Information Tradeoffs in Model Building: A Network Routing Application

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Abstract. An integral part of the model-building process is the modeler's choice of how much information to gather and encode in the decision model. Obtaining more detailed and accurate information enables a more precise problem representation which, in turn, leads to more effective decision making. However, acquiring extensive and accurate information entails higher costs and delays. This paper uses a network routing decision context to illustrate the tradeoff between model precision and decision effectiveness, and explores a formal decision-theoretic approach to determine an appropriate model specification that balances information gathering costs and decision quality. We propose optimal and heuristic methods for generating good information search strategies, and report computational results based on random test problems. Our results highlight the importance of simultaneously considering information costs and decision payoffs for constructing a decision model to support routing decisions. The issues raised in this paper are especially significant for modeling dynamic, real-time decision contexts where delays induced by information gathering activities could have significant economic impact.

Key words. Decision theory, information acquisition strategies, model building.

1. Introduction

Decision-makers often use mathematical models of real decision problems to gain insights and facilitate effective and efficient problem solving and decision-making. In many model-based decision contexts, modelers have a choice of how much information to gather and encode in the decision model. Obtaining more detailed and accurate information enables a more precise problem representation which, in turn, leads to more effective decision-making. However, acquiring additional and more accurate information entails costs as well as delays. Thus, the modeler
faces a fundamental tradeoff between the amount of information to acquire and the consequent impact on the quality of the decisions suggested by the model.

This tradeoff is especially critical in dynamic, real-time contexts such as message and traffic routing where delays induced by information acquisition activities may result in significant economic losses. Acquiring complete information is often inappropriate in such applications; instead, a more practical and effective strategy might permit possibly suboptimal decisions using only partial (i.e., incomplete) information. Essentially, this strategy recognizes the interrelationship between information systems concerns of data gathering and processing, and conventional model-building concerns of efficiency and effectiveness of solutions.

Despite its importance, this information cost-decision quality tradeoff has not been adequately addressed in much of the modeling reference disciplines including operations research (OR), artificial intelligence (AI) and decision support (DS). We briefly review the research emphasis and trends in these three disciplines.

In general, the OR literature mainly emphasizes the development of more effective and efficient solution methods for various generic models. For instance, the vast shortest path literature consisting of over 200 papers (e.g., Deo and Pant, 1984) deals primarily with solution algorithms for various deterministic, stochastic and constrained versions of the problem. Typically, researchers implicitly assume either that the accuracy levels of input parameters are prescribed by the modeler (perhaps, intuitively) or that the model must necessarily identify the best decision (effectively imputing a high cost for suboptimal solutions). The primary means suggested for handling information inaccuracies is some form of sensitivity analysis that merely identifies parameter ranges to preserve optimality of the current solution, rather than permitting the risk of suboptimal solutions.

Turning to the AI modeling literature, the primary emphasis is on devising: (i) various model representation schemes such as productions, semantic nets, and frames (e.g. Winston, 1984), and (ii) non-monotonic logics (e.g. McCarthy, 1981; McDermott and Doyle, 1980; McDermott, 1982; and Shoham, 1988) that permit defeasible inferences, i.e., inferences that might possibly be wrong but can be reversed when more information becomes available. The issue of what and how much information to gather and encode in the model is not explicitly addressed.

Finally, research on model management in the DS literature focuses on: (i) resolving difficulties in interfacing models, data, and the user (e.g. Bonczek et al., 1979; Dolk and Konsynski, 1984; Dutta and Basu, 1984; and Elam et al., 1980), (ii) identifying useful model representation paradigms (e.g. Sprague and Carlson, 1982; Holsapple and Whinston, 1988), and (iii) constructing model management frameworks based on data management concepts (e.g. Blanning, 1982, 1983; Stohr and Tanniru, 1980). Once again, the issue of information cost-decision quality tradeoff is essentially unresolved.

This paper explores systematic methods to resolve the tradeoff between the