Adding Cardinality Constraint Support to CryptoMiniSat for Analysing Neural Networks

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Abstract

Recently, reasoning over Boolean Cardinality Constraints (BCCs) gains in importance by the advent of deep learning approaches, or more precisely, by the formal verification of Binarized Neural Networks (BNNs). Another recent example of problems that can be encoded as BCCs is the optimization of Wireless Sensor Networks (WSNs). The encoding of such practical problems typically generates a large amount of BCCs. There exist approaches that can naturally reason over BCCs such as integer linear programming, Satisfiability Modulo Theories (SMT), pseudo-Boolean solving approaches, etc., but in most of the cases those are not efficient enough when solving large amount of BCCs, compared to SAT approaches. On the other hand, SAT approaches force BCCs to be converted to CNF, causing blowup in the encoding. There exists however a SAT solver called MiniCARD that provides native support for BCCs on the level of Conflict-Driven Clause Learning (CDCL). For large amount of BCCs, MiniCARD typically outperforms any of the aforementioned solvers, despite the fact that MiniCARD is considered to be an outdated solver and its source code did not get any update in the last 5 years. In this work, we add native support for BCCs to a state-of-the-art full-fledged SAT solver called CryptoMiniSat, in a similar way as it was done in MiniCARD, that is, on the CDCL-level, including the generalization of the clause datastructure and the watched literals scheme, Boolean constraint propagation, conflict analysis and clause learning. CryptoMiniSat is recently used as the underlying SAT solver inside the approximate model counter ApproxMC, due to CryptoMiniSat's native support for XOR clauses. Our work could make it feasible to count models over BNNs, which could be useful in the comparative analysis of BNNs.

Keywords: SAT, Boolean cardinality constraint, CDCL, model counting, neural network.