Readability and Understandability Scores for Snippet Assessment: an Exploratory Study

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ABSTRACT
Code search engines usually use readability feature to rank code snippets. There are several metrics to calculate this feature, but developers may have different perceptions about readability. Correlation between readability and understandability features has already been proposed, i.e., developers need to read and comprehend the code snippet syntax, but also understand the semantics. This work investigates scores for understandability and readability features, under the perspective of the possible subjective perception of code snippet comprehension. We find that code snippets with higher readability score has better comprehension than lower ones. The understandability score presents better comprehension in specific situations, e.g., nested loops or if-else chains. The developers also mentioned writability aspects as the principal characteristic to evaluate code snippets comprehension. These results provide insights for future works in code comprehension score optimization.

KEYWORDS
readability, understandability, code snippets, likert, code comprehension

1 INTRODUCTION
Code snippets (or code examples) are some lines of source code that can be reused to show how the developer can solve a specific programming task [9]. Developers often search for good reusable code snippets on the web [24]. In average, developers spend 70% of their time reading programs [14]. Some code search engines usually use readability metrics [21] [19] [3] trying to improve the code snippets ranking [8] [15]. These metrics have been employed in recent research, for instance to recommend readable APIs in code snippets [8] or to evaluate readability changes in projects history [18].

However, developers could have subjective perceptions of what means a readable code snippet. The readability metrics are often evaluated with personal opinions as response variable [16]. Consequently, these metrics could produce false positives/negatives. A potential opportunity to mitigate these mismatches in perception would be combining readability with other related features. Developers need to read and comprehend the code snippet syntax, but also need to understand the code snippet semantic, e.g., the statements, beacons or motifs [20]. If a source code is difficult to read, it is also difficult to understand [2]. Some metrics have also been proposed to calculate source code understandability [11] [12] [4]. For instance, the cognitive complexity metric of SonarSource tool1 is related with some aspects of understandability [1].

1 http://apisonar.com/

The main goal in this research is to investigate readability and understandability metric scores on code snippets, to verify their usability on code snippet comprehension assessment. We organize the investigation with the following research questions:

RQ #1) To what extent the readability and understandability metric scores can be used to code snippet assessment?

RQ #2) Which characteristics are important to developers on code snippets comprehension evaluation?

To evaluate the metric scores, we asked for five senior developers experienced in approve pull requests on git repositories (i.e., read, understand and evaluate source code produced by other developers) written in Java language, to evaluate the comprehension of two code snippets extracted from Google and CROKAGE for 30 input queries. A final open question was proposed for them to answer about the relevant code snippets characteristics in their evaluation.

The paper is organized as follows. Section 2 shows a motivating example. Section 3 discusses the related literature. Section 4 presents the study design proposed to collect data, modeling and data analysis approach. The results are reported and discussed in Section 5. Section 6 presents the threats that could affect the validity of this study. Finally, Section 7 summarizes our observations in lessons learned, and outlines directions for future work.

2 MOTIVATING EXAMPLE
A motivating example of subjective perceptions is shown in Figure 1. This example has the first code snippet suggested by Google, Microsoft Bing and CROKAGE 2 (tool that provides code snippets and their correspond comprehensive solution for each input query, both mined from Stack Overflow [5]) for the input query Find maximum element of ArrayList in Java. The Table 1 shows the readability [21] and understandability [4] score for each suggested code snippet. The CROKAGE code snippet has the lowest LOC (lines of code), but Google code snippet has more comments, and the Collections.max() method is implemented in a separate line. In CROKAGE, the line 13 has two concepts in the same line, which decreases the readability score in the used metric. The Microsoft Bing code snippet has highest LOC, and contains for loop statement instead the Collections.max() API call. In readability score, the CROKAGE code snippet is nearest to Microsoft Bing. But in understandability score, CROKAGE and Google has the same value, both better than Microsoft Bing code snippet.

The example shows the readability score could have divergent opinions, because some developers could prefer the lowest LOC instead of one concept per line. In this example, the understandability score has the trade-off between internal API call or a for-loop

2 http://isel.ufu.br:9000/
statement, which could be less divergent than readability metric because generally snippets using internal APIs has less complexity and are reusable in other programs [15]. The readability and understandability metrics could complement each other on code comprehension.

Table 1: Readability and understandability (higher is better) scores for Google, Microsoft Bing and CROKAGE code snippets in Figure 1

| Web Search Engine | Readability | Understandability |
|-------------------|-------------|--------------------|
| Google            | 0.67        | 1.0                |
| Microsoft Bing    | 0.51        | 0.8                |
| CROKAGE           | 0.55        | 1.0                |

3 RELATED WORK

Several code search engines have been purposed to rank code snippets using the readability feature as part of the overall score. Hora [7] investigated how Google, a general-purpose web search engine rank the code snippets in terms of readability and reusability features. Their findings show that readable and reusable code snippets are not necessarily top ranked, but other aspects as didactic code snippets or pages with multiple code snippets are more likely to be top ranked. Our research is not interested in discover how Google rank their code snippets, but to provide insights if readable and understandable code snippets are relevant for developers, and then other future researches could use these features as a part of overall score on new code search engines.

In other research, Hora [8] constructed the API Sonar tool, mining code snippets from 100 Java APIs on github to generate collections of API code snippets. He is also using readability to top rank readable API code snippets. The insights in our research could be useful to provide a better ranking, considering understandability in certain situations. Moreno et al. develop the Muse approach to rank code snippets producing an overall score using readability and reusability feature. But this research has employed other readability approach [3], and the other mentioned researches has used the Scalabrino et al. readability approach [20].

Another features could be used to produce an overall score. Oliveira et al. [16] introduced a separation between readability and legibility features, where legibility is related to how easy to identify elements in a program. For example, code without indentation or more than one statement in the same line contributes to decrease legibility. The readability tool used in this research consider some legibility aspects on their metrics, e.g., one concept per line.

Some researches studied the correlation between readability and understandability features. Boehm et al. [2] pointed the source code readability is related to its respective complexity and understandability, i.e., if the source code is difficult to read, it is also difficult to understand. But even easy-to-read source code can be difficult to understand, as presented by Scalabrino et al. [20]. Therefore, read-ability and understandability are employed as different features: while readability measures the effort to understand a code snippet in syntactic aspect, understandability measures complexity in dynamic aspect [19], i.e., both metrics complement each other in measure code comprehension.

The understandability feature has divergent results about metrics. Scalabrino et al. [20] made a study with 121 distinct metrics and found that none of them is relevant to measure understandability. However, Marvin et al. [1] found correlations between cognitive complexity metric [4] with subjective ratings of understandability, which is a relatively positive insight about the effectiveness of this metric. The cognitive complexity proposal is similar to the cyclomatic complexity of McCabe [13]. However, cognitive complexity aims to mitigate the limitations of cyclomatic complexity, such as source code nesting problem [22], and address modern language structures such as try/catch or lambdas.

4 STUDY DESIGN

The Figure 2 shows the overall approach to answer the two research questions. The major steps are: (1) Select Input Queries, (2) Extract Code Snippets, (3) Collect Metrics Values and (4) Developers Evaluation. The details of each step is in the following subsections. A replication package, including the readability and understandability tools, as the questions, code snippets characteristics, evaluations and the instructions for reproduction is available [6].
To measure understandability, we use the cognitive complexity code-based metric proposed by Campbell [4] and available in SonarSource tool. This metric were evaluated and employed in some past reaseaches [1] [23]. To measure understandability, we propose an adoption metric as follows:

$$\text{understandability}(cs_i) = \begin{cases} 1 - \frac{\#c_c}{\#mcc} & \text{if } \#c_c < 15 \\ 0.0 & \text{otherwise} \end{cases}$$

\(\#c_c\) is the complexity cognitive score extracted from SonarSource tool for the code snippet \(cs_i\). \(\#mcc\) is the maximum recommend complexity cognitive value \(6\), \#mcc = 15. If a code snippet reaches \#cc >= 15, the score output will be 0. This metric produces scores between 0 (low understandability) and 1 (high understandability).

4.4 Developers Evaluation

We invited five senior developers to analyse the comprehension of 60 code snippets. These developers are (5+ years) experienced as team leaders on Java projects, and they often evaluate pull requests submitted from other developers on their teams. Pull requests are usually rejected because could have issues in code comprehension or understanding [17].

For each of the 30 queries, the code snippets of each solution (Google and CROKAGE) were presented side by side, and asked for the developers to provide a likert value from 1 to 5 for the comprehension of each suggested code snippet. The code snippets for 30 questions are distributed on the following criteria:

1. 10 questions with higher readability in one code snippet and similar understandability in both code snippets.
2. 10 questions with higher understandability in one code snippet and similar readability in both code snippets.
3. 10 questions with higher readability and understandability in one code snippet compared to the other.

The objective is to obtain the developers comprehension evaluation on each feature isolated, and both combined, to evaluate if the code snippets with better readability and understandability score are significant better evaluated than the lower ones. And finally, the developers answered in a open question the characteristics they included to evaluate each code snippet comprehension.

5 RESULTS AND FINDINGS

In this section, the results will be shown according to each research question. This research used Krippendorff’s \(\alpha\) reliability coefficient [10] to verify the agreement between the five developers. We obtained \(\alpha = 0.334\), which is a low agreement. Only six of 30 code snippets with higher score had perfect agreement between the developers, as the same with one of 30 code snippets with lower score. The low agreement implies a subjective source code comprehension analysis.

RQ #1) To what extent the readability and understandability metric scores can be used to code snippet assessment

The Table 2 shows the likert evaluation results. We run Wilcoxon signed-rank test using a confidence level of 99% (p-value<0.01), and the comprehension of code snippets with higher readability score are statistically better than snippets with lower readability score. The Figures 4a and 4c shows a better rate for code snippets 3
with higher readability score. This result indicates the readability score match the developers perception on code comprehension. The Figure 4b shows statistically the same rate for higher and lower understandability score (as shown in Table 2), i.e., in this analysis, the understandability score is not relevant for the five developers on code snippets comprehension.

We investigate the understandability likert evaluation, and more significant likert differences were found in specific situations. For example, some code snippets with higher understandability code uses internal Java API methods to implement the task, and the code snippet with lower understandability score is using nested loops or if-else chains. However, the developers did not pointed difficult to comprehend few addictions of loop, condition or try/catch block on code snippets with lower understandability score. We extracted the highest understandability score differences between code snippets, and in this scenario, the effect size increases to $0.812$ with p-value $< 0.01$ and effect-size $0.838$.

Table 2: P-value and effect-size values for each feature

| Feature                  | p-value | effect-size |
|--------------------------|---------|-------------|
| Readability              | < 0.01  | 0.857       |
| Understandability        | 0.91    | -           |
| Readability + Understandability | < 0.01  | 0.838       |

RQ #1 Answer: The readability score is associated with code snippets comprehension, but the low agreement between developers suggests subjective perception. The understandability score is related to code comprehension in specific situations, e.g., nested loops or if-else chains. These specific situations has higher difference on code snippets understandability score.

RQ #2) Which characteristics are important to developers on code snippets comprehension evaluation?

The Table 3 shows the mentioned characteristics on code snippets evaluation. Four of five developers (80%) mentioned writability aspects, (e.g., simplicity and clarity on write code, expressiveness on self documented source code avoiding comment lines). Three of five developers (60%) mentioned about aspects of variables and methods (e.g., camel case pattern, easy naming comprehension, variable declarations aspects as default values). Also three of five developers (60%) mentioned comments, but all of them mentions that comments are only useful for source code with higher complexity. In their opinion, comments increases the number of lines, and may not be useful for code comprehension, giving a larger extension than the necessary. Other three of five developers (60%) mentioned complexity. Some nested for loops and if else chains were used in some code snippets instead of simple Java internal API calls. The reusability aspect was mentioned, i.e., more complex code snippets is more difficult to reuse in other software development project. One developer mentioned LOC, because in his opinion, fewer lines written in Java is generally easier to comprehend. Finally, one developer mentioned performance, i.e., if the solution is appropriate to run in production environment.

Table 3: Characteristics mentioned by the developers on code snippets evaluation

| Characteristic                  | % mentions |
|---------------------------------|------------|
| Writability                     | 80%        |
| Variable and method aspects     | 60%        |
| Comments                        | 60%        |
| Complexity                      | 60%        |
| Lines of Code (LOC)             | 20%        |
| Performance                     | 20%        |

RQ #2 Answer: Some characteristics mentioned by developers are related to readability feature (variable and method aspects, comments, LOC) and understandability feature (complexity). However, most of the developers mentioned aspects of writability, which opens for new approaches investigating metrics for this characteristic.

6 THREATS TO VALIDITY

The main threat in this research is related to study generalization (programming language, number of participants, number of queries and code snippets).

Programming Language: the results are restricted to Java programming language, specially because limitations of the queries and the readability tool. The cognitive complexity tool supports more programming languages, e.g., Python, Javascript.
Number of participants: the five senior developers work in different companies (i.e., different core business and applications). We try to mitigate the few number of developers selecting team leaders with experience in evaluate and approve pull requests written by other developers. But novice developers could have different perceptions about readable and understandable code snippets.

Number of queries and code snippets: this research extracted 60 code snippets for 30 queries. A higher number of queries is an important factor to future research (e.g. produce an unified score using a combination of features).

False positives/negatives: the readability and understandability metrics could have some false positives. Complexity cognitive metric uses static heuristics. To minimize the effect, we manually analysed the score of each code snippet.

7 CONCLUSIONS AND FUTURE WORK

In this exploratory study, a quality analysis is conducted across code snippet comprehension using readability and understandability metric score. Our findings suggest the readability score could be used on code snippet assessment, e.g., code search engines. The understandability score have more subjective perceptions, specially in lower score differences between code snippets.

These results provide insights for several improvements. Future research could propose an empirical study to optimize a new unified score based on fuzzy matrix. In 2008 IEEE International Conference on Fuzzy Systems (IEEE World Congress on Computational Intelligence) 887–892.

Figure 4: Box plots of Code Snippets comprehension

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