Research Review

Vishnuprakash Puthiya Kovilakath

July 23, 2017

1 Abstract

This paper surveys on some of the interesting developments in the field of artificial intelligence planning and search.

2 Problem definition languages

For every problem, a formal way to represent it clearly helps to boost the research specific to that area. Fikes and Nilsson came up with a formal language, STRIPS [Fikes and Nilsson1971] *Stanford Research Institute Problem Solver*, consisting of a set of operations, a set of conditions, a start state and a goal state under a closed world assumption (Every literal which is not mentioned is by default false). Pednault developed *Action Description Language* [Pednault1989] aka ADL added negative literals in the states, disjunctive goals and also formulated the problems in open world assumption (All unmentioned literals will have undefined truth values). A standard language for planning problems, PDDL *Planning Domain Definition Language* [Ghallab et al.1998] has been developed by Ghallab is generally treated as the standard language for planning problems as it is very rich in semantics. It adds object hierarchies, domains and requirements, conditional effects, continuous actions, constants and fluents to the scope.

3 Monte-Carlo search and planning

In [Silver and Veness2010], David Silver and Joel Veness introduces Monte-Carlo algorithm for online planning in large Partially Observable Markov Decision Process (POMDP). This algorithm combines Monte-Carlo update of agents belief state with a Monte-Carlo tree search from current state. The algorithm POMCP *(Parially Observable Monte-Carlo Planning)* uses Monte-Carlo sampling to improve

the performance of the algorithm during planning. This algorithm requires only a black box simulator than explicit probability distribution.

4 Partially ordered plans

Another idea was to add partially ordered plan than to operate directly on state space as mentioned in [Russell and Norvig2009]. Systems like *Systematic Non-linear Planner (SNLP)* [McAllester and Rosenblitt1991] and NONLIN [Tate1976] are built to search on partially specified plans and only partial constraints on action arguments and ordering decisions are maintained. Here, actions can be combined to smaller plans so that it can be reasoned much more efficient way. Partial ordering of the sub plans helps to execute them in parallel. This is similar to the idea of decomposing the search space in to easily solvable parts and solve them individually in parallel may be by employing something similar to a pattern databases. RePOP by Nguyen [Nguyen and Kambhampati2001] introduced domain independent heuristics in to SNLP like algorithms. Some of these heuristics are computed from planning graphs [Blum and Furst1995]. Gerevini's LPG [Gerevini and Serina2002] which uses partially ordered representations for planning won the 2002 International Planning Competition. LPG is a planner based on local search of planning graphs. LPG consists of *action graphs* , particular subgraphs of the planning graph representing partial plans which acts as the search space. Whereas search steps involve transformation of action graph to another one.

References

[Blum and Furst1995] Blum, A. and Furst, M. L. (1995). Fast planning through planning graph analysis. In *IJCAI*, pages 1636–1642.

[Fikes and Nilsson1971] Fikes, R. E. and Nilsson, N. J. (1971). Strips: A new approach to the application of theorem proving to problem solving. *Artificial Intelligence*, 2:189.

[Gerevini and Serina2002] Gerevini, A. and Serina, I. (2002). Lpg: A planner based on local search for planning graphs with action costs. In *AIPS*, pages 13–22. AAAI.

[Ghallab et al.1998] Ghallab, M., Howe, A., Knoblock, C., Mcdermott, D., Ram, A., Veloso, M., Weld, D., and Wilkins, D. (1998). PDDL - The Planning Domain Definition Language.

[McAllester and Rosenblitt1991] McAllester, D. and Rosenblitt, D. (1991). Systematic nonlinear planning. In *Proc. 9th National Conference on Artificial Intelligence*, pages 634–639.

[Nguyen and Kambhampati2001] Nguyen, X. and Kambhampati, S. (2001). Reviving partial order planning. In *Proceedings of the 17th International Joint Conference on Artificial Intelligence - Volume 1*, IJCAI'01, pages 459–464, San Francisco, CA, USA. Morgan Kaufmann Publishers Inc.

[Pednault1989] Pednault, E. P. D. (1989). ADL: Exploring the middle ground between STRIPS and the situation calculus. In *Proc. First International Conf. on Principles of Knowledge Representation and Reasoning*, pages 324–332.

[Russell and Norvig2009] Russell, S. J. and Norvig, P. (2009). *Artificial intelligence: a modern approach (3rd edition)*. Pearson.

[Silver and Veness2010] Silver, D. and Veness, J. (2010). Monte-carlo planning in large pomdps. In Lafferty, J. D., Williams, C. K. I., Shawe-Taylor, J., Zemel, R. S., and Culotta, A., editors, *Advances in Neural Information Processing Systems 23*, pages 2164–2172. Curran Associates, Inc.

[Tate1976] Tate, A. (1976). Project planning using a hierarchic non-linear planner. *D.A.I. Research Report No. 25, Department of Artificial Intelligence, University of Edinburgh*.