Automatized Decision Making for Autonomous Agents

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ABSTRACT

Utility theory and the principle of maximising the expected utility have, within the multi-agent community, had a great influence on multi-agent based decision. Even though this principle is often useful when evaluating a decision situation it is virtually impossible, except in very artificial situations, to use the more basic decision rules with its unrealistically strong requirements for the input data, and other candidate methods must be considered instead. This article provides an overview and brings attention to some of the possibilities to utilize more elaborated decision methods, while still keeping the computational issues at a tractable level.

Keywords: Automated Decision Making, Decision Support, Imprecise Reasoning, Multi-Agent Systems, Utility Theory

INTRODUCTION

Theories of intelligent agents offer means for dealing with the inherent complexity of developing distributed systems for decision support. The advances in distributed agent intelligence have affected the design methods of decision support systems in several ways. The field of distributed agent intelligence is often partitioned into distributed problem solving and multi-agent systems. Decision theory has become increasingly more important, especially to the latter. Regardless of the specific details, there are some common problems having to do with specification contra execution. One of the problems is the inherent dynamics in the environment many systems are exposed to. The properties of the environment are not known with any precision at the time of construction. This renders a specification of the system incomplete by definition. A traditional software agent is thus only prepared to handle situations conceived of and implemented at compile time (Ekenberg et al., 1995). Even though it can operate in varying contexts, its decision making abilities are static. A rational software agent needs both a representation of the decision problem at hand and means for evaluation (Ekenberg, 2000a,b). Such decision making often has to be carried out under severe uncertainty regarding several parameters. Thus, methods for independent decision making components should be able to handle uncertainties on the probabilities and utilities involved (Ekenberg et al., 1996). They have mostly been studied as means of representation, but are now being developed...

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into functional theories of decision making suitable for dynamic use by software agents and other dynamic distributed components. Such a functional theory will also benefit analytical decision support systems intended to aid humans in their decision making. Thus, the generic term agent below stands for a dynamic software component as well as a human or a group of humans assisted by intelligent software. This article provides an overview over strong uncertainty in decision analysis and suggests some more elaborated decision methods that can be used in the context of automatized reasoning.

DECISION THEORY

Ramsey (1926/78) was the first to suggest a theory that integrated ideas on subjective probability and utility in presenting (informally) a general set of axioms for preference comparisons between acts with uncertain outcomes (probabilistic decisions). von Neumann and Morgenstern (1947) established the foundations for a modern theory of utility. They stated a set of axioms that they deemed reasonable to a rational decision-maker (such as an agent), and demonstrated that the agent should prefer the alternative with the highest expected utility, given that she acted in accordance with the axioms. This is the principle of maximizing the expected utility. Savage (1954/72) published a thorough treatment of a complete theory of subjective expected utility. Savage, von Neumann, and others structured decision analysis by proposing reasonable principles governing decisions and by constructing a theory out of them. In other words, they (and later many others) formulated a set of axioms that they deemed reasonable to justify their particular attitude towards the utility principle, cf., e.g., Herstein and Milnor (1953), Suppes (1956), Jeffrey (1965/83), and Luce and Krantz (1971). In classical decision analysis, of the theories suggested by Savage and others, a widespread opinion is that utility theory captures the concept of rationality. After Raiffa (1968), probabilistic decision models are nowadays often given a tree representation.

A decision tree consists of a root, representing a decision, a set of event nodes, representing some kind of uncertainty and consequence nodes, representing possible final outcomes. Usually, the decision is symbolised by a square, circles symbolise events, and final consequences are denoted by triangles. Events unfold from left to right, until final consequences are reached. There may also be more than one decision to make, in which case the sub-decisions are made before the main decision.

In decision trees, probability distributions are assigned in the form of weights (numbers) in the probability nodes as measures of the uncertainties involved. Obviously, such a numerically precise approach puts heavy demands on the input capability of the agent. Among other things, the question has been raised whether people are capable of providing the input information that utility theory requires (cf., e.g., (Fischhoff et al., 1983)). For instance, most people cannot clearly distinguish between probabilities ranging roughly from 0.3 to 0.7 (Shapira, 1995). Similar problems arise in the case of artificial agents, since utility-based artificial agents usually base their reasoning on human assessments, for instance in the form of induced preference functions. The so-called reactive agents, for which this does not hold true, have not been put to use in dynamic domains involving uncertainty (cf., e.g., (Russell & Norvig, 1995)). Furthermore, even if an agent would be able to discriminate between different probabilities, very often complete, adequate, and precise information is missing.

Consequently, during recent years of rather intense research activities several alternative approaches have emerged. In particular, first-order approaches, i.e., based on sets of probability measures, upper and lower probabilities, and interval probabilities, have prevailed. A main class of such models has been focused on expressing probabilities in terms of intervals. In 1953, the concept of capacities was introduced (Choquet, 1953/54). This representation approach was further developed in Huber (1973) and Huber and Strassen (1973). Capacities have subsequently been used for modelling imprecise probabilities.
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