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A group decision making model with hybrid intuitionistic fuzzy information

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ABSTRACT

Group decision making (GDM) is among the most important activities that usually occurs in our daily life. This paper extends the TOPSIS (technique for order performance by similarity to an ideal solution) approach to deal with hybrid intuitionistic fuzzy information. Using a projection measure instead of a distance measure, the separations between each alternative decision and its ideal decisions are established in a hybrid intuitionistic fuzzy environment. There are no transformations between intuitionistic fuzzy numbers and interval-valued intuitionistic fuzzy numbers. The alternatives are ranked directly based on original information. An experimental analysis is used to illustrate the feasibility and practicability of introduced method.

1. Introduction

Decision making (Wei, Zhao, & Lin, 2013) is one of the most complex administrative processes in management, which is the procedure to find the best alternative among a set of feasible alternatives, and it may involve some conflicting and incommensurable attributes (criteria). The ongoing development of society and economy has led to profound changes in the decision environments. Sometimes a single decision maker (DM) or expert may be impossible to consider all relevant aspects of a problem. In this case, the decision making problems require to be further extended to group decision making (GDM).

Many existing studies use crisp values to express the decision information in GDM problems. However, with the increasing complexity of the decision system and the lack of knowledge or data about the problem domain, a DM may provide his/her preferences over alternatives with incomplete information, additional qualitative attributes and imprecision preferences. In this instance, fuzzy theory (Zadeh, 1965) might be more suitable for dealing with them.

It is well known that fuzzy set theory has been widely used in many aspects of modern society. However, the traditional fuzzy set faces certain limitations, as it fails to present an overall description of all of the information that is relevant to the studied problems. To improve it further, Atanassov (1986) introduced intuitionistic fuzzy set. Then Atanassov and Gargov (1989) generalized the intuitionistic fuzzy set to uncertain situations, and introduced the interval-valued intuitionistic fuzzy set. For convenience, Xu (2007) introduced the intuitionistic fuzzy number (IFN), and Xu and Chen (2007) introduced the interval-valued intuitionistic fuzzy number (IVIFN). The IFN and IVIFN are very useful decision information, which may express the imprecise or uncertain decision information more abundant and flexible than the fuzzy set, especially with respect to a lack of knowledge or experience, intangible or non-monetary criteria, or a complex and uncertain environment. Therefore, this paper attempts to establish a GDM method with IFN and IVIFN.

The attribute values of alternatives, provided by experts, are commonly represented by one form in one GDM problem. For example, Wibowo and Deng (2013) reported a GDM method with IFNs. İNtepe, Bozdag, and Koc (2013) provided a GDM method with IVIFNs. However, only a single information is sometimes difficult to grade all attributes in a complex GDM problem. Because some attributes might be better to be graded by using IFNs, but other attributes might be more suitable to be graded by using IVIFNs. In this case, if DMs are allowed to use multiple information representations, then they are much easier to provide their preferences over alternatives. However the next question is how to make a decision with hybrid fuzzy information. In general, the hybrid information representations need to be convert into a unified form. For example, the pair of the midpoints in an IVIFN can be regarded

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as an IFN. Thus, the IVIFNs can be converted to IFNs according to the midpoints of IVIFNs. If so, the information about intervals in IVIFNs will be lost in decision process. To solve this problem, this paper attempts to propose a direct GDM method with IFNs and IVIFNs based on an extended TOPSIS (technique for order preference by similarity to ideal solution) technique. There are no the transformations between IFNs and IVIFNs. In other words, in this model, the alternatives will be ranked directly based on the original decision information.

In addition, we often encounter the scenario where some decision information, provided by DMs, is very positive; while the others, provided by the same DMs, are very negative. The positive and the negative information are also very useful information. How to fully utilize them is an important problem in GDM. For this purpose, the TOPSIS (Hwang & Yoon, 1981) technique can just help us realize it. The TOPSIS technique can consider not only a positive ideal decision (PID), but also the negative ideal decision(s) (NID(s)). It is a compromise method (Chai, Liu, & Ngai, 2013; Yu, 1973) between PID and NID(s), which is achieved by a relative closeness. Since appearance of TOPSIS technique, it has been widely used in many applications in decision making (Kalbar, Karmakar, & Asolekar, 2013).

The Euclidean distance or the Hamming distance are commonly used in TOPSIS technique in order to obtain the relative closeness. In fact, the projection method (Yue, 2012a, 2013) is a much better measure than the distance measure. It considers not only the distance but also the module and included angle between objects measured. To improve the TOPSIS technique, this paper will modify the TOPSIS model, in which the separation measure will be replaced by the projection measure.

The rest of this paper is organized as follows. Section 2 introduces the related works. Section 3 gives some basic concepts and operations related to intuitionistic fuzzy information. Section 4 presents a GDM approach with hybrid intuitionistic fuzzy information. Section 5 gives an experimental analysis to illustrate the feasibility and practicability of introduced method. The final section discusses the conclusion and further research of this paper. Some corresponding measures and techniques are provided in Appendix section.

2. Related works

This section introduces the related works, which includes (1) GDM methods with hybrid decision information; (2) TOPSIS and fuzzy TOPSIS techniques; (3) projection methods and applications; and (4) intuitionistic fuzzy theory and applications.

2.1. Hybrid group decision making methods

Because of different experiential, cultural and educational backgrounds, different DMs may use different preference structures to express their individual preference information. Recently, the GDM methods with hybrid/heterogeneous decision information have attracted great attention from researchers (Chen, Zhang, & Dong, 2015). For example, Kar (2015) presented an application of a hybrid approach for the supplier selection problem. Khalili-Damghani and Sadi-Nezhad (2013) proposed a hybrid fuzzy GDM approach for sustainable project selection. Wan and Dong (2015) developed a novel interval-valued intuitionistic fuzzy mathematical programming method for hybrid GDM considering alternative comparisons with hesitancy degrees. Igoulalene, Benyoucef, and Tiwari (2015) presents two novel fuzzy hybrid GDM approaches for the strategic supplier selection problem. Li and Wan (2014) described a fuzzy inhomogenous multi-attribute GDM approach to solve outsourcing provider selection problems, in which the trapezoidal fuzzy numbers, intuitionistic fuzzy sets, intervals and real numbers are used to express the inhomogenous decision information. Wei (2011) investigated a dynamic hybrid multi-attribute decision making (MADM) method, in which the decision information is expressed in real numbers, interval numbers or linguistic labels (linguistic labels can be described by triangular fuzzy numbers).

A good review article is introduced by Chen et al. (2015), which divided the GDM methods with hybrid information into three categories: (1) direct approach (Herrera, Herrera-Viedma, & Verdegay, 1996). In the direct approaches, all standardized individual decisions are aggregated into a collective decision. The following step is that the hybrid information is transformed into a preference information. Then exploit and select the best alternative(s) from the collective decision; (2) indirect approach. In the indirect approaches, the hybrid decision information is transformed into a uniformed decision information, and aggregate all individual decisions into a collective one. Then the alternatives are ranked based on the collective decision with uniformed information; (3) optimization-based approach. Based on different multi-objective optimization models, the hybrid information is integrated in order to rank attributes and alternatives.

2.2. TOPSIS and fuzzy TOPSIS

TOPSIS was initially proposed by Hwang and Yoon (1981). It has been shown to be one of the best MADM methods in addressing the rank reversal issue, which is the change in the ranking of alternatives when a non-optimal alternative is introduced (Zanakis, Solomon, Wishart, & Dublish, 1998). Many researchers have employed the TOPSIS technique to solve the MADM and GDM problems (Li, Adeli, Sun, & Han, 2011; Chen, 2015). Roszkowska and Wachowicz (2015) analyzed an application of fuzzy TOPSIS to scoring the negotiation offers in ill-structured negotiation problems. Baykasoğlu and Gölcük (2015) developed a novel MADM model via fuzzy cognitive maps and hierarchical fuzzy TOPSIS. Şengül, Eren, Shiraz, Gezder, and Şengül (2015) developed a multi-criterion decision support framework for ranking renewable energy supply systems in Turkey. Chen (2015) presented an approach for addressing GDM problems with the interval-valued intuitionistic fuzzy sets. Bilbao-Terol, Arenas-Parra, Cañal-Fernández, and Antomil-Ibias (2014) provided a methodology to assess the sustainability of investments in sovereign bonds using TOPSIS. Yue (2014) introduced a TOPSIS-based GDM methodology in intuitionistic fuzzy setting.

A review article about TOPSIS techniques is introduced by Behzadian, Khanmohammadi Otaghsara, Yazdani, and Ignatius (2012).

2.3. Projection methods and applications

The projection method has widely used in MADM problems (Wang, Li, & Zhang, 2012; Zeng, Baležentis, Chen, & Luo, 2013). For example, Xu and Da (2004) modeled an uncertain MADM method. Wei (2009) proposed a MADM method based on the projection technique, in which the attribute values are characterized by IFNs. Xu and Hu (2010) established two projection models for GDM problems with IFNs and IVIFNs, respectively. Zheng, Jing, Huang, and Gao (2010) developed an application of improved grey projection method to evaluate sustainable building envelope performance. Fu et al. (2011) discussed the risk assessment of ad hoc networks, in which the risk values are assessed by grey projection value. Yue (2012a, 2012b, 2013) suggested three GDM methods by using the projection method. Xu and Liu (2013) described a GDM approach based on projection method under uncertain fuzzy environment. Zhang, Jin, and Liu (2013) proposed a grey relational projection method for MADM based on intuitionistic trapezoidal fuzzy number.