Symbiotic with CPAchecker

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Motivation

```
int main(void)
{
  int x = 10;
  for (int i = 0; i < 1000; ++i) {
    for (int j = 0; j < 1000; ++j) {
      for (int k = 0; k < 1000; ++k) {

        /* some code that does not touch x */
      }
    }
  }
  if (x > 0)
     __VERIFIER_error();
}
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Outline

- Symbiotic
  - What is Symbiotic?
  - How it works?
- CPAchecker in Symbiotic
  - How is it integrated?
  - Some results.

Symbiotic

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- It is highly modular.
- Internally works with LLVM.

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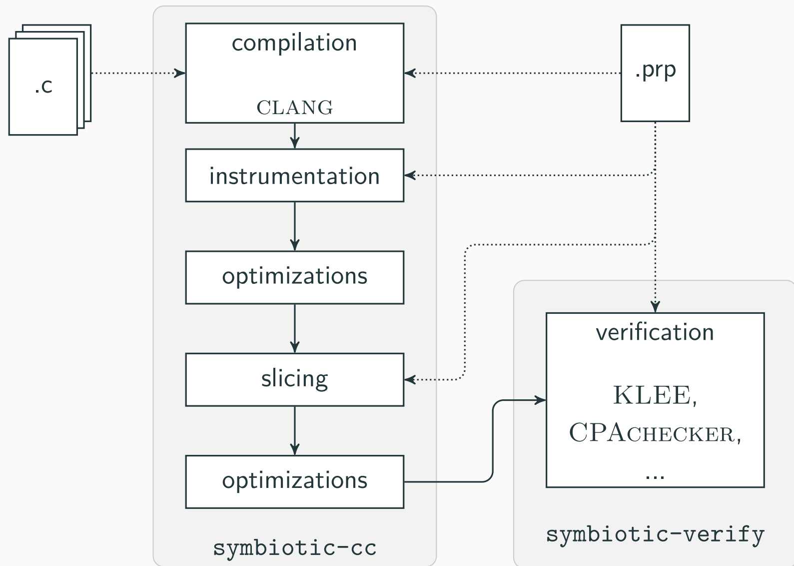
- It employs:
  - code instrumentation (combined with static analyses),
  - program slicing,
  - (compiler) optimizations.
- It is highly modular.
- Internally works with LLVM.
- Integrates several verification tools that can be seamlessly run on the generated code.

Symbiotic – schema



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- Symbiotic has a configurable instrumentation module
- Configuration in JSON
- It can use results of static analyses to prevent redundant code injection
- Can run in several stages, passing information from former to later stages
- Restriction: can insert only calls to functions at this moment

Instrumentation – example

```
1. %p = alloca i32*
   call check_pointer(%p, 8)
2. store null to %p
3. %addr = call malloc(20)
   call check_pointer(%p, 8)
4. store %addr to %p
   call check_free(%addr)
5. call free(%addr);
   call check_pointer(%p, 8)
6. %tmp = load %p
   call check_pointer(%tmp, 4)
7. store i32 1 to %tmp
```

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Program slicing

Program slicing removes instructions of a program that are irrelevant to a specified "behavior" of the program.

- The behavior is specified by slicing criterion $< V, l >$
  - V is a set of variables
  - l is a program location
  - meaning: preserve the value of variables in V at location l (and the reachability o fl) during any execution of the program
- Slicing criteria are (in our settings) error locations

Program slicing – how it works?

- Compute dependencies between instructions.
- We say that instruction A depends on instruction B if:
  - instruction A uses values generated by instruction B, or
  - instruction A is not executed if we go some other way at (branching) B.
- Slicing: keep only the instructions on which the error (transitively) depends.

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Program Slicing – example

```
int zeroing(char *buf, size_t size)
{
    int n = input();
    for (int i = 0; i < n; ++i) {
      assert(i < size && "Out␣of␣bounds");
      buf[i] = 0;
    }

    return 0;
}
```

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- Do nothing... (output the generated LLVM)
- Generate C from it and output it (`llvm2c` tool)
- Pass it to a verification engine (as LLVM or C, according to the verifier)

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So Symbiotic can be viewed as a

- C to LLVM compiler,
- C to C transformer,
- verification tool for C language

Verification engines

- Verification tools are integrated into Symbiotic by extending benchexec tool-info modules
- The extension adds methods for:
  - specifying the required LLVM version
  - (optional) setting the environment
  - (optional) hooks that run before or after compilation/instrumentation/slicing/verification

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- So far we have integrated KLEE, CPAchecker, DIVINE, SMACK, and SeaHorn
  - experimental support for CBMC, UltimateAutomizer, and IKOS

Symbiotic – Limits.

- No C++ (exceptions).
- Symbiotic still does not scale to large programs.
  - The current bottle-neck is data-dependence analysis in slicer

Symbiotic with CPAchecker

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- CPAchecker has LLVM backend
  - Parses LLVM and creates a CFA over C language
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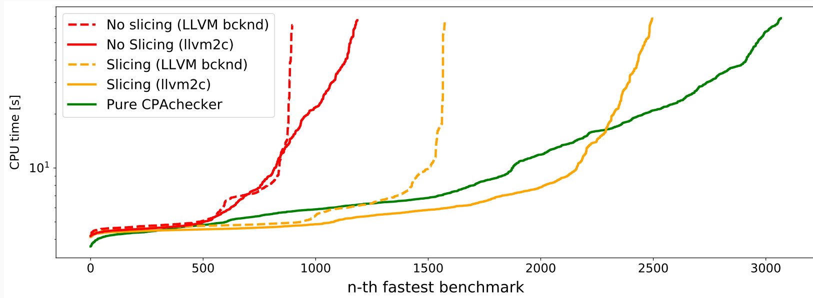
- We use the SV-COMP'19 configuration (`-svcomp19`) by default

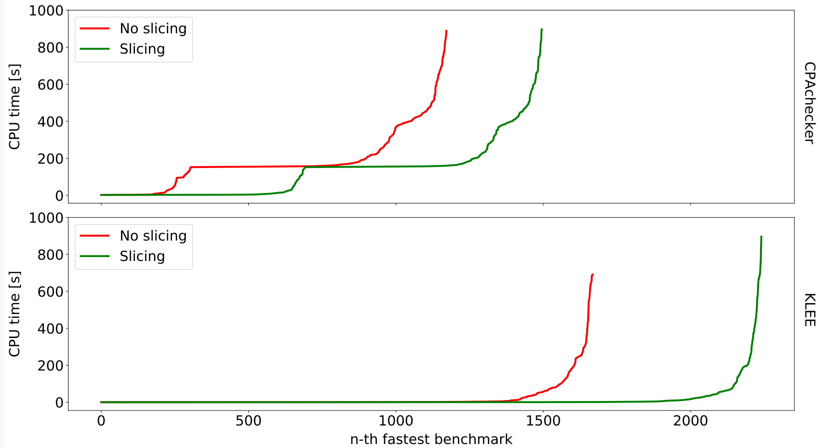
CPAchecker in Symbiotic

- Symbiotic + `llvm2c` + CPAchecker (with the C backend) now works better then Symbiotic + CPAchecker (LLVM backend)
- However, "pure" CPAchecker still works better then Symbiotic+CPAchecker

Experiments on ReachSafety category



Experiments with LLVM backend



Summary

- Symbiotic is a framework that generates optimized (LLVM or C) code for verification
- It is highly modular
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https://github.com/staticafi/symbiotic

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Thank you!