Who introduced the bug? The importance of the previous commit

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ABSTRACT

To fix a bug in a certain software product, some parts of its source code are modified. At first glance, it could seem reasonable that the fixed bug was introduced by the previous modification of those same parts of the source code (the previous commit). In fact, many studies on bug seeding start with this assumption. However, there is little empirical evidence supporting this assumption, and there are reasons to suppose that in some cases the bug was introduced by other actions, such as an older modification, or a change in called APIs.

This paper tries to shed some light on this area, by analyzing the relationship of bug fixes with their previous commits. To this end, we conducted an observational study on bug reports, their fixes, and their correspoonding previous commits for OpenStack. Our results show that the mentioned asumption does not hold for a large fraction of the analyzed bugs, which were not introduced by their previous commit.

Keywords

Bug introduction, bug seeding, SZZ algoritm, previous commit

1. INTRODUCTION

When a failure is found in the behavoir of a software, the developers try to fix it locating and modifiying the line/s that contains the bug in the source code. It seems reasonable to assign the previous modification of this/those lines, *The previous commit*, as the cause of the bug. But in fact, find when and where a bug was injected into the souce code is not a trivial task which has largely been ignored due to the data related about the origin of a bug is embedded in the evolution of the software [13].

In spite of some studies in bug seeding start with this implicit assumption, *"This earlier change is the one that caused the later fixed"* [16] or even we can find this assumption in tools that prevent for future bugs; *" We assume that a change/commit is buggy if its modifications has been later altered by a bug-fix commit"* [2]. We think that there is not empirical evidence supporting this assumption and we conducted an observational study on fix-bugs, expend significantly effort locating the bug origins into the source code.

The image 1 shows a clear example of we understand as responsible to cause the bug. In the image we can see three different versions of the same file in the history of the control version used in the project. The left code *(1)* was written to fix the bug inserted in the middle code *(2)* and with the *31f08423* as the id of change,the previous commit. The code in the right *(3)* is to ensure that in previous versions of the file did't exist the bug. In this example, the commit *31f08423* inserted for first time the line in where the bug was. And, according to the description of the commit log that fix the bug 2, this previous commit is responsible due to used the variable as string when had to be used as in the rest of the code, like as boolean.

Whereas the image 3 shows a clear example of we understand as no responsible to cause the bug. The bug fix commit log, 4, describes that in the update of the version, the name of an argument changed causing the failure in the sofware. This change done because of the new requirements in the version doesn't implicate that the previous commit was who inserted the bug.

We based on some reasons to suppose that the previous commit didn't insert the bug. But, our main idea to support this is that in a project which is evolving continuously and where many different developers are working on, the code that before was correct, now could be buggy. Thinking in called APIs, in the moment that this called was written there wasn't any bug and the software works fine, but in the addition of a new feauture or an enhancement the called API should be changed to support this new characteristic, but it didn't it. As a result, the software fails at this line. But in fact, the previous commit which wrote the called API is not responsible, due to the line did't contain any bug at the moment in which was written.

Unfortunately, not all times the code analyzed was so easy as the code showed in figures 1 and 3. So the principal aim of this paper to find the responsible of the bug is to know if the previous commits contained buggy code at the moment in which were added/modifyed or, another change in the software, related to the update of the software and its evolution, caused the bug.

In this paper, we attempt to address the following research question regarding who introduced the bug in the source code.

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- RQ1: How I can know that a change was done to fix a bug in the source code? How I can identify them?
- RQ2: In which cases the previous commit/s are responsible to cause the bug?

The remainder of this paper is structured as follows. First, we present the motivations that support our study, explaining the current body of knowleadge in section 2. Then, Section 3 describes the methodology used to identify the moment in which the bug was inserted in the source code, followed by the results obtained after applaying our approach to OpenStack in Section 5. Section 6 discusses potential applications and improvements of our approach. Section 7 reports threats to validity. Finally, Section 8 concludes the article.

2. RELATED WORK

The first algorithm to identifying bug-introducing code changes automatically was described in [14]. Currently, is a well-known algorithm called SZZ, which is based on text diferencing to discover modified, added and delete lines between the bug-fix and its previous version. SZZ uses CVS annotate command to identify the last commit that touched these lines.

An improvement on SZZ algorithm is described in [7], the authors used annotation graphs instead of CVS annotation to locate, in previous versions, the affected lines by modification and deletion. Also, they deleting some false positives as blank spaces, changes in the format or changes in the comments.

Other methodology to identify the origins of a bug is describes in [13], this work doesn't present a text-based technique as SZZ, the authors analized the effects of bug-fix changes on program dependences. Taking into account the semantic of the source code they achieved more accuracy identifying the origins of a bug.

These two approach have the similar ideas: (1) find the differences between the bug-fix version of and the previous version of the file to recognize those changes done by bug-fix commit. (2) look back in the code revision history until identify which version touched the lines affected in the bug-fix for the last time.

Exists several articles based on SZZ such as [16] revisied SZZ algorithm, tracking bug-inducing changes and identify change types of them. Also, in [18] the authors applyed this algorithm to find out what kind of bug-inducing changes are likely to become in a great threat after being marked as bug-fix changes.In addition, new techniques in bug prediction are based in this algotimh such as [6] which was the first work classifying file changes as buggy or clean using change information features and source code terms.

In addition some tools are based on SZZ too such as [] Finally our idea.

3. METHODOLOGY

We extract all the data necesary to analyze when the bug was inserted from the issue tracking system and the code review system used by the project we are analyzing. OpenStack uses Launchpad[1] and Gerrit[2].

[1]https://launchpad.net/openstack

[2]https://review.openstack.org/

The Launchapd of each project works with issues reports called tickets, which describe bug reports, feature requests, maintenance tickets, and even design discussions. But, in our study we are only interested in those tickets that describe a bug report and, in addition, have been closed with a merged in the code source to fix the bug. In this bug reports we can find a comment with the link of Gerrit where the bug was fixed. Is in Gerrit where we can see all the patchsets proposed and the comments done by the reviewers.

3.1 Fist Stage: The Filtering

In our approach, first of all we must identifying which of those issues extracted from Launchapd are bug reports. But, this is not a trivial task and we performed this identification using a web tool[3] development to provide the researcher with all the relevant information needed to decide if an issue corresponds to a bug report or not. The tool uses information extracted automatically from the project repositories, and offers a web-based interface which allows for collaboration, traceability and transparency of the identification of bug reports.

During the identification of the issues we have to take into account the next parameters for each ticket, the title and the description of the issue report and the description of the fix commit. Also, the code changes if neither the descriptions and the comments clarified the underlying ticket. Each ticket was then categorized into one of three following groups.

1. The ticket describes a bug report.
2. The ticket describes a feature, an optimization code, changes in test files or other not bug reports.
3. The ticket presents a vague description and cannot be classified without doubts.

Henceforth, we will refer to Group 1 as *Bug Report*, Group 2 as *Not Bug Report* and Group 3 as *Undecided*.

As result of analyze the tickets, main differences extracting data and to classifying tickets were found. So, we agree to follow the next four criteria:

- When there are only test files in the ticket, we classified it as note being a bug report. Test files in a ticket will not be analyzed, they are indispensables and used as testing method to determine whether the code is fit for use. Sometimes the developers inserted the bug only in the test files, in these cases the ticket was not considered as bug report because the software works as expected only failed the test.
- When the title described optimization, deletion of a dead code or the implementation of new characteristics, our criteria indicated that it was not a bug report because there is no failure.
- When the title described the program as not working as expected, our criteria indicated that it was a bug report.
- When the title described that updates were required, our criteria indicated that it was a bug report. We consider all tickets that require updating as bug reports,

[3]bugtracking.libresoft.es

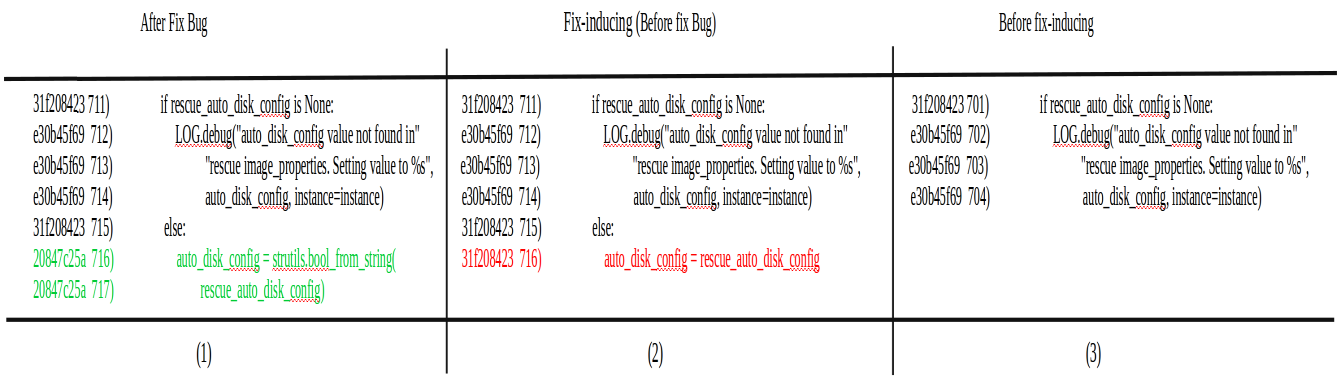

Figure 1: Example of when the previous commit,31f208423, inserted the bug

```
Xen: convert image auto_disk_config value to bool before compare

During rescue mode the auto_disk_config value is pulled from the rescue
image if provided.  The value is a string but it was being used as a
boolean in an 'if' statement, leading it to be True when it shouldn't
be.  This converts it to a boolean value before comparison.

Change-Id: Ib7ffcab235ead0e770800d33c4c7cff131ca99f5
Closes-bug: 1481078
```

Figure 2: Description of the bug-fix commit when the previous commit caused the bug

because updating a software hints to the software not operating as expected.

Sometimes we were unable to answer all the questions due to having insufficient data or because of the complexity of the issue. In this case, the ticket was classified into the *Undecided* group.

3.2 Second Stage: Responsability of Previous Commit

The next part is focusing on analyzing the previous commit in the *Bug Report* group. For that, we had to analyze the lines involved in the bug fix, in the commit parent of the bug fix commit, and be sure that the lines was inserted/modified in the previous commit. This, way we can sure that the previous commit didn't copied any line that contained the bug, because in this case, the previous commit is not responsible to cause the bug.

The analisys was done manually, and we used *git blame* to see all the previos commit in each line of a involved file. Also, we used *diff* to see all the differences between two files, in our case, the file is going to be the same but in different moment inside the control version system used.

Te procedure following in each file involved in a fix bug is describing below;

1. git checkout *commmit that fix the bug*, git blame *file involved*. In this step we can see the lines added, modified or deleted by the commit that fix the bug.

2. git checkout *parent of commmit that fix the bug*, git blame *file involved*. In this step we can see all the previous commits involved in the different lines touched in the fix bug.

3. git checkout *parent of previous commit*, git blame *file involved*. In this step we can esure that the previous commit inserted these lines.

Finally we need to discard some noise presents in our final resulst according to the responsability of the previous commit inserting the bug in the code source. Due to they were not responsibles for cause the bug, we delete those previous commit which presents the following criteria;

- Blank lines
- Format changes
- Copied lines
- Changes in the comment.
- Updatings in the version of a file.

4. EVALUATION

We validate our methodology anlayzing 459 tickets in OpenStack. OpenStack was particularly of interest because of its continuously evolving due to its very active community. Although its short life, only five years, more than 5 thousand of resarchers and more than 233 thousand of commits with more than 2 Million of lines of code have contributed in the development of the project [4]. Futhermore, all history is saved and available in a version control system, being able to access to its issue tracking system [5] and the source code review [6]

OpenStack is composed by 9 projects, but we only focused in the four of them, Nova, Cinder, Neutron and Horizon as we can see in table 1 these projects are really actives during all their history and in the last year.

In this four projects we analized the relationship of bug fixes with their previous commits. In order to identify the moment in which the bug was injected into the source code. The first stage we did automatically using the tool and a double bind between three researchers, three PhD student included me. The second stage was done manually and only me was involved analizing this relationship.

[4]http://activity.openstack.org/dash/browser/
[5]https://launchpad.net/openstack
[6]https://review.openstack.org/

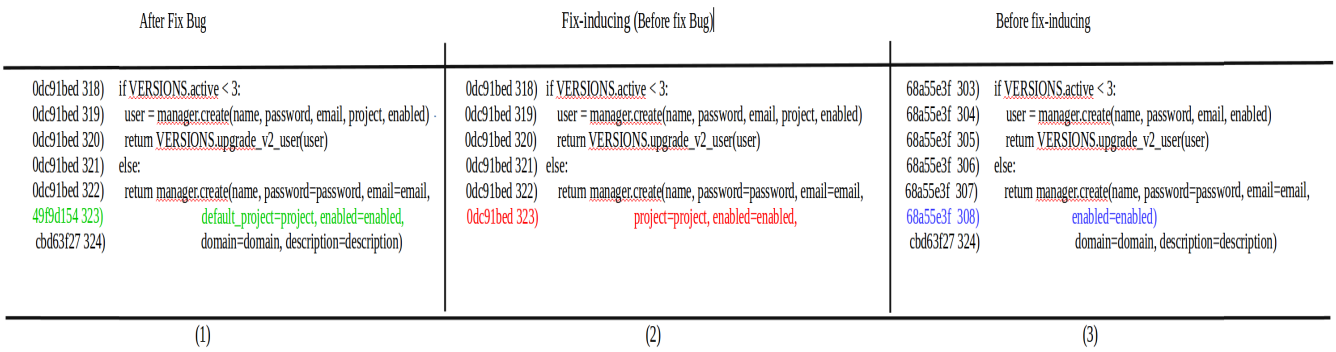

Figure 3: Example of when the previous commit,0dc91bed, did not inserted the bug

```
Update default_project param on create user

In keystone v3, the parameter to create user for the the default project
has changed from project to default_project and is no longer honored and
throws an exception. Also passing in '' rather than None causes keystone
issues, so moving to None.

Closes-Bug: #1478143
Change-Id: I73423433a42bf46769065a269a3c35f27175f185
```

Figure 4: Description of the bug-fix commit when the previous commit dind't cause the bug

Table 1: Commits per Project in OpenStack

	All History	Last Year (2015)
Nova	14,558	3,283
Fuel	9,139	5,123
Netron	8,452	3,855
Horizon	4,871	1,994
Cinder	4,556	1,832
Keystone	4,874	1,795
Heat	6,395	2,372
Glance	2,651	723
Tempest	4,141	1,312

5. RESULTS

We extracted a total of 459 different tickets from the Launchpad of the four principal projects in OpenStack, 125 tickets from Nova, 125 tickets from cinder, 125 tickets from Horizon and 84 tickets from Neutron. These tickets first, were analized to identify those ones which were real bug reports. And secondly, each file was analyzed to obtain which previous commit inserted the bug causing the failure of the system and reporting the bug report.

5.1 Fist Stage

We classify a total of 459 tickets using the tool. In 417 of the ticktes, we used double bind analysis, and only those tickets classified as bug report by two of us, were considered in the next stage to analyze the relevance of their previous commits.

The table 2 shows the percentage of each researcher after analyzing the tickets, and the number of tickets classifyed identically by two different researchers. Obtaining that the researchers R1 and R2 had a similar data in their results,

Table 2: Statistics of each researcher in the classification

	Bug Report	Not Bug Report	Undecided	Total
R1	(184)55%	(115)34%	(35)11%	334
R2	(188)76%	(54)22 %	(7)3%	249
R3	(188)56%	(116)35%	(30)9%	334
Finally	(209)72%	(74)25%	(9)3%	292

whereas research R2 got results significantly differents with a higher number of tickets classifyed as Bug Report.

Finally, the researchers identifyed in the same way 292 tickets, that is, their results matched in a 70% of the cases. Obtaining 209 tickets classifyed as Bug report, 74 tickets classifyed as Not Bug Report and 9 tickets classifyed as Undecided.

Also we had measured the concordance in the classification of each developer according to the project analized. The table 3 shows that the concordante got between all the three research was very similar, around a 70%. Furthermore, the concordance form each researcher with the rest alwas was up to 60%.

Table 3: Concordance between each developer in each repository

	Nova	Cinder	Horizon	Neutron	Total
R1&R2	(44)70%	(40)77%	(37)60%	-	68%
R1&R3	-	(46)73%	(48)76%	(26)62%	71 %
R2&R3	(41)66%	(10)100%	-	-	71%

5.2 Second Stage

At this stage, we analyzed the 209 we got a list with all the previous commits and we were be able to classifyed the previous commit/s as Responsible, Not Responsible or Undecided, taken into account that the bug could be inserted in different lines of different commits, but not everyone had to be responsible for the commit, sometimes the previous commit copied lines from its previous commit or inserted comments and blank spaces. In fact, the responsible can be only one of them, more than one or maybe none.

We identifyed a total of 348 previous commits which can

be responsible for inserting the line containing the bug. After analizing the Bug Reports and their previous commits and discarded 40 of them because were noise, Table 4, we got that 152 previous commit were responsibles to cause the bug whereas 114 previous commit had not any responsability in the failure of the system, and only in 42 previous commits we were unable to identify the cause of the bug.

Table 4: Responsability of each previous commit before and after deleting the noise in the results

	Before Deleting Noise	After Deleting Noise
Responsible	152	152
Not responsible	154	114
Undecided	42	42

Futhermore, focusing on how many previous commits presented each Bug Report, we obtained that 131 had one previous commit implicated, whereas 58 had more than one previous commit implicated in their file/s. According to Table 5, from the 131, we obtained that 65 of them inserted the bug, but 30 of them were not responsibles in the failure of the system. And from the 58 which had more than one previous commits, we obtained in total 189 previous commit, where 86 of them were respnsibles and 82 were not responsibles.

Table 5: Probability of cause the bug depending on how many previous commits had the bug report

	One previous commit	More than one previous commit
Responsible	65	86
Not responsible	30	82
Undecided	36	11

Also, we looked the distribution of the previous commit in each Bug Report, Table 6, we observed that the most commun distribuion in the relationship between previous commit and bug report is one previous commit per Bug Report, following by the second commun distribution, two previous commit per Bug Report.

Finally we wanted to know the responsability preactised by each previous commit in the failure of a system, in other words, we were interested in analize from those cases where exists more than one previous commit, how many of them inserted the bug in the code source, Table 7. We obtained that in 8 Bug Reports all the previous commits were responsibles, in 30 Bug reports at least one of their previous commit caused the bug and in 11 bug report none of their previous commits inserted the bug.

6. DISCUSSION

RQ1: asdasdasdasdasdsaddasdadasdasd

RQ2: asdasdasdasdasdsaddasdadasdasd - Como se responden las RQ1 y RQ2 - No todos los casos son tan claros como los mostrados en los ejemplos .... - Casuistica del common juidment - Hemos sido conservadores -Hemos utilizado la herramienta porque es un proceso complicado Once we have all the tickets analyzed by diferents researchers who have used a double blind, how to proceed if there are discordances between them:

1. Should they discuss after their analysis to reach a better classification?, Should the tool provide this?
2. Does the Bug report only the same ticket classified as Bug report for all the researchers?

How to proceed if looking for the responsability of a bug when only added lines are inserted? And we are talking about a bug report not a new feature, these kinds of cases use to be when a researcher forgot check some case inside a function. [reference]

1. Is responsible the function where these lines are content?
2. Is responsible the last commit that modify something in the function?

7. THREATS TO VALIDITY

The size of the tickets extracted form the Launcpad is medium, but doing the analisys manually we are sure that the results present in this paper are valid, being sure that the previous commits classifyed as not responsible, they are.

Although, we understand that the model presented has some threats, external and internal, that make our model not 100% valid. The internal threats related to the researchers that have conducted the study are following:

- We have not taken into account errors that have been classified into *Undecided*, and probably we are lost some real bug reports belonging this group .
- There could be some lax criteria involving the subjective opinion of the researchers.
- The researchers are not experts in OpenStack, and our inexperience may have influenced the results of the analysis.
- We are only using part of the information that the ticket provides, like comments and text. There could be a recognized pattern in teh data, unknown at first sight, that involves other parts of the information.
- Although we use a random script to extract the tickets reported in during the last year, 2015, from the launchpad, in this year could be some bias unidentified.
- In case of the researchers didn't find the information to know if the previous commit inserted the bug or in contrast, it was caused by the evolution of the software. They keep the traditionalist thought, classify these previous commits are responsibles.

The external threats, related to the case of the project, are following:

- The word *bug* is continuously mentioned in the description and commit of a ticket even when we found it is not an error. This could lead to the incorrect classification during the reviewing process.

Table 6: Distribution of number of previous commit per Bug Report in each project

	One previous commit	two previous commit	three previous commit	four previous commit	+five previous commit
Neutron	11	3	2	2	0
Horizon	39	8	3	2	4
Nova	44	5	2	4	4
Cinder	37	9	6	2	2
Total	131	25	13	10	10

Table 7: Probability of cause the bug depending on how many previous commits had the bug report

	two previous commit	three previous commit	four previous commit	+five previous commit	Total
All Responsible	4	3	0	1	8
At least one responsible	9	7	5	9	30
None Responsible	4	2	4	1	11
Undecided	1	0	1	0	2

- Some tickets are not explicitly described, which could increase the percentage of *Undecided*. This is especially true if the reviewers are not from OpenStack.
- OpenStack is a special project put down a constant evolution due to their active community of developers. Maybe, in other projects with less commits per year the statistics about the responsability of previous commit change.

8. CONCLUSIONS

The empirical experiment carried out in OpenStack, supported that the current premisse assumed does not hold for a large fraction of the analyzed bugs, because around the 40% of the previous commits were not responsibles inserting the bug. With our results we can identify which ones are real changes that introduced the bug, and this could be useful to improve the accuracy of those tools developed to prevent bugs. Also, the software developers stand to benefit from identifying where the bug was inserted, improve their methodology.

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