Information Fusion 27 (2016) 215–227

Contents lists available at ScienceDirect

Information Fusion

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

Fuzzy multiattribute group decision making based on intuitionistic fuzzy sets and evidential reasoning methodology

Shyi-Ming Chen [a,*], Shou-Hsiung Cheng [b,c], Chu-Han Chiou [a]

[a] Department of Computer Science and Information Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan
[b] Department of Information Management, Chienkuo Technology University, Changhua, Taiwan
[c] Department of Kinesiology Health Leisure Studies, Chienkuo Technology University, Changhua, Taiwan

ARTICLE INFO

Article history:
Received 8 December 2014
Received in revised form 24 February 2015
Accepted 23 March 2015
Available online 1 April 2015

Keywords:
Evidential reasoning methodology
Fuzzy multiattribute group decision making
Intuitionistic fuzzy sets
Similarity measures

ABSTRACT

In this paper, we propose a new fuzzy multiattribute group decision making method based on intuitionistic fuzzy sets and the evidential reasoning methodology. First, the proposed method uses the evidential reasoning methodology to aggregate each decision maker's decision matrix and the weights of the attributes to get the aggregated decision matrix of each decision maker. Then, it uses the obtained aggregated decision matrices of the experts, the weights of the experts and the evidential reasoning methodology to get the aggregated intuitionistic fuzzy value of each alternative. Finally, it calculates the transformed value of the obtained intuitionistic fuzzy value of each alternative. The smaller the transformed value, the better the preference order of the alternative. The proposed method can overcome the drawbacks of the existing methods for fuzzy multiattribute group decision making in intuitionistic fuzzy environments.

1. Introduction

In [1], Atanassov extended the theory of fuzzy sets [29] to propose the theory of intuitionistic fuzzy sets. Gau and Buehrer [8] proposed the concepts of vague sets. Bustince and Burillo [3] pointed out that the notion of vague sets coincides with that of intuitionistic fuzzy sets. In recent years, some methods [2,4,7,9,11–15,17–20,28,30] have been presented for fuzzy multiattribute group decision making based on intuitionistic fuzzy sets. Boran et al. [2] presented a fuzzy multicriteria group decision making method for supplier selection using the intuitionistic fuzzy TOPSIS (Technique for Order Performance by Similarity to an Ideal Solution). Chai and Liu [4] presented a multicriteria fuzzy group decision making approach with an Intuitionistic Fuzzy Superiority and Inferiority Ranking (IF-SIR) method to address the supply chain partner selection problem under an uncertain environment. Li et al. [9] presented a methodology to solve the multiattribute group decision-making problems with the fractional programming methodology, where both ratings of alternatives on attributes and weights of attributes are expressed by intuitionistic fuzzy sets. Szmidt and Kacprzyk [11] presented some solution concepts in group decision making under intuitionistic fuzziness (individual and social) fuzzy preference relations. Tan et al. [12] presented an intuitionistic fuzzy geometric aggregation operator based on a fuzzy measure for aggregating intuitionistic fuzzy information for fuzzy group decision making. Wang et al. [13] presented an intuitionistic fuzzy multiple attribute group decision making method based on the projection method. Wei [14] presented some induced geometric aggregation operators with intuitionistic information for group decision making. Wen [15] presented a fuzzy multicriteria group decision method based on intuitionistic fuzzy sets for information collaboration partner selection. Xu [17] presented multi-person multiattribute decision making models under an intuitionistic fuzzy environment. Xu [18] presented a deviation-based fuzzy multiattribute group decision method based on the deviation measure and the information theory. Xu [19] developed some operators for aggregating intuitionistic fuzzy sets and proposed some approaches for multiattribute group decision making with Atanassov's intuitionistic fuzzy information. Xu and Yager [20] presented dynamic fuzzy multiattribute group decision making methods based on intuitionistic preference relations and incomplete intuitionistic preference relations, respectively. Yue [28] presented a TOPSIS-based fuzzy group decision making methodology based on intuitionistic fuzzy sets for fuzzy multiattribute group decision making. Zeng and Su [30] presented some intuitionistic fuzzy ordered weighted distance operators of intuitionistic fuzzy sets for fuzzy multiattribute group decision making.

* Corresponding author.
E-mail addresses: smchen@mail.ntust.edu.tw (S.-M. Chen), shcheng@ctu.edu.tw (S.-H. Cheng), M10115014@mail.ntust.edu.tw (C.-H. Chiou).

http://dx.doi.org/10.1016/j.inffus.2015.03.002
1566-2535/

However, Xu's method [18] and Yue's method [28] have the drawbacks that they get unreasonable preference orders of alternatives in some situations. Moreover, Zeng and Su's method [30] has the drawbacks that (1) it cannot allow the attributes to have different weights assigned by different experts and (2) it gets unreasonable preference orders of alternatives in some situations. In order to overcome the drawbacks of Xu's method [18], Yue's method [28] and Zeng and Su's method [30], we need to develop a new method for fuzzy multiattribute group decision making to overcome the drawbacks of the methods presented in [18,28,30].

In this paper, we propose a new fuzzy multiattribute group decision making method based on intuitionistic fuzzy sets [1] and the evidential reasoning methodology [23–27]. In [23], Yang presented a rule and utility based evidential reasoning approach for multiattribute decision analysis under uncertainty. In [24], Yang et al. presented a belief rule-based inference methodology using the evidential reasoning approach. In [25], Yang and Singh presented an evidential reasoning approach for multiattribute decision making with uncertainty. In [26], Yang et al. presented an evidential reasoning approach for multiple attribute decision analysis under both probabilistic and fuzzy uncertainties. In [27], Yang and Xu presented an evidential reasoning algorithm for multiple attribute decision analysis under uncertainty. From [23–27], we can see that the evidential reasoning methodology has successfully been applied to deal with multiple attribute decision analysis and multiattribute decision making problems. Therefore, in this paper, we take the advantage of the evidential reasoning methodology and the powerful representation capability of intuitionistic fuzzy sets to propose a new fuzzy multiattribute group decision making method based on intuitionistic fuzzy sets and the evidential reasoning methodology. First, the proposed method uses the evidential reasoning methodology to aggregate each decision maker's decision matrix and the weights of the attributes to get the aggregated decision matrix of each decision maker. Then, it uses the obtained aggregated decision matrices of the experts, the weights of the experts and the evidential reasoning methodology to get the aggregated intuitionistic fuzzy value of each alternative. Finally, it calculates the transformed value of the obtained intuitionistic fuzzy value of each alternative. The smaller the transformed value, the better the preference order of the alternative. The proposed method can overcome the drawbacks of Xu's method [18], Yue's method [28] and Zeng and Su's method [30] for fuzzy multiattribute group decision making problems in intuitionistic fuzzy environments.

In [5], Chen et al. presented an evidential reasoning based approach for group decision making with partially ordered preference under uncertainty. In [6], Chen et al. presented a group decision making model for partially ordered preference under uncertainty. They developed a methodology based on belief structures to represent partially ordered preferences with belief degrees, where an evidential reasoning based preference combination approach is applied to combine the partially ordered preferences with belief degrees of the experts for group decision making under uncertainty and incompleteness. Although the proposed method and the methods presented in [5,6] used the evidential reasoning methodology for group decision making in intuitionistic fuzzy environments, the differences between the proposed method and the methods presented in [5,6] are that the proposed method is based on decision matrices, where the values in decision matrices are represented by intuitionistic fuzzy values, whereas the methods presented in [5,6] are based on fuzzy preference relations, where the values in fuzzy preference relations are represented by real values between zero and one.

The rest of this paper is organized as follows. In Section 2, we briefly review basic concepts of intuitionistic fuzzy sets [1], Xu and Yager's similarity measure [22] between intuitionistic fuzzy values and the evidential reasoning methodology [23–27]. In Section 3, we analyze the drawbacks of the fuzzy multiattribute group decision making methods presented in [18,28,30]. In Section 4, we propose a new fuzzy multiattribute group decision making method based on intuitionistic fuzzy sets and the evidential reasoning methodology. In Section 5, we use some examples to compare the experimental results of the proposed method with the ones of the methods presented in [18,28,30]. The conclusions are discussed in Section 6.

2. Preliminaries

2.1. Intuitionistic fuzzy sets

Let P be an intuitionistic fuzzy set in the universe of discourse X, where $P = \{\langle x_i, \mu_P(x_i), \nu_P(x_i)\rangle | x_i \in X\}$, μ_P and ν_P are the membership function and the non-membership function of the intuitionistic fuzzy set P, respectively, $\mu_P(x_i)$ and $\nu_P(x_i)$ are the membership degree and the non-membership degree of element x_i belonging to the intuitionistic fuzzy set P, respectively, $0 \leqslant \mu_P(x_i) \leqslant 1$, $0 \leqslant \nu_P(x_i) \leqslant 1, 0 \leqslant \mu_P(x_i) + \nu_P(x_i) \leqslant 1$ and $1 \leqslant i \leqslant m$. The degree of indeterminacy $\pi_P(x_i)$ of element x_i belonging to the intuitionistic fuzzy set P is equal to $1 - \mu_P(x_i) - \nu_P(x_i)$, where $0 \leqslant \pi_P(x_i) \leqslant 1$ and $1 \leqslant i \leqslant m$. According to [21], the intuitionistic fuzzy value of element x_i belonging to the intuitionistic fuzzy set P is represented by $(\mu_P(x_i), \nu_P(x_i))$, where $1 \leqslant i \leqslant m$. According to [22], the complement $(\mu_P(x_i), \nu_P(x_i))^c$ of the intuitionistic fuzzy value $(\mu_P(x_i), \nu_P(x_i))$ is equal to $(\nu_P(x_i), \mu_P(x_i))$, i.e., $(\mu_P(x_i), \nu_P(x_i))^c = (\nu_P(x_i), \mu_P(x_i))$, where $1 \leqslant i \leqslant m$.

2.2. Xu and Yager's similarity measure between intuitionistic fuzzy values

In [10], Szmidt and Kacprzyk presented the definition of the normalized Hamming distance between intuitionistic fuzzy values. Let (μ_a, ν_a) and (μ_b, ν_b) be two intuitionistic fuzzy values, where $\mu_a \in [0, 1], \nu_a \in [0, 1], 0 \leqslant \mu_a + \nu_a \leqslant 1, \pi_a = 1 - \mu_a - \nu_a, \mu_b \in [0, 1], \nu_b \in [0, 1], 0 \leqslant \mu_b + \nu_b \leqslant 1, \pi_b = 1 - \mu_b - \nu_b$. The normalized Hamming distance $d((\mu_a, \nu_a), (\mu_b, \nu_b))$ between the intuitionistic fuzzy values (μ_a, ν_a) and (μ_b, ν_b) is defined as follows:

$$\begin{aligned} d((\mu_a, \nu_a), (\mu_b, \nu_b)) &= \frac{1}{2}(|\mu_a - \mu_b| + |\nu_a - \nu_b| + |\pi_a - \pi_b|) \\ &= \frac{1}{2}(|\mu_a - \mu_b| + |\nu_a - \nu_b| + |1 - \mu_a - \nu_a \\ &\quad - (1 - \mu_b - \nu_b)|) \\ &= \frac{1}{2}(|\mu_a - \mu_b| + |\nu_a - \nu_b| + |\mu_b + \nu_b - \mu_a - \nu_a|), \end{aligned} \tag{1}$$

where $d((\mu_a, \nu_a), (\mu_b, \nu_b)) \in [0, 1]$. In [22], Xu and Yager presented a similarity measure between intuitionistic fuzzy values based on the normalized Hamming distance between intuitionistic fuzzy values. Let a and b be two intuitionistic fuzzy values and let b^c be the complement of the intuitionistic fuzzy value b. The degree of similarity $S(a, b)$ between the intuitionistic fuzzy values a and b is defined as follows [22]:

$$S(a,b) = \begin{cases} 0.5, & \text{if } a = b = b^c \\ \frac{d(a,b^c)}{d(a,b)+d(a,b^c)}, & \text{otherwise} \end{cases} \tag{2}$$

where the similarity measure $S(a, b)$ between the intuitionistic fuzzy values a and b has the following properties [22]:

(1) $0 \leqslant S(a, b) \leqslant 1$;
(2) $S(a, b) = S(b, a) = S(a^c, b^c)$, where a^c and b^c are the complement of the intuitionistic fuzzy values a and b, respectively;
(3) $S(a, b^c) = S(a^c, b)$;