# Comparing Transparent Static Analyzers with Open Verification Dashboard

Tom Goalard, Karoliine Holter, Simmo Saan,
Vesal Vojdani, Raphaël Monat

`rmonat.fr/ecoop26_tsa`

ECOOP
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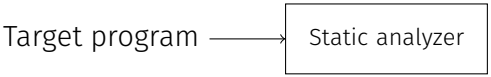
Inria

# Static Analysis

Target program

# Static Analysis



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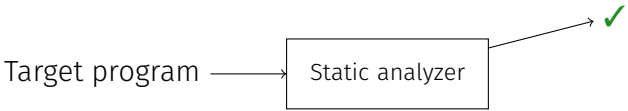

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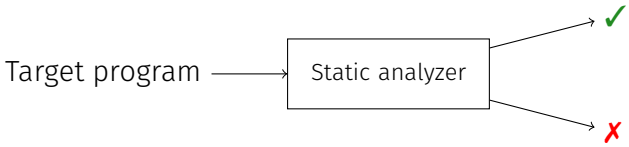

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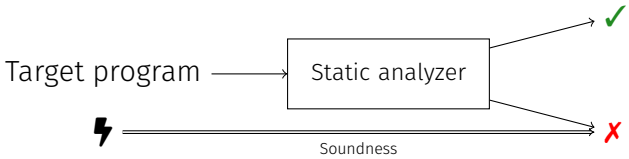

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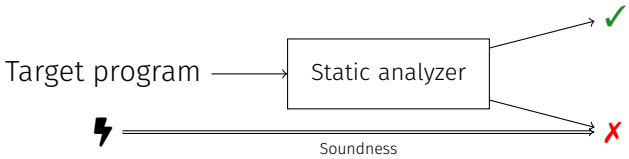


## Alarms

- Muske and Serebrenik [MS23]: 130 works on alarm postprocessing
- Alarms are only one side of the coin!

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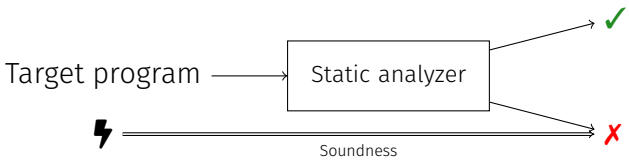


## Alarms

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## Transparency

- Log proof obligations (PO). Analogy with deductive verification.
- Enables semantics-directed, fine-grained output.

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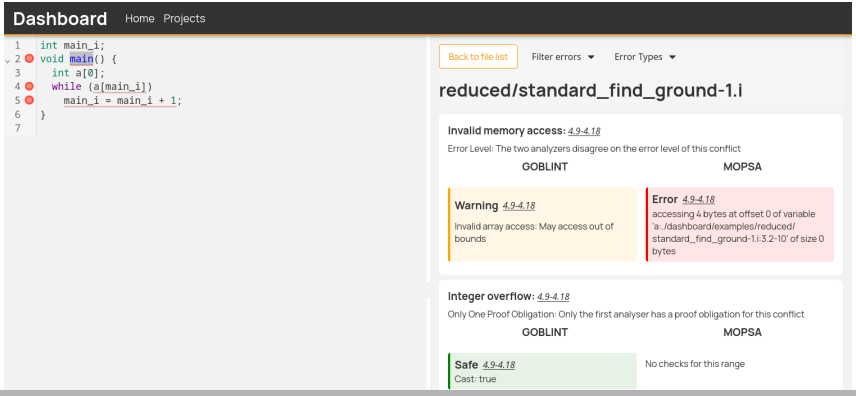

# Outline

1. Transparent Static Analysis
2. Open Verification Dashboard
3. Experimental Evaluation

# Transparent Static Analysis

# Safety check categories

Example on toy imperative language with mathematical integers

| | |
|---|---|
| $\mathcal{C} = \{\text{divByZero}\}$ | *Safety check categories* |
| $\mathcal{L}$ | *Program locations* |
| $\varphi \in \text{PO} = \mathcal{L} \times \mathcal{C}$ | *Proof obligations* |
| $\Theta \subseteq \text{CH} = \text{PO} \times \{\checkmark, \times\}$ | *Checks* |

# Concrete Collecting Semantics

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$$\textbf{let } M_1 = \mathbb{E}[\![e_1]\!]\sigma \textbf{ and } M_2 = \mathbb{E}[\![e_2]\!]\sigma \textbf{ in}$$
$$\{m_1 / m_2 \mid m_i \in M_i, m_2 \neq 0, m_1 / m_2 \in \mathbb{Z}\}$$

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$\Theta \subseteq \Theta^\sharp$ concisely encodes:

- If a check fails at runtime, the analysis should say so *true alarm*
- If a check is reachable at runtime, the analysis should check it *safe check, false alarm*

# Report postprocessing

From analysis checks (same location, multiple contexts) to analysis results:

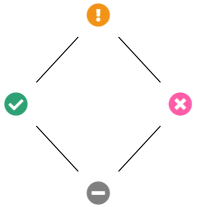
$$\text{checkStatus} : 2^{\{\checkmark,\times\}} \to \text{Status}$$

$$\emptyset \mapsto \ominus$$

$$\{\checkmark\} \mapsto \checkmark$$

$$\{\times\} \mapsto \times$$

$$\{\checkmark,\times\} \mapsto !$$



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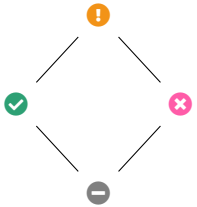

$$\{(l, \text{divByZero}), ✓\} \cup \{(l, \text{divByZero}), ✗\} \rightsquigarrow (l, \text{divByZero}), !$$

# Open Verification Dashboard

# Cross-Analyzer Comparison

| Status$_1$ \ Status$_2$ | ! | ✗ | ✓ | − |
|---|---|---|---|---|
| ! | **A$^-$** | P | P | D |
| ✗ | P | **A$^-$** | C | D |
| ✓ | P | C | **A$^+$** | D |
| − | D | D | D | **A$^+$** |

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- Coverage **disagreement** (D)
- Precision **asymmetry** (P)
- **Contradiction** (C)

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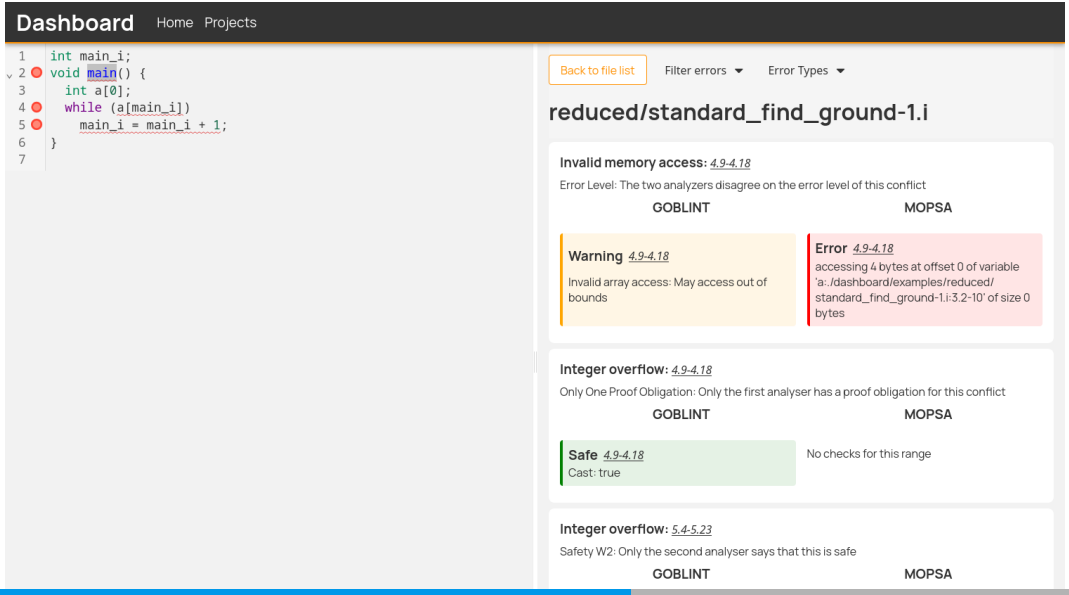
# Open Verification Dashboard GUI – Detailed view



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Following a systematic comparison, 6 categories identified:

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## Program Range Reporting

Multiple choices (line only, line+column, line+column**s**) in IKOS, Goblint, Mopsa

$\rightsquigarrow$ Heuristic location alignment (details in paper)

# Experimental Evaluation

# Protocol

## Benchmarks

- SV-COMP no-overflow (8,358 tasks)
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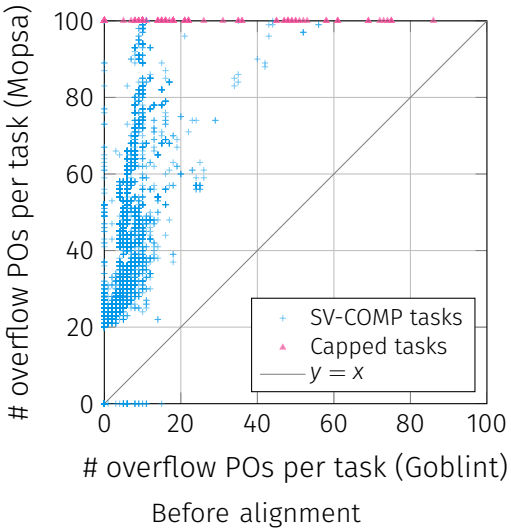
3. Distillation of Disagreements through Testcase Reduction?

# SV-COMP Benchmark Validity?




Before alignment

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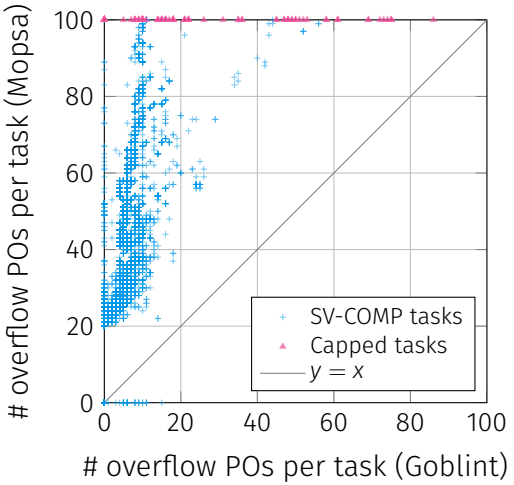


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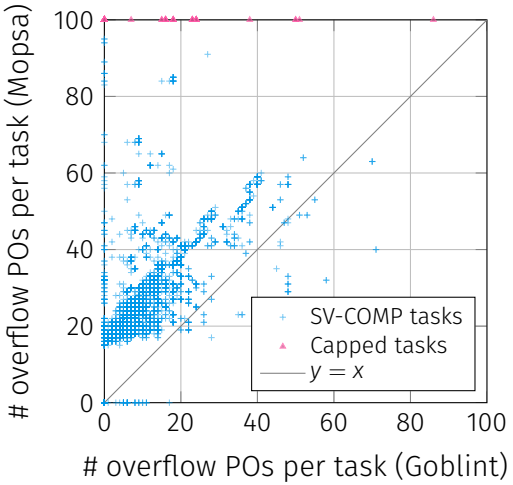


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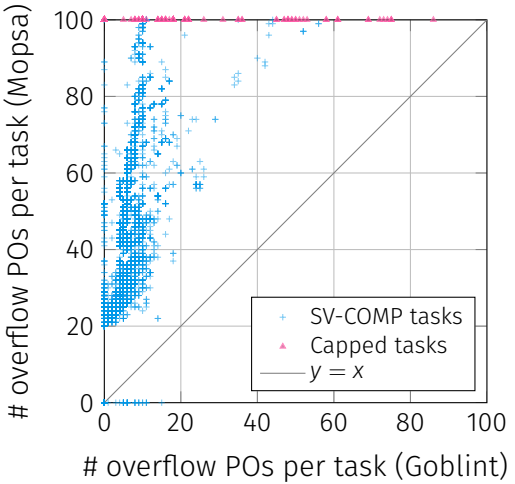


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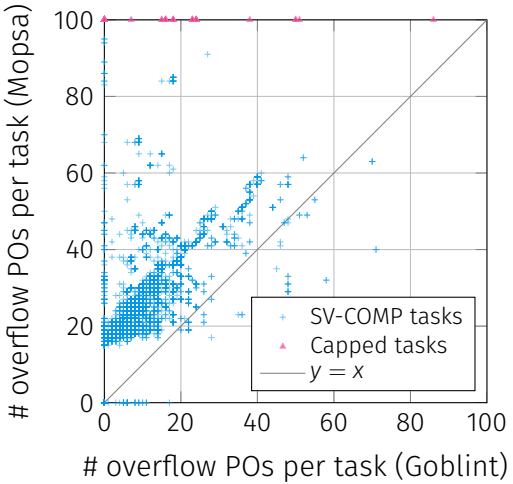


After alignment

N.B: Mopsa performs callstack-sensitive PO reporting.

# RQ1: Complementarity

| | Goblint | | | |
|---|---|---|---|---|
| Mopsa | ! | ✗ | ✓ | − |
| ! | 8122 | 0 | 2268 | 159 |
| ✗ | 1 | 0 | 0 | 6 |
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| Mopsa | ! | ✗ | ✓ | − |
| ! | 8122 | 0 | 2268 | 159 |
| ✗ | 1 | 0 | 0 | 6 |
| ✓ | 222 | 0 | 11 700 | 23 754 |
| − | 949 | 0 | 1804 | 0 |

Table 1: **before** PO alignment fixes.

| | Goblint | | | |
|---|---|---|---|---|
| Mopsa | ! | ✗ | ✓ | − |
| ! | 8123 | 0 | 2255 | **146** |
| ✗ | 1 | 0 | 0 | **0** |
| ✓ | 222 | 0 | 32226 | **652** |
| − | **944** | **0** | **2126** | 0 |

Table 2: **after** PO alignment fixes.

- No contradictions
- Overall agreement
- **Improved coverage consistency**

# RQ1: Complementarity

| | Goblint | | | |
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Table 2: **after** PO alignment fixes.

- No contradictions
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| Issue | Mopsa | Goblint |
|---|---|---|
| Missing check | | #1933, cil#215, cil#216 |
| Wrong location | #248 | cil#211 |
| **Spurious check** | **#251** | **#1909, #1910, #1932** |

# RQ2: Joint Benefit (Coreutils `uniq`)

| | Goblint | | | |
|---|---|---|---|---|
| Mopsa | ! | ✗ | ✓ | − |
| ! | 16 | 0 | 3 | 0 |
| ✗ | 0 | 0 | 0 | 0 |
| ✓ | 8 | 0 | 46 | 935 |
| − | 2 | 0 | 14 | 0 |

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**Joint Benefit**

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**Joint Benefit**

- Virtual combination improves precision
- But currently insufficient to prove whole program correct

# RQ3: Distillation

## Automated testcase reduction oracles

- Verdict-based: boolean output of SV-COMP verification

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| | Task Metrics | | | Verdict-Based | | | Dashboard-Based | |
|---|---|---|---|---|---|---|---|---|
| Folder | # | Lines | Conflicts | Final lines | Pres. (%) | Time (s) | Final lines | Time (s) |
| `float-benchs` | 6 | 196.17 | 1.00 | 8.67 | 100.00 | 184.50 | 8.67 | 233.17 |
| `nla-digbench` | 4 | 42.25 | 5.75 | 5.00 | 0.00 | 104.25 | 6.00 | 123.00 |
| `termination-crafted` | 11 | 26.18 | 1.55 | 3.73 | 18.18 | 119.73 | 5.91 | 156.45 |
| `termination-crafted-lit` | 11 | 27.18 | 1.73 | 5.27 | 45.45 | 92.00 | 7.00 | 102.73 |
| `termination-numeric` | 3 | 30.00 | 1.00 | 4.00 | 0.00 | 124.00 | 5.67 | 190.00 |
| `termination-restricted-15` | 13 | 21.62 | 1.00 | 4.31 | 7.69 | 83.62 | 8.77 | 98.62 |

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## Dashboard Strategy

- Less aggressive in reducing size,
- 100% preservation of disagreements.

# Conclusion

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- Exchanging results: SARIF [OAS20], SV-COMP's witnesses [Bey+16; Aya+24]

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`rmonat.fr/ecoop26_tsa`