UDACITY – Artificial Intelligence Nanodegree

Project 3 – Research Review

Important Historical Developments in the field of AI Planning and Search

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In 1971, scientists of the Stanford Research Institute proposed "a new problem-solving program called **STRIPS** (**ST**anford **R**esearch **I**nstitute **P**roblem **S**olver)"(R. E. Fikes, N. J. Nilsson)[1]. STRIPS uses a concept called "world model", which uses a set of first-order predicates and operators to describe and solve planning problems. Given an initial world model and a goal formula, STRIPS tries to find in a problem space a sequence of operators that transforms the initial model in a model on which the goal formula is satisfied, and it uses a combination of search and theorem proving to achieve that. Each operator has preconditions, corresponding to a state where the operator is applicable, and a description of its effects, corresponding to the resulting state after the operator is applied to the previous state. Unlike simpler problem solver systems, which searches for a sequence of operators through a search tree, that might be quite large, making the problem solving impractical, STRIPS uses a strategy of compute "differences" between the current world model and the goal and trying to find operators that reduces these differences until reaches the goal state. First, it applies a theorem prover to the initial model to verify if it satisfies the goal. If positive, the problem is solved. If negative, it computes the "difference" between the uncompleted proof and the goal, sets up a subgoal and tries to find operators that satisfied it, "reducing" the "difference" to the goal. This process continues until the goal is satisfied, thus, solving the problem.

A new approach to planning in STRIPS domains like that was introduced in 1997 by scientists of the Carnegie Mellon University, consisting of constructing and analyzing a structure they called "Planning Graph", which resulted in a new planner: Graphplan [2]. This new planner always returns the shortest possible valid plan or states that such plan doesn't exist. The "Planning Graph Analysis" paradigm consisted of build (in polynomial time) a graph, where nodes can correspond to *propositions* or *actions* and edges can correspond to *preconditions, add-effects* or *delete-effects*. The problem is divided into levels and time steps, with each time step consisting in a proposition level followed by an action level. The action nodes in level *i* are connected to preposition nodes on level *i* by "precondition-edges" and to proposition nodes in level *i+1* by "add-edges" and "del-edges". An important part in the planning graph analysis are the "mutual exclusion relations" among the nodes, that consists in relationships between pair of nodes where if a valid plan exists, it can not contain a condition where both are true. Examples of these exclusion relations are "Interference", where an action deletes a precondition or add-effect of the other, and "Competing Needs", where preconditions of a pair of actions are mutually exclusive in the previous proposition level. The Graphplan algorithm works by verifying on each time step if the goal is satisfied, stopping in case a valid plan is found or continuing to the next step until finds a valid plan or proving (in a finite time) that a valid plan doesn't exist. Experimental results demonstrated considerable improvements over previous planning approaches.

In 1998, the specification of the "Planning Domain Definition Language" (PDDL)[3], which expands many of the STRIPS representations, was defined by a committee of the "AIPS-98 Planning Competition" and a manual was produced with standards for Syntactic Notation, Domains and Actions definitions, Effects and Goals Descriptions, Action Expansions, Axioms and Safety Constraints. The main purpose of PDDL, according to the committee, was to "encourage sharing of problems and algorithms, as well as to allow meaningful comparison of the performance of planners on different problems", and as "a notation for problems to be used in the AIPS-98 planning contest".

These developments (and others) on planning techniques improved the efficiency of problem solvers, making possible to find solutions to more complex planning problems with reduced execution time. The combination of these with other AI techniques can give a great contribution to the field as a whole. As an example, M. Grounds and D. Sudenko [4], proposed a new reinforcement learning method called PLANQ-learning, combining a Q-learner with a STRIPS planner.

References

[1] Richard E. Fikes and Nils J. Nilsson - Stanford Research Institute. *STRIPS: A New Approach to the Application of Theorem Proving to Problem Solving.* North-Holland Publishing Company, 1971. Presented at the 2nd IJCAI, 1971

[2] Avrim L. Blum and Merrick L. Furst - School of Computer Science, Carnegie Mellon University. *Fast Planning Through Graph Analysis*. Final Version in Artificial Intelligence, 1997

[3] Malik Ghallab, et al. - AIPS-98 Planning Competition Committee. *PDDL – The Planning Domain Definition Language, Version 1.2*. AIPS-98 Planning Competition, 1998

[4] Mathew Grounds and Daniel Kudenko - Department of Computer Science, University of York. Combining Reinforcement Learning with Symbolic Planning