Presentation: SymDefFix - Sound Automatic Repair Using Symbolic Execution

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ABSTRACT

In this presentation, we introduce our constraint-based repair approach, called SymDefFix. SymDefFix is based on ExtractFix [3] and replaces the dynamic analysis steps of ExtractFix to detect the error and find the potential fix locations in an input program with symbolic execution. We first briefly motivate and introduce our modifications of ExtractFix, and then demonstrate it with an example.

1 INTRODUCTION

Fixing software bugs and vulnerabilities in programs is a time consuming task that researchers try to automate. During the last decade they proposed several approaches to address this issue. Most of them are based on executing a test suite to detect a bug or vulnerability and synthesize a patch for it [4, 4-12]. These approaches suffer from the problem of generating low-quality patches that over-fit the given test suite. ExtractFix [3] is an approach that addresses the over-fitting problem via symbolic reasoning. It uses sanitizers to extract the underlying cause of a vulnerability and uses that information to first find potential fix locations and then to generate a patch at each location. However, ExtractFix relies on the information from executing one test case that triggers the bug. In a first manual evaluation, we found that this limits the capabilities of ExtractFix and led us to the following research hypothesis:

We can use symbolic execution to obtain more complete information about the bug and use that information to find more accurate fix locations and generate more accurate patches.

In the following sections, we briefly present our modifications of ExtractFix and showcase our approach, that we call SymDefFix, with an example.

2 SYMBOLICALLY DEFINED FIX (SYMDEFFIX)

ExtractFix reads a C program, instruments it with a sanitizer, and then executes the given test case to generate a crash. When a crash occurs, the sanitizer outputs the crash location and the constraint that was found by the sanitizer to be violated, called the crash-free constraint (CFC). In addition, it records a call trace to the function in which the crash occurs. Next, using the CFC and the trace recorded for the failing test case, it identifies potential fix locations using control and data flow analysis. Then, it propagates the CFC to each fix location and, finally, it generates a patch that complies with the CFC at each fix location. For more information on ExtractFix, we refer the reader to [3]. We tried ExtractFix on several examples, provided with the ExtractFix tool, and adapted from the SV-COMP¹ benchmark with a focus on samples from the memsafety category. Through that, we found two main limitations of ExtractFix: first, developers need to provide a test case that triggers the error; second, only the trace that leads to the error is considered for finding the fix locations. The latter ignores cases in which multiple traces (i.e paths) might lead to the error.

In our approach, called SymDefFix, we address both shortcomings by using a static formal verification tool to detect the error(s) considering all potential program paths. Figure 1 presents our approach highlighting our modifications of the original ExtractFix. In particular, we replace ExtractFix's step to extract the CFC and the execution trace with Symbiotic [2]. Symbiotic is a framework for static program analysis and verification that uses KLEE. As shown on the left side of Figure 1 Symbiotic first instruments and slices the code and then it symbolically executes the remaining code using KLEE to detect any errors that exist in the code. The usage of KLEE as part of Symbiotic is illustrated in detail in [2].

We modified the KLEE implementation inside Symbiotic to output three types of information: a) crash free constraints (CFC); b) trace information, and c) path to the source file instrumented by Symbiotic. The CFC and the trace information are the same as output by ExtractFix, but this time determined using symbolic execution. In contrast to ExtractFix, our approach explores *all* possible paths and consequently finds all paths that can lead to the error plus the corresponding CFC. All three outputs are then provided to the original ExtractFix to find the candidate fix locations and the weak preconditions. These two inputs then are provided to program synthesis tool EUSolver [1] that, for each fix location, generates a valid patch that satisfies the CFC under all inputs.

3 EXAMPLE

We demonstrate the feasibility of our approach with the heapoverflow example shown in Figure 2. Note, instead of reading the command line argument, which is used by ExtractFix's test case, we hard coded the size of content variable to be 10. Furthermore note, in the current version of SymDefFix, we are using Extract-Fix's Global Malloc size instrumentor (GSInserter) that introduces a global variable to represent the size of the memory allocated with malloc.Analyzing this example with SymDefFix, Symbiotic correctly detects an error at line 19 and outputs:

CFC: access(buffer) < base(buffer) + size(buffer) Trace: ["IN, "main"] Path: ../tmp/output.txt

¹https://sv-comp.sosy-lab.org/2021/results/results-verified/



Figure 1: Overview of the SymDefFix approach.



Figure 2: Heap-Overflow example highlighting the crash and candidate fix location.

The example violates the CFC in line 19 when it assigns the sixth element of content to buffer, because the size of the buffer is only five bytes. This information is then provided to ExtractFix that determines the potential fix locations and uses the EUSolver[1] to generate the patch(es). The patch for this example is presented in Listing 1. It modifies the condition in the for loop at line 19 adding the boundary condition of the heap size that is stored in the variable "GLOBAL_MS_heap_overflow_malloc_7".

Listing 1: Generated Patch

```
- for (i; i<sizeof(content); i++)
```

- + **for** (i;(((i)<sizeof(content))&&((i)<
- (GLOBAL_MS__heap_overflow__malloc_7)));
- i ++)

4 FUTURE DIRECTION AND GOALS

Currently, we only consider the information from one symbolically executed path to determine the fix locations and generate patches. As a next step, we want to consider all paths explored by KLEE (inside Symbiotic) for this step to further investigate our hypothesis stated in the introduction. Furthermore, we will extend our approach to consider more error types, such as divide-by-zero.

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