Research Review: AI Planning and Search

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"Planning is bringing the future into the present so that you can do something about it now." Alan Lakein, How to Get Control of Your Time and Your Life (1973, New American Library, New York, New York).

AI Planning and Search has seen many seminal steps over the past half-century, and those advances have furthered the science and practice of AI as a whole. Chronicling all would require a tome, but below are a few noteworthy ones.

The field arose from the confluence of research needed for applications in robotics, scheduling, and other domains. Russell S.J., Norvig, P. (2010). Artificial Intelligence A Modern Approach (3rd Ed.). Noida (U.P.) India: Pearson India Education Services Pvt. Ltd. The Stanford Research Institute was the eponymous creator of the Stanford Research Problem Solver, or STRIPS, in the process formalizing the acronymous representational language STRIPS. (Files and Nilsson, 1971.) This allowed for a means to communicate and encode the logical problems in the automated planning domain. While I have been unable to locate any research corroborating the human benefits for scientists of the enablement of concise inner speech STRIPS almost assuredly accelerated progress in the field in this manner as well.

Planning is PSPACE-hard and can, as a result, initiate combinatorial explosion.[1] By incorporating, *inter alia*, negative literals, the Planning Domain Definition Language, or PDDL, was developed. McDermott, D., Ghallab, M., Howe, A., Knoblock, C., Ram, A., Veloso, M., Weld, D., Wilkins, D. (1998). PDDL---The Planning Domain Definition Language. Technical Report CVC TR98003/DCS TR1165. New Haven, CT: Yale Center for Computational Vision and Control. Retrieved from **http://icaps-conference.org/ipc2008/deterministic/data/mcdermott-et-al-tr-1998.pdf**. This factored representation of the world exponentially reduced many actions to one action schema.

GRAPHPLAN is one example of a planner that has increased performance further still. Blum, A., Furst, M. (1997) Fast Planning Through Planning Graph Analysis. Artificial Intelligence, 90:281--300. Retrieved from **www.cs.cmu.edu/~avrim/Papers/graphplan.ps**. GRAPHPLAN annotates truth values through a Planning Graph, in the process incorporating constraint propagation for increased search efficiency. This was taken one step further, incorporating probabilistic search. Blum, A. Langford, J. (1999) Probabilistic Planning in the Graphplan Framework. Retrieved from **www.cs.cmu.edu/~avrim/Papers/ecp.ps**.

The advent of probabilistic approaches better enabled AI and, in fact, Internet search in general. Google's original algorithm, PageRank especially with its damping factor, can be viewed simply as a standard normal probability distribution founded upon the heuristic - quantum of certain inbound links to the given Webpage. The scalar result, in turn, can be viewed as the probability of relevance of that Webpage to a searcher. Brin S., Page L. (1998) The Anatomy of a Large-

[1] *Ibid.*

Scale Hypertextual Web Search Engine. Retrieved from **http://infolab.stanford.edu/~backrub/google.html.**

In that same vein, and in response to the gaming of this original algorithm, today's paid search (for advertising) is increasingly reliant on real-time bidding based upon game theory. Yuan S., Wang J. Chen B, Mason P., Seljan (2017). An Empirical Study of the Reserve Price Optimisation in Real-time Bidding. Retrieved from **www.mediagamma.com/uploads/publisher_floor_price_optimisation_mediagamma.pdf**. Thus, planning, search, and probability are now nearly inextricably linked, and the AI domain has been furthered by advances in planning and search.