Symbolic Reasoning Methods for AI Planning

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Planning is the act of deliberative thinking before acting (Haslum 2006). It is based on a symbolic model of the world and the options to act in it, usually defined in function-free first-order logic. The planner has to find a sequence of actions (a plan) that leads from the current state to a desired goal state. The purely physical description may be augmented with a partially ordered grammar-like structure (a Hierarchical Task Network or HTN), describing expert knowledge, or practical, legal, or operational requirements.

In this talk, I will survey a variety of methods for automatically deriving plans using symbolic methods for planning.These symbolic methods – in some sense – translate planning problems into other, simpler symbolic representations and reason over them to find plans.

As a basis for these methods, I will firstly introduce relevant theoretical results on planning. First, I will discuss the expressive power of planning formalisms (Höller et al. 2014; Höller et al. 2016) and second, the computational complexity of HTN planning and related tasks such as HTN plan verification, plan modification, and plan recognition (Behnke, Höller, and Biundo 2015; Behnke et al. 2016).

Based on these theoretical results, I will develop why SAT-based HTN planning is possible and how it can be implemented. To this end, I will survey several of my publications at top-tier conferences (Behnke, Höller, and Biundo 2017, 2018, 2019a,b; Behnke et al. 2020; Behnke 2021) – in which I developed an highly SAT-based planner for HTN problems including the ability to find optimal plans as well as the grounding as a preprocessing step.

Next, I present the idea of expressing lifted classical planning as SAT (Höller and Behnke 2022). The resulting planner LiSAT was the first lifted SAT-based planner – and proved highly efficient and outperformed all other lifted planners at the time of publication. Notably, LiSAT was the first planner (lifted or grounded) and still is the only one to solve the challenging OrganicSynthesis benchmark – and could even prove optimality for all plans.

Lastly, I introduce the notion of planning with symbolic representations (Behnke and Speck 2021; Behnke et al. 2023) – using Binary Decision Diagrams (BDDs) to encode large sets of states compactly. Using a combination of finite automata annotated with BDDs, we can the structure of HTNs. Based on this representation, an efficient and optimal planning algorithm can be derived. This algorithm can be extended to also cover oversubscription planning.

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