Better Refactoring Tools for a Better Refactoring Strategy

Emerson Murphy-Hill and Andrew P. Black
Department of Computer Science
Portland State University
Portland, Oregon

February 7, 2008

Introduction

Refactoring tools can improve the speed and accuracy with which we create and maintain software — but only if they are used. In practice, tools are not used as much as they could be; this seems to be because they do not align with the refactoring strategy preferred by the majority of programmers: *floss refactoring*. We propose five principles that characterize successful floss refactoring tools — principles that can help programmers to choose the most appropriate refactoring tools and also help toolsmiths to design more usable tools.

1 What is Refactoring?

Refactoring is the process of changing the structure of software while preserving its external behavior. The term was introduced by Opdyke and Johnson in 1990 [1], and popularized by Martin Fowler's book [2], but refactoring has been practiced ever since programmers have been writing programs. Fowler's book is largely a catalog of refactorings; each refactoring is a pattern of change that has been observed repeatedly in various languages and application domains.

Some refactorings make localized changes to a program, while others make more global changes. For example, when you perform the Inline Temp refactoring, you replace each occurrence of a temporary variable with its value. Inspecting a method from `java.lang.Long`,

```
public static Long valueOf(long l) {
    final int offset = 128;
    if (l >= -128 && l <= 127) { // will cache
        return LongCache.cache[(int)l + offset];
    }
    return new Long(l);
}
```

we might apply the Inline Temp refactoring to the variable `offset`. Here is the result:

```
public static Long valueOf(long l) {
    if (l >= -128 && l <= 127) { // will cache
        return LongCache.cache[(int)l + 128];
    }
    return new Long(l);
}
```

The inverse operation, in which we take the second of these methods, introduce a new temporary variable to represent 128, is also a refactoring, which Fowler calls Introduce Explaining Variable. Whether the version of the code with or without the temporary variable is better depends on the context. The first version would be better if you were about to change the code so that `offset` appeared a second time; the second version might be better if you prefer more concise code. So, whether a refactoring improves your code depends on the context: you must still exercise good judgement.

Refactoring is an important technique because it helps you to make semantic changes to your program. For example, suppose that you want the ability to read and write to a video stream using `java.io`. The relevant existing classes are shown in black at the top of Figure 1. Unfortunately, this class hierarchy confounds two concerns: the direction of the stream (input or output) and the kind of storage that the stream works over (file or byte array). It would be difficult to add video streaming to the original `java.io` because you would have to add two new classes, `VideoInputStream` and `VideoOutputStream`, as shown by the grey boxes at the top of Figure 1. You would probably be forced to duplicate code between these two classes because their functionality would be similar.

Fortunately, we can separate these concerns by applying the Tease Apart Inheritance refactoring to produce the two hierarchies shown in black at the bottom of Figure 1. It's easier to add video streaming in the refactored version: all that you need do is add a class `VideoStorage` as a subclass of `Storage`, as shown by the grey box at the bottom of Figure 1. Because it enables software change, "Refactoring helps you develop code more quickly" [2, p. 57].

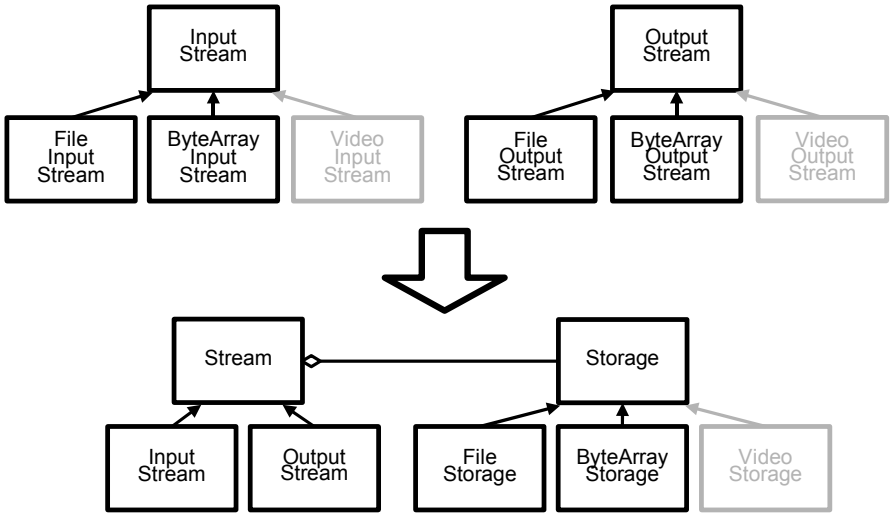

Figure 1: A stream class hierarchy in `java.io` (top, black) and a refactored version of the same hierarchy (bottom, black). In grey, an equivalent change is made in each version.

Not only has refactoring been prescribed by Fowler, but research suggests that many professional programmers refactor regularly. For example, Xing and Stroulia recently studied the Eclipse code base, and "discovered that indeed refactoring is a frequent practice and it involves a variety of restructuring types, ranging from simple element renamings and moves to substantial reorganizations of the containment and inheritance hierarchies" [3]. Murphy and colleagues studied 41 programmers using the Eclipse environment [4]: they found that every programmer used at least one *refactoring tool*.

2 Refactoring Tools

Refactoring tools automate refactorings that you would otherwise perform with an editor. Many popular development environments for a variety of languages now include refactoring tools: Eclipse (http://eclipse.org), Microsoft Visual Studio (http://msdn.microsoft.com/vstudio), Xcode (http://developer.apple.com/tools/xcode), and Squeak (http://www.squeak.org) are among them. You can find a more extensive list at http://refactoring.com/tools.html.

Let's see how a small refactoring might be performed using Eclipse. We will use the class `java.lang.Float` as the code to be refactored. First, we choose the code we want refactored, typically by selecting it in an editor. In this example,

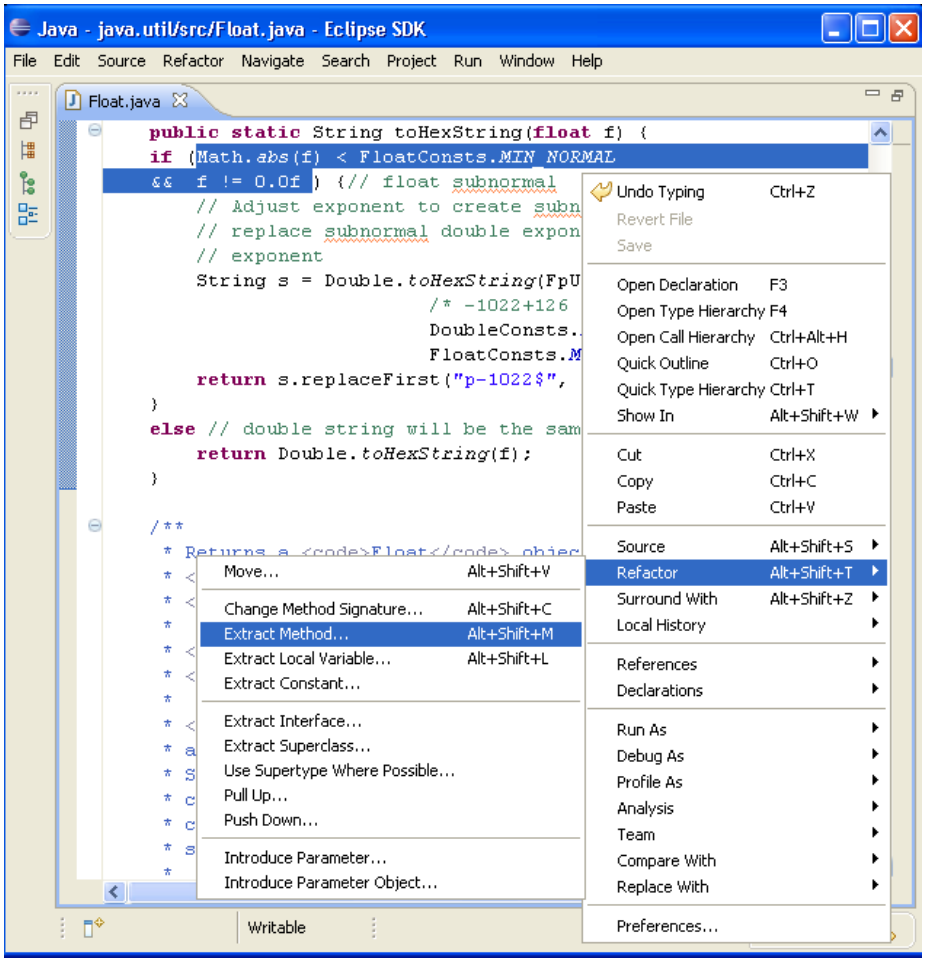

Figure 2: Selected code to be refactored in Eclipse, and a context menu. The next step is to select Extract Method... in the menu.

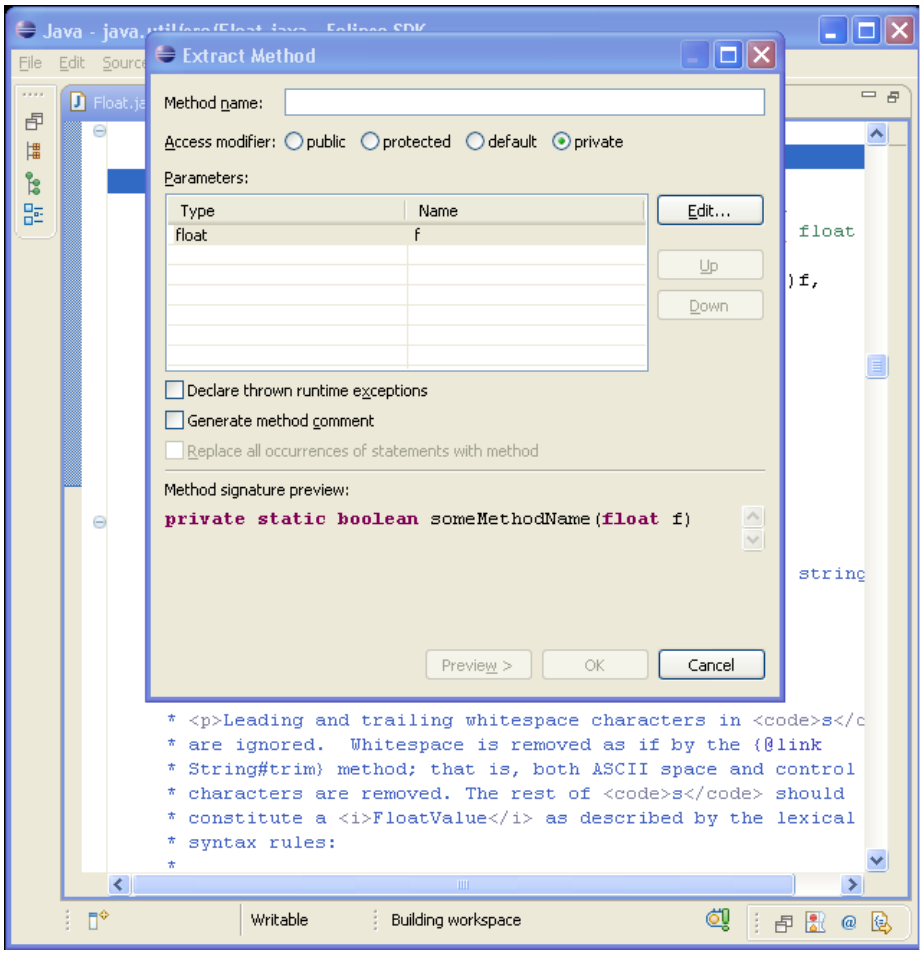

Figure 3: A configuration dialog asks us to enter information. The next step is to type "isSubnormal" into the Method name text box, after which the Preview > and OK buttons become active.

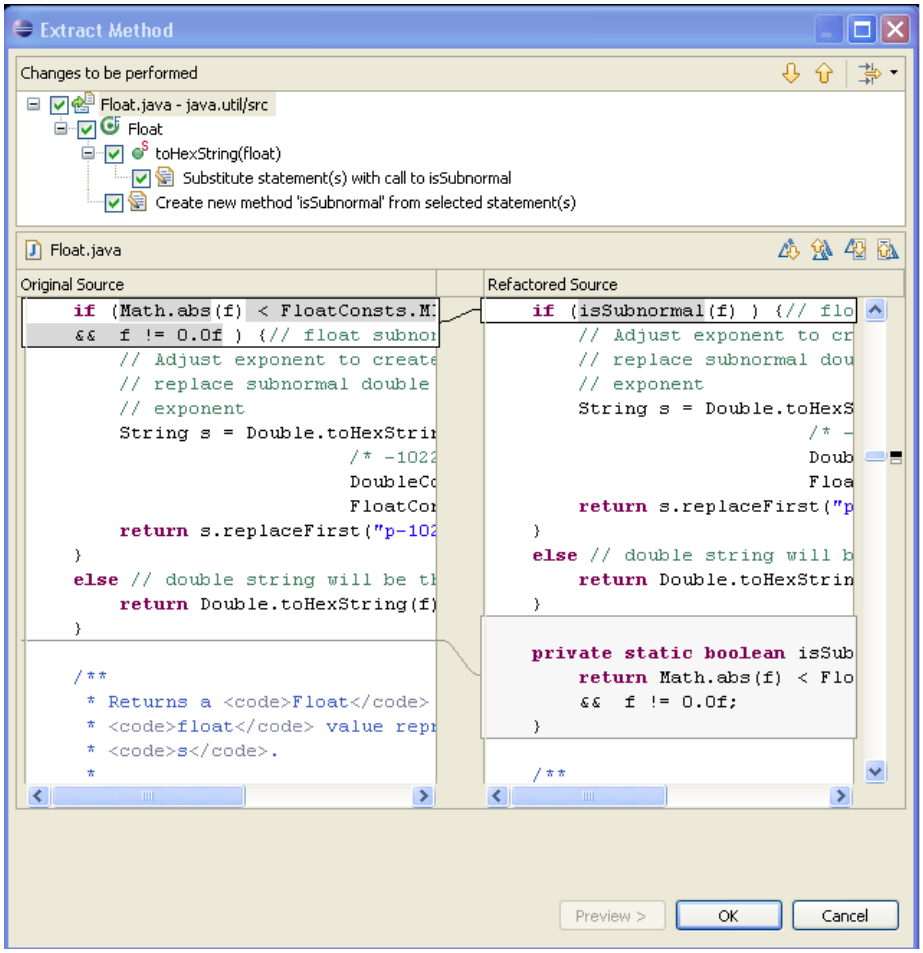

Figure 4: A preview of the changes that will be made to the code. At the top, you can see a summary of the changes. The original code is on the left, and the refactored code on the right. You press OK to have the changes applied.

we'll choose the conditional expression in an `if` statement (Fig. 2) that checks to make sure that `f` is in subnormal form. Let's suppose that we want to put this condition into its own method so that we can give it an intention-revealing name and so that we can reuse it elsewhere in the `Float` class. After selecting the expression, we choose the desired refactoring from a menu. The refactoring that we want is called Extract Method (Fig. 2).

The menu selection starts the refactoring tool, which brings up a dialog asking us to supply configuration options (Fig. 3). We have to provide a name for the new method: we'll call it `isSubnormal`. We can also select some other options. We then have the choice of clicking OK, which would perform the refactoring immediately, or Preview >.

The preview page (Fig. 4) shows the differences between the original code and the refactored version. If we like what we see, we can click OK to have the tool apply the transformation. The tool then returns us to the editor, where we can resume our previous task.

Of course, we could have performed the same refactoring by hand: we could have used the editor to make a new method called `isSubnormal`, cutting-and-pasting the desired expression into the new method, and editing the `if` statement so that it uses the new method name. However, using a refactoring tool can have two advantages.

1. The tool is less likely to make a mistake than is a programmer refactoring by hand. In our example, the tool correctly inferred the necessary argument and return types for the newly created method, as well as deducing that the method must be static. When refactoring by hand, you can easily make a mistake on such details.

2. The tool is faster than refactoring by hand. Doing it by hand, we would have to take time to make sure that we got the details right, whereas a tool can make the transformation almost instantly. In a file-based environment like Eclipse, refactorings that affect many source files, such as renaming a class, can be quite time-consuming to perform manually. They can be accomplished almost instantly by a refactoring tool.

In short, refactoring tools allow us to program faster and with fewer mistakes—but only if we choose to use them.

3 Refactoring Tools are Underused

Because they automate what you would otherwise do by hand, and because they are less error-prone and faster, we would expect programmers to use refactoring tools frequently. However, we have found that programmers do not always

use refactoring tools, even when they are available. Let's look at some of the evidence.

Evidence: Low Academic Usage

At Portland State University (PSU) we have observed many programmers not using refactoring tools. In a questionnaire administered in March 2006, we asked students in an object-oriented programming class if they had used refactoring tools in the past, and to what extent [5]. Of the 16 students who participated, only 2 reported having used refactoring tools. One of them reported that when the appropriate type of refactoring tool was available, he chose to use it over refactoring by hand just 60% of the time; the other student reported that he used a tool 20% of the time.

We have also studied the history of refactoring tool usage on networked computers in our college at PSU. Between September 2006 and December 2007, of the 42 people who used Eclipse, only 6 had tried Eclipse's refactoring tools.

These studies both suggest low usage of refactoring tools (about 14%) among academic programmers.

Evidence: Low Usage Among Professionals

Perhaps the situation is different among professional programmers? At the Agile Open Northwest conference in January 2007, we surveyed more than 90% of the attendees (112 surveyed) to ask about refactoring tool usage. 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.

While this usage is higher than our academic programmers, it may be an overestimate for professional programmers in general. This is because agile methodologies encourage vigorous refactoring, so we expect that the attendees at an agile conference would be more familiar with refactoring tools, and would use them more often, than would non-agile programmers.

Whatever the precise usage rates for refactoring tools, these data suggest that programmers could be using refactoring tools substantially more frequently.

Evidence: Predicted Usage Does Not Match Observed Usage

When we compare predicted usage rates of two refactorings against the usage rates of the corresponding refactoring tools observed in the field, we find a surprising discrepancy.

In a study of 37 students, most with programming work experience, Mäntylä and Lassenius asked each student to evaluate 10 pieces of code [6]. For each piece of code, the student was asked which refactorings were *needed*, and how likely the student would be to *perform* those refactorings. On average, subjects judged that they were about 38% more likely to *perform* Extract Method than Rename. Furthermore, Extract Method was *needed* more than 3 times as frequently as Rename. Using this data, we predict that programmers are more likely to perform Extract Method than Rename.

However, Murphy and colleagues' study [4] of 41 professional software developers shows that Eclipse's Extract Method tool is used significantly *less* often than its Rename tool. While all 41 programmers used the Rename tool at least once, only 20 programmers used the Extract Method tool (Fig. 5). Furthermore, the Rename tool was used 6.7 times more than the Extract Method tool. In short, programmers were observed to use refactoring tools to perform Rename substantially more than Extract Method.

Comparing these two studies, we can see that predicted refactoring tool usage does not match observed refactoring tool usage. From this, we infer that some refactoring tools — the Extract Method tool in this case — may be underused.

The Cause of Underuse

If indeed refactoring tools are not used as much as they could be, what is the cause? Until recently, the blame could be placed on the lack of available tools. However, in our Agile 2007 survey, of the 83 people surveyed who programmed, 73 had a refactoring tool available at least some of the time.

As we will explain, we believe that the reason that many programmers underuse refactoring tools is that the design of some refactoring tools doesn't fit their *refactoring strategy*.

4 Two Refactoring Strategies: Floss Refactoring and Root Canal Refactoring

When we talk about refactoring strategies, we are referring to the choices that you make about how to mix refactoring with your other programing tasks, and how frequently you choose to refactor. To describe the strategies, we use a dental metaphor. We call one strategy **floss refactoring**; this is characterized by frequent refactoring, intermingled with other kinds of program changes. In contrast, we call the other strategy **root canal refactoring**. This is characterized by infrequent, protracted periods of refactoring, during which time programmers perform few if any other kinds of program changes. You perform floss

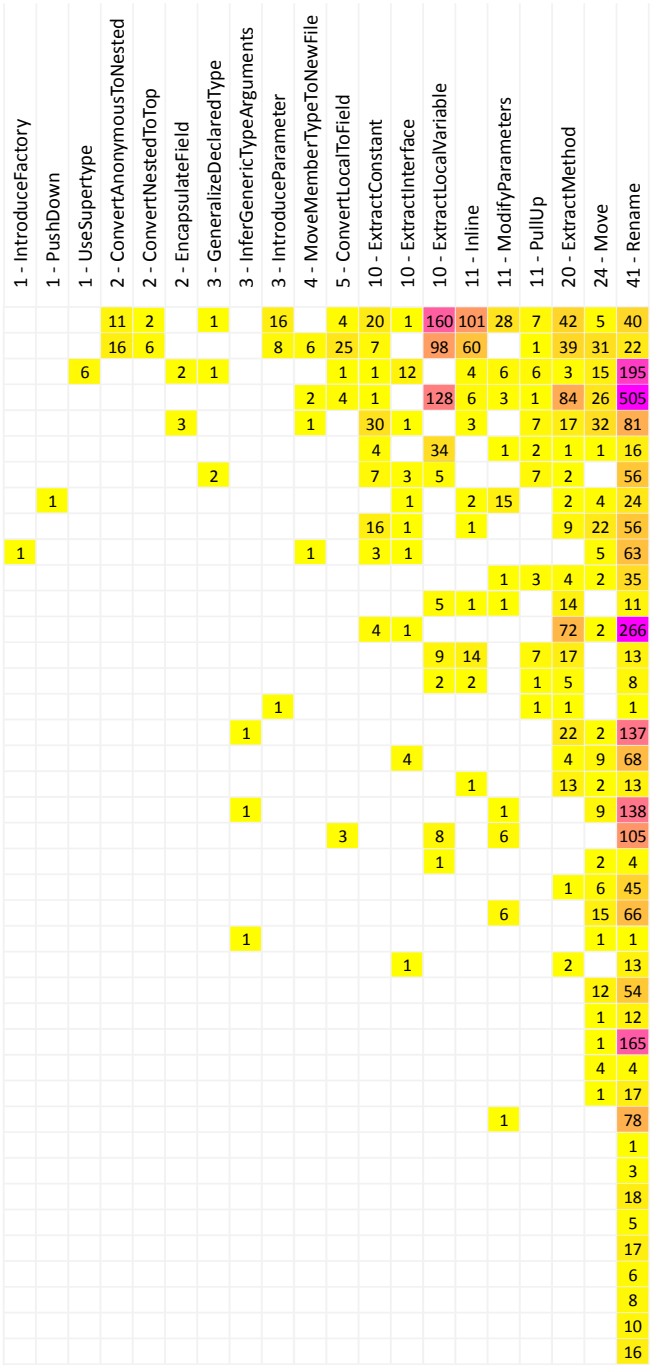

Figure 5: Uses of Eclipse refactoring tools by 41 developers. Each column is labeled with the name of a tool-initiated refactoring in Eclipse, and the number of programmers that used that tool. Each row represents an individual programmer. Each box is labeled by how many times that programmer used the refactoring tool. The darker pink the interior of a box, the more times the programmer used that tool. Data provided courtesy of Murphy and colleagues [4].

refactoring to maintain healthy code, and you perform root canal refactoring to correct unhealthy code.

We use the metaphor because, for many people, flossing one's teeth every day is a practice they know that they should follow, but which they sometimes put off. Neglecting to floss can lead to tooth decay, which can be corrected with a painful and expensive trip to the dentist for a root canal procedure. Likewise, a program that is refactored frequently and dutifully is likely to be healthier and less expensive in the long run than a program whose refactoring is deferred until the last bug can't be fixed or the next feature can't be added. Like delaying dental flossing, delaying refactoring is a decision developers may make to save time, but one that may have painful consequences later.

It is not the kind of refactoring (Rename, Extract Method, Tease Apart Inheritance, etc.) that determines whether the transformation is a floss or a root canal refactoring. The difference hinges on *why* the refactoring is performed. You are floss refactoring if your goal is to better understand a particular piece of code or to make a specific change that is difficult with the current structure. You are root canal refactoring if you are spending days cleaning up crufty code, preparing for some change that *may* be made in the future, or if you are improving the quality of your code, not to enable a specific change, but because you are aware that it has become a mess. Although we cannot know a programmer's motivation by examining their code, we can induce the difference between floss refactoring and root canal refactoring by seeing if other changes are intermingled with the refactorings (floss), or whether many refactorings take place without any intermingled edits (root canal).

Experts Recommend that Programmers should Floss

Experts have generally advocated that programmers perform floss refactoring rather than root canal refactoring. For instance, Fowler states:

> In almost all cases, I'm opposed to setting aside time for refactoring. In my view refactoring is not an activity you set aside time to do. Refactoring is something you do all the time in little bursts. You don't decide to refactor, you refactor because you want to do something else, and refactoring helps you to do that other thing. [2, p. 58]

Jim Shore has given similar advice:

> Avoid the temptation to stop work and refactor for several weeks. Even the most disciplined team inadvertently takes on design debt, so eliminating debt needs to be an ongoing activity. Have your team get used to refactoring as part of their daily work. [7]

Jeffries and colleagues have advocated floss refactoring as a key practice of Agile programming:

> We keep the code simple at all times. This minimizes the investment in excess framework and support code. We retain the necessary flexibility through refactoring. [8]

Empirical Evidence: Programmers Avoid Root Canals

Not only do experts recommend floss refactoring over root canal refactoring, but programmers appear to heed their advice. We mention two studies: although the data are limited, they suggest that programmers do floss refactoring rather than root canal refactoring.

Weißgerber and Diehl measured the proportion of daily code changes due to refactorings in three large open-source projects [9]. If root canal refactoring were taking place, there would be days in the development cycle on which refactoring occurred, but on which no other programming tasks were completed. However, the authors found that "in all three projects, there are no days which only contain refactorings", suggesting that although refactorings were being applied often, at no point did the programmers set aside a day or more for refactoring, as would be characteristic of root canal refactoring.

Murphy and colleagues' data [4] also suggests that root canal refactoring is not a popular strategy. These data show a total of 2671 programming episodes, delimited by commits to source-code repositories by 31 separate programmers. 283 of these episodes showed evidence of the use of one or more refactoring tools; at most 10 of the episodes contained just refactoring tool usage and no program edits. In other words, in only 10 of 283 episodes do we observe the possibility of root canal refactoring. The actual number is probably even smaller: in 9 of those 10 cases, the programmer used an editor for which edit events could not be captured.

5 Floss Refactoring and Refactoring Tool Design

So far we have argued that floss refactoring is both the recommended best-practice and a common current practice, while root canal refactoring is deprecated in both theory and practice. How does the dominance of floss refactoring affect refactoring tools? Is a tool designed to support floss refactoring different from a tool for root canal refactoring? How can we help toolsmiths to build tools better-suited for floss refactoring, and how can we help programmers to recognize such tools?

We propose five principles to characterize a tool that supports floss refactoring. Such a tool should allow the programmer to:

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.

Unfortunately, refactoring tools don't always follow these principles; as a result, floss refactoring with tools can be cumbersome. Let's revisit our refactoring tool example (Figures 2 through 4) to see how these principles apply to a typical refactoring tool.

After selecting the code to be refactored, we needed to choose which refactoring to perform, which we did using a menu (Fig. 2). Menus containing refactorings can be quite long and difficult to navigate; this problem gets worse as more refactorings are added to development environments. As one respondent complained in our Agile 2007 survey, the "menu's too big sometimes, so searching [for] the refactoring takes too long." Choosing the *name* that most closely matches the transformation that you have in your head is also a distraction: the mapping from the code change to the name is not always obvious. Thus, using a menu as the mechanism to initiate a refactoring tool violates Principle 1.

Next, most refactoring tools require configuration (Fig. 3). This makes the transition between editing and refactoring particularly rough, as you must change your focus from the code to the refactoring tool. Moreover, it's difficult to choose contextually-appropriate configuration information without viewing the context, and a modal configuration dialog like that shown in Fig. 3 obscures your view of the context. Furthermore, you cannot proceed unless you provide the name of the new method, even if you don't care what the name is. Thus, such configuration dialogs violate Principles 2, 3, and 4.

Before deciding whether to apply the refactoring, we were given the opportunity to preview the changes in a difference viewer (Fig. 4). While it is useful to compare your code before and after, presenting the code in this way forces you to stay inside the refactoring tool, where no other tools are available. For instance, in the difference view you cannot hover over a method reference to see its documentation. Thus, a separate, modal view for a refactoring preview violates Principle 5.

We have found similar problems with other tools; this makes them less useful for floss refactoring.

```
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();
}
```

Figure 6: At the top, a method in `java.lang.Long` in an X-develop editor. At the bottom, the resulting code immediately after the EXTRACT METHOD refactoring. The name of the new method is `m`, but the cursor is positioned to facilitate an immediate RENAME refactoring.

6 Tools for Floss Refactoring

Fortunately, some tools seem to have been built for floss refactoring, and embrace our principles. Let's look at some examples.

In Eclipse, while you initiate most refactorings with a cumbersome hierarchy of menus, you can perform a MOVE CLASS refactoring simply by dragging a class icon in the Package Explorer from one package icon to another. All references to the moved class will be updated to reflect its new location. This is analogous to dragging and dropping a file in your operating system's file explorer. This simple mechanism allows the refactoring tool to stay out of your way; since the class and target package are implicitly chosen by the drag gesture, you have already provided all the configuration information required to execute the refactoring. Because of the simplicity and speed of this refactoring initiation mechanism, it adheres to Principles 1, 2, and 4.

The X-develop environment (http://www.omnicore.com/xdevelop.htm) makes a significant effort to avoid modal dialog boxes for configuring its refactoring tools. For instance, the EXTRACT METHOD refactoring is performed without any configuration at all, as shown in Figure 6. Instead, the new method is given an automatic name. After the refactoring is complete, you can change the name

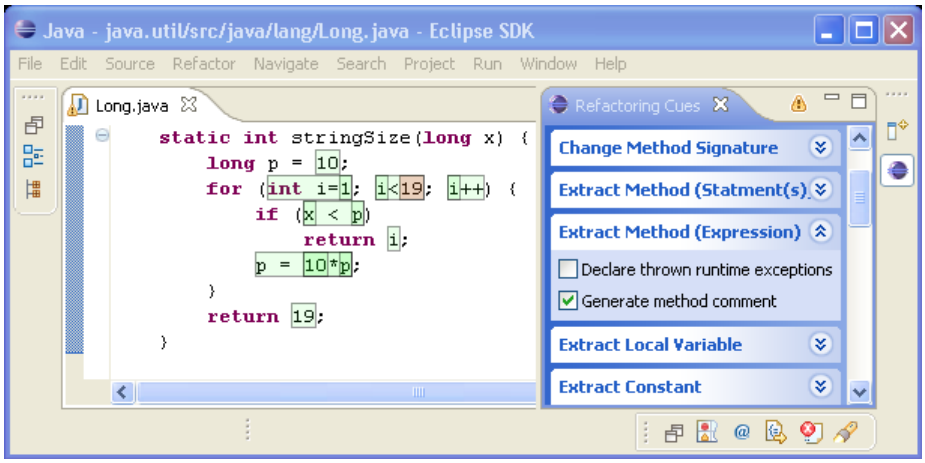

Figure 7: Refactoring Cues' non-modal view. Users can enter configuration information (right), or select the code fragment that they wish to refactor.

by placing the cursor over the default name, and simply typing a new name: this is actually a rename refactoring, and the tool makes sure that all references are updated appropriately. Because they stay out of your way, X-develop refactoring tools adhere to Principles 2 and 4.

To avoid modal configuration dialogs, and yet retain the flexibility of configuring a refactoring, we have built (in Eclipse) a tool called Refactoring Cues that presents configuration options non-modally [10]. To use Refactoring Cues, you ask Eclipse to display a refactoring view adjacent to the program code. You then select the desired refactoring in this view, and also configure it there, as shown in Figure 7. Because the Refactoring view is not modal, you can use other development tools at the same time. Moreover, because you select the refactoring *before* the code to which you wish to apply it, the tool can help you with the selection task, which can otherwise be surprisingly difficult [5]. Thus, this tool adheres to Principles 2, 3, and 5.

Rather than displaying a refactoring preview in a separate difference view, Refactor! Pro (http://www.devexpress.com/Products/NET/Refactor) marks the code that a refactoring will modify with *preview hints*. Preview hints are editor annotations that let you investigate the effect of a refactoring before you commit to it. Because you don't have to leave the editor to see the effect of refactoring, preview hints adhere to Principles 3 and 5.

7 Conclusion

We have explained what refactoring is and why it's important in modern software development. Refactoring is mainstream; Fowler's book [2] is the best starting point for those who want to know more. Our own contribution is the distinction between floss and root canal refactoring and our claim that floss refactoring is and should be the dominant strategy. We think that this distinction, and the observation that many tools are more suitable for root canal refactoring than for floss refactoring, helps to explain why refactoring tools have not had the impact that one might expect. We hope that our principles for building floss refactoring tools will serve two purposes.

First, the principles can help programmers to choose a refactoring tool that suits their daily programming tasks. If you are a programmer who usually performs floss refactoring, then you should choose tools that adhere to these principles. Second, the principles can help toolsmiths build better interfaces for refactoring tools. Because floss refactoring is the dominant strategy, tools that adhere to our principles should be useful to more programmers. This is true not just of refactoring tools themselves, but of any tool (such as a smell detector [11]) that is intended to help programmers keep their code clean as they work on it.

Our message, then, is that refactoring tools, like refactoring itself, have no *intrinsic* value. A tool is valuable only in so far as it "helps you do that other thing": develop better software.

References

[1] William F. Opdyke and Ralph E. Johnson. Refactoring: An aid in designing application frameworks and evolving object-oriented systems. In *SOOPPA '90: Proceedings of the 1990 Symposium on Object-Oriented Programming Emphasizing Practical Applications*, September 1990.

[2] Martin Fowler. *Refactoring: Improving the Design of Existing Code.* Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 1999.

[3] Zhenchang Xing and Eleni Stroulia. Refactoring practice: How it is and how it should be supported — an Eclipse case study. In *ICSM '06: Proceedings of the 22nd IEEE International Conference on Software Maintenance*, pages 458–468, Washington, DC, USA, 2006. IEEE Computer Society.

[4] Gail C. Murphy, Mik Kersten, and Leah Findlater. How are Java software developers using the Eclipse IDE? *IEEE Software*, 23(4):76–83, 2006.

[5] Emerson Murphy-Hill and Andrew P. Black. Breaking the barriers to successful refactoring. In *Proceedings, International Conference on Software*

Engineering, Leipzig, Germany, May 2008. IEEE Computer Society. In Press.

[6] Mika V. Mäntylä and Casper Lassenius. Drivers for software refactoring decisions. In *ISESE '06: Proceedings of the 2006 ACM/IEEE International Symposium on Empirical Software Engineering*, pages 297–306, New York, NY, USA, 2006. ACM.

[7] James Shore. Design debt. *Software Profitability Newsletter*, February 2004. http://jamesshore.com/Articles/Business/Software%20Profitability%20Newsletter/Design%20Debt.html.

[8] Ron E. Jeffries, Ann Anderson, and Chet Hendrickson. *Extreme Programming Installed*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2000.

[9] Peter Weißgerber and Stephan Diehl. Are refactorings less error-prone than other changes? In *MSR '06: Proceedings of the 2006 International Workshop on Mining Software Repositories*, pages 112–118, New York, NY, USA, 2006. ACM.

[10] Emerson Murphy-Hill and Andrew P. Black. High velocity refactorings in Eclipse. In *Proceedings of the 2007 OOPSLA workshop on Eclipse Technology eXchange*, New York, NY, USA, 2007. ACM. In Press.

[11] Eva van Emden and Leon Moonen. Java quality assurance by detecting code smells. In *Proc. 9th Working Conf. Reverse Engineering*, pages 97–107. IEEE Computer Society Press, October 2002.