Project 3:

AI Planning Research Review

INTRODUCTION

Every day millions of packages are shipped around the world, but people often don't give much thought to the planning that makes this possible. Perhaps we just take it for granted. But, somehow, logistics companies such as UPS and DHL can deliver packages anywhere in the world in a time- and cost-effective manner. So how do they do it? They do it using specialized planning software, like the agent we used to address the Air Cargo problem throughout Project 3. Although real-world logistics are much more complex than our Air Cargo problem, they're both good examples of problems we can now solve thanks to the progress made in the field of AI planning over the past 60 years.

IMPORTANT MILESTONES

There have been many milestones during this period, but I'd like to single-out three:

1. The General Problem Solver (1959) — The concept of heuristics is introduced in problem solving and AI planning.
2. STRIPS (1966) — The seminal framework for solving classical planning problems, which inspired frameworks still in use today.
3. Planning Graphs (1995) — The Graphplan algorithm ushers in new era of AI planning approaches based on graphs.

GENERAL PROBLEM SOLVER (1959)

The General Problem Solver (GPS) was a program created by Herbert A. Simon, J.C. Shaw, and Allen Newell. It was the first computer program that separated the knowledge about a problem from the strategy of how to solve it. [1] They later went on to publish the book *Human Problem Solving*, which outlined many foundational AI planning concepts and components, such as: [2]

- the problem space consists of the initial (current) state, the goal state, and all possible states in between,
- operators are actions taken to move from one state to another,
- problem spaces grow exponentially, so it's critical to find time- and memory-efficient ways to traverse them,
- and operator selection is guided by cognitive short-cuts, known as **heuristics**

The introduction of heuristics is particularly important to the history of AI and will later go on to play a major role in improving the performance of planning algorithms. Here is how Simon, Shaw, and Newell explain the role of heuristics: [3]

> "Many kinds of information can aid in solving problems: information may suggest the order in which possible solutions should be examined; it may rule out a whole class of solutions previously thought possible; it may provide a cheap test to distinguish likely from unlikely possibilities; and so on. All these kinds of information are <u>heuristics</u> — things that aid in discovery. Heuristics seldom provide infallible guidance; they give practical knowledge, possessing only empirical validity. Often they "work," but the results are variable and success is seldom guaranteed."

<u>STRIPS (1971)</u>

Building on components of GPS (specifically, means-end analysis), Richard Fikes and Nils Nilsson developed the first major planning system, STRIPS (Stanford Research Institute Problem Solver). [4] STRIPS was the planning component for the software used to run Shakey The Robot, the first general-purpose mobile robot capable of reasoning about its own actions. [5]

The representation language used by STRIPS was influential in the development of future languages such as Action Description Language (ADL) and Problem Domain Description Language (PDDL). PDDL is a standardized syntax that carefully balances the expressiveness of the language with the complexity of the algorithms that operate on it, and has been the *lingua franca* for the International Planning Competition over the past 20 years. [6]

<u>PLANNING GRAPHS (1995 - 2001)</u>

For many years, the performance of planning agents prevented them from being used in real-world applications. That changed after a series of breakthroughs using planning graphs: GraphPlan in 1995, Heuristic Search Planning (HSP) in 1998, and Fast Forward (FF) planning in 2001. [7]

Prior to 1995, research on AI planning had concentrated on partial-order planning algorithms. With the introduction of GraphPlan, algorithms could find plans of a fixed length using heuristics to prune the search tree. These advancements produced a significant increase in performance such that planning algorithms could now move beyond toy problems. They also motivated researchers to begin developing planning graph approaches for other computational problems. This, in turn, led to subsequent advancements such as Bonet and Geffner's HSP, which use plain forward or backward chaining, and Hoffman and Nebel's FF Planning System. [8]

These advancements have enabled automated planning to be applied to a variety of today's most important software applications such as configuration management, system integration, project planning, and even controlling autonomous vehicles. [9]

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