2IS55 Software Evolution

Implementing evolution: Refactoring

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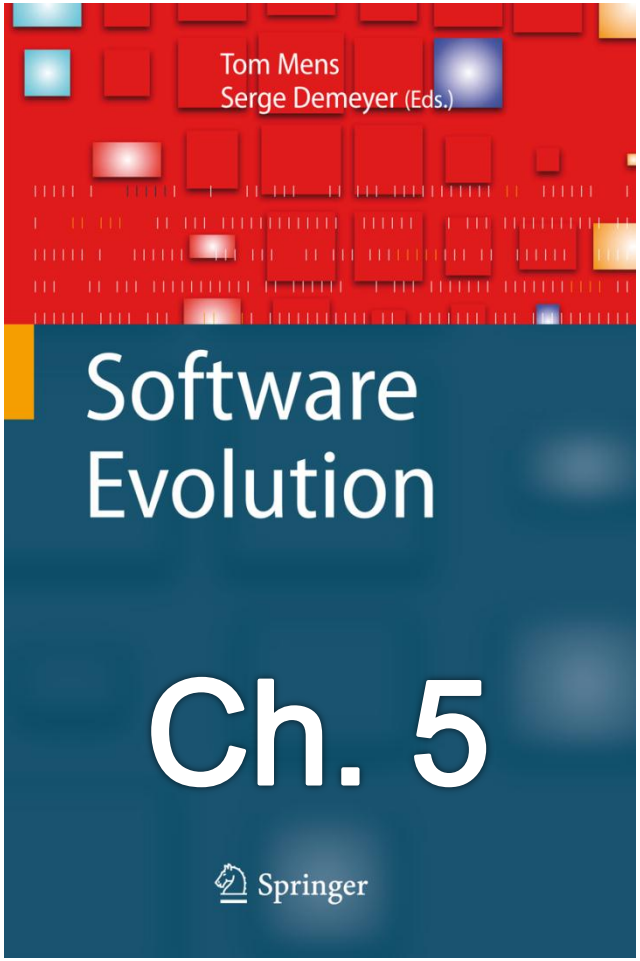
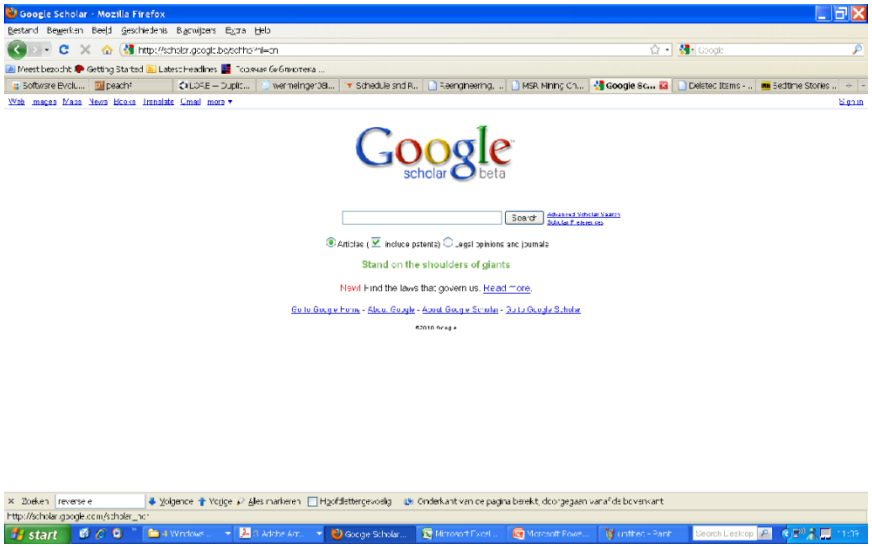
Where innovation starts

Sources


Tom Mens
Serge Demeyer (Eds.)
Software Evolution
Ch. 5
Springer


Google Scholar - Mozilla Firefox
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Stand on the shoulders of giants

Last week

- **How to implement evolution**
  - **Last week: evolution strategies and decision making**
  - **Today: refactoring**

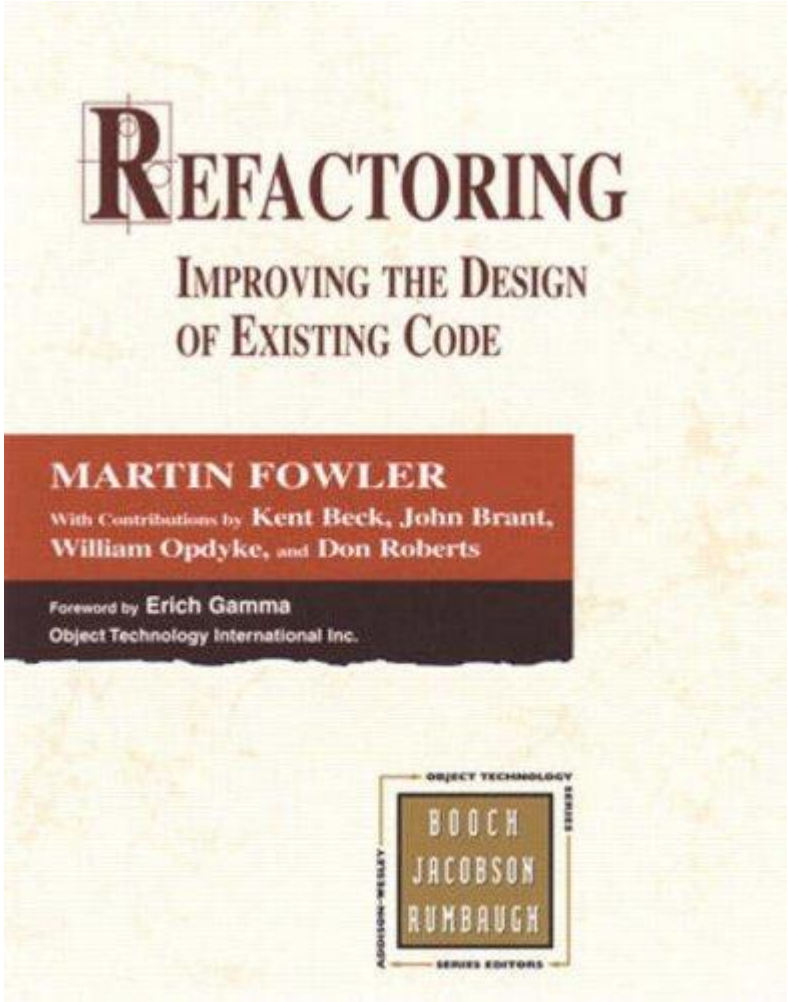
Problem: changing code is difficult

- **Correct code can be far from perfect:**
  - **Bad structure**
  - **Code duplication**
  - **Bad coding practices**
  - **…**

- **We need to change it**
  - **Undisciplined code modification may introduce bugs**
  - **… and does not guarantee that the code will actually be improved!**
  - **Manual work, not clear how to support it beyond "copy/paste" and "replace all"**

Refactoring

- **Refactoring – a disciplined technique for restructuring code, altering its internal structure without changing its external behavior.**
- **External behavior not changed**
  - **New bugs are not introduced**
  - **Old ones are not resolved!**
- **Aims at improving**
  - **maintainability, performance**



Examples of refactorings

- **Extract method**
  - **If similar series or steps are repeatedly executed, create a separate method**
- **Rename method**
  - **If the method's name no longer corresponds to its purpose/behaviour, rename the method**
- **Pull up**
  - **Move the functionality common to all subclasses to the/a superclass**
- **Push down**
  - **If the functionality is needed only in some subclasses move it to the subclass**

Refactoring catalogue [Fowler]: Example

- **Name: Inline Temp**
- **Applicability:**
  - **A temp is assigned to once with a simple expression, and it is getting in the way of other refactorings.**
  - **Replace all references with the expression**
- **Motivation: simplifies other refactorings, e.g., Extract Method**
- **Steps (Java):**
  - **Declare the temp as final, and compile**
  - **Find references to the temp and replace them**
  - **Compile and test after each change**
  - **Remove the declaration and the assignment of the temp**
  - **Compile and test**

Why would you declare the temp as final?

How many refactorings are there?

Author	Year	Language	Number
Fowler book and website	2000	Java	93
Thompson et al. website		Haskell	20 * 3 categories
Garrido	2000	C	29
Serebrenik, Schrijvers, Demoen	2008	Prolog	21
Fields et al.	2009	Ruby	>70

- One has to organize refactorings by categories
- We will discuss some of the refactorings in more detail!

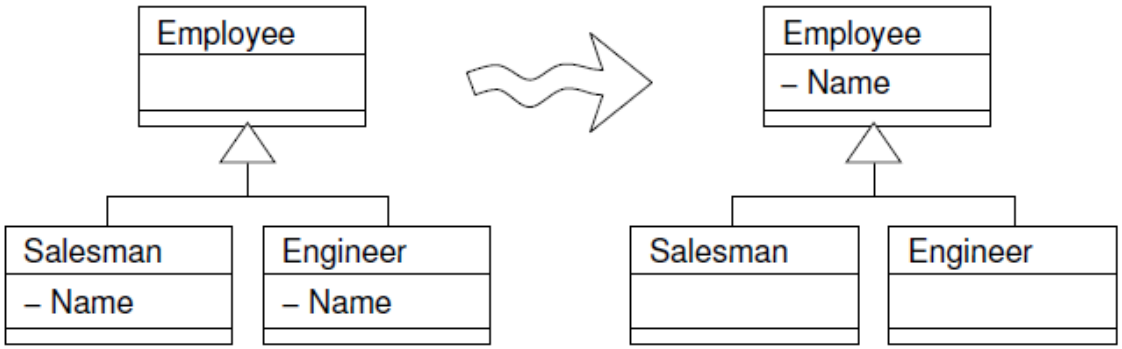
Categories of refactorings [Fowler]

- **Composing methods (extract method, inline temp)**
- **Moving features between objects (move field, remove middle man)**
- **Organizing data (change value to reference)**
- **Simplifying conditional expressions**
- **Making method calls simpler (rename method)**
- **Dealing with generalization (pull up field)**

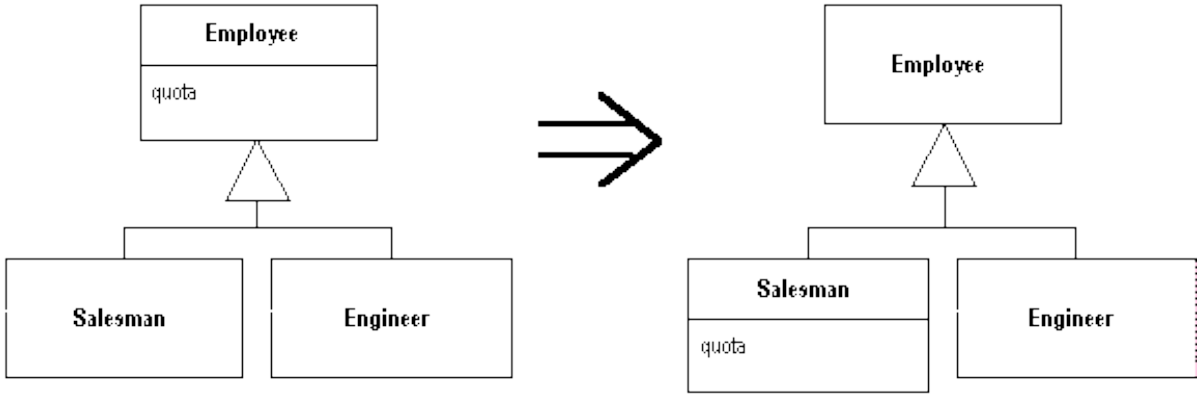
- **Big refactorings (separate domain from presentation)**

Closer look: Pull Up Field / Push Down Field

Pull Up



Push Down



- **When would you use each one of the refactorings?**
  - **Pull Up: field is common to all subclasses**
  - **Push Down: field is used only in some subclasses**

Pull Up: Seems simple…

- Inspect all uses of the candidate fields
  - Ensure they are used in the same way.
- If the fields do not have the same name, rename
  - The candidate fields should have the name you want to use for the superclass field.
- Compile and test.
- Create a new field in the superclass.
- If the fields are private, protect the superclass field
  - The subclasses should be able to refer to it.
- Delete the subclass fields.
- Compile and test.
- Consider using Self Encapsulate Field on the new field.

Another example: Extract method: Without parameters

```
static Order order;
static char name[ ];
void printOwing ( ) {
    Enumeration e = elements (order) ;
    double outst = 0.0 ;
    // print banner
    printf ( " ********************* \n" ) ;
    printf ( " Customer Owes      \n" ) ;
    printf ( " ********************* \n" ) ;
    // calculate outstanding
    while ( hasMoreElements ( e ) ) {
        Order each = nextElement (e) ;
        outst += getAmount ( each ) ;
    }
    // print details
    printf ( "name %s \n" , name ) ;
    printf ( "amount %s \n" , outst) ;
}
```

```
static Order order;
static char name[ ];
// print banner
void printBanner() {
    printf ( " ********************* \n" ) ;
    printf ( " Customer Owes      \n" ) ;
    printf ( " ********************* \n" ) ;
}
void printOwing ( ) {
    Enumeration e = elements (order) ;
    double outst = 0.0 ;
    printBanner();
    // calculate outstanding
    while ( hasMoreElements ( e ) ) {
        Order each = nextElement (e) ;
        outst += getAmount ( each ) ;
    }
    // print details
    printf ( "name %s \n" , name ) ;
    printf ( "amount %s \n" , outst ) ;
}
```

Extract method: With input parameters

```
static Order order;
static char name[ ];
// print banner
void printBanner() {
    printf ( " ********************** \n" ) ;
    printf ( " Customer Owes      \n" ) ;
    printf ( " ********************** \n" ) ;
}
void printOwing ( ) {
    Enumeration e = elements (order) ;
    double outst = 0.0 ;
    printBanner();
    // calculate outstanding
    while ( hasMoreElements ( e ) ) {
        Order each = nextElement (e) ;
        outst += getAmount ( each ) ;
    }
    // print details
    printf ( "name %s \n" , name ) ;
    printf ( "amount %s \n" , outst ) ;
}
```

```
static Order order;
static char name[ ];
// print banner
...
// print details
void printDetails(double outst) {
    printf ( "name %s \n" , name ) ;
    printf ( "amount %s \n" , outst ) ;
}
void printOwing ( ) {
    Enumeration e = elements (order) ;
    double outst = 0.0 ;
    printBanner();
    // calculate outstanding
    while ( hasMoreElements ( e ) ) {
        Order each = nextElement (e) ;
        outst += getAmount ( each ) ;
    }
    printDetails(outst);
}
```

Extract method: With output parameters

```
static Order order;
static char name[ ];
// print banner
…
// print details
void printDetails(double outst) {
      printf ( "name %s \n" , name ) ;
      printf ( "amount %s \n" , outst ) ;
}
void printOwing ( ) {
      Enumeration e = elements (order) ;
      double outst = 0.0 ;
      printBanner();
      // calculate outstanding
      while ( hasMoreElements ( e ) ) {
            Order each = nextElement (e) ;
            outst += getAmount ( each ) ;
      }
      printDetails(outst);
}
```

```
static Order order;
static char name[ ];
// print banner
…
// print details
…
// calculate outstanding
double getOutst(Enumeration e,
                double outst) {
      while ( hasMoreElements ( e ) ) {
            Order each = nextElement (e)
            outst += getAmount ( each ) ;
      }
      return outst;
}
void printOwing ( ) {
      Enumeration e = elements (order) ;
      double outst = 0.0 ;
      printBanner();
      outst = getOutst(e, outst) ;
      printDetails(outst);
}
```

Extract method: Further simplification

```
static Order order;
static char name[ ];
// print banner
…
// print details
…
// calculate outstanding
double getOutst(Enumeration e,
                double outst) {
    while ( hasMoreElements ( e ) ) {
        Order each = nextElement (e) ;
        outst += getAmount ( each ) ;
    }
    return outst;
}
void printOwing ( ) {
    Enumeration e = elements (order) ;
    double outst = 0.0 ;
    printBanner();
    outst = getOutst(e, outst) ;
    printDetails(outst);
}
```

```
static Order order;
static char name[ ];
// print banner
…
// print details
…
// calculate outstanding
double getOutst() {
    Enumeration e = elements (order) ;
    double outst = 0.0 ;
    while ( hasMoreElements ( e ) ) {
        Order each = nextElement (e) ;
        outst += getAmount ( each ) ;
    }
    return outst;
}
void printOwing ( ) {
    printBanner();
    printDetails(getOutst());
}
```

But is the new program really better than the old one?

- **Assume that we want to improve maintainability**

Metrics	Old	New
LOC	18	26
Comments	3	3
Ave McCabe	2	5/4
Halstead volume	156	226
Maintainability index	57	77
	Difficult to maintain	Average maintainability

The refactoring process

- **Select the maintainability metrics**
  - **Recall: Goal – Question – Metrics!**

- **Refactoring loop**
  - **Calculate maintainability metrics**
  - **Identify a problem: "bad smell"**
  - **Check that the refactoring is applicable**
  - **Refactor**
  - **Compile and test**
    - **Recall: "*without changing its external behavior*"**
  - **Recalculate the maintainability metrics**

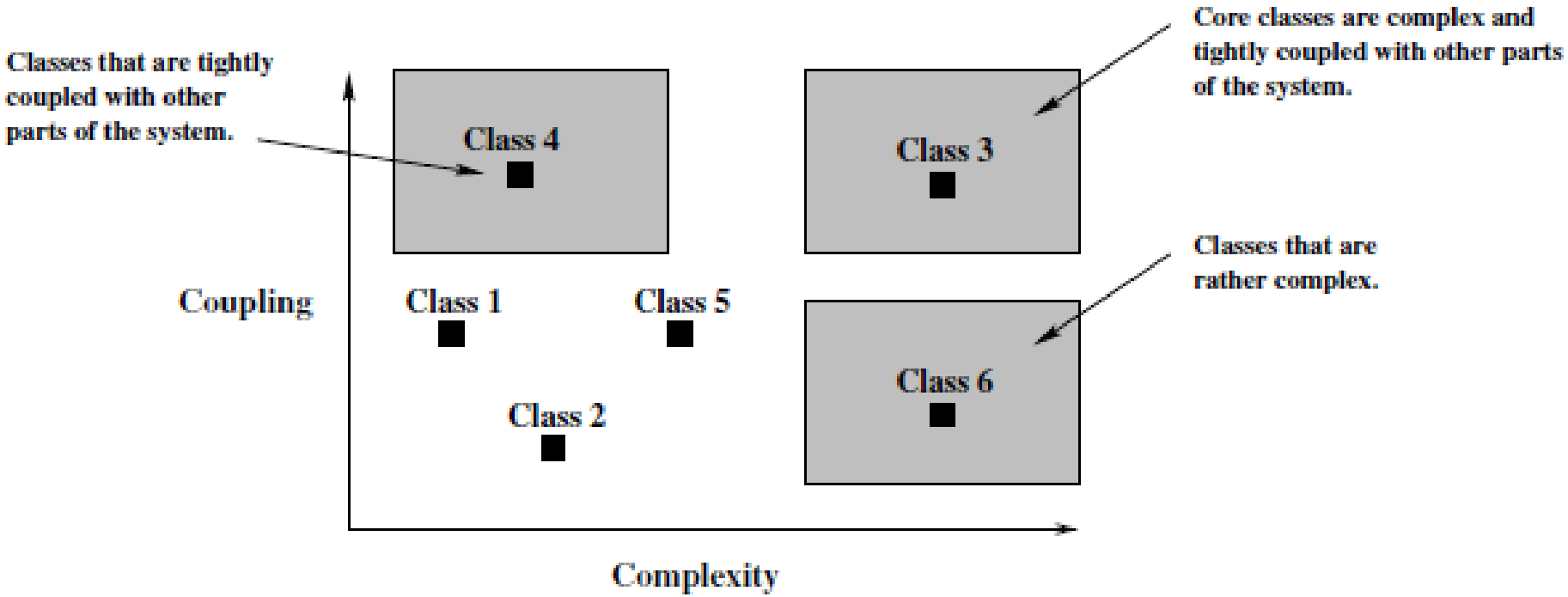
How to identify bad smells?

- **Software metrics**
  - **Size: Large class, large method, long parameter list**
  - **Dependencies: feature envy, inappropriate intimacy**
  - **% comments: comments**

- **Code duplication**

- **Changes (based on version control)**
  - **Divergent change (one class is changed in different ways for different reasons)**
  - **Shotgun surgery (many small changes)**
    - **Parallel inheritance hierarchies**

[Tahvildari and Kontogiannis]



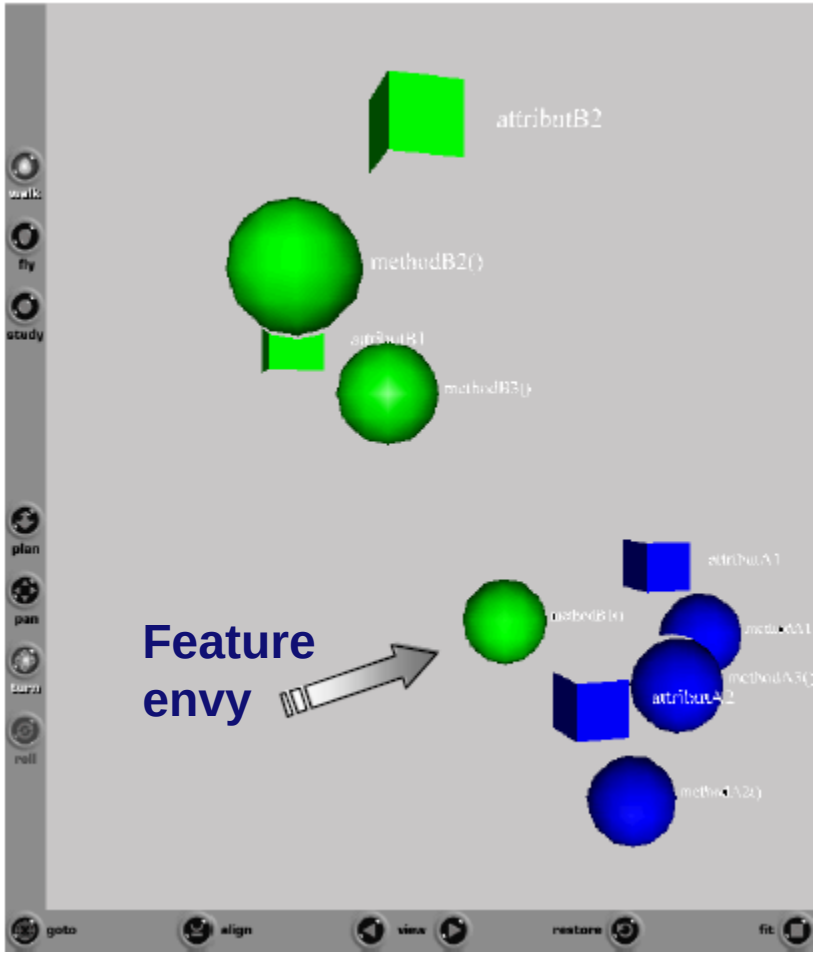
- **Start with complex and tightly coupled classes**

Feature envy [Simon, Steinbrückner, Lewerentz]

- Fields – boxes, methods – balls
- Green – Class A, blue – Class B
- Distance

$$1-\frac{|p(X)\cap p(Y)|}{|p(X)\cup p(Y)|}$$

- p(X) – properties of X
  - Method: the method, methods called and fields used
  - Field: the field and methods that use it



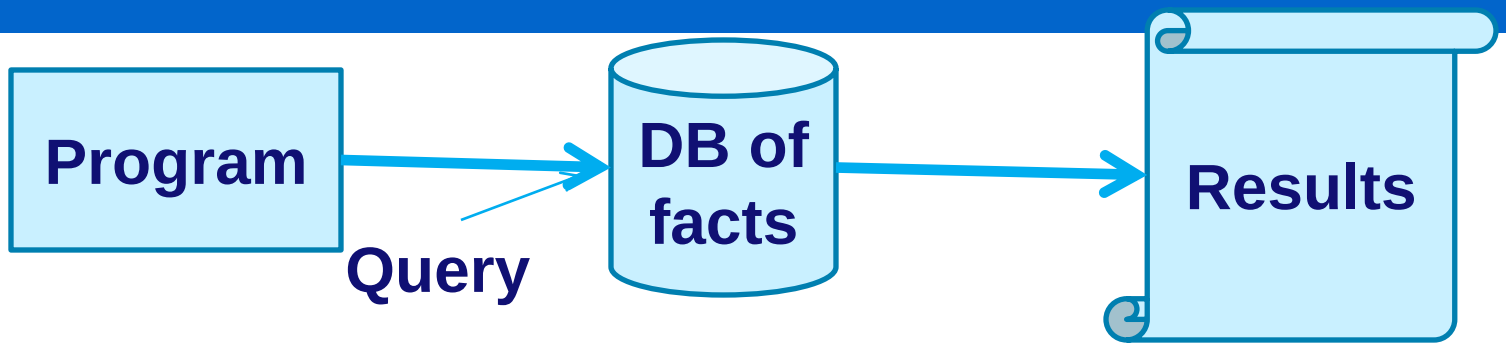
How to identify bad smells?

- **Structural problems: obsolete parameters, inappropriate interfaces, …**

- **Parameter p of C.m is obsolete if**
  - **Neither C.m itself uses p**
  - **Nor any of the classes inheriting from C and reimplementing m uses p**

- **Naïve approach: check all parameters of all methods of all classes**
  - **Not feasible**
  - **Better ideas?**

Querying the structure [Tourwe, Mens]

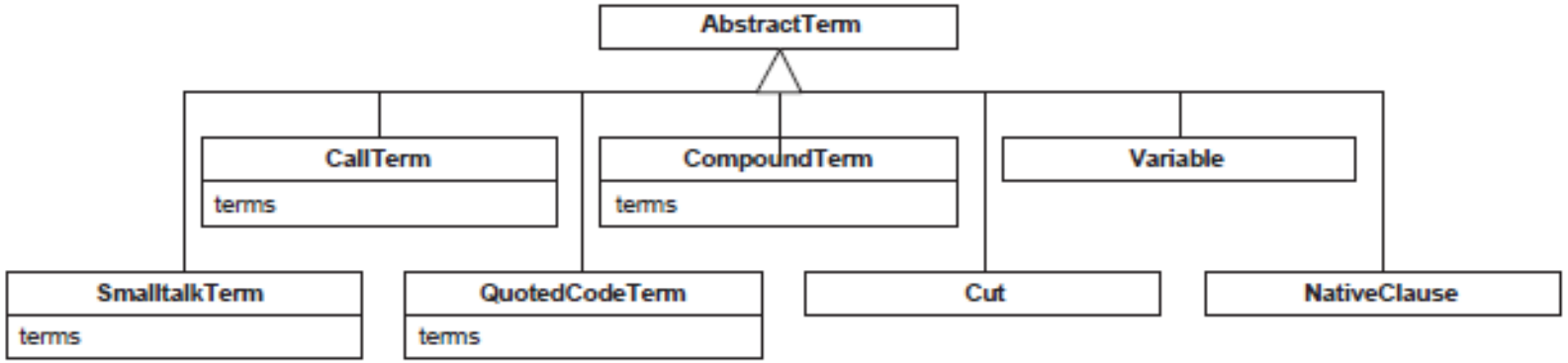


- **Query (a la Datalog):**

```
obsolete(Class,Method,Parameter):-
    classImplements(Class,Method),
    parameterOf(Class,Method,Parameter),
    forall(subclassImplements(Class,Method,Subclass),
            not(methodUsesParameter(Subclass,Method,Parameter)))
```

- **Advantage:**
  - **Once the DB is populated one can look for different smells**

Another example: Inappropriate interface



- **AbstractTerm cannot be easily extended**
  - **not clear which subclass should implement terms**
- **Query**

```
commonSubclInt(Class,Int,Subcs) :-
    classInterface(Class,ClassInt),
    allSubclasses(Class,SubcList),
    sharedInterface(SubcList,commonInt,Subcs),
    difference(commonInt,ClassInt,Int)
```

How to chose appropriate refactorings?

Bad smell	Refactoring
Comments	Extract method Introduce assertion
Duplicated code	Extract method Extract class Pull Up method Form Template method
Feature envy	Move method Extract method
Long method	Extract method Decompose conditional

- Akin to critique tables discussed last week!

Refactoring never comes alone

- Usually one can find many different bad smells
- And for each one many different refactorings…
- Guidelines when refactorings should be applied

- Still even with strict guidelines [DuBois 2004]
  - org.apache.tomcat.{core,startup}
  - 12 classes, 167 methods and 3797 lines of code
  - Potential refactorings
    - Extract Method 5
    - Move Method 9
    - Replace Method with Method Object 1,
    - Replace Data Value with Object 3
    - Extract Class 3

Refactoring never comes alone

- **Which one is “better”?**
- **The most beneficial for the maintainability metrics we want to improve**
  - **We can do this a posteriori but the effort will be lost!**
  - **So we would like to assess this a priori**

- **Extract method from multiple methods**
  - **decreases LOC**
  - **decreases #dependencies on other classes**

Refactorings and metrics

Meta-Pattern Name	Description	CDE	DAC	LCOM	NOM	RFC	TCC	WMC
ABSTRACTION	adds an interface to a class which enables another class to take a more abstract view of the first class by accessing via interface	−	*NI*	*NI*	+	+	−	*NI*
EXTENSION	constructs an abstract class from an existing class and creates an extends relationship between the two classes	*NI*	+	+	*NI*	+	+	−
MOVEMENT	moves parts of an existing class to a component class and sets up a delegation relationship from the existing class to its component	−	+	+	*NI*	−	+	−
ENCAPSULATION	weakens the association between two classes by packaging the object creation statements into dedicated methods	−	+	+	*NI*	−	+	+
BUILDRELATION	operates the relationship between the classes in a more abstract fashion via an interface	+	+	*NI*	*NI*	−	+	+
WRAPPER	wraps an existing receiver class with another class in such a way that all requests to an object of the wrapper class are passed to the receiver object it wraps and similarly any results of such requests are passed back by the wrapper	+	+	*NI*	*NI*	+	+	−

- **CDE – class definition entropy**
  - **N – number of strings in the class**
  - **f_i – frequency of the string i**

$$CDE = -\sum \frac{f_i}{N} \ln\left(\frac{f_i}{N}\right)$$

- **DAC – number of ADTs in a class**
- **WMC – WMC/McCabe**

The refactoring process

- **Select the quality metrics**
  - **maintainability, performance, …**
  - **Recall: Goal – Question – Metrics!**

- **Refactoring loop**
  - **Calculate the metrics value**
  - **Identify a problem: "bad smell"**
  - **Check that the refactoring is applicable**
  - **Refactor**
  - ➢ **Compile and test**
    - **Recall: "*without changing its external behavior*"**
  - **Recalculate the metrics value**

Inconsistency

- Refactoring can introduce inconsistency
  - In tests by breaking the interfaces
  - In models by making them out-of-date

- We need to detect such inconsistencies
  - A priori: using classification of refactorings
    - We know when the things will go wrong
  - A posteriori:
    - Using a logic formalism
      - Inconsistency = unsatisfiability of a logic formula
    - Using change logs
      - eROSE

Interface preservation by refactorings

- **Refactoring can violate the interface**

- **Classify refactorings [Moonen et al.]**
  - **Composite: series of small refactorings,**
  - **Compatible: interface is not changed**
  - **Backwards compatible: interface is extended**
  - **Make backwards compatible: interface can be modified to keep it backwards compatible**
  - **Incompatible: interface is broken, tests should be adapted**

Refactoring and tests

Compatible	Inline temp Extract class Decompose conditional
Backwards compatible	Extract method Push down/Pull up field
Make backwards compatible	Add/Remove parameter Rename/Move method
Incompatible	Inline method Inline class

- To which group belong
  - Replace Exception with Test
  - Self Encapsulate Field (create getters and setters)

But tests are also code!

- **Smells [Moonen et al.]**
  - **Mystery guest (dependency on an external resource)**
  - **Resource optimism (availability of resources)**
  - **Test run war (concurrent use of resources)**
  - **General fixture (too many things are set-up)**
  - **Eager test (several methods are tested together)**
  - **Lazy tests (the same method for the same fixture)**
  - **Assertions roulette (several assertions in the same test with no distinct explanation)**
  - **For testers only (production code used only for tests)**
  - **Sensitive equality (toString instead of equal)**
  - **Test code duplication**

Smells are there, what about refactorings?

Refactoring	Bad smell
Inline resource	Mystery guest
Setup External Resource	Resource optimism
Make resource unique	Test run war
Reduce data	General fixture
Add assertion explanation	Assertions roulette
Introduce equality method	Sensitive equality

Alternative: A posteriori inconsistency

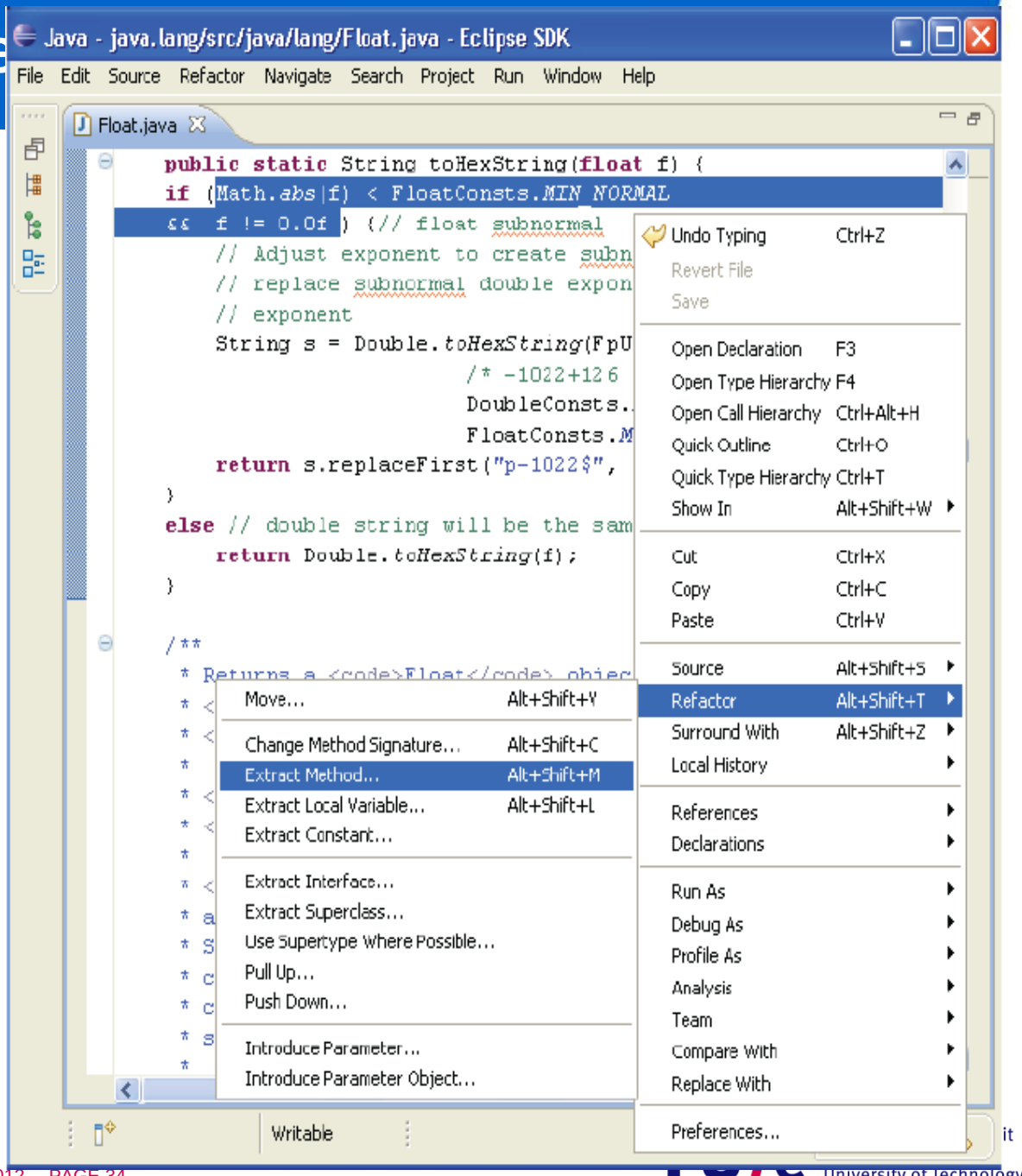
- **Sometimes we do not know what refactorings took place**

- **Van Der Straeten et al.: inconsistencies in UML models using encoding as logic formulas**
  - **Similar technique can be used for code/model**
  - **Syntax adapted:**

```
inconsistent(ClassDiagram,SeqDiagram,Class,Obj) :-
    class(Class),
    not(inNamespace(Class,ClassDiagram)),
    instanceOf(Class,Obj),
    inNamespace(Obj,SeqDiagram)
```

Putting it all toge

- **IntelliJ IDEA – first popular commercial refactoring browser for Java**
  - **Today: additional languages**
- **A number of alternatives**
  - **Eclipse**
  - **MS Visual Studio**
  - **…**



Eclipse Europa 3.3

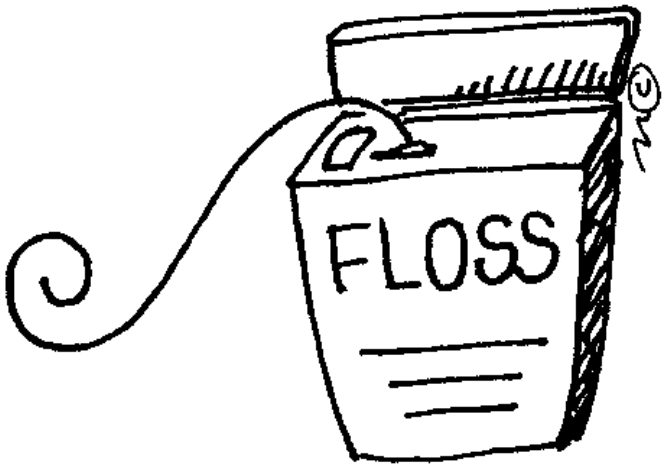
Refactoring browsers have a lot of potential but are they used?

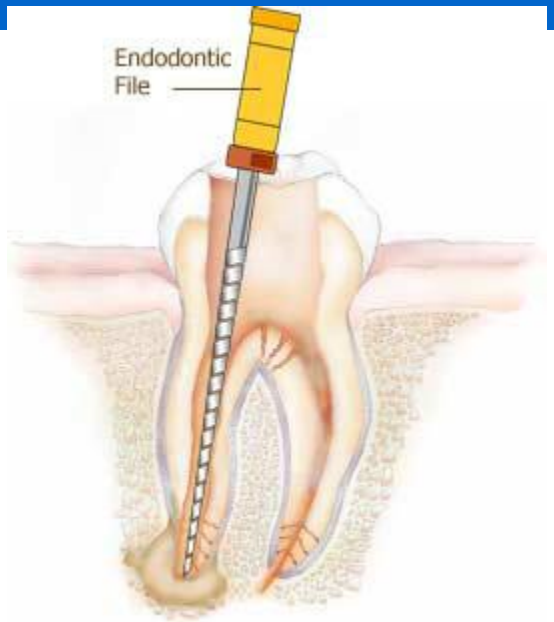
- **Students [Murphy-Hill and Black]**
  - **16 used Eclipse, 2 used refactoring**
  - **42 used Eclipse, 6 used refactoring**

- **Professionals**
  - **112 agile programmers, 68% used refactoring**
  - **Traditional programmers are expected to be less enthusiastic**

- **Are refactoring browsers fit to what the developers want to do?**

How do people refactor [Murphy-Hill and Black]





- **Floss refactorings: frequent, intertwined with usual development activities**
- **Root canal refactorings: concentrated refactoring effort, infrequent, no usual development activites take place**

  - **Regular flossing prevents root canal treatment**
  - **Programmers prefer to floss [Weißgerber, Diehl]**

We need to focus on floss refactorings

1. Choose the desired refactoring quickly,
2. Switch seamlessly between program editing and refactoring,
3. View and navigate the program code while using the tool,
4. Avoid providing explicit configuration information, and
5. Access all the other tools normally available in the development environment while using the refactoring tool.

Eclipse Europa revisited

Java - java.lang/src/java/lang/Float.java - Eclipse SDK

File Edit Source Refactor Navigate Search Project Run Window Help

Float.java

```
public static String toHexString(float f) {
if (Math.abs(f) < FloatConsts.MIN_NORMAL
&&  f != 0.0f ) {// float subnormal
    // Adjust exponent to create subn
    // replace subnormal double expon
    // exponent
    String s = Double.toHexString(FpU
                        /* -1022+126
                        DoubleConsts.
                        FloatConsts.M
    return s.replaceFirst("p-1022$",
}
else // double string will be the sam
    return Double.toHexString(f);
}

/**
 * Returns a <code>Float</code> objec
```

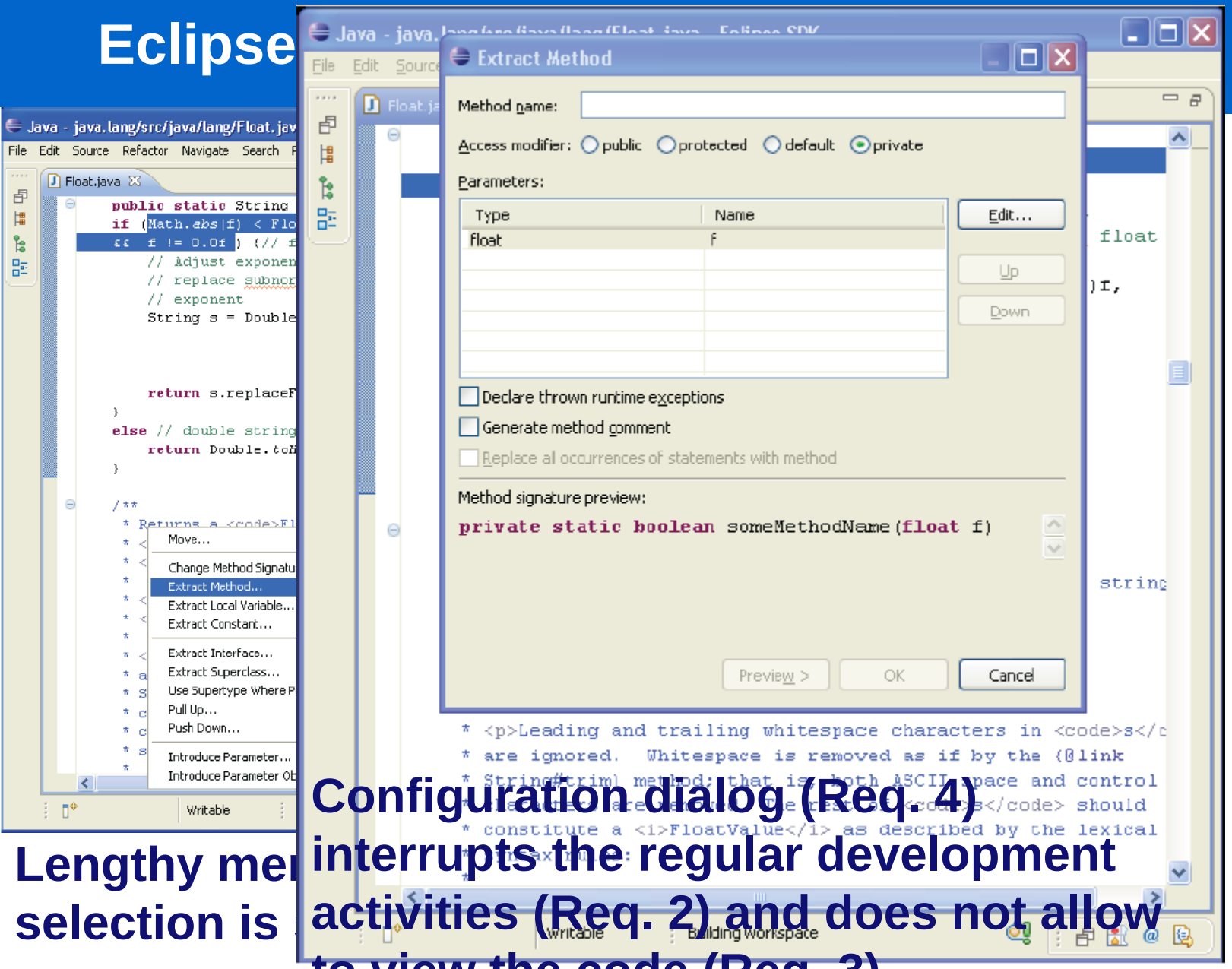
Move... Alt+Shift+V
Change Method Signature... Alt+Shift+C
Extract Method... Alt+Shift+M
Extract Local Variable... Alt+Shift+L
Extract Constant...
Extract Interface...
Extract Superclass...
Use Supertype Where Possible...
Pull Up...
Push Down...
Introduce Parameter...
Introduce Parameter Object...

Undo Typing Ctrl+Z
Revert File
Save
Open Declaration F3
Open Type Hierarchy F4
Open Call Hierarchy Ctrl+Alt+H
Quick Outline Ctrl+O
Quick Type Hierarchy Ctrl+T
Show In Alt+Shift+W
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Source Alt+Shift+S
Refactor Alt+Shift+T
Surround With Alt+Shift+Z
Local History
References
Declarations
Run As
Debug As
Profile As
Analysis
Team
Compare With
Replace With
Preferences...

Writable

Lengthy menus: refactoring selection is slow (Req. 1)

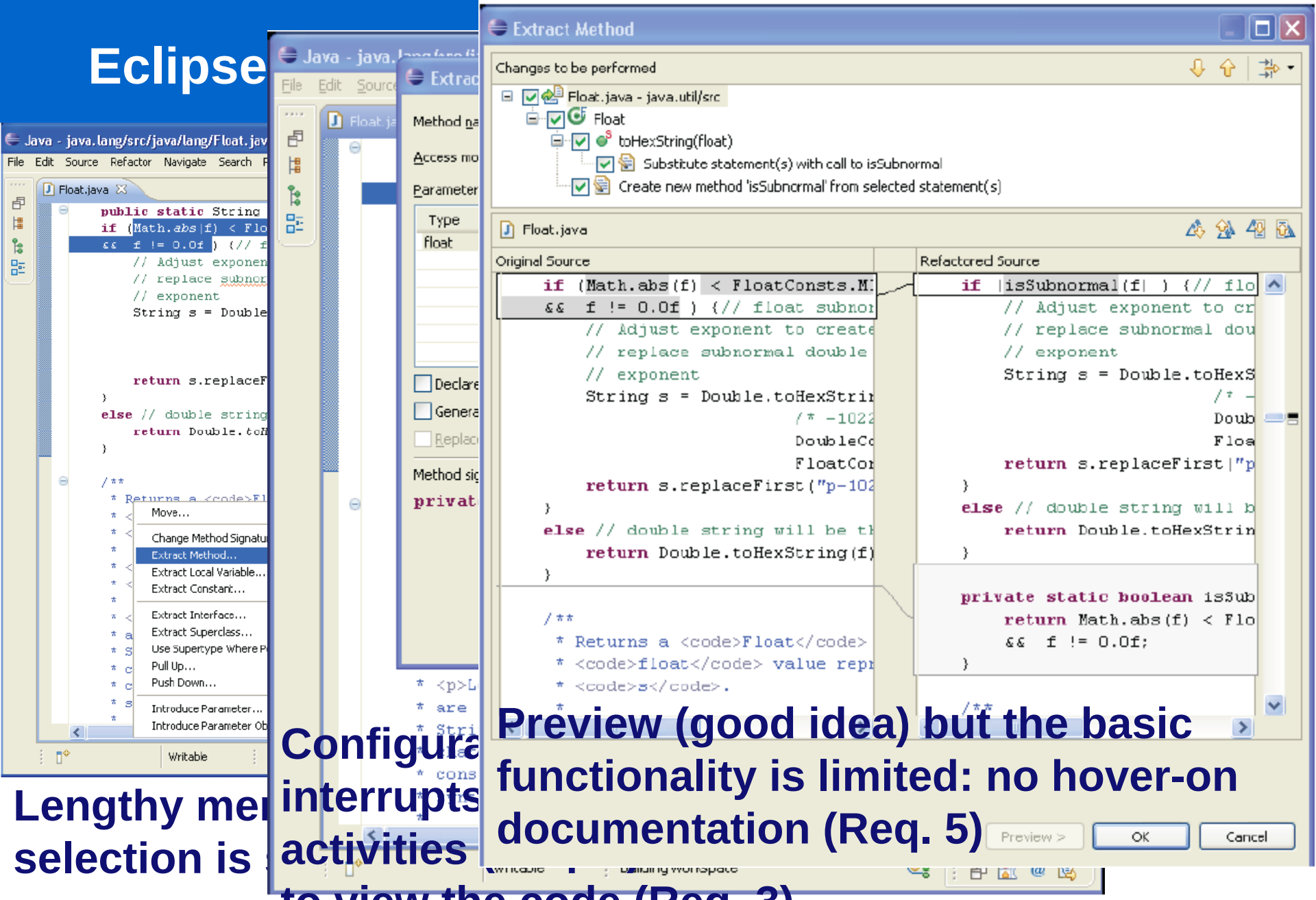
Eclipse



Lengthy mer
selection is

Configuration dialog (Req. 4) interrupts the regular development activities (Req. 2) and does not allow to view the code (Req. 3).

Eclipse



Lengthy mer
selection is

Configura
interrupts
activities
to view the code (Req. 3).

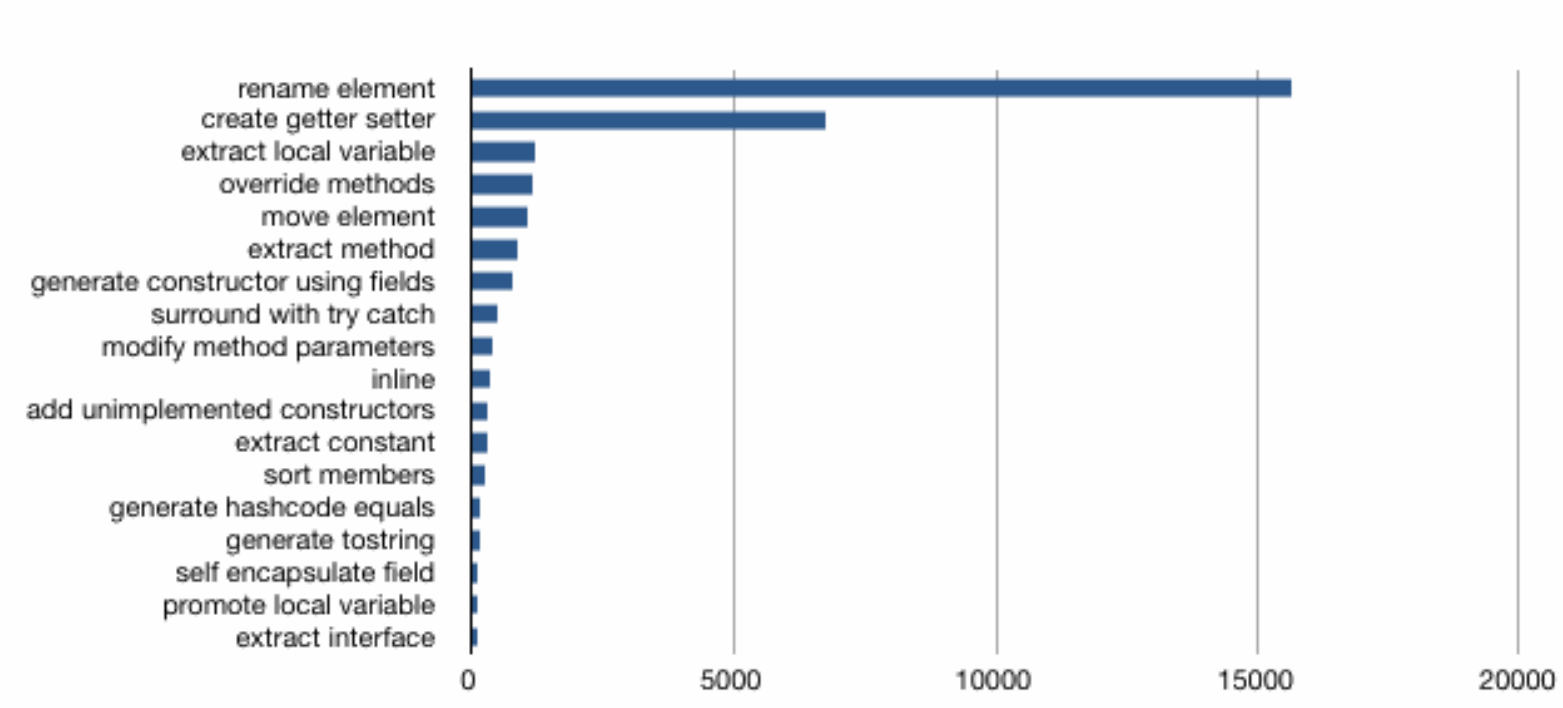
Preview (good idea) but the basic functionality is limited: no hover-on documentation (Req. 5)

Fast access means limited choice

1 - IntroduceFactory	1 - PushDown	1 - UseSupertype	2 - ConvertAnonymousToNested	2 - ConvertNestedToTop	2 - EncapsulateField	3 - GeneralizeDeclaredType	3 - InferGenericTypeArguments	3 - IntroduceParameter	4 - MoveMemberTypeToNewFile	5 - ConvertLocalToField	10 - ExtractConstant	10 - ExtractInterface	10 - ExtractLocalVariable	11 - Inline	11 - ModifyParameters	11 - PullUp	20 - ExtractMethod	24 - Move	41 - Rename
			11	2		1		16		4	20	1	160	101	28	7	42	5	40
			16	6				8	6	25	7		98	60		1	39	31	22
		6			2	1				1	1	12		4	6	6	3	15	195
									2	4	1		128	6	3	1	84	26	505
					3				1		30	1		3		7	17	32	81
											4		34		1	2	1	1	16
						2					7	3	5			7	2		56
	1											1		2	15		2	4	24
											16	1		1			9	22	56
1									1		3	1						5	63
															1	3	4	2	35
													5	1	1		14		11
											4	1					72	2	266
													9	14		7	17		13
													2	2		1	5		8
								1								1	1		1
							1										22	2	137
												4					4	9	68
														1			13	2	13
							1								1			9	138
										3			8		6				105
													1					2	4
																	1	6	45
															6			15	66
							1											1	1
												1					2		13
																		12	54
																		1	12
																		1	165
																		4	4
																		1	17
															1				78
																			1
																			3
																			18
																			5
																			17
																			6
																			8
																			10
																			16

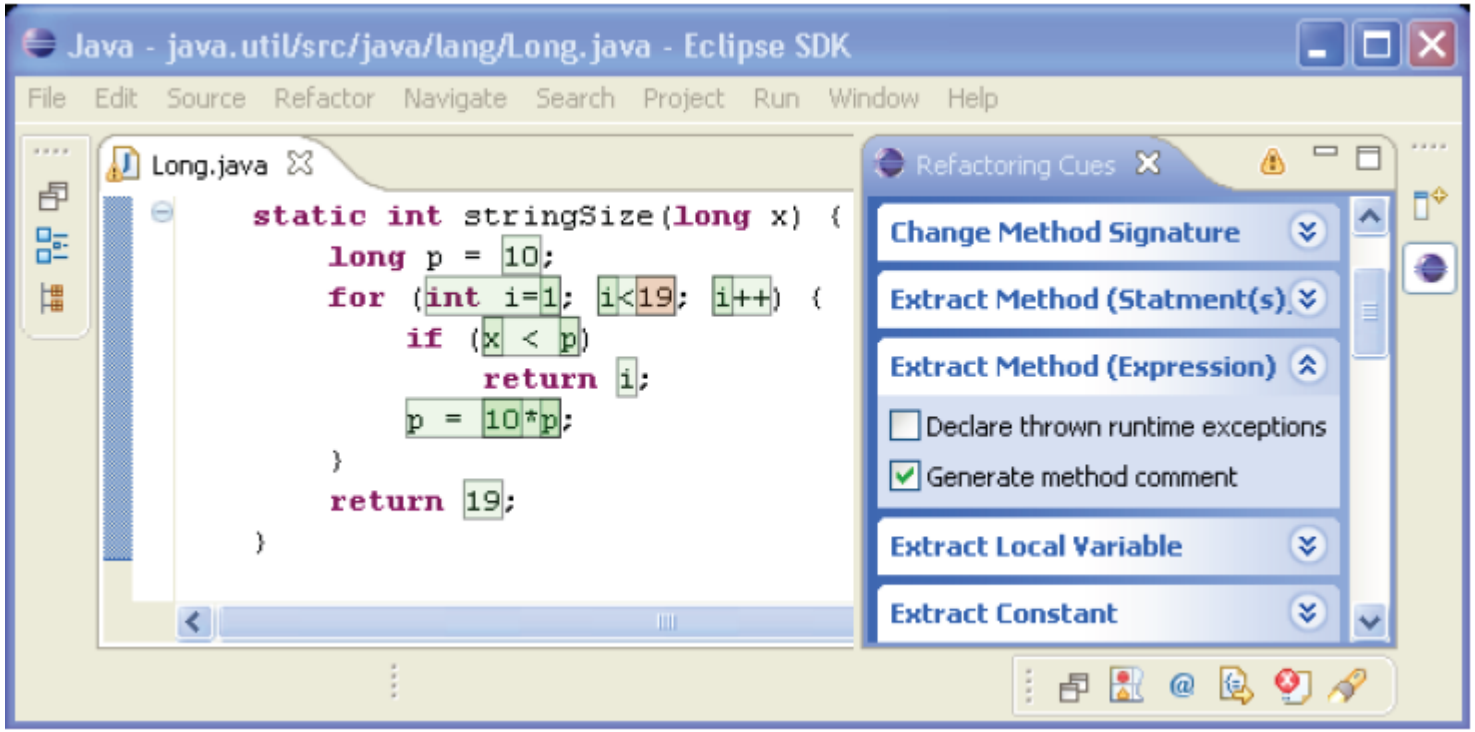
- **Which refactorings are actually used?**
  - **Column – refactoring**
  - **Row – developer**
  - **Colour – times used**
- **Leaders**
  - **Rename, move**
  - **Extract method, pull up**
  - **ModifyParameters**
  - **ExtractLocalVariable**
  - **ExtractInterface**
  - **ExtractConstant**

Eclipse Usage Data Collector (2009)



- **Formatting changes excluded**
- **More or less the same leaders:**
  - **Rename, move**
  - **Extract method + getters/setters**
  - **Extract local variable**

Proposed solution: Refactoring Cues



- Short menu (Req. 1)
- Switch is easy (Req. 2)
- Code is visible (Req. 3)
- Dialog is non-modal (Req. 5)
- Configuration (Req. 4) is an issue

No explicit configuration: X-Develop

```
public boolean equals(Object obj) {
    if (obj instanceof Long) {
        return value == ((Long)obj).longValue();
    }
    return false;
}
```

```
public boolean equals(Object obj) {
    if (obj instanceof Long) {
        return value == m(obj);
    }
    return false;
}

private long m(Object obj){
    return ((Long)obj).longValue();
}
```

- **Up: Original source code**
- **Down: After the extract method refactoring**

- **Default method name: m**
- **The name is pre-selected: the rename method refactoring is intended**

How does this look now? Eclipse Indigo

```
@SuppressWarnings("restriction")
public static String toHexString(float f) {
if (Math.abs(f) < FloatConsts.MIN_NORMAL
```

- Extract to local variable (replace all occurrence
- Extract to local variable
- Extract to constant
- Extract to method
- Remove surrounding method invocation

```
...
public static String toHexString(float f) {
float abs = Math.abs(f);
if (abs < FloatConsts.MIN_NORMAL
&& f != 0.0f ) {// float subnormal
...
```

Press 'Tab' from proposal table or click for focus

```
}
else

}
```

- **Ctrl+1**
- **Context-sensitive menu**
- **Results of refactoring are shown in the yellow box**
  - **Academic research ⇒ main-stream IDE**

But there is more

- **Direct shortcuts in the yellow box.**

```
@SuppressWarnings("restriction")
public static String toHexString(float f) {
if (Math.abs(f) < FloatConst
    &&  f != 0.0f ) {// floa
    // Adjust exponent to cr
    // replace subnormal dou
    // exponent
    String s = Double.toHexS
                        /* -
                        Doub
                        Floa
    return s.replaceFirst("p
}
else // double string will b
    return Double.toHexStrin
}
```

Rename in file (⌘2 R)
Rename in workspace (⌥⌘R)

Link all references for a local rename (does not change references in other files)

Press 'Tab' from proposal table or click for focus

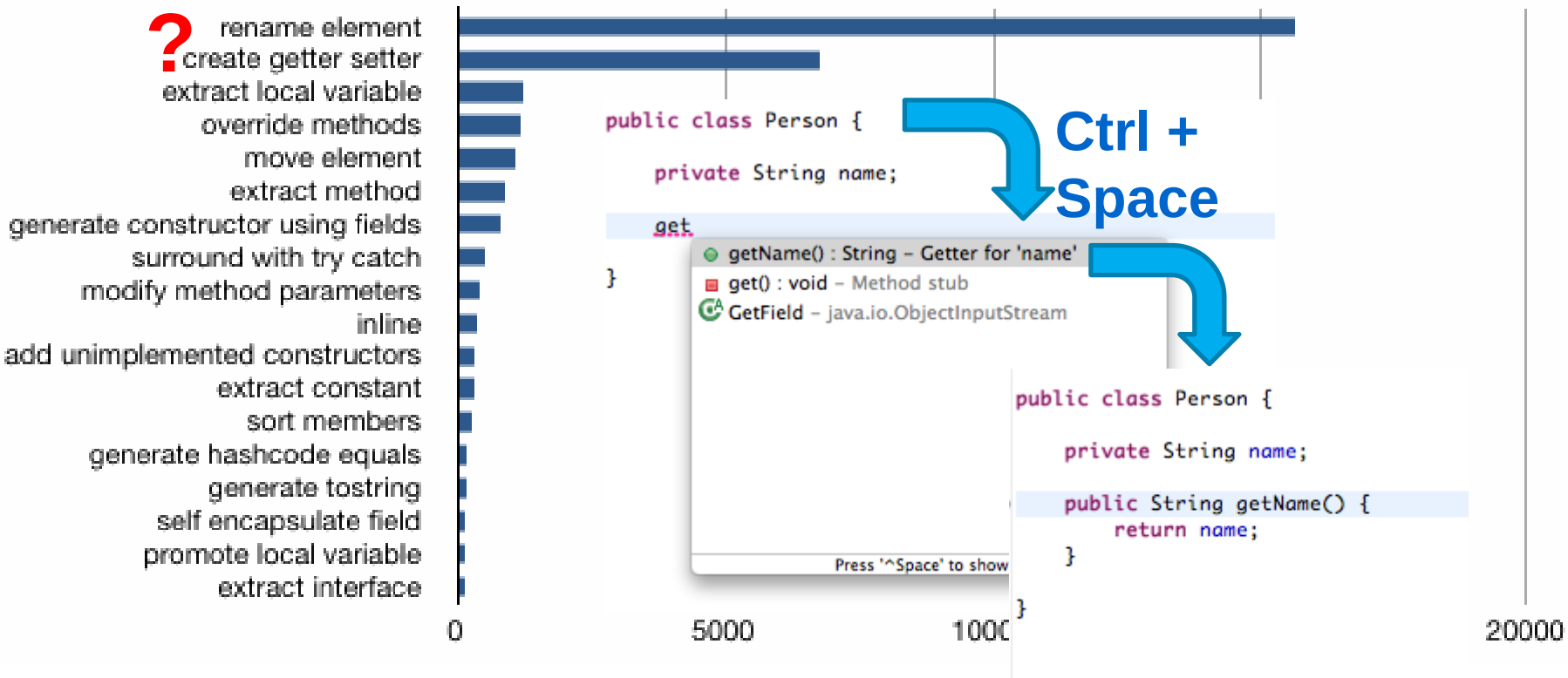
```
public static int floatToIntBits(float value) {
int result = floatToRawIntBits(value);
// Check for NaN based on values of bit fields, maximum
// exponent and nonzero significand.
if ( ((result & FloatConsts.EXP_BIT_MASK) ==
      FloatConsts.EXP_BIT_MASK) &&
     (result & FloatConsts.SIGNIF_BIT_MASK) != 0)
    result = 0x7fc00000;
return result;
}

/**
 * Returns a representation of the specified floating-point value
 * according to the IEEE 754 floating-point "single format" bit
 * layout, preserving Not-a-Number (NaN) values.
 * <p>
 * Bit 31 (the bit that is selected by the mask
 * <code>0x80000000</code>) represents the sign of the floating-point
 * number.
 * Bits 30-23 (the bits that are selected by the mask
 * <code>0x7f800000</code>) represent the exponent.
 * Bits 22-0 (the bits that are selected by the mask
```

Quick Assist - Assign to field	⌘2 F		
Quick Assist - Assign to local variable	⌘2 L		
Quick Assist - Rename in file	⌘2 R		

⌘2 | Writable | Smart Insert | 681 : 13

Closer look at



- **The same idea works for**
  - **default constructors**
  - **overridden methods from the superclass**

Additional features of Eclipse Indigo

- **Ctrl + Shift + O removes unused imports:**
  - **Why would this feature be interesting?**

- **Ctrl + Shift + F formats the code according to a predefined style.**
  - **length of the lines in a source code, placement of brackets, etc.**
  - **Why would this feature be interesting?**

Conclusion

- **Refactoring – a disciplined technique for restructuring code, altering its internal structure without changing its external behavior.**
- **Refactoring loop**
  - **Calculate maintainability metrics**
  - **Identify a problem: “bad smell”**
  - **Check that the refactoring is applicable**
  - **Refactor**
  - **Compile and test**
  - **Recalculate the maintainability metrics**
- **Refactoring browsers should better support flossing**