10th International Satisfiability Modulo Theories Competition

SMT-COMP 2015

Sylvain Conchon David Déharbe Tjark Weber

Introduction

The SMT problem

Satisfiability

$$
\begin{aligned}
\varphi \quad : \quad & a + b = 3 \\
\wedge \quad & 2 \times a - 3 \times b = -1.5 \\
\wedge \quad & (\, f(a) - f(b) < 0 \ \vee \ f(b) - f(a) < 0 \,)
\end{aligned}
$$

Introduction

The SMT problem

Satisfiability Modulo Theories

$$
\begin{array}{rcl}
\varphi & : & a + b = 3 \\
 & & \wedge \quad 2 \times a - 3 \times b = -1.5 \\
 & & \wedge \quad (\, f(a) - f(b) < 0 \ \vee \ f(b) - f(a) < 0 \,) \\
\text{Reals} & : & -1.5, 0, 2, 3, +, -\times, <
\end{array}
$$

Introduction

The SMT problem

Satisfiability Modulo Theories

$$
\begin{array}{rcl}
\varphi & : & a + b = 3 \\
 & \wedge & 2 \times a - 3 \times b = -1.5 \\
 & \wedge & (f(a) - f(b) < 0 \vee f(b) - f(a) < 0)
\end{array}
$$

$$\text{Reals} \quad : \quad -1.5, 0, 2, 3, +, -\times, <$$

```
(set-logic QF_UFLRA)
(declare-fun a () Real)
(declare-fun b () Real)
(declare-fun f (Real) Real)
(assert
  (and (= (+ a b) 3))
       (= (- (* 2 a) (* 3 b))  (- 1.5))
       (or (< (- (f a) (f b)) 0)
           (< (- (f b) (f a)) 0)))
(check-sat)
```

The SMT-LIB initiative

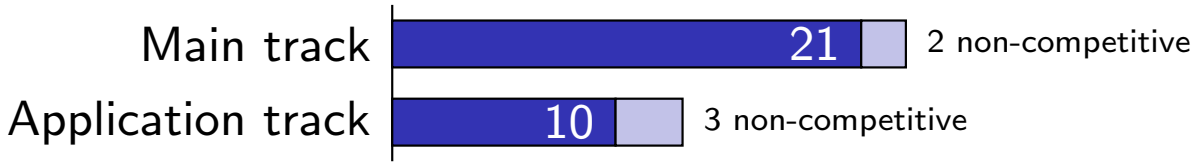
- SMT-LIB standard
  - several theories
  - several sub-logics: theory combination / restrictions / extensions
  - language to formulate problems
  - command language: batch $\rightsquigarrow$ interactive
- SMT-LIB repository
- SMT-COMP

Solvers involved

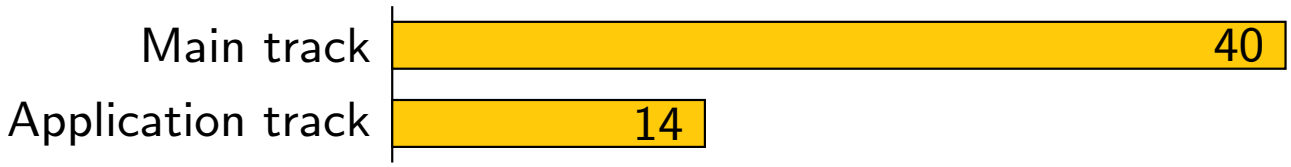
- Solvers
  - **competing** AProVe, Boolector, CVC3, CVC4, openSMT, raSAT, SMTInterpol, SMT-RAT, STP-MiniSat, STP-CryptoMiniSat, veriT, Yices2
  - **demonstration** MathSat, Z3
- Tracks
  - **main** batch mode, one check-sat command
  - **application** interactive mode, multiple check-sat commands
- Divisions
  - one per logic
  - at least two competing solvers from different teams

The Numbers

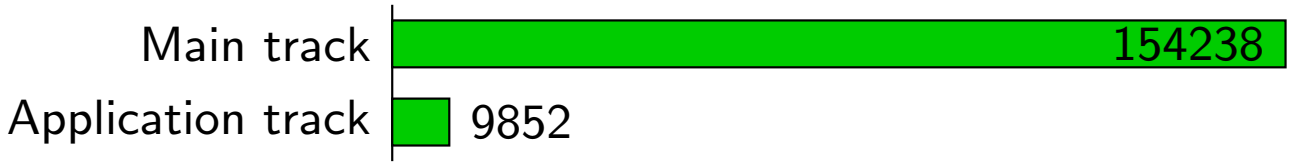
- 11 teams participated
- Solvers:



- Logics:



- Benchmarks:



Record numbers of solvers, logics, and benchmarks!

Infrastructure

All job pairs executed on StarExec (`starexec.org`)

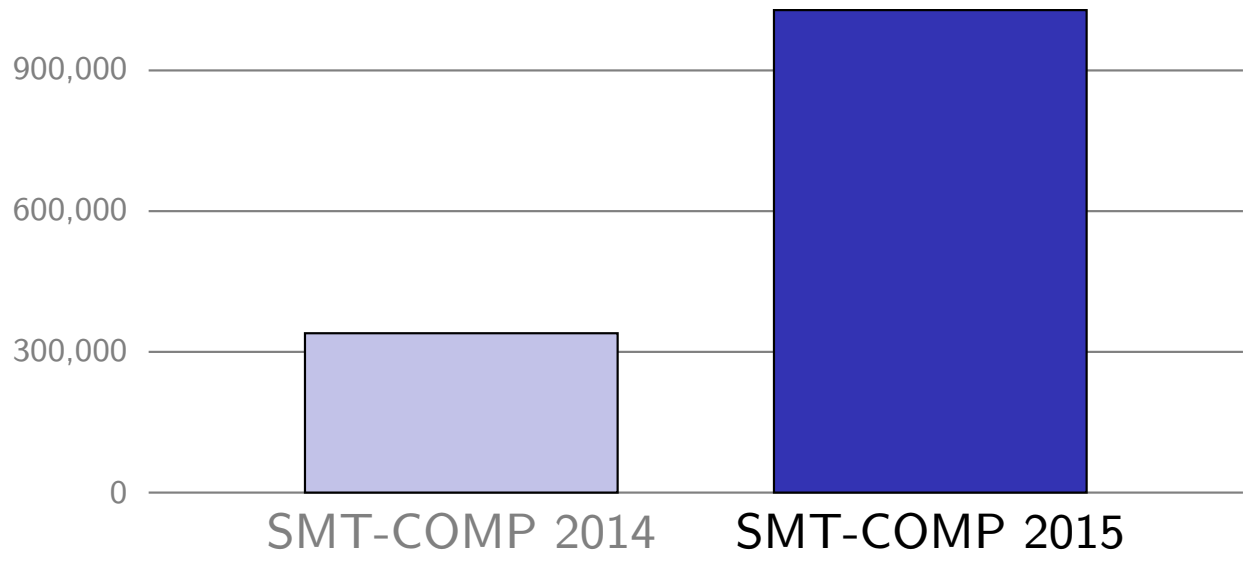
- Dual quad-core Intel Xeon CPU E5-2609 @ 2.4 GHz, 10 MB cache
- RHEL 6.3, kernel 2.6.32-431, gcc 4.4.6, glibc 2.12
- 60GB RAM, 2400s timeout
- Over 9,000 job pairs/hour completed
- $\sim$ 20 feature requests and (minor) bug reports; quickly handled to the StarExec developers

File repository on SourceForge

- Tools to prepare jobs and to process results
- Web site with detailed results

Job Pairs

- 1,028,615 job pairs executed (+ some repeats)
- $\sim$ 5 days $\times$ 150 nodes $\times$ 2 processors/node of compute time



More than 3 times as many job pairs as in 2014!

Scoring

Raw Scores

A solver's raw score for each benchmark is $\langle e, n, \mathit{wall}, \mathit{cpu} \rangle$, with

- $e \in \{0, 1\}$, the number of erroneous results
- $0 \leq n \leq N$, the number of correct results (N is the number of `check-sat` commands in the benchmark)
- *wall* is the wall-clock (or real) time
- *cpu* is the CPU time
  $\rightarrow$ For programs running in parallel, *cpu* is the sum of CPU times devoted to each task

Scoring

Track Scoring

Main track

- *Timeouts*, *aborts* (no answer), `unknown`: $\langle 0, 0, \mathit{wall}, \mathit{cpu} \rangle$
- *Incorrect* answers: $\langle 1, 0, \mathit{wall}, \mathit{cpu} \rangle$
- *Correct* answers: $\langle 0, 1, \mathit{wall}, \mathit{cpu} \rangle$

Application track (multiple `checksat` per benchmark)

- *Any incorrect* result : $\langle 1, 0, \mathit{wall}, \mathit{cpu} \rangle$
- Otherwise : $\langle 0, n, \mathit{wall}, \mathit{cpu} \rangle$

Scoring

Sequential Performances

Given a wall-clock time limit T and a raw score $\langle e, n, wall, cpu \rangle$, we derive a sequential score to evaluate sequential performances:

- If $cpu > T$ then $\langle 0, 0, T \rangle$
- Otherwise $\langle e, n, cpu \rangle$

Scoring

Division Scoring

For each division, scores are summed component-wise:

- **Sequential performances** = sum all **sequential scores**
- **Parallel performances** = sum all **raw scores**

We compute :

- **Sequential** and **parallel** performances for main track divisions
- Only **parallel** performances for application track divisions

Division scores are compared lexicographically :

Fewer errors takes precedence over more correct solutions, which takes precedence over less wall-clock time taken, which takes precedence over less CPU time taken

Scoring

Competition Wide Scoring

We define the competition wide score of each solver for the **main track**, separately for sequential and parallel performances

For each *competitive* division i, let N_i be the total number of benchmarks in that division and $\langle e_i, n_i, ... \rangle$ the raw (resp. sequential) score of the solver for i

The competition-wide score of a solver is :

$$\sum_i (\text{if } e_i = 0 \text{ then } (n_i/N_i)^2 \text{ else } -e_i) \times logN_i$$

Results

Main Track

40 divisions but only 28 declared as competitive

Sequential performances (parallel perfs. are identical)

Solver	# Divisions won	Divisions
CVC4 (2 versions)	12	ALIA, AUFLIA, AUFLIRA, LIA, LRA QF_AUFBV, QF_LIA, QF_LRA, QF_NIRA UF, UFIDL, UFLIA
Yices (2 versions)	11	QF_ALIA, QF_AUFLIA, QF_AX, QF_IDL QF_LIRA, QF_NRA, QF_RDL, QF_UF QF_UFIDL, QF_UFLIA, QF_UFLRA
Boolector (2 versions)	3	QF_ABV, QF_BV, QF_UFBV
AProVE	1	QF_NIA
CVC3	1	UFLRA

Results

Application Track

14 divisions but only 7 declared as competitive

Solver	# Divisions won	Divisions
Yices	6	QF_ALIA, QF_AUFLIA, QF_BF, QF_LIA QF_LRA, QF_UFLRA
CVC4	1	QF_UFLIA

Results

Competition-Wide Scoring

Main Track:

Rank	Solver	Seq. Score	Paral. Score
-	[Z3]	159.36	159.36
1	CVC4	144.67	144.74
2	CVC4 (exp)	140.47	140.51
3	Yices	101.91	101.91
-	[MathSat]	79.77	79.77
4	veriT	70.68	70.68

Other recognitions

Open Source Solvers:

- In all divisions, except QF_NIA, winners are *all open source*
- In QF_NIA, the first open source solvers is **raSAT 0.2**

Industrial performances:

- Makes no difference, except for QF_LIA and UFLRA
- **Yices2** is best performing on industrial benchs for QF_LIA
- **veriT** is best performing on industrial benchmarks for UFLRA

New Entrant:

- Two new entrants in 2015
- **SMT-RAT 2.0** obtained the best scores

Breadth of logics:

- **CVC4** covers the most theories and logics

Questions