

Hybrid1: A Local Search Algorithm That Switches Between Two Heuristics

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1 Local Search Algorithms $adaptG^2WSAT_P$ and VW

The local search algorithm $adaptG^2WSAT_P$ [3, 4] flips the promising decreasing variable with the largest computed promising score if there are promising decreasing variables. It selects a variable to flip from a randomly chosen unsatisfied clause using heuristic $Novelty_{++P}$ [3, 4] otherwise. This heuristic $Novelty_{++P}$ is described as follows.

$Novelty_{++P}(p, dp)$: With probability dp (diversification probability), flip a variable in c whose flip can falsify the least recently satisfied clause. With probability $1 - dp$, do as $Novelty$, but flip $second$ if $best$ is more recently flipped than $second$ and if $pscore(second) \geq pscore(best)$.

The local search algorithm VW [6] introduces variable weighting. This algorithm initializes the weight of a variable x , $variable_weight[x]$, to 0 and updates and smoothes $variable_weight[x]$ each time x is flipped, using the following equation:

$$variable_weight[x] = (1 - s)(variable_weight[x] + 1) + s \times t \quad (1)$$

where s is a parameter and $0 \leq s \leq 1$, and t denotes the time when x is flipped. This algorithm uses a unique variable selection rule. We call this rule the *low variable weight favoring rule*. If a randomly selected unsatisfied clause c contains freebie variables,³ VW randomly flips one of them. Otherwise, with probability p , it flips a variable chosen randomly from c , and with probability $1 - p$, it flips a variable in c according to the low variable weight favoring rule.

Based on $adaptG^2WSAT_P$ and VW , we develop a new local search algorithm called *Hybrid1*, which can switch between $adaptG^2WSAT_P$ and VW , according to the evenness or non-evenness of the distribution of variable weights. Although several local search algorithms can switch between heuristics [1, 5, 2–4], none of the alternating or switching heuristics uses any weighting.

1.1 Algorithm *Hybrid1*

Assume that variable weights are updated using Equation 1. Assume that γ is an integer and that $\gamma > 1$. If the maximum variable weight is at least γ times as high as the average variable weight, the distribution of variable weights is considered *uneven*. Otherwise, the distribution of variable weights is considered *even*.

Hybrid1 is described in Fig. 1. This algorithm switches between two heuristics. When the distribution of variable weights is uneven, *Hybrid1* chooses a variable to flip according to heuristic VW . Otherwise, it selects a variable to flip according to heuristic $adaptG^2WSAT_P$.

To distinguish these heuristics from the original algorithms $adaptG^2WSAT_P$ introduced in [3, 4] and VW introduced in [6], we call these heuristics *heuristic $adaptG^2WSAT_P$* and *heuristic*

³ A freebie variable is a variable with a break of 0.

Algorithm: *Hybrid1*(SAT-formula \mathcal{F})

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1:  $A \leftarrow$  randomly generated truth assignment;
2: for each variable  $x$  do initialize  $flip\_time[x]$  and  $variable\_weight[x]$  to 0;
3: initialize  $p$ ,  $wp$ ,  $max\_weight$ , and  $ave\_weight$  to 0;
4: store promising decreasing variables in stack  $DecVar$ ;
5: for  $flip=1$  to  $Maxsteps$  do
6:   if  $A$  satisfies  $\mathcal{F}$  then return  $A$ ;
7:   if  $max\_weight \geq \gamma \times ave\_weight$ 
8:     then  $y \leftarrow$  heuristic  $VW(p)$ ;
9:     else  $y \leftarrow$  heuristic  $adaptG^2WSAT_P(p, wp)$ 
10:     $A \leftarrow A$  with  $y$  flipped; adapt  $p$  and  $dp$ ;
11:    update  $flip\_time[y]$ ,  $variable\_weight[y]$ ,  $max\_weight$ ,  $ave\_weight$ , and  $DecVar$ ;
12: return Solution not found;

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Fig. 1. Algorithm *Hybrid1*

VW . In *Hybrid1*, heuristic $adaptG^2WSAT_P$ is improved in two ways, based on the preliminary $adaptG^2WSAT_P$ described in [3, 4]. The first improvement is that, when promising decreasing variables exist, heuristic $adaptG^2WSAT_P$ no longer computes the promising scores for the δ promising decreasing variables with higher scores, where δ is a parameter, but chooses the least recently flipped promising decreasing variable among all promising decreasing variables to flip. As a result, heuristic $adaptG^2WSAT_P$ no longer needs parameter δ . The second improvement is that, when there is no promising decreasing variable, heuristic $adaptG^2WSAT_P$ uses $Novelty_{+P}$ instead of $Novelty_{++P}$ [3, 4], to select a variable to flip from a randomly chosen unsatisfied clause c . The difference between $Novelty_{+P}$ and $Novelty_{++P}$ is that, with wp (random walk probability), $Novelty_{+P}$ randomly chooses a variable to flip from c , but with dp (diversification probability), $Novelty_{++P}$ chooses a variable in c , whose flip will falsify the least recently satisfied clause. In *Hybrid1*, heuristic VW is the same as the algorithm VW described in [6].

2 Contest Implementation

For the SAT 2007 competition, parameter γ in *Hybrid1* is set to 15.

References

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