User-Centered Planning

A Discussion on Planning in the Presence of Human Users

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Abstract. AI planning forms a core capability of intelligent systems. It enables goal directed behavior and allows systems to react adequately and flexibly to the current situation. Further, it allows systems to provide advice to a human user on how to reach his or her goals. Though the process of finding a plan is, by itself, a hard computational problem, some new challenges arise when involving a human user into the process. Plans have to be generated in a certain way, so that the user can be included into the plan generation process in case he or she wishes to; the plans should be presented to the user in an adequate way to prevent confusion or even rejection; to improve the trust in the system, it needs to be able to explain its behavior or presented plans. Here, we discuss these challenges and give pointers on how to solve them.

1 Introduction

Automated planning provides a main capability of intelligent systems. It enables systems to adapt their behavior flexibly to their environment (and user); and to provide courses of action to a user who wants to achieve a goal. Such systems may assist in operating a modern mobile phone [10], or in the task of setting up a complex home entertainment system [5, 9, 15]. Whenever human users are involved, there arise several new challenges. In this paper, which is an extended abstract of the book chapter *User-Centered Planning* [7], we discuss some capabilities a system should have when planning for human users and how they can be realized using the hybrid planning approach.

We focus on some properties of hybrid planning and discuss them with respect to the given challenges of domain modeling, plan generation, plan execution (here especially the linearization and presentation of plans), and plan explanation.

2 Hybrid Planning

Hybrid planning is based on a function-free first-order logic [11]. It fuses Hierarchical Task Network (HTN) planning with concepts known from Partial-Order Causal-Link (POCL) planning. In hybrid planning, the goal of a planning task is specified in two orthogonal ways: as it is done in classical and in POCL planning, there is a goal description specifying all state features that must hold after the execution of a plan; as it is done in HTN planning, there is also an initial plan consisting of primitive and/or abstract tasks that needs to be refined into a solution.

For refining abstract tasks, the domain model contains a number of so-called decomposition methods, each mapping an abstract task to its "implementation" [11] – a plan that is a standard solution for that task. In contrast to most other hierarchical planning approaches, abstract tasks in hybrid planning have preconditions and effects. These allow to formally define legality criteria for plans that implement abstract tasks.

Plans in hybrid planning are partially ordered sets of primitive and abstract tasks. Causal dependencies between tasks are explicitly represented by so-called causal links – a concept borrowed from POCL planning. A solution to a hybrid planning problem is a plan that satisfies the goal description and that is a refinement of the initial plan meaning that it can be obtained from the initial plan by decomposing abstract tasks and by inserting variable constraints, ordering constraints, and causal links to ensure executability.

Domain Modeling. As every model, a planning domain has to represent facts that are important to the problem while abstracting from others. The modeling is a challenging task and it is quite important to provide assistance even at that early stage of planning.

The hierarchy of a planning problem provides an intuitive way to model planning problems. Knowledge about a specific application domain is often structured in a hierarchical manner, thus it is quite natural to model it as an hierarchical domain. Relying on the criteria when an abstract task is regarded an actual abstraction of a plan (or, the other way round: when a plan is regarded a valid implementation of an abstract task) [11], a domain modeler can be supported in the hierarchical domain modeling process – independently of whether the modeling is done in a top-down or a bottom-up approach. This is one advantage of hybrid planning over other planning approaches where there are basically no restrictions which decomposition methods may be specified for an abstract task.

The underlying hierarchy may in part even be inferred automatically given that the respective domain knowledge is represented using ontologies [4, 3].

A further practical benefit of using a hierarchical planning approach is its expressivity: by exploiting the hierarchical solution criterion, one can restrict the desired structure of solutions, which is why hierarchical planning approaches may be more expressive than classical non-hierarchical approaches [13, 1, 2]. Certain executable plans satisfying the goal description can be excluded from the set of allowed solutions. That way, one has more control on how solutions look like - which is an important feature when they have to be carried out by a human user.

Plans in hybrid planning include causal links that explicitly represent the causality between actions. This can be exploited in the modeling process by including such dependencies in plans used by decomposition methods. It can also be exploited to realize capabilities like plan explanation – as explained later on.

Plan Generation. Typically, the plan generation process works fully autonomously: a planning system uses some domain-independent heuristics [12, 6, 8] to find a good solution for the given problem quickly. In case only solution plans are presented to a user, and the user preferences can be adequately respected by the (fully autonomous) planning process, then the way how the planning process works is not important for the user.

However, sometimes the user needs or wants to be included into the process of generating a solution. Such a mixed initiative planning (MIP) approach benefits from a plan generation process that is intuitive to the user [16]. Since in hybrid planning also abstract tasks show preconditions and effects, it is possible to generate non-solution plans in which the abstract tasks in the plan are causally justified. This makes the plan more plausible as the causal link structure enables the presentation of causal dependencies that helps the user to understand (possibly non-solution) plans during the planning process. This is in particular useful in a MIP approach, where the planning system obtains feedback from the user on how to further refine the presented plan.

Plan Presentation. Solutions have to be processed. They may be executed automatically by a system (like a smartphone or an intelligent environment) or directly by a user. In the latter case, they have to be presented in an adequate way before a user can start to carry them out.

In hybrid planning, plans are only partially ordered; each induced total order is an executable solution to the problem. That way, hybrid planning solutions allow for a large flexibility with respect to the actual order in which the tasks are executed. Although all linearizations are valid solutions, some might be more plausible for a human user than others - some might even be considered confusing and rejected. Several of the hybrid planning features can be exploited to come up with good, user-friendly linearizations. One may rely on the constants used by tasks to determine the similarity between tasks, one may rely on the causal structure, or on the task hierarchy [14].

After a total order is chosen, tasks are presented step-by-step to the user. Here, the underlying predicate logic can be exploited to automatically generate a visualization of the respective task. For instance, the constants referenced by a task can be associated with pictures, videos, or text to illustrate what objects the respective action is manipulating. In the example domain of setting up complex home entertainment system [5, 9], interfaces can be generated that tell the user exactly which cable is to be plugged into which port of which device.

Plan Explanation. Even in cases where plans are adequately presented to a user, he or she might wonder why to execute a certain task. That is, the user might want to get a justification for a certain task in the solution. The user might also want to know about other parts of the plan, for instance why two actions are ordered in the way they are, or why a task requires to use/manipulate a specific object. Such questions can be answered by analyzing the generated plan and its generation process [18, 5]. Here the causal links make it more easy to explain decisions of the planning system. The hierarchy can be used in two ways, first it can be the justification for a certain task to be in the plan; second it can be exploited to generate shorter explanations by increasing its level of abstraction. Plan explanation based on causal dependencies can look like "That task is required because it establishes the precondition φ of the task X". The hierarchy provides explanations like "Task Y is required because it belongs to the task Z". Despite the hierarchy is considered to be expert knowledge and does not need to be justified further, we can provide more detailed (hierarchical) explanations if the respective decomposition method has been inferred from an ontology as mentioned earlier [4, 3]. Using so-called ontology explanations [17], a logical argument in form of a formal proof can be generated to explain *why* the task Y belongs to Z, which can be transformed into natural language text and provided to the user.

3 Conclusion

In this paper, we discussed some challenges when planning for human users and how the properties of hybrid planning can be exploited to solve them. We focused on a discussion with respect to the modeling of a domain, the plan generation process, the presentation of plans to a user, and the generation of explanations.

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