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Nonlinear Planning in Artificial Intelligence

Early planning systems were limited to solving problems in specifically ordered sequences that resulted in a single plan. They were rigid systems that could be overwhelmed by simple problems that required a nonlinear solution, such as the Sussman block-stacking anomaly (Russell and Norvig, 2009). This review examines three developments in artificial intelligence planning systems that made complex problem-solving possible.

NOAH and Partial-Order Planning

NOAH was one of the first attempts at creating a nonlinear planning system. Developed in 1975, it introduced partial-order planning, which breaks problems into a collection of simplified plans that are treated as independent operations (Sacerdoti, 1975). The main idea behind plan-space planning the *least commitment principle*, in which a plan is refined over time through the application of constraints, such as preconditions, to avoid or eliminate conflicts (Ghallab, Nau, and Traverso, 2004). Partial-order planning allows for actions to be executed in parallel and are generally considered more efficient than total-order planners (Veloso, 2001).

One of the major limitations of this system is that it is incapable of backtracking to undo mistakes. NONLIN was built upon a similar framework as NOAH, but tracked decisions, thus allowing it to try a different path upon reaching a fail state (Tate, 1977).

Heuristic Search Planning (HSP)

State-based models, such as STRIPS, were some of the first planning systems, but were largely overlooked following the introduction of partial-order planning. They were revisited in the 1990s with the creation of UnPOP and Heuristic Search Planning (Russell and Norvig, 2009). Using heuristics to guide state-space searches makes it possible to quickly solve large-scale problems that would be too challenging for uninformed planners (Ghallab, Nau, and Traverso, 2004).

Heuristic search planners also excel as general problem-solvers. In many instances, the same heuristic search can be applied to a variety of problems, whereas other problem solvers usually need to be specialized for specific tasks (Bonet and Geffner, 2000).

GRAPHPLAN

GRAPHPLAN expands upon partial-order planning and state-space planning through the introduction of the planning graph. The planning graph recreates problems as a tree of all possible actions, effects, constraints, and conflicts, which reduces the amount of searching required to find a solution (Blum and Furst, 2000). This makes planning graph searches significantly faster than earlier plan-space or state-space search techniques.

Another advantage to GRAPHPLAN is that the structure is easily modified or expanded, which makes it desirable for planning research (Ghallab, Nau, and Taverso, 2004).

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