

# System Description: Yices 1.0

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## 1 Introduction

Yices is a decision procedure for formulas containing uninterpreted function symbols, linear real and integer arithmetic, fixed-size bitvectors, extensional arrays, lambda expressions, tuples, records, quantifiers, scalar types, recursive datatypes, and dependent types. Yices is the main decision procedure used by SAL. It is being integrated to PVS, and it is the main component of the probabilistic consistency engine of SRI's CALO system<sup>1</sup>. Yices supports a rich specification language similar to those of PVS and SAL. It can also read problems in the SMT-LIB and DIMACS CNF formats. Yices can be used in an incremental fashion via a push/pop mechanism. It can produce models and compute unsatisfiable cores, and it supports weighted MaxSAT.

Yices 1.0 is a complete reimplementaion of SRI's previous SMT solvers. It has a new architecture, and it uses new algorithms and a better SAT solver. Yices 1.0 is generally faster than the solvers that participated in SMT-COMP'05 [1]. Yices can be downloaded at <http://yices.cs1.sri.com>.

## 2 Algorithms and Implementation

Yices is implemented in C++. The architecture integrates a modern DPLL-based SAT solver, a *core theory solver* that handles equalities and uninterpreted functions, and *satellite solvers* (for arithmetic, arrays, tuples, etc.). Yices uses an extension to the standard Nelson-Oppen combination method: The core and satellite theories communicate via *offset equalities*, that is, equalities of the form  $x = y + k$  where  $x$  and  $y$  are terms and  $k$  is a rational constant. By using offset equalities, the core handles simple arithmetic constraints directly, which, in many cases, avoids the overhead of communicating with a dedicated solver. The core algorithm is similar to the one used by Simplify [3], with extensions for producing precise explanations and for handling offset equalities.

Satellite theories are not required to propagate all implied equalities. Yices case splits on (offset) equalities between shared variables to achieve completeness. Each theory is responsible for creating the required case splits, and simple filters are used to minimize the number of case splits. For example, if the core contains four terms  $f(x_1, x_2)$ ,  $f(x_3, x_4)$ ,  $g(x_5)$ , and  $g(x_6)$ , and  $x_1$  to  $x_6$  are the only shared

<sup>1</sup> <http://caloproject.sri.com/>

variables then case splitting on the three interface equalities  $x_1 = x_3$ ,  $x_2 = x_4$  and  $x_5 = x_6$  is sufficient.

The linear arithmetic solver uses a novel Simplex-based algorithm [4,5]. This algorithm is very efficient for sparse problems in both full linear arithmetic and the difference logic fragment. On sparse problems, this solver is competitive with (and often outperforms) state-of-the-art tools specialized for difference logic. For dense difference-logic problems, Yices uses a specialized algorithm based on incremental Floyd-Warshall.

Yices employs a dynamic form of Ackermann's reduction when uninterpreted functions are present. Yices creates the clause  $x \neq y \vee f(x) = f(y)$  whenever the congruence rule  $x = y \rightsquigarrow f(x) = f(y)$  is used to deduce a conflict. Using this technique, Yices can perform the propagation  $f(x) \neq f(y) \rightsquigarrow x \neq y$ , which is missed by traditional congruence-closure algorithms. This propagation rule has a dramatic performance benefit on many problems. Creating Ackermann clauses during the search rather than all from the start avoids flooding the SAT solver with unnecessary instances. Furthermore, the DPLL solver clause-deletion heuristics can safely remove any of the dynamically created instances since they are not required for completeness.

Yices uses three methods for handling universally quantified expressions. The main approach is an extension of egraph-matching [3] that supports offset equalities and terms. Yices can use several triggers for each universally quantified expression, and the triggers are fired using a heuristic that gives preference to the most conservative ones. Yices also uses Fourier-Motzkin elimination to simplify quantified expressions involving linear arithmetic. Finally, Yices uses an instantiation heuristic based on the approach described in [2].

The array-theory solver uses lazy instantiation of the array axioms. The fixed-size bit-vectors theory applies bit-blasting to all bitvector operators but equality. This solver just implements a bridge between the core theory and the encoding of the bitvector operations in the SAT solver.

### 3 Problem Divisions

Yices will participate in all divisions of SMT-COMP'06.

### 4 Acknowledgments

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