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Fuzzy decision making based on likelihood-based comparison relations of hesitant fuzzy linguistic term sets and hesitant fuzzy linguistic operators

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ABSTRACT

In this paper, we propose a new fuzzy decision making method and propose a new fuzzy group decision making method based on the proposed likelihood-based comparison relations of hesitant fuzzy linguistic term sets and the proposed hesitant fuzzy linguistic weighted average (HFLWA) operator, the proposed hesitant fuzzy linguistic weighted geometric (HFLWG) operator, the proposed hesitant fuzzy linguistic ordered weighted average (HFLOWA) operator, and the proposed hesitant fuzzy linguistic ordered weighted geometric (HFLOWG) operator of hesitant fuzzy linguistic term sets. The proposed fuzzy decision making method can overcome the drawback of Rodriguez et al.'s method (2012) and Wei et al.'s method (2014) for fuzzy decision making, which cannot distinguish the preference order of alternatives in some situations. The proposed fuzzy group decision making method is more flexible than Rodriguez et al.'s method (2013) for fuzzy group decision making because it considers different hesitant fuzzy linguistic operators for fuzzy group decision making. The proposed methods provide us with a useful way for decision making in fuzzy environments.

1. Introduction

The fuzzy linguistic approach represents qualitative aspects as linguistic values by means of linguistic variables, which has successfully been applied to deal with some fuzzy decision making problems [3–9,11–22,25–29,31–36,40]. However, in some situations, an expert may not easily use a single linguistic term as the assessment expression based on his/her knowledge, where he/she would like to use several linguistic terms simultaneously or would like to look for a more complex linguistic term as the assessment expression. In a fuzzy decision making environment, experts may be hesitating to choose appropriate linguistic terms to assess alternatives in some situations for reaching a final agreement. In order to deal with such situations, in [30], Torra presented the concept of hesitant fuzzy sets, which is a generalization of fuzzy sets [39]. He also presented different generalizations and extensions of fuzzy sets and 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 [10,23], type n fuzzy sets [10] and fuzzy multisets [24]. Based on the concept of hesitant fuzzy sets presented in [30], some researchers [3,8,15,26–28,36,38,40,41] have studied some related issues of hesitant fuzzy sets. In [27], Rodriguez et al. presented the

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concept of hesitant fuzzy linguistic term sets for decision making. Similar to the concept of hesitant fuzzy sets, hesitant fuzzy linguistic term sets are used when experts hesitate to choose appropriate linguistic terms to assess a linguistic variable. Rodriguez et al. [27] pointed out that the fuzzy linguistic approach is very limited due to the fact that it assesses a linguistic variable by using a single linguistic term, whereas the hesitant fuzzy linguistic term sets approach assesses a linguistic variable by using several linguistic terms for decision making. They presented two symbolic aggregation operators to obtain a linguistic interval associated with each alternative and presented an exploitation process to get a preference order for fuzzy decision making based on the nondominance choice degree of a preference relation obtained from linguistic intervals. In [3], Beg and Rashid presented a method to aggregate the opinions of experts or decision makers on different criteria regarding a set of alternatives, where the opinions of the experts are represented by hesitant fuzzy linguistic term sets and an illustrative example is provided to elaborate their method for the selection of the best alternative. In [15], Lee and Chen presented a fuzzy decision making method based on hesitant fuzzy linguistic term sets. In [16], Liao et al. presented a family of distance and similarity measures between hesitant fuzzy linguistic term sets. They also presented a variety of weighted or ordered weighted distance and similarity measures between two collections of hesitant fuzzy linguistic term sets. They applied these measures to multicriteria decision making problems, where the satisfaction degrees for different alternatives are established and are then used to rank alternatives in multicriteria decision making. In [17], Liu and Rodriguez presented a representation of the hesitant fuzzy linguistic term sets by means of a fuzzy envelope to carry out the computing with words processes for fuzzy multicriteria decision making. In [18], Meng et al. defined linguistic hesitant fuzzy sets (LHFSs), which can address the qualitative preferences of experts as well as reflect their hesitancy, uncertainty and inconsistency. Based on their defined operational laws of LHFSs and the order relationship, they presented the generalized linguistic hesitant fuzzy hybrid weighted averaging (GLHFHWA) operator and the generalized linguistic hesitant fuzzy hybrid geometric mean (GLHFHGM) operator. To address the situation in which the elements in a set are interdependent, they also presented the generalized linguistic hesitant fuzzy hybrid Shapley weighted averaging (GLHFHSWA) operator and the generalized linguistic hesitant fuzzy hybrid Shapley geometric mean (GLHFHSGM) operator, which are extensions of the GLHFHWA and GLHFHGM operators. They presented an approach to linguistic hesitant fuzzy multiattribute decision analysis under a linguistic hesitant fuzzy environment. In [19], Rodriguez et al. presented a linguistic group decision model that facilitates the elicitation of flexible and rich linguistic expressions, in particular through the use of comparative linguistic expressions, close to human beings' cognitive models for expressing linguistic preferences based on hesitant fuzzy linguistic term sets and context-free grammars. In [28], Rodriguez et al. presented a group decision making model based on hesitant fuzzy linguistic term sets. In [32], Wang et al. presented an approach for multicriteria decision making, which combines a hesitant fuzzy linguistic term set with an outranking method involving systematic comparisons of the assessment values of alternatives for each criterion. In [33], Wei et al. defined operations on hesitant fuzzy linguistic term sets and gave possibility degree formulas for comparing hesitant fuzzy linguistic term sets. They presented the hesitant fuzzy linguistic weighted averaging (LWA) operator and the hesitant fuzzy linguistic-weighted OWA (LOWA) operator and used these operators and the comparison methods to deal with multicriteria decision making problems with different situations in which importance weights of criteria or experts are known or unknown.

However, the drawbacks of Rodriguez et al.'s method [27] and Wei et al.'s method [33] for fuzzy decision making are that they cannot distinguish the preference order of alternatives in some situations. Moreover, the drawback of Rodriguez et al.'s method [28] for fuzzy group decision making is that it only uses one kind of operator (i.e., the arithmetic mean aggregation operator of 2-tuples) for dealing with the aggregation, thus, it lacks room for more flexibility. Therefore, we need to develop a new fuzzy decision making method to overcome the drawbacks of Rodriguez et al.'s method [27] and Wei et al.'s method [33] and develop a new fuzzy group decision making method based on hesitant fuzzy linguistic term sets to overcome the drawback Rodriguez et al.'s fuzzy group decision making method [28], respectively.

In this paper, we propose the concept of likelihood-based comparison relations of hesitant fuzzy linguistic term sets. We also propose the hesitant fuzzy linguistic weighted average (HFLWA) operator, the hesitant fuzzy linguistic weighted geometric (HFLWG) operator, the hesitant fuzzy linguistic ordered weighted average (HFLOWA) operator, and the hesitant fuzzy linguistic ordered weighted geometric (HFLOWG) operator of hesitant fuzzy linguistic term sets. Based on the proposed likelihood-based comparison relations and the proposed fuzzy linguistic operators of hesitant fuzzy linguistic term sets, we propose a new fuzzy decision making method and propose a new fuzzy group decision making method based on hesitant fuzzy linguistic term sets. The proposed fuzzy decision making method can overcome the drawback of Rodriguez et al.'s method [27] and Wei et al.'s method [33] for fuzzy decision making, which cannot distinguish the preference order of alternatives in some situations due to the fact that their methods only uses the max and the min operators of hesitant fuzzy linguistic term sets, whereas the proposed method considers different hesitant fuzzy linguistic operators for fuzzy group decision making. Moreover, the proposed fuzzy group decision making method is more flexible than Rodriguez et al.'s method [28] for fuzzy group decision making because it considers different hesitant fuzzy linguistic operators for fuzzy group decision making.

The rest of this paper is organized as follows. In Section 2, we briefly review the concepts of the fuzzy linguistic approach [39] and hesitant fuzzy sets [30]. In Section 3, we briefly review the concepts of hesitant fuzzy linguistic term sets [27]. In Section 4, we propose the concept of likelihood-based comparison relations of hesitant fuzzy linguistic term sets, propose a similarity measure between hesitant fuzzy linguistic term sets, and propose the definitions of the hesitant fuzzy linguistic weighted average (HFLWA) operator, the hesitant fuzzy linguistic weighted geometric (HFLWG) operator, the hesitant fuzzy linguistic ordered weighted average (HFLOWA) operator, and the hesitant fuzzy linguistic ordered weighted geometric (HFLOWG) operator of hesitant fuzzy linguistic term sets. In Section 5, we propose a fuzzy decision making method based