OptiPlan - a CSP-based partial order HTN planner

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Introduction

In this paper, we introduce OptiPlan, a planner that participated in partial-order HTN track of IPC 2023. OptiPlan is a hierarchical planner capable of solving partial-order problems by encoding them as CSPs (Brailsford, Potts, and Smith 1999) and generating partial order solution plans.

Encoding resolution techniques, particularly SAT encodings, have proved their worth in various IPC competitions. Solving HTN problems via CSP was little studied (Surynek and Barták 2005) compared to SAT (Georgievski and Aiello 2015). These techniques, however, offer a number of advantages over SAT: (1) CSP encoding provides a natural way of expressing numerical constraints, which is not possible with SAT; (2) CSP encoding lets naturally express constraints on method decompositions (logical or numerical) and (3) CSP techniques are much more mature than SAT, and are covered by multiple industrial-level solvers(Puget 2004).

The most distinct, property of OptiPlan is its capability to produce partial-ordered solution plans. The reasoning behind this feature is twofold. First, in various contexts, oftentimes industrial, it is crucial to make plans as flexible as possible, as it helps anticipate unforeseeable events (Liu et al. 2016, 2019). A natural answer to this are partial-ordered solutions, which allow shifting tasks without any impact on the quality of the plan. Second, unlike deordering of total-order plans (Muise, McIlraith, and Beck 2012) which cannot guarantee quality, or optimality, of the produced plans, OptiPlan can guarantee these properties.

Optiplan Principle

OptiPlan is based on hybrid planning formalization (Biundo and Schattenberg 2001), which combines the concepts of HTN with POCL (McAllester and Rosenblatt 1991). Optiplan represents the search space with a structured called Task Decomposition Tree (TDT) inspired from the Task Decomposition Graph (Bercher et al. 2017). A TDT is an AND-OR tree where

- OR nodes represent possible method decompositions,
- AND nodes represent abstract and primitive tasks.

Only tasks can be *leaves*, and only primitive tasks are considered *terminal* leaves.

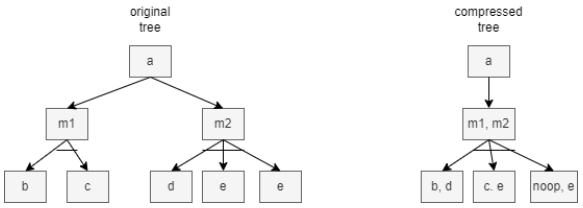

Figure 1: Example of TDT compression

OptiPlan operates using an iterative deepening search. Initially, a TDT consists of an artificial root and its children: abstract tasks of initial HTN, as well as dummy primitive tasks t_0 and t_∞, that correspond to the initial and goal states. Along with the tree, we keep track of ordering constraints introduced by initial task network and method decompositions.

In this search space, we attempt to find a subtree, such that:

1. It has exclusively terminal leaves (i.e., plan is concrete)
2. Every precondition of the subtree has a causal link supporting it (i.e., no open goals)
3. There are no threats on the causal links
4. There are no conflicting ordering constraints

If a solution cannot be found, it means that the search space is not big enough to support it. So we update the search space by expanding the non-terminal leaves of the tree, and try to solve the problem again. This process is repeated until either a solution is found, or failure termination conditions are met (e.g., there are no abstract leaves left), in which case problem is deemed unsolvable.

Implementation

OptiPlan requires a grounded instance of the problem. Thus, OptiPlan uses PDDL4J (Pellier and Fiorino 2018) to parse, pre-process, and instantiate it.

To fully benefit from numeric variables, OptiPlan performs a compression procedure on the tree, where we attempt to merge mutex nodes from the same depth level into a single node. This can be best explained on a simple example in Fig. 1, where we compress two methods *m1, m2* of an abstract task a.

To find the solution, OptiPlan uses Chuffed (Chu et al. 2016) as its CSP solver.

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