Integrating Planning and Scheduling in a CP Framework
A Transition-based Approach

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1 Motivation

Many potential real-world planning applications are on the border of planning and scheduling. Consider a group of robots (like NASA's Mars Rovers), that can maneuver over a designated area, perform soil tests, and can take pictures of interesting objects. There are many temporal and resource constraints that the robots have to satisfy while preforming any given set of tasks. For example, robots can only communicate via satellite within certain time-windows, some target objects are only visible within certain times, robots have limited battery power and batteries are solar powered, and each action (for example moving from one place to the other) requires a fixed amount of power etc. To achieve a set of goals (like testing soil of different locations and taking picture of different objects), the robots have to decide how to achieve those goals (planning choices) and also they need to achieve these goals without violating any temporal and resource constraints (scheduling choices). For any automated system, that is able to handle the complexity of this type of problems, it is essential to integrate planning and scheduling techniques.

2 Outline of the Research Project

This project aims to investigate techniques for integrating planning and scheduling in a constraint programming (CP) framework, to solve the class of planning problems which are on the border of planning and scheduling. There are two main parts of this research project:

Developing Compilation Techniques: This means putting a bound on a problem and converting the bounded problem into a CSP, such that each solution of the CSP represents a valid solution for the planning problem. There are two questions to be answered: what are the effective ways of bounding a planning problem? and how to adjust the initial bound intelligently if the initial encoding fails?

Solving the CSP: This involves finding an assignment that satisfies all causal, temporal and resource constraints. We would like to investigate ways to improve CSP solution techniques by integrating techniques from constraint-based scheduling and domain-independent planning. In other words we would like to customise CSP solution techniques for temporal and resource constrained planning problems. Mainly we aim to find good heuristics based on domain independent planning and constraint-based scheduling heuristics, and to investigate how to adopt constraint-based scheduling specific propagation techniques effectively for this kind of planning problems.

3 Our Approach and Progress

The main idea behind our approach is to compile a planning problem, represented in the multi-valued state variable representation (a.k.a SAS), into a CSP and to extract the final plan from the solution of the CSP. Here, each solution of the planning problem corresponds to building a contiguous path in each state variable's domain transition graph (DTG), such that all goals are achieved. To solve a planning problem efficiently as a constraint-based search problem, one needs to restrict the planning problem in some way. Planning problems, that are in between planning and scheduling, often need an action at most once in a solution. This observation leads us to believe that bounding a problem by the number of times each action can occur in the plan will create a CSP that more likely to have solution in the first instance. Based on this assumption, we have developed a **transition-based formulation** for multi-valued state variable planning problems[1].

Present: We are extending the transition-based formulation for temporal and resource constrained planning problems, which are similar to scheduling problems with alternative choices of resources. The aim of this phase is to develop search and heuristic techniques (for example slack-based heuristics and distance-based heuristics), and efficient temporal and resource constraint propagators for planning problems where goals have deadlines, actions have effects with variable durations, release dates, delayed effects and (unary) resource requirements, and each state variable's values can have time-windows specifying when it can be changed or achieved. We are extending the multi-valued state variable representation for representing the above mentioned features and developing benchmark problem instances for different planning and scheduling domains.

Future: Currently, we first compile a planning problem into a CSP encoding where each action can occur at most once. If the initial encoding fails, then we add one more copies of actions and search again. Since this is unlikely to be effective for any moderate size problem, we would like to investigate how can we add actions that are needed more than once on-the-fly during the search. We also want to extend the transition-based formulation to handle more complex resources, such as cumulative resources. If time permits, we wish to explore the possibility of guarantying optimality of some sort and as an orthogonal extension, how we can represent uncertainty in this setting.

4 Conclusion

Many potential planning applications lie between planning and scheduling. Based on recent advancements in domain-independent planning heuristics, constraint programming,and constraint-based scheduling, the proposed project aims to investigate how we can integrate planning and scheduling in a homogeneous way using the constraint-based framework.

[1]The details of the formulations for classical and temporal planning have been reported in ICAPS-DC 2008 and ICAPS 2009 (as a short paper) respectively.