

Alt-Ergo*

Alt-Ergo is a SMT solver developed by Université Paris-Sud and the OCamlPro company. Since its first release in 2006, Alt-Ergo has been mainly designed for discharging proof obligations generated by software development frameworks. In particular, some of its features directly come from the Why/Why3 platforms for deductive program verification (also developed at Université Paris-Sud) which provide a rich specification language based on a *polymorphic* type system *à la* ML.

In order to directly handle proof tasks from this system, Alt-Ergo has a native input language for a polymorphic first-order logic and built-in capabilities to reason about parametric user-defined data-structures. The solver also supports quantifiers reasoning (based on E-matching), the free theory of equality, the theory of (integer and rational) arithmetic, enumerations, record data types and the theory of arrays. Recently, a procedure for the theory of floating-point arithmetic has been integrated. Last but not least, Alt-Ergo integrates a powerful mechanism for reasoning about associative-commutative function symbols.

In order to work closely with the SMT community, we have implemented in Alt-Ergo 2.2 a new frontend for a polymorphic conservative extension of the SMT-LIB 2 standard, presented at SMT2018[3].

Alt-Ergo is written in OCaml. Each module is implemented in a modular way as a set of (parameterized) modules. Most of the code (except very few parts like the CDCL algorithm and hashing used for maximal sharing) is written in a purely applicative programming style.

Alt-Ergo provides decision procedures for reasoning in the combination of the following built-in theories: the free theory of equality with uninterpreted symbols, linear arithmetic over integers and rationals, fragments of non-linear arithmetic, polymorphic functional arrays with extensionality, enumerated datatypes, record datatypes, associative and commutative (AC) symbols, floating-point arithmetic [5], and fixed-size bit-vectors with concatenation and extraction operators. Universal quantifiers are handled using the usual e-matching technique, extended to deal with type variables.

The main differences of Alt-Ergo from other SMT solvers are:

- Shostak combination. The algorithm which implements the *equational reasoning* for convex theories is reminiscent of Shostak combination called CC(X) [2]. Its extension to handle associative and commutative user-defined symbols is called AC(X) [1].
- Non-linear arithmetic. To reason about non-linear integer arithmetic, Alt-Ergo implements an algorithm which relies on the extension and collaboration of the AC(X) framework and interval calculus to handle NIA axioms in a built-in way [4].
- Polymorphism. The historical input language of Alt-Ergo is a first-order logic with some built-in theories and polymorphic data types. We recently added a partial support for the SMT-LIB 2 standard extended with ML-style prenex polymorphism[3].
- Tableaux-like and CDCL procedures. Since its first versions, Alt-Ergo integrates a Tableaux like SAT solver modulo theories implemented in a purely functional programming style. We recently worked on a new SAT solver that combines the efficiency of a CDCL engine with the nice properties of the Tableaux-like solver (construction of a small Boolean model, interaction with theories and instantiation engine using a small set of literals and terms).

*This work is partially supported by VOCaL (ANR-15-CE25-0008) and SOPRANO (ANR-14-CE28-0020) ANR projects.

- Graphical User Interface. To the best of our knowledge, Alt-Ergo is the only SMT solver equipped with a graphical user interface[6].

Current team members

- Guillaume Bury, OCamlPro SAS
- Sylvain Conchon, OCamlPro SAS, LRI, Université Paris Saclay, CNRS, INRIA Saclay–Île-de-France
- Albin Coquereau, OCamlPro SAS
- Mohamed Iguernlala, OCamlPro SAS
- Mattias Roux, OCamlPro SAS

Former contributors

- Francois Bobot, CEA List
- Evelyne Contejean, CNRS, INRIA Saclay–Île-de-France, LRI Université Paris Sud
- Claire Dross, AdaCore
- Stephane Lescuyer, Prove&Run
- Alain Mebsout and Steven de Oliveira, OCamlPro SAS
- Other contributors (Post-doc, internship) : David Baudet, Denis Cousineau, Kylian Ji, Frédéric Lang, Arthur Milchior, Samia Nabili, Samuel Risbourg, Thibaut Tachon

For more informations visit our website at <https://alt-ergo.ocamlpro.com/> and our public repo on github : <https://github.com/OCamlPro/alt-ergo>

References

- [1] Sylvain Conchon, Evelyne Contejean, and Mohamed Iguernelala. Canonized Rewriting and Ground AC Completion Modulo Shostak Theories: Design and Implementation. *Logical Methods in Computer Science*, 8(3), 2012.
- [2] Sylvain Conchon, Evelyne Contejean, Johannes Kanig, and Stéphane Lescuyer. CC(X): Semantic Combination of Congruence Closure with Solvable Theories. *Electronic Notes in Theoretical Computer Science*, 198(2):51–69, May 2008.
- [3] Sylvain Conchon, Albin Coquereau, Mohamed Iguernelala, and Alain Mebsout. Alt-Ergo 2.2. In *Proceedings of the 16th International Workshop on Satisfiability Modulo Theories, SMT 2018*, Oxford, UK, 2018.
- [4] Sylvain Conchon, Mohamed Iguernelala, and Alain Mebsout. A collaborative framework for non-linear integer arithmetic reasoning in Alt-Ergo. In *15th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing, SYNASC 2013, Timisoara, Romania, September 23-26, 2013*, pages 161–168, 2013.
- [5] Sylvain Conchon, Mohamed Iguernlala, Kailiang Ji, Guillaume Melquiond, and Clément Fumex. A Three-Tier Strategy for Reasoning About Floating-Point Numbers in SMT. In Rupak Majumdar and Viktor Kunčák, editors, *Computer Aided Verification*, pages 419–435, 2017.
- [6] Sylvain Conchon, Mohamed Iguernlala, and Alain Mebsout. AltGr-Ergo, a Graphical User Interface for the SMT Solver Alt-Ergo. In *Proceedings of the 12th Workshop on User Interfaces for Theorem Provers, UITP 2016, Coimbra, Portugal, 2nd July 2016.*, pages 1–13, 2016.