Chapter II

A Framework for Hybrid and Analogical Planning

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ABSTRACT

This chapter describes a model and an underlying theoretical framework for hybrid planning. Modern planning domain description languages are based on sentential representations. Sentential formalisms produce problem encodings that often lead the system to carry out large amounts of superfluous operations, causing a loss in performance. This chapter illustrates how techniques from the area of knowledge representation and reasoning (in particular, analogical representations) can be adopted to develop more efficient domain description languages. Although often more efficient, analogical representations are generally less expressive than sentential ones. A framework for planning with hybrid representations is thus proposed, in which sentential and analogical descriptions can be integrated and used interchangeably, thereby overcoming the limitations and exploiting the advantages of both paradigms.

INTRODUCTION

“Planning” is the process of deciding which course of action to undertake in order to achieve a future state of affairs (goal) that does not hold in the present situation. Planning our daily activities, a trip, a political campaign or a military operation are just a few of the countless examples. We take a planning domain to be an abstract, simplified
description of the world, consisting of a set of possible world states and a set of possible actions for transforming a state into another one. A planning problem (or planning instance) is specified by providing a planning domain, an initial state and a goal. Solving a planning problem requires finding a sequence of actions (plan) that will (or is expected to) transform the initial state into one in which the given goal is achieved.

Clearly, an automatic system for the solution of planning problems must be able to internally represent states, actions and goals. In particular, in order to build an automated planning system, one must provide at least the following elements: (1) a syntax for representing world states, goals and actions; (2) a general algorithm \( \Theta \) for calculating the state description \( s' = \alpha(s) \) resulting from applying any action description \( \alpha \) to any given state description \( s \); and (3) a general algorithm \( \Gamma \) for deciding whether any goal description \( G \) holds (or is satisfied) in a given state description. Given these elements, an automatic system can use algorithm \( \Theta \) to interpret any of the action descriptions and apply them so as to transform the initial state representation into new ones, while algorithm \( \Gamma \) can be used to determine whether the assigned goal has been achieved.

In view of the above considerations, the representation adopted by an automated planner for modelling world states, goals and actions appears to be of crucial importance in determining the effectiveness and efficiency of the planning process. Although in the last decade the field of knowledge representation and reasoning has witnessed the birth of several new formalisms [among others, qualitative reasoning (Forbus, 1995; Forbus, Nielsen, & Faltings, 1987, 1991), semantic networks (Lehmann, 1992; Sowa, 1984), and diagrammatic representations (Glasgow, Narayanan & Chandrasekaran, 1995; Kulpa, 1994)], planning research has generally failed to assimilate and exploit such developments. In particular, the modelling languages for reasoning about action have remained, since their origins, purely sentential (i.e., textual, or based on predicate and propositional logic) (McCarthy & Hayes, 1969; Fikes & Nilsson, 1971; Pednault, 1989; McDermott, Knoblock, Veloso, Weld & Wilkins, 1998). Even the most recent version of PDDL, the de facto standard planning domain description language (Fox & Long, 2003) requires the domain modeller to describe all aspects of a problem (including spatial and topological relations) using only sets of propositions.

The rest of this introductory section argues that, although very expressive and flexible, sentential languages are often inefficient for describing and solving even simple planning problems. In particular, sentential planning representations tend to produce inefficient encodings of domains that involve the movement of a number of distinct objects subject to even simple spatial constraints. The remainder of the chapter is divided into two main parts: the first one, consisting of two sections, introduces analogical planning representations and illustrates, first with an example and then through the analysis of an actual implementation, how such formalisms can help overcome some of the shortcomings of sentential descriptions. The second part, entirely contained in one section, proposes a framework for hybrid planning, in which sentential and analogical descriptions are integrated. These two parts are linked by an intermediate section (“Characterising Analogical Models”) that provides some background on analogical formalisms and compares them to sentential ones. The two final sections discuss related work, advantages and limitations of the analogical and hybrid approach.
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