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Decision Support

Evidential reasoning based preference programming for multiple attribute decision analysis under uncertainty

Min Guo [a,b,*], Jian-Bo Yang [c,a,*], Kwai-Sang Chin [b], Hongwei Wang [a]

[a] *Institute of Systems Engineering, Key Laboratory of Image Processing and Intelligent Control, Huazhong University of Science and Technology, Wuhan, China*
[b] *Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong, Hong Kong, China*
[c] *Manchester Business School, The University of Manchester, Booth Street East, Manchester, England M60 1QD, UK*

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Abstract

Multiple attribute decision analysis (MADA) problems having both quantitative and qualitative attributes under uncertainty can be modelled and analysed using the evidential reasoning (ER) approach. Several types of uncertainty such as ignorance and fuzziness can be consistently modelled in the ER framework. In this paper, both interval weight assignments and interval belief degrees are considered, which could be incurred in many decision situations such as group decision making. Based on the existing ER algorithm, several pairs of preference programming models are constructed to support global sensitivity analysis based on the interval values and to generate the upper and lower bounds of the combined belief degrees for distributed assessment and also the expected values for ranking of alternatives. A post-optimisation procedure is developed to identify non-dominated solutions, examine the robustness of the partial ranking orders generated, and provide guidance for the elicitation of additional information for generating more desirable assessment results. A car evaluation problem is examined to show the implementation process of the proposed approach.

Keywords: Multiple attribute decision analysis; The evidential reasoning approach; Uncertainty modelling; Interval evaluation; Non-linear optimization

1. Introduction

Many complex multiple attribute decision analysis (MADA) problems involve both quantitative and qualitative attributes as well as various types of uncertainties such as local and global ignorance (incomplete or no information) and fuzziness (vague information). Such complex MADA problems can be consistently modelled using the evidential reasoning (ER) approach (Yang and Sen, 1994; Yang and Singh, 1994; Yang, 2001; Yang and Xu, 2002a,b; Wang et al., 2006b; Xu et al., 2006; Yang et al., 2006). The ER approach models both

* Corresponding authors. Address: Manchester Business School, The University of Manchester, Booth Street East, Manchester, England M60 1QD, UK. Tel.: +44 161 200 3427; fax: +44 161 200 3505 (J.-B. Yang).
E-mail addresses: guomin_like@sina.com.cn (M. Guo), jian-bo.yang@mbs.ac.uk (J.-B. Yang).

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quantitative and qualitative attributes using a distributed modelling framework, in which each attribute is assessed using a set of collectively exhaustive and mutually exclusive assessment grades, probabilistic uncertainty including local and global ignorance is characterized by a belief structure, and fuzzy uncertainty by fuzzy linguistic variables (Yang et al., 2006).

In certain decision situations, due to the complexity and uncertainty involved in real world decision problems and the inherent subjective nature of human judgments, it may not always be realistic or feasible to acquire exact judgments. In group decision making, for example, group members' different views could be better captured using interval judgments, which also leave rooms for discussion, negotiation and further analysis. In the ER approach and its extensions, both belief degrees and weight estimation may take interval values. In such cases, the aggregated evaluations of alternatives may no longer be single values but become interval judgments. According to the interval belief structures proposed in the ER models, Wang et al. (2006b) constructed pairs of non-linear optimisation models to estimate the upper and lower bounds of the combined belief degrees and to compute the maximum and the minimum expected utilities of each alternative. The purpose of this paper is to handle both the interval beliefs and interval weights in an integrated manner, in order to develop an enhanced ER approach for MADA under two types of interval uncertainties.

The recent literature reviews conducted by the authors and their colleagues (Wang et al., 2006b) show that the estimation of interval weights and their use in decision making processes have attracted a lot of attention and several weight evaluation methods have been developed. Among other frameworks, pairwise comparison matrices provide an easy-to-use framework to elicit preferences from decision makers and have been used in several weight generation methods such as the principal right eigenvector method (Saaty, 1977, 1980, 1988, 1994) and the logarithmic least squares method (Saaty and Vargas, 1984a,b; Crawford and Williams, 1985; Barzilai et al., 1987), which is also known as the geometric mean method (Crawford, 1987; Barzilai, 1997). For interval pairwise judgments, a number of techniques have been developed to generate a single weight vector from a feasible region. Saaty and Vargas (1987) proposed interval judgments for the AHP method as a way to model subjective uncertainty and used a Monte Carlo simulation approach to generate weight intervals from interval comparison matrices. Arbel (1989, 1991) interpreted interval judgments as linear constraints on local priorities and applied a linear programming approach to generate weights, which is simple to implement and can generate true weight intervals from a consistent interval comparison matrix.

The feasible region of a weight vector was also analysed by Arbel and Vargas (1992, 1993). They formulated maximization and minimization problems for establishing bounds for the components of principal right eigenvectors. They characterized weight intervals as solutions to non-linear programmes in which all local priorities in a hierarchy are included as decision variables. On the other hand, Salo and Hämäläinen (1992a,b, 1995), Salo (1993) developed the "preference programming" approach. They computed the maximum and minimum feasible values for each weight using linear programming techniques and incorporated the resultant intervals into further synthesis to obtain global weight intervals. They also defined the concept of local "dominance" given interval judgments. Islam et al. (1997) used lexicographic goal programming to generate weights from inconsistent pairwise interval judgment matrices and explored its properties and advantages as a weight estimation technique. Haines (1998) proposed a statistical approach to extract preferences from interval judgment matrices. Two specific distributions on a feasible region were examined and the mean of the distributions was used as a basis for assessment and ranking.

In this paper, the framework proposed by Wang et al. (2006b) for handling interval beliefs is extended to take into account interval weights together with interval beliefs. Based on the original evidential reasoning algorithm, several pairs of preference programming (referred to as ER-PP) models are developed to cater for incomplete or imprecise weight information either assigned directly or through pairwise comparisons. In the ER-PP models, both assessment and preference information is treated as constraints. Instead of generating interval weight vectors, preference information is used to generate combined interval beliefs and interval values (utilities) to support global sensitivity analysis and further information elicitation. Interval uncertainty may lead to local non-dominance between different options. In the paper, the dominance structure caused due to interval uncertainty will be defined and analysed. New procedures are designed and investigated to support the further elicitation of additional information for discriminating locally non-dominated options.

The paper is organized as follows. In Section 2, the original ER approach is first introduced. Section 3 investigates the relevant theoretical issues raised in the existing interval belief ER models (Wang et al.,