SATenstein: Automatically Building Local Search SAT Solvers From Components

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SATenstein?

- Frankenstein
  - Create “perfect” human being from scavenged body parts
- SATenstein
  - Create high-performance SAT solvers using components scavenged from existing solvers

Algorithm Design Approach

- Traditional approach
  – Hard-code various design choices
  – Iteratively conduct small experiments to improve the design

- Our approach
  – Make all design options explicit, encoding them as parameters
    - Results in a generalized, highly parameterized algorithm
    - Instantiation produces many different solvers
  – Given a distribution, set the parameters using an automatic algorithm configuration procedure

SATenstein

- A highly parameterized, generalized SLS solver built on top of UBCSAT solver framework [Tompkins & Hoos, 2004]
  - 3 categories of SLS algorithms
    - WalkSAT, G^2WSAT, dynamic local search algorithms
  - 25 known algorithms
  - 41 parameters
  - $> 2 \times 10^{11}$ possible instantiations
- For each distribution, configured using ParamILS [Hutter et al., 2007-2009]

Related Work

- SLS SAT solvers
  - GSAT [Selman et al., 1992]
  - WalkSAT [Selman et al., 1994]
  - SAPS [Hutter et al., 2002]
  - gNovelty$^+$ [Pham and Gretton, 2007]
- UBCSAT [Tompkins & Hoos, 2004]
  - SLS solver development framework
- Genetic programming [Fukunaga, 2002; 2004]
  - Evolve variable selection mechanism for SLS solver
- SATzilla [Xu et al., 2008]
  - Instance-based algorithm selection from portfolio of SAT solvers

SATenstein vs SATzilla

SATzilla [Xu et al., 2008]

- Relatively small number of known solvers
- Selects a given algorithm on a per-instance basis
- Creates empirical hardness model from given run-time data

SATenstein

- Can instantiate billions of solvers, most never studied before
- Selects a given configuration on a per-distribution basis
- Does not use runtime prediction

- The approaches are complementary
- SATenstein solvers can be used in SATzilla
  - Satzilla2009_R in SAT competition 2009
    - Gold in random SAT+UNSAT
    - 4th in random SAT

Performance objective

Penalized Average Runtime (PAR)

- Want: Minimize mean runtime
    - What about capped runs?

PAR = avg(completed runs + penalty × cutoff time)

- here: penalty = 10

Experimental setup

- 6 well-known distributions of SAT instances
  - Application/Industrial: FAC, CBMC-SE
  - Crafted: QCP, SW-GCP,
  - Random: HGEN, R3SAT

- 11 challenger algorithms (medal-winning SLS solvers in the 2003 - 2008 SAT competitions)

Automatic configurator: ParamILS 2.2 [Hutter et al., 2007-2009]

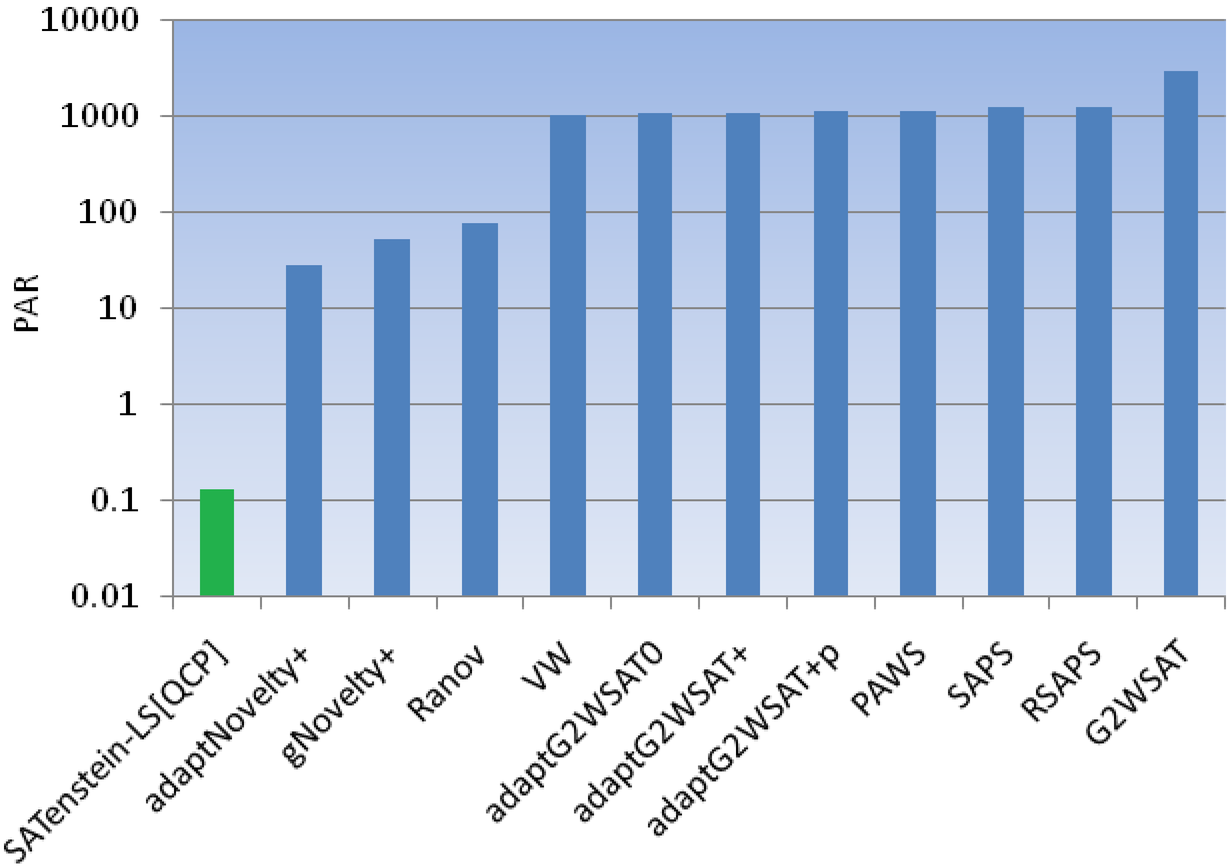
- Iterated local search (ILS) based automated parameter tuning tool

- Previously used to tune:
  - SPEAR, a highly parametric DPLL solver [Hutter et al., 2007a]
  - SLS algorithm for timetabling [Chiarandini et al., 2008]
  - CPLEX for mixed integer programming [Hutter et al., 2009]

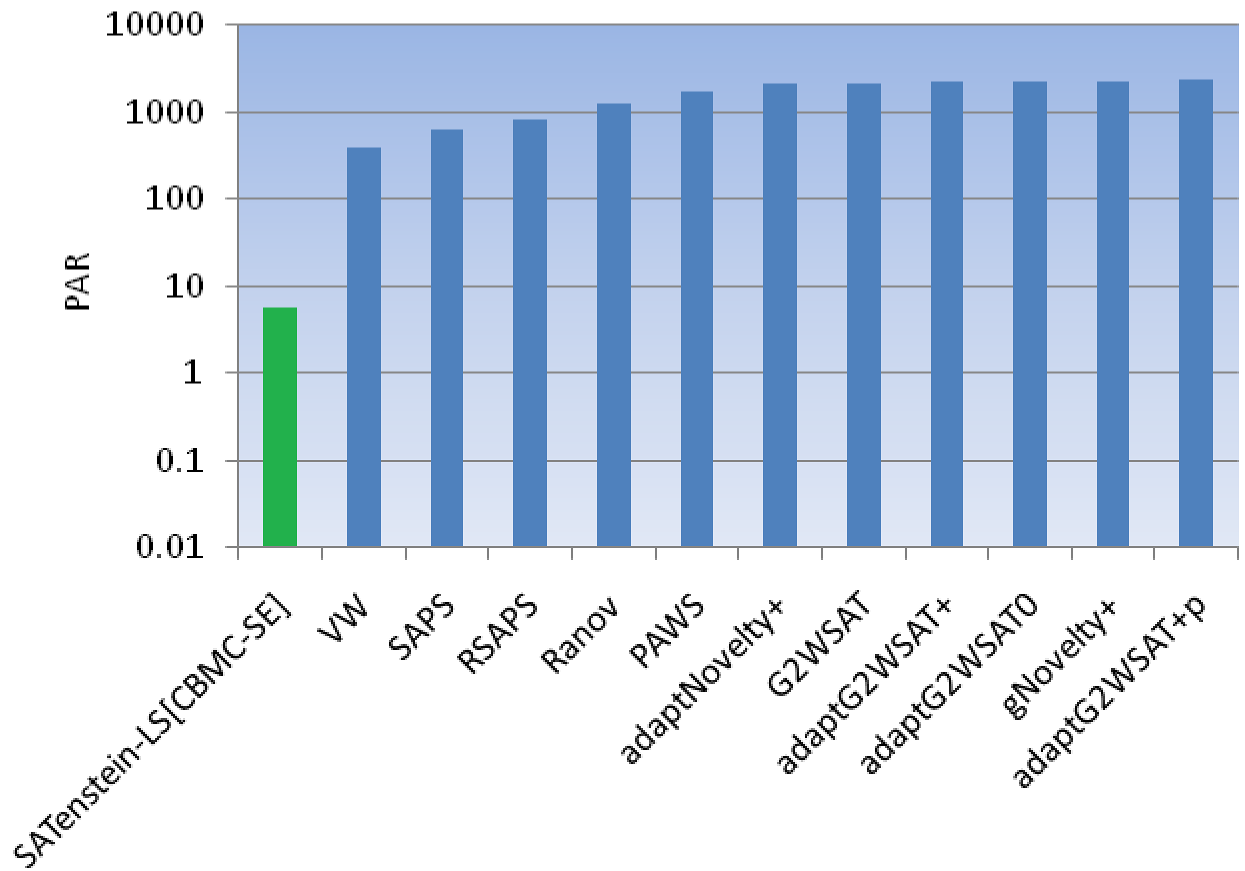
Results

- Factor of 70 - 1000 performance improvement over best challenger on QCP, HGEN, CBMC-SE
- Factor of 1.4 - 2 performance improvement over best challenger on SW-GCP, R3SAT and FAC
- Improved the state-of-the-art across all the solvers on SW-GCP, QCP , HGEN and R3SAT
- On CBMC-SE and FAC, reduced the gap between complete solvers and SLS solvers

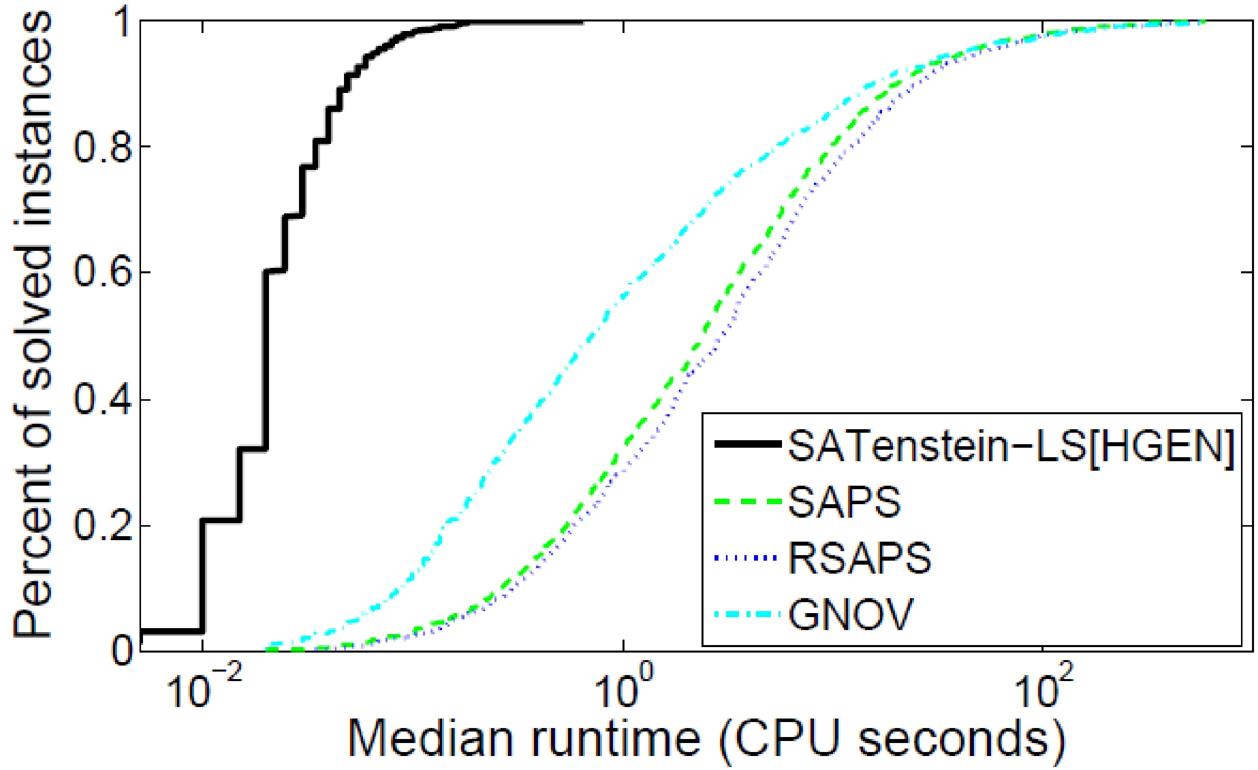
PAR comparison on QCP



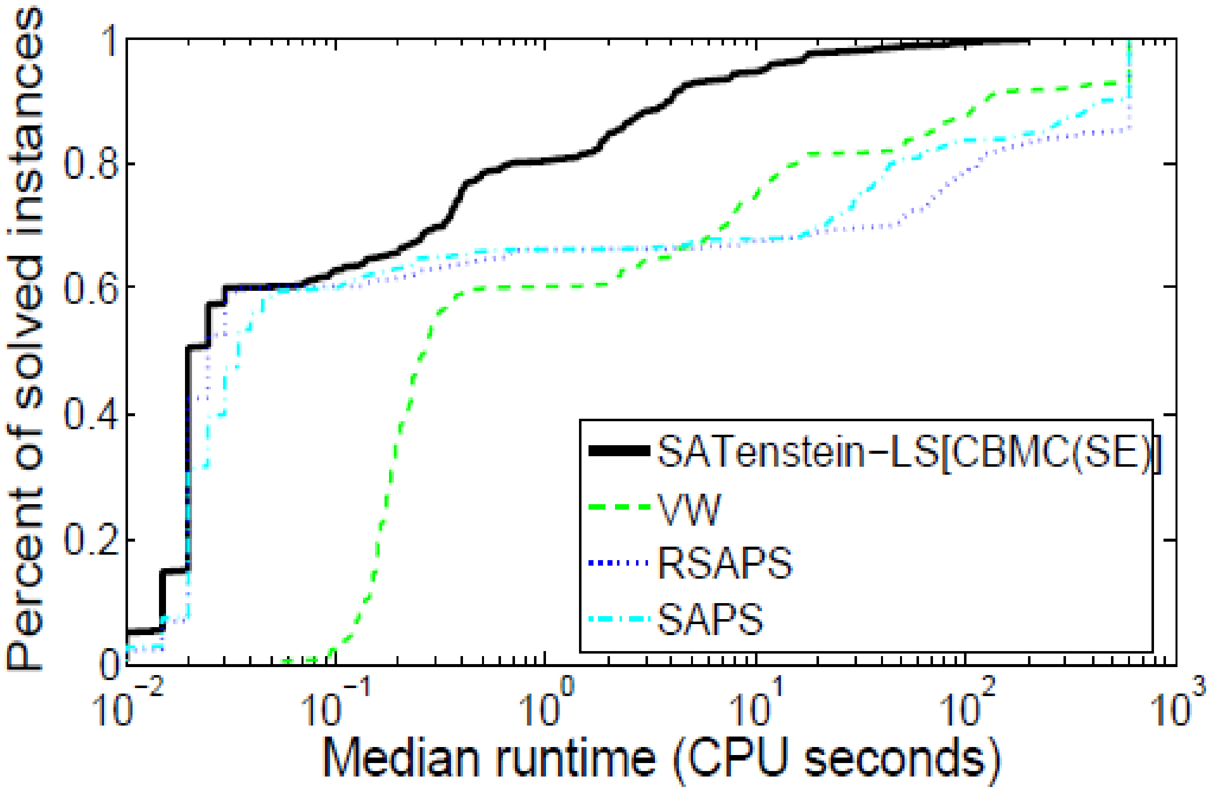
PAR comparison on CBMC(SE)



SATenstein-LS vs Top 3 challengers on HGEN

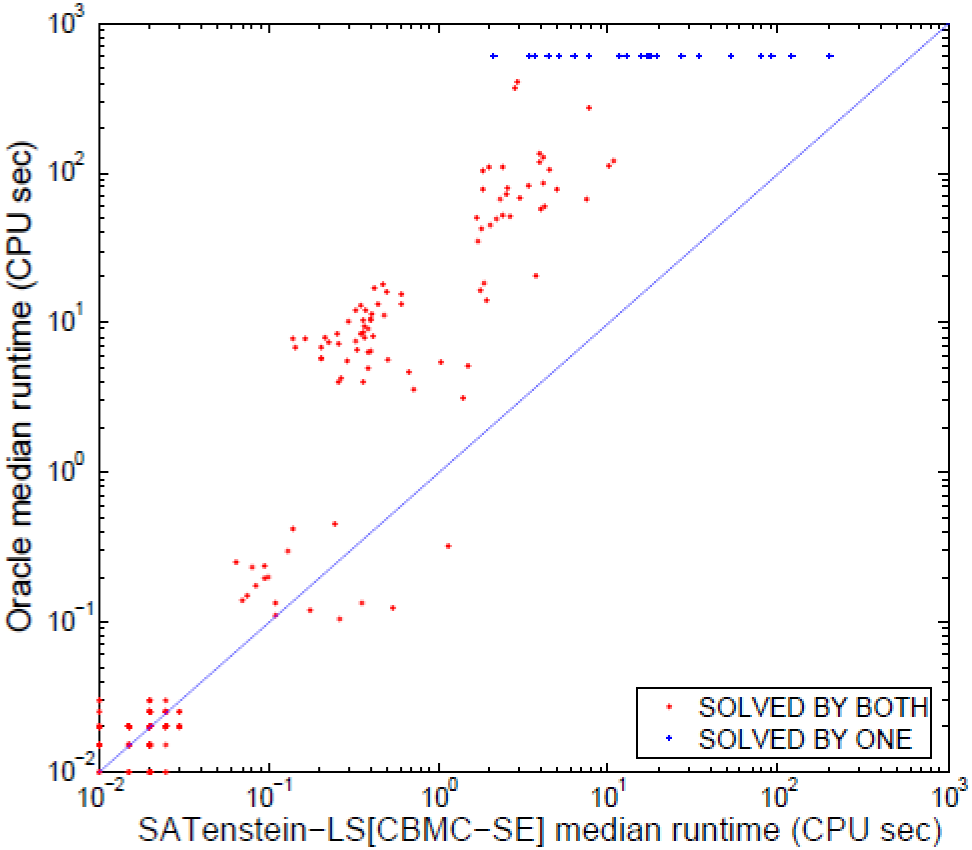


SATenstein-LS vs Top 3 challengers on CBMC-SE



SATenstein-LS vs Oracle on CBMC-SE

- Oracle selects the challenger with minimum median runtime on a per-instance basis



Conclusion

- SATenstein: A new approach for building high-performance algorithms.
  - A framework that flexibly combines components from high-performance algorithms
  - A powerful algorithm configuration tool
- New state-of-the-art SAT solvers in 4 distributions
- Substantial improvement on 3 distributions (QCP, HGEN, CBMC-SE)
- Reduced gap between DPLL solvers and SLS solvers on CBMC-SE

Future Work

- Use of preprocessing
- Mixed strategies
- Better understanding of the configurations found
- More problem distributions / other problems