Research Review - Historical Developments in AI Planning and Search

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Historically, multiple approaches to planning and search have competed for prominence with each other. Over time, different strategies have gone between dominating research interest, going out of favor, and being rediscovered and identified as worthy of reinvestigation. While there is no general consensus on what approach is best, their variety has been beneficial, as competition has spurred progress and inspired creative hybrid approaches. I have chosen to highlight three important developments in the history of planning. Though the multitude of different approaches does indeed characterize much of progress in search and planning, I believe that Raymond Reiter's formulation of situation calculus and the introduction of Planning Domain Description Language to be important in that they provided some sense of unity and standardization to the research community, and with it an easy common ground for comparison. The Heuristic Search Planner on the other hand is to me an important turning point that helped bring research out of a state of fixation on partial-order planning, and continued to be competitive even as newer techniques such as Graphplan developed, thus upholding the sense of competition and variety that has helped move the field forward.

Situation calculus was introduced as an approach to planning utilizing first-order logic in 1963. However, a problem termed the "Frame Problem" was identified - many axioms would often be required simply in order to point out that certain objects would not change arbitrarily, a common feature in many environments (McCarthy and Hayes 1969). Raymond Reiter later reintroduced the situation calculus, synthesizing recent developments into a solution to the frame problem under special circumstances. At this time, much of planning research was on goal-regression, and so the paper also showed that through analysis of its special case solution, it could treat goal-regression planning in a way that was both systematic and complete in the formal sense (Reiter 1991). Although planning approaches using situation calculus have not been prominent due to effective heuristics not yet having developed, the 1991 treatment of goal-regression did much to define the formal semantics of planning in later, and thus had an influence on both other developments I will be discussion (Russell and Norvig 2009).

One dimension in which planning research progressed was in the development of representation languages expressive enough to describe environments at a certain level of detail, but not too complex. Indeed, the most lasting contribution of the first planning system, the 1971 Strips program, was its representational language. The Action Description Language was proposed as a middle ground between situational calculus and the very constrained language of strips (Pednault 1989). PDDL represented probably the most significant step forward, and became the standardized language for representing planning problems using a factored representation. It combined the expressiveness of ADL for propositions with that of another recent representation language, UMCP, for actions (Ghallab et. al. 1998). Furthermore, it was intended to express the "physics" of a domain, yet remain neutral regarding how specific goals could best be solved, thus providing a baseline for other researchers to extend based on the direction of their particular solutions (Ghallab et. al. 1998). PDDL accelerated and standardized planning research, and is still used as the language of the International Planning Competition.

Partial-order planning had commanded the majority of researchers' attention from the mid 1970s until the mid 1990s. While Drew McDermott with his Unpop program suggested that state-space search was perhaps worthy of further research, it was the Heuristic Search

Planner that first made it practical for large planning problems (Russell and Norvig 2009). Even a year after the introduction of PDDL, the representation language's influence was already apparent, as HSP preprocessed PDDL problems into C (Bonet and Geffner 1999). HSP implemented progression search, with an heuristic function estimating the distance to the goal node. This opened the door to more state space search approaches, and even was shown to have a correspondence with Graphplan (Bonet and Geffner 2001). Certainly, HSP had a large impact on research going forward, as researchers realized the viability of competing techniques, yet had common languages and formalizations to express them in, thanks in part to the contributions of situation calculus and PDDL.

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