Research in Decision-Theoretic Planning and Scheduling

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The Bayesian Problem-Solving (BPS) project aims to reconstruct and extend AI methods using probabilistic inference and normative decision-making principles. To date, we have applied BPS to single-agent problem-solving [1] [2], adversarial games [4], planning [3], scheduling, constraint satisfaction [5], and securities trading.

BPS chooses actions according to the principle of maximum expected utility. These actions include search decisions, such as heuristic evaluations and node expansions. As BPS searches, it incrementally constructs a Bayesian network in which each state in the partially expanded state-space is represented by a variable node corresponding to utility attributes (such as true cost to the goal state), together with evidence nodes corresponding to the heuristic evaluations for that state. The explicit representation of uncertainty in BPS makes it possible to use information-value theory to control search actions.

Our early work on planning [3] (with Stuart Russell) attempted to generalize our work in single-agent search to classical AI planning problems. In particular, we discussed the design of a decision-theoretic system for goal-directed, abstraction-based planning. We conjectured that a decision-theoretic planner would elaborate abstract plans (or add ordering constraints to partial plans) to the extent that their vagueness created uncertainties that were relevant to top-level decisions.

Our recent research has focussed on continued experimentation and theoretical development in single-agent problems [7], and on the development of DTS, a decision-theoretic scheduling system for industrial applications [6]. Two aspects of our work on DTS are particularly relevant to decision-theoretic planning:

- *Search Control.* DTS uses decision-theoretic criteria to control its search. We have developed decision-theoretic versions of the well-known backtracking and Min-Conflicts algorithms, and are experimenting with a least-commitment search algorithm based on BPS. We have also done very preliminary experiments on preprocessing and branch-and-bound techniques that reason about the utility function to achieve tighter bounds.
- *Problem Elicitation.* AI researchers have surprisingly little experience with how well users can specify problems for use in problem-solving systems. The addition of utility considerations may complicate rather than simplify this elicitation problem. In DTS, we permit the user to annotate familiar constraint types with utility information. Constraint violations are associated with attributes (e.g., if a delivery is late, that is counted against the attribute for customer satisfaction), and the attributes are combined in a single utility function (a function mapping from schedules and computation costs to utility values). This interface is crude but easy to understand. We are very interested in planners that include interfaces for utility elicitation.

Selected Publications

[1] O. Hansson and A. E. Mayer. Heuristic Search as Evidential Reasoning. In *Proceedings of the the Fifth Workshop on Uncertainty in Artificial Intelligence*, Windsor, Ontario, August 1989.

[2] O. Hansson and A. E. Mayer. Probabilistic Heuristic Estimates. *Annals of Mathematics and Artificial Intelligence*, 2:209–220, 1990.

[3] O. Hansson, A. E. Mayer, and S. J. Russell. Decision-Theoretic Planning in BPS. In *Proceedings of the AAAI Spring Symposium on Planning in Uncertain, Unpredictable, or Changing Environments*, Stanford, March 1990.

[4] O. Hansson and A. E. Mayer. A New and Improved Product Rule. Paper presented at *The Eighth International Congress of Cybernetics & Systems*, New York, June 1990.

[5] O. Hansson and A. E. Mayer. DTS: A Decision-Theoretic Scheduler for Space Telescope Applications. In *Intelligent Scheduling,* M.S. Fox and M. Zweben (eds.), Morgan Kaufmann, San Mateo, CA, 1994.

[6] O. Hansson *Bayesian Problem-Solving Applied To Scheduling.* Ph.D. Dissertation, University of California, forthcoming.

[7] A. E. Mayer. *Rational Search.* Ph.D. Dissertation, University of California, forthcoming.