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A possibility degree method for interval-valued intuitionistic fuzzy multi-attribute group decision making

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ABSTRACT

The ranking of interval-valued intuitionistic fuzzy sets (IVIFSs) is very important for the interval-valued intuitionistic fuzzy decision making. From the probability viewpoint, the possibility degree of comparison between two interval-valued intuitionistic fuzzy numbers (IVIFNs) is defined by using the notion of 2-dimensional random vector, and a new method is then developed to rank IVIFNs. Hereby the ordered weighted average operator and hybrid weighted average operator for IVIFNs are defined based on the Karnik–Mendel algorithms and employed to solve multi-attribute group decision making problems with IVIFNs. The individual overall attribute values of alternatives are obtained by using the weighted average operator for IVIFNs. By using the hybrid weighted average operator for IVIFNs, we can obtain the collective overall attribute values of alternatives, which are used to rank the alternatives. A numerical example is examined to illustrate the effectiveness and flexibility of the proposed method in this paper.

1. Introduction

Fuzzy set (FS) theory has long been introduced to handle inexact and imprecise data by Zadeh [56]. The drawback of using the single membership value in FS theory is that the evidence for $x \in X$ and the evidence against $x \in X$ are in fact mixed together (Here X is the universe of discourse). In order to tackle this problem, Atanassov [1] proposed the intuitionistic fuzzy set (IFS) using two characteristic functions expressing the degree of membership and the degree of non-membership of elements of the universal set to the IFS. It can cope with the presence of vagueness and hesitancy originating from imprecise knowledge or information. IFS has been widely applied to the multi-attribute decision making (MADM) [3,5,6,9–13,19,22,23,25–30,32,33,36,47,50–52,54,57] and multi-attribute group decision making (MAGDM) [17,18,20,27,35,37,39,41]. These researches can be roughly classified into four types: aggregation operators, similarity (or distance) measures, extension of classic decision making methods and preference relation, which are respectively reviewed as follows.

In the aspect of aggregation operators, Li [11,12] and Li et al. [18] proposed the generalized OWA operators with IFSs. Liu and Wang [23] proposed the intuitionistic fuzzy point operators. Xu [39] developed the intuitionistic fuzzy power aggregation operators. Xu and Yager [48] developed some geometric aggregation operators based on IFS, such as the intuitionistic fuzzy weighted geometric operator, the intuitionistic fuzzy ordered weighted geometric operator, and the intuitionistic fuzzy hybrid geometric (IFHG) operator, and applied them to MADM. Xu [35] used the IFHG operator to propose a MAGDM method with incomplete weight information under intuitionistic fuzzy environment. Yang and Chen [52] defined the quasi-arithmetic intuitionistic fuzzy OWA operators. Zeng and Su [57] proposed the intuitionistic fuzzy ordered weighted distance operator. Wei [27] proposed the induced intuitionistic fuzzy ordered weighted geometric (I-IFOWG) operator and applied to

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MAGDM with intuitionistic fuzzy numbers (IFNs [48]). Zhao et al. [58] developed some new generalized aggregation operators, such as generalized intuitionistic fuzzy weighted averaging operator, generalized intuitionistic fuzzy ordered weighted averaging operator, generalized intuitionistic fuzzy hybrid averaging operator, and applied to MADM with intuitionistic fuzzy information. These aggregation operators for IFNs may be viewed as the extension of the ones for the real numbers, which mainly involve the arithmetic aggregation operators, geometric aggregation operators, power aggregation operators, generalized average operators and induced aggregation operators.

In the aspect of similarity (or distance) measures, Li [9] discussed some measures of dissimilarity in intuitionistic fuzzy structures. Xu [32] defined the normalized Hamming and distance between two IFNs and proposed the intuitionistic fuzzy MADM method. Xu [33] defined similarity measures of IFSs based on the geometric distance model, the set-theoretic approach and the matching function, respectively, and applied the similarity measures to the MADM under intuitionistic fuzzy environment. Xu and Yager [49] also defined some new similarity measures of IFSs based on the distance measures. These similarity (or distance) measures of IFSs also can be applied to pattern recognitions and approximate reasoning.

In the aspect of extension of classic decision making methods, Li [13] and Li et al. [17] extended the classic LINMAP method to the intuitionistic fuzzy environments. Wu and Chen [28] proposed the ELECTRE multicriteria analysis approach based on IFSs. Xu and Hu [47] constructed the projection models for intuitionistic fuzzy MADM. These decision making methods under intuitionistic fuzzy environments generalize the classic decision making methods, such as TOPSIS, ELECTRE and LINMAP.

In the aspect of preference relation, Xu [36] defined some concepts, such as consistent intuitionistic preference relation, incomplete intuitionistic preference relation and acceptable intuitionistic preference relation, etc. He also developed an approach to group decision making based on intuitionistic preference relations and an approach to group decision making based on incomplete intuitionistic preference relations, respectively, in which the intuitionistic fuzzy arithmetic averaging operator and intuitionistic fuzzy weighted arithmetic averaging operator are used to aggregate intuitionistic preference information, and the score function and accuracy function are applied to the ranking and selection of alternatives. Xu and Yager [49] investigated some intuitionistic fuzzy preference relations and their measures of similarity for the evaluation of agreement within a group. The intuitionistic fuzzy preference relations enrich the research content of intuitionistic fuzzy decision making theory.

Atanassov and Gargov [2] further generalized the IFS in the spirit of the ordinary interval-valued fuzzy set (IVFS) and defined the concept of an interval-valued intuitionistic fuzzy set (IVIFS), which enhances greatly the representation ability of uncertainty than IFS. Recently, IVIFSs were also used in the fields of MADM [4,14–16,26,32,42,53] and MAGDM [27,31,34,38, 40,43–45,49,58]. Similar to the IFS, these researches on IVIFSs are mainly focused on the aggregation operators, similarity (or distance) measures, extension of classic decision making methods and preference relation, which are respectively reviewed as follows.

In the aspect of aggregation operators, Xu [31] defined some operational laws of interval-valued intuitionistic fuzzy numbers (IVIFNs) and then proposed the interval-valued intuitionistic fuzzy weighted arithmetic aggregation operator and interval-valued intuitionistic fuzzy weighted geometric aggregation operator. Xu [38] used the Choquet integral to propose the interval-valued intuitionistic fuzzy correlated averaging operator and the interval-valued intuitionistic fuzzy correlated geometric operator to aggregate interval-valued intuitionistic fuzzy information. Xu and Chen [44] developed some geometric aggregation operators for IVIFNs. Wei [27] proposed the induced interval-valued intuitionistic fuzzy ordered weighted geometric (I-IIFOWG) operator and applied to MAGDM with IVIFNs. Xu and Chen [45] proposed the interval-valued intuitionistic fuzzy Bonferroni means. Zhao et al. [58] developed generalized interval-valued intuitionistic fuzzy weighted averaging operator, generalized interval-valued intuitionistic fuzzy ordered weighted averaging operator, generalized interval-valued intuitionistic fuzzy hybrid average operator, and applied to MADM with interval-valued intuitionistic fuzzy information. These aggregation operators for IVIFNs may be roughly divided into two kinds. One is the aggregation operators with independent attributes, including arithmetic aggregation operators and geometric aggregation operators, the other is the aggregation operators with dependent attributes, such as the interval-valued intuitionistic fuzzy correlated averaging operator and the interval-valued intuitionistic fuzzy correlated geometric operator [38].

In the aspect of similarity (or distance) measures, Xu [32] defined the normalized Hamming distance between two IVIFNs and proposed the interval-valued fuzzy MADM method. Xu [34] defined the Hamming and Euclidean distances, the Hamming and Euclidean distances based on the Hausdorff metric for IVIFSs. The corresponding similarity measures for IVIFSs are also defined and applied to pattern recognitions. The similarity measures for IVIFSs also can be applied to MADM with interval-valued fuzzy assessment information.

In the aspect of extension of classic decision making methods, Li [14] developed the closeness coefficient-based nonlinear-programming method for interval-valued intuitionistic fuzzy MADM with incomplete preference information. Li [15] proposed the TOPSIS-based nonlinear-programming methodology for MADM with IVIFSs. Li [16] proposed the linear-programming method for MADM with IVIFSs. These decision methods under interval-valued intuitionistic fuzzy environments also generalize the classic decision making methods, such as TOPSIS and LINMAP. The other methods, such as ELECTRE and PROMETHEE, are expected to be applied to MADM and MAGDM with IVIFSs.

In the aspect of preference relation, Xu and Cai [42] investigated the incomplete interval-valued intuitionistic fuzzy preference relations. Xu and Chen [43] developed the ordered weighted aggregation operator and hybrid aggregation operator for aggregating interval-valued intuitionistic preference information. Interval-valued intuitionistic judgment matrix and its score matrix and accuracy matrix were defined. Some of their desirable properties were investigated in detail. The rela-