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Abstract

Algorithmic Applications of Propositional Proof Complexity

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This thesis explores algorithmic applications of proof complexity theory to the areas of exact and approximation algorithms for graph problems as well as propositional reasoning systems studied commonly by the artificial intelligence and formal verification communities. On the theoretical side, our focus is on the propositional proof system called resolution. On the practical side, we concentrate on propositional satisfiability algorithms (SAT solvers) which form the core of numerous real-world automated reasoning systems.

There are three major contributions in this work. (A) We study the behavior of resolution on appropriate encodings of three graph problems, namely, independent set, vertex cover, and clique. We prove lower bounds on the sizes of resolution proofs for these problems and derive from this unconditional hardness of approximation results for resolution-based algorithms. (B) We explore two key techniques used in SAT solvers called clause learning and restarts, providing the first formal framework for their analysis. Formulating them as proof systems, we put them in perspective with respect to resolution and its refinements. (C) We present new techniques for designing structure-aware SAT solvers based on high-level problem descriptions. We present empirical studies which demonstrate that one can achieve enormous speed-up in practice by incorporating variable orders as well as symmetry information obtained directly from the underlying problem domain.