

Static Analysis Debugging with Symbolic Execution

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Outline

- 1 Static Analysis
- 2 Debugging a Static Analysis Implementation
- 3 Related Work
- 4 Our Idea
- 5 System Status Overview
- 6 Implementation
- 7 Questions?

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- Examples:
 - Pointer Analysis
 - Liveness Analysis
- Applications:
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 - Security
 - Software Engineering
- Inferred properties true for any execution

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Debugging a Static Analysis Implementation

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 - small regression tests

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- Compiler testing through miscompilation detection:

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- Symbolic execution (KLEE, OSDI 08)

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- Symbolic execution (KLEE, OSDI 08)
- Concolic execution (zesti, ICSE 12 - SAGE, ICSE13)

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 - Apply analysis to an input program
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- Static analysis inferences checked thoroughly
 - High path coverage of the input program
 - Big input program size

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- Reachability analysis for inputs affecting pointer values [under implementation]
- Testing with LLVM test suite programs

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Symbolic Execution

- Symbolic execution using klee
- Migration from Klee to Zesti (a variant of klee)

Debugger Logic for Pointer Analysis

```
foreach(loadI = load instructions) {  
    base_address = 'base address' of the loadI  
    foreach( 'pointer' in the same function scope as the load instruction) {  
        result = mustAlias_OR_mayNOTAlias('base_address ', 'pointer') // Querying the alias analysis.  
        if( result == must-alias) {  
            if ('base_pointer' and 'pointer' DO NOT point to the same run-time memory object) {  
                error  
            }  
        }  
        if (result == mayNot-alias) {  
            if ('base_pointer' and 'pointer' point to the same run-time memory object) {  
                error  
            }  
        }  
    }  
}
```

Implicitly adding klee_assumes

```
struct S {
    int member;
};
struct S data[] =
{
    { 1,2 },
    { 3,4 },
};
int main(int argc, char** argv) {

    int x= 0 ;
    struct S* z;

    klee_make_symbolic(&x, sizeof(x), "X");
    /*
    ** Without the following klee_assume, the dereference z->x gets resolved to many
    ** spurious memory objects.
    ** Generated in-bound constraints on the fly to prevent this.
    */
    klee_assume(x >= 0 & x <= 1 );

    z = &data[x];
    ... = z->member ;

    return 0;
}
```

Importance of choosing a variable as symbolic

```
1. int main() {
2.     int x=1 , y=2;
3.     int* p = (int *)malloc(sizeof(int));

4.     klee_make_symbolic(&x, sizeof(x), "x");
5.     klee_make_symbolic(&y, sizeof(y), "y");
   /*
   ** If we skip to make y symbolic, then we may miss the
   ** opportunity of catching a potential pointer analysis
   ** bug. For ex. what if the pointer analysis infers that
   ** *p and the heap object at line 7 mayNOT alias.
   */

   if(0 != x*y) {
6.       p = (int *)malloc(4);
   } else {
       if(y == 0) {
7.         p = (int *)malloc(4);
       }
   }
8.     return *p;
}
```

Which variables to make symbolic

- Explicitly specifying which variables to make symbolic is difficult.
 - Instrumented the code by inserting appropriate `klee_make_symbolic`.
 - Reachability Analysis to figure out candidates to be made symbolic.

Bugs Found

```
/* The bug shows up when there is a must alias check between
** x (at line 1) and the bitcast of x (at line 3).
*/
int main(int argc, char **argv) {
    int *A[5];
    for (int i = 0; i < 5; ++i) {
        A[i] = (int*) malloc((i+1)*sizeof(int));
    }

    int *x, a;
    char *y;

    for (int i = 0; i < 5; ++i) {
1.   x = A[i];
2.   a = *x;
3.   y = (char *) x;
    }
    return *y;
}
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