

Mea culpa: How developers fix their own simple bugs differently from other developers

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Abstract—In this work, we study how the authorship of code affects bug-fixing commits using the *SStuBs* dataset, a collection of single-statement bug fix changes in popular Java Maven projects. More specifically, we study the differences in characteristics between simple bug fixes by the original author — that is, the developer who submitted the bug-inducing commit — and by different developers (i.e., non-authors). Our study shows that nearly half (i.e., 44.3%) of simple bugs are fixed by a different developer. We found that bug fixes by the original author and by different developers differed qualitatively and quantitatively. We observed that bug-fixing time by authors is much shorter than that of other developers. We also found that bug-fixing commits by authors tended to be larger in size and scope, and address multiple issues, whereas bug-fixing commits by other developers tended to be smaller and more focused on the bug itself. Future research can further study the different patterns in bug-fixing and create more tailored tools based on the developer’s needs.

Index Terms—*SStuBs*, bug fix, empirical software engineering, Open source, Open source development

I. INTRODUCTION

Research has shown that both bugs [1] and bug fixes [2] have different patterns. For example, fixing GUI related bugs is different from fixing database related bugs. Fixing GUI bugs often involves manual inspection of the GUI and is hard to automate. On the other hand, database related bugs often require extra attention to avoid damaging the integrity of the underlying database. A deeper understanding of how and why bugs occur can help developers focus on the weaker aspects of the system and its development practices to produce better software in the long run [3]. Large software systems require many developers to contribute in different subsystems. As the software system evolves, the set of developers working on the project also changes; over time, developers will often edit code that was originally written by another developer. The authorship of code can make a huge difference in software quality and bug prediction [4]–[6].

In this work, we use the *SStuBs* [7] dataset to better understand how bug fixes differ when they are fixed by the developer who wrote the original code (the “author”) compared to when they are fixed by another developer. While differences in bug-fixes have been studied from the code perspective [2], we examine it from the developer perspective. Moreover, previous studies on the characteristics of bug fixes have mostly based on a small sample size from a few projects [1] with a few

hundred samples [8]. Our work here uses the *SStuBs* dataset, which comprises of 10,231 instances of single-statement bug fixes across the top 100 Java Maven projects. This allows us to investigate bug fixes at a larger scale both in the number of projects and in the number of samples compared to previous studies.

In this paper, we perform an empirical study on the differences in bug-fixing commits for simple bugs across two dimensions: bug fixes submitted by the original author of the code, and bug fixes submitted by other developers. We compare the bug fixes in terms of size and scope of the commit, and the time taken to fix. We address three research questions:

RQ1 How often are simple bugs fixed by a different author?

We find developers fix simple bugs from another developer’s code in 44.3% of the cases.

RQ2 Does bug fix authorship affect the bug fix time?

Developers fix simple bugs in their code faster — with a median of time of less than one day — compared to fixing simple bugs from another developer, with a median time of 148 days.

RQ3 Does bug fix authorship affect the commit size of simple bug fixes?

Simple bug fixes by the same developer have larger commit size with a wide variation in range: we found an interquartile range (IQR) of 734 LOC from 4 LOC at the first quantile to 738 LOC at the third quantile. Meanwhile, simple bug fixes by a different developer are small and vary less: we found an IQR of 13 LOC from 2 LOC at the first quantile to 15 LOC at the third quantile.

Our study suggests that bug fixes by different developers exhibit different patterns: Bug fixes by the same developer tend to occur within a short amount of time of the original bug-inducing commit, and are usually embedded within a larger commit. By contrast, bug fixes by a different developer tend to happen later in time, and the commit that fixes the bug tends to be confined in scope to the bug fix itself.

II. DATA COLLECTION

In this work, we use the *SStuBs* [7] dataset which contains single-statement bug fixes. We use the variation that contains

10,231 bug fixes from the top 100 Java Maven projects in the dataset as the basis for our analysis. We also provide a full replication package for our work¹.

We cloned every project from the list of top 100 Maven projects from the *SStuBs* dataset in Jan 2021. One of the projects *b3log/solo* has moved to another location to *88250/solo*, so we opted to use the later repository. The change of location does not affect the history of the commit, so it does not affect our analysis.

III. METHODOLOGY

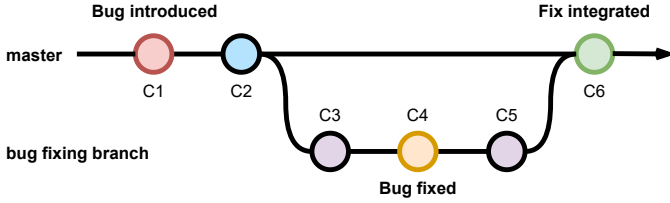


Fig. 1. Illustration of separate fix and integration commit

A. Bug-inducing and bug-fixing commits

SStuBs already stores the bug-fixing commit and the last commit where the bug still exists in the codebase using the SZZ algorithm [9]. We go one step further and use a slightly modified version of the SZZ algorithm to locate the authorship of the bug-inducing and bug-fixing commits by ignoring merging commits. As shown in Fig. 1, when applying the SZZ algorithm, *C6* will be identified as the bug-fixing commit. However, *C6* is the branch merging commit, therefore does not represent the actual commit that implements the bug fix. In this case, the bug fix is implemented in another commit, *C4*. In practice, this typically happens when a developer implements the bug fix in another branch and they submit a pull request to the codebase. When the pull request is accepted, a merge commit will be created which adds the bug-fixing change into the codebase. Since we are interested in the authorship of both the bug-inducing and bug-fixing commit, we make the distinction between the implementation and integration of the bug-fixing and bug-inducing change. In the rest of the paper, we use the following abbreviations to refer to the bug-fixing related commits. Note that C_{fix} and I_{fix} can refer to the same commit. This is also true for C_{induce} and I_{induce} .

- C_{fix} : Bug fix integration commit
- I_{fix} : Bug fix implementation commit
- C_{induce} : Bug induce integration commit
- I_{induce} : Bug induce implementation commit

We removed 11 bug fixes where their related commits do not exist anymore in the corresponding *git* repositories. The missing commits can be caused by deleted branches in the repository or lost from pull requests from another no longer available source².

¹<https://anonymous.4open.science/r/344cf208-ea32-49f4-90fe-59bdb6e5d7fe/>

²It is a common practice to delete no longer required forks if the changes integrate back.

B. Author determination

With both the integration and implementation commits available for bug-inducing and bug-fixing changes, the authorship of both changes can be easily determined by investigating the commit information. In this work, we are mostly interested in the developers writing the bug-inducing and bug-fixing changes, so we use the authorship information from both the implementation commits, I_{fix} and I_{induce} .

C. Bug fix time

The bug fix time refers to the time between the bug-inducing commit and the bug-fixing commit. Unlike the authorship of the code change where we need to trace to the implementation commit, bug fixes relative to the project development timeline. Therefore, we use the time difference between C_{fix} and C_{induce} as a measurement for the bug fix time. Specifically, we use $commit_time(C_{fix}) - commit_time(C_{induce})$ to calculate the bug fix time for each bug.

D. Code Churn

In this paper, code churn is considered as the number of lines of code (LOC) changed in a commit. Since simple bugs in *SStuBs* refer to bugs that occur within a single statement, a bug-fixing change often modifies only a single line and thus not change the total number of lines in the codebase. Consequently, when calculating the code churn as $lines_added - lines_removed$, a large proportion of bug fixes will have a net code churn of zero. In fact, 68.5% (i.e., 7,013) of all simple bugs in the dataset exhibit this property. Hence, to capture more information in the change, we use an alternative calculation of code churn as $abs(lines_added) + abs(lines_removed)$ to reserve information on the total lines modified.

IV. RESULTS

A. RQ1: How often are simple bugs fixed by a different author?

In industry, developers often need to fix bugs written by others. This is particularly evident in open source systems, where developers are often volunteers whose commitment and participation levels may vary over time. In this RQ, we explore how often simple bugs are fixed by a developer other than the original author.

For each bug-fixing commit, by comparing I_{fix} and I_{induce} , we can determine whether the bug is fixed by the same developer who contributed the original code. Using our modified version of the SZZ algorithm in tracing the implementation commit, we find that 44.3% (i.e., 4,508) of simple bug fixes are from developers fixing bugs in another developer's code. This observation shows a non-trivial amount of bug fixes by a different developer contributing to the understanding of developer bug-fixing activities. Researchers should be aware of the difference in developer fixing the bug as they can represent different workflow and therefore require different attention.

TABLE I
BUG FIXES BY AUTHOR

Total bug fixes	Fixed by same author	Fixed by different author
10,182	5,674	4,508

B. RQ2: Does bug fix authorship affect the bug fix time?

Despite the hope of producing perfect software with no bugs, during development in practice, bugs can not be prevented. Alternatively, there has been a substantial effort to improve the bug-fixing quality and time. High-quality bug reports [10] for example are a useful asset for developers when fixing bugs. In this RQ, we study how the difference in the authorship of the bug fix affects the bug fix time.

As discussed above, we consider the bug fix time from the project perspective. More specifically, we consider the bug fix time as the time from when the buggy code is committed to the code base to the time the bug fix change is committed to the code base.

As shown in Fig. 2, simple bug fixes by different authors (with a median of 148 days) occur much longer compared to simple bug fixes by the same author (with a median of less than 1 day). The large difference in bug fix time suggests these may be inherently different patterns of development activity. For example, the short fix time of simple bugs for the same author might be an artifact from the normal development process. How often and how much to commit is an ongoing argument in the development process. For example, even with continuous integration tools (CI), it is hard to ensure every commit of a project resembles a running state. The enforcement of a complete project is often only ensured at releases or pull requests. In this case, the simple bug fixes by the same author may be a result of the artifact of the normal development process. On the other hand, simple bug fixes by a different author have a wider time range with a median bug fix time of 148 days. In future work, a qualitative study can be performed to better understand the intent and cause of simple bugs to explain the large difference in the bug fix time between the same and a different author.

C. RQ3: Does bug fix authorship affect the commit size of simple bug fixes?

Following RQ2 where we discovered a difference in bug fix time between simple bug fixes by the same and a different author, we continue to investigate whether there are also differences in bug fix size. In theory, each commit should do one thing. However, this is often not the case in practice. Developers often combine multiple things in one commit and do not follow best practices [11]. When these situations happen, it is often hard to untangle the commit. In this RQ, we explore the bug fix size of simple bug fixes to explore whether there are differences between bug fixes by the same developer and a different developer.

Fig. 3 shows the churn of simple bug fixes by the same author and a different author. Simple bug fixes by different

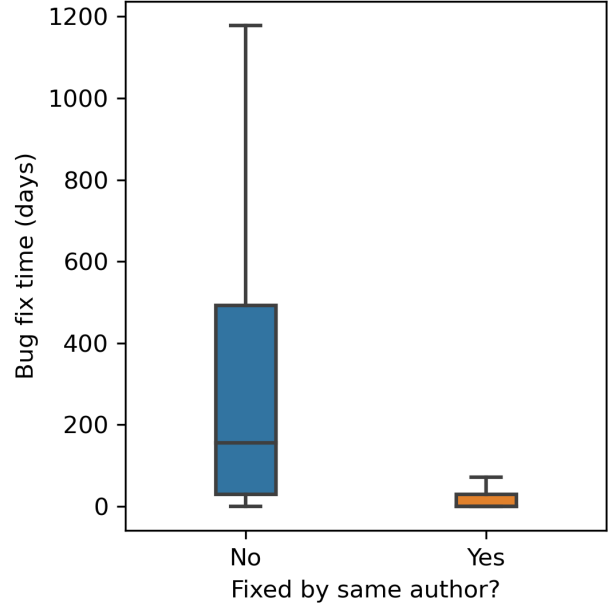


Fig. 2. Bug fix time by same author and different author

authors are typically small (e.g., a median of 6 LOC) compared to a larger range of commit size of simple bug fixes by the same author (with a median of 14 LOC). Bug-fixing commits by same developers also vary by a large amount with the interquartile range (IQR) of 734 LOC ranging from 4 LOC at the first quantile to 738 LOC at the third quantile. Meanwhile, simple bug fixes are smaller and have a small range by a different developer. The IQR is only 13 LOC ranging from 2 LOC to 15 LOC from the first to third quantile. The observed difference in commit size echoes our finding in RQ2 that simple bug fixes by the same developer may represent a different pattern than the bug fixes by a different developer. The large size in the bug-fixing commit suggests that simple bug fixes are embedded in a larger commit and therefore the simple bug fix may not be the main purpose of the commit. On the other hand, the bug-fixing commits by a different developer is relatively small in size, suggesting the purpose of these bug-fixing commits are more pin-pointed at fixing the simple bugs.

V. DISCUSSION

Our observations show that simple bug fixes have different patterns depending on whether the bug is fixed by the same developer writing the original code. When developers are fixing simple bugs from their code, they tend to fix the bug quickly in a short amount of time and often include the bug fix in a larger patch. On the other hand, bug fixes by a different developer tends to be small and often occur a long time after the original code is introduced. The difference in characteristics suggests that simple bug fixes by the same author may be inherently different from bug fixes by a different developer. We raise the following theory on why this occurs. Our observation

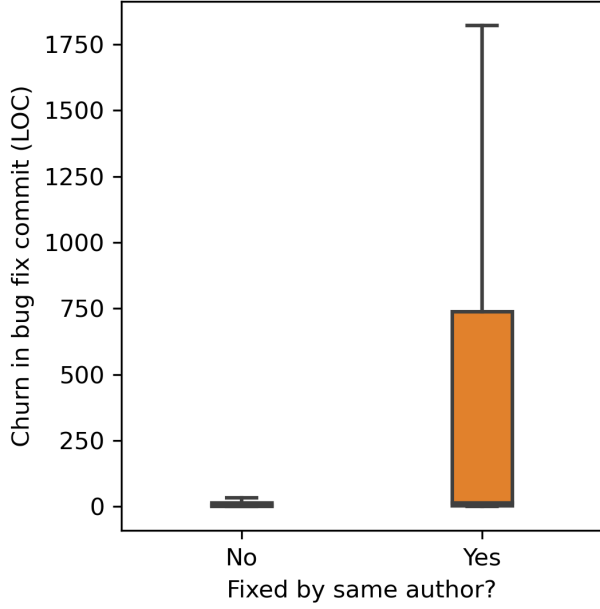


Fig. 3. Code churn in bug-fixing commits by authorship

suggests that simple bugs are fixed by the same developer quickly with a median time of less than one day. During development, the developer may not be able to perform large scale testing at every stage to ensure the contributed code functions correctly. After the rapid development phase with many changes in source code with commits recording the changes, simple bugs will appear and be fixed promptly. And when the period of development is finished, some simple bugs will be caught and fixed quickly. Therefore, resulting in our observation of quick simple bug fixes by the same developer. On the other hand, bug fixes by a different developer do not go through the development cycle and therefore do not suffer from the artifacts resulting in a more natural distribution of bug fix times. Our observation on the larger commits containing simple bug fixes by the same author also supports this theory.

As the bug-fixing activities are different for authors and non-authors, future research can further investigate the intent and cause of simple bugs. With a better understanding of why they happen, researchers can build more intelligent tools to help developers. For example, when predicting bugs, tools may consider the factor on whether the piece of code have been modified by another developer as suggested by our work that such activity is different than modifying code by the same developer. Another example, as one of the goals for the *SStuBs* dataset is to evaluate program repair techniques, our observations indicate that not every simple bug fix in the dataset is a good target for program repair tools as the bug fixes by the same author may come from artifacts during software development and therefore do not necessarily represent a good bug-fixing example.

VI. THREATS TO VALIDITY

A. Internal Validity

1) *Determine Implementation Commit*: We rely on the *git-blame* build-in command and the bug fix location information from *SStuBs* to retrieve the history of source code modification. However, the history of *git* can be overwritten and the bug fix location may not be precise from *SStuBs*. Therefore yielding inaccurate implementation commit being determined affecting our accuracy in bug fix time and code churn measured. Moreover, the bug may have been induced unrelated to the bug fix location, hence not correctly representing the actual bug-fixing process.

2) *Determining Commit Authorship*: We used the author's e-mail as the unique identifier for the author's identity. However, in practice, the same developer may use different configuration files on different machines, resulting in two different identifier mapping to the same developer. Consequently, during our analysis, we may have bug fixes by the same author categorized as different authors.

B. External Validity

Our study only looked at simple bug fixes in top *Maven* projects in *Java* managed through *git*, therefore may not be generalised to other projects using different languages or different version control systems. Our study also may not be generalized to other types of bugs as study has shown not all bugs are the same [1].

VII. CONCLUSION

We conducted an empirical study on how the authorship affects simple bug fixes from the *SStuBs* dataset. We traced the bug fixes to determine the developers writing and fixing the buggy code. We observe that developers fix simple bugs from another developer's code in 44.3% of the cases. Our result shows that when developers are fixing simple bugs in their own code, they tend to fix quickly and often embed the bug fix in a larger commit. On the other hand, simple bug fixes by a different developer tend to occur later in time, and the bug fix commit tends to be confined in scope to the bug fix itself. Our observations indicate different patterns in fixing simple bugs from the authorship. Future work on bug-fixing should consider incorporating this information when designing tools that better suit the developer's needs.

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