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An extended intuitionistic fuzzy TOPSIS method based on a new distance measure with an application to credit risk evaluation

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ABSTRACT

In the process of multi-criteria decision making (MCDM), decision makers or experts usually exploit quantitative or qualitative methods to evaluate the comprehensive performance of all alternatives on each criterion. How the decision-makers or the experts make the evaluations relies on their professional knowledge and the actual performances on the criteria characters of the alternatives. However, because of both the objective complexity of decision making problem and the uncertainty of human subjective judgments, it is sometimes too hard to get the accurate evaluation information. Intuitionistic fuzzy set (IFS) is a useful tool to deal with uncertainty and fuzziness of complex problems. In this paper, we propose a new distance measure between IFSs and prove some of its useful properties. The experimental results show that the proposed distance measure between IFSs can overcome the drawbacks of some existing distance and similarity measures. Then based on the proposed distance measure, an extended intuitionistic fuzzy TOPSIS approach is developed to handle the MCDM problems. Finally, a practical application which is about credit risk evaluation of potential strategic partners is provided to demonstrate the extended intuitionistic fuzzy TOPSIS approach, and then it is compared with other current methods to further explain its effectiveness.

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1. Introduction

Fuzzy set (FS) theory presented by Zadeh (1965) [34] has been widely used as an efficient tool to dispose of vagueness and uncertainty, meanwhile it has revealed prosperous applications in various fields of economy, management and industry. The most distinctive feature of Zadeh's FS is the considerations of membership degrees to the elements. Over the past few decades, some extensions of the traditional FS theory and relevant applications have been widely made. Specifically, as one of the well-known extensions of ordinary fuzzy set, intuitionistic fuzzy set (IFS) proposed by Atanassov (1986) [1], is characterized by a membership degree, a non-membership degree, and a hesitation degree. It has been found to be highly useful in dealing with fuzziness, therefore many researchers have investigated this topic and have got some meaningful results [23].

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Distance and similarity measures between IFSs, which are used as the important decision-making tools, have received great attention over the last decades. A lot of researches on the distance and similarity measures between IFSs have been done in the literature. For example, Szmidt and Kacprzyk (2000) [24] first defined four basic distance measures between IFSs: the Hamming distance, the normalized Hamming distance, the Euclidean distance, and the normalized Euclidean distance. Grzegorzewski (2004) [10] extended some new methods for measuring distances between IFSs and interval-valued FSs based on the Hausdorff metric. Xu (2007) [29] introduced some similarity measures between IFSs and used them to solve the real MCDM problems. Yang and Chiclana (2012) [31] proposed a three dimensional Hausdorff distance and compared its consistency with its two dimensional counterparts, which shows the usefulness of the three dimensional functions. Ye (2011) [33] presented a cosine similarity measure and a weighted cosine similarity measure between IFSs and applied them to pattern recognition and medical diagnosis. More recently, Boran and Akay (2014) [2] defined a new general type of similarity measure between IFSs depending on two parameters and applied it to pattern recognition. Chen et al. (2016) [4] proposed a new similarity measure between IFSs based on the centroid points of the transformed right-angled triangular fuzzy numbers and proved some properties of the proposed similarity measure. However, some existing distance and similarity measures between IFSs are not effective in some cases. For example, Mitchell (2003) [21] pointed out that Dengfeng-Chuntian similarity measure (2002) [16] may get counter-intuitive results in some situations. Chen (2007) [7] pointed out that some errors existing in Grzegorzewski (2004) [10] by showing some counter examples, where he found that the inequalities of the Euclidean distances and the normalized Euclidean distances for IFSs are not valid. The distance and similarity measures in [16], [19] and [33] do not satisfy the properties of distance measures in some situations [2]. Chen and Chang (2015) [3] pointed out that the distance measures in Ye (2011) [33] and Zhang et al. (2013) [36] have the drawback of "the division by zero". Chen et al. (2016) [4] indicated that the distance and similarity measures in [2,3,6,12,13,16–21,33] and [36] may get unreasonable results in some situations. Therefore, we need to develop a new distance measure between IFSs to overcome these drawbacks of the existing distance and similarity measures.

Multi-criteria decision making (MCDM) provides a systematic quantitative approach for the decision making problems involving multiple criteria and actions and can assist decision makers in rationally considering all the important objective and subjective criteria for a problem [11]. The TOPSIS is one of the most well-known classical MCDM approaches, and was first introduced by Hwang and Yoon (1981) [14]. The essential goal of the TOPSIS approach is that the most preferred alternative should have not only the shortest distance from the positive ideal solution, but also the farthest distance from the negative ideal solution [22]. The TOPSIS has been widely applied to solve the MCDM problems because it has a reasonable logic [8]. In classical TOPSIS methods, crisp numerical values are used to express the performance rating of criteria. Over the past decade, the combination of TOPSIS method and IFSs has been widely exploited by many researchers. Ye (2010) [32] proposed an extension of the TOPSIS method with interval-valued intuitionistic fuzzy numbers to solve the partner selection problem under incomplete and uncertain environment. Zhang and Yu (2012) [35] also extended the TOPSIS with interval-valued intuitionistic fuzzy numbers, and proposed a cross-entropy based weights of attributes determination method. Wang et al. (2016) [27] developed an integrating OWA-TOPSIS approach in intuitionistic fuzzy environment to tackle fuzzy MCDM problems. Joshi and Kumar (2014) [15] proposed an intuitionistic fuzzy TOPSIS method based on distance measure and intuitionistic fuzzy entropy for MCDM problem to rank the alternatives. However, these TOPSIS methods under intuitionistic fuzzy environment proposed in [15,27,32] have some drawbacks in the real decision making process. As is known to all, distance measure is the key to the TOPSIS method, which determines the accuracy and rationality of decision making. The distance measures used in Ye (2010) [32] and Wang et al. (2016) [27] are the Euclidean distance between IFSs. As discussed above, this distance measure itself has some drawbacks in some situations, which could have an adverse effect on the TOPSIS procedure. In Joshi and Kumar's method [15], the distance measure that it used has the drawback of "division by zero problem" described in [5], so this method sometimes cannot get the preference orders of alternatives.

In this study, we consider the distance measure and the characteristics of the IFS to propose a novel intuitionistic fuzzy distance measure, then investigate some of its useful properties and compare it with the existing distance measures between IFSs. The experimental results show that the proposed distance measure between IFSs can overcome the drawbacks of some existing distance and similarity measures. Then, we develop an extended intuitionistic fuzzy TOPSIS approach based on the proposed new distance measure so as to solve the real MCDM problems, and it is compared with other methods to further explain its effectiveness and advantages.

This paper is organized as follows: In Section 2, we introduce some basic concepts on IFSs and the properties of distance measure between IFSs. In Section 3, a new type of distance measure for IFSs is proposed. We compare some existing distance measures between IFSs with the proposed distance measure. In Section 4, an extended intuitionistic fuzzy TOPSIS method based on the proposed distance measure for MCDM is presented. Section 5 presents a case study about credit risk evaluation of potential strategic partners to demonstrate the proposed approach. Some discussions are given in Section 6, and finally, the conclusions are given in Section 7.

2. Preliminaries

In this section, we give a brief introduction to some basic concepts on IFSs, the distance measure and the normalized Euclidean distance between IFSs.

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