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Decision Support

A group decision-making approach based on evidential reasoning for multiple criteria sorting problem with uncertainty

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ABSTRACT

A new group decision-making approach is developed to address a multiple criteria sorting problem with uncertainty. The uncertainty in this paper refers to imprecise evaluations of alternatives with respect to the considered criteria. The belief structure and the evidential reasoning approach are employed to represent and aggregate the uncertain evaluations. In our approach, the preference information elicited from a group of decision makers is composed of the assignment examples of some reference alternatives. The disaggregation–aggregation paradigm is utilized to infer compatible preference models from these assignment examples. To help the group reach an agreement on the assignment of alternatives, we propose a consensus-reaching process. In this process, a consensus degree is defined to measure the agreement among the decision makers' opinions. When the decision makers are not satisfied with the consensus degree, possible solutions are explored to help them adjust assignment examples in order to improve the consensus level. If the consensus degree arrives at a satisfactory level, a linear program is built to determine the collective assignment of alternatives. The application of the proposed approach to a customer satisfaction analysis is presented at the end of the paper.

1. Introduction

The multiple criteria sorting (MCS) problem is concerned with the assignment of a set of decision alternatives evaluated on a family of criteria into predefined ordered categories. In practice, MCS is used in many fields, such as supplier management (Araz & Ozkarahan, 2007), water resource planning (Chen, Hipel, & Kilgour, 2007), ABC inventory classification (Chen, Li, Kilgour, & Hipel 2008), energy management (Neves, Martins, Antunes, & Dias, 2008), credit rating (Doumpos & Zopounidis, 2011), assisted reproduction (Figueira et al., 2011), construction project management (Mota & Almeida, 2012), regional competitiveness analysis (Fernandez, Navarro, Duarte, & Ibarra, 2013), water contamination risk assessment (Macary, Almeida-Dias, Uny, & Probst, 2013), recommender system (Marin, Isern, Moreno, & Valls, 2013), climate classification (Mailly, Abi-Zeid, & Pepin, 2014), and research unit evaluation (Kadziński & Słowiński, 2015).

Various approaches for addressing the MCS problem have been proposed in the literature. These approaches can be classified into the following four categories: (1) the methods inspired by the outranking relations (e.g., Almeida-Dias, Figueira, & Roy, 2010, 2012; Janssen & Nemery, 2013; Köksalan, Mousseau, Özpeynirci, & Özpeynirci, 2009; Kadziński, Tervonen, & Figueira, 2014; Nemery & Lamboray, 2008; Rocha & Dias, 2008); (2) the methods motivated by the value functions (e.g., Doumpos, Zanakis, & Zopounidis, 2001; Doumpos & Zopounidis, 2004; Greco, Kadziński, & Słowiński, 2011; Greco, Mousseau, & Słowiński, 2010; Kadziński, Ciomek, & Słowiński 2015; Köksalan & Özpeynirci, 2009; Kadziński & Tervonen, 2013; Köksalan & Ulu, 2003); (3) the methods based on the weighted Euclidean distance (e.g., Chen et al., 2007, 2008; Vetschera, Chen, Hipel, & Kilgour, 2010); and (4) the rule induction-oriented methods (e.g., Dembczyński, Greco, & Słowiński, 2009; Greco, Matarazzo, & Słowiński, 2010; Kadziński, Greco, & Słowiński, 2014). These methods were originally designed to address the MCS problem for which the preferences are expressed by a single decision maker (DM). However, group decision-making is the most important and frequently encountered process within companies and organizations (Greco, Kadziński, Mousseau, & Słowiński, 2012). Therefore, it is important to study the MCS problem in the context of group decision-making. Moving from a single-DM setting to a multiple-DM setting introduces a great deal of complexity into the MCS problem. In the extant literature, Dias and Clímaco (2000) addressed the sorting problem of a group of DMs with imprecise information on the parameters. Damart, Dias, and Mousseau (2007) provided a methodology that could help a group

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iteratively reach an agreement on how to sort exemplary alternatives. Jabeur and Martel (2007) proposed a sorting method that determines at least one collective assignment from the individual preference systems. Bregar, Györkös, and Jurič (2008) implemented an active iterative mechanism for group consensus seeking that could automatically unify the opinions of the DMs. Greco et al. (2012) and Kadziński, Greco, and Słowiński (2013) extended the robust ordinal regression to the sorting problem in the context of group decision-making. Cai, Liao, and Wang (2012) proposed an interactive sorting approach based on the assignment examples of multiple DMs with different priorities. Bezerra, Melo, and Costa (2014) applied the visual, interactive and comparative analysis methodology to the ELECTRE Tri method (Yu, 1992) for the consensus-building in cooperative groups.

Most of the MCS approaches proposed in the literature assume that the evaluation of alternatives on criteria is accurately defined. However, in real life, the evaluation of certain alternatives on particular criteria may involve various types of uncertainties such as ignorance, fuzziness, interval data, and interval belief degrees (Fu & Yang, 2010). It is therefore necessary to use a scheme to represent and process such uncertain information. Within the field of MCS, few methods suit scenarios in which the evaluation of alternatives is not precisely defined. One of the exceptions is the study developed by Janssen and Nemery (2013) in which the authors extended the FlowSort method (Nemery & Lamboray, 2008) to the case of imprecision in the input data which are defined by intervals. Dembczyński et al. (2009) considered an extension of DRSA (the Dominance-based Rough Set Approach) to the context of the imprecise evaluation of alternatives on criteria and the imprecise assignment of alternatives to categories. However, the two methods are not suitable for handling situations in which the data for measuring the performance of an alternative on a criterion is absent or incomplete or in the form of a probability distribution.

Within the field of multiple criteria decision analysis (MCDA), the evidential reasoning (ER) approach (Yang & Xu, 2002a, 2002b) is a well-known method for addressing decision situations characterized by uncertainty. Unlike the majority of conventional MCDA methods, the ER approach describes the performance of an alternative on a criterion with a distributed assessment using a belief structure. In addition, the ER approach uses a new procedure for aggregating multiple criteria based on the distributed assessment framework. The ER approach provides a new avenue for handling various types of uncertainties in a unified format that includes precise data, the absence of data, incomplete data and probability uncertainty. It has been applied to decision problems in many areas, such as engineering design (Chin, Yang, Guo, & Lam, 2009; Yang, Xu, Xie, & Maddulapalli, 2011), environmental impact assessment (Wang, Yang, & Xu, 2006), business management (Hilhorst, Ribbers, van Heck, & Smits, 2008), and group decision-making (Fu & Yang, 2010).

In this paper, we propose a group decision-making approach based on ER to address the MCS problem with uncertainty. We employ the belief structure and the ER algorithm to represent and aggregate uncertain assessments, respectively. In the ER approach, it is necessary for the DMs to specify the utilities of grades in the assessment framework to obtain the global evaluation of alternatives. This elicitation of the preference information is often referred to as the direct elicitation technique, in which the DMs are guided to directly specify the values of the parameters used in the preference model (Greco, Mousseau, & Słowiński, 2008). However, such direct elicitation is considered to be cognitively cumbersome and difficult for the DMs. Alternatively, there is a preference elicitation technique known as indirect elicitation, which is of interest because it requires relatively less cognitive efforts from the DM (Corrente, Greco, & Słowiński, 2012; Kadziński & Słowiński, 2013; Köksalan et al., 2009). For the indirect elicitation technique, the DMs specify certain examples of holistic judgments, from which compatible values of the preference model parameters are induced using the disaggregation–aggregation (or regression) paradigm. The approach proposed in this paper utilizes the indirect preference elicitation technique. Specifically, the DMs participating in the sorting process are required to provide assignment examples for some reference alternatives. A methodology using the disaggregation–aggregation paradigm is then adopted to infer a set of compatible utility function models integrating the utilities of grades from these assignment examples, which is applied to sort other alternatives.

In the context of group decision-making, one major issue to consider is how to help a group cooperatively develop a common MCS model to sort alternatives into categories. However, due to the DMs' different knowledge bases and levels of experience, there may be a diversity of opinions among the group members. What makes the process more difficult is that an agreement between the DMs may have to be reached in spite of the diversity of judgments and the subjective perception of reality (Damart et al., 2007). Thus, prior to the actual sorting of alternatives it is necessary to reach some type of consensus among the DMs in the decision process. In the proposed approach, a consensus-reaching process is developed to help the DMs to interact for the purpose of iteratively reaching an agreement on how to sort alternatives, with consistency preserved at both the individual level and the collective level. A consensus degree is defined to analyze, control and monitor the consensus-reaching process. The consensus degree measures the agreement among the DMs' opinions. The iterative process is composed of several rounds of consensus-reaching. When the consensus degree is at a low level and the DMs are not satisfied with it, we explore possible solutions to help the group adjust assignment examples in order to improve the consensus level. If the consensus degree arrives at a satisfactory level, we build a linear program to determine the collective assignment of alternatives.

The approach proposed in this paper is distinguished from the previous methods by the following new features. First, the ER approach is extended to the case of the sorting problem for the first time. Despite its successful application to ranking and choice problems with uncertainty, no previous method has introduced the ER approach to the sorting problem. The approach proposed in this paper reveals the applicability and flexibility of the ER approach in modelling the uncertainty in the MCS problem. Second, the proposed approach employs the disaggregation–aggregation paradigm to infer a compatible utility function model from the assignment examples provided by the DMs. This technique reduces the cognitive efforts of the DMs to specify the utilities of assessment grades in the ER approach. Third, this paper develops a consensus-reaching process to support interaction among the DMs, helping them to reach a consensus on how to sort the alternatives. The process contributes to the search for a transparent, justifiable and collectively constructed consensus. An additional appeal of this paper stems from the fact that it provides a definition of the consensus measure for the MCS problem in the context of group decision-making. The definition of this consensus measure could be easily integrated with the other existing MCS approaches to the case of group decision-making and could help accelerate the consensus-reaching process.

The remainder of this paper is organized as follows. In Section 2, we provide a brief introduction to the ER approach. In Section 3, we present a group decision-making approach based on ER for the MCS problem with uncertainty. Section 4 demonstrates the approach using an example. The paper ends with conclusions and discussion regarding future research.

2. Brief introduction to the ER approach

The ER approach is a general approach for analyzing MCDA problems characterized by various types of uncertainty using a unified framework – belief structures (Xu, 2012). With belief structures, the