

Decision Diagrams for Constraint Reasoning and Optimization

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Abstract

Since their original inception to represent Boolean functions for verification problems in the 1950s, decision diagrams have found wide applicability across academic disciplines and industry. This presentation discusses the use of decision diagrams as a compact representation of feasible solutions to constrained optimization problems, where solutions correspond to paths in a layered graph. By using relaxed and restricted decision diagrams of bounded size, one can balance the strength of the representation and computational effort.

We highlight three roles of decision diagrams in constrained optimization. First, they enable a model-and-solve approach for dynamic programming, where a dynamic programming model and a merging rule define the compilation of decision diagrams that yield primal and dual bounds within a state-based search. Second, in constraint programming, they strengthen constraint propagation through multi-valued decision diagrams and provide optimization bounds within the search process. Third, in integer programming, they yield arc-flow formulations and establish connections with Dantzig-Wolfe decomposition, leading to strong bounds and state-of-the-art computational results.

These approaches are illustrated on applications including machine scheduling, graph multi-coloring, and vehicle routing, where decision diagram-based methods have led to substantial improvements on benchmark instances. They have also been adopted in practice, both as a dual bounding component within a general-purpose optimization solver and in industrial applications for routing and scheduling.

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