How are IF-Conditional Statements Fixed Through Peer CodeReview?

Yuki UEDA\(^{a,}\), Nonmember, Akinori IHARA\(^1\), Takashi ISHIO\(^1\), Members, Toshiki HIRAO\(^1\), Nonmember, and Kenichi MATSUMOTO\(^1\), Fellow

SUMMARY Peer code review is key to ensuring the absence of software defects. To reduce review costs, software developers adopt code convention checking tools that automatically identify maintainability issues in source code. However, these tools do not always address the maintainability issue for a particular project. The goal of this study is to understand how code review fixes conditional statement issues, which are the most frequent changes in software development. We conduct an empirical study to understand if-statement changes through code review. Using review requests in the Qt and OpenStack projects, we analyze changes of the if-conditional statements that are (1) requested to be reviewed, and are (2) revised through code review. We find the most frequently changed symbols are "( )", ",", and "!". We also find project-specific fixing patterns for improving code readability by association rule mining. For example "!" operator is frequently replaced with a function call. These rules are useful for improving a coding convention checker tailored for the projects.

key words: codeReview, if statement, code readability

1. Introduction

Peer code review, a manual inspection of code changes by developers who do not create them, is a well-established practice to ensure the absence of software defects. Many open source software (OSS) and commercial projects have adopted the peer code review.

Code review requires much time [1]. Code review requires about 50% of the overall software development resources [2]. For example, patch authors tend to spend a long time revising their own patches due to technical issues [1]. Indeed, 75% of discussions in code review are about maintainability issues [3], [4].

To reduce the review cost, software developers adopt code convention checking tools that automatically identify general maintainability issues in source code. However, these tools just cover the general issues [5], in particular, programming languages. To completely detect maintainability issues, completely, reviewers may need to conduct code reviews manually with their own eyes.

The goal of our study is to understand how patch authors fix maintainability issues based on reviewers’ feedback. To understand maintainability issues, we focus on if-statement changes. Previous studies reported that since a change in if-statements frequently occur [6], [7], improving if-statement readability is important [8]. Tan et al. [9] also reported that binary operators in the conditional expression are more frequent changes in a programming contest. While if-statements are considered important, little is known about how if-statements are fixed in practical software development.

First, as a preliminary study, we identify frequently changed symbols of the if-conditional statements in submitted patches (Sect. 4). Secondly, we discover tacit fixing patterns between submitted patches and merged patches by using association rule mining (Sect. 5). As a case study, we target 69,325 patches in the Qt and 60,197 patches in the OpenStack project.

This paper is an extension of our previous study [10] in two ways. First, we analyze all symbols in programming languages (e.g., Arithmetic, Logical or Relational operators and String or Number literal). Second, the previous study obtained only Qt project written in C++ language. This paper includes OpenStack** project written in Python to obtain language-independent results.

This paper is structured as follows. Section 2 describes the background to our study. Section 3 introduces our target if-statement changes. Section 4 details an empirical study to analyze the changes in code review requests, and Sect. 5 presents our analysis of the changes through code reviewing. Section 6 considers the validity of our empirical study. Section 7 introduces related works. Section 8 concludes our study and discusses future works.

2. Background

Various dedicated tools exist for managing the peer code review process. Gerrit Code Review*** and ReviewBoard**** are commonly used by OSS practitioners to receive the lightweight reviews. Technically, these code review tools are used for patch submission triggers, automatic tests and manual reviewing to decide whether or not a patch should be integrated into a version control system.

Figure 1 shows an overview of the code review process in Gerrit Code Review which our target Qt and OpenStack projects that large OSS projects use as a code review man-

\(^{a}\)E-mail: ueda.yuki.un7@is.naist.jp
DOI: 10.1587/transinf.2018EDP7004
1. A patch author submits a patch to Gerrit Code Review. We define the submitted patch as Patch1.
2. The reviewers verify Patch1. They send feedback and ask to revise the patch if it has any issues.
3. The patch author revises Patch1 and submits the revised patch as Patch2. The revision process may be repeated n times. We define the last patch as Patchn.
4. Once the patch author completely addresses the concerns of the reviewers, the patch will be integrated into the project repository.

The validity of code review has been demonstrated by many prior studies [11]–[15]. Raymond et al. [16] discussed how code review is able to detect crucial issues in large-scale code before release. These prior studies show the relationship of software defects after release, anti-patterns in software design and security vulnerability issues.

While code review is effective in improving the quality of software artifacts, it requires a large amount of time and many human resources [2]. Rigby et al. [17] found that six large-scale OSS projects needed approximately one month to integrate a patch. Reviewers may disagree with one another and take even longer for discussion [18]. The process also requires identifying appropriate reviewers for each patch. Various methods are proposed to select appropriate reviewers based on the reviewer’s experience [19]–[23] and complexity of code changes [1].

Most published code review studies focused on review processes or the reviewers’ communications. They do not focus on source code changes through the review. We focus on source code changes especially if statements to clarify how a submitted patches were revised, because if-statements are the most frequently changed [6], [7], [9].


This section introduces if-statements fixed through code review. We investigate the changes between Patch1 and Patchn in Fig. 1.

This research targets the Qt and OpenStack projects. Qt is a cross-platform application framework, and OpenStack is a software platform for cloud computing, respectively. Table 1 shows the numbers of reviews, the numbers of if-statements changed in submitted patches (Patch1), and the numbers of if-statements fixed through code review. We sample 380 patches from the original Qt review dataset and then manually read them to identify typical fixing patterns. The sample size was used to obtain a proportion of patterns within the 5% bounds of the proportion with a 95% confidential level.

Listings 1 through 3 show concrete examples of if-fixing patterns between Patch1 and Patchn obtained from the Qt project. In Listing 1, a logical AND operator (“&&”) is deleted by splitting the condition into two if-statements†.

†https://codereview.Qt-project.org/#/c/16570/1..2/src/lib/tools/fileinfo.cpp
In Listing 2, a pair of a logical NOT operator (“!”) and a logical AND operator is replaced with a logical OR operator (“||”) and an additional NOT operator. In Listing 3, equality operators (“==” and “=”=”) are replaced with function calls.

This manual reading shows that code review often changes operators in conditional expressions of if-statements. Based on this observation, we characterize fixing patterns of if-statements using the numbers of symbols changed through code review. Section 4 details a preliminary study to analyze the changes in Patch1, and Sect. 5 finds fixing patterns between Patch1 and Patchn.

4. Preliminary Study: Source Code Changes in the Review Request

This section counts symbols changed in Patch1 to understand symbols frequently used in if-statements.

4.1 Approach

This study collects changes of if-statements in Patch1 obtained from the review management system. Each patch is represented by a unified diff format. Although all versions of source code are available in the source code repositories of the projects, we do not use the original source code in order to shorten the time to collect analysis data. We analyze if-statements whose conditional expression is written in a changed line. We excluded conditional expressions across multiple lines from analysis; this filtering is not a strong limitation since multi-line if-statements are included in only 425 (0.6%) patches of the Qt project and 553 patches (0.9%) of the OpenStack project. Our dataset includes 5,778 (Qt) and 7,725 (OpenStack) if-statements changed in the submitted patches. Also, each reviews have 4 (Median) changes in Qt project and 4 (Median) changes in OpenStack Project between Patch1 and Patchn.

We count the number of each symbol in the condition of each if-statement changed in Patch1. We employ ANTLR [24] with its official grammars for C++ and Python[13] to recognize reserved words and symbols used in conditional expressions. Note that the analyzed if-statements include else-if-statements(C++) and elif-statements(Python) in addition to regular if-statements. Figure 2 describes the process of data extraction.

We collect 176 reserved words and symbols in Qt and

<table>
<thead>
<tr>
<th>Table 1 Project summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>project name</td>
</tr>
<tr>
<td>Qt</td>
</tr>
<tr>
<td>OpenStack</td>
</tr>
</tbody>
</table>

124 reserved words and symbols in OpenStack. Table 2 shows the frequent program elements in patches. The column “Name” indicates the name of each element used in the rest of this paper. In this analysis, we excluded identifiers to simplify the result; various identifiers are used in conditional expressions.

To analyze the frequency in the co-occurrence of symbols, we apply closed frequent itemset mining. The mining provides a Support metric for a set of items. The metric represents the relative frequency with respect to the total number of transactions, i.e. if-statements changed in the patches.

We employ the arules package [25] as an implementation of the mining algorithm. We extract item sets whose size is at most five elements and whose Support score is equal to or greater than 0.01, since the mining results in a huge number of item sets. If an item set is a superset of another item set and has the same Support score, then the algorithm uses only the larger one. For example, a set {“LeftParen”, “RightParen”} is extracted and its subset {“LeftParen”} is filtered out, if the parentheses always appear as pairs.

4.2 Result

Figure 3 and Fig. 4 show the rate of symbols that appeared in more than 5% of all if-statements of Patch1. We extract 477 (Qt) and 162 (OpenStack) item sets obtained by frequent itemset mining whose Support score is greater than 0.01. Due to the limited space, Table 3 and Table 4
show frequent item sets whose Support score is greater than 0.10. For example, Id 1 in Table 3 shows “LeftParen”, “RightParen” which means “(” and “)” are included at the same time in the if-statement.

Parentheses are the most frequent symbols in the changed if-statements.

Table 2  Frequency appeared symbols list.

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol+</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal</td>
<td>==</td>
<td>compare same or not</td>
<td>if(a == b)</td>
</tr>
<tr>
<td>NotEqual</td>
<td>!=</td>
<td>compare not same or same</td>
<td>if(a != b)</td>
</tr>
<tr>
<td>Not</td>
<td>!</td>
<td>inverse logical result</td>
<td>if(!a)</td>
</tr>
<tr>
<td>And</td>
<td>&amp;&amp;</td>
<td>and condition</td>
<td>if(a &amp; &amp; b)</td>
</tr>
<tr>
<td>Or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LeftParen</td>
<td>(</td>
<td>surround condition or call function</td>
<td>if(a</td>
</tr>
<tr>
<td>RightParen</td>
<td>)</td>
<td>surround condition or call function</td>
<td>if(a</td>
</tr>
<tr>
<td>FunctionBrace++</td>
<td>func()</td>
<td>call function</td>
<td>if(func(a,b))</td>
</tr>
<tr>
<td>Bracket++</td>
<td>[]</td>
<td>reference list items and dictionaries (Python)</td>
<td>if(a[0])</td>
</tr>
<tr>
<td>Dot</td>
<td>.</td>
<td>reference individual members of classes</td>
<td>if(a.b())</td>
</tr>
<tr>
<td>Comma</td>
<td>,</td>
<td>separate expressions</td>
<td>if(func(a, b))</td>
</tr>
<tr>
<td>Less</td>
<td>&lt;</td>
<td>compare(greater than)</td>
<td>if(a &lt; b)</td>
</tr>
<tr>
<td>Greater</td>
<td>&gt;</td>
<td>compare(less than)</td>
<td>if(a &gt; b)</td>
</tr>
<tr>
<td>Arrow</td>
<td>-&gt;</td>
<td>call member from pointer</td>
<td>if(a&gt;b(l)</td>
</tr>
<tr>
<td>Doublecolon</td>
<td>::</td>
<td>reference individual members of classes</td>
<td>if(a:b())</td>
</tr>
<tr>
<td>In</td>
<td>(N/A)</td>
<td>identified one variable has another variable</td>
<td>if a in b:</td>
</tr>
<tr>
<td>Is</td>
<td>(N/A)</td>
<td>compare objects are same or not</td>
<td>if a is b:</td>
</tr>
<tr>
<td>None</td>
<td>(N/A)</td>
<td>represent the absence of a value</td>
<td>if a is None:</td>
</tr>
<tr>
<td>Number</td>
<td>1,2,3...</td>
<td>literal for number</td>
<td>if a &gt; 0:</td>
</tr>
<tr>
<td>String</td>
<td>“String”</td>
<td>literal for string</td>
<td>if a == &quot;a&quot;:</td>
</tr>
</tbody>
</table>

* (N/A) means the symbol is unavailable in the programming language of the project.
** the symbol will be used in Sect. 5

Fig. 3  Symbol change frequency with if-statement changes (Qt: C++).

Fig. 4  Symbol change frequency with if-statement changes (OpenStack: Python).

Qt: Figure 3 shows that parentheses (“LeftParen” and “RightParen”) are likely included in an if-statement. It should be noted that those numbers do not include the beginning and end parentheses for if-statements. While the parentheses often control the order of evaluation in a condi-
Listing 4  
Example of the added “(” and “)” to the function call

```c++
if (!QFileInfo(systemRoot() + "/epoc32/release/udeb/epoc.exe").exists())
    return false;
```

Listing 5  
Example of the added “!” to detecting the fail of function execution

```c++
if (!ComponentComplete() || !d->model || !d->model->isValid() )
    return;
```

As shown in Listing 4, in two projects, the parentheses also call functions representing some conditions. An example of such function call is shown in Listing 4. 

OpenStack: Figure 4 shows that parentheses also frequently appear in OpenStack. However, the frequency of parentheses is lower than Qt project, because some functions in C++ are defined as reserved words in Python standard library. For example, “std::find” function in C++ are semantically similar to “in” reserved words in Python. Also, a patch author might define functions instead of “is” to compare objects.

“Dot” and “Not” are frequently used in the if-statements. “Dot” is used for accessing a member of an object, and it is frequently used in both projects. “Not” is used to inverse logical result. In Table 3 and Table 4, approximately 30% if-statements used “Not” in two projects. The “Not” reserved word or symbol is often used to detect the fail of a function execution as in Listing 4 or to use the output of a function as in Listing 5.

Qt: In Table 3, the Support score of “Dot” with “Parentheses” are 30.1% (Id 4) of all’s “Dot” 34.3 (Id 2). Qt project could have used “Dot” to call other object’s function.

OpenStack: While “Dot” is the most frequently changed symbol with if-statement changes, nearly half of if-statements used “Dot” symbols (Id 1 in Table 4).

5. Analysis: Source Code Fixes after Review

This section extracts symbol changes as a fixing pattern between Patch1 and Patchn by using association rule mining.

5.1 Approach

This analysis describes how a patch author fixed if-statements through the review. In this section, we identify changed if-statements using diffs’ changed chunks between source code that has been fixed by Patch1 and Patchn. Figure 5 shows an approach to extract fixed symbols.

1. Get the added single line with includes the if-statement
2. Count the number of symbols in 3,343 if-statements for Qt and 3544 if for OpenStack statements that the patch author fixed from Patch1 to Patchn. For example, Fig. 5 shows one “&&” and two “!” changes in Patch1. After reviewing Patch1 to Patchn, the patch author added “||”, “&&” and “!” in Patchn, and deleted “&&” and “!”.
3. Compare the difference in the number of symbols between Patch1 and Patchn such as “And_deleted” (And symbol(s) is deleted between Patch1 and Patchn), “Or_added” (Or symbol(s) is added between Patch1 and Patchn), “LeftParen_added”, “RightParen_added” and “Not_deleted” to understand changed contents.

Using this dataset, we conducted an empirical study to understand the fixed symbols through code review using an association rule mining technique that is a popular method for the generation of usage rules [26], [27].
Fig. 5) by the association rule mining.

1. Replaced symbols pairs
   (e.g. “And_deleted” ⇒ “Or_added”)
2. Added symbols pairs
   (e.g. “And” ⇒ “Or_added”)

We measure three evaluation scores from the association rule mining. They are Support, Confidence and Lift. Support of a rule is its relative frequency with respect to the total number of transactions in the history. Confidence is its relative frequency of the rule with respect to the number of historical transactions containing the antecedent LHS.

\[
\text{Confidence}([\text{LHS}] \Rightarrow [\text{RHS}]) = \frac{\text{Support}([\text{LHS}] \Rightarrow [\text{RHS}])}{\text{Support}(\text{LHS})}
\]

Lift measures the magnification of the data where pre-condition LHS and post-condition RHS exist in rules with post-condition RHS.

\[
\text{Lift}([\text{LHS}] \Rightarrow [\text{RHS}]) = \frac{\text{Confidence}([\text{LHS}] \Rightarrow [\text{RHS}])}{\text{Support}(\text{RHS})}
\]

For association rule mining, we use the arules package again. Since the association rule mining outputs many rules, we extract item sets with less than 6 items as well as the extracted item sets whose support score is greater than 0.01, confidence score is greater than 0.1, and Lift score is greater than 1.0.

In our preliminary study, we found that more than 99% of “LeftParen” and “RightParen” pairs represent function calls. Similarly, “LeftBracket” and “RightBracket” pairs usually represent array access. Hence, we regard those pairs as “FunctionBrace” and “Bracket” in this analysis.

5.2 Result

Figures 6 and 7 show the rate of fixed symbols that appeared is more than 5% of all if-statement fixes. Table 5 and Table 6 show the extracted 7 rules and 31 rules for the fixing patterns from Qt and OpenStack by association rule mining.

Observation 1: If-statement fixes frequently add or delete FunctionBrace through code review.

Qt: 35% of if-statement are added (23%) or deleted (12%) FunctionBrace in Fig. 6. In our manual reading, we found that there are examples for excepting redundant function calls (Listings 6) or including necessary function calls (Listings 7).

OpenStack: From Fig. 7, “FunctionBrace” frequently deleted or added too. 40% of if-statements are added (20%) and deleted (20%) in FunctionBrace in Fig. 7. As we showed in our preliminary study, these findings are according to the python language in OpenStack such as the reserved words (“in” and “is”) instead of the functions (“contain” and “equal”).

Observation 2: Patch authors are likely to replace “Not” with “FunctionBrace” through code review in Qt project. Figure 6 shows the rate of “Not” is likely to be deleted (13% for “Not_deleted”) more than added (6% for “Not_added”) through code review. From Id 4 in Table 5, we found that “Not” is likely to be deleted to use

\[https://codereview.Qt-project.org/#c/1779/1..2/src/plugins/qmlprojectmanager/qmlprojectruncontrol.cpp\]

\[https://codereview.Qt-project.org/#c/1843/1..2/src/plugins/qt4projectmanager/qt-desktop/simulatorqt\version.cpp\]
**Table 5** Frequency of changed symbol sets with 3,343 if fixes (sort by Lift) (Qt: C++)

<table>
<thead>
<tr>
<th>Id</th>
<th>LHS</th>
<th>RHS</th>
<th>Support * 100</th>
<th>Confidence * 100</th>
<th>Lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FunctionBrace, Doublecolon_deleted</td>
<td>Arrow_added</td>
<td>1.0</td>
<td>30.4</td>
<td>4.03</td>
</tr>
<tr>
<td>2</td>
<td>Number_deleted</td>
<td>Not_added</td>
<td>1.1</td>
<td>24.8</td>
<td>3.89</td>
</tr>
<tr>
<td>3</td>
<td>Doublecolon_deleted</td>
<td>Arrow_added</td>
<td>1.0</td>
<td>24.8</td>
<td>3.29</td>
</tr>
<tr>
<td>4</td>
<td>Not_deleted</td>
<td>FunctionBrace_added</td>
<td>10.0</td>
<td>72.8</td>
<td>3.20</td>
</tr>
<tr>
<td>5</td>
<td>Doublecolon, FunctionBrace</td>
<td>Arrow_added</td>
<td>1.2</td>
<td>13.9</td>
<td>1.84</td>
</tr>
<tr>
<td>6</td>
<td>FunctionBrace_deleted</td>
<td>Not_added</td>
<td>1.2</td>
<td>11.7</td>
<td>1.84</td>
</tr>
<tr>
<td>7</td>
<td>Not</td>
<td>FunctionBrace_added</td>
<td>11.6</td>
<td>36.2</td>
<td>1.59</td>
</tr>
</tbody>
</table>

**Table 6** Frequency of changed symbol sets with 3,544 if fixes (sort by Lift) (OpenStack: Python).

<table>
<thead>
<tr>
<th>Id</th>
<th>LHS</th>
<th>RHS</th>
<th>Support * 100</th>
<th>Confidence * 100</th>
<th>Lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is_added, Number_deleted</td>
<td>None_added</td>
<td>1.0</td>
<td>94.9</td>
<td>15.42</td>
</tr>
<tr>
<td>2</td>
<td>None_added, Number_deleted</td>
<td>Is_added</td>
<td>1.0</td>
<td>100.0</td>
<td>15.15</td>
</tr>
<tr>
<td>3</td>
<td>Is_added, FunctionBrace_deleted</td>
<td>None_added</td>
<td>1.1</td>
<td>90.5</td>
<td>14.71</td>
</tr>
<tr>
<td>4</td>
<td>FunctionBrace, FunctionBrace_added, Bracket_deleted</td>
<td>Dot_added</td>
<td>1.2</td>
<td>97.8</td>
<td>5.54</td>
</tr>
<tr>
<td>5</td>
<td>FunctionBrace_added, Bracket_deleted</td>
<td>Dot_added</td>
<td>1.3</td>
<td>95.9</td>
<td>5.43</td>
</tr>
<tr>
<td>6</td>
<td>FunctionBrace_added, String_deleted</td>
<td>Dot_added</td>
<td>1.9</td>
<td>89.5</td>
<td>5.07</td>
</tr>
<tr>
<td>7</td>
<td>Dot_added, In_deleted</td>
<td>FunctionBrace_added</td>
<td>1.7</td>
<td>92.2</td>
<td>4.52</td>
</tr>
<tr>
<td>8</td>
<td>String, FunctionBrace_added, In_deleted</td>
<td>Dot_added</td>
<td>1.3</td>
<td>79.3</td>
<td>4.49</td>
</tr>
<tr>
<td>9</td>
<td>String, Equal_deleted</td>
<td>In_added</td>
<td>1.2</td>
<td>20.4</td>
<td>3.21</td>
</tr>
<tr>
<td>10</td>
<td>String, FunctionBrace, Bracket_deleted</td>
<td>Dot_added</td>
<td>2.1</td>
<td>40.3</td>
<td>2.28</td>
</tr>
<tr>
<td>11</td>
<td>String, Bracket_deleted</td>
<td>Dot_added</td>
<td>2.2</td>
<td>39.8</td>
<td>2.23</td>
</tr>
<tr>
<td>12</td>
<td>String, FunctionBrace_deleted</td>
<td>In_added</td>
<td>1.2</td>
<td>13.9</td>
<td>2.19</td>
</tr>
<tr>
<td>13</td>
<td>Equal_deleted, FunctionBrace_deleted</td>
<td>Not_added</td>
<td>1.4</td>
<td>33.8</td>
<td>2.15</td>
</tr>
<tr>
<td>14</td>
<td>None, Is_deleted</td>
<td>Not_added</td>
<td>1.8</td>
<td>33.0</td>
<td>2.09</td>
</tr>
<tr>
<td>15</td>
<td>Is_deleted, None_deleted</td>
<td>Not_added</td>
<td>1.7</td>
<td>32.8</td>
<td>2.08</td>
</tr>
<tr>
<td>16</td>
<td>Is, None_deleted</td>
<td>Not_added</td>
<td>1.7</td>
<td>32.6</td>
<td>2.07</td>
</tr>
<tr>
<td>17</td>
<td>String_deleted, Bracket_deleted</td>
<td>Dot_added</td>
<td>1.6</td>
<td>36.4</td>
<td>2.06</td>
</tr>
<tr>
<td>18</td>
<td>Is_deleted</td>
<td>Not_added</td>
<td>2.0</td>
<td>32.0</td>
<td>2.03</td>
</tr>
<tr>
<td>19</td>
<td>None_deleted</td>
<td>Not_added</td>
<td>1.9</td>
<td>31.8</td>
<td>2.02</td>
</tr>
<tr>
<td>20</td>
<td>Number_deleted</td>
<td>Not_added</td>
<td>2.1</td>
<td>31.5</td>
<td>2.00</td>
</tr>
<tr>
<td>21</td>
<td>FunctionBrace, Bracket_deleted</td>
<td>Dot_added</td>
<td>2.3</td>
<td>35.0</td>
<td>1.98</td>
</tr>
<tr>
<td>22</td>
<td>String, In_deleted</td>
<td>Dot_added</td>
<td>1.4</td>
<td>34.5</td>
<td>1.95</td>
</tr>
<tr>
<td>23</td>
<td>Bracket, String_deleted</td>
<td>Dot_added</td>
<td>1.7</td>
<td>34.3</td>
<td>1.94</td>
</tr>
<tr>
<td>24</td>
<td>Bracket_deleted</td>
<td>Dot_added</td>
<td>2.4</td>
<td>34.3</td>
<td>1.94</td>
</tr>
<tr>
<td>25</td>
<td>String, In_deleted</td>
<td>FunctionBrace_added</td>
<td>1.6</td>
<td>39.2</td>
<td>1.92</td>
</tr>
<tr>
<td>26</td>
<td>FunctionBrace, Equal_deleted</td>
<td>Not_added</td>
<td>2.1</td>
<td>29.0</td>
<td>1.84</td>
</tr>
<tr>
<td>27</td>
<td>In_deleted</td>
<td>FunctionBrace_added</td>
<td>2.2</td>
<td>37.4</td>
<td>1.83</td>
</tr>
<tr>
<td>28</td>
<td>Equal_deleted</td>
<td>Not_added</td>
<td>2.6</td>
<td>28.4</td>
<td>1.81</td>
</tr>
<tr>
<td>29</td>
<td>In_deleted</td>
<td>Dot_added</td>
<td>1.8</td>
<td>31.1</td>
<td>1.76</td>
</tr>
<tr>
<td>30</td>
<td>None</td>
<td>Not_added</td>
<td>2.8</td>
<td>24.7</td>
<td>1.57</td>
</tr>
<tr>
<td>31</td>
<td>String, Bracket</td>
<td>Dot_added</td>
<td>3.2</td>
<td>26.3</td>
<td>1.49</td>
</tr>
</tbody>
</table>

**Listing 8** Example of the deleted “!” to make clear the object’s type

Source 1
```python
if (! hoverItems)
```

Source n
```python
if (hoverItems.isEmpty())
```

“FunctionBrace” as in Listing 8. In this example, using the function instead of “Not” made it easier for the developer to understand object’s type such as the array. Also, from Id 6 in Table 5, “FunctionBrace” is less likely to be deleted to use “Not”. Hence, we found that the Qt project often used “FunctionBrace” instead of “Not” as one of the project specific rules.

Observation 3: Patch authors are likely to delete “String” through code review in the OpenStack project.

When using python, some patch authors often use “String” and “Bracket” to identify the object’s dictionary status. However, we found in Id 5, 6 in Table 6, “String” or “Bracket” should be replaced with “Dot” to call the function in OpenStack as in Listing 9†† or Listing 10†††. In Listing 9, the patch author improved readability by using “bytes.startswith()” and “.endswith()”, especially expecting “String”. In Listing 10, the patch author deleted “String” to reduce access to “values”. Replacing “Dot” with “Bracket” not only improves maintainability but avoids the error. Hence, our approach can extract rules for not only maintenance but can contribute to improving quality.

††https://review.openstack.org/#/c/60425/1..3/cafe/engine/http/behaviors.py
†††https://review.openstack.org/#/c/15708/1..5/glance/db/sqlalchemy/apt.py
Conventions

The OpenStack (Python) project replaces reserved
words with “Number” and “String” through code re-
view. Python has reserved words such as “in” and “not”.
These reserved words instead of used “0” and the dic-
tionary to improve readability and to avoid the index
errors.

The concept of these project-specific rules are simi-
lar for improving readability and maintainability. However,
the concrete rules are difference between programming lan-
guages or projects. Our approach extracted the project-
specific concrete rules that are not supported by current cod-
ning check tools like pylint†††.

6. Threats to Validity

6.1 Internal Validity

A factor that potentially affects the internal validity of our
study is that we extracted symbol changes in if-statement
by syntactic analysis to extract fixed code patterns through
code review. The changes are analyzed based on the patch
files and the original source code to identify spots with if-
statements. However, to collect the original source code,
we focused on patch files and we collected if-statements on
each single line change. This methodology has no signifi-
cant impact on our results since the number of if-
statement changes across multiple lines is merely 425 patches of our
target 69,325 patches (0.6%) and 553 patches out of Open-
Stack project’s 60,197 patches (0.9%).

We collected not only if-condition statements, but also
switch, and for and while condition statements. Switch, for and while condition statements do not appear more fre-
quently than the if-statements in the code review as with
integrated code changes[6].

Also, we compared Patch1 and Patchn to detect source
code changes in code review. Although the number of changed times (size of n) may be related to change contents,
the analysis is out of scope of this paper.

6.2 External Validity

The project-specific nature of our dataset has many limits.
This research conducted an empirical study using only the
Qt and OpenStack project code review dataset. When we
target the other projects, some findings of our study may be
different. For example, other projects may use “<” or “>”
in Table 3 instead of “>” or “<”. Despite such variabil-
ity, we contend that our approach should provide a frame-
work for understanding individual rules or trend fixes in
each project.

7. Related Work

7.1 Code Review

Many researchers have conducted empirical studies to un-
derstand code review[3], [4], [11]–[15], [29], [30]. Un-
like our focus most published code review studies focus on
the review process or reviewers’ communication. For ex-
ample, Tsay et al. found those patch authors and reviewers
often discuss and propose solutions with each other to fix
patches[29]. In particular, Czerwonka et al.[30] found that
15% of the discussions for patch fixes are about functional
issues while Mäntylä et al. [3] and Beller et al.[4] found that
75% of discussions for patch fixes are about software main-
tenance and 15% are about functional issues. These studies
help us understand which issues should be solved in the code
review process and our work focuses on how those issues
are fixed. Towards this goal, we focused on source code

Listing 9 Example of the replacing “Bracket” with
“FunctionBrace” to avoiding index error

<table>
<thead>
<tr>
<th>Source 1</th>
<th>Source n</th>
</tr>
</thead>
<tbody>
<tr>
<td>if bytes_[0] != '-' and bytes_[1] != '-'</td>
<td></td>
</tr>
</tbody>
</table>

Listing 10 Example of the deleting “String” to reduce
the value access

<table>
<thead>
<tr>
<th>Source 1</th>
<th>Source n</th>
</tr>
</thead>
<tbody>
<tr>
<td>if 'size' in values and values['size']</td>
<td></td>
</tr>
<tr>
<td>if values.get('size') is not None</td>
<td></td>
</tr>
</tbody>
</table>

5.3 Summary

In summary, we found valuable code fixing patterns that can
be an additional coding rule to reduce the costs of a reviewer.
Also, we compared our fixing rules to each projects’ cod-
ing rules (Qt† and OpenStack††). Our fixing rules are not included in these rules. Hence, the fixing rules that we iden-
tified are valuable for patch authors to reduce redundant fix.
We can recommend to reviewers the symbols that are likely
to be fixed in the submitted patch (Patch1).

- The Qt (C++) project is likely to replace “Not” with
  function calling through code review.

- The OpenStack (Python) project replaces reserved
  words with “Number” and “String” through code re-
  view

†https://wiki.qt.io/Coding_Conventions
††https://docs.openstack.org/hacking/latest/user/hacking.html
†††https://www.pylint.org/
changes through code review, specifically those involving `if` changes.

7.2 Coding Conventions

Code convention issues also relate to our study because some code reviews are refactoring based on coding convention [5], [31], [32]. Smit et al. [32] found that CheckStyle is useful for detecting whether or not source codes follow its coding rules. Also, some convention tools such as Pylint released by Thennault check the format of coding conventions. In addition, Allamanis et al. [33] have developed a tool to fix code conventions. However, to the best of our knowledge, little is known about how a patch author fixes conditional statement issues based on reviewers feedback.

8. Conclusion

This research conducted an empirical study on how `if`-statements are fixed based on reviewers feedback.

The results of our case study on the Qt and OpenStack project showed that in each specific fixing pattern that approximately 35% of the code is likely to be added or deleted parentheses through code review. The contribution of this study is the discovery of frequent patterns for fixing `if`-statements through code review. We think this, in turn, may help to design an issue detection approach. Also, we created a coding convention checker that detects project-specific rules. If a patch author detects the possibility of changing these symbols before the code review request, the reviewers might be able to spend more time on other additional review requests and thus save time and costs.

In the future, we intend to propose a method to review and automatically fix a symbol in `if`-statements, such as a change impact analysis that can be conducted based on code review data with a history of integrated code changes.

Acknowledgments

We would like to thank the Support Center for Advanced Telecommunications (SCAT) Technology Research Foundation. This work was supported by JSPS KAKENHI Grant Number JP17J09333 and 17H00731. For proofreading our paper, thanks to Prof. Hiromi Teramoto.

References


[33] Akinori Ihara received the B.E. degree in Science and Technology from Ryukoku University, Japan in 2007, and the ME degree (2009) and DE degree (2012) in information science from Nara Institute of Science and Technology, Japan. He is currently Assistant Professor at Nara Institute of Science and Technology. His research interests include program analysis, program comprehension, and software reuse. He is a member of the IEEE and IPSJ.

Takashi Ishio received the Ph.D. degree in information science and technology from Osaka University in 2006. He was a JSPS Research Fellow from 2006–2007. He was an assistant professor at Osaka University from 2007–2017. He is now an associate professor of Nara Institute of Science and Technology. His research interests include program analysis, program comprehension, and software reuse. He is a member of the IEEE, ACM, IPSJ and JSSST.

Toshiki Hirao is currently working in the Ph.D. Program in Information Science at Nara Institute of Science and Technology in Japan. He has been a fellowship researcher of the JSPS (DC1) since April 2017. His research interests include empirical software engineering and mining software repository. He received the B.E. degree (2015) in department of education from Osaka Kyoiku University, and the M.E. degree (2017) in Information Science from Nara Institute of Science and Technology.

Kenichi Matsumoto received the B.E., M.E., and Ph.D. degrees in Engineering from Osaka University, Japan, in 1985, 1987, 1990, respectively. Dr. Matsumoto is currently a professor in the Graduate School of Information Science at Nara Institute Science and Technology, Japan. His research interests include software measurement and software process. He is a senior member of the IEEE and a member of the IPSJ and SPM.