Three AI Planning and Search Developments

A report by David Box

One way to understand the historical progress in many fields is to track the improvements and innovations in a relevant competition. This is true for the improvements in the field of AI planning and search. The *International Planning Competition*[1] *(IPC)* has been held every year since 1998 and contains several different competition categories. In this report I'll be looking at the winning innovations in AI planning and search field made in three different categories of this competition.

One of the longest running competitions is to come up with an automated system than can solve problems across a wide variety of domains satisfyingly. Almost every year this competition has been held a forward search approach has won[2]. However, innovative variants of forward search have been made. FastForward[3] (FF), winner in 2000, improved by extracting an explicit solution to the relaxed problem rather than using the relaxed heuristic solely as a cost estimate to help solve the original planning solution. This opened up FF to get stuck but it turned out using this technique and needing to back up some was still faster. LAMA[4] won in 2008 by making use of a landmark heuristic in its multi-heuristic search approach. This is defined by the LAMA authors as "propositional formulas that must be true in every solution of a planning task". Landmarks complements the other heuristic estimates (such as FF) by directing the search towards states where landmarks have already been solved.

As the AI planning field has developed, researchers have been interested in finding optimal as opposed to solely satisfying solutions. Accordingly IPC implemented an optimal competition starting in 2004. A variant of bidirectional search has won in 2008 (GAMER) and 2011 (Fast Downward Stone Soup). GAMER's[5] twist is to combine bidirectional search with Binary Decision Diagrams (BDDs) and A* search. Fast Downward Stone Soup[6] (FDSS), on the other hand, uses the Fast Downward planning system which transforms the original problem into a multi-valued representation that allows multiple heuristics/algorithms in the fast downward suite of planning algorithms to be used on the problem. FDSS then implements a parameterized local search algorithm to develop portfolios of planning algorithms to optimally solve planning problems.

Another track at IPC, the learning competition, is where contestants develop a generic planner that can learn domain-specific knowledge from a training set to improve its performance on new problems. The quality metric for most problems is to minimize total cost. When this competition was first run in 2008 even the winning program barely saw any improvement after the learning phase[1]. The 2014 winner, Fast Downward Cedalion[7], of the "best learner prize" saw an adjusted quality delta of over 10 in the competition. It works similarly (using a fast downward planning system) to FDSS but instead of a rather simple local search method for determining the optimal portfolio, Cedalion implemented an optimization function that maximizes quality per time spent. Cedalion keeps searching through its configuration space adding configurations to

the portfolio and then keeping them only if they improve the portfolio's score. This new approach for finding the best portfolio and the better pool of search heuristics to search through lead to the win in competition.

[1] “ICAPS Competitions”, www.icaps-conference.org/index.php/Main/Competitions
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[3] J. Hoffmann, FF: The Fast-Forward Planning System, in: AI Magazine, Volume 22, Number 3, 2001, Pages 57-62.
[4] S. Richter, M. Westphal, The LAMA Planner: Guiding Cost-Based Anytime Planning with Landmarks, in: Journal of Artificial Intelligence Research, Vol 39, 2010, pg 127-177
[5] P. Kissmann, S. Edelkamp, GAMER: Fully-Observable Non-Deterministic Planning via PDDL-Translation into a Game, IPPC-2008, 2008
[6] M. Helmert, G. Roger, F. Karpas, Fast Downward Stone Soup: A Baseline for Building Planner Portfolios, IPPC-2011, 2011
[7] J. Seipp, S. Sievers, F. Hutter, Fast Forward Cedalion, IPPC-2014, 2014