Jan-Benedikt Jagusch

AI Planning Historical Developments

Research Review

Abstract

In this paper, I will briefly summarize the historical development of automated planning and scheduling in the field of artificial intelligence. I will explain three major milestones in detail: Shakey the robot (Nilsson, 1984), the A* search algorithm (Hart, Nilsson & Raphael, 1968) and Stanford Research Institute Problem Solver (Fikes & Nilsson, 1971).

Shakey the Robot

Shakey was an intelligent mobile robot that was developed at the Stanford Research Institute (today SRI) starting from 1966. At that time, research on artificial intelligence was in a premature stage and intelligent robots belonged to the realm of Science-Fiction. Shakey was the first system that integrated all components of AI: it could perceive its environment, reason about the perceived situation and take reasonable actions.

The work on Shakey is one of the most important milestones in AI research, since it caused the development of the A* search algorithm and STRIPS, which will be introduced subsequently. Today, Shakey is considered the great-grandfather of modern robots, such as the Mars Rover or autonomously driving cars.

A* Search Algorithm

A* is a widely used pathfinding algorithm, invented by Peter Hart, Nils Nilsson and Bertram Raphael in 1968 at the Stanford Research Institute (today SRI International). The researchers developed A* while working on the mobile robot Shakey. The first problem the team encountered was how to navigate Shakey through a room without bumping into the placed obstacles. For this purpose, they set up waypoints that were adjacent to the positioned obstacles. By connecting waypoints with straight lines, they converted the coordinate representation of the map into a network, where navigating from one point to another is equivalent to finding the shortest path in the graph.

At that time, the prevalent approach to finding the shortest path in a network was the Dijkstra's algorithm. However, the major flaw in Dijkstra's algorithm was that it searched outward into any direction, rather than focusing on the direction of the goal. The A* search algorithm was an enhancement of Dijkstra's algorithm. When searching for the shortest path between start node s and goal node g, the cost of moving to a node n is calculated as the sum of the cost from s to n and the estimated cost from n to g. They showed that A* will always find the shortest path, given that the estimation from n to g is admissible, meaning that it never overestimates.

STRIPS

STRIPS is an automated planner that was developed by Richard Fikes and Nils Nilsson in 1971 as a result of continuous research on the Shakey robot. After solving the navigational problem, using A*, the researchers were confronted with the task of achieving high level goals with high level actions. To give an example, how do you explain a robot to achieve a situation where box B is inside room R, by moving to rooms and pushing boxes?

STRIPS answers this question by converting the coordinate-based information into a database of facts that represented situations that the robot could get itself into. This way, graph searching approaches could be applied to accomplish the desired task. In short, STRIPS contains three main components:

- Start node: List of states that are true in Shakey's initial situation.
- Goal node: List of states that must be true in Shakey's goal situation.
- STRIPS rules: List of actions that Shakey can perform. An action consists of preconditions (required state of the world in order to perform action) and postconditions (state of the world after action is executed).

This way, Shakey can move through a network of situations, trying to find the shortest path to the goal situation in the process. Interestingly, the research team realized that the A* search algorithm can be applied to high level tasks as well, by defining a good heuristic that estimates the distance between states.

References

Fikes, R., & Nilsson, N. (1971). Strips: A new approach to the application of theorem proving to problem solving. Artificial Intelligence, 2(3-4), 189-208. http://dx.doi.org/10.1016/0004-3702(71)90010-5

Hart, P., Nilsson, N., & Raphael, B. (1968). A Formal Basis for the Heuristic Determination of Minimum Cost Paths. IEEE Transactions On Systems Science And Cybernetics, 4(2), 100-107. http://dx.doi.org/10.1109/tssc.1968.300136

Nilsson, N. (1984). Shakey the robot. Menlo Park, Calif.: SRI International.