Complexity Results in Epistemic Planning

Paper Summary [1]

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The primary focus of AI is the development of rational, autonomous agents. In the field of automated planning, these agents should exhibit goal-directed behavior. In Automated planning, there is a planning task that consists of initial state, the finite set of actions and the goal formula. The aim is to compute a plan that is a sequence of actions which leads to goal formula starting from the initial state. In this planning, the domain models employed are formulated using propositional logic. However, when we reach more complex settings such as multi-agent domains, such models come up short due to the limited expressive power of propositional logic. To overcome this limitation, the Epistemic Planning is being used. Epistemic Planning is where agents can reason about their own and other agents' beliefs as part of the planning process. For example, in games with strong epistemic components would be what will the other agents know if I choose to announce that I have this card? or in robotics "Fetch a cup of tea, the leafs are in the cupboard". This paper [1] establishes a framework for epistemic planning based on Dynamic Epistemic Logic (DEL). From classical planning to epistemic planning, the propositional logic replaces by DEL.

	Classical planning	Epistemic planning
States	models of prop. logic	models of MA epist. logic
Goal formula	formula of prop. logic	formula of MA epist. logic
Actions	induced by action schemas	action models of DEL

Epistemic planning task is the planning task in epistemic planning and Planing existence for a class of epistemic planning tasks X: "Given a planning task in X, does there exist a plan for it?". In this paper complexity results for the plan existence problem for various classes of epistemic planning tasks.

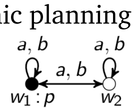

Figure 1: Initial State

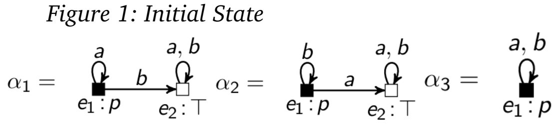

Figure 2: Actions

For example, we can consider the epistemic planning tasks with initial state (Figure 1) and actions (Figure 2). α_1 privately announcing p to a, α_2: privately announcing p to b; α_3: publicly announcing p to both agents. The Goal formula is defined as:

$$K_a P \wedge K_b p \wedge \neg K_a K_b p \wedge \neg K_b K_a p \tag{1}$$

A plan for this task is α_1, α_2. Another plan is α_2, α_1. Also, α_1, α_2, α_1 and α_1, α_1, α_2 are plans, etc. Actions are graphs. Different graph structures allow different actions to be formed. We study how the underlying graph structure impact complexity of plan existence. Summary of complexity results for plan existence. Summary of complexity results for plan existence (Table 1) [2]

Underlying graphs of actions	Types of epistemic actions: Non-factual, propositional preconditions	Factual, propositional preconditions	Factual, epistemic preconditions
Singletons	NP-complete (Theorem 5.1)	PSPACE-hard [Jensen, 2014]	PSPACE-hard [Jensen, 2014]
Chains	NP-complete (Theorem 5.2)	? (open question)	? (open question)
Trees	PSPACE-complete (Theorem 5.3, Theorem 5.4)	? (open question)	? (open question)
Graphs	in EXPSPACE (Theorem 5.8)	in NON-ELEMENTARY [Yu *et al.*, 2013]	Undecidable [Bolander and Andersen, 2011]

Table 1: Complexity results for the plan existence problem.

There are reasons to study the complexity of very restrictive of epistemic planning are this is relevant to many interesting applications, and to understand where does the complexity come from and constructing search heuristics for planning engines (relaxed problems)

Since propositional STRIPS planning is PSPACE-complete, efficient planning systems have used relaxed planning tasks to compute precise heuristics efficiently. For instance, the highly influential Fast-Forward planning system relaxes planning tasks by ignoring delete lists. This paper contribution here show restrictions on the graphs underlying epistemic actions crucially affect computational complexity. This, in the combination with restrictions on preconditions and postconditions (factual change), provides a platform for investigating (tractable) relaxations of epistemic planning tasks, and hence for the development of efficient epistemic planning systems.

References

[1] G. Aucher, B. Maubert, and S. Pinchinat. Automata Techniques for Epistemic Protocol Synthesis. *ArXiv e-prints*, April 2014.

[2] Thomas Bolander and Mikkel Birkegaard Andersen. Epistemic planning for single- and multi-agent systems. *Journal of Applied Non-Classical Logics*, 21(1):9–34, 2011.