Chapter 1.9
Declarative Planning and Knowledge Representation in an Action Language

Thomas Eiter
Technische Universität Wien, Austria

Wolfgang Faber
Technische Universität Wien, Austria

Gerald Pfeifer
Technische Universität Wien, Austria

Axel Polleres
Leopold-Franzens-Universität Innsbruck, Austria

ABSTRACT

This chapter introduces planning and knowledge representation in the declarative action language K. Rooted in the area of Knowledge Representation & Reasoning, action languages like K allow the formalization of complex planning problems involving non-determinism and incomplete knowledge in a very flexible manner. By giving an overview of existing planning languages and comparing these against our language, we aim on further promoting the applicability and usefulness of high-level action languages in the area of planning. As opposed to previously existing languages for modeling actions and change, K adopts a logic programming view where fluents representing the epistemic state of an agent might be true, false or undefined in each state. We will show that this view of knowledge states can be fruitfully applied to several well-known planning domains from the literature as well as novel planning domains. Remarkably, K often allows to model problems more concisely than previous action languages. All the examples given can be tested in an available implementation, the DLV^K planning system.

INTRODUCTION

While most existing planning systems rely on "classical" planning languages like STRIPS (Fikes & Nilsson, 1971) and PDDL (Ghallab et al., 1998; Fox & Long, 2003), the last few years have seen the development of action languages which provide expressive and flexible tools for describing the relation between fluents and actions. Action languages have received considerable attention in the Knowledge Representation & Reasoning community and their formal properties (complexity, etc.) have been studied in depth. Less effort has been spent on how to use the constructs offered by these languages for problem solving.

In this chapter, we tackle this shortcoming and elaborate on knowledge representation & reasoning with action languages, which are significantly different from the strict operator-based frameworks of STRIPS and PDDL.

To that end, we present the planning language K (Eiter, Faber, Leone, Pfeifer & Polleres, 2004) via its realization in the DLV$^\mathcal{K}$ planning system (Eiter, Faber, Leone, Pfeifer & Polleres, 2003a), available at http://www.dbai.tuwien.ac.at/proj/dlv/K/. We discuss knowledge representation issues and provide both general guidelines for encoding action domains and detailed examples for illustration.

The language K significantly stands out from other action languages in that it offers proven concepts from logic programming to represent knowledge about the action domain. This includes the distinction between negation as failure (or default negation) and strong negation. In K, it is possible to reason about states of knowledge, in which a fluent might be true, false or unknown, and states of the world, in which a fluent is either true or false. In this way, we can deal with uncertainty in the planning world at a qualitative level, in which default and plausibility principles might come into play when reasoning about the current or next state of the world, the effects of actions, etcetera. This allows different approaches to planning, including traditional planning (with information and knowledge treated in a classical way) and planning with default assumptions or forgetting.

STATES, TRANSITIONS, AND PLANS

Intuitively, a *planning problem* consists of the following task: given an *initial state*, several *actions*, their *preconditions* and *effects*, find a sequence of actions (viz. a *plan*) to achieve a state in which a particular *goal* holds. In the following, we will describe and discuss these concepts in more detail.

Fluents and States

Fluents represent basic properties of the world, which can change over time. They are comparable to first-order predicates or propositional assertions. *States* are collections (usually sets) of fluents, each of which is associated with a truth-value.

We distinguish between so called *world states* and *knowledge states*: The current state of the world, with respect to a set of fluents $F = \{f_1, ..., f_n\}$, can be defined as a function $s : F \rightarrow \{true, false\}$, that is, a set of literals which contains either f or $\neg f$ for any $f \in F$. From an agent's point of view, states can also be seen as partial functions s', that is, consistent sets of fluent literals, where for a particular fluent $f \in F$ neither f nor $\neg f$ may hold. The state s' then only consists of the subset of s which is *known*; it is a *state of knowledge*.

Note that this view of the epistemic state of an agent differs from other approaches where incomplete knowledge states are defined as the set of all possible worlds an agent might be in (Son & Baral, 2001; Bonet & Geffner, 2000; Bertoli, Cimatti, Pistore & Traverso, 2001). Such sets of (compatible) world states are often referred to as *belief states*. Knowledge states as described

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