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Multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets and the aggregation of fuzzy sets

Shyi-Ming Chen *, Jia-An Hong

Department of Computer Science and Information Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan, ROC

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ABSTRACT

In this paper, we present a new method for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets using the pessimistic attitude and the optimistic attitude of the decision-maker. The proposed method aggregates the fuzzy sets in each hesitant fuzzy linguistic term set into a fuzzy set and performs the α-cut operations to these aggregated fuzzy sets to get intervals, respectively, where $\alpha \in (0, 1]$. For each alternative, it performs the minimum operations and the maximum operations among the obtained intervals to get the derived intervals, respectively, where the minimum operation and the maximum operation among intervals denote the pessimistic attitude and the optimistic attitude of the decision-maker, respectively. Then, for each alternative, it uses the likelihood method for ranking the priority between the obtained intervals to get the preference order of the alternatives for the decision-maker with the pessimistic attitude and the optimistic attitude, respectively. The proposed method is more flexible than the existing methods for multicriteria linguistic decision making due to the fact that it considers the pessimistic attitude and the optimistic attitude of the decision-maker.

1. Introduction

In a fuzzy decision making environment, experts may be hesitant to choose an appropriate linguistic term for assessing an alternative in some situations. In order to deal with such situations, Torra [16] presented the concept of hesitant fuzzy sets, which are generalizations of fuzzy sets [23]. He also discussed the relationships among hesitant fuzzy sets and the other generalizations of fuzzy sets, such as intuitionistic fuzzy sets [1,2], type-2 fuzzy sets [6,12], type-*n* fuzzy sets [6] and fuzzy multisets [13]. Rodriguez et al. [14] pointed out that hesitant fuzzy sets provide a very interesting extension of fuzzy sets, where they try to manage those situations in which a set of values is possible in the definition process of the membership value of an element. Farhadinia [7] presented some information measures for hesitant fuzzy sets and interval-valued hesitant fuzzy sets. Xu and Xia [22] presented a variety of distance measures for hesitant fuzzy sets. Zhu et al. [25] extended the geometric Bonferroni mean (GBM) to the hesitant fuzzy environment and defined the hesitant fuzzy geometric Bonferroni mean (HFGBM) of hesitant fuzzy sets. Torra and Narukawa [17] presented an extension principle to generalize existing operations on fuzzy sets to hesitant fuzzy sets. Zhang [24] presented hesitant fuzzy power aggregation operators for multiple attributes group decision making. Xia and Xu [20] presented some aggregation operators of hesitant fuzzy information for group decision making.

* Corresponding author. Tel.: +886 2 27376417; fax: +886 2 27301081.
E-mail address: smchen@mail.ntust.edu.tw (S.-M. Chen).

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Based on the concept of hesitant fuzzy sets, Rodriguez et al. [14] presented the concept of hesitant fuzzy linguistic term sets for multicriteria linguistic decision making. Hesitant fuzzy linguistic term sets provide a very interesting research topic of multicriteria linguistic decision making, where they try to manage those situations in which the evaluating values of the attributes of the alternatives are described by a set of possible linguistic terms represented by fuzzy sets. In recent years, some methods [4,8,11,14,15,19,26] have been presented for decision making based on hesitant fuzzy linguistic term sets. Chen and Hong [4] presented a method for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets. Hajlaoui and Halouani [8] presented a group decision making method based on hesitant linguistic preference relations. Lee and Chen [11] presented a multicriteria linguistic decision making method based on likelihood-based comparison relations of hesitant fuzzy linguistic term sets. Rodriguez et al. [15] presented a group decision making model dealing with comparative expressions based on hesitant fuzzy linguistic term sets. Wei et al. [19] developed comparison methods of hesitant fuzzy linguistic term sets and presented the hesitant linguistic weighted averaging (HLWA) operator and the hesitant linguistic ordered weighted averaging (HLOWA) operator to deal with multicriteria decision making problems in different situations, where importance weights of criteria or experts are known or unknown. Zhu and Xu [26] developed two optimization methods to improve the consistency of hesitant fuzzy linguistic preference relations for multicriteria decision making. However, the drawback of the methods presented in [11,14] is that they do not consider the pessimistic attitude and the optimistic attitude of the decision-maker for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets. Therefore, we must develop a new method to overcome the drawback of the methods presented in [11,14] for considering the pessimistic attitude and the optimistic attitude of the decision-maker for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets.

In this paper, we present a new method for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets and the aggregation of fuzzy sets. First, the proposed method aggregates the fuzzy sets in each hesitant fuzzy linguistic term set into a fuzzy set. Then, it performs the α-cut to these aggregated fuzzy sets to get intervals, respectively, where $\alpha \in (0,1]$. Then, for each alternative, it performs the minimum operations and the maximum operations among the obtained intervals to get the derived intervals, respectively, where the minimum operation and the maximum operation among intervals are used to denote the pessimistic attitude and the optimistic attitude of the decision-maker, respectively. Finally, for each alternative, it uses the likelihood method for ranking the priority among the obtained intervals to get the preference order of the alternatives for the decision-maker with the pessimistic attitude and the optimistic attitude, respectively. The difference between the proposed method and Chen's method [5] is that the proposed method is based on hesitant fuzzy linguistic term sets, whereas Chen's method [5] is based on interval-valued fuzzy sets. The proposed method is more flexible than Chen's method [5] due to the fact that it allows the decision-maker to evaluate the attributes of each alternative using hesitant fuzzy linguistic term sets, whereas Chen's method [5] only allows the evaluating values of the alternatives to be represented by interval values between zero and one. In other words, the drawback of Chen's method [5] is that it cannot deal with fuzzy decision making problems in which the evaluating values of the alternatives are represented by hesitant fuzzy linguistic term sets. Moreover, the proposed method is more flexible than the methods presented in [11,14] due to the fact that the proposed method considers the pessimistic attitude and the optimistic attitude of the decision-maker. It provides us with a useful way for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets.

The rest of this paper is organized as follows. In Section 2, we briefly review the concepts of fuzzy sets [3,23], the α-cuts of fuzzy sets [9], the minimum operation and the maximum operation between intervals [10], and the likelihood method for ranking the priority among intervals [21]. In Section 3, we briefly review the concepts of hesitant fuzzy sets [16] and hesitant fuzzy linguistic term sets [14]. In Section 4, we present a new method for multicriteria linguistic decision making based on hesitant fuzzy linguistic term sets using the pessimistic attitude and the optimistic attitude of the decision-maker, respectively. The conclusions are discussed in Section 5.

2. Preliminaries

In this section, we briefly review the concepts of fuzzy sets [3,23], the α-cuts of fuzzy sets [9], the minimum operation and the maximum operations between intervals [10], and the likelihood method [21] for ranking the priority among intervals.

(A) Fuzzy sets

In 1965, Zadeh proposed the theory of fuzzy sets [23]. Let X be the universe of discourse, $X = \{x_1, x_2, \ldots, x_n\}$. A fuzzy set A in the universe of discourse X can be represented as follows:

$$A = \mu_A(x_1)/x_1 + \mu_A(x_2)/x_2 + \cdots + \mu_A(x_n)/x_n, \tag{1}$$

where μ_A is the membership function of the fuzzy set A, $\mu_A : X \to [0,1]$, $\mu_A(x_i)$ denotes the degree of membership of x_i belonging to the fuzzy set A, and $\mu_A(x_i) \in [0,1]$. Chen and Chang [3] represented the trapezoidal fuzzy set A shown in Fig. 1 by a quadruple (a_1, a_2, a_3, a_4), where $A = (a_1, a_2, a_3, a_4)$. If $a_2 = a_3$, then the trapezoidal fuzzy set A shown in Fig. 1 becomes a triangular fuzzy set, as shown in Fig. 2, where $A = (a_1, a_2, a_2, a_4) = (a_1, a_3, a_3, a_4)$.

Let A be a fuzzy set in the universe of discourse X and let μ_A be the membership function of the fuzzy set A. The α-cut A_α of the fuzzy set A is an interval in the universe of discourse X, defined as follows [9]: