

SMT SOLVER COMPARISON

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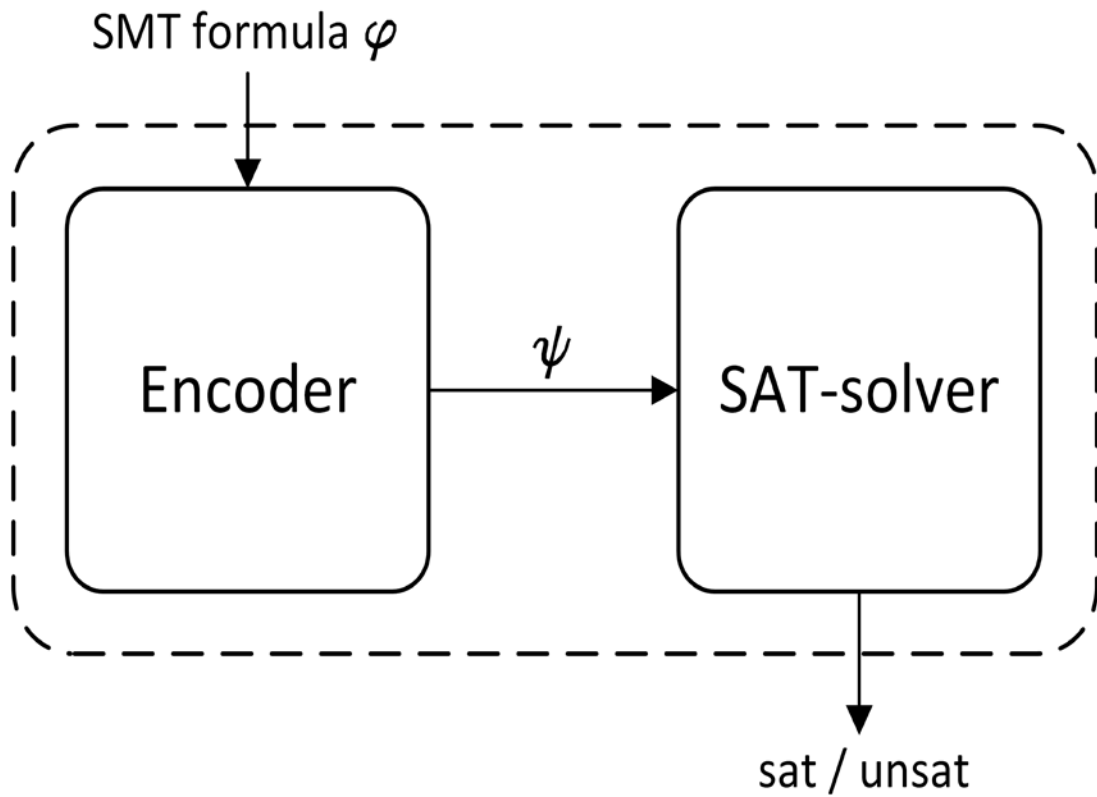
Structure

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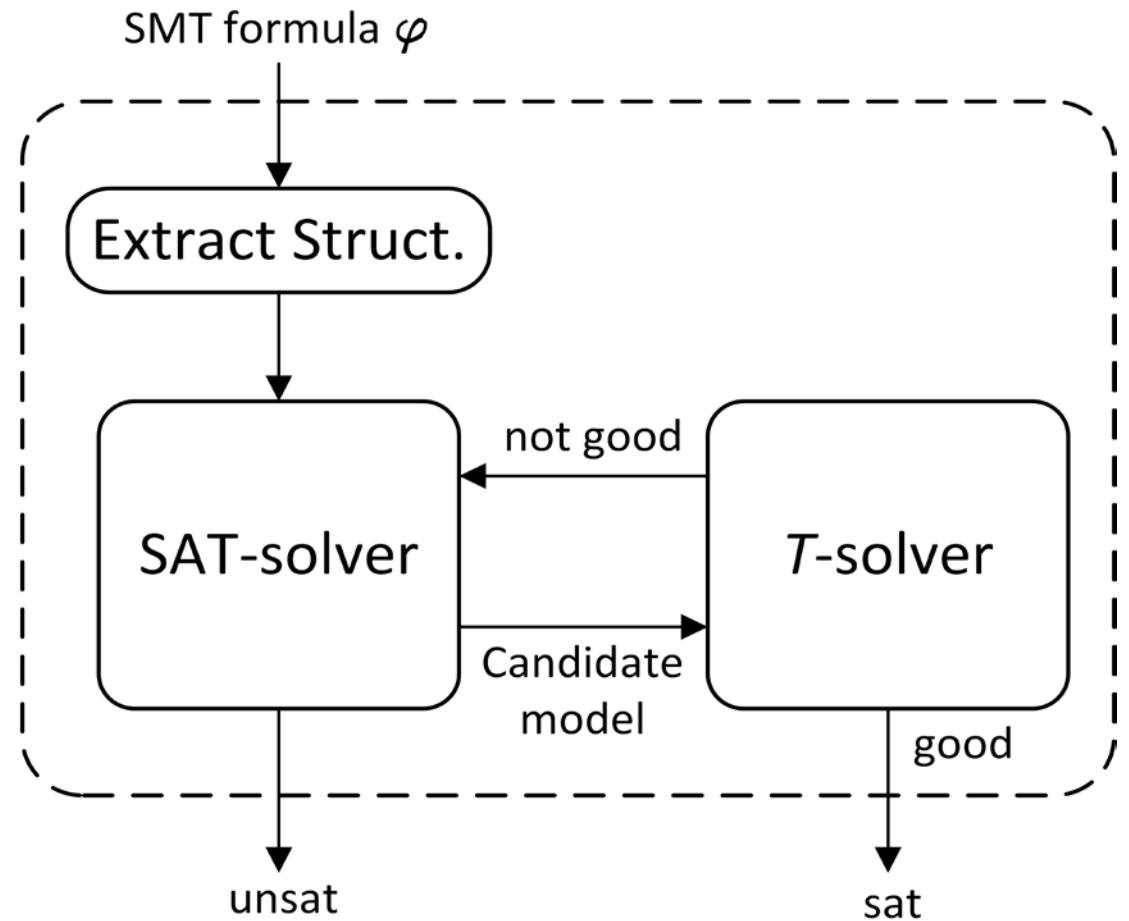
SMT Solver Basics

- Satisfiability Modulo Theories
- First -order logic
- Interact with SAT Solvers
 - Eager approach
 - Lazy approach
- DPLL(T)
 - Davis-Putnam-Logemann-Loveland
 - Different Theory Solvers
 - Uninterpreted functions with equality
 - Non-linear, linear, difference arithmetic
 - Arrays, Bit-vectors
 - Combinations

Eager Approach



Lazy Approach



Problem

- Given:
 - Framework comparing Constraint- and SMT Solvers
 - Minion (Constraint Solver)
 - Choco (Constraint Solver)
 - Z₃ (SMT Solver)
 - Algorithms to debug spreadsheets with SMT Solvers
 - MCSes
 - MCSes-U
- Find:
 - Suitable candidate for spreadsheet debugging

Motivation

- Spreadsheet Debugging:
 - Millions of people use spreadsheet programs
 - 95% of the U.S. companies use spreadsheets
 - Most of the time very complex
 - the average business spreadsheet has 60.000 cells
 - Often contain errors
 - ~88% of spreadsheets investigated during 1995 – 2007 were erroneous
- Spreadsheet debugging with SMT Solvers:
 - Z3 on average 6 times faster than Choco and Minion

Requirements

- Real numbers
- Non-linear arithmetic
- Functionality to:
 - Produce models for satisfiable formulas
 - extract unsatisfiable-cores for unsatisfiable formulas (MCSes-U)
- SMT-LIB language v2

Solvers Supporting Reals

Name	SMT-COMP
Barcelogic (*)	2006-2009
CVC/CVCLite/CVC ₃ (*)	2005-2012
CVC ₄	2010-2014
MathSAT	2005-2014
SMTInterpol	2011-2014
veriT	2009-2011, 2013, 2014
Yices	2005-2009, 2014
Z ₃	2007, 2008, 2011, 2013, 2014

(*) Solvers are no longer in development or a newer version is available.

General Overview

Name	Affiliation	Coding Language	Licence	API
CVC4	NYU, U. Iowa	C++	BSD	C++
MathSAT 5	U. Trento, FBK-irst	C++	Proprietary	C
SMTInterpol	U. Freiburg	Java	LGPL v3	Java
veriT	U. Nancy, INRIA, UFRN	C	BSD	C
Yices 2	SRI	C	Proprietary	C
Z3	Microsoft	C++	MSR-LA	C, C++, .NET, Python, Java, OCaml

Technical Overview

Name	Input Language	Models	Proofs	Unsat-Cores
CVC ₄	SMT-LIB v1.0/v2.0, native language	Yes	Yes	No
MathSAT 5	SMT-LIB v1.2/v2.0, DIMACS format, native language	Yes	Yes	Yes
SMTInterpol	SMT-LIB v1.2/v2.0, DIMACS format	Yes	Yes	Yes
veriT	SMT-LIB v2.0, DIMACS format	Yes	Yes	No
Yices 2	SMT-LIB v1.2/v2.0, native language	Yes	No	No
Z ₃	SMT-LIB v2.0, Simplify format, DIMACS format	yes	Yes	Yes

Supported Theories (1)

Name	Uninterpreted functions with equality	Arrays	Bit-vectors
CVC ₄	Yes	Yes	Yes
MathSAT 5	Yes	Yes	Yes
SMTInterpol	Yes	No	No
veriT	Yes	No	No
Yices 2	Yes	Yes	Yes
Z ₃	Yes	Yes	Yes

Supported Theories (2)

Name	Difference arithmetic	Linear arithmetic	Non-linear arithmetic	Quantifiers
CVC4	Yes	Yes	Yes (*)	Yes
MathSAT 5	No	Yes	No	No
SMTInterpol	No	Yes	No	No
veriT	Yes	Yes	No	Yes
Yices 2	Yes	Yes	No	No
Z3	Yes	Yes	Yes	Yes

(*) only limited support through conversion into linear arithmetic

Result

- All Solvers support real numbers
- Only Z₃ supports non-linear arithmetic
- All Solvers are able to produce models
- Only MathSAT 5, SMTInterpol and Z₃ are able to extract unsatisfiable-cores
- All Solvers support SMT-LIB v2 as input language

- Only suitable candidate for spreadsheet debugging
 - Z₃

Future Work

- Wait for better non-linear arithmetic support
 - Integrate new solver into the framework
 - SMT-LIB
 - API
 - Compare solvers concerning execution time and performance when debugging spreadsheets
- Consider other solving methodologies
 - Dependency-based spreadsheet debugging

QUESTIONS?
