TECHNISCHE UNIVERSITÄT DRESDEN

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KLEE's Solver Chain Revisited - *Opportunities for Improvement?*

London, 19. April 2018

Outline

Intro - Query Caching (in KLEE)

- Global Caching

- Parallel Portfolio Solving

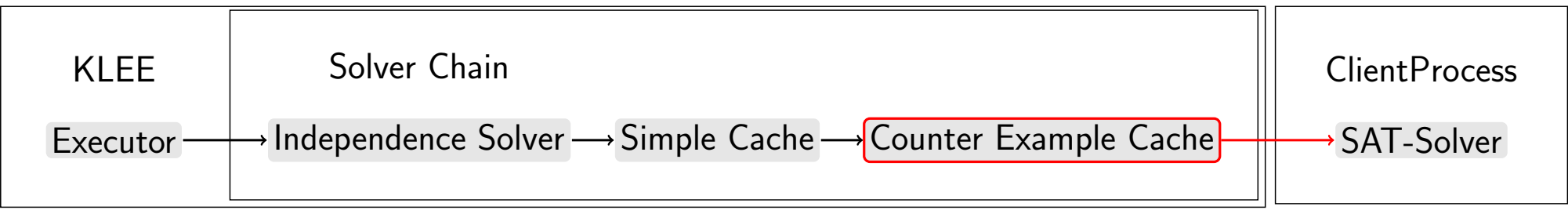
Query Caching (in KLEE)

- SAT (SMT) solving is NP-complete
  $\rightarrow$ 92% of runtime for SAT solving[1]

$\Rightarrow$ Caching as space-time trade-off
  $\searrow$ 41% of runtime for caching and SAT solving[1]

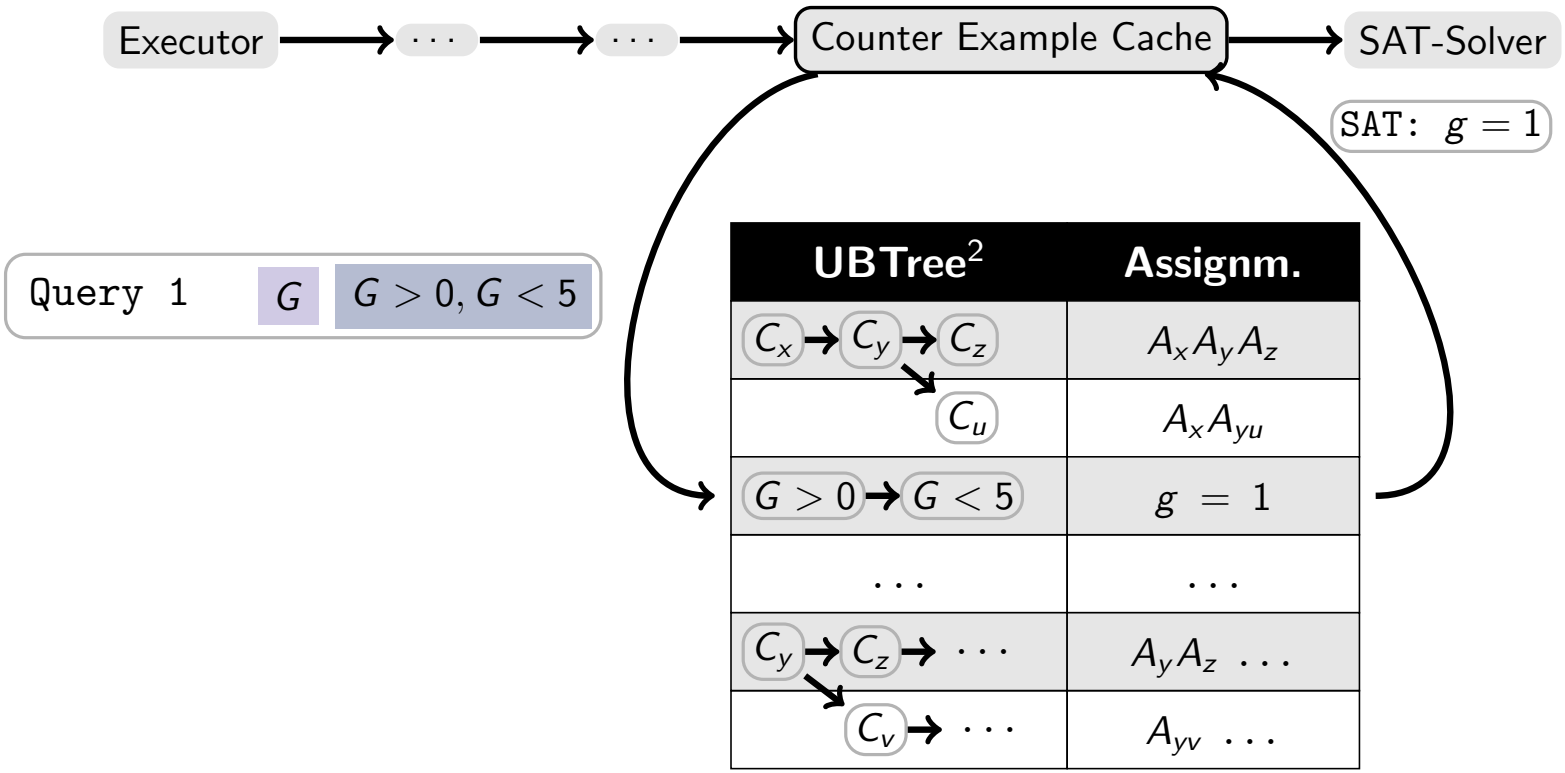
1) **KLEE: Unassisted and Automatic Generation of High-Coverage Tests for Complex Systems Programs**, Proceedings of OSDI 2008, Cadar et al. [4]

Query Caching (in KLEE)
Solver Chain



Query Caching (in KLEE)
Counter Example Cache

Reuse of concrete assignments via sub-/superset matching[2]



Global Caching
Idea

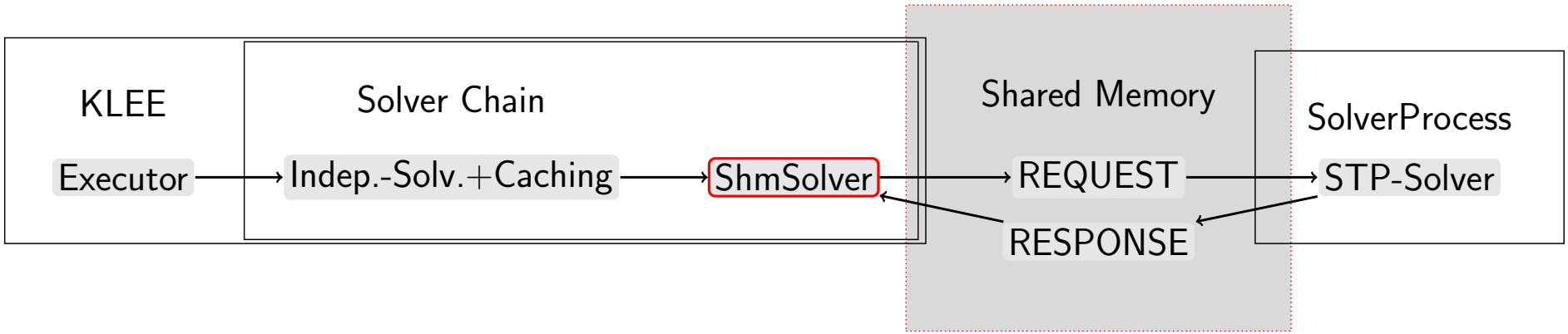
Reuse of cached assignments:

1. across runs? → Regression testing
2. across runs with different configurations of KLEE? → Coverage
3. across runs of different programs?

→ GNU coreutils reuse code for:

- argument parsing
- IO handling
- error handling
- configuration
- shared types

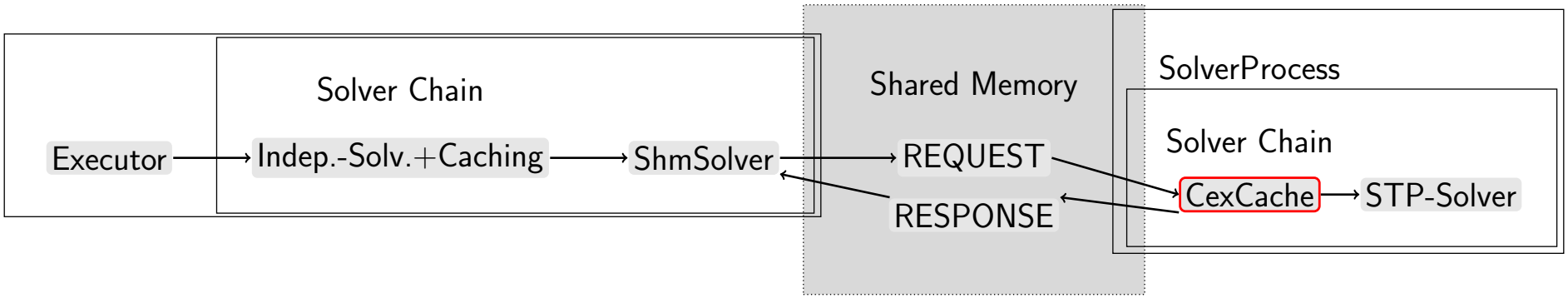
Global Caching
Architecture



- 3rd party solver connected via new IPC [3]

3) **New IPC-infrastructure based on cap'n'proto**, Nowack [14]
4) **EXE: automatically generating inputs of death**, Cadar et al. [5]
5) **Green: Reducing, Reusing and Recycling Constraints in Program Analysis**, Jia et al. [10], Visser et al. [18]

Global Caching
Architecture



- 3rd party solver connected via new IPC [3]

  > Decouple cache and solver

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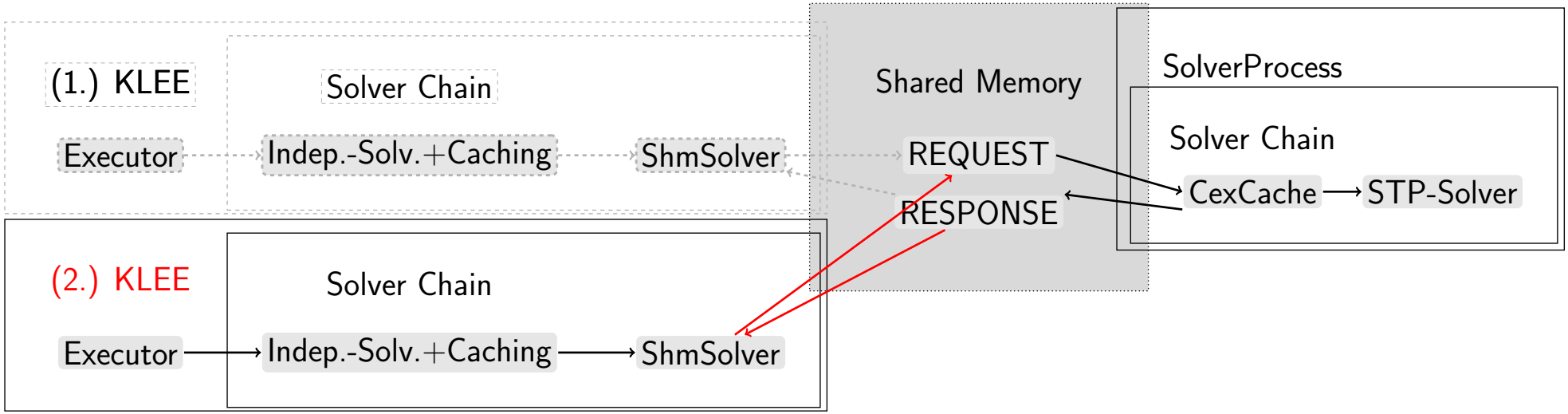
Global Caching
Architecture



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  > Decouple cache and solver

⇒ Global reuse of concrete assignments (other literature[4],[5])

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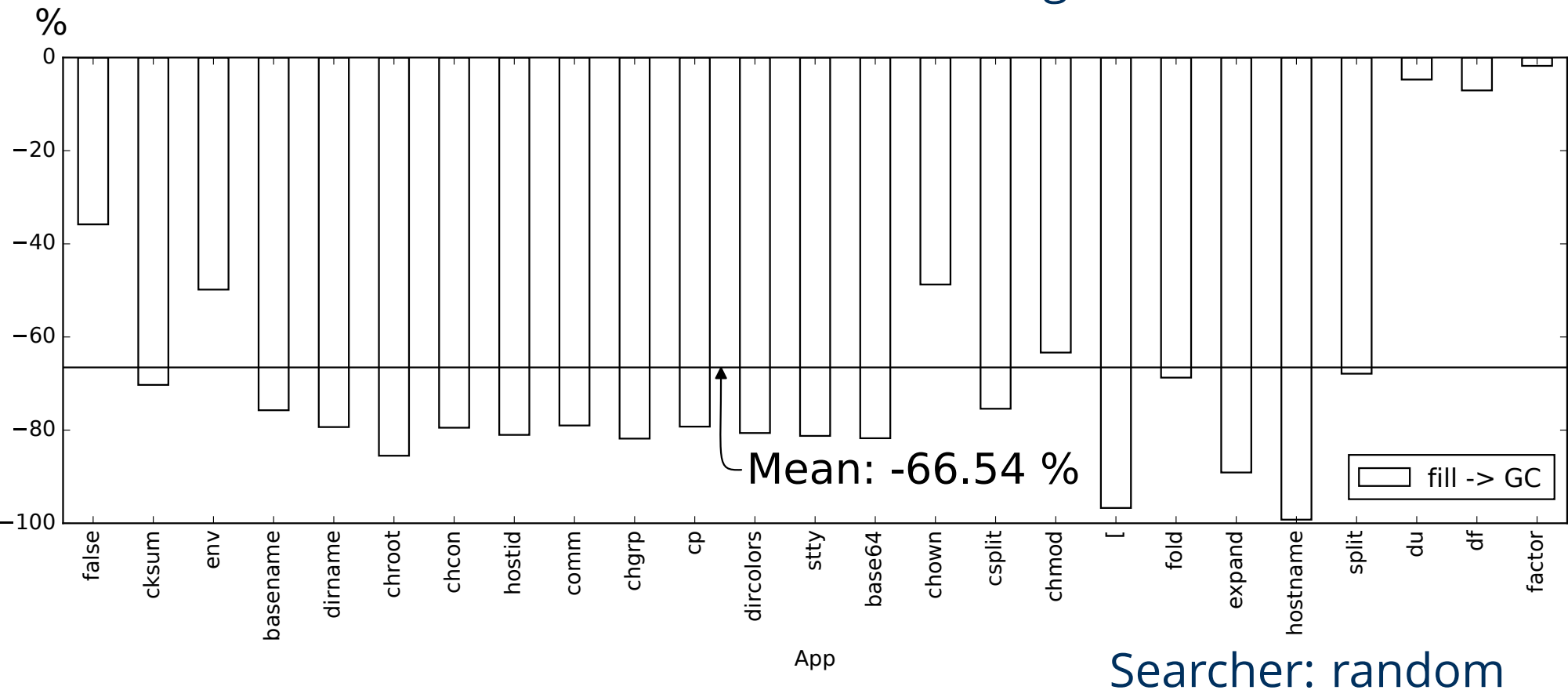
Global Caching

Evaluation - same configuration twice

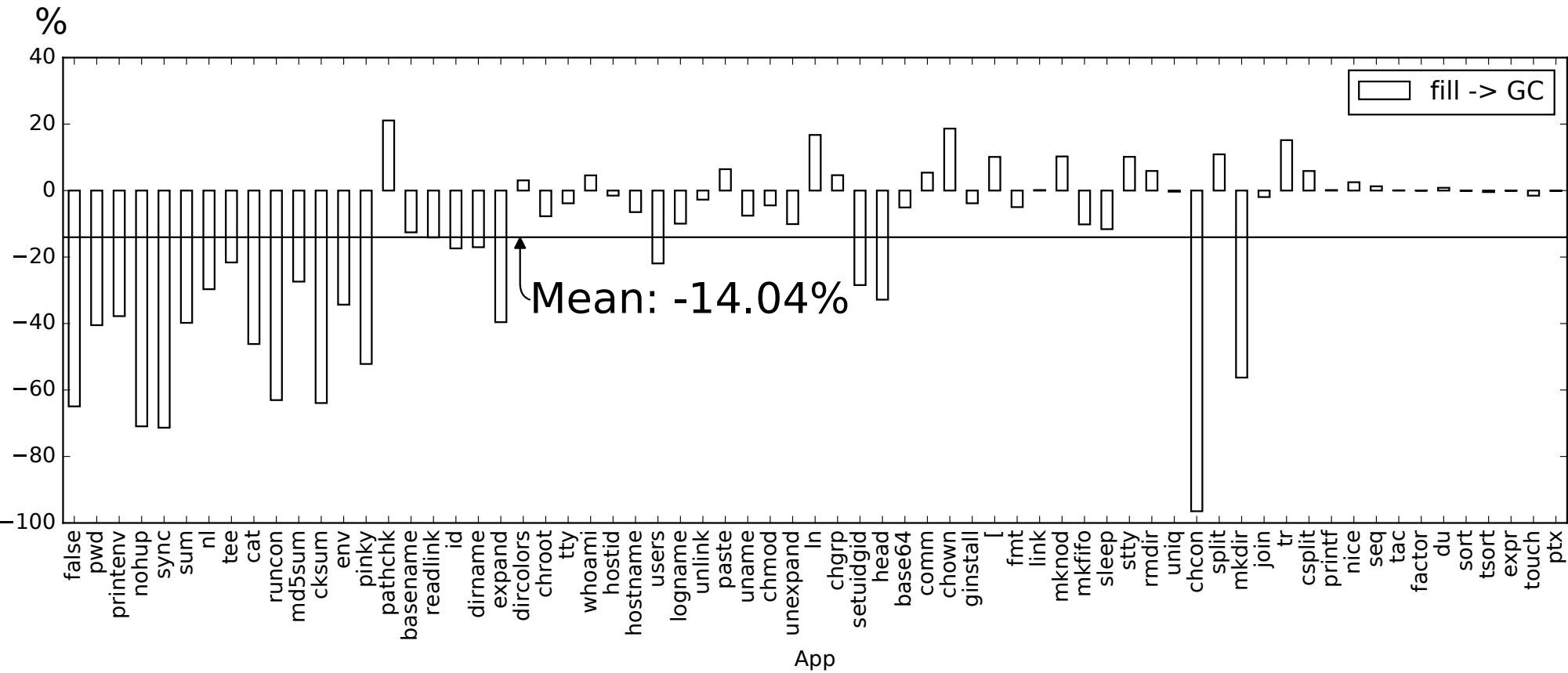
Relative Solver Time savings



Searcher: random

Global Caching

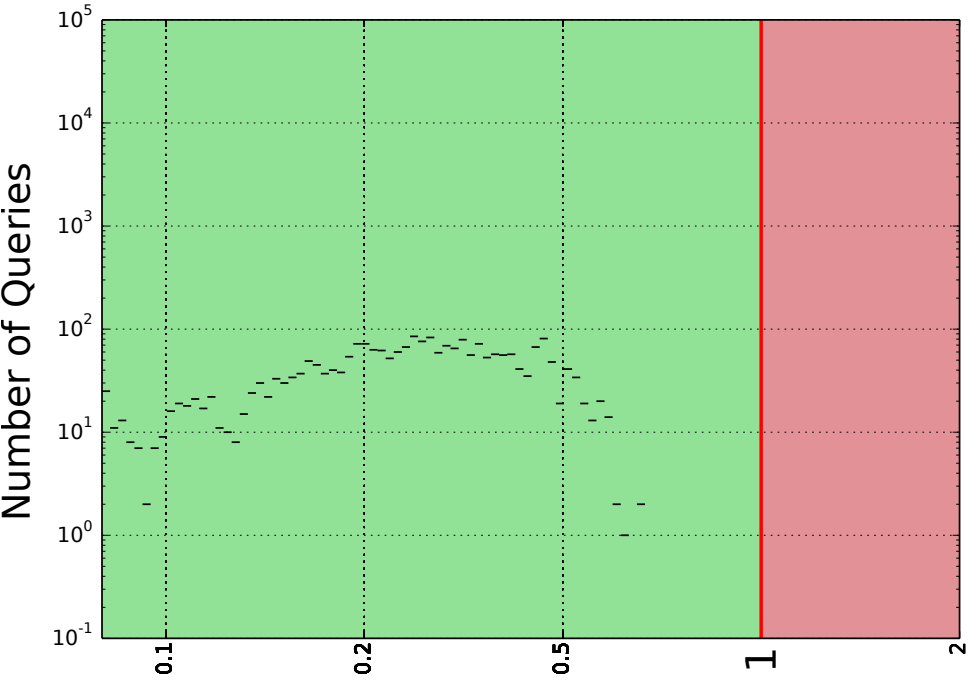
Evaluation - 1. BFS → 2. DFS searcher



Relative Solver Time savings of second run compared to first run .

Global Caching
+ Parallel Portfolio Solving
Motivation

pathchk



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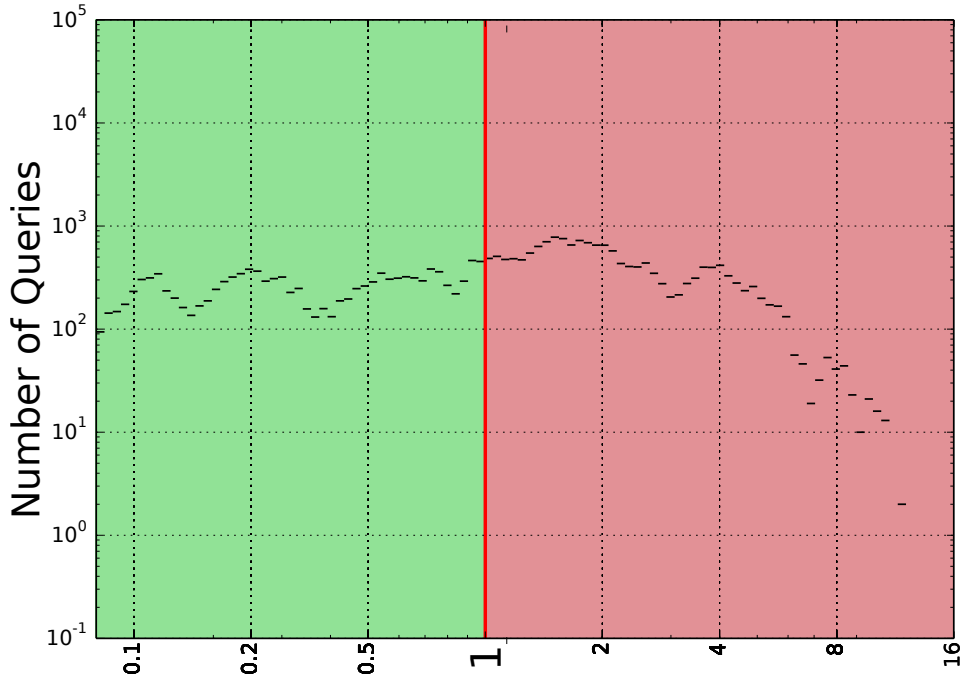

ratio = CacheTime / SolverTime

Parallel Portfolio Solving
Idea

Annual ranking in SMT-COMP[6]:

- STP[7]
- Z3[8]
- Boolector[9]
- Yices[10]
- CVC[11]

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6) **SMT-COMP'16**, `http://smtcomp.sourceforge.net/2016` Conchon et al. [6]
7) **A Decision Procedure for Bit-Vectors and Arrays**, (STP) Ganesh and Dill [8]
8) **Z3: An Efficient SMT Solver**, Moura and Bjørner [13]
9) **Boolector: An efficient SMT solver for bit-vectors and arrays**, Brummayer and Biere [3]
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11) **CVC4**, in *Computer Aided Verification* Barrett et al. [2]

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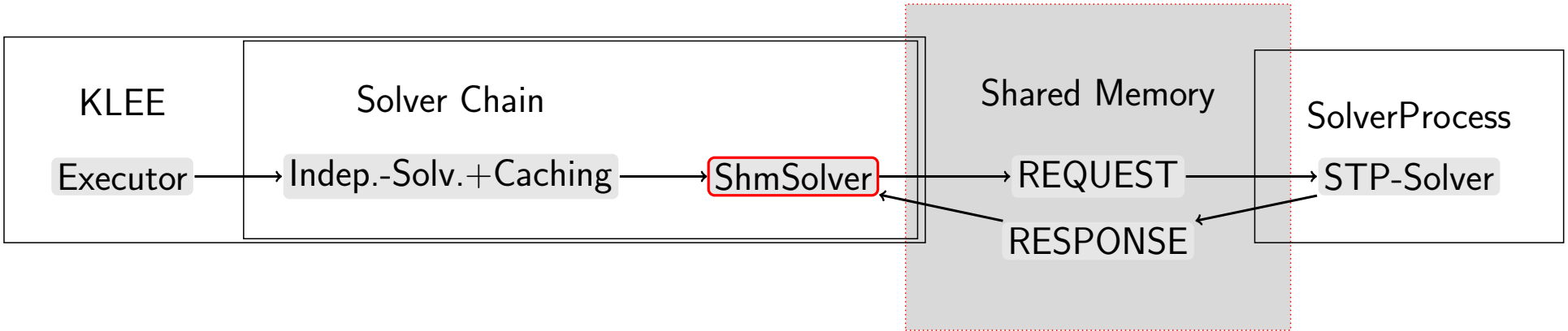
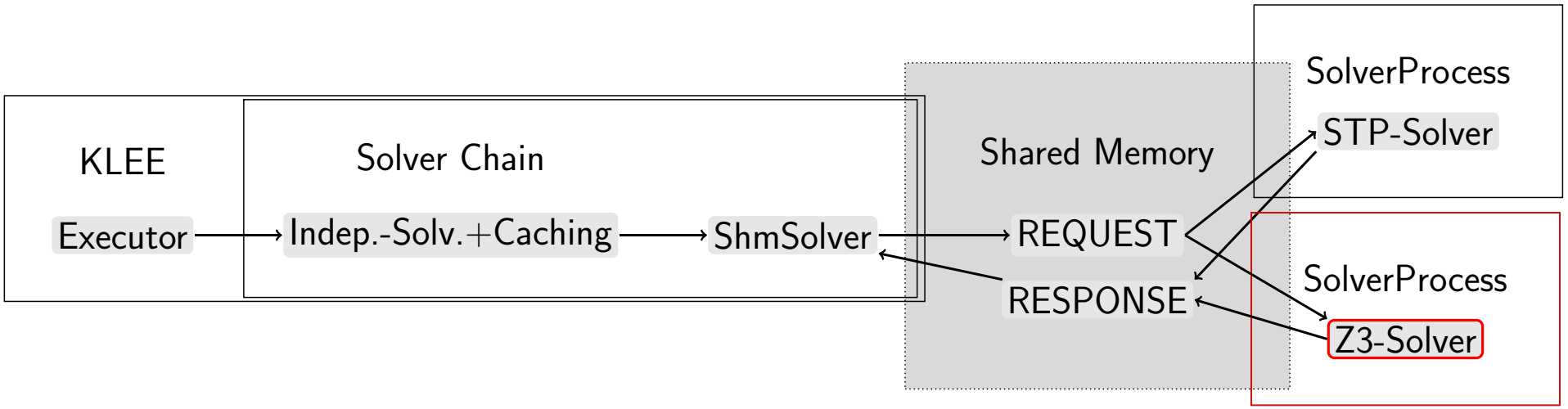
Parallel Portfolio Solving
Architecture



- ✓ SHM-based IPC protocol
- ✓ Handle solver crashes / timeouts.
- ✓ Portfolio of Solvers[12,13]

12) **metaSMT: A unified interface to SMT-LIB2**, Riener et al. [17]
13) **Multi-solver Support in Symbolic Execution**, (KLEE), Palikareva and Cadar [16]

Parallel Portfolio Solving
Architecture



- ✓ SHM-based IPC protocol
- ✓ Handle solver crashes / timeouts.
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⇒ Parallel Portfolio Solving ⇒ More resource utilization

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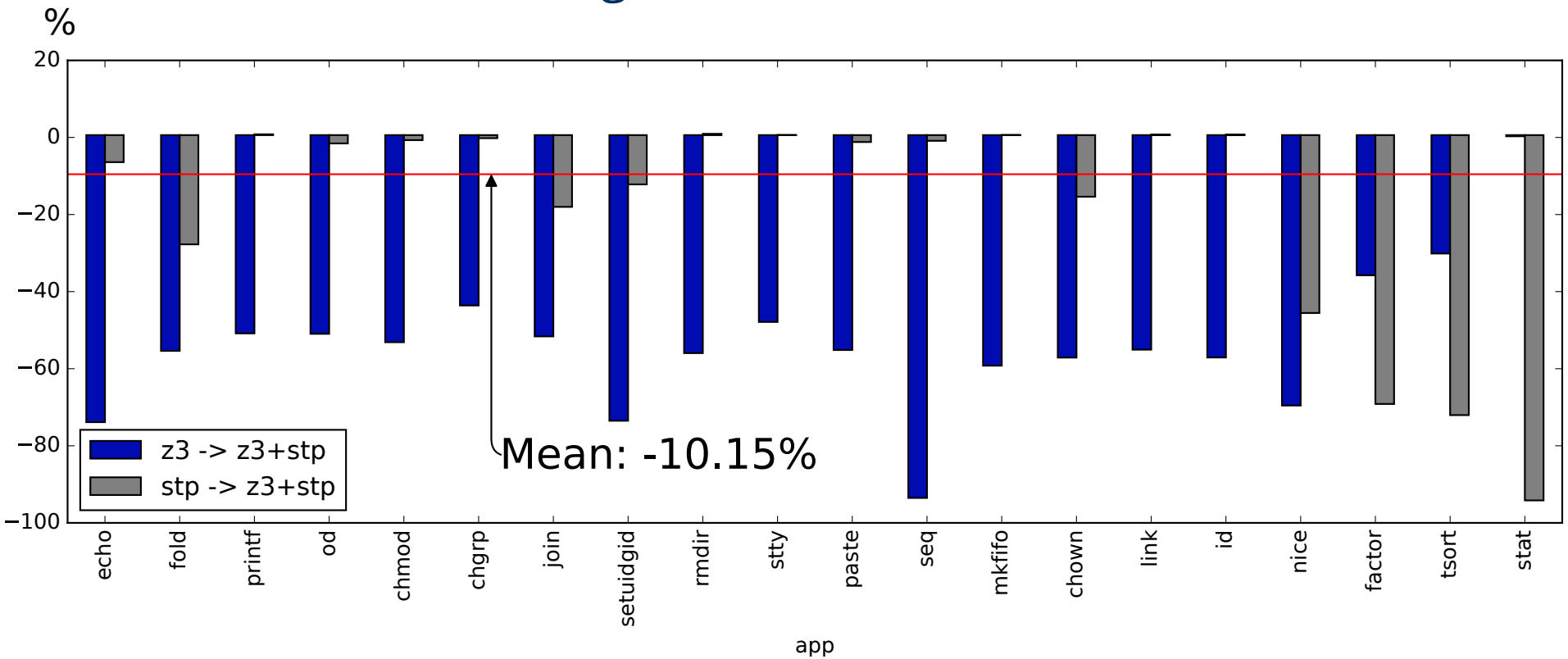
Parallel Portfolio Solving
Evaluation

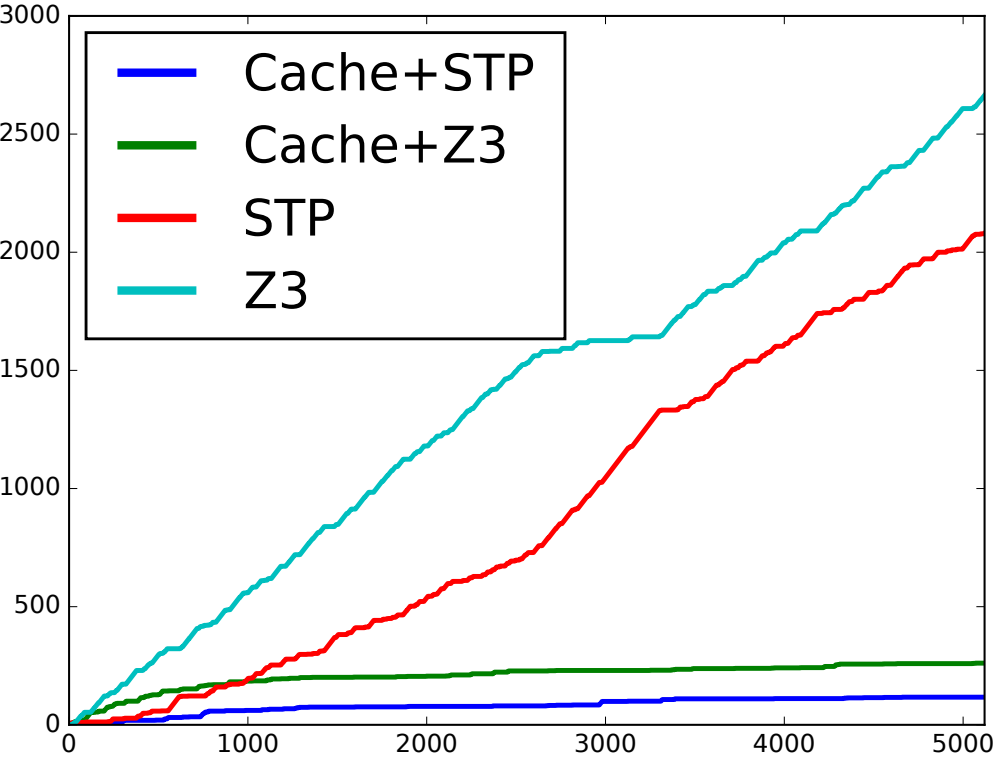
Solver Time savings STP+Z3-Portfolio vs. STP vs. Z3



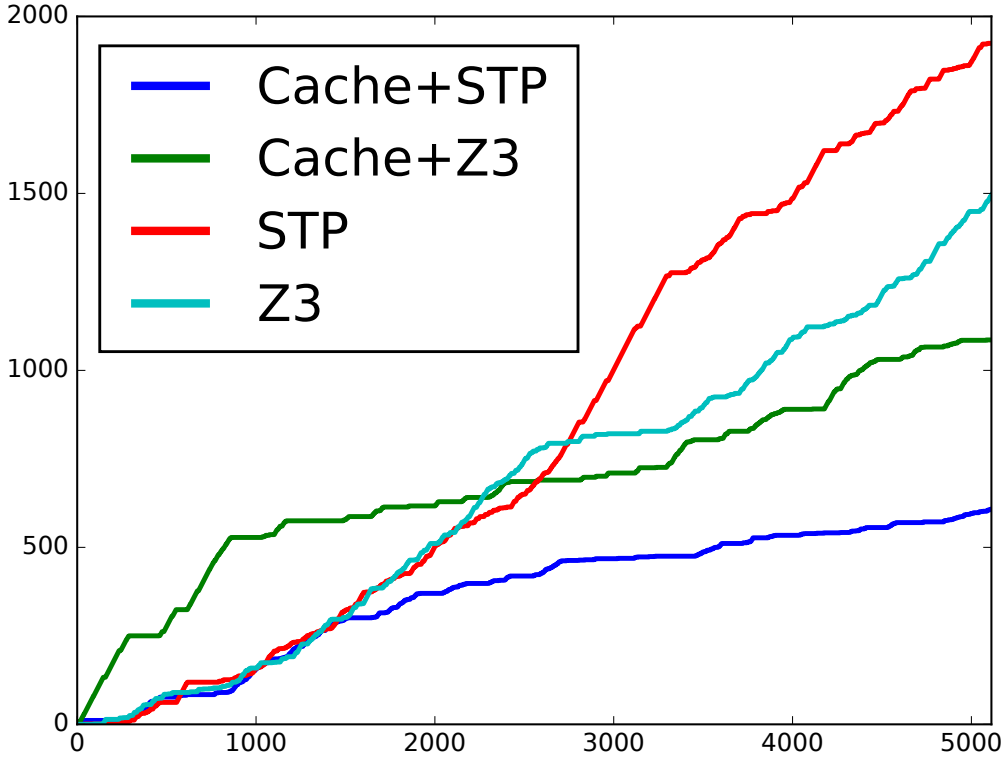
Searcher: BFS

Parallel Portfolio S. & Global Caching
Evaluation

Cumulative Number of Queries per Solver for `tsort`



1. without Global Cache



2. with Global Cache

Summary

- ✓ Global Caching ⇒ prototype
  - ✓ across multiple runs (same configuration)
    ⇒ -66% Solver Time
  - ✓ across multiple runs (using different strategies)
    ⇒ -14% Solver Time
- ✓ Parallel Portfolio Solving ⇒ -10% to -16% Solver Time

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