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AI Planning and Search Review

Planning research has played an integral role in the evolution of the AI field since the early days. Significant developments in planning and search include:

STRIPS

The first major planning system, STRIPS (Stanford Research Institute Problem Solver), is an automated planner developed by Richard Fikes and Nils Nilsson in 1971 at SRI International.

STRIPS uses the GPS[1] search strategy of “attempting to apply operators that are relevant to reducing a difference between a world model and a goal or subgoal”[2]. In 1994, Tom Bylander showed that “propositional STRIPS planning is PSPACE-complete in general and for many restrictive problems”[3].

It's important to note that the representation language used by STRIPS has been remarkably influential[4] and has served as the basis for many action languages known today, such as PDDL (The Problem Domain Description Language)[5].

GRAPHPLAN

Developed by Avrim Blum and Merrick Furst in the mid-1990s, Graphplan is a planning algorithm that takes an input represented in STRIPS and yields a sequence of operations required to reach a goal, if at all possible.

> “Given a problem statement, Graphplan explicitly constructs and annotates a compact structure called a Planning Graph, in which a plan is a kind of "flow" of truth-values through the graph. This graph has the property that useful information for constraining search can quickly be propagated through the graph as it is being built.”[6]

The slow speeds and high computational costs of partial-order planners[7] being used at the time fueled the urge to finding more efficient strategies. The introduction of a *graph* to reduce the size of the search was quite novel, and the efficiency of this new approach for solving classical planning problems proved undeniable.

SATPLAN

Around the same time Graphplan was proven highly successful, Boolean Satisfiability (SAT) algorithms such as GSAT and WalkSat were also working well in certain contexts.[8]

Satplan emerged as a method of automated planning that converts planning problems into Boolean Satisfiability problems.

> "Given a problem instance in planning, with a given initial state, a given set of actions, a goal, and a horizon length, a formula is generated so that the formula is satisfiable if and only if there is a plan with the given horizon length."[9]

Automated planning has a 40-year history of research and discoveries. Today, the most popular and effective strategies are based on planning graphs, translation to Boolean Satisfiability problems and forward state-space search with carefully crafted heuristics.[10]

References

[1] GPS - *General Problem Solver* (Newell and Simon, 1961).

[2] Richard E. Fikes, Nils J. Nilsson (1971). "*STRIPS: A New Approach to the Application of Theorem Proving to Problem Solving*". Artificial Intelligence. 2 (3–4): pp. 189–208.

[3] Tom Bylander (1994). "*The Computational Complexity of Propositional STRIPS Planning*". Artificial Intelligence. 69 (1–2): pp. 165–204.

[4] Stuart J. Russell, Peter Norvig (2010), Artificial Intelligence: A Modern Approach (3rd edition): p. 393.

[5] Ghallab *et al.*, 1998.

[6] School of Computer Science, Carnegie Mellon University website: *Avrim Blum's Graphplan webpage.*

[7] *Partial-order planning* dominated planning research from mid-1970s to the mid-1990s.

[8] MIT OCW Lectures: *Techniques in Artificial Intelligence (SMA 5504) - Lecture13.*

[9] Wikipedia Page: *Satplan.*

[10] Same as [4]: p. 387.

Additional Resources

* A. Blum and M. Furst, "*Fast Planning Through Planning Graph Analysis*", Artificial Intelligence, 90: pp. 281-300 (1997).

*** Photo: Sven Wahlstrom and Nils Nilsson with Shakey. SRI International, 1970.*