On Continuous Local Search for Hybrid SAT Solving

Anastasios Kyrillidis, Moshe Vardi, Zhiwei Zhang
Department of Computer Science, Rice University
Motivation

Boolean Constraints and Satisfiability (SAT)

- Boolean variables: $x, y, z, w, \ldots \in \{0, 1\}$
- Examples of Boolean Constraints:
  - CNF constraints: $x + y + z \geq 1$
  - XOR constraints: $(x + y + z) \mod 2 \equiv 1$
  - Cardinality constraints: $x + y + z + w \geq 2$
  - All-equal constraints: $x = y = z = w$
- Boolean Satisfiability (SAT) Solving: finding a solution of a system consists of Boolean constraints.

\[
\begin{align*}
  x + y + z &\geq 1 \\
  (x + y + z) \mod 2 &\equiv 1 \\
  x + y + z + w &\geq 2 \\
  x = y = z = w &\equiv 1
\end{align*}
\]

$x = y = z = w = 1$ is the only solution!

Current SAT solvers can not handle different types of constraints uniformly.

Applications

SAT can represent a lot of discrete optimization problems, e.g., minimum vertex covering and vertex coloring in graph theory.

SAT can be used to solve discrete integration problems such as computing the partition function, a fundamental problem in AI.

SAT can represent problems in motion planning problems from robotics.

SAT solver is a critical tool in hardware design and software verification.
Methodology

Workflow of solving SAT **continuously** (FourierSAT)

Drawback: The gradient is **expensive** to compute

Use Binary Decision Diagrams (BDDs) to replace polynomials and accelerate gradient computation by message passing algorithms (GradSAT)

Gradient is as cheap as evaluation accept more types of constraints (e.g. Pseudo-Boolean constraints)
Experimental Results

Our tool, GradSAT, is good at handling CARD/PB constraints and small-size MaxSAT problems. We also observe the limitations of our tool on large instances and XOR-rich instances.

Figure 1: Results on random CARDs and PBs. GradSAT is second only to CDPB-based RoundingSAT.

Figure 2: Results on random XORs-1CARD and CNF-XORs. CDCL solvers outperform local-search solvers while GradSAT performs best among local-search solvers.

Table 3: Results on MaxSAT instances. GradSAT achieves the best avg. score and improves the VBS.