An Improved Multi-agent Epistemic Planner via Higher-Order Belief Change Based on Heuristic Search

Zhongbin Wu(✉)

Department of Computer Science, Sun Yat-sen University, Guangzhou 510006, China
wuzhb3@mail2.sysu.edu.cn

Abstract. Recently, multi-agent epistemic planning has drawn attention from both dynamic logic and planning communities. Existing implementations are based on compilation into classical planning, which suffers from limitations such as incapability to handle disjunctive beliefs, or higher-order belief change and forward state space search, as exploited by the planner MEPK. However, MEPK does not scale well. In this paper, we propose two improvements for MEPK. Firstly, we exploit another normal form for multi-agent KD45, which is more space efficient than the normal form used by MEPK, and propose efficient reasoning, revision, and update algorithms for it. Secondly, we propose a heuristic function for multi-agent epistemic planning, and apply heuristic search algorithm AO* with cycle checking and two heuristic pruning strategies. We implement a multi-agent epistemic planner called MEPL. Our experimental results show that MEPL outperforms MEPK in most planning instances, and solves a number of instances which MEPK cannot solve.

Keywords: Modal logic · Multi-agent epistemic planning
Heuristic search

1 Introduction

Many intelligent tasks involve the collaboration and communication among multiple agents, raising the need of reasoning about knowledge and beliefs, and their change. For example, reasoning is performed before taking an action to check whether its precondition has been satisfied. Belief change is incurred because the performance of actions may change not only the environment but also the beliefs of agents. Reasoning and progression about higher-order knowledge and beliefs are also needed in some cases. For example, an agent may wish that she knows some information and the other agents know that she knows the information.

In recent years, multi-agent epistemic planning has drawn great attention from both dynamic logic and planning communities. On the theory side, Bolander and Andersen [1] formalized multi-agent epistemic planning based on dynamic epistemic logic [2] and showed that it is undecidable in general. On the implementation side, both Kominis and Geffner [3], and Muise *et al.* [4]

W. Liu et al. (Eds.): KSEM 2018, LNAI 11062, pp. 102–116, 2018.
https://doi.org/10.1007/978-3-319-99247-1_10

the domain, and the 2nd-4th columns indicate the number of agents, the number of sensing actions and deterministic actions, and the modal depth, respectively. In the last two columns, $A-B(X/Y)$ denotes A seconds of total time, B seconds of search time, X depth of the solution tree, and Y nodes explored during search. N/A denotes that the instance is unsolvable within the allotted time (1000 s).

The experimental results show that our planner outperforms MEPK in three aspects. Firstly, from the aspect of the total time, MEPL performs much better than MEPK for most instances, especially when the size of the instances grows. Also, MEPL can solve some instances that MEPK cannot within the allocated time. It's reasonable due to the more space efficient normal forms and the more efficient reasoning and progression algorithm. Secondly, for all instances, the number of nodes explored by MEPL is less than that explored by MEPK, which shows the viability of our heuristic function and pruning strategies. Finally, the preprocessing of MEPL is much faster than that of MEPK in a way that MEPL can complete the preprocessing within 1 s while MEPK may take more than 100 s in some domains like SC. It's reasonable too since MEPL doesn't need to transform a random formula into an ACDF. In conclusion, MEPL outperforms MEPK in most instances, and solves some instances that MEPK cannot solve, which means that MEPL can handle larger instances, i.e., scales better.

6 Conclusions

In this paper, we have proposed two improvements, which are based on higher-order belief change and heuristic search, for the multi-agent epistemic planner MEPK. Firstly, we exploited alternating disjunctive normal form (ADNF) for multi-agent KD45, which is more space efficient than the normal form used by MEPK and also saves time in compilation, and proposed efficient reasoning, revision, and update algorithms for it. Secondly, we proposed a heuristic function for multi-agent epistemic planning based on the distance between ADNFs, and as the planning algorithm, we applied heuristic research AO* with cycle checking and two heuristic pruning strategies. We have implemented a multi-agent epistemic planner MEPL, which outperformed MEPK in most planning instances, and solved a number of instances that MEPK cannot solve. Like MEPK, MEPL can handle propositional common knowledge, called constraints. Nonetheless, MEPL does not handle complex constraints well. In the future, we are interested in overcoming this limitation and further dealing with general common knowledge.

Acknowledgement. We acknowledge support from the Natural Science Foundation of China under Grant Nos. 61572535.