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Decision making with combined states under interval uncertainty

Lala M.Zeinalova*

Department of Computer Engineering, Azerbaijan State Oil and Industry University,Baku, Azadlyg ave. 20, AZ1010, Azerbaijan

Abstract

The impact of the decision maker features on decision making process sometimes contradicts with the traditional theories. Modeling a decision making model it should be noted that it is primarily a behavioral model and behavior is influenced by ambiguity. Decision making is a behavioral process highly conditioned by the primary motives beliefs of a DM. In this paper we consider an imprecise hierarchical decision-making model where the first and the second level are described by interval probabilities. This method associates with the construction of a non-additive measure as a lower prevision and uses this capacity in Choquet integral for constructing a utility function. This method uses combined state of nature and decision maker's state which allows distinguishing the ambiguity and ambiguity attitude. We provide an experiment showing application of the suggested analysis.

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Keywords: Behavioral modeling, decision making, combined states, low prevision, Choquet inteqral

1. Introduction

Depending upon structure of available information, a large number of decision-making methods exist. One of the well-known methods is the one of the expected utility proposed by von Neumann and Morgenstern[1], and subjective expected utility by Savage[2]. But in real-world in many cases it becomes impossible to determine the values of objective probabilities[3]. It is more plausible to determine the values of subjective probabilities, reflecting the beliefs of a decision maker. Particularly, when there is no precise information (subjective or objective), an interval of probability can be used. The upper and lower probabilities are adequate for modeling the available information4. There are methods, using which it becomes possible to solve a problem with interval of probabilities, for example,

* Correspponding author. Tel.: (050)2501646
E-mail address: Zeynalova-69@mail.ru

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the method of maximum expected utility. However, this method uses first–order probabilities. The assessed intervals of probabilities are often reflective of expert's or decision maker's experience. His/her confidence itself is also imprecise and thus it can be described as intervals. This forms an immediate motivation behind this study- a decision making problem with the second-order uncertainties, where the probabilities at the first and at the second levels are given as intervals5,6. The method, proposed in5 uses a Choquet integral for determination the values of utility functions for further comparing the preferences among acts. The authors construct a low prevision as non-additive measure and use this capacity in Choquet integral. The Choquet integral has many advantages: it is continuous, none decreasing, located between min and max7. In5 an imprecise hierarchical decision-making model has the first and the second levels described by interval of probabilities. In8, where is a hierarchical uncertainty model which exhibits imprecision at its second level in sense of the use of lower probabilities at this level is represented. The first level of this model may be either precise or imprecise. Author shows that no matter whether the first level is precise or imprecise the suggested hierarchical model has the same implications for decision analysis and decision reasoning. The model is a generalization of imprecise probabilities, Bayesian models and fuzzy probabilities. However one should mention that this model doesn`t deal with probability of distribution (multiple priors), which has more general description of incomplete probability of relevant information. When modeling a decision making model it should be noted that it is primarily a behavioral model and behavior is influenced by ambiguity. Usually an ambiguity is related to an uncertainty about unknown probability. How ambiguity can affect decisions? Research shows that the decision makers use reference points in decision-making. During the past few years there has been a great effort to model the preferences of the decision maker based on the identification of his/her behavioral features. The most often cited in the literature behavioral models are the ones of risk taking in decisions. As risk related decision making we understand the most commonly considered situations involving uncertainty where the precise consequences are uncertain but their probabilities are known9,10. Risk seekers take choices that involve a higher probability of a loss. Risk averters tend to demand more information on probabilities, adopting worst-case scenarios10. The experiment in Ellsberg showed that people are ambiguity averse in preferring the urn with known probabilities. In Ellsberg's experiment ambiguity aversion leads to a violation of the Savage axioms. There are two main directions of research concerning uncertainty averse preferences: by using of non-additive measures, technically known as capacities (Choquet integral of a utility function)11 and by taking into consideration the distribution of priors (Maximin Expected utility with probability distributions)12. The first cited in literature axiomatization of ambiguity is given in11 and12. According to the first representation a decision maker constructs a model using Choquet integral with non-additive measure and chooses the appropriate alternative with the maximal value of the utility function. It is shown in11 that when the non-additive probability is convex the Choquet utility decision rule corresponds to ambiguity aversion13. In the maxmin expected utility framework beliefs are represented by a set of probability measures and a decision maker maximizes the expected utility according to the worst case belief. Choquet expected utility does not presuppose uncertainty aversion, and is, in that sense, more general than maxmin expected utility14. In15 authors suggested a two stage model (with second-order probabilities), rationalizing Ellsbergian attitudes and suggesting the distinguishing of an ambiguity attitudes and risk attitudes across decision makers using multiple distinct sources. It is shown in15 that attitudes towards pure risk are characterized by the shape of utility function and attitudes towards ambiguity are characterized by the shape of increasing transformation function. The probability of distribution over expected utilities "smoothly" aggregates the information, the decision maker has about the relevant utility profiles. In this smooth ambiguity model only the second–order probability is allowed and the order of utility is unrestricted16. The main advantage of the "smooth" ambiguity model is that it gives an opportunity to separate an ambiguity as the level of uncertainty and ambiguity aversion as the decision maker's taste. The second advantage is related to a nonreduction of a second-order belief by using the usual expectations of utilities. It should be noted that the considered model avoids non differentiability relevant to maxmin expected utility model. But in15 the second-order acts or beliefs are only in the mind of the decision-maker, representing the precise values. In a real world in many cases it is usually impossible to assign the precise value of the second-order probability to any event. Some of these aspects were critically discussed in study17. In this study we consider the second-order interval hierarchical models as the more adequate and intuitively meaningful models for formalizing information structure of a decision making problem. The method associates with the construction of a non-additive measure as a lower prevision and uses this capacity in Choquet integral for constructing a utility function5. This method uses combined state of nature and decision maker's state which allows distinguishing the ambiguity and ambiguity attitude. The paper is organized as follows. In Section 2 we present required preliminaries and cover some prerequisite material (such as lower prevision, Choquet integral, joint