# CPSC 310 – Software Engineering

# Lecture 10 – Refactoring

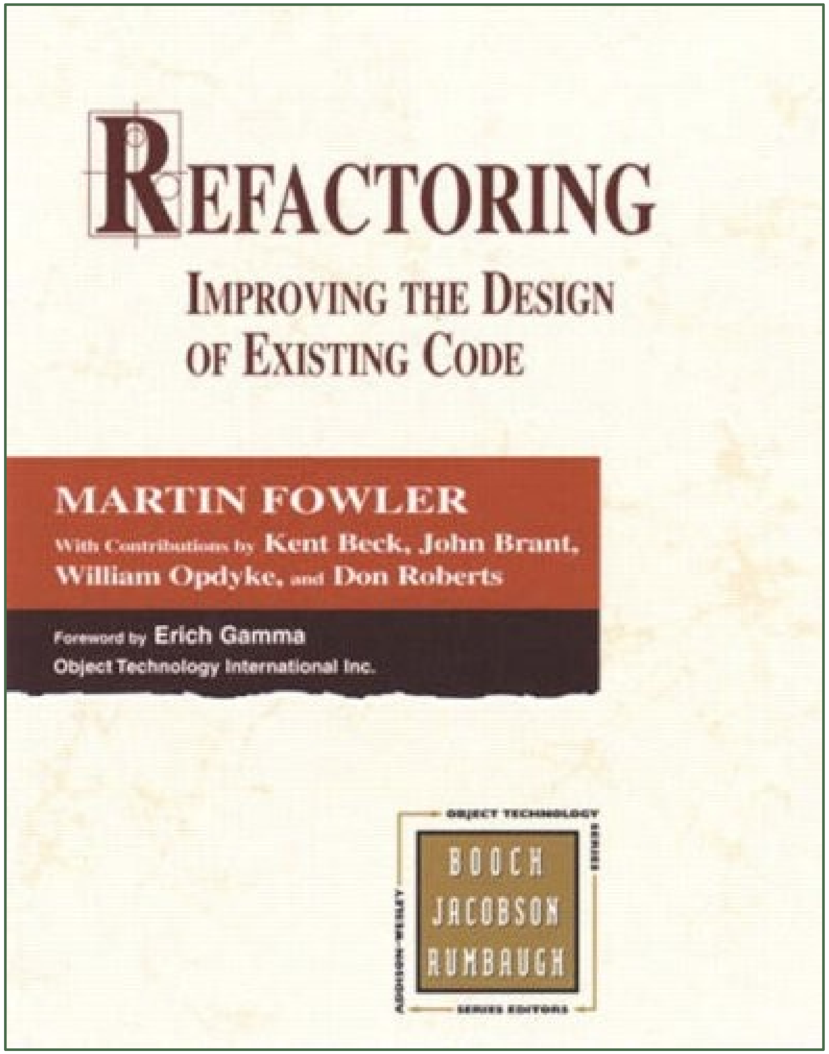
*Any fool can write code that a computer can understand. Good programmers write code that humans can understand.*

Martin Fowler

Refactoring: Improving the design of existing code

# Overview

- Introduction
- Why refactor?
- Refactoring: What,
- When, How?
- Drawbacks
- How to refactor



REFACTORING

IMPROVING THE DESIGN OF EXISTING CODE

MARTIN FOWLER

With Contributions by Kent Beck, John Brant, William Opdyke, and Don Roberts

Foreword by Erich Gamma
Object Technology International Inc.

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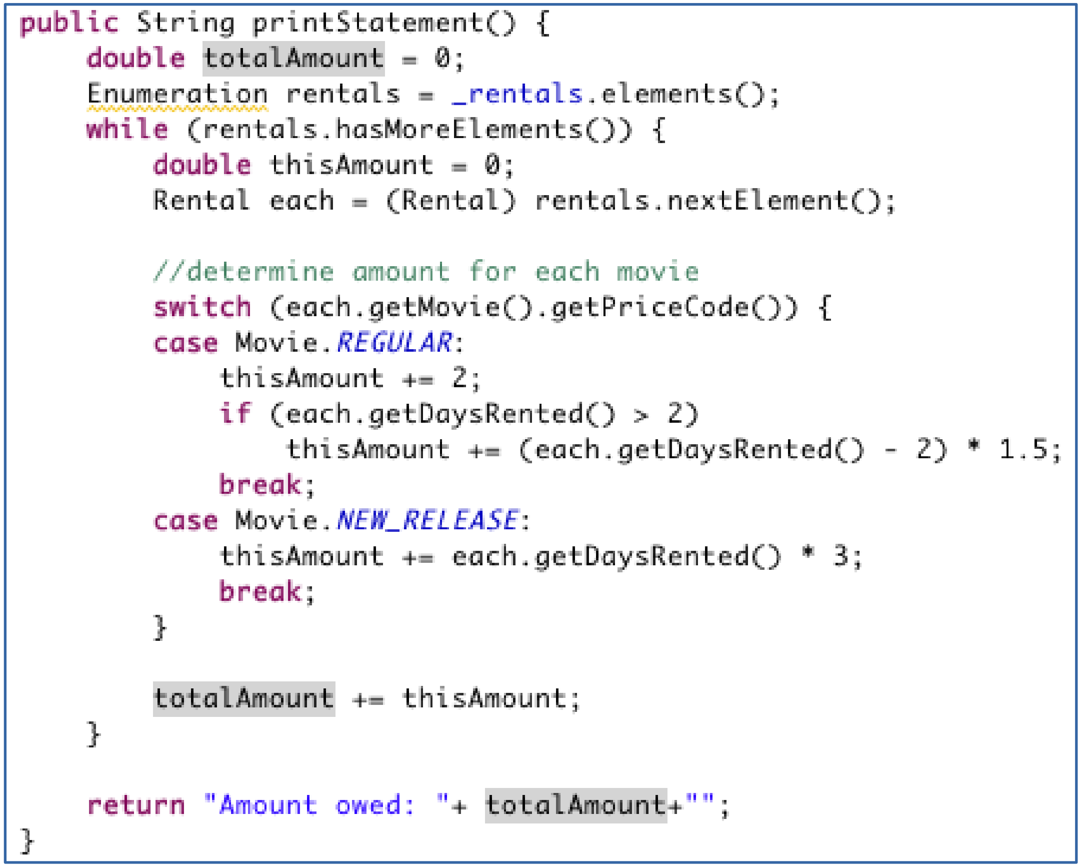
# Learning Goals

After this unit, you will be able to:

- Describe concrete reasons why code can become smelly over time
- Explain the benefits of refactoring
- Describe the textbook process you should follow when refactoring
- Given code, be able to identify code smells and apply appropriate refactorings

# Change in Software is a constant

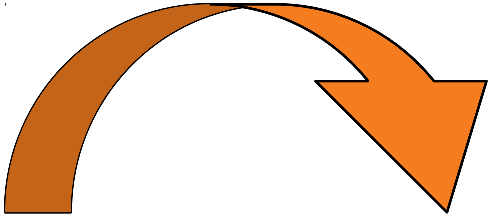


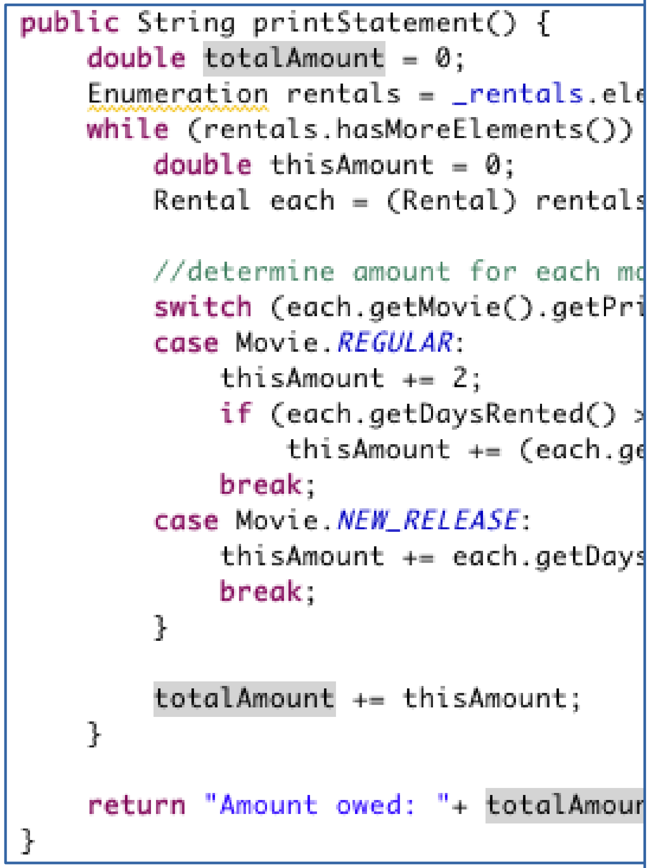
```
public String printStatement() {
    double totalAmount = 0;
    Enumeration rentals = _rentals.elements();
    while (rentals.hasMoreElements()) {
        double thisAmount = 0;
        Rental each = (Rental) rentals.nextElement();

        //determine amount for each movie
        switch (each.getMovie().getPriceCode()) {
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() > 2)
                thisAmount += (each.getDaysRented() - 2) * 1.5;
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDaysRented() * 3;
            break;
        }

        totalAmount += thisAmount;
    }

    return "Amount owed: "+ totalAmount+"";
}
```





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public String printStatement() {
    double totalAmount = 0;
    Enumeration rentals = _rentals.ele
    while (rentals.hasMoreElements())
        double thisAmount = 0;
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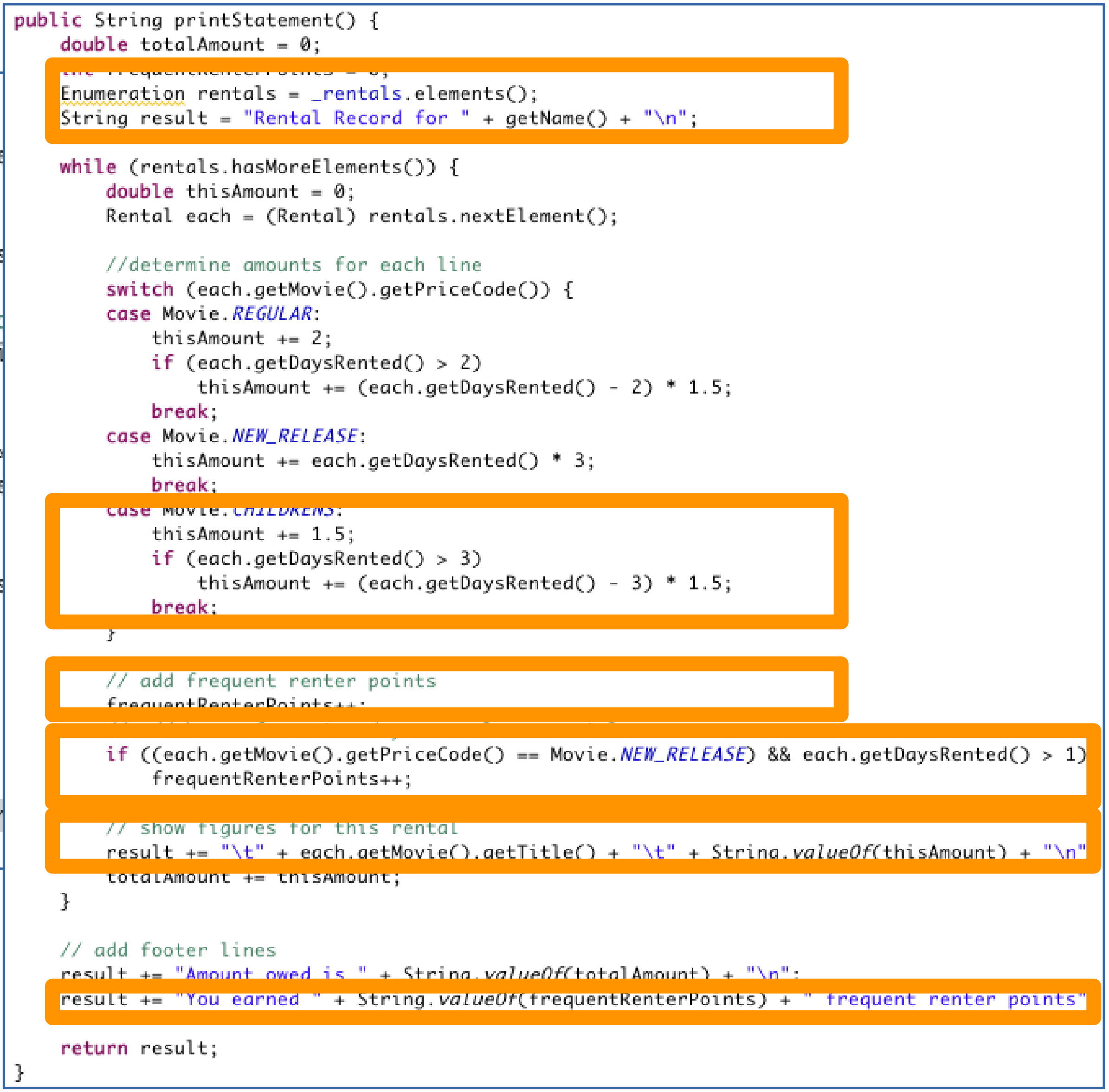
        //determine amount for each mo
        switch (each.getMovie().getPri
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() >
                thisAmount += (each.ge
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDays
            break;
        }

        totalAmount += thisAmount;
    }

    return "Amount owed: "+ totalAmour
}
```



```
public String printStatement() {
    double totalAmount = 0;
    int frequentRenterPoints = 0;
    Enumeration rentals = _rentals.elements();
    String result = "Rental Record for " + getName() + "\n";

    while (rentals.hasMoreElements()) {
        double thisAmount = 0;
        Rental each = (Rental) rentals.nextElement();

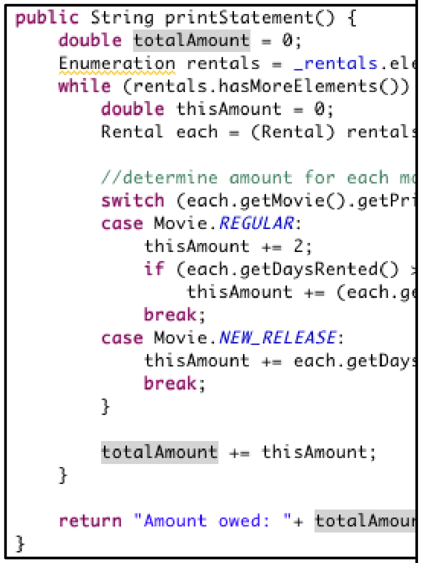
        //determine amounts for each line
        switch (each.getMovie().getPriceCode()) {
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() > 2)
                thisAmount += (each.getDaysRented() - 2) * 1.5;
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDaysRented() * 3;
            break;
        case Movie.CHILDRENS:
            thisAmount += 1.5;
            if (each.getDaysRented() > 3)
                thisAmount += (each.getDaysRented() - 3) * 1.5;
            break;
        }

        // add frequent renter points
        frequentRenterPoints++;
        [illegible]
        if ((each.getMovie().getPriceCode() == Movie.NEW_RELEASE) && each.getDaysRented() > 1)
            frequentRenterPoints++;

        // show figures for this rental
        result += "\t" + each.getMovie().getTitle() + "\t" + String.valueOf(thisAmount) + "\n"
        totalAmount += thisAmount;
    }

    // add footer lines
    result += "Amount owed is " + String.valueOf(totalAmount) + "\n";
    result += "You earned " + String.valueOf(frequentRenterPoints) + " frequent renter points"

    return result;
}
```



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            break;
        }

        totalAmount += thisAmount;
    }

    return "Amount owed: "+ totalAmour
}
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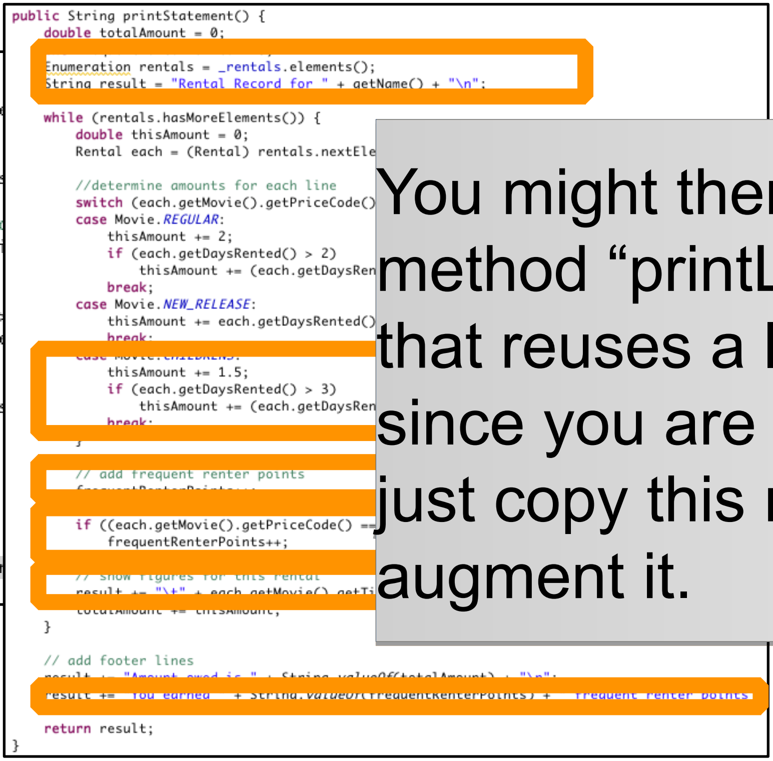

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            break;
        case Movie.CHILDRENS:
            thisAmount += 1.5;
            if (each.getDaysRented() > 3)
                thisAmount += (each.getDaysRen
            break;
        }

        // add frequent renter points
        frequentRenterPoints++;

        if ((each.getMovie().getPriceCode() ==
            frequentRenterPoints++;

        // show figures for this rental
        result += "\t" + each.getMovie().getTi
        totalAmount += thisAmount;
    }

    // add footer lines
    result += "Amount owed is " + String.valueOf(totalAmount) + "\n";
    result += "You earned " + String.valueOf(frequentRenterPoints) + " frequent renter points

    return result;
}
```

You might then add another method “printLongFormStatement” that reuses a lot of this code. And since you are in a hurry, you might just copy this method, and augment it.

*don’t pretend you haven’t done this*

# Yes But…

- No one would *really* introduce code duplication like that, would they?

- So what’s the problem?

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
- But…
  - Others alter your code
  - You alter other people’s code
  - This is good: collaboration = better product!

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - ***Code like that emerges after a collaborative effort!***

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
- But…
  - You won’t get it right the first time around
  - Defects show up at all points of the lifecycle
  - Code is being constantly revisited

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
  - ***Accumulated modifications lead to this code!***

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
  - Accumulated modifications lead to this code!
- But…
  - There is no such thing as a *perfect coder*
  - External conditions can affect the quality of your work
    - Approaching deadlines, stress, skunks…

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
  - Accumulated modifications lead to this code!
  - ***This code can appear in suboptimal conditions!***

```
q = ((p<=1) ? (p ? 0 : 1) : (p==-4) ? 2 : (p+1));

while (*a++ = *b--) ;

char b[2][10000],*s,*t=b,*d,*e=b+1,**p;main(int c,char**v){int n=atoi(v[1]);
strcpy(b,v[2]); while(n--){for(s=t,d=e;*s; s++)    {for(p=v+3;*p;p++) if(**p==*s)
{strcpy(d,*p+2);d+= strlen(d);goto x;}*d++=*s;x:} s=t;t=e;e=s; *d++=0;}puts(t);}
```

yes, even code like this!!

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
  - Accumulated modifications lead to this code!
  - This code can appear in suboptimal conditions!
- But…
  - Agility means very small upfront design
    - “The simplest thing that could possibly work!”

# What’s the problem?

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
  - Accumulated modifications lead to this code!
  - This code can appear in suboptimal conditions!
  - ***This code is expected in an agile process!***
    - ***If it doesn’t show up, then you’re probably not agile…***

# Motivating Thought Experiment

Case: Imagine you’ve written a piece of code but then accidentally deleted and lost it.

Question:

- How much time would it take you to reconstruct from scratch what you had – the same amount, or more, or less?
- Would the code have a better design the second time you write it?

From Razmov’s slides

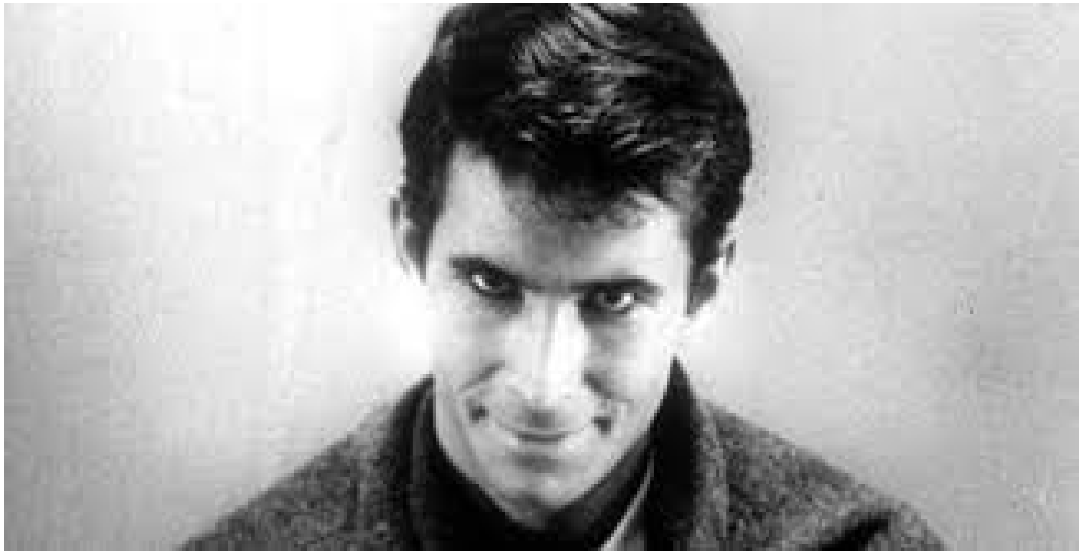
# Code Evolves

- Rule of thumb: It’s harder to maintain (someone else’s) code than it is to write new code.
  - Most developers hope that they won’t have to deal with code maintenance.
  - NIH syndrome
- Reality: Evolving/maintaining code is what most developers do most of the time.

- Advice: It pays off to keep code simple and easy to understand.

From Razmov’s slides

# You're not alone



*“Always code as if the person who ends up maintaining your code is a violent psychopath who knows where you live.”*

# The problem is: CODE SMELLS!

- Facts:
  - “Nobody” writes code like that.
  - Your code is (probably) great.
  - Code like that emerges after a collaborative effort!
  - Accumulated modifications lead to this code!
  - This code can appear in suboptimal conditions!
  - ***This code is expected in an agile process!***
    - ***If it doesn’t show up, then you’re probably not agile…***

Gradually, code begins to rot in places.

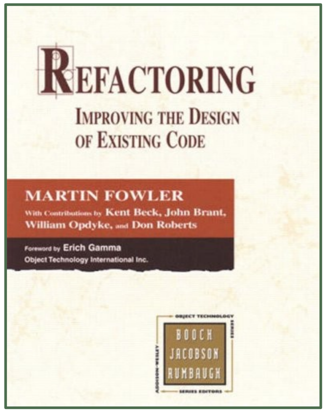
Those places are said to “smell”

We, as designers/software developers, have to chase down these code smells and fix them.

# What is a Code Smell?

- A ***recognizable*** indicator that something ***may*** be wrong in the code
- Can occur in the ***product code*** as well as in the ***test code***!

The smells/refactorings in the following slides are from Martin Fowler, Refactoring, “Improving the design of existing code”.
For test code smells: van Deursen et al. “Refactoring Test Code”.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# Some common smells

- Magic Numbers
- Duplicated Code
- Long Method
- Complicated Conditionals
- Switch Statements
- Large class (doing the work of two)

within-class smells

- Divergent Change
- Shotgun Surgery
- Comments

between-class smells

http://www.soberit.hut.fi/mmantyla/badcodesmellstaxonomy.htm

http://en.wikipedia.org/wiki/Code_smell

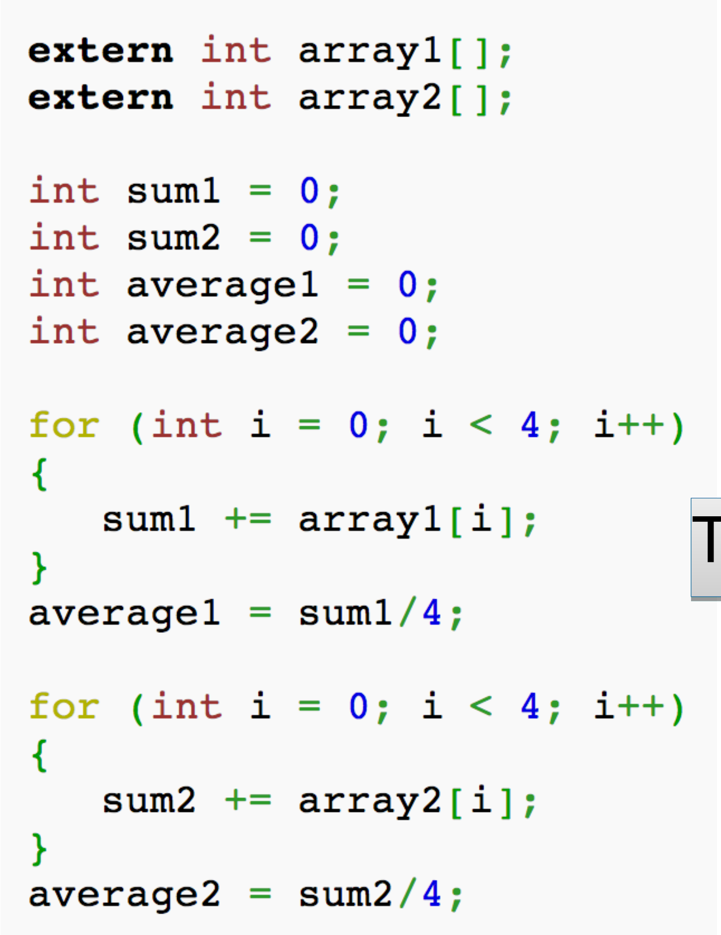
# Magic Numbers?!

```
double potentialEnergy(double mass, double height) {
    return mass * 9.81 * height;
}
```

Any use of an actual number right in the code

http://sourcemaking.com/refactoring/replace-magic-number-with-symbolic-constant

# Duplicate code

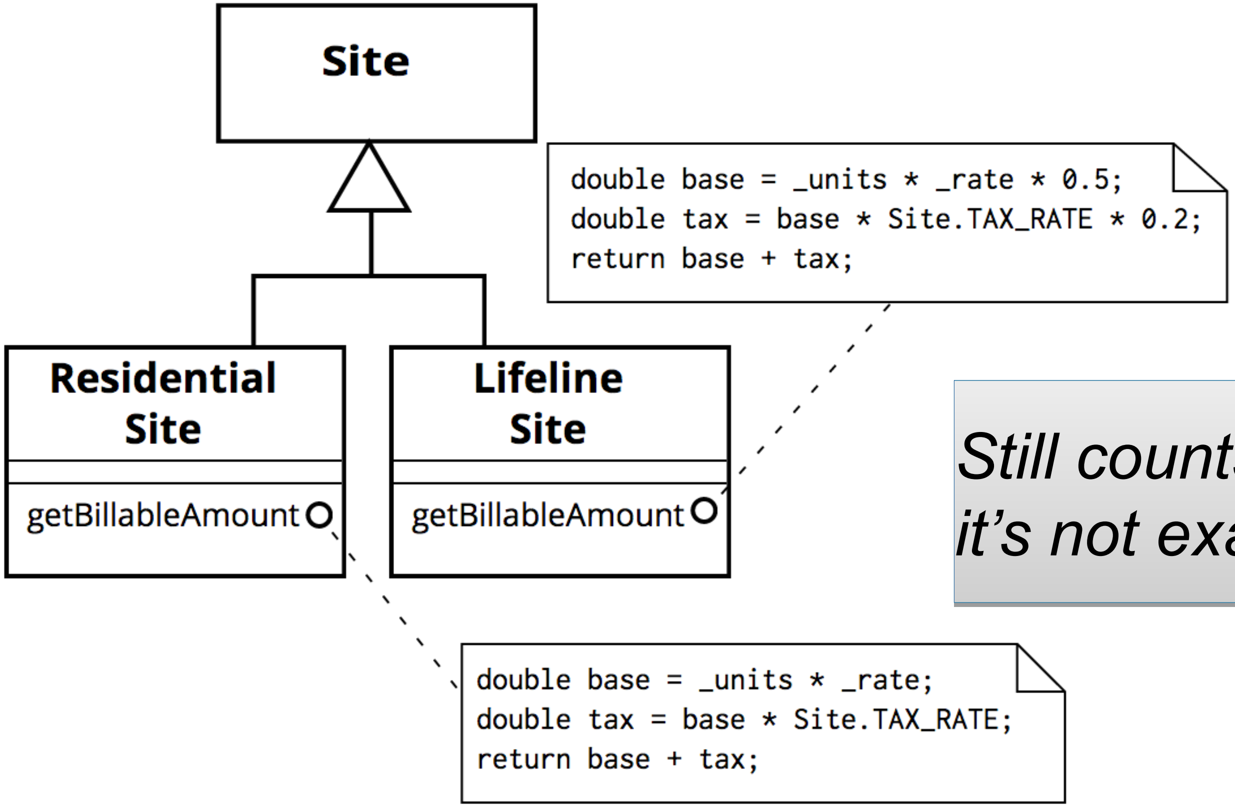


```
extern int array1[];
extern int array2[];

int sum1 = 0;
int sum2 = 0;
int average1 = 0;
int average2 = 0;

for (int i = 0; i < 4; i++)
{
   sum1 += array1[i];
}
average1 = sum1/4;

for (int i = 0; i < 4; i++)
{
   sum2 += array2[i];
}
average2 = sum2/4;
```

These two loops are the same!

http://en.wikipedia.org/wiki/Duplicate_code

# Sometimes the duplication is not as exact



```
double base = _units * _rate * 0.5;
double tax = base * Site.TAX_RATE * 0.2;
return base + tax;
```

```
double base = _units * _rate;
double tax = base * Site.TAX_RATE;
return base + tax;
```

*Still counts, even though it's not exact duplication*

http://refactoring.com/catalog/formTemplateMethod.html

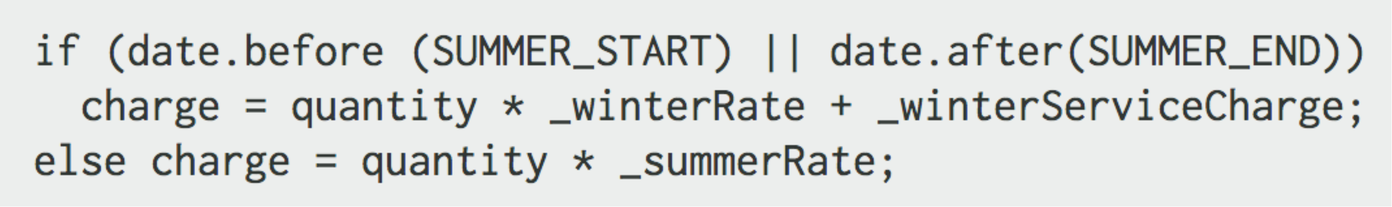
# When is a method too long?

some red flags…

- **Deeply nested control structures**: e.g. for-loops 3 levels deep or even just 2 levels deep with nested if-statements that have complex conditions.
- **Too many state-defining parameters**: By state-defining parameter, I mean a function parameter that guarantees a particular execution path through the function. Get too many of these type of parameters and you have a combinatorial explosion of execution paths (this usually happens in tandem with #1).
- **Logic that is duplicated in other methods**: poor code re-use is a huge contributor to monolithic procedural code. A lot of such logic duplication can be very subtle, but once re-factored, the end result can be a far more elegant design.
- **Excessive inter-class coupling**: this lack of proper encapsulation results in functions being concerned with intimate characteristics of other classes, hence lengthening them.
- **Unnecessary overhead**: Comments that point out the obvious, deeply nested classes, superfluous getters and setters for private nested class variables, and unusually long function/variable names can all create syntactic noise within related functions that will ultimately increase their length.
- **Your massive developer-grade display isn't big enough to display it**: Actually, displays of today are big enough that a function that is anywhere close to its height is probably way too long. But, if it is larger, this is a smoking gun that something is wrong.
- **You can't immediately determine the function's purpose**: Furthermore, once you actually do determine its purpose, if you can't summarize this purpose in a single sentence or happen to have a tremendous headache, this should be a clue.

http://stackoverflow.com/a/475762

# When do you have a complicated conditional.?

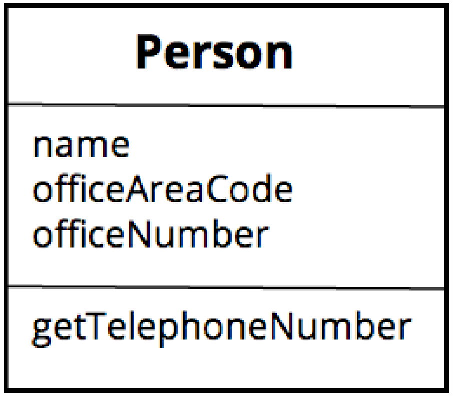


```
if (date.before (SUMMER_START) || date.after(SUMMER_END))
  charge = quantity * _winterRate + _winterServiceCharge;
else charge = quantity * _summerRate;
```

http://sourcemaking.com/refactoring/divergent-change

# Large Class
# (One class is actually two)

*This reveals a failure of the single-responsibility principle.*



**Person**

name
officeAreaCode
officeNumber

getTelephoneNumber

http://sourcemaking.com/refactoring/shotgun-surgery

# What’s Divergent Change?

*When you have to alter a class for more than one kind of change*

*This reveals a failure of the single-responsibility principle.*

Divergent change occurs when one class is commonly changed in different ways for different reasons. …
Any change to handle a variation should change a single class, and all the typing in the new class should express the variation.

If you look at a class and say, "Well, I will have to change these three methods every time I get a new database; I have to change these four methods every time there is a new financial instrument," you likely have a situation in which two objects are better than one. That way each object is changed only as a result of one kind of change. Of course, you often discover this only after you've added a few databases or financial instruments.

http://sourcemaking.com/refactoring/divergent-change

# What’s shotgun surgery?

*A change that alters many classes*

> You whiff this when every time you make a kind of change, you have to make a lot of little changes to a lot of different classes. When the changes are all over the place, they are hard to find, and it's easy to miss an important change.

*this is the inverse of divergent change.*
*One change in lots of places, versus one place with lots of changes*

http://sourcemaking.com/refactoring/shotgun-surgery

# Is a comment really a smell?

*no*

… comments often are used as a deodorant. It's surprising how often you look at thickly commented code and notice that the comments are there because the code is bad.

*but do keep commenting!*

> A good time to use a comment is when you don't know what to do. In addition to describing what is going on, comments can indicate areas in which you aren't sure. A comment is a good place to say why you did something. This kind of information helps future modifiers, especially forgetful ones.

http://sourcemaking.com/refactoring/comments

# How to Deal with a Smell?

- First, determine if it is a *bad smell*!
  - Some smells are always bad
  - Others you can live with
    - (My opinion: Some purists would disagree.)
- Then apply the appropriate refactoring(s)

http://www.industriallogic.com/wp-content/uploads/2005/09/smellstorefactorings.pdf

# Code Smells require Refactoring

- When a code smell is detected, you can re-work the code to fix it.
- In our code duplication example from earlier, what could we have done?

# What is Refactoring?

*“[Refactoring is] the process of changing a software system in such a way that it does not alter the external behavior of the code yet improves its internal structure”* – Martin Fowler

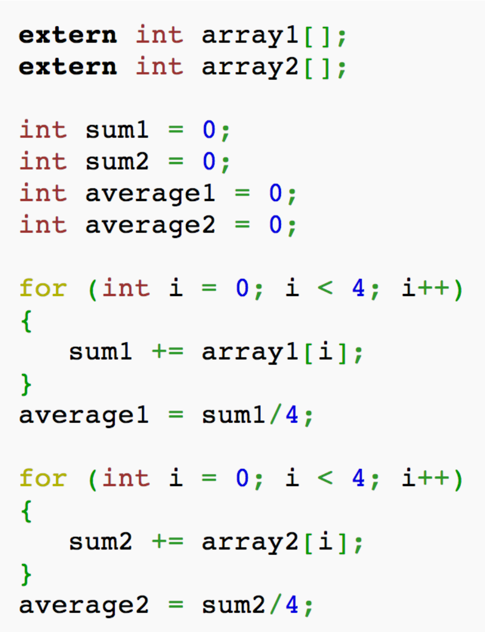
Changes made to a system that:

- ***Do not change observable behavior***
- Remove duplication or needless complexity
- Enhance software quality
- Make the code easier and simpler to understand
- Make the code more flexible
- Make the code easier to change

- Requires Tests!

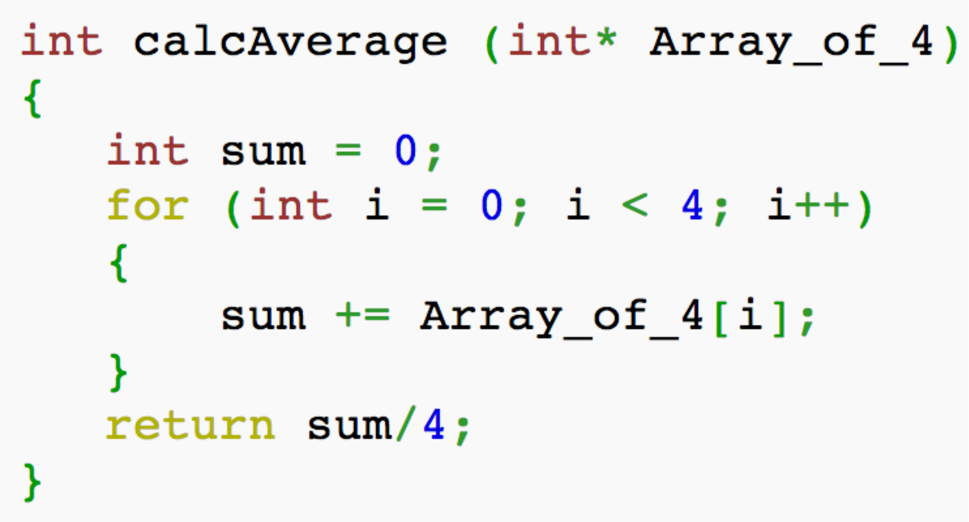
# What is Refactoring?

- At its simplest, it’s just a ***small***, ***behaviour-preserving***, ***source-to-source*** transformation.
- Example:



```
extern int array1[];
extern int array2[];

int sum1 = 0;
int sum2 = 0;
int average1 = 0;
int average2 = 0;

for (int i = 0; i < 4; i++)
{
   sum1 += array1[i];
}
average1 = sum1/4;

for (int i = 0; i < 4; i++)
{
   sum2 += array2[i];
}
average2 = sum2/4;
```

⇒



```
int calcAverage (int* Array_of_4)
{
    int sum = 0;
    for (int i = 0; i < 4; i++)
    {
        sum += Array_of_4[i];
    }
    return sum/4;
}
```

# Why Refactor?

- Long-term investment in the quality of the code and its structure
- No refactoring may save costs / time in the short term but incurs a huge penalty in the long run

From Razmov’s slides

# Why fix it if it ain’t broken?

Every module has three functions:

- To execute according to its purpose
- To afford change
- To communicate to its readers

If it does not do one or more of these, it *is* broken.

```
q = ((p<=1) ? (p ? 0 : 1) : (p==-4) ? 2 : (p+1));

while (*a++ = *b--) ;

char b[2][10000],*s,*t=b,*d,*e=b+1,**p;main(int c,char**v){int n=atoi(v[1]);
strcpy(b,v[2]); while(n--){for(s=t,d=e;*s; s++)   {for(p=v+3;*p;p++) if(**p==*s)
{strcpy(d,*p+2);d+= strlen(d);goto x;}*d++=*s;x:} s=t;t=e;e=s; *d++=0;}puts(t);}
```

From Razmov’s slides

# When to Refactor?

- ***NOT:*** 2 weeks every 6 months
- Do it as you develop - Opportunistic Refactoring
- Boy Scout principle: leave it better than you found it.
- If you recognize a warning sign (a *bad smell*)
  - When you add a function
    - Before, to start clean   and/or
    - After, to clean-up
  - When you fix a bug
  - When you code review
  - You can use *The Rule of Three*

http://martinfowler.com/bliki/OpportunisticRefactoring.html

# The Rule of Three

- The first time, just do it!
- Need it somewhere else? Cut and paste it!
- The third time, ***refactor***!

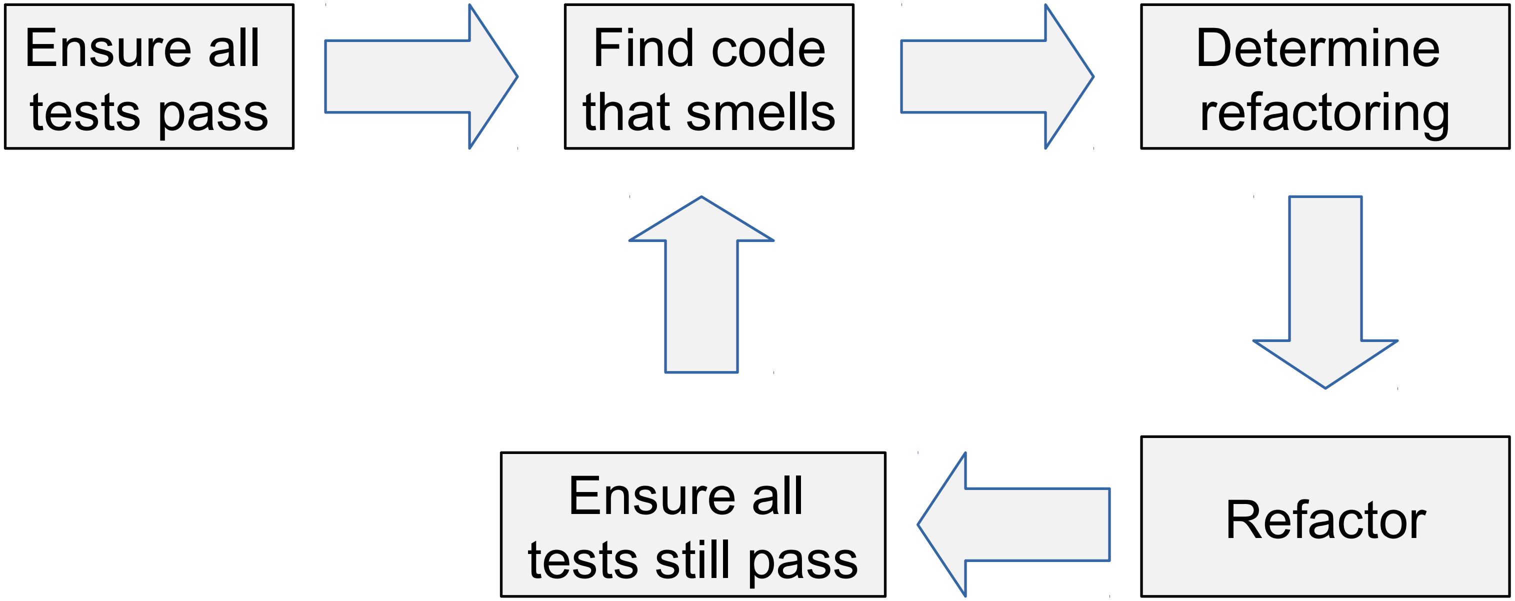
  (*if you remember/know that it has been duplicated before*)

- Often associated with Extreme Programming

# When Not to Refactor?

- When the tests are failing
- When you should just rewrite the code
- When you have impending deadlines

# How to Refactor?



Ensure all tests pass

Find code that smells

Determine refactoring

Refactor

Ensure all tests still pass

# Use refactorings to fix code smells

- Add Parameter
- Change Bidirectional Association to Unidirectional
- Change Reference to Value
- Change Unidirectional Association to Bidirectional
- Change Value to Reference
- Collapse Hierarchy
- Consolidate Conditional Expression
- Consolidate Duplicate Conditional Fragments
- Convert Procedural Design to Objects
- Decompose Conditional
- Duplicate Observed Data

- Encapsulate Collection
- Encapsulate Downcast
- Encapsulate Field
- Extract Class
- Extract Hierarchy
- Extract Interface
- Extract Method
- Extract Subclass
- Extract Superclass
- Form Template Method
- Hide Delegate
- Hide Method
- Inline Class
- Inline Method
- Rename Constant

Each of these is one predictably meaning preserving code transformation.

Online: http://www.refactoring.com/catalog and http://sourcemaking.com/refactoring#

# One Smell – Multiple Refactorings

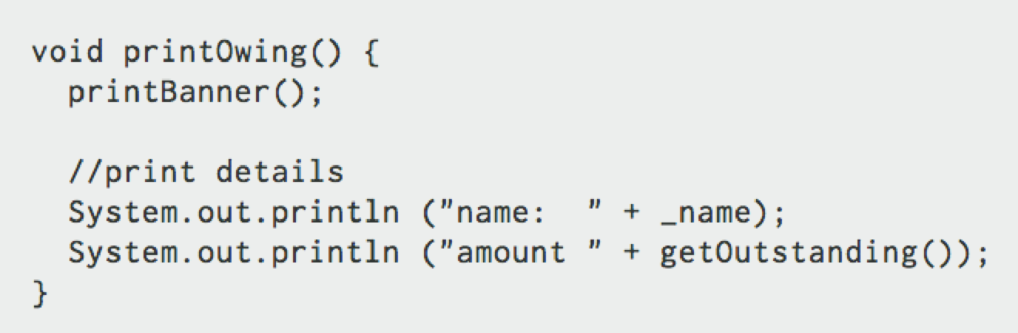
Duplicated Code (Smell):

- Code repeated in multiple places
- Multiple possible refactorings
  - Extract Method
  - Extract Class
  - Pull Up Method
  - Form Template Method

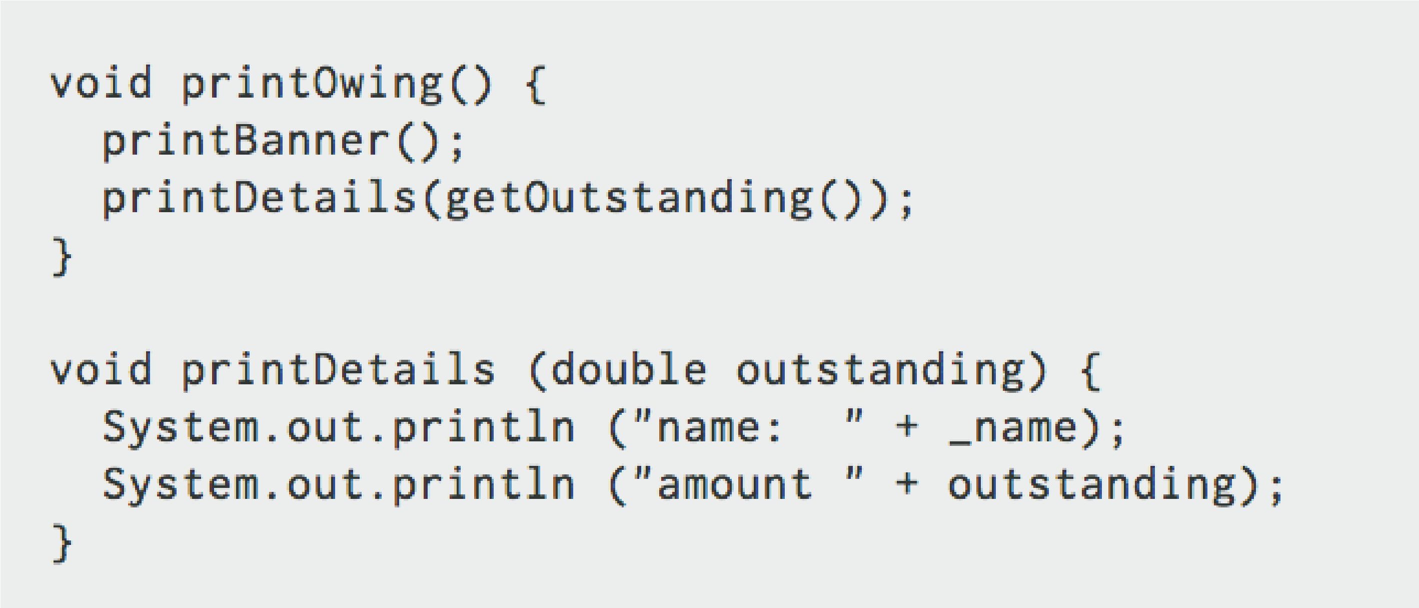
- Choose appropriate one depending on context

# Refactoring: Extract Method Example

*Duplicated Code (Smell)*



```
void printOwing() {
  printBanner();

  //print details
  System.out.println ("name:  " + _name);
  System.out.println ("amount " + getOutstanding());
}
```



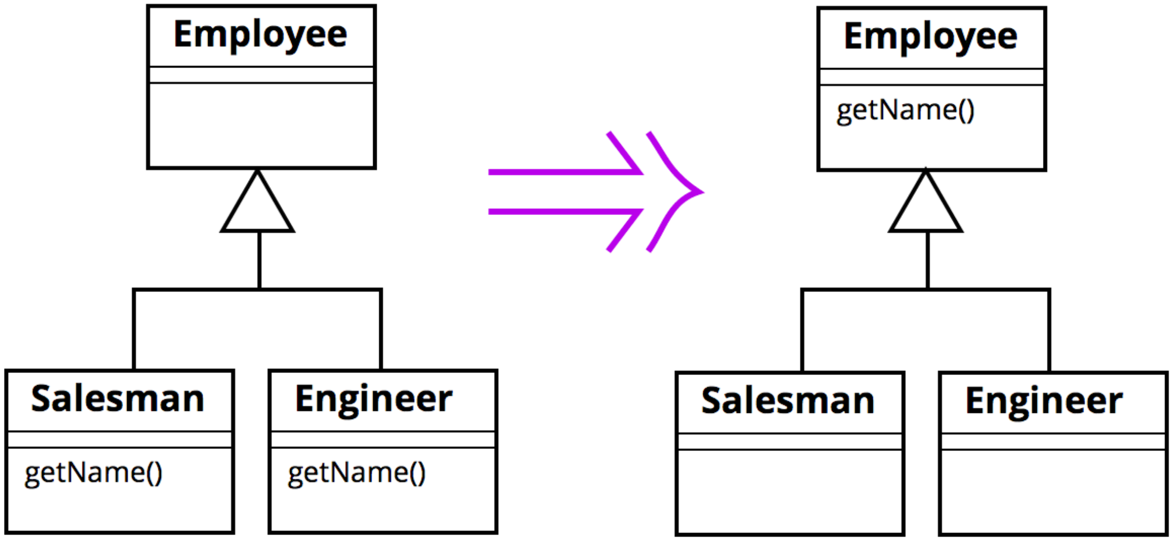
```
void printOwing() {
  printBanner();
  printDetails(getOutstanding());
}

void printDetails (double outstanding) {
  System.out.println ("name:  " + _name);
  System.out.println ("amount " + outstanding);
}
```

http://refactoring.com/catalog/extractMethod.html

# Example Refactoring: Pull Up Method

*Duplicated Code (Smell)*

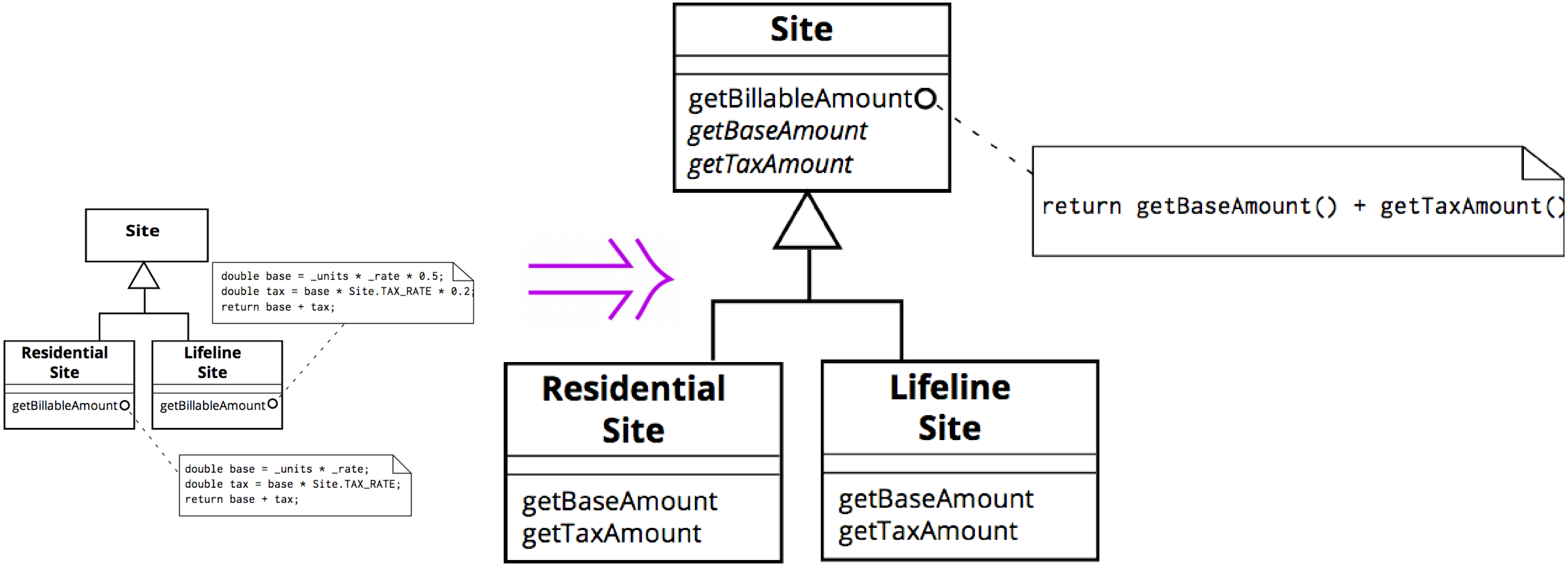
Refactoring: Pull up method - If there are identical methods in more than one subclass, move it to the superclass



http://www.refactoring.com/catalog/pullUpMethod.html

# Fixing Not Quite Duplicate Code

- Our early knotty code not quite duplication problem can be solved using refactoring.
- We can take that code, and transform it into a template method:



```
double base = _units * _rate * 0.5;
double tax = base * Site.TAX_RATE * 0.2;
return base + tax;
```

```
double base = _units * _rate;
double tax = base * Site.TAX_RATE;
return base + tax;
```

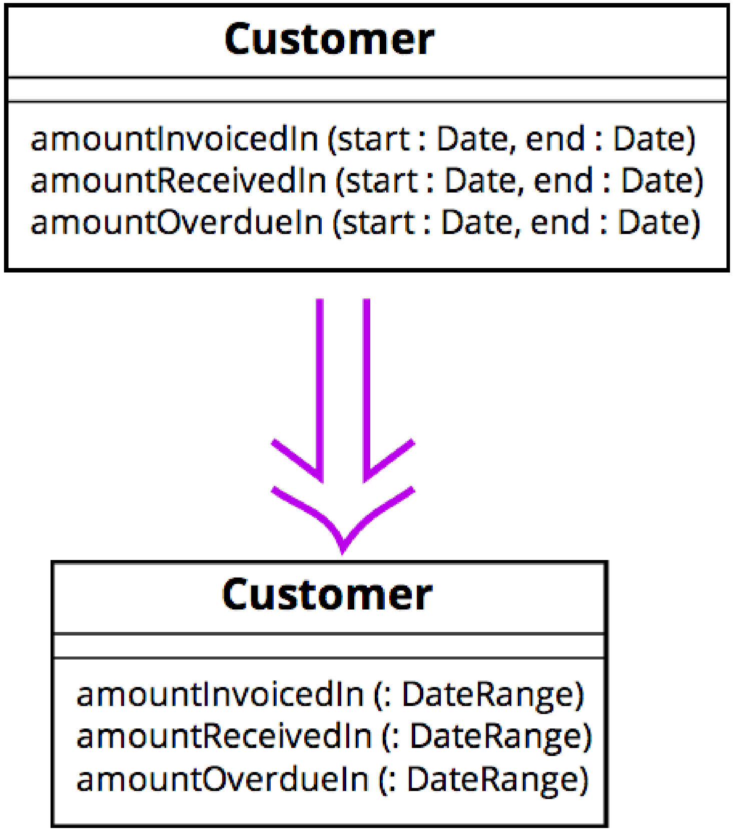
```
return getBaseAmount() + getTaxAmount()
```

# Example Refactoring: Introduce Parameter Object

Smell: long parameter list / data clump

*constantly see the same few data items passed around together.*

Refactoring:
Introduce parameter object - If you have a group of parameters that naturally go together then you can replace them with an object.



**Customer**

amountInvoicedIn (start : Date, end : Date)
amountReceivedIn (start : Date, end : Date)
amountOverdueIn (start : Date, end : Date)

**Customer**

amountInvoicedIn (: DateRange)
amountReceivedIn (: DateRange)
amountOverdueIn (: DateRange)

http://martinfowler.com/bliki/DataClump.html

# Smell: Long Method

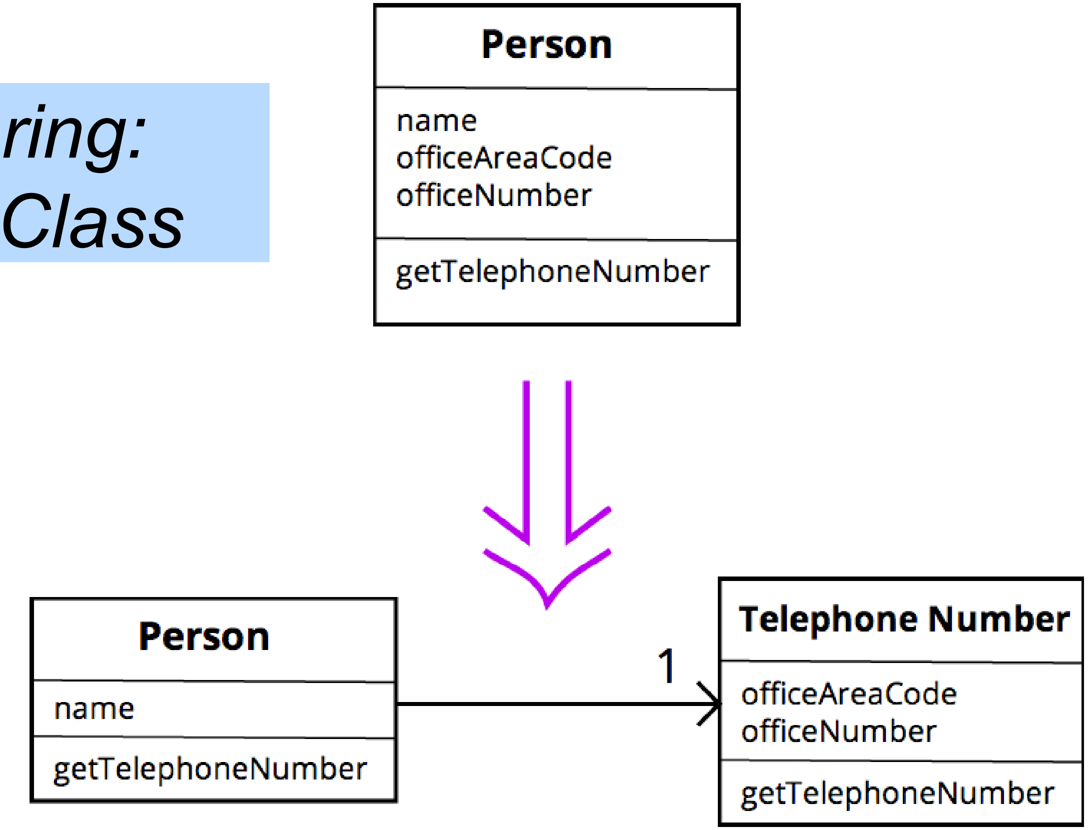
- Methods with many statements, loops, or variables
- Possible refactorings
  - Extract Method
  - Replace Temp with Query
  - Replace Method with Method Object
  - Decompose Conditional
  - Consolidate Conditional Expression

# Refactoring: Extract Method (again)

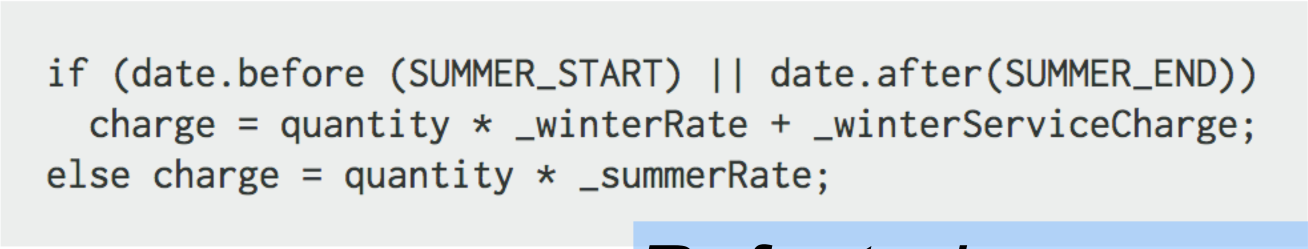
- Pull code out into a separate method when the original method is long or complex
- Name the new method so as to make the original method clearer
- Each method should have just one task

# Smell: One class doing the work of two

*Refactoring: Extract Class*



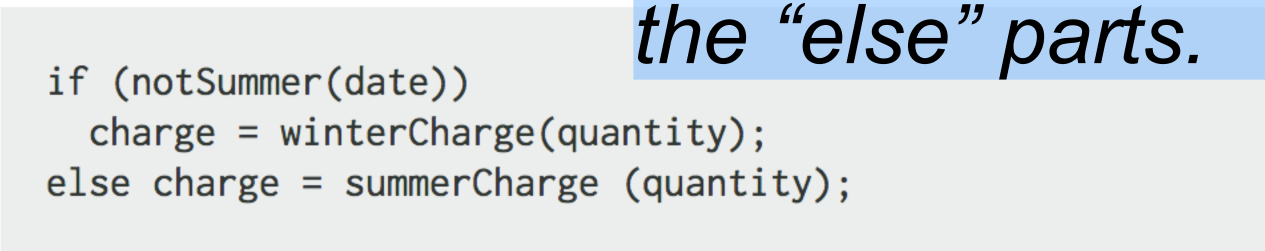
# Smell: Complicated Conditional



```
if (date.before (SUMMER_START) || date.after(SUMMER_END))
  charge = quantity * _winterRate + _winterServiceCharge;
else charge = quantity * _summerRate;
```

*Refactoring:*
***Decompose Conditional***

*extract methods from the condition, the “then” and the “else” parts.*



```
if (notSummer(date))
  charge = winterCharge(quantity);
else charge = summerCharge (quantity);
```

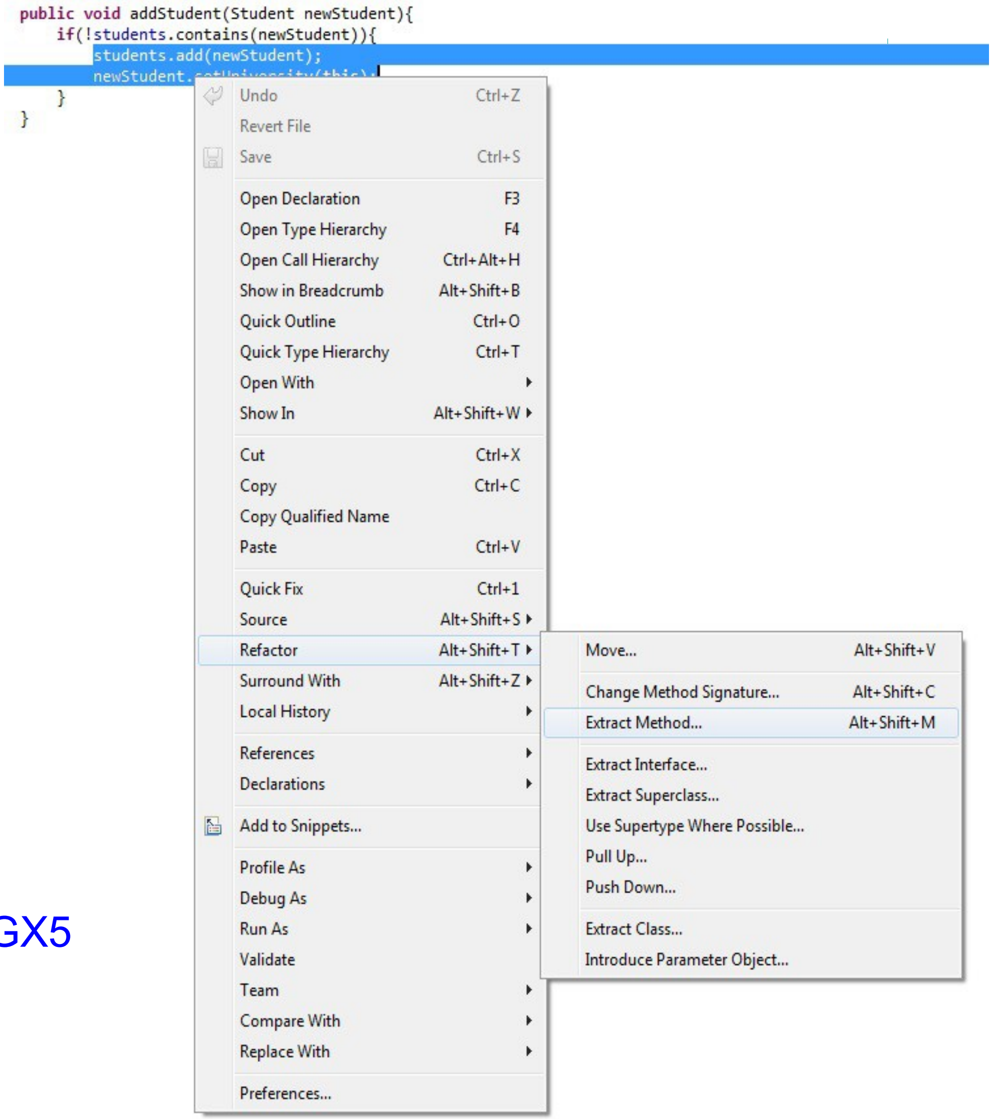
# How to refactor?

## Options

- Sloppy (manually)
- By the book (manually, but following a specific process)
- Automatic, using IDE support

Demos: http://xp123.com/xplor/xp0605/index.shtml

# How to refactor?



```
public void addStudent(Student newStudent){
    if(!students.contains(newStudent)){
        students.add(newStudent);
        newStudent.setUniversity(this);
    }
}
```

Using IDE support is the best option. You are least likely to make mistakes using this approach.

## Learn about Eclipse support:

http://www.ibm.com/developerworks/opensource/library/os-eclipse-refactoring/?ca=dgr-lnxw97Refractoringdth-OS&S_TACT=105AGX59&S_CMP=grlnxw97

# Refactoring Truths

- Most of the time your intuition is good
- Doing it *by the book* is hard
  - Use IDE tools
- Unit tests are the key
  - Run Unit tests
  - Refactor
  - Run Unit tests

# Refactor Every Chance You Get

- Improve the design of existing code without changing functionality
  - Simplify code
  - Improve design
  - Remove duplicate code
- The ability to refactor is your reward for spending time writing unit tests

# Remember!

- A potential for refactoring ***is not a smell***
  - Just because you see a potential for refactoring doesn’t mean you should apply it.  Only refactor if the code suffers from a code smell.
  - Some refactorings are opposites of one another (you could get caught in a loop of refactorings if you do them just for the sake of it! Inline versus Extract method, for instance.)

- First smell, then refactor

# Refactoring Drawbacks

- When taken too far
  - Incessant tinkering with code
  - Trying to make it *perfect*
- Attempting refactoring when the tests don’t work – or without tests – can lead to dangerous situations!
- Refactoring published interfaces propagates to external users relying on these interfaces

# Why Developers Fear Refactoring?

1. “I don’t understand the code enough to do it”
2. Short-term focus (Adding a new working feature is cooler!)
3. Not paid for overhead tasks such as refactoring?

- Solutions:
  1. Test!
  2. Learn to appreciate beauty!
  3. Teach the benefits of better code!

# Resources

- “The” Book, by Martin Fowler
  - Refactoring: Improving the design of existing code
- Code Smells
  - http://sourcemaking.com/refactoring/bad-smells-in-code
- Refactorings List
  - http://www.refactoring.com/catalog
  - http://sourcemaking.com/refactoring
- A refactoring “cheat sheet”
  - http://industriallogic.com/papers/smellstorefactorings.pdf

# Summary

- Code decays for many reasons
  - Collaboration, rework, external conditions, agility
- Refactoring improves existing code
  - Does not change existing behaviour
- Refactoring improves maintainability and hence productivity
- Refactor continuously
- Refactoring is an iterative process
  - Tests pass → Find smell → Refactor → Repeat
- Many smells, even more refactorings!