Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
Proposal for Thesis Research in Partial Fulfillment
of the Requirements for the Degree of
Master of Science

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Title: Rational Partial Evaluation of Decision Trees

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Laboratory where thesis will be done: MIT Laboratory for Computer Science

Supervision Agreement:

The program outlined in this proposal is adequate for a Master's thesis. The supplies and facilities required are available, and I am willing to supervise the research and evaluate the thesis report.

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Jon Doyle, Principal Research Scientist
MIT Laboratory for Computer Science

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Contents

1 Introduction

Expert decision-making systems often evaluate decision trees to determine what action has the best expected utility. But sometimes the decision tree implied by the system's model of the domain is intractably large; not only too large to store explicitly, but also too large to evaluate in a reasonable time. System designers typically avoid such difficulties by simplifying the model of the domain so that it will not produce large decision trees, or by abandoning decision trees when they are too large and using some other method to come to a decision.

An alternative, explored in this research, is to partially evaluate the decision tree, using estimates for the utilities of non-leaf nodes. This is analogous to the standard computer game-playing (CGP) technique of partially evaluating the typical intractably-large game trees.

The problem now (as in game tree search) becomes two: estimating utilities of non-leaf nodes, and exploring those parts of the tree that are expected to contribute the most to the quality of the overall decision.

In CGP, the problem of tree-search can be partially handled using cheap and provably-correct algorithms such as Alpha-Beta and Scout. Recently, researchers have gone further with methods that use information about the degree of uncertainty of utility estimates to select those search actions that will most improve the quality of the overall decision. These methods have met with some success. Especially appropriate are the decision-theoretic metareasoning techniques of Russell and Wefald, which search those parts of the tree expected to contribute the most to the utility of the final decision.

Can this sort of decision-theoretic metareasoning be profitably used to control the partial evaluation of large decision trees? That is the primary question that this research will explore.

2 Relation to Existing Work

Although this research will be based in part on Russell and Wefald's metareasoning techniques, it will go beyond that work in several ways.

- This work will focus on decision trees rather than game trees, leading to somewhat different details for the propagation of utilities.
- I intend to reevaluate some of the simplifying assumptions Russell and Wefald make, and make different and hopefully more general assumptions of my own.
- I plan to generalize their representations of probability distributions over future utilities.
- I plan to make an abstract characterization of the metareasoning problem, with a clear interface between the metareasoning strategy and the non-metareasoning parts of the algorithm, so that different metareasoning strategies can be plugged in and their effectiveness compared. I will investigate several alternative metareasoning strategies and compare them.

- I will focus on demonstrating that metareasoning is actually helpful. In particular, if the metareasoning overhead causes the system to perform poorly in comparison with a non-metareasoning evaluation strategy, that will be considered unacceptable. I hope to make a metareasoning module that can adjust the amount of time spent in metareasoning so as not to decrease overall performance.
- I hope to make a clean, elegant implementation of the system that will be useful for pedantic purposes.
- I hope to apply these techniques in a large, real-world domain such as medical decision-making as well as in a small, well-defined domain such as game-playing.

I hope to also make use of decision-theoretic control techniques developed by other researchers such as Pearl, Horvitz, Heckerman, Hansson and Mayer, and others. From preliminary investigations, much of that work seems very relevant.

3 Research Plan

My research on this topic, which has already started, will continue throughout this year and should be completed in December. I have divided this year into three periods during which I will focus on different phases of the work. Work I have planned to do during these periods is summarized below.

3.1 January to March

In this period I will research existing work on techniques for evaluation of problems involving large decision trees. In addition, I will study and become acquainted with the existing research on the application of decision-theoretic control techniques to large search and game-playing problems.

This work will involve talking to experts in application of AI to real-world decision-making problems, such as Steve Pauker at NEMC. In these discussions I hope to learn more about the nature of the large decision problems encountered, to learn about the problems with the use of existing techniques, and to determine to what degree my own approach would be appropriate for various kinds of real-world decision problems.

I also plan to look into the computer-game playing research relevant to one-player games with chance, to determine whether partial evaluation of decision trees would be a profitable approach in that domain as well, and if so, to study other techniques against which to make objective comparisons of performance. Also, there is the possibility that I may find some techniques in the solitaire-playing literature that could be applied to some real-world decision problems.

Also, I will study in detail the metareasoning work of Russell & Wefald, Horvitz, Hansson & Mayer, and others, to thoroughly learn how to correctly apply decision theory to the selection and control of computational actions when searching for approximate solutions to hard problems.

3.2 April to August

During this period I will focus on the detailed development of my techniques for partial evaluation of decision trees, incorporating what I will have learned about the nature of the decision problems that I think my techniques will be best suited to address, and incorporating what I will have learned about rational control of computation.

I will also design and implement a program for testing these ideas on example problems in various domains. I hope to be able to compare the performance of my system with that of existing approaches.

3.3 September to December

In this final period I will write the thesis. It will describe in detail the motivation for the work, the mathematical basis for the metareasoning techniques, the design and implementation of the system for solving large decision problems, and the results of experiments involving the system. It will also point towards possible directions for related research.

4 Future Work

I plan to continue and generalize this work, or something closely related, for my Ph.D. work. For example, I would like to explore the design of reflective systems that can reason effectively about their own past and future computational behavior, including their reflective behavior, and act rationally to change what their future behavior will be. The ultimate goal would be a system that knew enough about itself, and about programming, that it could adaptively refine or restructure parts of itself, with the aim of improving its own performance. Such a system would greatly facilitate further development of complex AI programs.

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