An Empirical Study on Real Bug Fixes

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Background

“The long battle with software bugs began ever since software existed”
Hyatt Regency walkway collapse

- Kansas City 1981
- 144 killed
- 216 injured
- Civil Engineering bug
Therac-25

- 6 accidents
- 100x overdose
- Race condition
Future of bugs?
“Bugs lead to incorrect results, deadlocks, or even crashes”

• 20 minute outage cost Amazon about $3.75 million in March 2016
Related Work

“At ICSE 2014, Monperrus criticized Kim et al.’s recent work and discussed a number of issues concerning this research direction”
Automatic program repair

Buggy program. Line 1920 throws an Array Index Out of Bound exception when `getShort(iCode, pc + 1)` is equal to or larger than `strings.length` or smaller than 0.

```java
1918 if (lhs == DBL_MRK) lhs = ...;
1919 if (lhs == undefined) {
1920+   i = getShort(iCode, pc + 1);
1921+   if (i != -1) 
1922+     lhs = strings[i];
1923 } 
1924 Scriptable calleeScope = scope;
```

Patch generated by human

```java
1918 if (lhs == DBL_MRK) lhs = ...;
1919 if (lhs == undefined) {
1920+   if (getShort(iCode, pc + 1) < strings.length &&
1921+       getShort(iCode, pc + 1) >= 0)
1922     {
1923+       lhs = strings[getShort(iCode, pc + 1)];
1924     }
1925 Scriptable calleeScope = scope;
```

Patch generated by pattern-based automatic program repair (PAR)
Critical Review by Monperrus

• Strongly disagree with paper on PAR
• PAR fix does not address root causes of bugs
• Methodology of PAR is faulted
Problem Statement

“The research community has limited knowledge on the nature of bug fixes.”
Motivation for study

- Existing studies claim it requires much time and expertise to fix bugs
- PAR paper claims it can automatically fix 55 out of 105 bugs
Benefits of study

1. How many types of bugs can be fixed with a simple change?
2. What types of bugs exist?
3. What is the direction of future work?
Approach

“To answer these [six] research questions we should analyze thousands of bug fixes”
Research questions

• RQ1: To what extent are bugs localized?
• RQ2: How complicated is it to fix bugs?
• RQ3: What operators are essential for fixing bugs?
• RQ4: What is the importance of API knowledge to fix bugs?
• RQ5: What kind of files are necessary to be modified to fix bugs?
• RQ6: How many files are necessary to be added or deleted to fix bugs?
Dataset

• “9000 bug fixes from six popular Java projects”

<table>
<thead>
<tr>
<th>Name</th>
<th>Lines of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aries</td>
<td>142,110</td>
</tr>
<tr>
<td>Cassandra</td>
<td>121,170</td>
</tr>
<tr>
<td>Derby</td>
<td>659,426</td>
</tr>
<tr>
<td>Lucene/Solr</td>
<td>677,873</td>
</tr>
<tr>
<td>Mahout</td>
<td>121,084</td>
</tr>
</tbody>
</table>
Evaluation

“Our empirical study has analyzed bug fixes to gain insights on automatic program repair, providing a different research angle than previous work”
Insight 1: Fault localization

- It is reasonable to assume a bug can be found within only a few files
- A bug can be repaired by modifying less than 30% of files
Insight 2: Faulty code fix

• It is reasonable to assume the bug exists in a modified source file
• In total programmers did not add any files for more than 80% of fixes
Insight 3: Search space

• Automatic program repair can potentially fix only half of the buggy files due to the huge search space
Insight 4: Non-source bugs

• 10% of bugs reside in non-source files
• Configuration files and natural language documents
Discussion
Claims by author

• “Neither manual fixes nor automatic fixes are perfect”
• “We reported our detected documentation errors as bugs”
• “Low-level knowledge of operating systems and hardware are essential to fix some bugs”
Critique

- What are more facts on bugs you would like to know?
- What about bugs in other languages or smaller projects?
- What questions can you pose for future studies?
In general, is bug fixing a problem computers can solve?

• Philosophical question
• “With advanced techniques, it is conceivable that a computer algorithm may produce better patches than we humans do”