C Program Specification and Verification with ACSL and Frama-C/WP

VerifyThis Tutorial

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CEA Tech List

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Overview of the tutorial

- short general introduction to Frama-C and ACSL
- examples of writing ACSL specifications
- verification of implementations with the WP plugin of Frama-C
- All material available on Frama-C github:

  `https://frama.link/fc-tuto-2019-04`

  - `Examples` contains plain (unannotated) C code
  - `Solutions` contains the corresponding annotations...
  - ... that should be provable by Frama-C 18.0, Alt-Ergo and Coq

It's 2019! Why bother with proving C programs?

- ✗ Lack of modularity and high-level constructs
- ✗ Many quirks in the semantics (pointers)
- ✗ Small standard library
- ✓ Lot of legacy code
- ✓ Embedded world (aka IoT) still uses it in many places
- ✓ And in some cases they care about safety and (cyber)security

A few recent use cases

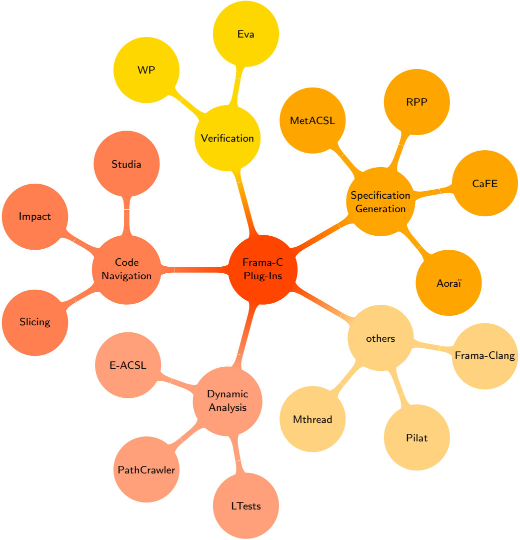
- S2OPC OPC (communication protocol for industrial systems), result of INGOPCS French project
- Bureau Veritas Cybersecurity Guidelines
- Vessedia H2020 project

  including verification of parts of Contiki OS

Frama-C at a glance

- A Framework for modular analysis of C code.
- http://frama-c.com/
- Developed at CEA Tech List and Inria
- Released under LGPL license (v18.0 Argon in November 2018)
- Kernel based on CIL (Necula et al. – Berkeley).
- ACSL annotation language.
- Extensible platform
  - Collaboration of analyses over same code
  - Inter plug-in communication through ACSL formulas.
  - Adding specialized plug-in is easy

Frama-C plugins



What is verified by Frama-C?

Code Properties

- Functional properties (contract)
- Absence of run-time error
- Termination
- Dependencies
- Non-interference
- Temporal properties

Perimeter of the verification

- Which part of the code is under analysis?
- Which initial context?

Trusted Code Base

- ACSL Axioms
- Hypotheses made by analyzers
  - WP memory model
- Stub Functions
- Frama-C itself

ANSI/ISO C Specification Language

Presentation

- Based on the notion of contract, like in Eiffel
- Allows users to specify functional properties of their code
- Allows communication between various plugins
- Independent from a particular analysis
- `https://github.com/acsl-language/acsl`

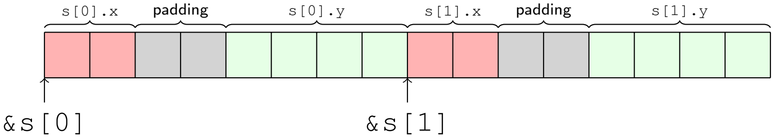
Basic Components

- First-order logic
- Pure C expressions
- C types $+ \mathbb{Z}$ (integer) and $\mathbb{R}$ (real)
- Built-ins predicates and logic functions, particularly over pointers.

Integer Arithmetic in ACSL

- All operations are done over $\mathbb{Z}$: no overflow
- ACSL predicate `INT_MIN <= x + y <= INT_MAX`
  $\Leftrightarrow$
  C operation `x+y` does not overflow (undefined behavior)
- $\texttt{(int)z} \equiv \texttt{z} \mod 2^{8*\texttt{sizeof(int)}}$
- and `INT_MIN <= (int)z <= INT_MAX`

Memory description in ACSL



```
struct S {
short x;
int y;
} s[2];
```

```
\valid(&s[0]+(0 .. 1))
\valid((char*)&s[0] + (0 .. 15))
!\initialized(*((char*)&s[0].x+2))
\block_length(&s[0]) == 16
\base_addr(&s[0].y) == s
\offset(&s[1].y) == 12
\separated(&s[0],&s[1])
```