An exercise in mind reading: Automatic contract inference for Frama-C

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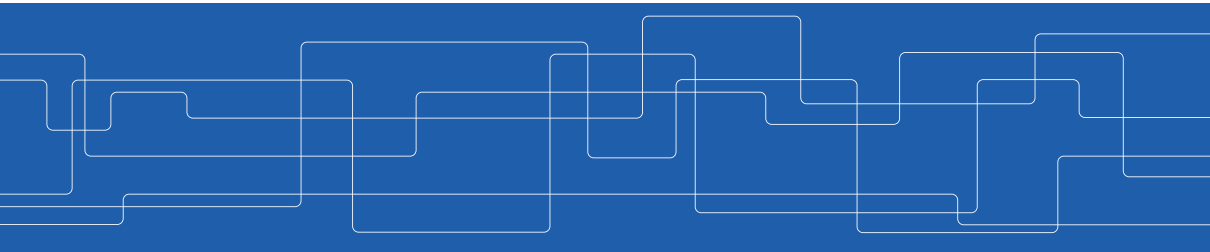

Automating deductive verification

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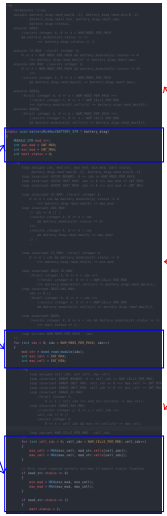
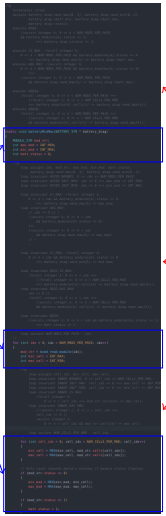


Code

Annotations

Automating deductive verification

Code



Specification inference techniques

- Dynamic
- Strongest post-condition
- Abstract Interpretation
- Property-guided
- etc

Contract inference – for helper functions

```
1
2
3  void helper1() { ... }
4
5
6
7  void helper2() { ... }
8
9  /*@ requires P;
10     ensures Q; */
11 void main() {
12     ...
13     helper1();
14     helper2();
15     ...
16 }
```

Idea

- Manually specify the main function.
- Infer contracts for all *helper* functions.
- The SAIDA plugin

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```

Where's my contract?

Idea

- Manually specify the main function.
- Infer contracts for all *helper* functions.
- The SAIDA plugin

Contract inference – for helper functions

Here they are!
(automatically inferred)

```
1  /*@ requires ...;
2      ensures  ...; */
3  void helper1() { ... }
4
5  /*@ requires ...;
6      ensures  ...; */
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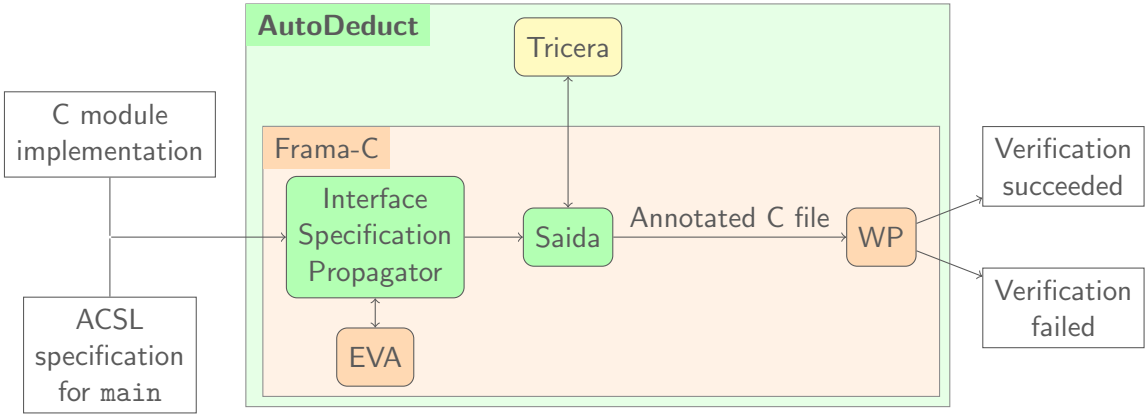
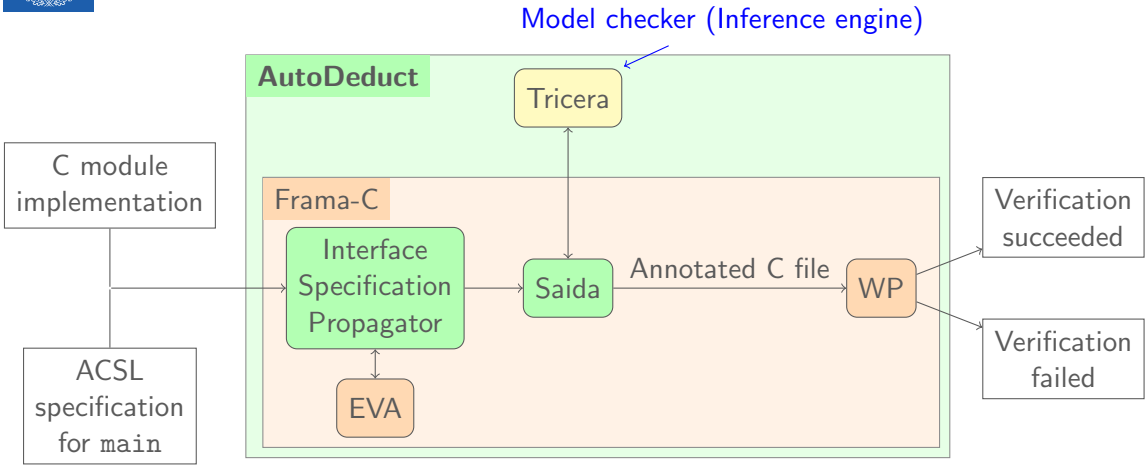
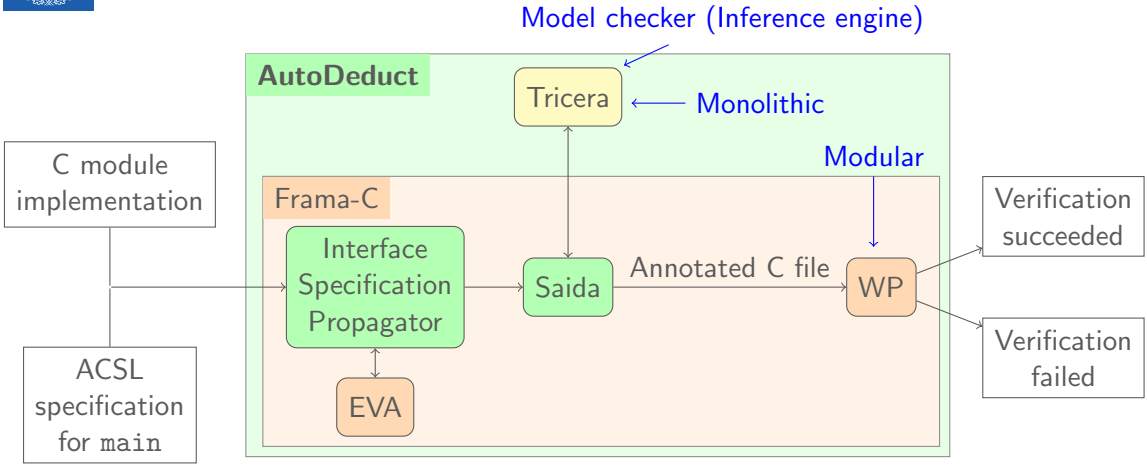
Workflow and toolchain



Workflow and toolchain



Workflow and toolchain



The TriCera model checker

```
1  int mc91(int n) {
2    if (n > 100) {
3      return n - 10;
4    } else {
5      return mc91(mc91(n + 11));
6    }
7  }
8
9  void harness() {
10   int x,y = _; // nondet init
11   assume(x <= 100);
12   y = mc91(x);
13   assert(y==91);
14 }
```

- Assertion-based
- Example, McCarthy 91:

$$mc91(n) = \begin{cases} n - 10 & \text{if } n > 100 \\ mc91(mc91(n + 11)) & \text{if } n \leq 100 \end{cases}$$

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Satisfies property:

$$mc91(n) = \begin{cases} n - 10 & \text{if } n > 100 \\ 91 & \text{if } n \leq 100 \end{cases}$$

Contract inference with TriCera

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Horn clause encoding CHCs (uninterpreted predicates):

mc91:

$mc91_{post}(n, n-10) \leftarrow mc91_{pre}(n) \wedge n > 100$

$mc91_{pre}(n+11) \leftarrow mc91_{pre}(n) \wedge n \leq 100$

$mc91_{post}(n, r) \leftarrow mc91_{post}(n+11, r') \wedge mc91_{post}(r', r)$

harness:

$harness1(x, y) \leftarrow x \leq 100$

$mc91_{pre}(x) \leftarrow harness1(x, y)$

$harness2(r, y) \leftarrow mc91_{post}(x, r) \wedge harness1(x, y)$

$false \leftarrow harness2(x, y) \wedge y \neq 91$

Contract inference with TriCera

Verification, find a solution:

$harness1(x, y) = ?$

$harness2(x, y) = ?$

$harness3(x, y) = ?$

$mc91_{pre}(n) = ?$

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Contract inference with TriCera

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$$harness1(x, y) = \ldots$$
$$harness2(x, y) = \ldots$$
$$harness3(x, y) = \ldots$$
$$mc91_{pre}(n) = 111 \geq n$$
$$mc91_{post}(n, r) = 111 \geq n \wedge (r = 91 \vee n - r \geq 10 \wedge r = 92)$$

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/*@ requires 111 >= n;
    ensures 111 >= \old(n) &&
     (\result == 91 || (\old(n)
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Contract inference for Frama-C (SAIDA)

1. Create Harness
2. Verify Harness *and* Program in TRICERA
3. Extract contracts from solution

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1  int mc91(int n) {
2    if (n > 100) {
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8  /*@ requires x <= 100;
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10 int entry(int x, int y) {
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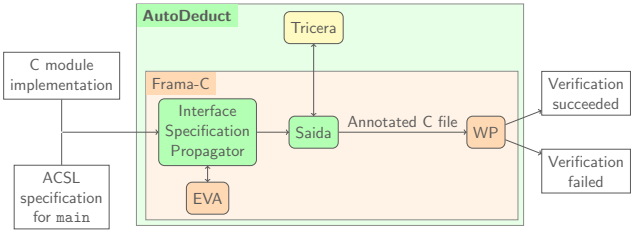
1. Create Harness
2. Verify Harness *and* Program in TRICERA
3. Extract contracts from solution
4. Verify program with inferred contracts using WP

```
void harness() {
  int x,y = _; //nondet init
  assume((x <= 100)); //requires
  int res = entry(x, y);
  assert((2*res == 91));  //ensures
}
```

Why back to Frama-C?

- Frama-C more powerful
- Partial inference
- Relax constraints on TriCera



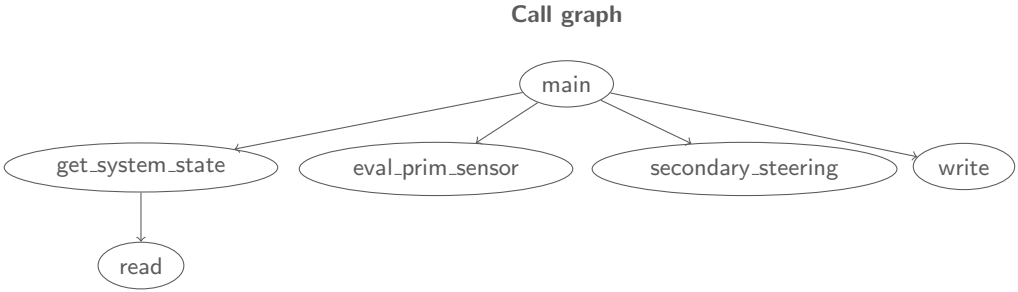
Loop invariants

```
1  /*@
2    requires N > 0 && x > y;
3    ensures x > y;
4  */
5  int main(int N, int x, int y) {
6    int i = 0;
7
8    /*@loop invariant N >= 1 && x - y >= 1 && i >= 0;*/
9    while (i < N) {
10     x = x*2;
11     y = y*2;
12     i++;
13   }
14 }
```

Demo

- Simplified version of module controlling secondary steering
- Five requirements, specified at top-level (main)

Demo



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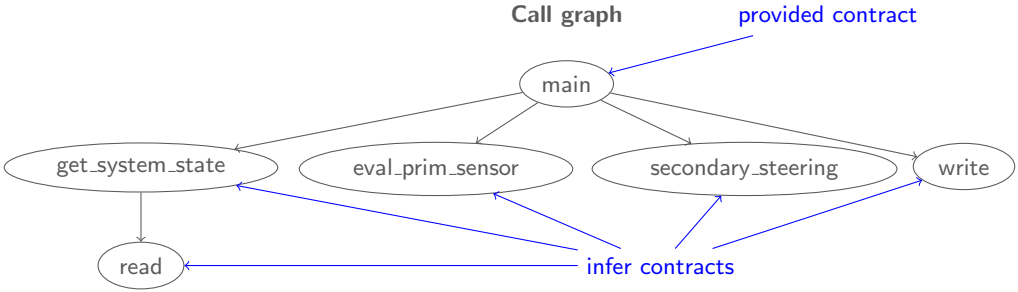

Outlook

- Show industrial-scale utility
- TriCera ACSL support
- Partial contract inference
- Library/API functions
- Support more language features

Saida Andersson (mind reader)

Saida: `https://github.com/rse-verification/saida`
TriCera: `https://github.com/uuverifiers/tricera`