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Decision Support

A group evidential reasoning approach based on expert reliability

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ABSTRACT

The reliability of an expert is an important concept in multiple attribute group decision analysis (MAGDA). However, reliability is rarely considered in MAGDA, or it may be simply assumed that all experts are fully reliable and thus their reliabilities do not need to be considered explicitly. In fact, any experts can only be bounded rational and their various degrees of reliabilities may significantly influence MAGDA results. In this paper, we propose a new method based on the evidential reasoning rule to explicitly measure the reliability of each expert in a group and use expert weights and reliabilities to combine expert assessments. Two sets of assessments, i.e., original assessments and updated assessments provided after group analysis and discussion are taken into account to measure expert reliabilities. When the assessments of some experts are incomplete while global ignorance is incurred, pairs of optimization problems are constructed to decide interval-valued expert reliabilities. The resulting expert reliabilities are applied to combine the expert assessments of alternatives on each attribute and then to generate the aggregated assessments of alternatives. An industry evaluation problem in Wuhu, a city in Anhui Province of China is analyzed by using the proposed method as a real case study to demonstrate its detailed implementation process, validity, and applicability.

1. Introduction

Reliability is an important concept in various domains, such as engineering (Sriramdas, Chaturvedi, & Gargama, 2014), industry (Gonzalez-Gonzalez et al., 2014), transportation (Prabhu Gaonkar, Xie, & Fu, 2013), computer networks (Lin & Yeng, 2013), wireless networks (Chen & Lyu, 2005), software (Yacoub, Cukic, & Ammar, 2004), power (Kwag & Kim, 2014), and satellite (Guo, Monas, & Gill, 2014). In these domains, system reliability is assessed in order to improve system performance or safety. However, a very important factor that influences system reliability, i.e., human behavior, is not taken into account (Purba, Lu, Zhang, & Pedrycz, 2014). Human behavior can significantly influence system performance and safety. Without proper management human factor may result in system accidents (Wang, Luo, Tu, & Liu, 2011).

To decrease human errors and prevent system degradation, human reliability analysis (HRA) has become an important topic in the study of reliability. It focuses on human-machine interaction and integrates human factors into system safety analysis (Vanderhaegen, 2001). Many HRA methods have been developed and applied in different systems, including railway system (Vanderhaegen, 2001), drinking water system (Wu, Hrudey et al., 2009), medical device (Lin et al., 2014), cargo tank cleaning (Akyuz & Celik, 2015), and nuclear power plants (Jung, Yoon, & Kim, 2001). Data collection is key to HRA and limits its practicability (Groth & Mosleh, 2012; Konstandinidou, Nivolianitou, Kiranoudis, & Markatos, 2006). Overall, HRA is conducted to reduce or even prevent the negative influence of human errors on system performance and safety.

Expert reliability in multiple attribute group decision analysis (MAGDA) is different from human reliability in HRA. Expert reliability is usually used to assess the proficiency of specialists in MAGDA. Specifically, they can be profiled by changes in the assessments of experts on the condition that the experts have discussions to clarify the decision problem under consideration and avoid misunderstanding. It is clear that expert reliability in MAGDA is not intended for reducing or preventing system safety problems caused by human-system interaction. As such, introducing expert reliability in MAGDA is a new problem rather than a problem in HRA.

In literature, many researchers have analyzed MAGDA problems. Some have focused on generating consensus-based solutions by partitioning a MAGDA process into a consensus process and an exploitation process (e.g., Choudhury, Shankar, & Tiwari, 2006; Dong, Chen, & Herrera, 2015; Dong, Xu, Li, & Feng, 2010; Fu, Huhns, & Yang, 2014; Fu & Yang, 2010, 2011,2012; Herrera-Viedma, Alonso, Chiclana, & Herrera, 2007; Li, Liechty, Xu, & Lev, 2014; Mata, Martínez, & Herrera-Viedma, 2009). The consensus process aims to reach group

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consensus required, while the exploitation process intends to generate a consensus-based solution. Others have developed different aggregation operators and methods to analyze group decision problems (e.g., Fan & Liu, 2010; Gao, Li, & Liu, 2015; Liu, 2014; Merigó, Casanovas, & Yang, 2014; Wang & Li, 2015) or MAGDA problems (e.g., Feng & Lai, 2014; Jin, Pei, Chen, & Zhou, 2014; Liu & Yu, 2014). However, none has considered expert reliability. This has significant impact on the rationality and validity of decisions made. In MAGDA, experts (or decision makers) are not necessarily reliable. Simon (1955, 1956) believed that experts have bounded rationality due to their limited computational ability and selective memory and perception, and not integrating environmental factors in decision making. As such, expert reliability should be effectively measured and used to analyze MAGDA problems.

In this paper, we propose a new method based on the evidential reasoning (ER) approach (Yang, 2001; Yang, Wang, Xu, & Chin, 2006) to analyze MAGDA problems. We employ the new ER rule established by Yang and Xu (2013) to combine the assessments of experts in a group on each attribute for each alternative. The aggregated group assessments depend not only on expert weights but also on expert reliabilities. In order to determine the final rating, the reliabilities of experts on each attribute for each alternative are measured by the utilities of assessment grades (a concept demonstrated in Section 2) and two sets of experts' assessments, including original assessments and updated assessments provided after group analysis and discussion (GAD), in which the decision problem under consideration is clarified and misunderstanding is avoided as far as possible. Note that the stubbornness of an expert in a group contributes nothing to his reliability due to the fact that the reliability measure is developed from the viewpoints of other experts weighted by their initial reliabilities, as demonstrated in Section 3.1.

After the aggregated group assessments on each attribute for each alternative are generated, they are further combined by the ER rule with attribute weights and reliabilities to produce the aggregated assessments of alternatives, on the basis of which a solution in consideration of expert reliabilities can be made. When there are one or more incomplete expert assessments (see Section 2) on any attribute for an alternative, pairs of optimization problems are constructed to generate the interval-valued aggregated assessment of the alternative.

The rest of this paper is organized as follows. Section 2 presents the ER distributed modeling framework for MAGDA problems. Section 3 focuses on discussing the proposed method in detail. An industry evaluation problem is analyzed in Section 4 to demonstrate the detailed implementation process of the proposed method, and its validity and applicability. Section 5 discusses the influence of the interval-valued combined weight of expert assessments on the solution generated by the proposed method using the problem in Section 4. Finally, this paper is concluded in Section 6.

2. ER distributed modeling framework for MAGDA problems

For the convenience of introducing the proposed method, in the following we present basic notations used to model MAGDA problems in the ER context.

Suppose that a MAGDA problem includes T experts t_j $(j = 1, \ldots, T)$ and a facilitator. The relative weights of the T experts on attribute e_i for alternative a_l are denoted by $\lambda(e_i) = (\lambda^1(e_i), \lambda^2(e_i), \ldots, \lambda^T(e_i))$ such that

$$0 \le \lambda^j(e_i) \le 1 \quad \text{and} \quad \sum_{j=1}^{T} \lambda^j(e_i) = 1. \tag{1}$$

All experts deal with a common multiple attribute decision analysis problem which has M alternatives a_l $(l = 1, \ldots, M)$ and L attributes e_i $(i = 1, \ldots, L)$. The relative weights of the L attributes are signified by $w = (w_1, w_2, \ldots, w_L)$ such that

$$0 \le w_i \le 1 \quad \text{and} \quad \sum_{i=1}^{L} w_i = 1. \tag{2}$$

In addition to w_i, attribute e_i is also associated with its reliability symbolized by r_i. The reliability of an attribute is the inherent property of the attribute and is defined as the degree to which the assessment of an alternative on the attribute is consistent with the correct assessment of the alternative. In other words, the reliability of an attribute is interpreted as the degree to which the assessment of an alternative on the attribute is correct for the alternative. In general, there is a positive correlation between r_i and w_i; that is, a larger r_i indicates a larger w_i and vice versa. However, r_i is not normalized and different from the above w_i in Eq. (2) because w_i characterizes the relative importance of attribute e_i in comparison with other attributes while r_i is regarded to be unrelated to the reliabilities of other attributes in the ER rule.

Assume that $\Omega = \{H_1, H_2, \ldots, H_N\}$ symbolizes a set of grades which is increasingly ordered from worst to best. That is, the utilities of grades $u(H_n)$ $(n = 1, \ldots, N)$ satisfy the constraint $0 = u(H_1) < u(H_2) < \cdots < u(H_N) = 1$ in the ER context. The M alternatives are assessed at the L attributes using H_n $(n = 1, \ldots, N)$. Let expert t_j assess alternative a_l on attribute e_i to grade H_n with a belief degree of $\beta^j_{n,i}(a_l)$, then the assessment can be profiled by $B^j(e_i(a_l)) = \{(H_n, \beta^j_{n,i}(a_l)), n = 1, \ldots, N; (\Omega, \beta^j_{\Omega,i}(a_l))\}$, where $\beta^j_{n,i}(a_l) \ge 0$, $\sum_{n=1}^{N} \beta^j_{n,i}(a_l) \le 1$, and $\beta^j_{\Omega,i}(a_l) = 1 - \sum_{n=1}^{N} \beta^j_{n,i}(a_l)$ represents the degree of global ignorance (Fu & Wang, 2015; Xu, 2012; Yang & Xu, 2013). If $\beta^j_{\Omega,i}(a_l) = 0$, the assessment is complete; otherwise, it is incomplete.

3. The proposed method

In this section, we describe how to determine expert reliabilities and how to generate solutions to MAGDA problems with attribute weights and expert reliabilities, which demonstrate the proposed method by an integrated procedure.

3.1. Determination of expert reliabilities

When the assessments of experts $B^j(e_i(a_l))$ $(j = 1, \ldots, T)$ are combined using the ER algorithm (Wang, Yang, & Xu, 2006; Yang, 2001), the reliability of $B^j(e_i(a_l))$ denoted by $R^j(e_i)$ is assumed to be equal to the weight of $B^j(e_i(a_l))$, i.e., $\lambda^j(e_i)$. Under this assumption, it can be inferred from Eq. (A.2) in Appendix A of the supplementary material that the hybrid weight of $B^j(e_i(a_l))$ is equal to $\lambda^j(e_i)$. However, this cannot be always assumed. In situations where one or more experts may have their own special interests and thus give biased assessments, $R^j(e_i)$ $(j = 1, \ldots, T)$ cannot be simply determined using $\lambda^j(e_i)$ $(j = 1, \ldots, T)$. On the other hand, $R^j(e_i)$ $(j = 1, \ldots, T)$ objectively measures the ability of expert t_j to provide reasonable or unbiased assessments, as demonstrated in Section 1. As such, $R^j(e_i)$ $(j = 1, \ldots, T)$ should be determined by an objective method. To conduct it, GAD is organized by a facilitator, in which the following assumption should be satisfied.

Assumption 1. In GAD organized by a facilitator, it is required that

(1) experts freely communicate with each other to clarify a decision problem under consideration, avoid misunderstanding, and minimize bias;
(2) the facilitator does not provide suggestions on the assessments of the experts; and
(3) each expert does not put pressure on other experts to follow his or her views.

After GAD under Assumption 1, experts independently determine whether and how to renew their assessments. The implication of independence is defined as follows: