Software Analyzers

Abstract Interpretation of Recursive Logic Definitions for Efficient Runtime Assertion Checking

Thibaut Benjamin, Julien Signoles

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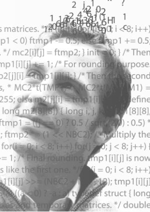
Université Paris-Saclay, CEA, List, F-91120, Palaiseau, France
University of Cambridge



RAC of Arithmetic Properties in E-ACSL

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- Specification language: ACSL (Baudin, Filliâtre, et al. n.d.)
- E-ACSL is a runtime assertion checker
  Give it a program with assertions, and it gives you a monitored program

Basic Principle of Inline Monitoring

C with
Logical Annotations

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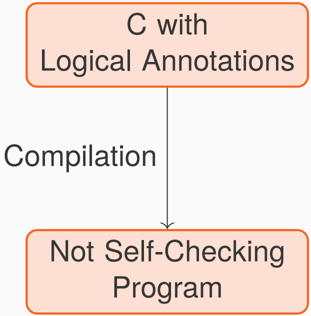

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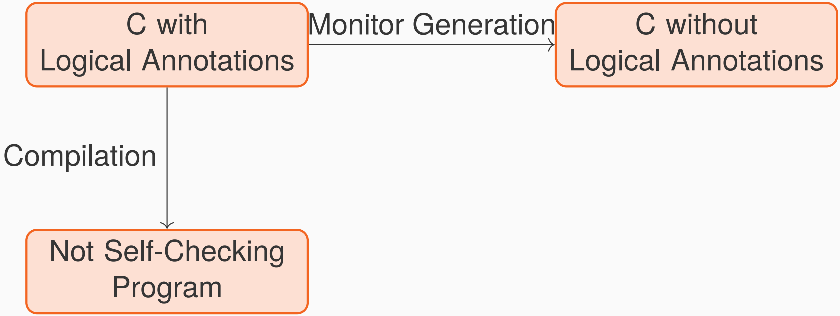

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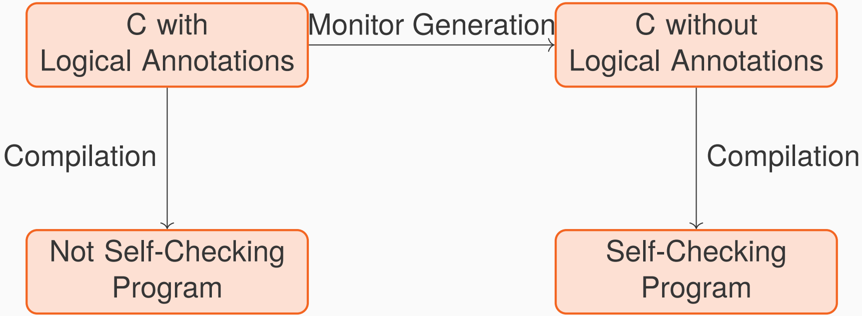

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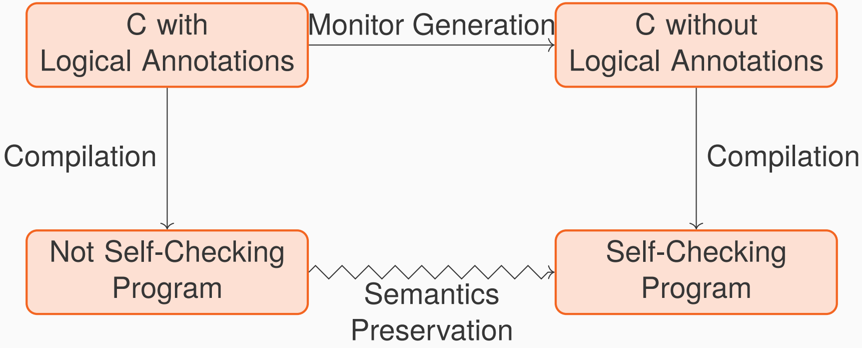

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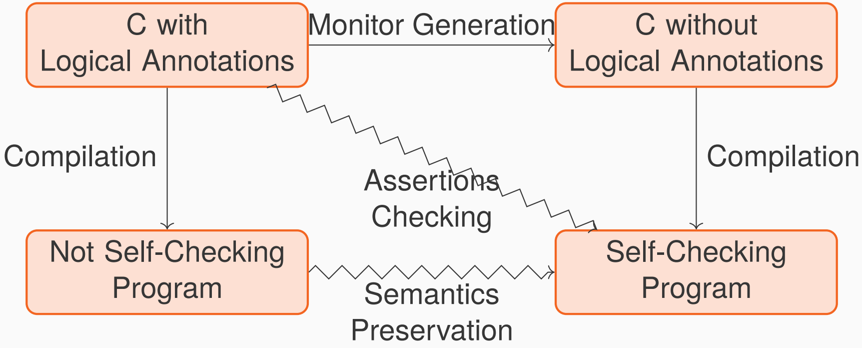

Minimal Example

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int main (){
  int x = 5;
  //@ assert x + 1 == 6;
  return 0;
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int main (){
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- Expressiveness : The more properties the monitor can handle the better

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  - User-defined Functions and Predicates

```
logic integer f (integer x) = t     ...     f(y)
predicate p (integer x) = b         ...     p(y)
```

Related Works

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  No mathematical integer at the time
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- Formlisation effort on E-ACSL
  In, particular: memory properties (Ly et al. 2020)

Correctness vs. Efficiency

Arithmetic Overflow Issues

Naive Approach:

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Arithmetic Overflow

Undefined Behavior

Solution: Arbitrary Precision Arithmetic

A correct translation generated using the GMP library:

```
// x is an int
//@ assert (x+1 == 0);
```

```
// x is an int
mpz_t y, z, o, r;
mpz_init_set_si(y, x);
mpz_init_set_si(o, 1);
mpz_init(r);
mpz_add(r, y, o);
mpz_init_set_si(z, 0);
int c = mpz_cmp(r, 0);
assert (c == 0);
mpz_clear(y);
mpz_clear(z);
mpz_clear(o);
mpz_clear(r);
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	machine integers	GMP integers
correct		✓
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Can we get the best of both worlds?

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Translating annotations this way in the presence of user-defined functions is challenging.

Out of scope for today (Benjamin and Signoles 2023)

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Build the static analysis with the following constraints

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↳ Interval arithmetic, with rules like

$$\frac{\vdash t : [a, b] \qquad \vdash u : [c, d]}{\vdash t + u : [a + c; b + d]}$$

Abstract Interpretation for User-Defined Logic Functions

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- We only present the case of functions.
  Predicates are the particular case of Boolean-valued functions.

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- The same logic function may be specialised several times
- Example:

```
//@ logic integer f (integer x) = x * 1024
...
//@ assert f(2097152) > f(256)
```

Specialise using GMP on the RHS, and `int` on the LHS

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- Way too many specialisations
  Essentially unrolls all recursive calls

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- Base case for argument fixpoint

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- In practice: $I \nabla I'$ extends I to the next machine integer boundary in the "direction of the growth"
  E.g. $[0, 5] \nabla [1, 6] = [0, 2^{31} - 1]$

Benchmarks

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- Benchmarks were run on minimal examples, since execution quickly fails without using this analysis.

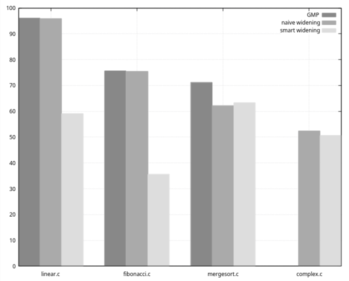

Figure: Evaluation of Monitor Efficiency.

Formal Guarantees

abstract semantics = interval inferred for a logic term in our system
concrete semantics = actual semantics of the ACSL language.

Theorem

Every term has an abstract semantics, and if the term has a concrete semantics, it is necessarily an element of the abstract semantics.

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  Terminates quickly even on ill-formed functions.
- Implemented and benchmarked in Frama-C/E-ACSL

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- Apply this idea to other systems dealing with integers
  E.g. Simulation software

THANK YOU

References I

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