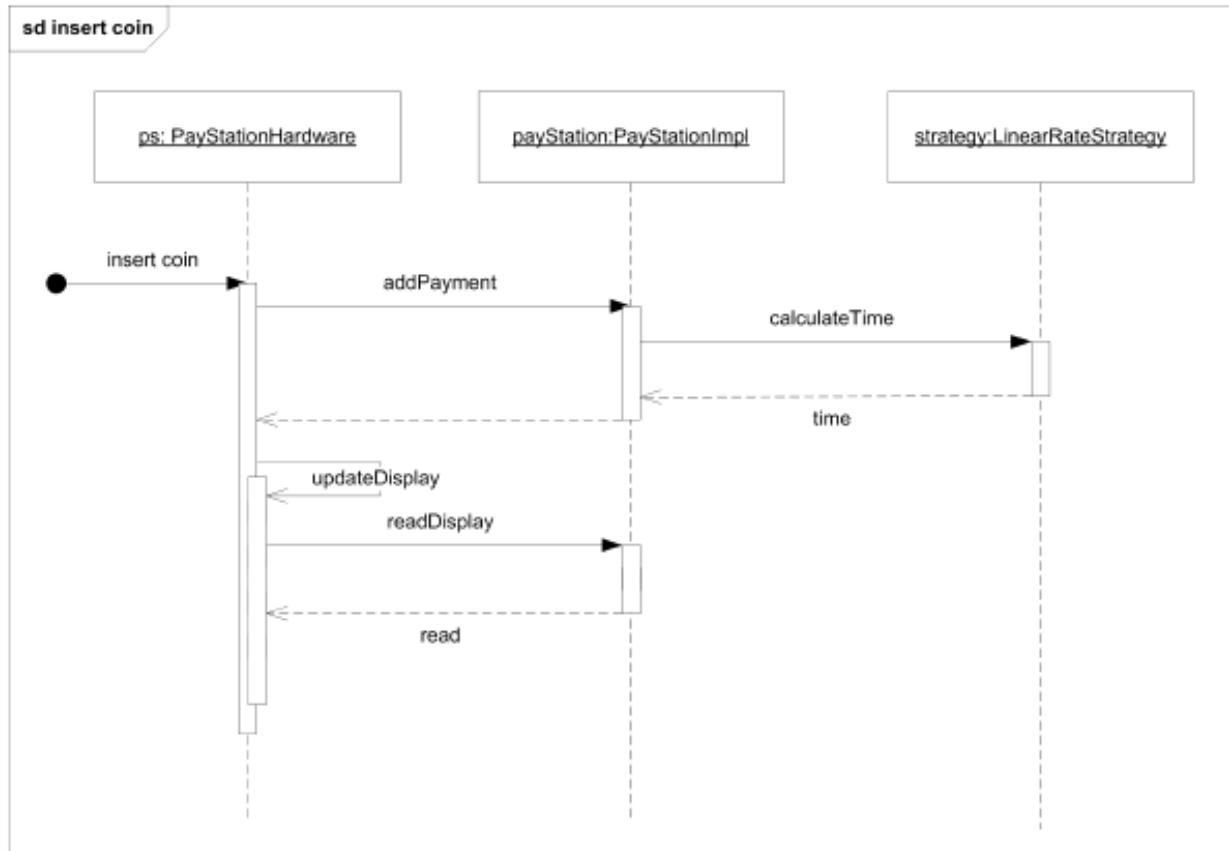


```
public class PayStationImpl implements PayStation {  
    private int insertedSoFar;  
    private int timeBought;  
  
    /** the strategy for rate calculations */  
    private RateStrategy rateStrategy;  
    ...
```

and modify the `addPayment` method:

```
public void addPayment( int coinValue ) throws IllegalCoinException {  
    switch ( coinValue ) {  
        case 5:  
        case 10:  
        case 25: break;  
        default:  
            throw new IllegalCoinException("Invalid coin: " + coinValue + " cent.");  
    }  
    insertedSoFar += coinValue;  
    timeBought = rateStrategy.calculateTime(insertedSoFar);  
}
```

Behaviour



Exercise

- The pay station needs to know which rate strategy object to use, of course!
- *How do we tell it ???*



Choosing pricing

- Several possibilities

- Constructor
- Set-method
- Creational patterns (later on ☺)

```
/** the strategy for rate calculations */
private RateStrategy rateStrategy;

/** Construct a pay station instance with the given
     rate calculation strategy.
     @param rateStrategy the rate calculation strategy to use
*/
public PayStationImpl( RateStrategy rateStrategy ) {
    this.rateStrategy = rateStrategy;
}
```

- What are the benefits and liabilities of
 - Using the constructor to define the strategy?
 - Using a set-method to define the strategy?

- Constructor
 - Compiler will tell you that you have forgotten to make it!
 - Much less cost than letting the customer find out !!!
 - Early binding that cannot be changed at run-time
- Set-method
 - You **will** forget to set it !!!
 - ... but you can change your mind at run-time !
 - (at least for stateless objects like strategy objects...)

- Benefits
 - Readability
 - Run-time binding
 - Separation of responsibilities
 - Variant selection is localized
 - Combinatorial
- Liabilities
 - Increased number of interfaces, objects
 - Clients must be aware of strategies

- ☺ Readability
 - no code bloat of conditional statements

```
    }  
    insertedSoFar += coinValue;  
    timeBought = rateStrategy.calculateTime(insertedSoFar);  
}
```

- ☺ Run-time binding
 - I can actually change the rate policy while the system is running. Leads to lower maintenance costs as no shut down required

- 😊 Responsibilities clearly stated in interfaces
 - Leads to No Odd Naming:
 - **PayStation** and **RateStrategy**: The responsibilities
 - `LinearRateStrategy` etc: Concrete behaviour fulfilling responsibilities
 - The pay station has “lost some fat”
 - by separating responsibilities the cohesion of the code within each abstraction is higher
 - Note though that from the GUI/hardware’s perspective, the pay station *still* has the ‘formal’ responsibility to calculate rates!

- ☺ Variant selection localized
 - There is only one place in the code where I decide which rate policy to take
 - namely in the configuration/main code where I instantiate the pay station!
 - contrast to the parametric solution where selection and decision code is smeared all over the place
 - **No variant handling code at all** in the pay station code !

- 😊 Combinatorial
 - I have not used inheritance – we can still subclass it to provide new behavior on other aspects – without interfering with the rate calculation!
 - But – much more on that later...

- Increased number of objects
 - Similar to the polymorphic solution you ‘trade’ complexity within the code (many if’s handling variants) with complexity outside the code
 - Instead you have many RateStrategy implementations to overview
- Clients must be aware of strategies
 - Never ever instantiate the strategies *within* the Context object (here the PayStationImpl)
 - (Argue why it has *all* the liabilities of the parametric approach!)
 - Thus the client (the one instantiating the Context) must be aware of the particular strategy object to pass to the Context
 - Thus, this code creates a hard binding between the two...



The 3-1-2 process

So – Pizza from the ingredients 😊

- ③ We have *identified some behavior* that is *likely to change*...
 - rate policies
- ① We have clearly stated a responsibility that covers this behavior and expressed it in an interface:

```
<<interface>>  
RateStrategy  
-- calculate Parkingtime
```

- ② The parking machine now perform rate calculations by letting a *delegate* object do it: the RateStrategy object.
 - time = rateStrategy.calculateTime(amount);



The 3-1-2 process

- I call this “mini-process” of handling variability for the 3-1-2 process
- The reason for the odd numbering is its relations to the *compositional design principles* that were first put forward in the Design Pattern book (GoF) by Gamma et al. / Chapter 1.6
- *The number refer to the sequence in the GoF book that the principle is mentioned.*



Transferring responsibilities

- Actually this is a common thing in everyday life
- Many years ago I transferred the responsibility to empty the garbage can to my eldest son
 - (not without some heated arguments though ☺)
- I delegate correcting HotStone exercises to my TAs
- Project leaders' main responsibility is – to delegate responsibility to other people
- And why? Because
 - A) we cannot do everything ourselves and
 - B) too many responsibilities leads to stress and errors!



Key technique: Delegation

- In software this simple technique "*let someone else do the dirty job*" is called **delegation**.
- Instead of an object doing it itself:
 - `time = this.calculateTime(amount);`
 - `this.takeGarbageToGarbageCan();`
- we let some **specialist** object do it for us:
 - `time = rateStrategy.calculateTime(amount);`
 - `son.takeGarbageToGarbageCan();`

- We have *derived* the strategy pattern by analysing our problem in a certain way!

Conclusion

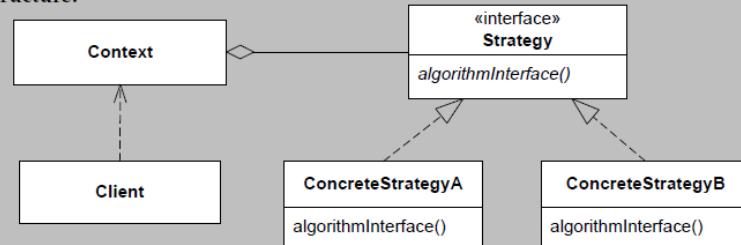
[7.1] Design Pattern: Strategy

Intent Define a family of business rules or algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithms vary independently from clients that use it.

Problem Your product must support variable algorithms or business rules and you want a flexible and reliable way of controlling the variability.

Solution Separate the selection of algorithm from its implementation by expressing the algorithm's responsibilities in an interface and let each implementation of the algorithm realize this interface.

Structure:



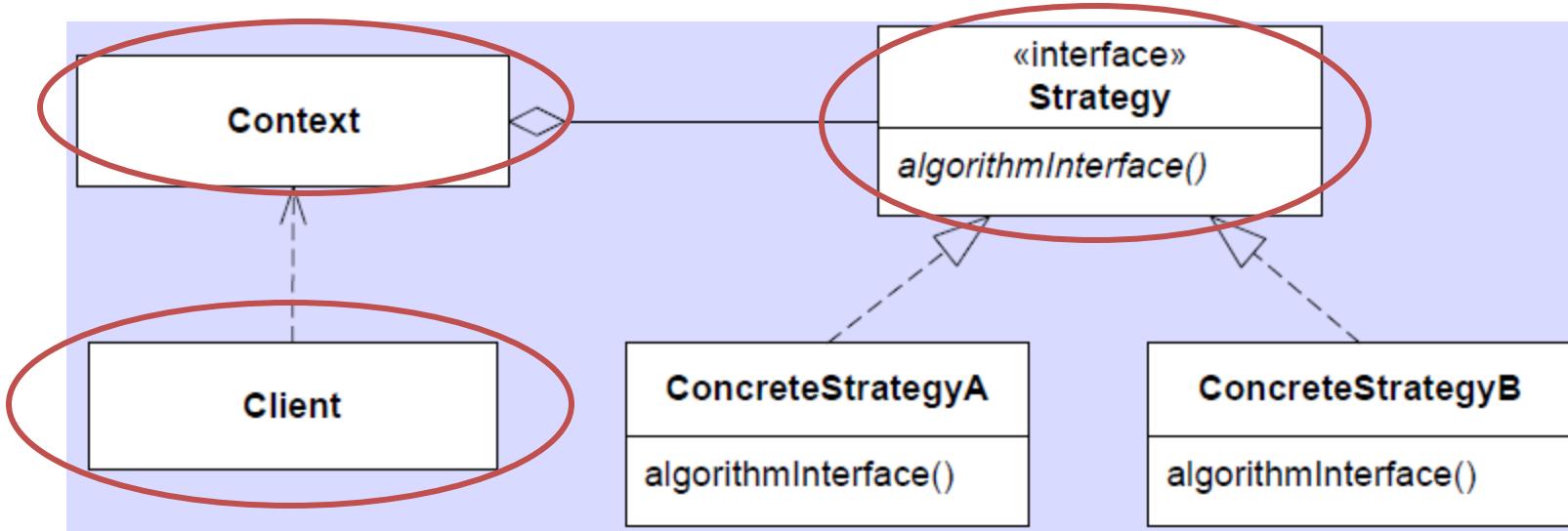
Roles **Strategy** specifies the responsibility and interface of the algorithm. **ConcreteStrategies** defines concrete behavior fulfilling the responsibility. **Context** performs its work for **Client** by delegating to an instance of type **Strategy**.

Cost - Benefit The benefits are: *Strategies eliminate conditional statements.* It is an *alternative to subclassing*. It facilitates *separate testing* of **Context** and **ConcreteStrategy**. Strategies may be changed at run-time (if they are stateless).

The liabilities are: *Increased number of objects.* *Clients must be aware of strategies.*

Terminology

- Strategy defines three roles:
- **Client, Context and Strategy**



- From the ingredients
 - ③ identified behaviour likely to change
 - ① express responsibility for behaviour as interfaces
 - ② use delegation to support behaviour
- we have derived a pattern *automagically* ☺
- This is the nuts and bolts for most (behavioural) patterns !