Toward Verification of Unchecked Codes in Checked C

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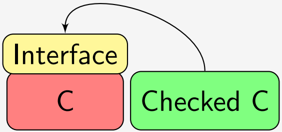

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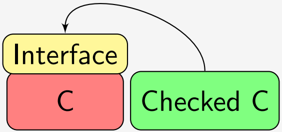

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Question

How do we provide security guarantees for a mix of checked and unchecked C codes?

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Goal

Verify the safety of unchecked functions against their bounds-safe interface.

Outline

Ep. 1: Finding Violations (Fantastic Bugs and Where to Find them)

Clang Static Analyzer

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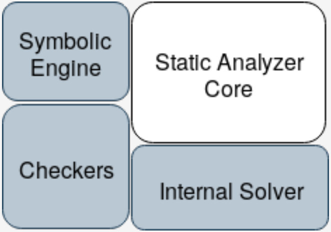
  - Explores all paths
  - Tracks program states
  - Maintains a hierarchical memory model



Clang Static Analyzer

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- Clang has a Static Analyzer
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- Core engine
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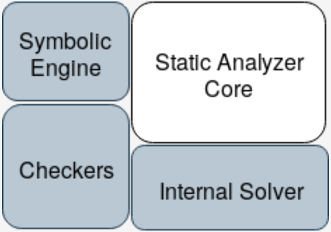
- A set of checkers that look for specific types of bugs



Clang Static Analyzer

- **Problem 1:** None of the checkers make use of the available Bounds information

Clang Static Analyzer

- Performs Symbolic Execution

```
int x;
int y;
int z = 2 * x;
int w = y - z;
```

```
x : $1
y : $2
z : 2 * $1
w : $2 - (2 * $1)
```

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int x;                                    x : $1
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  - Limited power on handling complex arithmetic
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```

- Internal solver
  - Limited power on handling complex arithmetic
  - Reasons about the ones with concrete starting point
- Bounds-safe information:

```
void foo(int *a: count(n), int n);
```

- **Problem 1:** None of the checkers make use of the available Bounds information.
- **Problem 2:** Bounds are commonly defined over non-concrete symbols.

SimpleBounds Checker

A new checker:

- Reads and make use of Bounds expressions
- Uses SMT solvers for handling complex bounds checking expression

Bounds Checking and Solvers

- Checking if the accessed location is within bounds

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- Solution: working example that could breaks the code!

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    int k = n + n;
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    int k = n + n;
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    int t = (n & 1) | ((n & 1) ^ 1);
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    a[t - 2] = 1;
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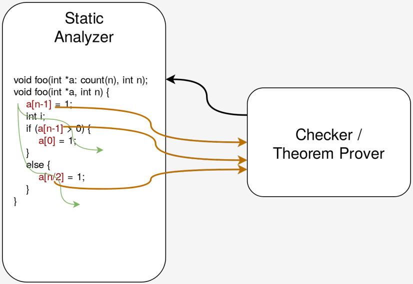

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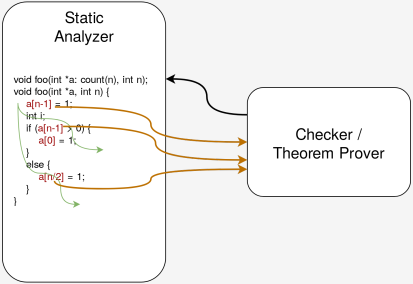


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    int i;
    for(i=0; i<n+1; i++)
        a[i] = 0;
}
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void foo(int *a : count(n), int n);
void foo(int *a : count(n), int n) {
    int i;
    for(i=n+1; i>=0; i--)
        a[i] = 0;
}
```

Ep.2: Safety Checking (Fantastic Bugs: The Crimes of Programmer)

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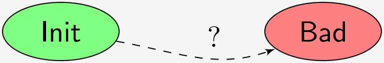

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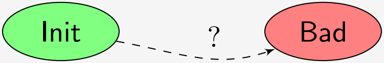

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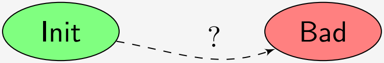

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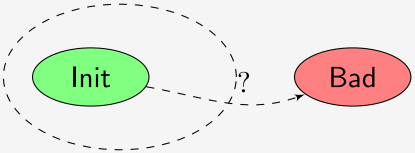

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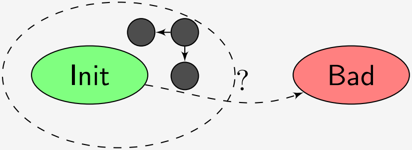

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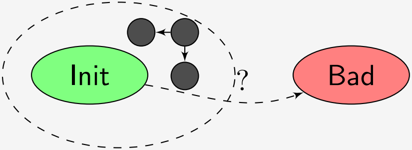

$$
\begin{aligned}
Init &\Rightarrow Inv \\
Inv(X) \wedge Tr(X, X') &\Rightarrow Inv(X') \\
Inv &\Rightarrow \neg Bad
\end{aligned}
$$

Seahorn

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```
{Pre: x_old = x, y_old = y}
int n = non_deterministic_value();
while (n--) {
    int t1 = x;
    int t2 = y;
    x = t1 + 1;
    y = t2 - 1;
}
{Post: x_old + y_old == x + y}
```

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Unchecked Code Verification

- **Problem 1:** How do we put verification conditions at each memory access location?
- Use the dynamic checks as verification conditions
- **Problem 2:** There is no dynamic checks in unchecked codes
- Use the same logic as in checked codes to inject checks for unchecked pointers
- More relaxed than being a checked code
- Assumption: all function calls within an unchecked region should call to functions with bounds-safe interface

Unchecked Code Verification

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Unchecked Code Verification

Replace the front-end of Seahorn with Checked C clang

1. Add bounds for unchecked pointers
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Merged into Master (PR #736)

Unchecked Code Verification

```
int sum(int *a : count(n), int n);
int sum(int *a, int n) {



  int i = 0, s = 0;
  for(i=0; i<n; i++) {
    s += a[i+1];


  }

  a[n / 2] = 1;

  return s;
}
```

Unchecked Code Verification

```
int sum(int *a : count(n), int n);
int sum(int *a, int n) {
  assume(a != NULL);
  assume(n > 0);

  int i = 0, s = 0;
  for(i=0; i<n; i++) {
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  for(i=0; i<n; i++) {
    s += a[i+1];
    sassert(i+1 < n);
    sassert(i+1 >= 0);
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```

The result should be "SAT": there exists a path to failing an assertion!

Limitations

- Checked C+Seahorn is sound if the conditions are sound
- Conditions are sound if the bounds inference is sound
- Seahorn works completely on LLVM side.

Conclusions

Demo.

Summary

Having an unchecked function with bounds-safe interface:

- Bounds-aware static analyzer checker finding OOB accesses
- Safety verification with Checked C+Seahorn

- Identifying limitations of static analysis and verification in Checked C
- Paths for future work in verification of checked/unchecked C codes

Future Work

- Bounds for unchecked pointers:
  - back-propagating the assumptions
  - forward-propagating the bounds
- Improving bounds inference
- Expanding the checker

Thanks!

Questions?