On computing Minimal Independent Support and its applications to sampling and counting (Extended Abstract) ⋆ ⋆⋆

Alexander Ivrii[1], Sharad Malik[2], Kuldeep S. Meel[3], and Moshe Y. Vardi[3]

[1] IBM Research Lab, Haifa, Israel
[2] Princeton University
[3] Department of Computer Science, Rice University

Constrained sampling and counting are two fundamental problems arising in domains ranging from artificial intelligence and security, to hardware and software testing. Recent approaches to approximate solutions for these problems rely on employing combinatorial (SAT/SMT) solvers and universal hash functions that are typically encoded as XOR constraints of length $n/2$ for an input formula with n variables. It has been observed that lower density XORs are easy to reason in practice and the runtime performance of solvers greatly improves with the decrease in the length of XOR-constraints. Therefore, recent research effort has focused on reduction of length of XOR constraints. Consequently, a notion of *Independent Support* was proposed, and it was shown that constructing XORs over independent support (if known) can lead to a significant reduction in the length of XOR constraints without losing the theoretical guarantees of sampling and counting algorithms [1].

In this paper, we present the first algorithmic procedure (and a corresponding tool, called MIS) to determine minimal independent support for a given CNF formula by employing a reduction to group minimal unsatisfiable subsets (GMUS). Extensive experiments demonstrate that MIS scales to large formulas with tens of thousands of variables, and the minimal independent support computed by MIS is typically of 1/10 to 1/100th size of the support of the formulas. By utilizing minimal independent supports computed by MIS, we provide new tight theoretical bounds on the size of XOR constraints for constrained counting and sampling – in some cases, even better than previously observed empirical bounds. Furthermore, the universal hash functions constructed from independent supports computed by MIS provide one to two orders of magnitude performance improvement in state-of-the-art constrained sampling and counting tools, while still retaining theoretical guarantees.

References

1. S. Chakraborty, K. S. Meel, and M. Y. Vardi. Balancing scalability and uniformity in SAT witness generator. In *Proc. of DAC*, pages 1–6, 2014.

⋆ Authors names are ordered alphabetically by last name and does not indicate contribution.

⋆⋆ The full version appears in Constraints 21(1).