frama C
Software Analyzers

Innovating Tool for Software Security

the Frama-C Framework

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list
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Software Analyzers

Outline

1. Frama-C
2. Value Analysis
3. Runtime Monitoring

Frama-C at a Glance

- extensible framework for C code verification [Kirchner et al @FAC'15]
- strong safety & security guarantees for critical applications
- open source, with close-source extensions
- both academic and industrial usage

http://frama-c.com

ACSL = ANSI/ISO C Specification Language

langua franca of Frama-C's analyzers :

- verify annotations
- generate annotations to be verified by other means
-
```
/*@ assert \valid(p); */
/*@ assert y+1 != 0; */
x = *p / (y+1);
```

Example : Function Contract in ACSL

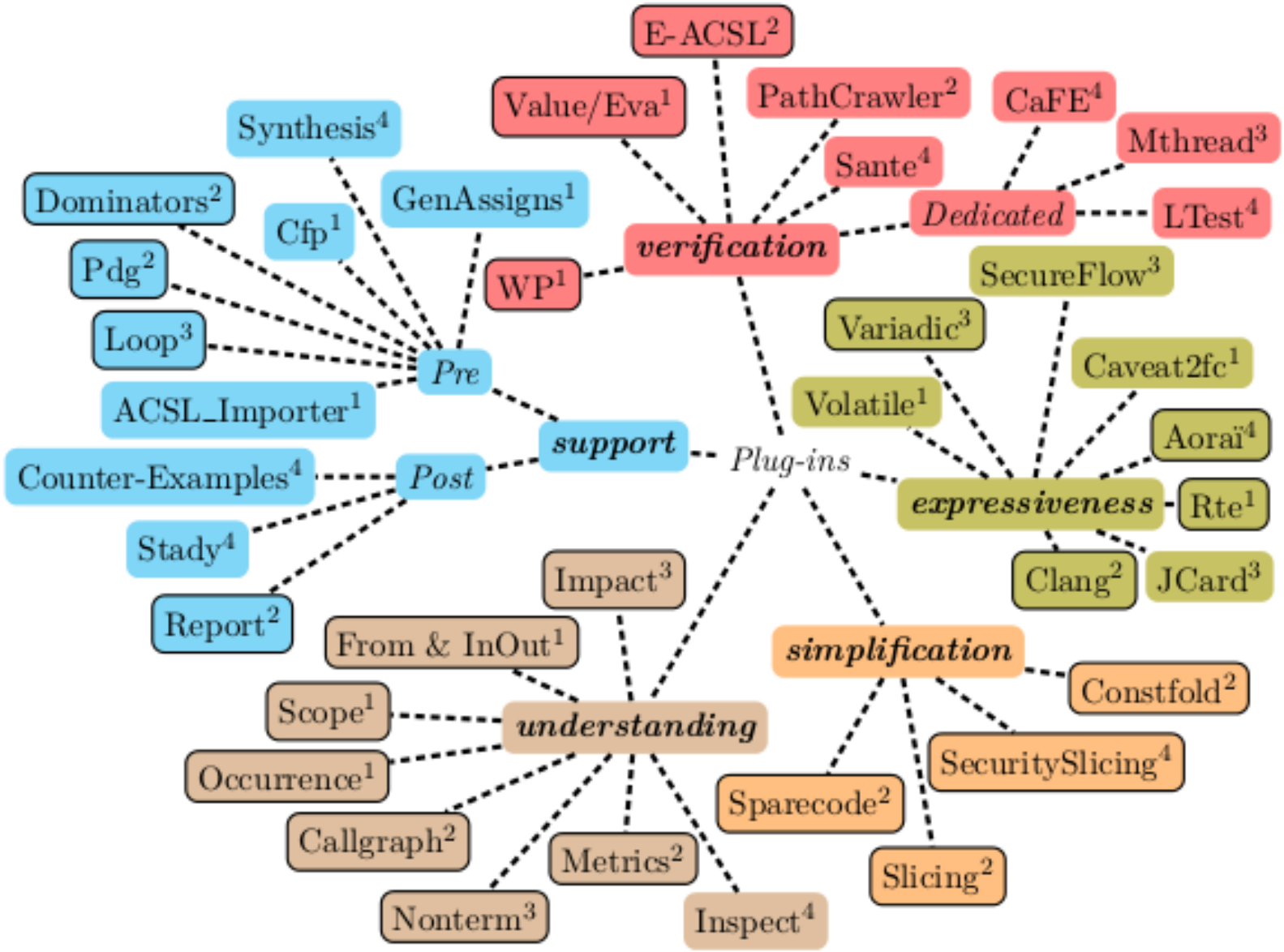
```
/*@ predicate sorted{L}(int* a, int length) =
      \forall integer i,j; 0 <= i <= j < length ==> a[i] <=a [j]; */

/*@ requires \valid(a+(0..length-1));
    requires sorted(a,length);
    requires length >= 0;

    assigns \nothing;

    behavior exists:
      assumes \exists integer i; 0 <= i < length && a[i] == key;
      ensures a[\result] == key;

    behavior not_exists:
      assumes \forall integer i; 0 <= i < length ==> a[i] != key;
      ensures \result == -1;

    complete behaviors;
    disjoint behaviors; */
int search(int* a, int length, int key);
```

Frama-C, a Collection of Tools

Several tools inside a single platform

- plug-in architecture *à la* Eclipse [S. @F-IDE'15]
- tools provided as plug-ins
  - 21 plug-ins in the open source distribution
  - a few outside open source plug-ins
  - close source plug-ins, either at CEA (about 20) or outside
- plug-ins connected to a kernel
  - provides an uniform setting
  - provides general services
  - synthesizes useful information
  - analyzer combinations [Correnson & S. @FMICS'12]

Plug-in Gallery



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Value Analysis Overview

Domain of variations of variables of the program

- abstract interpretation [Cousot & Cousot @POPL'77]
- automatic analysis, but fine tuning required
- correct over-approximation (e.g. $x \in [1..99], 1\%2$)
- alarms for potential undefined behaviors
- may ensure absence of undefined behaviors
- alarms for potential invalid ACSL annotations
- graphical interface : display the domain of each variable at each program point

Plug-in Eva

Main Features

- Frama-C plug-in for Value Analysis
- generic analysis on the abstract domain
- allow combination of abstract domains and some inter-reductions of their states
- should be easy to add new domain
  - domains was added (e.g. Apron) and are still being added

Plug-in Eva

Design

the design relies on the separation between :

- values
  - abstraction of the possible C values of an expression
  - abstract transformers for arithmetic operators on expressions
  - communication interface for abstract domains
- domains
  - abstraction of the set of reachable states at a program point
  - abstract transformers of states through statements
  - can be queried for the values of some C expressions
- [Bühler, Yakobowski and Blazy @VMCAI'17]

Value Analysis Applications

Scada System

can we guarantee absence of defaults in large system-level code ?

- scada systems of 100+ kloc of C code
- highest certification requirements (IEC60880 class 1)
- pinpoint the undefined behaviors and help investigate their cause
- structural properties on memory separation and cyclic behaviors
- 80% code coverage, 200 alarms
- [Ourghanlian in Nuclear Engineering and Technology, 2015]

EDF

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Runtime Verification

E-ACSL at a Glance

- E-ACSL plug-in [Delahaye, Kosmatov & S. @SAC'13]
- program transformation which generates an inline monitor
- verify annotations at runtime
- input : program P annotated with (E-)ACSL
- output : program P' which
  - is equivalent to P for valid inputs ; otherwise
  - fails on the first violated annotation

Runtime Verification

E-ACSL at a Glance

- E-ACSL plug-in [Delahaye, Kosmatov & S. @SAC'13]
- program transformation which generates an inline monitor
- verify annotations at runtime
- input : program P annotated with (E-)ACSL
- output : program P' which
  - is equivalent to P for valid inputs ; otherwise
  - fails on the first violated annotation

```
char succ(char x) {
  /*@ assert x+1 <= 127; */
  return x+1;
}
```

E-ACSL →

```
char succ(char x) {
  /*@ assert x+1 <= 127 ; */
  e_acsl_assert(x+1 <= 127);
  return x+1;
}
```

Runtime Verification with E-ACSL

Applications

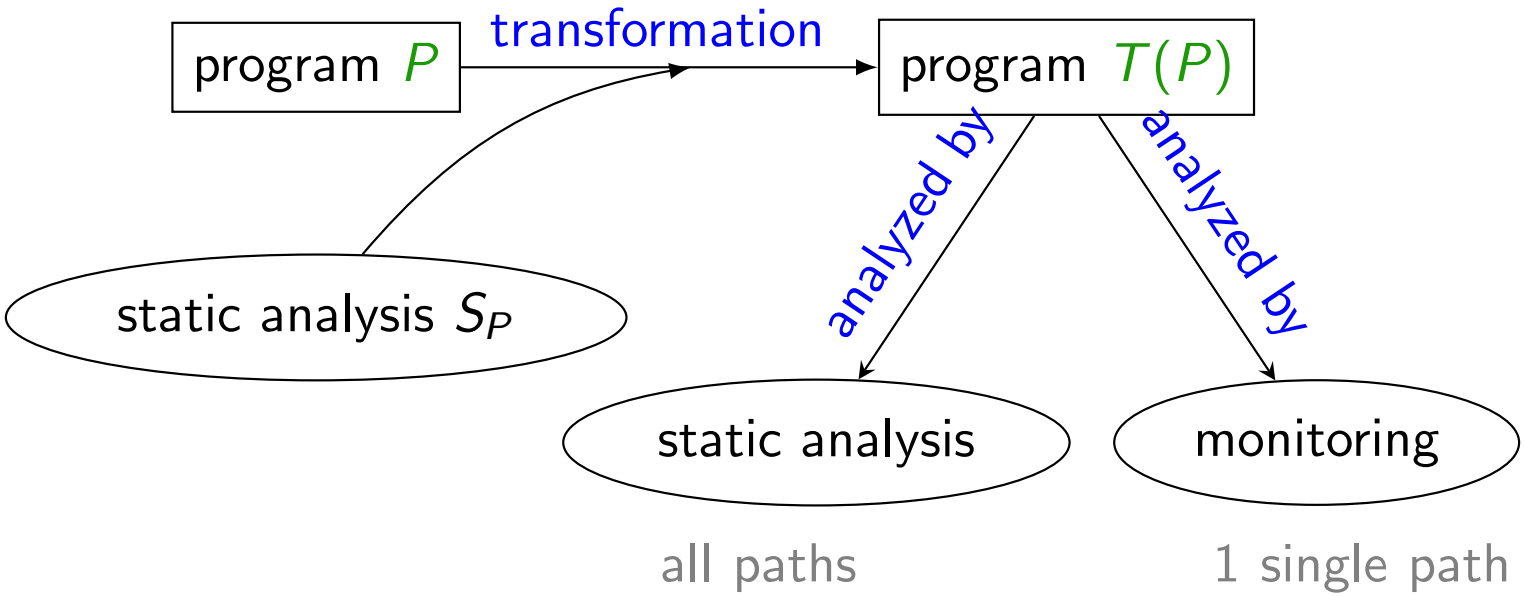
Monitoring

- undefined behaviors with plug-in RTE
  - memory accesses
  - arithmetic overflows
- complex functional properties
- memory consumption
- correct API usage with plug-in Aoraï
- information flow issue with plug-in SecureFlow

Information Flow Analysis

SecureFlow

- information flow analysis : verify absence of leakage of sensitive data (termination insensitive non interference)



- [Assaf et al @SEC'13, Barany @VPT'16]

Other Security Analyses within Frama-C

Frama-C is also a tool of choice for your security analyses

- TIS-analyzer and TIS-interpreter [TrustInSoft]
- taint analysis [Ceara, Mounier and Potet @ICSTW'10]
- source code model for physical attacks on smart cards [Berthomé et al @PLAS'10]
- fault injection in implementations of cryptographic protocols [Christofi's PhD thesis, 2013]
- secure generative programming [Anin and Rompf @POPL'17]
- security counter-measures based on static detection and runtime assertion checking of CVEs [Pariente & S., submitted]

Conclusion

- Frama-C, collaborative framework for C code verification
  - open and extensible framework
  - both academic and industrial usage
- Eva (Frama-C plug-in)
  - verify the absence of undefined behaviors
  - may help prevent security flaws
- E-ACSL (Frama-C plug-in)
  - runtime verification
  - bug finding tool
  - verify more properties than testing or other dynamic tools
- SecureFlow (Frama-C plug-in)
  - verify non-interference
  - in combination with Eva and/or E-ACSL

Selected Publications

http ://frama-c.com

- F. Kirchner, N. Kosmatov, V. Prevosto, J. Signoles, and B. Yakobowski.
  Frama-C : a Software Analysis Perspective. FAC'2015.
- D. Bühler, B. Yakobowski, and S. Blazy.
  Structuring Abstract Interpreters through State and Value Abstractions VMCAI'17.
- N. Kosmatov, and J. Signoles.
  A lesson on runtime assertion checking with Frama-C (tutorial). RV'2013.
- M. Assaf, J. Signoles, É. Totel, and F. Tronel.
  Program transformation for non-interference verification on programs with pointers. SEC'2013.