Applied Soft Computing 38 (2016) 988–999

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

A new generalized improved score function of interval-valued intuitionistic fuzzy sets and applications in expert systems

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ARTICLE INFO

Article history:
Received 22 March 2015
Received in revised form 17 October 2015
Accepted 18 October 2015
Available online 28 October 2015

Keywords:
Multi-criteria decision making
Attribute weights
Score function
Interval-valued intuitionistic fuzzy number

ABSTRACT

The objective of this paper is divided into two folds. Firstly, a new generalized improved score function has been presented in the interval-valued intuitionistic fuzzy sets (IVIFSs) environment by incorporating the idea of weighted average of the degree of hesitation between their membership functions. Secondly, an IVIFSs based method for solving the multi-criteria decision making (MCDM) problem has been presented with completely unknown attribute weights. A ranking of the different attributes is based on the proposed generalized improved score functions and the sensitivity analysis on the ranking of the system has been done based on the decision-making parameters. An illustrative examples have been studied to show that the proposed function is more reasonable in the decision-making process than other existing functions.

1. Introduction

Multi-criteria decision making (MCDM) is one of the process for finding the optimal alternative from all the feasible alternatives according to some criteria or attributes. Traditionally, it has been generally assumed that all the information which access the alternative in terms of criteria and their corresponding weights are expressed in the form of crisp numbers. But it has been widely recognized that most of the decisions in the real-life situations are taken in the environment where the goals and constraints are generally imprecise or vague in nature and hence cannot estimate his preference with an exact numerical value. This is due to the fact that most of the information given by the decision-makers should be under time pressure and lack of knowledge or data. Moreover, it may be that the decision makers have limited information processing capacities. Therefore, the analysis conducted under such circumstances are not ideal and hence does not tell the exact information to the system analyst. To cope with such situation, fuzzy set theory [1] has been widely used for handling the uncertainties and vagueness of the data. After their successful application of the fuzzy set theory, researchers are engaged in their extensions and out of that intuitionistic fuzzy set theory [2] is one of the most permissible extensions of the fuzzy set theory and has been widely used in MCDM. The concept of IFSs is an alternative approach to define the fuzzy set in terms of their degree of membership and nonmembership such that their sum is less than or equal to one. Atanassov and Gargov [3] found that IFSs need the decision maker to give the exact values of the membership degree, the non-membership degree and the hesitancy degree. This is still difficult in some situations. For handling this issue, it is convenient to express the decision makers information/preferences in the form of interval values rather than point values and hence called interval valued intuitionistic fuzzy sets (IVIFSs) that are characterized by an interval membership function, an interval non-membership function and an interval hesitancy function. Such a generalization further facilitates representing inherent imprecision and uncertainty of the decision makers.

Wang and Wang [4] presented a method for multi-attribute decision making under the interval-valued intuitionistic fuzzy environment, where all the information is characterized by interval-valued intuitionistic fuzzy numbers and the information about the weights of the attributes are incomplete. Ye [5] presented a method for multicriteria fuzzy decision making based on an accuracy function under the interval-valued intuitionistic fuzzy environment. Nayagam et al. [6] presented a method for multicriteria decision making based on ranking interval-valued intuitionistic fuzzy sets. Wang et al. [7] presented multi-attribute decision making models and methods under the

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http://dx.doi.org/10.1016/j.asoc.2015.10.040

interval-valued intuitionistic fuzzy environment. Xiao and Wei [8] presented a method to deal with the supplier selection problem in supply chain management with interval-valued intuitionistic fuzzy information. Liu and Xie [9] presented the weighted score function and the weighted accuracy function of interval-valued intuitionistic fuzzy sets for multicriteria fuzzy decision making. Luo et al. [10] presented a method for multicriteria fuzzy decision making based on the weighted correlation coefficient of interval-valued intuitionistic fuzzy sets. Wei [11] developed an intuitionistic fuzzy weighted geometric operator-based approach to solve multi-attribute group decision making problems. Bai [12] proposed an improved score function for the effective ranking order of the interval-valued IFSs and interval-valued intuitionistic fuzzy TOPSIS method based on the score function to solve MADM in which information about the criterion weights is known. Zhang et al. [13] proposed an entropy based decision making method to solve MADM problems with completely unknown attribute weights. Mitchell [14] and Nayagam et al. [15] studied ranking of intuitionistic fuzzy numbers. Xu [16] and Xu and Chen [17] proposed score function and accuracy function to rank interval-valued intuitionistic fuzzy numbers. Ye [18] proposed an improved algorithm for score functions by taking into account the effect of an unknown degree (hesitancy degree) of vague sets and a multi criteria decision-making method based on the score function of vague sets. Xu [19] developed some aggregation operators for IVIFSs, such as the interval-valued intuitionistic fuzzy weighted geometric aggregation (IIFWGA) operator and the interval-valued intuitionistic fuzzy weighted arithmetic aggregation (IIFWAA) operator, and gave an application of the IIFWGA and IIFWAA operators to multi criteria decision-making problems by using the score function and accuracy function of interval-valued intuitionistic fuzzy numbers. Wang et al. [20] developed a method for comparing two IVIFNs by introducing two new functions: the membership uncertainty index and the hesitation uncertainty index. Chen et al. [21] proposed a new method for ranking interval-valued intuitionistic fuzzy values to overcome the drawback of Ye [5] accuracy function. Chen [22] gave a comparative analysis of score functions for multi criteria decision-making in intuitionistic fuzzy settings. Xu and Wang [23,24] developed an aggregation operators to solve the multiple attribute decision making problems under Atanassov's intuitionistic fuzzy environment. Garg et al. [25] proposed entropy based multi-criteria decision making method under the fuzzy environment and by unknown attribute weights. Garg [26] developed some new intuitionistic fuzzy multiplicative interactive weighted geometric (IFMIWG), intuitionistic fuzzy multiplicative interactive ordered weighted geometric (IFMIOWG) and intuitionistic fuzzy multiplicative interactive hybrid weighted geometric (IFMIHWG) operators to solve the multiple criteria decision making problems. Wu and Chiclana [27] presented a risk attitudinal ranking method for interval-valued intuitionistic fuzzy numbers based on novel score and accuracy expected functions.

As the ranking of intuitionistic fuzzy numbers plays a main role in real life problems involving intuitionistic fuzzy decision-making, intuitionistic fuzzy clustering. However, in some cases the existing proposed technique for ranking interval-valued intuitionistic fuzzy numbers using a score or accuracy functions do not give sufficient information about the alternatives. Therefore, there is a need of such improved score function which will handle the shortcomings of the above score functions and give the decision maker regarding the sufficient information about the alternatives. Moreover, from the survey, it has been observed that the final ranking order of alternatives highly depends on the attribute weights and hence the proper assessment of the attribute weights play a dominant role in the decision-making process. Based on the information acquisition, the attribute weights in multi-criteria decision making is classified as subjective as well as objective. The former ones are determined by preference information on the attributes as given by the decision-maker while the latter one are determined by the decision-making matrix. The Shannon entropy method is one of the most famous approach for determining the objective attribute weights, which express the relative intensities of attribute importance to signify the average intrinsic information transmitted to the decision maker. Thus, it is an important task for finding the proper attribute weights which will help the decision maker for obtaining the efficient decision under a reasonable time.

Therefore, the objective of this paper is divided into two folds. Firstly, generalized improved score function has been proposed by taking into account the unknown degree (hesitancy degree) of IVIFSs. Secondly, based on these generalized score functions, decision making method has been proposed for solving the MCDM problems. In order to see the relative importance of criteria, weights to each criteria have been given by using the intuitionistic fuzzy entropy measure and a generalized interval-valued intuitionistic fuzzy averaging operator (GIVIFWA) emphasizing the individual influence is used to aggregate all individual decision makers' opinion for rating candidates. The proposed score function has been applied to compare the IVIFSs and the grade of alternatives. The rest of the manuscript has been described as follows. Section 2 presented the brief overview of the interval-valued intuitionistic fuzzy sets and the existing score and accuracy function. The shortcoming of the existing and the proposed generalized improved score function is described in Section 3. Section 4 presented the MCDM approach in an IVIFSs environment for choosing the best alternative among the feasible alternatives. Finally the approach has been illustrated through a case studies given in Section 5. The concrete conclusion about the manuscript is described in Section 6.

2. Interval valued intuitionistic fuzzy sets and its score functions

Intuitionistic fuzzy set (IFS) is one of the widely used and successful extension of the concept of fuzzy set [1]. In order to model the hesitation and uncertainty about the degree of membership, Atanassov in 1986 [2] add an extra degree, called as degree of non-membership, to the notion of the fuzzy set. In fuzzy set, the hesitation degree or degree of non-membership of an element of the universe is simply defined as one minus the degree of membership functions and therefore it is fixed. But in real-life or many situations, there is a degree of hesitation between the membership functions and hence they are independent.

2.1. Intuitionistic fuzzy set (IFS)

An intuitionistic fuzzy set (IFS) $\widetilde{A}$ in a finite universe of discourse $X = \{x_1, x_2, \ldots, x_n\}$ is given by [2]

$$\widetilde{A} = \{\langle x, \mu_A(x), \nu_A(x)\rangle | x \in X\}$$

where $\mu_A(x)$ and $\nu_A(x)$ are the membership and non-membership functions of $\widetilde{A}$. The numbers $\mu_A(x)$ and $\nu_A(x)$ describes respectively the degree of belonging and rejection of $x \in X$ in $\widetilde{A}$. For convenience, an IFN α is expressed as $\langle \mu, \nu \rangle$, where

$$\mu \in [0, 1], \quad \nu \in [0, 1] \quad \text{and} \quad \mu + \nu \in [0, 1]$$