Efficient Reasoning About Action and Change in the Presence of Incomplete Information and Its Application in Planning

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Introduction. Many domains that we wish to model and reason about are subject to change due to the execution of actions. Representing and reasoning about dynamic domains play an important role in AI because they serve as a fundamental basis for many applications, including planning, diagnosis, and modelling. Research in the field focuses on the development of formalisms for reasoning about action and change (RAC). Such a formalism normally consists of two components: a representation language and a reasoning mechanism. It has been well known in the field that two criteria for the success of a formalism are its *expressiveness* and *efficiency*. The former means that the representation language is rich enough to describe complicated domains; the latter implies the reasoning mechanism is computationally efficient, making it possible to be implemented on a machine. Besides, in daily life, we have to face the absence of complete information and thus any formalism should take this matter into account.

Most of the existing work on RAC relies on the *possible world approach* [6]. The main weakness of this approach is its high complexity. It was proved in [1], in conformant setting, e.g., the problem of finding a (polynomial length) conformant plan using this approach is $\Sigma_2^{\mathbf{P}}$-complete. An alternative is the *approximation-based approach*, adopted by the authors in [4,7]. The main advantage of the approximation-based approach is its lower complexity in reasoning and planning tasks in comparison with the possible world approach as shown in [1]. The price that one has to pay when using an approximation is its incompleteness (w.r.t. the possible world approach). Another limitation of the existing approximations [7,4] is that they do not allow for domain constraints or just allow for a limited class of domain constraints. In a recent paper [10], it is shown that directly handling domain constraints in a planner can indeed improve its performance.

Planning is an important application of RAC. Basically, a planning problem is the problem of finding a structure of actions, called *plan*, that leads to the goal from the initial state. In the absence of complete information, a plan normally exists in two forms: *conformant plan* and *contingent plan*. The former is simply a sequence of actions that leads to the goal from any possible initial state, while the latter is a more sophisticated structure (see [5]). Most of the existing conformant/contingent planners are written in imperative programming languages and their representation languages are somewhat limited – they either do not allow for state constraints or just allow for a limited class of state constraints. There

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has been a very limited effort [2,8] in adding preferences of a plan to planning systems and none of them deals with incomplete information.

Goal of the Research. This research is aimed at developing approximations for action theories in the presence of incomplete information and domain constraints, and building a family of conditional and conformant planners based on the proposed aprpoximations, taking into account preferences and domain knowledge. The approximations may be incomplete but are expected to be strong enough to solve most of the benchmarks in the literature. Logic programming is chosen for the development of planners because of its declarativeness and expressiveness, making it easy to add modules for handling user preferences and exploiting the knowledge of the domain.

Current Results. In [9], we study the completeness of the 0-approximation [7] for action theories with incomplete information and propose a sufficient condition for which an action theory under the 0-approximation semantics is complete. We then suggest a method to modify an action theory in such a way that the modified theory under the 0-approximation is complete with the original theory. This method was implemented in a conformant planner. The planner is sound and complete and our experimental results show that its performance can be competitive with other state-of-the-art conformant planners.

Ongoing and Future Work. The framework in [9], however, is only for action theories without domain constraints. At present, I have an initial proposal for approximations of action theories with domain constraints but there are still open issues: are they strong enough? under what circumstances are they complete? can we modify them so as to be complete? In addition, I am investigating the use of constraint logic programming and constraint handling rules [3] to implement the planners.

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