The PANDADealer System for Totally Ordered HTN Planning in the 2023 IPC

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Abstract

The PANDADealer system is an HTN planning system for solving totally ordered HTN planning problems. It builds on the heuristic progression search of the PANDApro system, and extends it with a look-ahead technique to detect dead-ends and inevitable refinement choices. The technique is based on inferred preconditions and effects of tasks, or more precisely, their decomposition methods.

Introduction

The PANDADealer (Dead-End Analysis with Look-Aheads and Early Refinements) system is a progression search-based planner that has been enhanced with a look-ahead technique based on inferred preconditions and effects of decomposition methods. It is specifically designed to solve totally ordered HTN planning problems. The system is build upon the PANDApro system and uses its pure heuristic search-based configurations (Höller 2023b) and also those using a combined heuristic- and landmark-based search guidance (Höller 2023a).

Search-based systems in HTN planning can be divided into plan space-based systems and progression-based systems (see Bercher, Alford, and Höller, 2019). The latter only process the first task in the task ordering of the current task network. PANDADealer is builds on the systematic progression search introduced by Höller et al. (2020) and uses the graph search described by Höller and Behnke (2021), i.e., it maintains a black-list of already visited search nodes to process every node only a single time.

The system uses the common preprocessing stack of the PANDA framework: HDDL (Höller et al. 2020) as standard input language, followed by the grounding procedure introduced by Behnke et al. (2020).

The search is guided by using heuristics estimating the goal distance (or the remaining costs in case of optimal planning), some configurations additionally exploit landmarks for search guidance. Next we briefly describe the look-ahead technique, followed by the used heuristics and landmarks.

Look-Ahead Technique

The look-ahead technique employed in PANDADealer is based on inferred preconditions and effects of decomposition methods (Olz, Biundo, and Bercher 2021). These preconditions and effects are derived from the primitive tasks within the refinements of a method. Preconditions specify the facts that must hold in the state before executing the refinements, while effects indicate the changes in the state (additions or deletions) that occur after execution. Calculating the exact sets of preconditions and effects is computationally expensive; therefore, we only calculate a relaxed version in a preprocessing step, which disregards the executability of the refinements.

During the actual search, we treat the task network for each search node as a sequence of primitive tasks, where the compound tasks are enriched with their inferred preconditions and effects. Starting from the first task, we check the preconditions of its methods in relation to the current state. For the "applicable" methods, we add all possible positive effects and remove the guaranteed negative effects, resulting in a new state. The new state is then used to evaluate the preconditions of the methods associated with the second task, propagating their effects in a similar manner. This process continues until the end of the task network. If the preconditions of a primitive task are not satisfied or no method of a compound task is applicable in its respective state, the search node is pruned as it represents a dead-end. If this is not the case but if a compound task has only one applicable method, we immediately decompose that task to eliminate future branching points. Further be aware that this "early application" of methods might help getting better heuristic estimates, because heuristics might not be able to detect that there is only a single applicable method.

For a comprehensive and detailed explanation of the look-ahead technique we refer to the respective paper by Olz and Bercher (2023).

RC Heuristics

The family of relaxed composition (RC) heuristics (Höller et al. 2018, 2019, 2020) uses classical heuristics to estimate the goal distance during HTN search. This is done based on a relaxation of the HTN model to a classical model. This model is only used for heuristic calculation. It is created in a way that the set of solutions increases compared to the HTN model. HTN planning starts with the initial task(s) and decomposes them until only actions are left. This process can be seen as the building process of a tree. The RC model captures (a relaxation of) the building process of that tree in the state of the classical model, but in a bottom-up manner,

track	config	landmarks	search	heuristic
agile	agile-1	none	GBFS	rc(add)
	agile-lama	LM-Cut	GBFS	rc(add)
satisf.	agile-lama	LM-Cut	GBFS	rc(add)
optimal	optimal	none	A*	rc(lmc)

Table 1: Overview over the winning configurations.

compositing tasks.

The RC model is computed once in a preprocessing step and updated during search. It is linear in the size of the HTN model and can be combined with arbitrary classical planning heuristics. In the IPC, we combine it with the Add (Bonet and Geffner 2001), the FF (Hoffmann and Nebel 2001), and the LM-Cut (Helmert and Domshlak 2009) heuristic. Höller et al. (2018) have shown that the combination of the RC model with an admissible heuristic from classical planning results in an admissible HTN heuristic, so we use the latter (RC with LM-Cut) for optimal planning.

Landmarks

Similar to the LAMA system from classical planning (Richter and Westphal 2010), our configurations using landmarks combine heuristic-based and landmark-based guidance in a multi-fringe search, where one fringe is sorted by a heuristic, and one by an LM-count heuristic computed on the landmarks. The system extracts nodes from the fringes in turn and each successor node is inserted into both fringes with the respective heuristic estimate. We combine it with two approaches for landmark generation.

The first one computes LM-Cut heuristic on the RC model of the initial search node. The generated landmarks are stored and tracked during search.

The second one generates the landmarks using the approach of Höller and Bercher (2021). It extends the work from classical planning by Keyder, Richter, and Helmert (2010), who represent a delete-free classical planning problem as AND/OR graph, and extract landmarks from this graph afterwards. We extend the AND/OR graph to also represents parts of the decomposition hierarchy, and applies the unchanged extraction algorithm afterwards. We again generate the landmarks on the initial search node and track them afterwards during search.

Configurations

PANDADealer won all of the total-order HTN tracks of the IPC 2023. In Table 1 we give an overview over the details of the configurations.

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