Developments In AI Planning & Search

Introduction

Planning has been one of the core research areas in AI since the very beginning of the field. A planning system produces a set of actions that can be executed to achieve the goal from some specified initial state. Although some planning systems are domain specific, the majority of development in the field of planning are domain independent (Hendler, Tate, and Drummond, 1990). That is, the planning system should be able to represent the problems and solve them across reasonably wide domains. In this write-up, the development and implications of three aspects in the field of planning are described.

Problem Representation

Before the system can solve the problem and come up with a plan, it must be able to understand and manipulate the problem. To achieve this, the problem must be represented in such a way that is computable by the machine, and also accurately representing the problem we are trying to solve. The first system that did this is the General Problem Solver (GPS) by Newell and Simon (1963). Every operation on the states are verbs describing the actions, and the states are nouns that describes what action has been performed. After the problem domain is formally described, the GPS attempt to solve it by removing the difference between the goal state and the initial state by using the operators (actions).

Expanding on the GPS, Strips by Fikes and Nilsson (1971) assumed that the initial world model would only be changed by a set of additions and deletions from the statements representing the world state, and everything else remain static. Hence, the operators in Strips have an add list, delete list and a set of preconditions, which is more expressive than GPS. Later, Strips were improved upon by reducing some of the restrictions, which made it possible to represent more realistic problems. The system is known as Action Description Language (ADL) by Pednault (1986). More recently, the representation system used in ADL and Strips has been combined into the more standardized Problem Domain Description Language (PDDL) by Ghallab et al. (1998). It has since been used as the standard language to represent planning problems for the International Planning Competition.

The representation of problems in a formalized and computer-understandable format forms the fundamental framework for the planning systems to operate in.

Planning as Search

Essentially, planning is a search problem. To find the best solution to the problem, the planning system need to traverse and explore various actions and evaluate the corresponding effects.

One major roadblock for searching is the immense search space of the problems. In real world, the problems are often complex with many states and operations, which lead to the “combinatorial explosion” of the search space. One way to solve this issue is making the search more directed and informed using some heuristics (Korf, 1987). Instead of searching by brute force, the searching algorithm used heuristic functions that estimate the “distance” to the goal state. One of the very useful search algorithm that uses heuristic evaluations is the A* search (Hart, Nilsson, and Raphael, 1968). Nonetheless, it was shown to be difficult in finding a performant heuristic that can handle the exponential state space effectively.

An alternative to the state space search method is the GPS, as discussed previously. Instead of traversing the search space, GPS uses means-end analysis as the heuristic, in a way it can be seen as a constraint satisfaction algorithm (Newell and Simon, 1963). Furthermore, the more advanced system, such as Noah (Sacerdoti, 1975) allows the state space to include partial plans. Now the system is able to use any previously constructed plans represented as a single state, in addition to the basic world state as actions. The technique introduced in traversing this kind of state space is called the least commitment plan representations (Hendler et al., 1990).

The introduction of partially ordered plans in conjunction to the primitive world state in the state space has allowed the planning systems to solve more complex problems, although it still remains a challenging task for any AI agents.

Conjunctive Goals

Other than representation and searching, the order where simultaneous goals are solved also has significant impact on the efficiency of the search and also the quality of the plans (Hendler et al., 1990). Some early planner struggles with this because they would repeatedly iterate on the same goals and get redundant solutions when the goals were solved in the wrong order. In other words, the solution found in such problem is not optimal, as they contained repeated steps that can be removed without affecting the outcome of the plan.

There are two approaches to solving this issue. First, ordering the various goals by levels of importance. For example, Abstrips by Sacerdoti (1973) and Lawaly by Siklossy and Dreussi (1975) uses levels to partially solve the issue. How they achieve this was by separating the goals into levels of importance, where the more abstract goals are being solved first then only the concrete ones. Second, analyzing and avoiding the interactions caused by interactions between conjunctive goals. This can be achieved by partially merging two separate plans into one (Sacerdoti, 1977). According to Hendler et al. (1990), the planners that uses this approach can be classified into two groups: linear planners (no interleaving of goals and subgoals) and nonlinear planners (allows interleaving of goals and subgoals).

The development to solve the issue of conjunctive goals has uncovered some of the pitfalls of the “classical” planning systems. They would produce suboptimal results when multiple goals need to be satisfied simultaneously.

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