Bitwuzla at the SMT-COMP 2021

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***Abstract*—In this paper, we present Bitwuzla, our Satisfiability Modulo Theories (SMT) solver for the theories of bit-vectors, floating-points, arrays and uninterpreted functions and their combinations. We discuss selected features and provide details of its configuration and participation in the 2021 edition of the annual SMT competition.**

I. Introduction

Bitwuzla is a Satisfiability Modulo Theories (SMT) solver for the theories of bit-vectors, floating-points, arrays and uninterpreted functions and their combinations. Its name is derived from an Austrian dialect expression that can be translated as "someone who tinkers with bits". Bitwuzla is the successor of our SMT solver Boolector [20], which supports bit-vectors, arrays and uninterpreted functions.

Bitwuzla implements a lemmas on demand procedure for logics with arrays and uninterpreted functions that generalizes the lemmas on demand for arrays approach from [10] to non-recursive first-order lambda terms [21, 22]. For quantifier-free bit-vectors, it supports the classic bit-blasting approach [13], different approaches to local search [14, 17, 18, 19], and a sequential combination of both. For floating-point logics, Bitwuzla includes SymFPU [8], a C++ library of bit-vector encodings of floating-point operations. It further supports unsat core extraction for all supported quantifier-free logics.

This paper serves as system description for Bitwuzla as entered into the SMT competition 2021 [3]. Bitwuzla is licensed under the MIT license. Source code, releases and more information is available on the Bitwuzla website [1].

II. Features

A. Arrays and Uninterpreted Functions

Bitwuzla generalizes the lemmas on demand for extensional arrays approach [10] to non-recursive first-order lambda terms [21, 22], which enables compact representations for operations such as memset and memcpy [23] and constant arrays. It further supports dual propagation-based and justification-based optimization techniques for lemmas on demand, where the overhead for consistency checking is reduced by extracting partial candidate models via don't care reasoning on full candidate models [16].

B. Quantifier-Free Bit-Vectors

Bitwuzla implements two orthogonal strategies for solving quantifier-free bit-vector constraints: the classic bit-blasting approach employed by most state-of-the-art bit-vector solvers, and local search. Since local search procedures are only able to determine satisfiability, Bitwuzla allows to combine local search with bit-blasting in a sequential portfolio setting, where the local search procedure is run until a certain limit is reached, before falling back to the bit-blasting engine.

Local Search for Quantifier-Free Bit-Vectors. Bitwuzla supports the stochastic local search (SLS) approach presented in [12], an improved variant where SLS is augmented with a propagation-based strategy [19], and mainly the complete propagation-based local search procedure presented in [18]. The latter can both be applied on the bit-level and word-level. The word-level strategy, however is superior to the bit-level implementation, which operates on the circuit representation of the input formula. Bitwuzla further implements a novel generalization of the propagation-based approach in [18] to ternary values [15]. This generalization addresses the main weakness of the propagation-based local search strategy [14, 18], its obliviousness to bits that can be simplified to constant values. The local search engines can now also be combined with the lemmas on demand engine and quantified bit-vectors.

Bit-Blasting. Bitwuzla implements bit-blasting in two phases. Initially, it generates an And-Inverter Graph (AIG) circuit representation of the simplified input formula and then applies AIG-level rewriting [9]. The rewritten AIG representation is then converted into Conjunctive Normal Form (CNF) and sent to one of following SAT back ends: MiniSat [11], PicoSAT [5], Lingeling [6], CaDiCaL [7], CryptoMiniSat [24], or Kissat [2].

Bitwuzla uses CaDiCaL version sc2021 as default SAT back end. It further utilizes Lingeling for preprocessing the Boolean skeleton of the input formula.

C. Floating-Points

For the theory of floating-points, Bitwuzla implements an eager translation of the simplified input formula to the theory of bit-vectors. This approach is sometimes also referred to as *word-blasting*. To translate floating-point expressions to the word-level, Bitwuzla integrates SymFPU [8], a C++ library of bit-vector encodings of floating-point operations. SymFPU uses templated types for Booleans, (un)signed bit-vectors, rounding modes and floating-point formats, which allows to plug it in as a back end while utilizing solver-specific representations. It is also integrated in the SMT solver CVC4 [4].

D. Unsat Cores

Bitwuzla implements unsat core extraction via solving under assumptions [11]. When unsat core extraction is enabled, all assertions in the formula are assumed in the SAT back end. If given input formula is unsatisfiable, Bitwuzla returns all unsatisfiable (failed) assumptions as unsat core. Unsat Core extraction is not yet supported for quantified formulas.

III. CONFIGURATIONS

Bitwuzla participates in the single query, incremental, unsat core, and model validation tracks in the following divisions:

- *Single Query Track (SQ):*
  QF_BV, QF_ABV, QF_AUFBV, QF_UFBV, QF_FP, QF_FPLRA, QF_BVFP, QF_BVFPLRA, QF_ABVFP, QF_AUFBVFP, QF_ABVFPLRA, QF_UFFP
- *Incremental Track (INC):*
  QF_BV, QF_ABV, QF_AUFBV, QF_UFBV, QF_FP, QF_BVFP, QF_ABVFP, QF_UFFP
- *Unsat Core Track (UC):*
  QF_BV, QF_ABV, QF_AUFBV, QF_UFBV, QF_FP, QF_FPLRA, QF_BVFP, QF_BVFPLRA, QF_ABVFP, QF_AUFBVFP, QF_ABVFPLRA, QF_UFFP
- *Model Validation Track (MV):*
  QF_BV, QF_UFBV

For the QF_BV division in the SQ and MV track, Bitwuzla uses a sequential combination of bit-blasting and propagation-based local search with a limit of 10k propagation steps and 2M model update steps.

IV. LICENSE

Bitwuzla is licensed under the MIT license. For more details, refer to the actual license text, which is distributed with the source code.

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