Research Review

Over the last 50 years, AI has experienced numerous breakthroughs across the entire discipline. Planning and search methods especially have experienced a rapid evolution of ideas, each building on the last and encouraged by a cooperative research community. This paper aims to summarize Three of these breakthroughs, each of which built on the last.

The STRIPS Domain and linear planning

In 1971, Stanford researchers Richard E. Fikes and Nils J. Nilsson build the Stanford Research Institute Problem Solver (STRIPS). The STRIPS problem solver was built in conjunction with the university's robotics team and aimed to use "well formed formulas" (wffs) in first-order predicate calculus to solve problems involving robotic tasks and movement [1]. The STRIPS system was built to solve a different class of problem from game-playing agents developed before that time, and the researchers were careful to define the type of problem and a syntax to describe it: [1]

1. *An initial World model which is a set of wffs describing the present state of the world*
2. *A set of operators including a description of their effects and their precondition wff schemata*
3. *A goal condition state as a wff*

Once solved, STRIPS produces a world model that satisfies the goal condition. The STRIPS machine carried out this task with an adopted General Problem Solver (GPS) strategy. The strategy extracted differences between the present and goal state and applied operators that would reduce the differences [1].

The STRIPS research was built on a PDP-10 mainframe computer which was common in universities at the time. This likely made the solver results easy to reproduce and measure against. Additionally, the clear syntax which the paper defined for states and actions established a language which the AI community could use to communicate problems in this domain. This likely led the "STRIPS problem domain" to be so named.

Non-linear Planning

Over the next 20 years, several researchers studied the STRIPS domain. In 1985, John Canny noted that the STRIPS problem domain is PSPACE complete, and therefore sound and complete planners hoping to conquer the space should incorporate search [2].

In 1991, MIT researchers McAllester and Rosenblitt presented a search alternative to STRIPS' linear GPS method of solving STRIPS problems [3]. While linear planning tries to satisfy goals one at a time, their algorithm chooses a goal from the goal set and an operator which will satisfy that goal when performed, and adds the preconditions of that operation to the goal state until the goal set matches the initial state. This algorithm, known as NonLinear planning, became the state of the art algorithm for solving STRIPS problems.

GraphPlanning

In 1997, Carnegie Mellon researchers Avrim L. Blum and Merrick L. Furst presented their method of solving STRIPS domain problems which built on non-linear planning [4]. The algorithm uses a novel structure called a Planning Graph to quickly create a tree of the possible state manipulations in the problem space. The most important development is that "If a valid plan exists using t or fewer time steps, then that plan exists as a subgraph of the Planning Graph.[4]" Therefore, one only needs to search for this subgraph to solve the problem. The Planning Graph quickly expands all possible actions and states which could be reached from the initial state as if all actions are performed in parallel. However, actions and states are marked by "mutex" relationships when both could not occur at the same time. Once the goal state exists without mutexes present among its conditions, then a solution exists.

Blum and Furst compared their GraphPlan algorithm to other state-of-the-art non-linear and partial-order planners, UCPOP and Prodigy. The algorithm performed extremely well, especially on large problem sizes.

In their conclusion, the researchers noted that the largest drawback of their Graphplan Algorithm is that it is limited to STRIPS domain problems. "In particular, actions cannot create new objects and the effect of performing an action must be something that can be determined statically." Future work like Koehler's 1997 IPP project attempt to expand Graphplan outside of the STRIPS domain. But those domains will have to wait for another summary.

Citations

[1] Richard E. Fikes, Nils J. Nilsson. 1971. *STRIPS: A New Approach to the Application of .Theorem Proving to Problem. Solving*, IJCAI '71 Proceedings of the 2nd international joint conference on Artificial intelligence. Pages 608-620. http://ai.stanford.edu/~nilsson/OnlinePubs-Nils/PublishedPapers/strips.pdf

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[3] David McAllester, David Rosenblitt. 1991. *Systematic Nonlinear Planning.* AAAI-91 Proceedings. Pages 634-639. http://www.aaai.org/Papers/AAAI/1991/AAAI91-099.pdf

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