Goblint: Mixed Flow-Sensitive Abstract Interpretation

Simmo Saan[1] Julian Erhard[2,3] **Michael Schwarz**[2] Karoliine Holter[1] Michael Petter[2]
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SV-COMP Community Meeting 2025

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Goblint in 4 Bullet Points

- Static Analyzer for C programs
- Based on abstract interpretation — sound!
- Overapproximating — no violations!
- Specializes in multi-threaded programs

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- Static Analyzer for C programs
- Based on abstract interpretation — sound!
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A basic example approach:

- Accumulate all possible values for globals
- Track local states per program point

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

```
t1:
    g = 10;
    ...
    g = 42;
```

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

$\top$

```
t1:
    g = 10;
    ...
    g = 42;
```

$[g]$:

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
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t1:
    g = 10;
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$[g]:$

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

$\top$

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 0]$$

```
int g = 0;

main:                 ⊤
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 0]$$

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

$\top$

$\{x \mapsto [3,3]\}$

```
t1:
    g = 10;
    ...
    g = 42;
```

$[g] : [0,0]$

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
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$\{x \mapsto [3,3]\}$

```
t1:
    g = 10;
    ...
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$[g] : [0,0]$

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int g = 0;

main:
    x = 3;
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$\{x \mapsto [3,3]\}$

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0,8]$$

```
int g = 0;

main:
    x = 3;
    g = 8;
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      error();
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```

$\top$

$\{x \mapsto [3,3]\}$

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0,8]$$

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

$\top$

$\{x \mapsto [3,3]\}$

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```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 8]$$

```
int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
    }
    ...
```

$\top$

$\{x \mapsto [3,3]\}$

$\{x \mapsto [3,3]\}$

```
t1:
    g = 10;
    ...
    g = 42;
```

$[g] : [0, 8]$

```
int g = 0;

main:                    ⊤
    x = 3;               {x ↦ [3,3]}
    g = 8;               {x ↦ [3,3]}
    if(g > 10) {
      error();
    }
    ...
```

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 8]$$

```
int g = 0;

main:
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$\{x \mapsto [3,3]\}$

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t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 8]$$

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int g = 0;

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    x = 3;
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$$[g] : [0, 8]$$

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```

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 10]$$

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int g = 0;

main:
    x = 3;
    g = 8;
    if(g > 10) {
      error();
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    ...
```

```
t1:
    g = 10;
    ...
    g = 42;
```

$$[g] : [0, 10]$$

```
int g = 0;

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```

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t1:
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```

$$[g] : [0, 10]$$

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int g = 0;

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t1:
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    ...
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$$[g] : [0, 42]$$

```
int g = 0;

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t1:
    g = 10;
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$$[g] : [0, 42]$$

```
int g = 0;

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```
t1:
    g = 10;
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$[g] : [0, 42]$

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main:
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t1:
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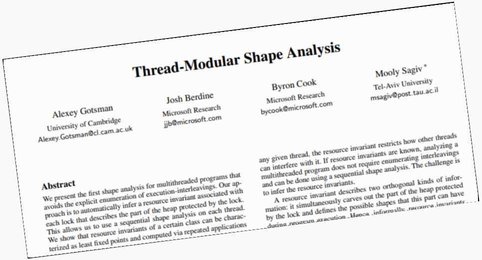
$$[g] : [0, 42]$$

Zooming out:

- Accumulate information for global variables
- Track local states per program point



Thread-Modular Shape Analysis

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Byron Cook
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Mooly Sagiv [*]
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Abstract

We present the first shape analysis for multithreaded programs that avoids the explicit enumeration of execution-interleavings. Our approach is to automatically infer a resource invariant associated with each lock that describes the part of the heap protected by the lock. This allows us to use a sequential shape analysis on each thread. We show that resource invariants of a certain class can be characterized as least fixed points and computed via repeated applications

any given thread, the resource invariant restricts how other threads can interfere with it. If resource invariants are known, analyzing a multithreaded program does not require enumerating interleavings and can be done using a sequential shape analysis. The challenge is to infer the resource invariants.

A resource invariant describes two orthogonal kinds of information: it simultaneously carves out the part of the heap protected by the lock and defines the possible shapes that this part can have

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STATIC ANALYSIS OF RUN-TIME ERRORS IN EMBEDDED REAL-TIME PARALLEL C PROGRAMS

ANTOINE MINÉ

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Abstract. We present a static analysis by Abstract Interpretation to check for run-time errors in parallel and multi-threaded C programs. Following our work on Astrée, we focus on embedded critical programs without recursion nor dynamic memory allocation, but extend the analysis to a static set of threads communicating implicitly through a shared memory and explicitly using a finite set of mutual exclusion locks, and scheduled according to a real-time scheduling policy and fixed priorities. Our method is thread-modular. It is

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Relational Thread-Modular Static Value Analysis by Abstract Interpretation*

Antoine Miné

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Abstract. We study thread-modular static analysis by abstract interpretation to infer the values of variables in concurrent programs. We show how to go beyond the state of the art and increase an analysis precision by adding the ability to infer some relational and history-sensitive properties of thread interferences. The fundamental basis of this work is the formalization by abstract interpretation of a rely-guarantee concrete semantics which is thread-modular, constructive, and complete for safety

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Improving Thread-Modular
Abstract Interpretation

Michael Schwarz[1], Simmo Saan[2], Helmut Seidl[1], Kalmer Apinis[2],
Julian Erhard[1], and Vesal Vojdani[2]

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Abstract. We give thread-modular non-relational value analyses as abstractions of a local trace semantics. The semantics as well as the analyses are formulated by means of global invariants and side-effecting constraint systems. We show that a generalization of the analysis provided by the static analyzer GOBLINT as well as a natural improvement of Antoine Miné's approach can be obtained as instances of this general scheme. We show that these two analyses are incomparable w.r.t. precision and

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Clustered Relational Thread-Modular Abstract Interpretation with Local Traces

Michael Schwarz[1](✉), Simmo Saan[2], Helmut Seidl[1], Julian Erhard[1], and Vesal Vojdani[2]

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Improving Thread-Modular Abstract Interpretation

Global Invariants for Analyzing Multi-threaded Applications

Helmut Seidl*
Universität Trier, Germany

Varmo Vene†
Tartu University, Estonia

Markus Müller-Olm‡
FernUniversität Hagen, Germany

Abstract

We exhibit an interprocedural framework for the analysis of multi-threaded programs based on *partial invariants* of a new kind of constraint systems which we call *side-effecting*. We explore the formal properties of these constraint systems and provide general techniques for computing partial invariants. We demonstrate the practicality of this approach by designing and implementing a reasonably efficient flow- and context-sensitive interprocedural data-race analyzer of multi-threaded C.

Clustered … Abstract Interpretation with Local Traces

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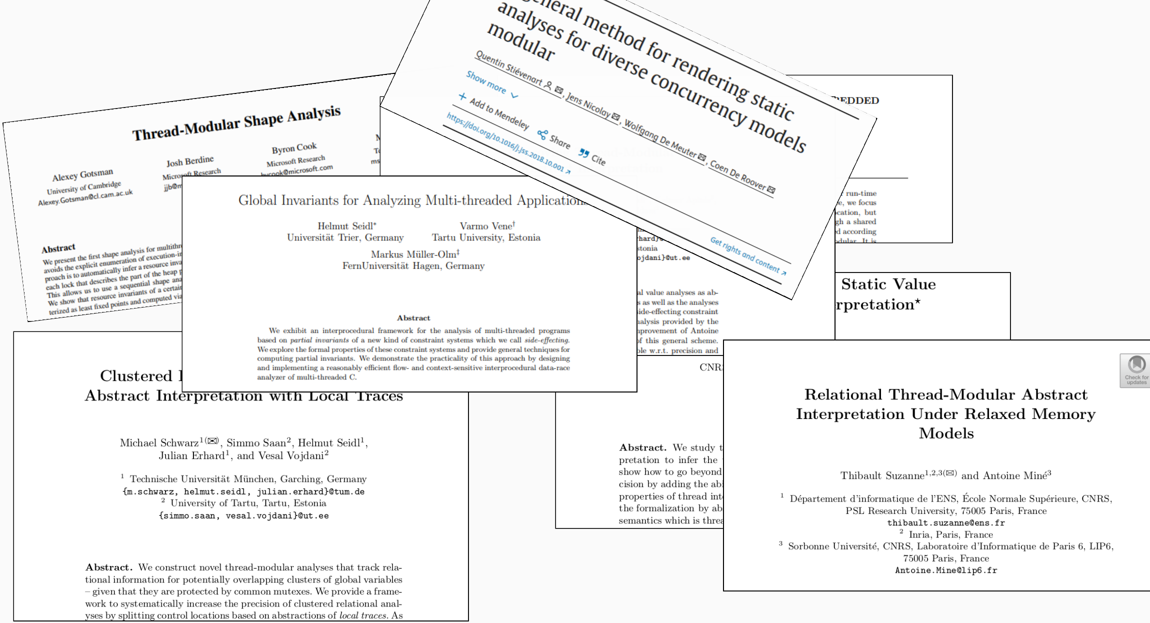
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Relational Thread-Modular Abstract Interpretation Under Relaxed Memory Models
Thibault Suzanne1,2,3(✉) and Antoine Miné3
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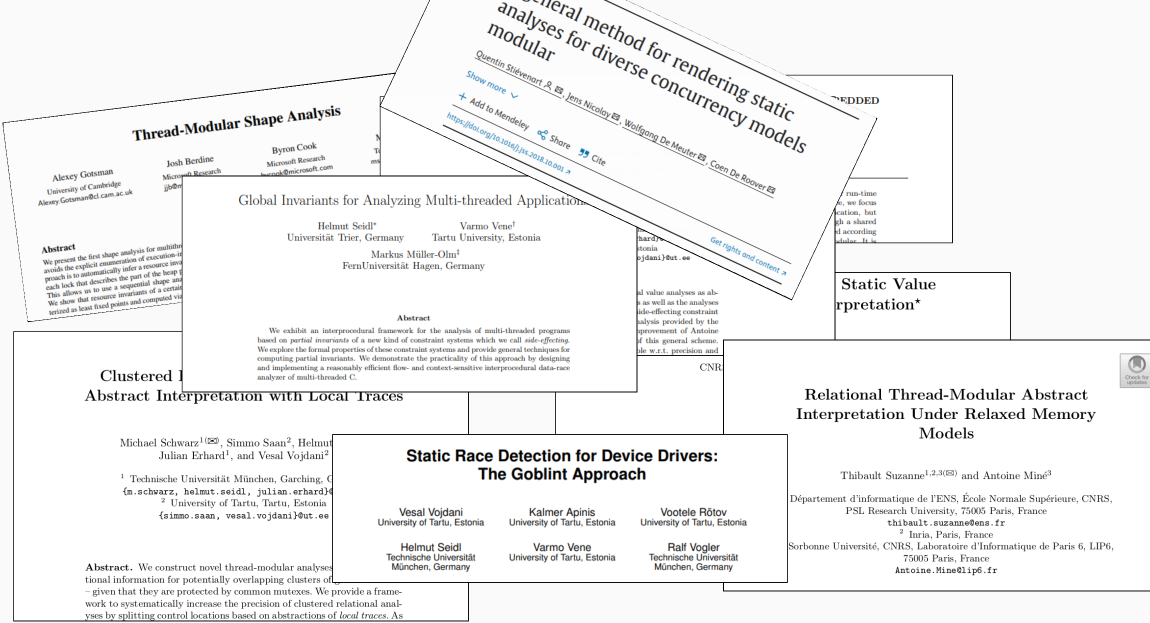

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Vesal Vojdani
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Relational Thread-Modular Abstract Interpretation Under Relaxed Memory Models
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Zooming out further

Differentiate:

- Flow-insensitive for some information:
- Flow-sensitive for other information:

Zooming out further

Differentiate:

- Flow-insensitive for some information: **Globals**
- Flow-sensitive for other information: **Locals**

Zooming out further

Differentiate:

- Flow-insensitive for some information: **Globals**
- Flow-sensitive for other information: **Locals**

Mixed Flow-Sensitivity

Example: Thread-Modular Analysis of Multi-Threaded Programs

- **Globals**: program globals
- **Locals**: program points of threads

Further Examples within Goblint

Partial Contexts / Context Lifters

- **Globals**: Start points of procedures
- **Locals**: Other program points of procedures

Further Examples within Goblint

Non-Local Control Flow via `setjmp/longjmp`

- **Globals**: Targets of longjumps
- **Locals**: Other program points of procedures

Mixed Flow-Sensitivity

Differentiate:

- Flow-insensitive for some information: **Globals**
- Flow-sensitive for other information: **Locals**

Generic concept arising in many settings

Mixed Flow-Sensitivity

Differentiate:

- Flow-insensitive for some information: **Globals**
- Flow-sensitive for other information: **Locals**

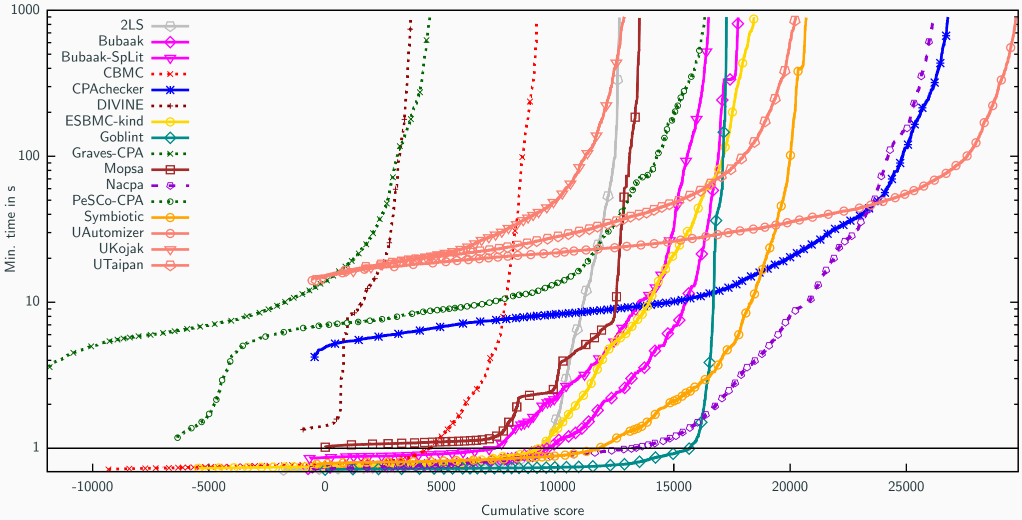
Generic concept arising in many settings

An implementation using side-effecting constraint systems lies at the heart of GOBLINT

Results in this year's competition

- Best in class for data race freedom
  - behind metaverifier CoOpeRace which incorporates Goblint
- Only tool to support all properties without producing any incorrect verdicts
  - (**Second year in a row**, this needs to change!)

Overall



2LS
Bubaak
Bubaak-SpLit
CBMC
CPAchecker
DIVINE
ESBMC-kind
Goblint
Graves-CPA
Mopsa
Nacpa
PeSCo-CPA
Symbiotic
UAutomizer
UKojak
UTaipan
Min. time in s
1000
100
10
1
-10000
-5000
0
5000
10000
15000
20000
25000
Cumulative score

Ockham Criterion

Proposed by [Black and Ribeiro, '16] for SATE V:

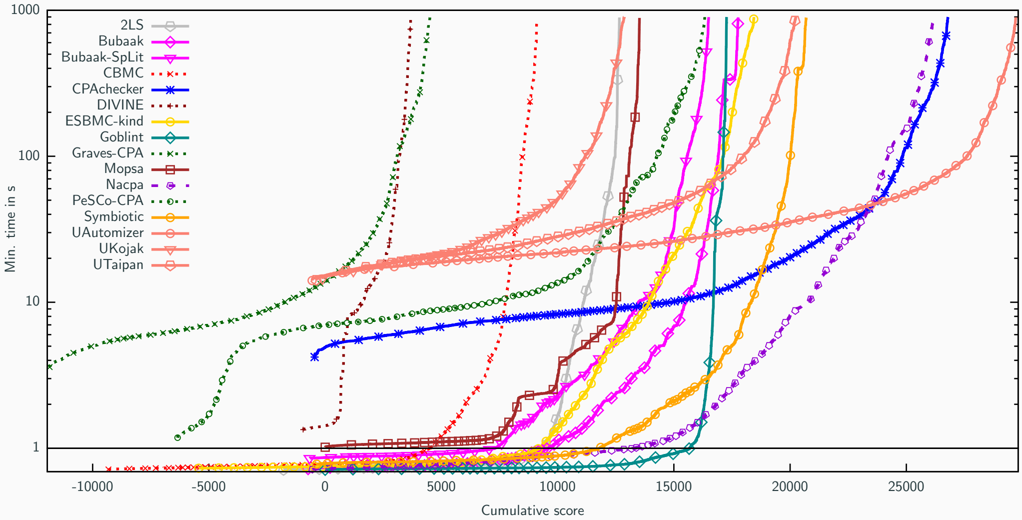
(1) The analyzer's findings are claimed to always be correct.

(2) It produces findings for most of a program.

(3) **Even one incorrect finding disqualifies an analyzer**.

William of Ockham
(c. 1287-1347 CE)

Overall



1000
100
10
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Min. time in s
-10000
-5000
0
5000
10000
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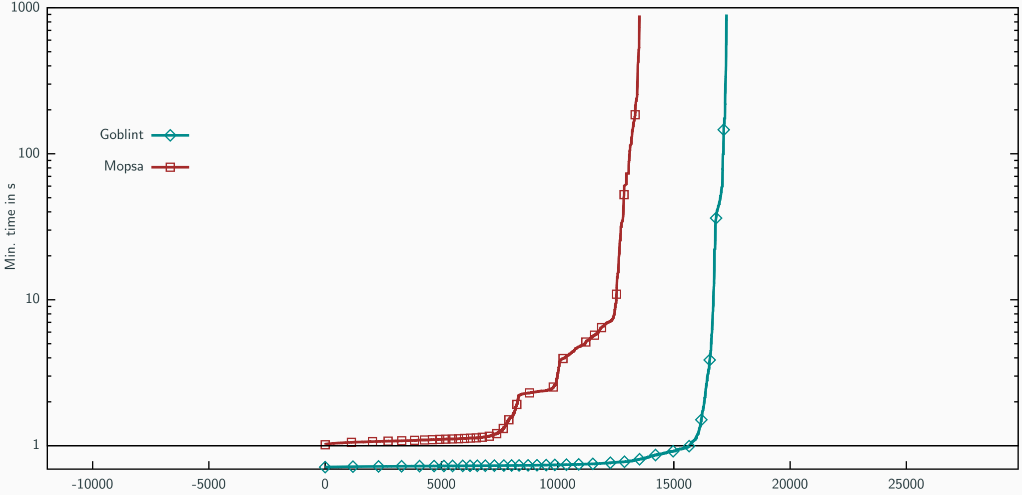
Goblint
Graves-CPA
Mopsa
Nacpa
PeSCo-CPA
Symbiotic
UAutomizer
UKojak
UTaipan

Overall (Ockham)



Thank you!

- Mixed Flow-Sensitivity
  - Flow-sensitive for some unknowns
  - Flow-insensitive for others
- Best contestant for data races
- Best overall score without incorrect verdicts

/goblint/analyzer

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