Interval-Valued Intuitionistic Fuzzy Sets based Method for Multiple Criteria Decision-Making

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ABSTRACT

Due to the huge applications of fuzzy set theory, many generalizations were available in literature. Atanassov (1983) and Atanassov and Gargov (1989) introduced the notions of intuitionistic fuzzy sets (IFSs) and interval-valued intuitionistic fuzzy sets (IVIFSs) respectively. It is observed that IFSs and IVIFSs are more suitable tools for dealing with imprecise information and very powerful in modeling real life problems. However, many researchers made efforts to rank IVIFSs due to its importance in fusion of information. In this paper, a new ranking method is introduced and studied for IVIFSs. The proposed method is compared and illustrated with other existing methods by numerical examples. Then, it is utilized to identify the best alternative in multiple criteria decision-making problems in which criterion values for alternatives are IVIFSs. On the basis of the developed approach, it would provide a powerful way to the decision-makers to make his or her decision under IVIFSs. The validity and applicability of the proposed method are illustrated with practical examples.

KEYWORDS

Accuracy Function, Fuzzy Sets, Interval-Valued Intuitionistic Fuzzy Sets, Multiple Criteria Decision-Making, Score Function

1. INTRODUCTION

Zadeh (1965) introduced the concept of fuzzy sets as the generalization of traditional classical sets. Atanassov (1983, 1986) introduced the concept of intuitionistic fuzzy set (IFS), which is characterized by a membership degree, non-membership degree, and a hesitancy degree. So IFS is more powerful tool to deal with uncertainty and vagueness in real applications than fuzzy sets and received more and more attention since its appearance. Gau and Buehrer (1993) gave the concept of vague set. However, Bustine and Burillo (1996) proved that the notion of vague set is the same as that of IFS. Turksen (1986) and Gorzaleczan (1987) studied the notion of interval-valued fuzzy sets (IVFSs). A generalization of the notion of ordinary interval valued fuzzy sets was given by Atanassov and Gargov (1989), and introduced the notions of interval-valued intuitionistic fuzzy sets (IVIFSs), which is characterized by a membership degree range and a non-membership degree range. Atanassov (1994) defined some operators over IVIFSs. The book published by Li (2014) provides theoretical researches and practical applications from different fields especially decision science, fuzzy system theory, and intuitionistic fuzzy system theory.

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Chen and Tan (1994) and Hong and Choi (2000) presented methods for handling multi-criteria fuzzy decision-making problems under vague set theory. Li (2005), Lin et al. (2007), Liu and Wang (2007), Xu (2007a, 2007b) and Tan and Chen (2010) developed some methods for multi-criteria fuzzy decision-making methods based on IFSs. The pioneering work of Atanassov and Gargov (1989) has received much more attention from practitioners due to the huge applications in decision making. Xu (2007c), Xu and Chen (2007a, 2007b), Ye (2009) and Yu et al. (2012) were studied multi-criteria fuzzy decision-making methods based on IVIFSs. He et al. (2013) developed a series of generalized interval-valued Atanassov’s intuitionistic fuzzy power aggregation operators by generalizing the power averaging operators to interval-valued Atanassov’s intuitionistic fuzzy environments. He et al. (2015) presented a multiple attribute decision making method under intuitionistic fuzzy environment based on Bonferroni mean (BM) and it was further extended by He and He (2015). Recently, Li and Liu (2015) developed a new methodology for solving matrix games with payoffs of Atanassov’s intuitionistic fuzzy (I-fuzzy) numbers. Wan and Li (2015) developed a mathematical programming method for the IVIF on the basis of the attribute weights and fuzzy ideal solution (FIS).

In multi-criteria fuzzy decision-making problems under IFSs, the notion of ranking of intuitionistic fuzzy numbers (IFNs) plays a vital role in real life applications. Mitchell (2004) and Nayagam et al. (2008) studied ranking of intuitionistic fuzzy numbers. In many real life problems, it is necessary to rank interval-valued intuitionistic fuzzy numbers (IVIFNs) for decision makers to make decisions. Hence, ranking of IVIFNs is an important component of the decision-making process. Xu (2007c) and Xu and Chen (2007a) proposed score function and accuracy function to rank IVIFNs. Ye (2009), Nayagam et al. (2011) also proposed a novel accuracy function to rank IVIFNs. A new score function is developed by Yu, Wu and Lu (2012) to rank IVIFNs. One of main reason of the present study is that in some situations the existing techniques for ranking IVIFNs using a score function or an accuracy function do not give sufficient information about alternatives.

To do this, a novel accuracy function is developed to overcome this situation. The remaining part of this paper is organized as follows. In Section 2, we briefly studied the definitions of IVIFSs, accuracy function, novel accuracy function, score function, arithmetic and geometric aggregation operators, interval-valued intuitionistic fuzzy prioritized weighted average (IVIFPWA) and interval-valued intuitionistic fuzzy prioritized weighted geometric (IVIFPWG) operators for IVIFSs. In Section 3, illustrative examples are given to show the inapplicability of the existing functions and motivations to introduce a new accuracy function to compare IVIFSs. A novel accuracy function by taking into account the unknown degree (hesitancy degree) of IVIFSs is introduced in Section 4, whose desirable properties are also studied in this section. In section 5, the importance of the proposed accuracy function is studied by giving illustrative examples to show that the proposed function is more reasonable and effective to decision makers than the methods developed by Xu (2007c), Ye (2009), Nayagam et al. (2011) and Yu et al. (2012).

2. PRELIMINARIES

In this section, some definitions related to the present study are studied, summarized and presented.

Definition 2.1. (Atanassov, 1986): Let X be a non-empty set called a universe of discourse. An IFS A in X is defined as an object of the following form

\[ A = \{ (x, t_A(x), f_A(x)) : x \in X \} , \]

where the functions \( t_A : X \rightarrow [0,1] \) and \( f_A : X \rightarrow [0,1] \) define the “degree of membership” and the “degree of non-membership” of the element \( x \in X \) respectively, and for every element x...
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