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Recent Advances in AI Planning[1]

A Summary

The author reports in some detail on recent (as of 1999) advances in AI planning. In particular, he focuses on three areas of development: the GRAPHPLAN planning algorithm, SAT compilation, and interleaved planning and execution.

GRAPHPLAN is a planning algorithm, first revealed in 1995, that can generate a plan for a system to transition from an initial state to a goal state through a sequence of actions. GRAPHPLAN had a significant impact on the AI planning community. First, it was capable of generating a plan at speeds that were orders of magnitude higher than previous systems (and therefore capable of solving problems that were orders of magnitude harder). Second, it became the basis for further research into AI planning[2]. Many researchers used GRAPHPLAN as a starting point to create their own planning systems that introduced, refined and optimized planning concepts. Examples include IPP (implementing universal quantification and conditional effects), STAN (performs sophisticated type analysis), and SGP (handles universal quantification, conditional effects, and uncertainty)[3] and are covered in more detail.

"SAT" is an abbreviation for the propositional satisfiability problem, which is the problem of determining whether a given Boolean formula can be satisfied by an appropriate assignment of the individual Boolean variables in the formula. The "compilation of planning to SAT" is the conversion of a planning problem into such a Boolean formula, which can then be tested for satisfiability. SAT-based planning systems introduced in the late 1990s include BLACKBOX and MEDIC[4]. They demonstrated advances in the ability to compile (convert) planning problems to SAT problems. Other contemporaneous systems demonstrated numerous improvements in SAT solvers, which determine the satisfiability of the formula output by the compiler. As a result of these research efforts, SAT-based planning systems were brought into competition with GRAPHPLAN-based systems on speed[5].

The author then proceeds to detail advances in interleaved planning and execution monitoring by describing the Remote Agent software used in the NASA deep space probe *Deep Space 1*, launched in 1998. This in itself is sufficient to relay the impact on AI research – it demonstrated that planning systems were reaching a sufficient level of maturity, and their potential utility, to be deployed as a critical component of a NASA mission. The Remote Agent software included a "partially SAT-based reactive control system" executing fault protection and configuration management functions[6]. An execution monitor reads the onboard sensors to determine the current physical state of the spacecraft. Then a goal interpreter determines the goal states that are reachable from that current state. Finally the incremental replanner calculates the first action of a plan to reach those goal states[7]. Planning systems are typically envisioned with the entire plan being determined before execution, but this high profile use case demonstrated the ability of planning systems to be implemented for real time, ongoing execution.

The author concludes with additional notes on advancements in the search aspect of planning, "causal link planning", and handling uncertainty.

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[1] "Recent Advances in AI Planning" Daniel S. Weld, AI Magazine 20 (1999) 93-123, https://www.aaai.org/ojs/index.php/aimagazine/article/viewFile/1459/1358

[2] Ibid., p. 95

[3] Ibid., Fig. 1, p. 94
[4] Ibid., Fig. 1, p. 94
[5] Ibid., p. 106
[6] Ibid., p. 114
[7] Ibid., p. 115