Patterns for Extracting High Level Information from Bug Reports

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***Abstract*—Bug reports record tasks performed by users and developers while collaborating to resolve bugs. Such data can be transformed into higher level information that helps data scientists understand various aspects of the team's development process. In this paper, we present patterns that show, step by step, how to extract higher level information about software verification from bug report data.**

***Index Terms*—data analysis, mining software repositories, patterns, bugs.**

I. Introduction

Bug tracking systems record in their bug reports the collaboration between final users and developers in order to fix bugs. Such rich exchange of information can be used by data scientists to reason about the software development process of a team.

Bug reports help compute many statistics related to quality and software development. For example, how many bugs are reported per day, on average? What proportion of bugs are considered invalid? What is the average bug lifetime?

Even better, the raw data can be transformed into higher level information about developers and the software development process. With such information, one can infer developer roles, developers' workflow [1], software lifecycle phases, and so on.

In this paper, we present patterns to transform bug data into higher level information about the software verification process. A pattern consists of 7 sections: (1) a short *name*; (2) the *problem* being solved; (3) a *context* in which the pattern can be applied; (4) one or more *solutions* to the problem; (5) a *discussion* of trade-offs and common mistakes to consider when using the pattern; (6) *examples* of the pattern in use; and (7) *related patterns*.

The next section presents the data set used in this paper. Section III presents a pattern, called *Not Everyone is a Programmer*, that helps discover quality engineers using only bug report data. Finally, Section IV, *Testing Phase*, shows how to detect testing phases in the software development life cycle.

TABLE I
Sample of `bugs` table, hour info omitted.

bug	severity	priority	creation.time	modif.time
397	normal	P4	1998-07-31	2008-12-23
427	normal	P4	1998-08-08	2008-12-23
479	normal	P2	1998-08-19	2008-12-23
500	normal	P4	1998-08-22	2008-12-23

II. Data Set

Each pattern contains an *Examples* section with code snippets showing how to apply the pattern on real data. The snippets are written in R, a programming language for data analysis[1]. The data used are bug reports from the projects NetBeans/Platform and Eclipse/Platform, made available for the 2011 edition of the MSR Mining Challenge[2].

Both projects use Bugzilla[3] as their bug tracking system, which stores all data in a MySQL database. The source code presented here refers to database tables and columns used by Bugzilla, but it should work with any bug tracking system with minor changes.

Although the full data set contains almost 60 database tables, in this paper only two are used: `bugs` and `changes` (originally, `bugs_activity`). The `bugs_activity` table and a few columns were renamed for clarity purposes.

The `bugs` table contains general information about each bug report, which is identified by a unique number (column `bug`). Each bug report has a `severity`, a `priority`, and two timestamps: the time of creation (`creation.time`), and the time of the last modification (`modif.time`). Table I shows a sample of the `bugs` table.

The `changes` table contains all modifications users made on bug reports over time. This includes changes in priority, status, resolution, or any other field in a bug report. Each row contains the `new value` of a `field` that was modified

[1]http://www.r-project.org/
[2]http://2011.msrconf.org/msr-challenge.html
[3]http://www.bugzilla.org/

TABLE II
SAMPLE OF `changes` TABLE, HOUR INFO OMITTED.

bug	user	time	field	new.value
427	17822	2009-10-30	resolution	WONTFIX
500	182	2002-04-12	bug_status	CLOSED
755	182	2002-01-11	bug_status	REOPENED
755	182	2002-01-11	resolution	

by a `user`[4] at some point in `time`. Table II shows a sample of the `changes` table.

The `bug_status` field is used to track the progress of the bug fixing activity. A bug report is created with status `NEW` or `UNCONFIRMED`. Then, its status may be changed to `ASSIGNED`, to denote that a user has taken responsibility on the bug. After that, the bug is `RESOLVED`, then optionally `VERIFIED` by the quality assurance team, and finally `CLOSED` when the next software release comes out. If, after resolving the bug, someone finds that the resolution was not appropriate, the status is changed to `REOPENED`.

There are many ways to resolve a bug. To reflect that, when a bug status is changed to `RESOLVED`, the `resolution` field is changed either to `FIXED` (if the software was changed to solve the issue), `WORKSFORME` (if developers were not able to reproduce the problem), `DUPLICATE` (if a previous bug report describes the same problem), among other resolutions.

All the data and code used in this paper is available online[5].

III. NOT EVERYONE FIXES BUGS

Problem

Find the quality engineers on a team, if there is any.

Context

Developers tend to assume specific roles in the software development process. While many developers participate by fixing bugs, quality engineers usually take bug fixes and verify if they are appropriate. Making the distinction between quality engineers and other developers is important when studying the influence of human factors on outcomes of the software development process.

Solution

Analyze each developer's activity in the bug tracking system, such as status and resolution changes. In particular, count how many times each developer has...

- ... changed the status to `VERIFIED` (number of verifications);
- ... changed the resolution to `FIXED` (number of fixes).

Then, compute the ratio between verifications and fixes for each developer (add 1 to the number of fixes to avoid division by zero). If such ratio is greater than some threshold (e.g., 5 or 10), it suggests that the developer is specialized in verifications. Select all such developers and compute the total number of verifications performed by them, compared to the total number of verifications in the project. If they perform a great part of the verifications in the project (e.g., more than 50%), then the project has a quality engineering team, formed by that developers.

Choosing a suitable threshold is a hard problem. If the threshold is too high, then only the most active quality engineers are chosen; if it is too low, then sporadic contributors, who have contributed with a few verifications, are also regarded as quality engineers.

One possible criterion is to choose a threshold that results in the smallest quality team that still contributes to a large part of the verifications performed in the project. First, compute, for each candidate threshold (e.g., from 1 to 50), the size of the quality team and the number of verifications its members performed in the project. Then create a scatter plot of number of verifications vs. size of quality team. Finally, look for a point in the plot such as that increasing the size of the quality team does not significantly increase the number of verifications[6]. The value used to compute this point is the chosen threshold.

Discussion

It is a common mistake to use the absolute number of verifications to determine if a developer is a quality engineer. The absolute number is a poor indicator because, in some projects, developers that fix bugs also mark them as `VERIFIED`.

Developers can change roles over time. If this is the case, consider analyzing a shorter period of time. Even better, use sliding windows, i.e., analyze multiple consecutive short periods, one at a time.

Examples

This solution was used by Souza and Chavez [2]. They used a threshold of 10 for the ratio between verifications and fixes (referring to the ratio usually used to distinguish between order of magnitudes). In the following source code, we show how to apply this solution to NetBeans/Platform. First, compute the number of verifications and fixes for each user:

```
> resolution <- subset(changes, field == 'resolution')
> status <- subset(changes, field == 'bug_status')
> t1 <- table(resolution$user, resolution$new.value)
> t2 <- table(status$user, status$new.value)
> user <- merge(as.data.frame.matrix(t1),
+             as.data.frame.matrix(t2),
+             by="row.names")
> user$ratio <- user$VERIFIED / (1 + user$FIXED)
```

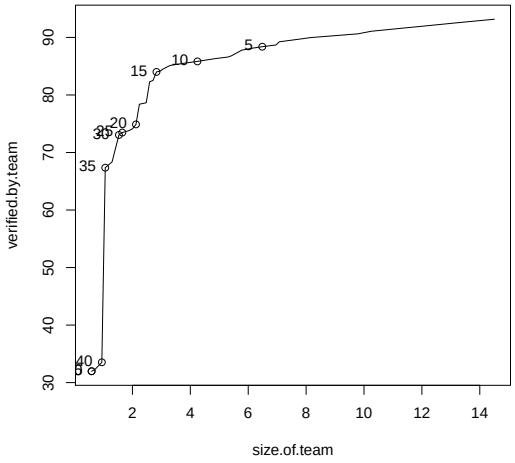
Next, choose a threshold. For that, plot for each possible threshold between 1 and 50, the relative number of verifications vs. the relative size of quality team (for simplicity, we use percentages and label only thresholds that are multiples of five):

[4]In this context, user denotes a user of the bug tracking system, which can be either a developer or a final user.

[5]https://github.com/rodrigorgs/dapse13-bugpatterns

[6]This is similar to the elbow criterion, used to find the optimal number of clusters in a data set.

```
> thresholds <- seq(1, 50, by=0.5)
> size.of.team <- 100 * sapply(thresholds,
+   function(t) mean(user$ratio > t))
> verified.by.team <- 100 * sapply(thresholds, function(t)
+   sum(user$VERIFIED[user$ratio > t]) / sum(user$VERIFIED))
> plot(verified.by.team ~ size.of.team, type='l')
> df <- data.frame(thresholds, size.of.team, verified.by.team)
> df <- subset(df, thresholds %% 5 == 0)
> points(df$size.of.team, df$verified.by.team)
> text(df$size.of.team, df$verified.by.team, df$thresholds, pos=2)
```



By visually inspecting the plot, we choose 15 as the threshold. By inspecting the plot and the data, we find that the quality engineering team is formed by 24 members (about 2.8%), who contributed with 11310 verifications (about 84%).

Related Patterns

While this patterns helps locate people who concentrate quality efforts, the pattern *Testing Phase* (Section IV) helps find periods in which such efforts are concentrated.

IV. Testing Phase

Problem

Identify testing phases in the software development life cycle.

Context

Before a new version is shipped to final users, it is common to test new features and bug fixes. In some projects, most of the testing effort is concentrated on a well-defined testing phase, that precedes the release of the next version of the software.

In a bug tracking system, testing efforts are recorded as bug status changes, from `RESOLVED` to `VERIFIED`. Testing phases, therefore, show up as a relatively large number of verifications comprised in a relatively short period.

Failing to recognize testing phases mislead analyses. For example, if most bugs are verified during a testing phase, then measuring the time from `RESOLVED` to `VERIFIED` does not measure verification effort. Instead, it reflects how early a bug was resolved with respect to the next testing phase.

Solution

Solution 1. Select verifications, i.e., changes that set the bug status to `VERIFIED`. Then, plot the accumulated number of verifications over time using a line chart. If you know the software release dates, highlight them in the chart with vertical lines. Although the chart is monotonically increasing, some portions may exhibit a steeper ascent, that represents a period with high verification activity. Such periods probably are testing phases, particularly if they precede a release date.

Solution 2. Select verifications, i.e., changes that set the bug status to `VERIFIED`. Then, apply Kleinberg's algorithm [3] to verification times in order to detect bursts, i.e., periods of intense verification activity.

The algorithm is based on a Markov model and outputs a hierarchical burst structure. The first level comprises the entire period; the second level contains bursts in the period; the third level, bursts within second-level bursts, and so on. In the data we analyzed, second-level bursts spanned a few days, which seems right for a testing phase, while higher level bursts tended to span a few hours.

Discussion

The first solution is suitable for visual exploration of the data. If the data set is too large, however, it becomes difficult to visualize. The second solution is objective, though computationally expensive.

Be suspicious if the number of verifications per day is too high (e.g., above 50). Such verifications may be the result of a mass verification, when multiple bug reports are simultaneously updated in order to tidy the bug tracking system. To determine if this is the case, analyze the individual verifications on that day. If most of them were performed by the same person, a few seconds or minutes apart from each other, then they are likely the result of a mass verification.

Examples

The first solution was used by Souza and Chavez [2] (see Figure 2 in their paper). The following R code shows how to apply the solution to Eclipse/Platform. Only a subset of the data is used, otherwise testing phases would be difficult to visualize. Assume `releases$date` is a vector with release dates.

```
> ver <- subset(changes,
+         field == "bug_status"
+     & new.value == "VERIFIED")
> ver <- ver[order(ver$time), ]
> ver$n.changes <- 1:nrow(ver)
> ver <- subset(ver,
+         time >= as.POSIXct("2009-06-10")
+     & time < as.POSIXct("2010-06-09"))
> with(ver, plot(n.changes ~ time, type="l"))
> abline(v=releases$date, lty=2)
```

The result is shown in Figure 1. Notice how verification activity (steep ascents) is concentrated just before release

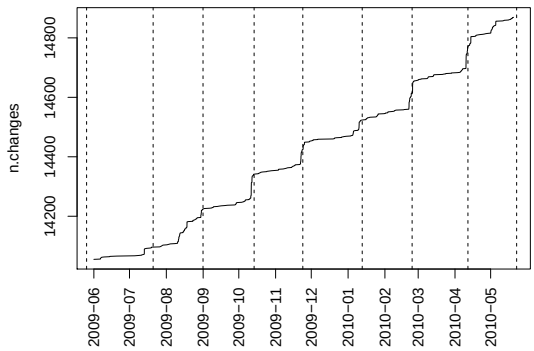


Fig. 1. Accumulated number of verifications over time.

TABLE III
PERIODS WITH INTENSE VERIFICATION ACTIVITY (SAMPLE).

start	end	count	per.day
2009-07-29 09:07:15	2009-07-29 16:21:58	17	17
2009-08-26 11:07:36	2009-09-03 12:24:38	71	7
2009-09-15 02:36:27	2009-09-16 12:54:35	26	13
2009-10-26 09:47:55	2009-10-29 12:00:26	82	20
2009-12-07 13:11:33	2009-12-11 10:57:28	74	14

dates (dashed vertical lines), suggesting there are well-defined testing phases in Eclipse/Platform.

The following R code shows how to apply the second solution, using Kleinberg's algorithm and taking second-level bursts. Then, we count the number of verifications, total and per day, in each burst. The variable `ver` is reused from the previous snippet of code. The first 5 bursts are shown in Table III.

```
> library(bursts)
> k <- kleinberg(unique(ver$time))
> bursts <- subset(k, level == 2)
> # Num. of verifications (total and per day average)
> bursts$count <- apply(bursts, 1, function(x)
+   sum(ver$time > as.POSIXct(x["start"])
+       & ver$time < as.POSIXct(x["end"])))
> days <- as.Date(bursts$end) - as.Date(bursts$start)
> days <- days + 1
> bursts$per.day <- bursts$count %/% as.numeric(days)
```

Related Patterns

It should be noted that *Not Everyone is a Programmer* (Section III): some teams have dedicated quality engineers that are responsible for testing. Well-defined testing phases are less common in such teams, because quality engineers constantly test features and bug fixes, and therefore do not need to switch between programming and testing activities.

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