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# Code Refactoring

CS356 Object-Oriented Design and Programming

<http://cs356.yusun.io>

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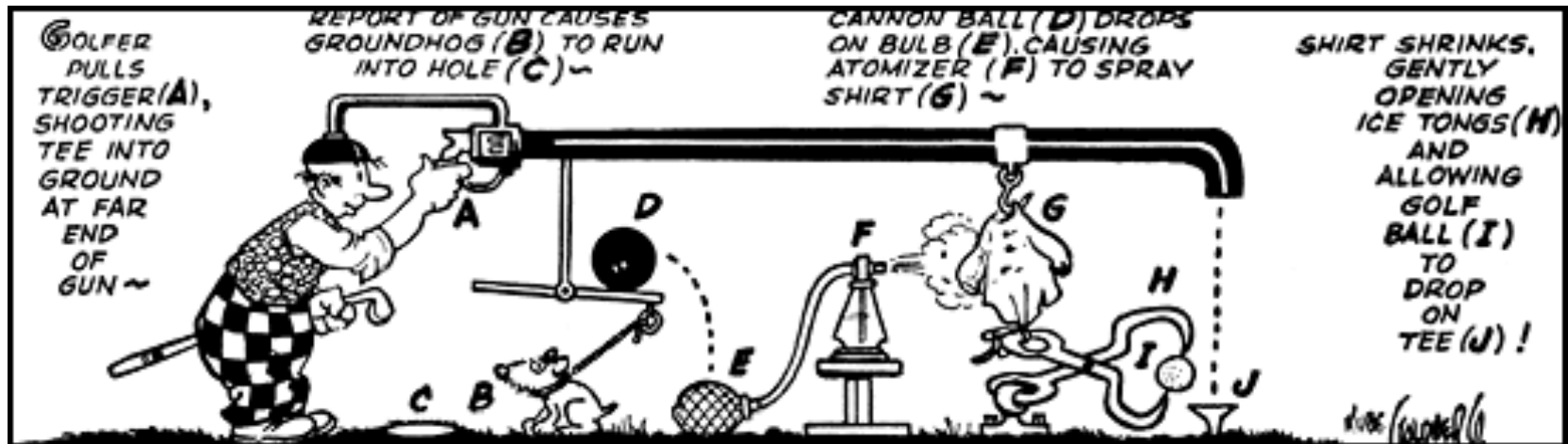
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# The Problem: Software Drift

- ◆ Over many phases of maintenance, structure begins to decay (entropy)
- ◆ Begins to resemble Rube Goldberg machine



# Software Nature – Software Entropy

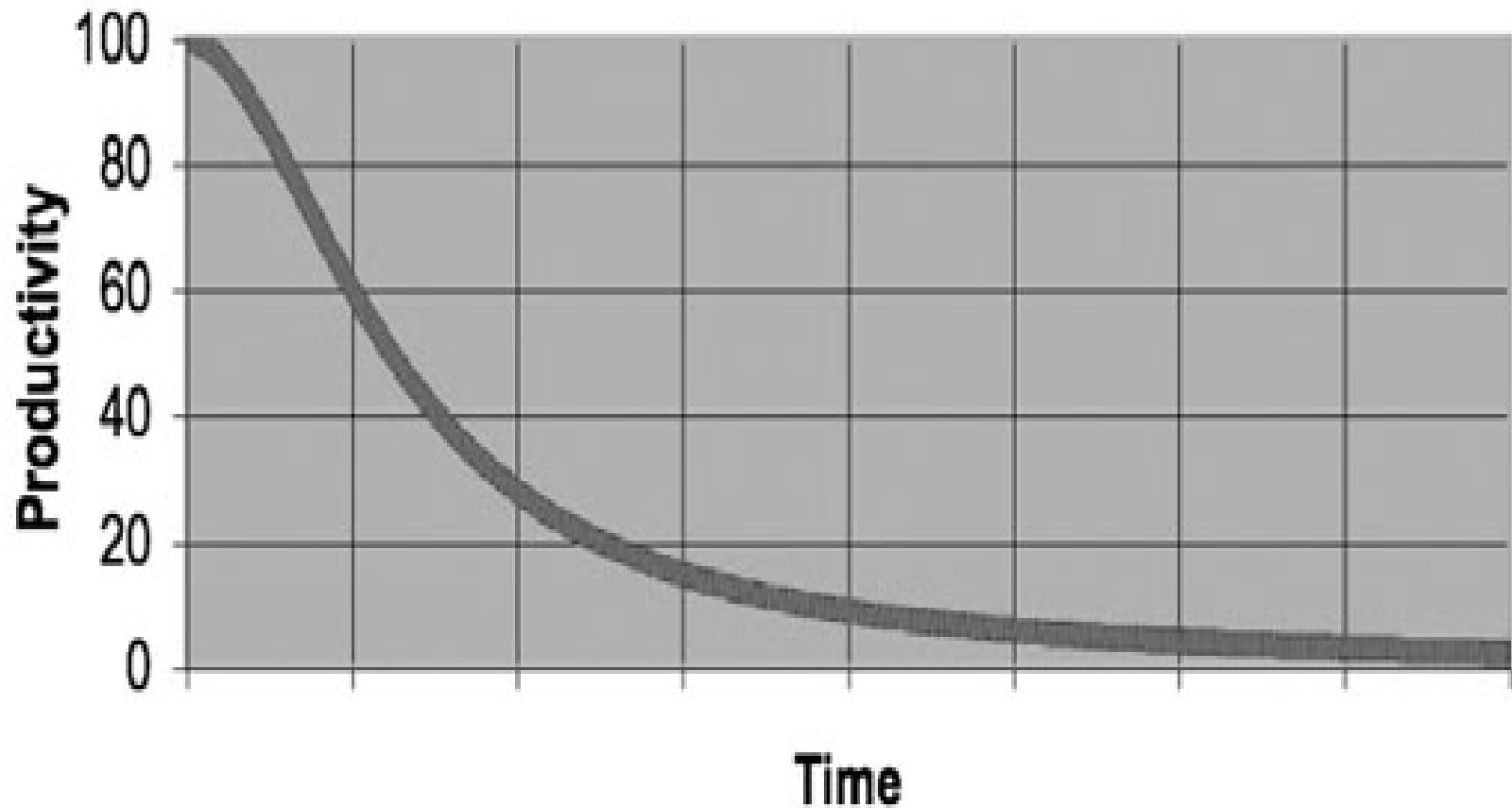
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- ◆ Software tends to degrade / decay
- ◆ Software rot – like a piece of bad meat



# Developers Productivity vs. Time

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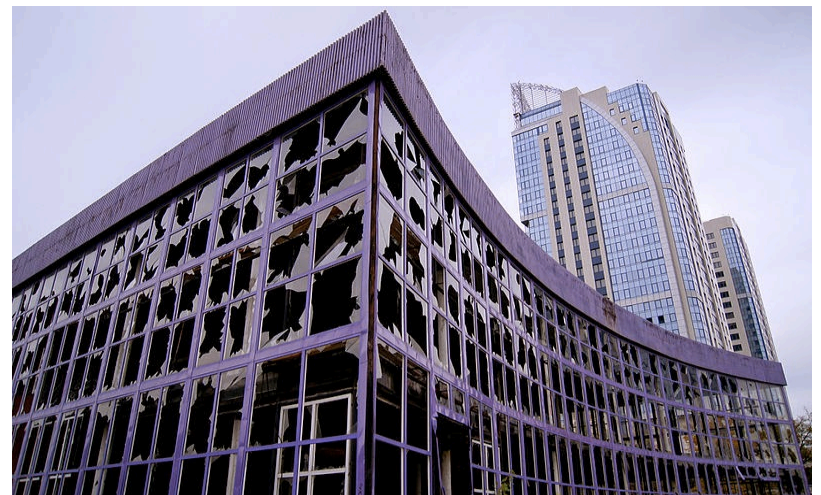


# Psychology Reason: Broken Window Theory

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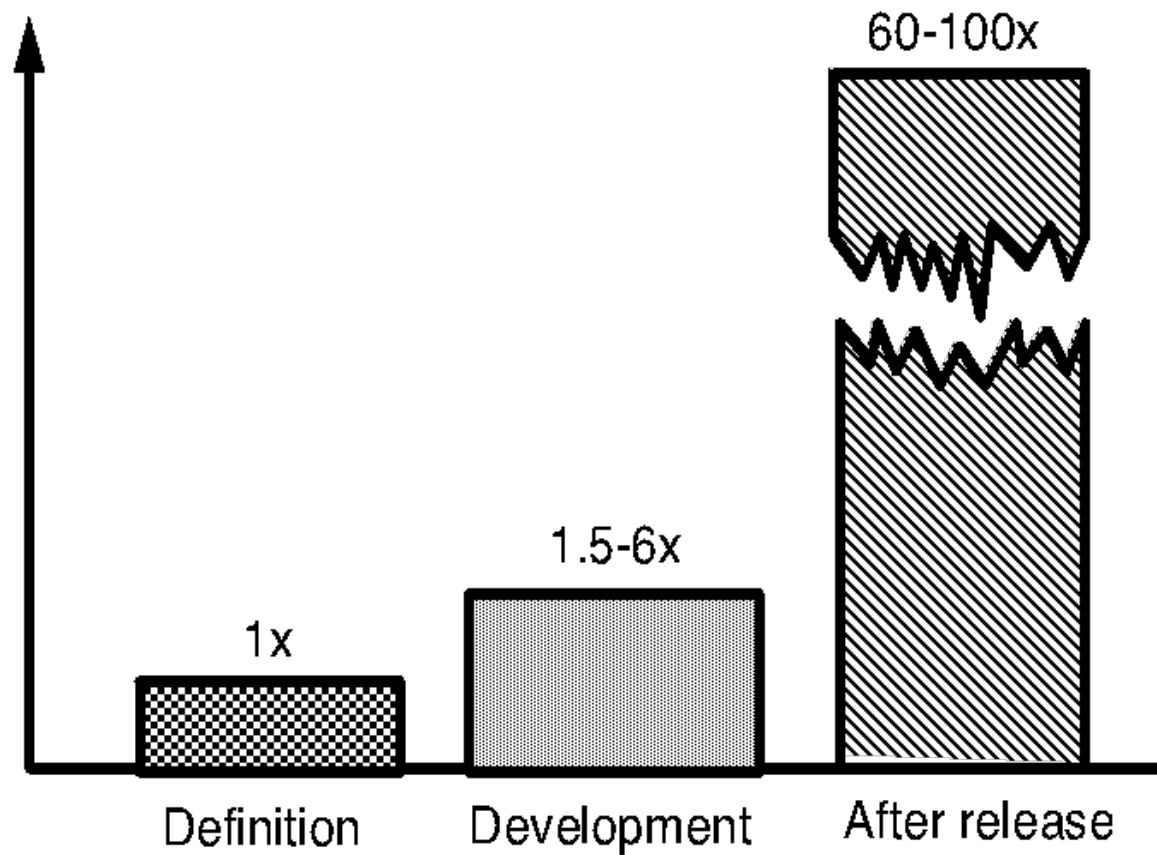


- Came from city crime researcher
- A broken window will trigger a building into a smashed and abandoned derelict
- So does the software
- Don't live with the Broken window



# The Cost of Change

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# How to Prevent Software from Rotting?

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- ◆ Applies OO design principles
- ◆ Uses design patterns
- ◆ Follows agile practices
- ◆ **Refactoring** will reduce the software entropy



# What is Refactoring?

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- ◆ “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” – [Fowler]
- ◆ “A behavior-preserving source-to-source program transformation” – [Roberts]
- ◆ “A change to the system that leaves its behavior unchanged, but enhances some non-functional quality - simplicity, flexibility, understandability” – [Beck]



# Refactor to Understand

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- ◆ The Obvious
  - ◆ Programs hard to read
    - ◆ Programs hard to understand
      - ◆ Programs hard to modify
  - ◆ Programs with duplicated logic are hard to understand
  - ◆ Programs with complex conditionals are hard to understand



# Refactor to Understand

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- ◆ Refactoring code creates and supports understanding
  - ◆ Renaming instance variables helps understanding methods
  - ◆ Renaming methods helps understanding responsibility
  - ◆ Iterations are necessary



# Typical Refactorings

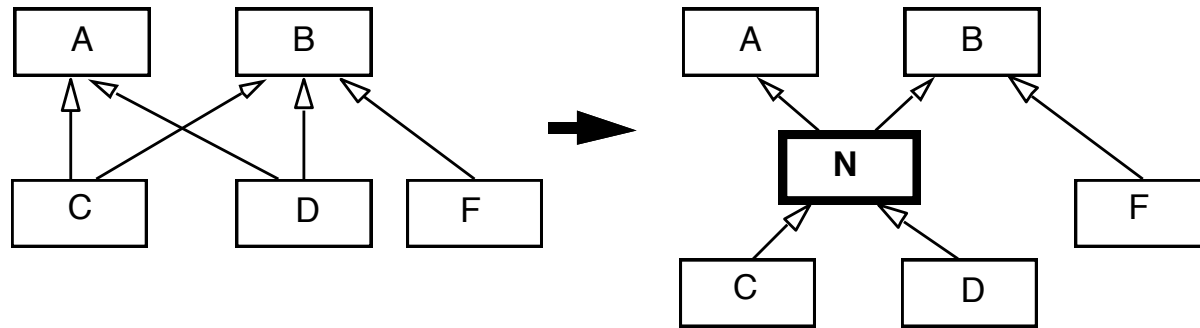
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Class Refactorings	Method Refactorings	Attribute Refactorings
add (sub)class to hierarchy	add method to class	add variable to class
rename class	rename method	rename variable
remove class	remove method	remove variable
	push method down	push variable down
	push method up	push variable up
	add parameter to method	create accessors
	move method to component	abstract variable
	extract code in new method	

These simple refactorings can be combined to provide bigger restructurings such as the introduction of design patterns

# Example: Add Class

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- ◆ Add Class (new name, package, superclasses, subclasses)
  - ◆ Preconditions
    - ◆ No class or global variable exists with new name in the same scope
    - ◆ Subclasses are all subclasses of all superclasses
  - ◆ Postconditions
    - ◆ New class is added into the hierarchy with superclasses as superclasses and subclasses as subclasses
    - ◆ New class has name new name
    - ◆ Subclasses inherit from new class and not anymore from superclasses

# Example: Rename Method

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- ◆ Rename Method (new name, method)
- ◆ Preconditions
  - ◆ No method exists with the signature implied by **new name** in the inheritance hierarchy that contains **method**
- ◆ Postconditions
  - ◆ **Method** has **new name**
  - ◆ Relevant methods in the inheritance hierarchy have **new name**
  - ◆ Invocations of changed method are updated to **new name**

# Rename Method: Manual Steps

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- ◆ Do it yourself approach
  - ◆ Check if a method does not exist in the class and superclass/subclasses with the same “name”
  - ◆ Browse all the implementers (method definitions)
  - ◆ Browse all the senders (method invocations)
  - ◆ Edit and rename all implementers
  - ◆ Edit and rename all senders
  - ◆ Remove all implementers
  - ◆ Test
- ◆ Automated refactoring is better!



# Refactoring Tools

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- ◆ Based on provable transformations
  - ◆ Build parse tree of programs
  - ◆ Research – mathematical proof that refactoring does not change semantics; graph transformation
  - ◆ Embed refactoring in tool
- ◆ Speeds up refactoring
  - ◆ Extract method: select code, type in method name
- ◆ In Eclipse for Java and other languages

```
void goOnVacation(){  
    Bike roadBike = getRoadBike();  
    Bike mountainBike = getMtnBike();  
    loadOnCar(roadBike, mountainBike);  
}
```

# Refactoring Tool Usage

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- ◆ “Refactoring Tools: Fitness for Purpose” [Murphy-Hill and Black]
  - ◆ Includes survey of 112 people at the Agile Open Northwest 2007
  - ◆ On average, when a refactoring tool is available for a refactoring that programmers want to perform, they choose to use the tool 68% of the time; the rest of the time they refactor by hand





# Typical Refactorings

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Class Refactorings	Method Refactorings	Attribute Refactorings
add (sub)class to hierarchy	add method to class	add variable to class
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	push method down	push variable down
	push method up	push variable up
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These simple refactorings can be combined to provide bigger restructurings such as the introduction of design patterns

# When to Apply Refactoring?

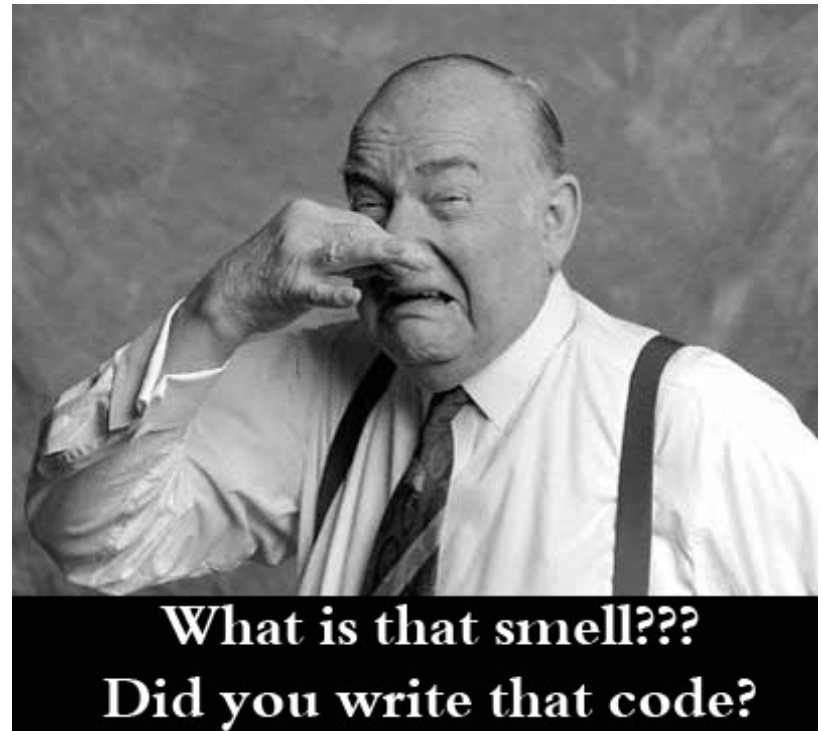
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# Bad Smells in Code

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- ◆ Duplicated code
- ◆ Long method
- ◆ Divergent change
- ◆ Shotgun surgery
- ◆ Data clumps
- ◆ Switch statements
- ◆ Lazy class
- ◆ Inappropriate intimacy



# Duplicated Code

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## ◆ “The #1 bad smell”

```
if (!delete(file)) {
    String message = "Unable to delete file "
        + file.getAbsolutePath();
    if (failonerror) {
        throw new BuildException(message);
    } else {
        log(message, quiet ? Project.MSG_VERBOSE
            : Project.MSG_WARN);
    }
}
```

```
if (!delete(f)) {
    String message = "Unable to delete file "
        + f.getAbsolutePath();
    if (failonerror) {
        throw new BuildException(message);
    } else {
        log(message, quiet ? Project.MSG_VERBOSE
            : Project.MSG_WARN);
    }
}
```

```
if (!delete(f)) {
    String message = "Unable to delete file "
        + f.getAbsolutePath();
    if (failonerror) {
        throw new BuildException(message);
    } else {
        log(message, quiet ? Project.MSG_VERBOSE
            : Project.MSG_WARN);
    }
}
```

```
if (!delete(dir)) {
    String message = "Unable to delete directory "
        + dir.getAbsolutePath();
    if (failonerror) {
        throw new BuildException(message);
    } else {
        log(message, quiet ? Project.MSG_VERBOSE
            : Project.MSG_WARN);
    }
}
```

# Duplicated Code

---

- ◆ Same expression in two methods in the same class?
  - ◆ Solution – make it a private ancillary routine and parameterize it (**Extract method**)
- ◆ Same code in two related classes?
  - ◆ Solution – push commonalities into closest mutual ancestor and parameterize (**Pull up method**)
- ◆ Same code in two unrelated classes?
  - ◆ Ought they be related?
    - ◆ Solution – introduce abstract parent (**Extract class, Pull up method**)
  - ◆ Does the code really belong to just one class?
    - ◆ Solution – make the other class into a client (**Extract method**)

# Not All Clones are Harmful

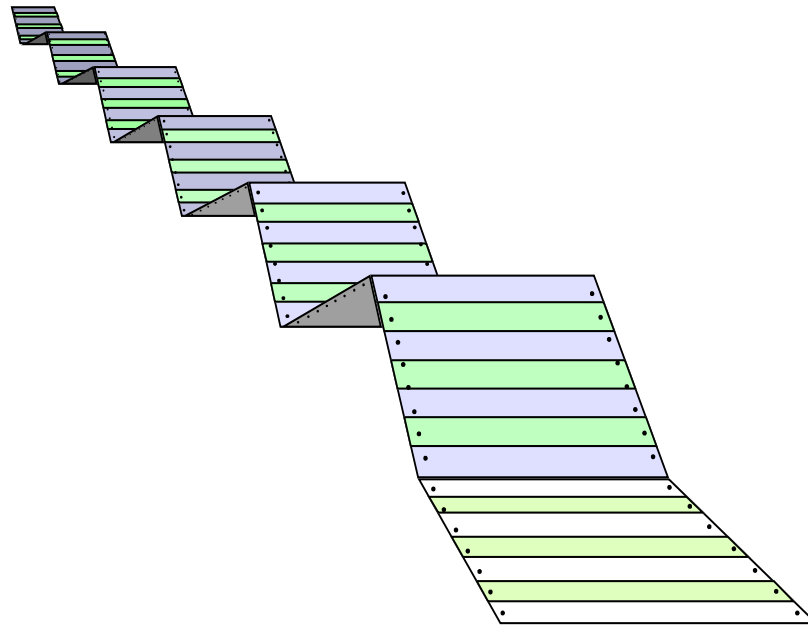
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- ◆ “‘ Clones Considered Harmful’ Considered Harmful” [Kapsler and Godfrey]
  - ◆ Forking – used to bootstrap development of similar solutions, with the expectation that evolution of the code will occur somewhat independently
  - ◆ Templating – directly copy behavior of existing code but appropriate abstraction mechanisms are unavailable
  - ◆ Customization – currently existing code does not adequately meet a new set of requirements

# Long Method

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- ◆ Often a sign of
  - ◆ Bad cohesion
  - ◆ Trying to do too many things
  - ◆ Poorly thought out abstractions and boundaries



# Long Method

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- ◆ Best to think carefully about the major tasks and how they inter-relate
  - ◆ Solution – break up into smaller private methods within the class (**Extract method**)
- ◆ Fowler's heuristic
  - ◆ When you see a comment, make a method
  - ◆ Often, a comment indicates
    - ◆ The next major step
    - ◆ Something non-obvious whose details detract from the clarity of the routine as a whole.
  - ◆ In either case, this is a good spot to “break it up”



# Divergent Change

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- ◆ If, over time, you make changes to a class that touch completely different parts of the class
  - ◆ Likely, this class is trying to do too much and contains too many unrelated subparts
- ◆ Over time, some classes develop a “God complex”
  - ◆ They acquire details/ownership of subparts that rightly belong elsewhere
- ◆ This is a sign of poor cohesion
  - ◆ Unrelated elements in the same container
- ◆ Solution – break it up, reshuffle, reconsider relationships and responsibilities (**Extract class**)

# Shotgun Surgery

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- ◆ ... the opposite of divergent change
  - ◆ Each time you want to make a single, seemingly coherent change, you have to change lots of classes in little ways
- ◆ Also a classic sign of poor cohesion
  - ◆ Related elements are not in the same container!
- ◆ Solution – look to do some gathering, either in a new or existing class (**Move method/field**)



# Data Clumps

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- ◆ You see a set of variables that seem to “hang out” together
  - ◆ e.g., passed as parameters, changed/accessed at the same time
- ◆ Usually, this means that there’s a coherent subobject just waiting to be recognized and encapsulated

```
void Scene::setTitle (string titleText,  
                    int titleX, int titleY,  
                    colour titleColour){...}
```

```
void Scene::getTitle (string& titleText,  
                    int& titleX, int& titleY,  
                    colour& titleColour){...}
```

# Data Clumps

---

- ◆ In the example, a Title class is dying to be born
- ◆ If a client knows how to change a title's x, y, text, and colour, then it knows enough to be able to “roll its own” Title objects
  - ◆ However, this does mean that the client now has to talk to another class
- ◆ This will greatly shorten and simplify your parameter lists (which aids understanding) and makes your class conceptually simpler too.

# Switch Statements

---

```
Double getSpeed () {
    switch (_type) {
        case EUROPEAN:
            return getBaseSpeed();
        case AFRICAN:
            return getBaseSpeed() -
                getLoadFactor() * _numCoconuts;
        case NORWEGIAN_BLUE:
            return (_isNailed) ? 0
                : getBaseSpeed(_voltage);
    }
}
```

# Switch Statements

---

- ◆ This is an example of a lack of understanding polymorphism and a lack of encapsulation
- ◆ Solution – redesign as a polymorphic method in a hierarchy (**Replace conditional with polymorphism, replace type code with subclasses**)

# Lazy Class

---

- ◆ Classes should pull their weight
  - ◆ Every additional class increases the complexity of a project
  - ◆ If you have a class that isn't doing enough to pay for itself, can it be collapsed or combined into another class?
- ◆ If there are several sibling classes that don't exhibit polymorphic behavioural differences, then consider just collapsing them back into the parent and add some parameters
- ◆ Often, lazy classes are legacies of ambitious design or a refactoring that gutted the class of interesting behaviour
- ◆ Solution – (**Collapse hierarchy, Inline class**)

# Inappropriate Intimacy

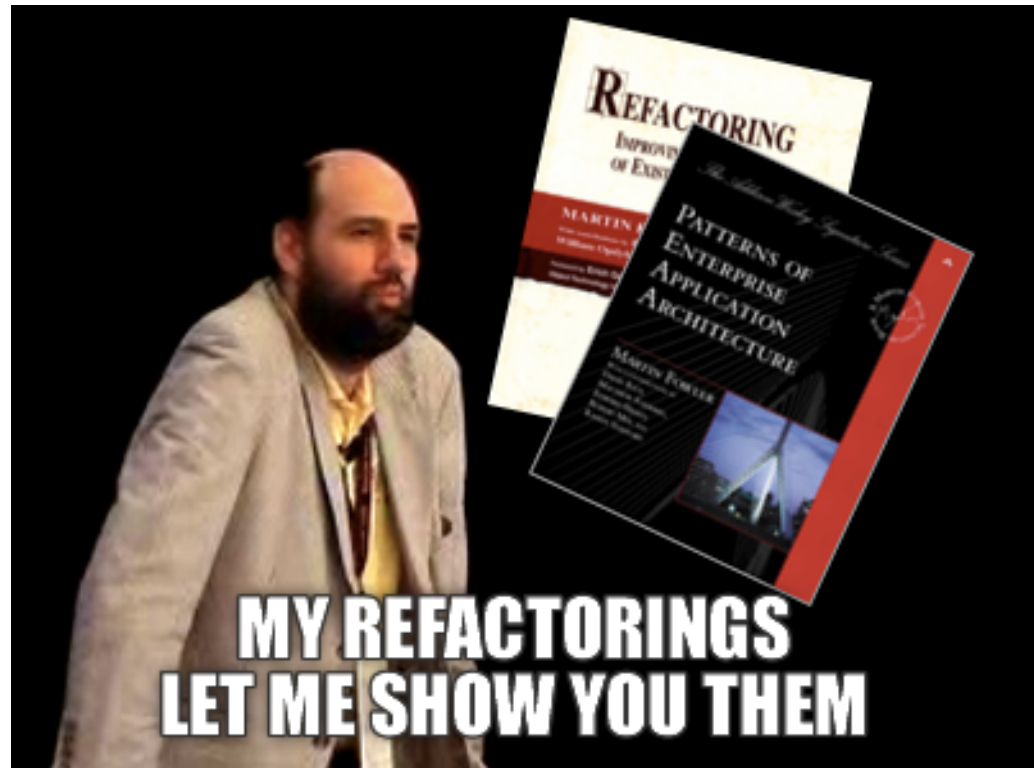
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- ◆ Sharing of secrets between classes
  - ◆ e.g., public variables, indiscriminate definitions of get/set methods
- ◆ Leads to data coupling, intimate knowledge of internal structures and implementation decisions
- ◆ Solution
  - ◆ Appropriate use of get/set methods
  - ◆ Rethink basic abstraction
  - ◆ Merge classes if you discover “true love”
  - ◆ (Move/extract method/field, Change bidirectional association to unidirectional, Hide delegate)



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# Case Study – from Martin Fowler



# Sample Output

---

```
Rental Record for Dinsdale Pirhana
Monty Python and the Holy Grail    3.5
Ran                                  2
Star Trek 27                        6
Star Wars 3.2                       3
wallace and Gromit                  6
Amount owed is 20.5
You earned 6 frequent renter points
```

# Class Movie

---

```
public class Movie {
    public static final int CHILDRENS = 2;
    public static final int REGULAR = 0;
    public static final int NEW_RELEASE = 1;

    private String title;
    private int priceCode;

    public Movie(String _title, int _priceCode) {
        title = _title;
        priceCode = _priceCode;
    }

    public int getPriceCode() {
        return priceCode;
    }

    public void setPriceCode(int arg) {
        priceCode = arg;
    }

    public String getTitle () {
        return title;
    }
}
```

# Class Rental

---

```
public class Rental {
    private Movie movie;
    private int daysRented;

    public Rental(Movie _movie, int _daysRented) {
        movie = _movie;
        daysRented = _daysRented;
    }

    public int getDaysRented() {
        return daysRented;
    }

    public Movie getMovie() {
        return movie;
    }
}
```

# Class Customer

---

```
public class Customer {
    private String name;
    private Vector rentals = new Vector();

    public Customer (String _name) {
        name = _name;
    }

    public void addRental(Rental arg) {
        rentals.addElement(arg);
    }

    public String getName ()    {
        return _name;
    }

    // see next slide
    ...
}
```

# Class Customer (continued)

---

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

        //determine amounts for each line
        double thisAmount = 0;
        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;
        }

        result += "\t" + each.getMovie().getTitle() + "\t" + each.getDaysRented() + "\t" + thisAmount + "\n";
        totalAmount += thisAmount;
        frequentRenterPoints++;
    }

    // see next slide
    ...
}
```

# Class Customer (continued)

---

```
// add frequent renter points
frequentRenterPoints ++;

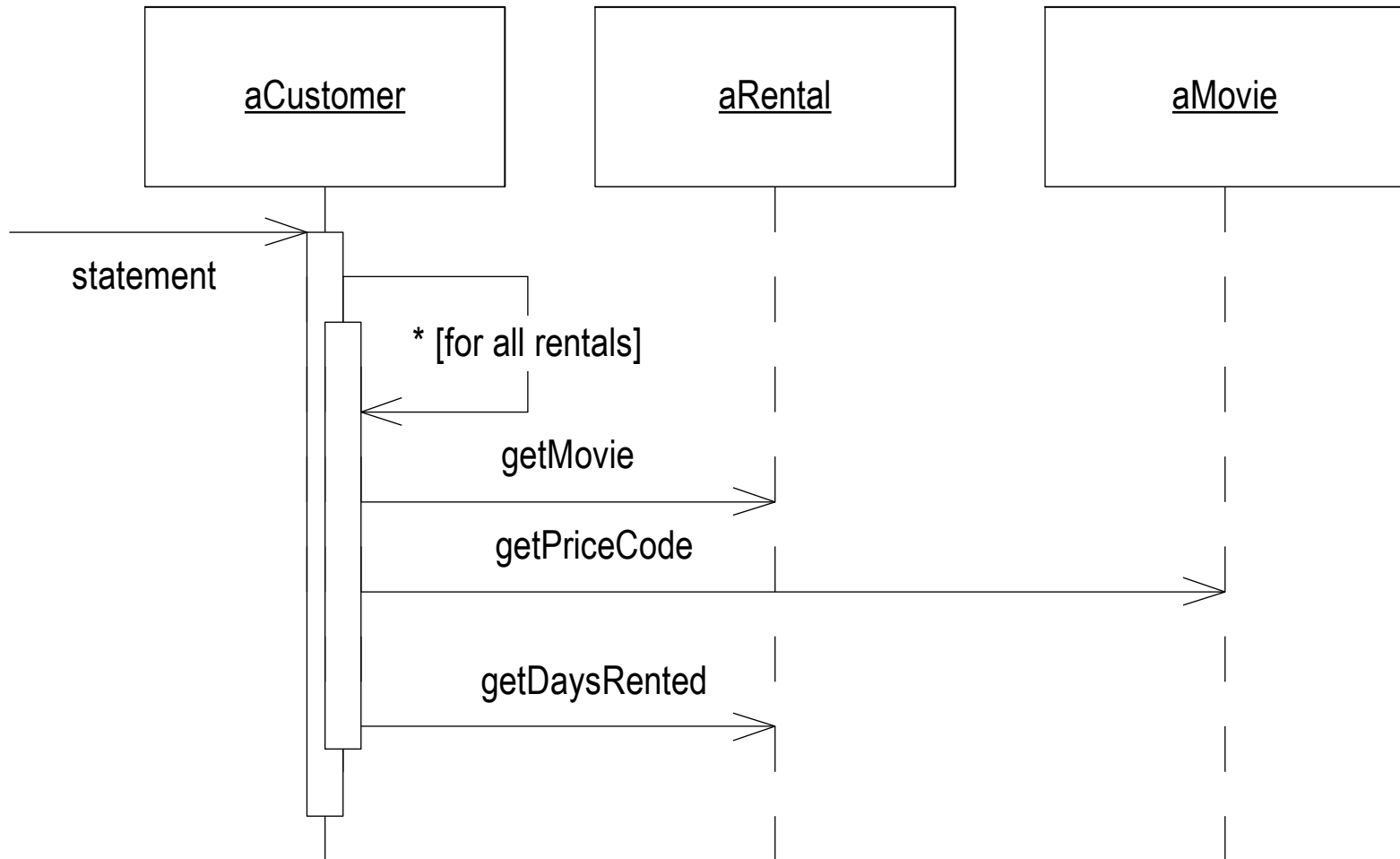
// add bonus for a two day new release rental
if ((each.getMovie().getPriceCode() == Movie.NEW_RELEASE) &&
    each.getDaysRented() > 1) frequentRenterPoints ++;

//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;
}
```

# Interactions for Method statement

---





# Steps for Extract Method

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- ◆ Create method named after intention of code
- ◆ Copy extracted code
- ◆ Look for local variables and parameters
  - ◆ Turn into parameter
  - ◆ Turn into return value
  - ◆ Declare within method
- ◆ Compile
- ◆ Replace code fragment with call to new method
- ◆ Compile and test

# Candidate Extraction

---

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

        //determine amounts for each line
        double thisAmount = 0;
        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;
        }
    }
}
```

# Extracting the Amount Calculation

---

```
private double amountFor(Rental each) {
    double thisAmount = 0;
    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;
    }
    return thisAmount;
}
```

# Method statement After Extraction

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

        thisAmount = amountFor(each);

        // add frequent renter points
        frequentRenterPoints ++;

        // add bonus for a two day new release rental
        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;
}
```

# Extracting the Amount Calculation

---

- ◆ Is this important?
- ◆ Is this method in the right place?

```
private double amountFor(Rental each) {
    double thisAmount = 0;
    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;
    }
    return thisAmount;
}
```

# Change Names of Variables

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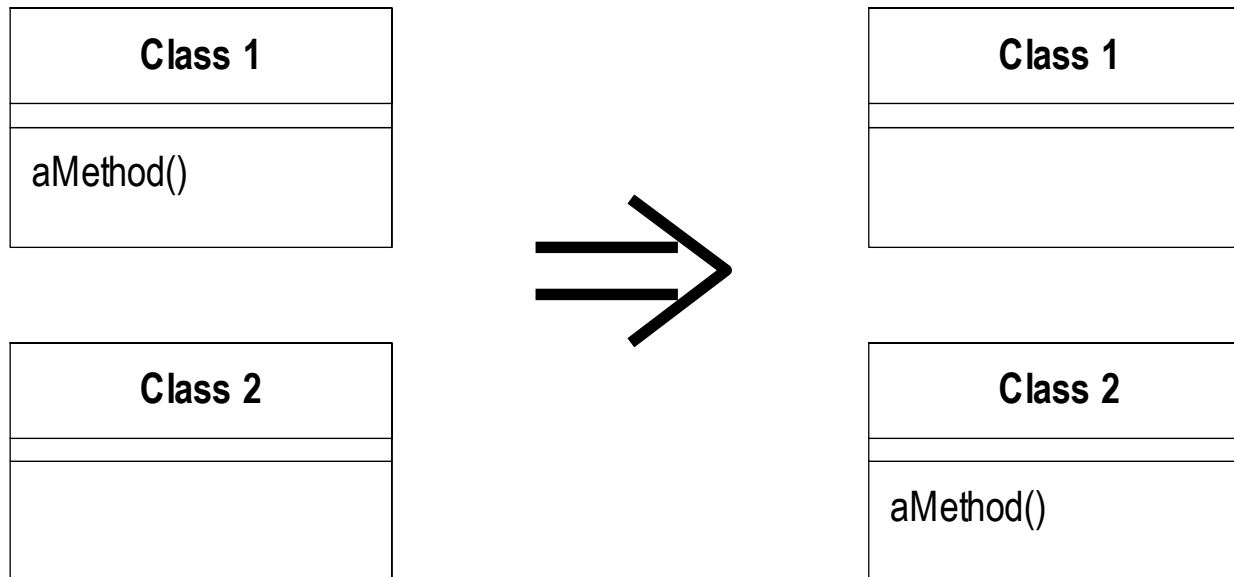
- ◆ Should this method really be in the Customer class?

```
private double amountFor(Rental aRental) {
    double result = 0;
    switch (aRental.getMovie().getPriceCode()) {
        case Movie.REGULAR:
            result += 2;
            if (aRental.getDaysRented() > 2)
                result += (aRental.getDaysRented() - 2) * 1.5;
            break;
        case Movie.NEW_RELEASE:
            result += aRental.getDaysRented() * 3;
            break;
        case Movie.CHILDRENS:
            result += 1.5;
            if (aRental.getDaysRented() > 3)
                result += (aRental.getDaysRented() - 3) * 1.5;
            break;
    }
    return result;
}
```

# Move Method

---

- ◆ A method is, or will be, using or used by more features of another class than the class it is defined on
- ◆ Create a new method with a similar body in the class it uses most
- ◆ Either turn the old method into a simple delegation, or remove it altogether



# Steps for Move method

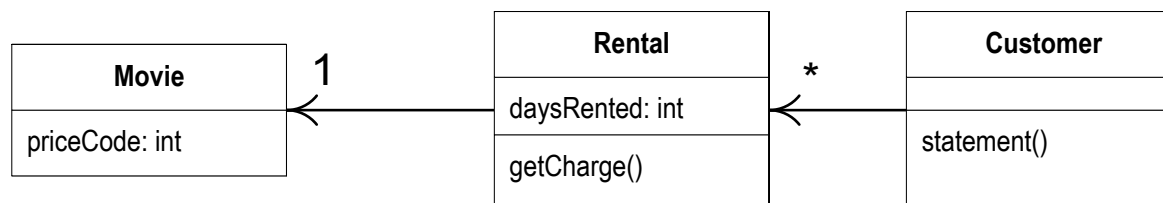
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- ◆ Declare method in target class
- ◆ Copy and fit code
- ◆ Set up a reference from the source object to the target
- ◆ Turn the original method into a delegating method
  - ◆ `amountFor(Rental aRental) {return aRental.getCharge();}`
  - ◆ Check for overriding methods
- ◆ Compile and test
- ◆ Find all users of the method
  - ◆ Adjust them to call method on target
- ◆ Remove original method
- ◆ Compile and test



# Moving Method amount to Rental

```
public class Rental {  
    ...  
    public double getCharge() {  
        double result = 0;  
        switch (getMovie().getPriceCode()) {  
            case Movie.REGULAR:  
                result += 2;  
                if (getDaysRented() > 2)  
                    result += (getDaysRented() - 2) * 1.5;  
                break;  
            case Movie.NEW_RELEASE:  
                result += getDaysRented() * 3;  
                break;  
            case Movie.CHILDRENS:  
                result += 1.5;  
                if (getDaysRented() > 3)  
                    result += (getDaysRented() - 3) * 1.5;  
                break;  
        }  
        return result;  
    }  
}
```



# Altered statement

---

```
public String statement() {
    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();

        thisAmount = each.getCharge();

        // add frequent renter points
        frequentRenterPoints ++;
        // add bonus for a two day new release rental
        if ((each.getMovie().getPriceCode() == Movie.NEW_RELEASE) &&
            each.getDaysRented() > 1) frequentRenterPoints ++;

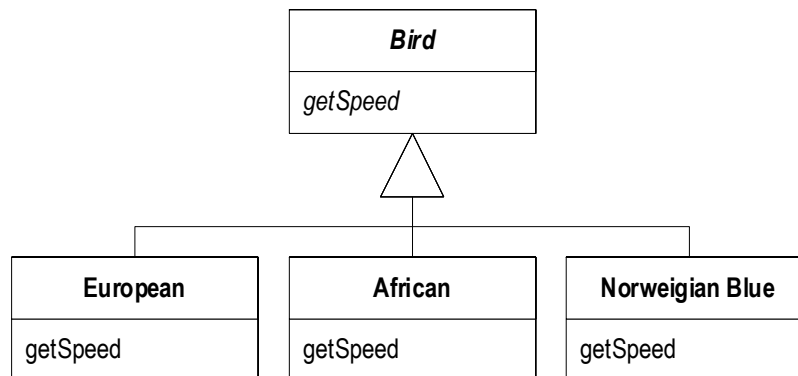
        //show figures for this rental
        result += "\t" + each.getMovie().getTitle() + "\t" + String.valueOf(thisAmount) + "\n";
        totalAmount += thisAmount;
    }

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

# Replace Conditional With Polymorphism

You have a conditional that chooses different behavior depending on the type of an object  
*Move each leg of the conditional to an overriding method in a subclass*  
*Make the original method abstract*

```
double getSpeed() {  
    switch (_type) {  
        case EUROPEAN  
            return getBaseSpeed();  
        case AFRICAN:  
            return getBaseSpeed() - getLoadFactor() * _numberOfCoconuts;  
        case NORWEGIAN_BLUE:  
            return (_isNailed) ? 0 : getBaseSpeed(_velocity);  
    }  
    throw new RuntimeException("Should be unreachable");  
}
```



## Steps for Replace Conditional with Polymorphism

---

- ◆ Move switch to superclass of inheritance structure
- ◆ Copy one leg of case statement into subclass
- ◆ Compile and test
- ◆ Repeat for all other legs
- ◆ Replace case statement with abstract method

# Move getCharge to Price

---

```
public class Movie...
    public double getCharge(int daysRented) {
        return _price.getCharge(daysRented);
    }

public class Price...
    public double getCharge(int daysRented) {
        double result = 0;
        switch (getPriceCode()) {
            case Movie.REGULAR:
                result += 2;
                if (daysRented > 2)
                    result += (daysRented - 2) * 1.5;
                break;
            case Movie.NEW_RELEASE:
                result += daysRented * 3;
                break;
            case Movie.CHILDRENS:
                result += 1.5;
                if (daysRented > 3)
                    result += (daysRented - 3) * 1.5;
                break;
        }
        return result;
    }
}
```

# Override getCharge in the subclasses

---

```
Class Price...  
abstract public double getCharge(int daysRented);
```

```
Class RegularPrice...  
public double getCharge(int daysRented){  
    double result = 2;  
    if (daysRented > 2)  
        result += (daysRented - 2) * 1.5;  
    return result;  
}
```

```
Class ChildrensPrice...  
public double getCharge(int daysRented){  
    double result = 1.5;  
    if (daysRented > 3)  
        result += (daysRented - 3) * 1.5;  
    return result;  
}
```

```
Class NewReleasePrice...  
public double getCharge(int daysRented){  
    return daysRented * 3;  
}
```

Do each leg one at a time then...

# Obstacles to Refactoring

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- ✘ Complexity
  - ◆ Changing design is hard
  - ◆ Understanding code is hard
- ✘ Possibility to introduce errors
  - ◆ Run tests if possible
  - ◆ Build tests
- ✘ Clean first, then add new functionality
- ✘ Cultural Issues
  - ◆ Producing negative lines of code, what an idea!
  - ◆ “We pay you to add new features, not to improve the code!”
- ✘ If it ain’ t broke, don’ t fix it
  - ◆ “We do not have a problem, this is our software!”

# Obstacles to Refactoring

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- ◆ Performance
  - ◆ Refactoring may slow down the execution
  - ◆ The secret to writing fast software
    - ◆ “Write tunable software first then tune it”
    - ◆ Typically only 10% of your system consumes 90% of the resources so just focus on 10 %
  - ◆ Refactorings help to localize the part that need change
  - ◆ Refactorings help to concentrate the optimizations
- ◆ Development is always under time pressure
  - ◆ Refactoring takes time
  - ◆ Refactoring better right after a software release



# Conclusion: Know-when & Know-how

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- ◆ “Know when” is as important as “know-how”
- ◆ Use “code smells” as symptoms
- ◆ Rule of the thumb
  - ◆ “Once and Only Once” (Kent Beck)
    - ◆ A thing stated more than once implies refactoring