SAT TIG Challenge Description

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1 Problem Description and Formulation

The *Boolean Satisfiability Problem (SAT)* is the canonical NP-complete decision problem: given a Boolean formula, determine whether there exists an assignment of TRUE/FALSE values to its variables that makes the entire formula evaluate to TRUE.

The TIG challenge focuses on the special case *3-SAT*, where the formula is expressed in *conjunctive normal form* (CNF) and each clause contains exactly three literals.

Formally, a 3-SAT instance is defined over:

- a set of n Boolean variables $x_1, \ldots, x_n$, where each $x_i \in \{\text{FALSE}, \text{TRUE}\}$;
- a set of m clauses $C_1, \ldots, C_m$;
- each clause C_k is a disjunction of exactly three literals:

$$C_k = \ell_{k1} \vee \ell_{k2} \vee \ell_{k3},$$

  where each literal ℓ_{kj} is either x_i or $\neg x_i$ for some variable index $i \in \{1, \ldots, n\}$.

The overall formula is the conjunction of all clauses:

$$F(x_1, \ldots, x_n) = \bigwedge_{k=1}^{m} C_k.$$

A *satisfying assignment* is a vector

$$(x_1, \ldots, x_n) \in \{\text{FALSE}, \text{TRUE}\}^n$$

such that every clause evaluates to TRUE. The goal of the challenge is to find a satisfying assignment for each provided instance.

2 Random Instance Generation

Currently, instance generation supports one type of instance, random 3-SAT problems. Each instance is defined by:

- The number of variables, n;
- The clauses to variables ratio, α.

Given n and a density parameter α, the number of clauses is:

$$m = \left\lfloor n \cdot \frac{\alpha}{1000} \right\rfloor.$$

Clause and Literal Construction

Random 3-SAT instances are constructed as follows:
Given n variables and m clauses:

1. For each clause $k = 1, \ldots, m$ and each literal position $j \in \{1, 2, 3\}$:
   (a) a variable index i is drawn uniformly from $\{1, \ldots, n\}$;
   (b) a sign $s \in \{-1, +1\}$ is drawn uniformly at random;
   (c) the corresponding literal is stored as $s \cdot i$.
2. The final instance is a list of m clauses, each clause being a vector of three signed integers.

3 Challenge Tracks

While only supporting random 3-SAT instances, each challenge track is determined by a choice of the number of variables, n and the clauses to variables ratio, α.

Following the instances defined in the 2017 SAT competition, we include the following tracks [1]:

$$\alpha = 4267,\ n \in \{5000, 7500, 10000\}$$
$$\alpha = 4150,\ n = 1000000$$
$$\alpha = 4100,\ n = 1000000$$

In these configurations TIG is placing the instances near the classical *phase transition* region where random 3-SAT formulas are empirically hardest.

4 Quality

3-SAT is a decision problem: an instance is either satisfiable or unsatisfiable. Unsatisfiable instances are not asymmetric to verify. Hence, TIG only reward identification of satisfiable instances. A solution that finds a satisfiable instance is given a quality score of 1, an instance for which a satisfiable solution is not found is given a quality score of 0.

References

[1] Tomáš Balyo, Marijn JH Heule, and Matti Järvisalo. "Proceedings of sat competition 2017: Solver and benchmark descriptions". In: (2017).