

Combining BandMaxSAT and FPS with SPB-MaxSAT-c

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Abstract—This document describes our MaxSAT solvers SPB-MaxSAT-c, SPB-MaxSAT-c-Band and SPB-MaxSAT-c-FPS submitted to the MSE 2024. All of the three solvers are submitted to both the weighted and unweighted incomplete tracks.

I. INTRODUCTION

Algorithms for MaxSAT can be categorized into complete and incomplete solvers, depending on their ability to provide optimality guarantees.

An important technique in MaxSAT complete-solving is the Soft conflict Pseudo Boolean (SPB) constrain. A Pseudo Boolean (PB) constraint [1] is a particular type of linear constraint in the form of $\sum_{i=1}^n q_i x_i \# K$, where $\# \in \{<, \leq, =, \geq, >\}$ and can be normalized to $<$, q_i and K are integer constants, and x_i are 0/1 variables, $i \in \{1, \dots, n\}$. In many complete MaxSAT solvers, once a better solution is found, a PB (or Cardinality for unweighted problem) constraint is added naturally to prohibit the procedure from finding solutions that are no better than the current best.

On the other hand, incomplete algorithms for MaxSAT mainly focus on the local search approach. Recent research in this domain has concentrated on refining clause weighting schemes, such as SATLike [2] and NuWLS [3]. The anytime algorithms based on them, i.e., SATLike-c and NuWLS-c, combine them with a famous SAT-based solver, TT-Open-WBO-Inc [4] and have achieved excellent rankings in the previous MaxSAT Evaluations.

Based on Nuwls-c-2023, we integrate SPB constraints into the clause weighting system and develop a new local search algorithm SPB-MaxSAT-c [5]. Then we combine BandMaxSAT [6] and FPS [7] with the SPB-MaxSAT-c solver, resulting in SPB-MaxSAT-c-Band and SPB-MaxSAT-c-FPS, respectively.

II. SPB-MAXSAT

SPB-MaxSAT [5] associate each hard clause with a dynamic weight and add a SPB constraint to the MaxSAT formula with a dynamic weight. When the algorithm hits a local optimum, the dynamic weights of the falsified hard clauses and SPB constraint are increased. Additionally, when a better solution is found through local search, the SPB constraint is updated. This method guides the search directions and helps the algorithm find better solutions without restricting the search space.

SPB Constraint

Algorithm 1: SPB-Weighting

Input: MaxSAT instance $\mathcal{F}$, current solution A , hard clause dynamic weight increment h_{inc} , increment proportion δ

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1 for each clause  $c \in \text{Hard}(\mathcal{F})$  falsified by  $A$  do
2    $w_h(c) \leftarrow w_h(c) + h_{inc}$ ;
3 if  $SPB$  is falsified by  $A$  then
4    $w(SPB) \leftarrow \delta \cdot (w(SPB) + 1)$ ;

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Suppose A^* is the best solution found so far during the local search. Finding solutions no better than A^* is meaningless, so an SPB constraint, denoted as SPB , is naturally added as follows.

$$SPB : \sum_{c \in \text{Soft}(\mathcal{F})} w_s(c) \cdot \text{unsat}(c) < \text{cost}(A^*), \quad (1)$$

where $\text{unsat}(c)$ equals 1 if clause c is falsified by the current solution A . Denote the left part of the SPB as $\text{obj}(A)$.

Scoring Function

In the local search MaxSAT algorithms, the scoring function $\text{score}(v)$ of a variable v is commonly used to evaluate the benefit of flipping v in the current solution.

Suppose A' is the solution obtained by flipping variable v in A . $SPB\text{score}(v)$ is defined to evaluate the influence of flipping v in A to the SPB constrain.

$$SPB\text{score}(v) = w(SPB) \cdot (\text{obj}(A) - \text{obj}(A')). \quad (2)$$

The scoring function $\text{score}(v)$ is defined as follows:

$$\text{score}(v) = h\text{score}(v) + SPB\text{score}(v). \quad (3)$$

where $h\text{score}(v)$ is the decrement of the total dynamic weight of falsified hard clauses caused by flipping v in A .

Adaptive SPB Weighting

The proposed SPB-Weighting function is shown in Algorithm 1. The function is used to update the dynamic weights once the algorithm falls into a local optimum.

III. BANDMAXSAT

BandMaxSAT [6] integrates a multi-armed bandit with the soft clauses, where each arm corresponds to a soft clause. This approach employs the bandit model to strategically choose the search direction, aiding in the evasion of feasible local optima.

IV. FPS

The Farsighted Probabilistic Sampling (FPS) method [7] combines the look-ahead strategy with the probabilistic sampling strategy in an effective way. Upon encountering a local optimum, FPS first randomly samples sc_num (10 by default) falsified clauses, then proceeds to perform a look-ahead from a randomly chosen variable within each sampled clause. This step evaluates the potential improvement achievable by flipping a pair of variables in the current solution. If this attempt proves unsuccessful, FPS then selects the optimal variable or pair of variables among the sampled set to flip.

With the help of the look-ahead strategy, FPS can improve the local optima for the single flipping mechanism, so as to find higher-quality solutions. Meanwhile, the probabilistic sampling strategy contributes to the algorithm's efficiency enhancement, augmenting its overall performance.

REFERENCES

- [1] Li C M, Xu Z, Coll J, et al. "Combining clause learning and branch and bound for MaxSAT," In Proceedings of the 27th International Conference on Principles and Practice of Constraint Programming, volume 210, pages 38:1–38:18, 2021.
- [2] S. Cai, Z. Lei, "Old techniques in new ways: Clause weighting, unit propagation and hybridization for maximum satisfiability," Artificial Intelligence, 287: 103354, 2020.
- [3] Chu Y, Cai S, Luo C. "NuWLS: Improving local search for (weighted) partial MaxSAT by new weighting techniques," AAAI 2023, 37(4): 3915-3923.
- [4] N. Alexander, "Anytime weighted maxsat with improved polarity selection and bit-vector optimization," FMCAD 2019: 193–202.
- [5] Zheng J, Chen Z, Li C M, et al. "Rethinking the Soft Conflict Pseudo Boolean Constraint on MaxSAT Local Search Solvers," arXiv preprint arXiv:2401.10589, 2024.
- [6] J. Zheng, K. He, J. Zhou, Y. Jin, C. M. Li, F. Manyà, "BandMaxSAT: A Local Search MaxSAT Solver with Multi-armed Bandit," IJCAI 2022: 1901-1907.
- [7] J. Zheng, J. Zhou, K. He, "Farsighted Probabilistic Sampling based Local Search for (Weighted) Partial MaxSAT," AAAI 2023.