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A new method for multiple criteria group decision making with incomplete weight information under linguistic environment

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ABSTRACT

A new method is proposed to solve multiple criteria group decision making (MCGDM) problems, in which both the criteria values and criteria weights take the form of linguistic information, and the information about linguistic criteria weights is partly known or completely unknown. Firstly, to get reasonable decision result, instead of assigning the same weight to the decision maker (DM) for all criteria, we propose a method to determine the weight of DM with respect to each criterion under linguistic environment by calculating the similarity degree between individual 2-tuple linguistic evaluation value and the mean given by all decision makers (DMs). Secondly, for the situations where the information about the criteria weights is partly known or completely unknown, we establish optimization models to determine the criteria weights by defining 2-tuple linguistic positive ideal solution (TL-PIS), 2-tuple linguistic right negative ideal solution (TL-RNIS) and 2-tuple linguistic left negative ideal solution (TL-LNIS) of the collective 2-tuple linguistic decision matrix. Thirdly, we propose a new method to solve MCGDM problems with partly known or completely unknown linguistic weight information. Finally, an illustrative example is given to demonstrate the calculation process of the proposed method.

1. Introduction

Multiple criteria decision-making (MCDM) is a familiar decision activity that usually occurs in our daily life, such as investment decision making, medical diagnosis, personnel examination, and military system efficiency evaluation [1]. However, the increasing complexity of the socio-economic environment makes it less and less possible for single decision maker (DM) to consider all relevant aspects of a problem [2]. Multiple criteria group decision making (MCGDM) problem has been receiving more and more attention from researchers [3–15]. For traditional MCGDM problem, decision makers are used to expressing their preferences on alternatives with numerical values. However, in many situations, because of the fuzziness and uncertainty, criteria especially qualitative ones involved in decision making problem may not be represented by numerical values, and some of them are more suitable to be described by linguistic variables [16]. For instance, when evaluating the "rescue capacity" or "recovering capacity" of an emergency alternative, terms like "good", "medium", "poor" are usually used [17], and evaluating the importance of criteria, terms like "unimportant", "important", "very important" can be used instead of numeric values.

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Since the concept of linguistic variable was proposed by Zadeh [18], many MCGDM problems have been studied in linguistic environment [19–30]. Fuzzy linguistic representation model, proposed by Herrera and Martinez [31], is one of the most important tools to solve MCGDM problems [32]. Since its appearance, it has been widely applied to MCGDM problems. Many aggregation operators have been proposed to aggregate 2-tuple linguistic information, such as, the 2-tuple arithmetic averaging (TAA) operator, the 2-tuple ordered weighted averaging (TOWA) operator [31]; the 2-tuple hybrid weighted average (THWA) operator, the 2-tuple hybrid linguistic weighted average (T-HLWA) operator [28]; 2-tuple linguistic harmonic (2TLH) operator [33]; the extended ordered weighted averaging (EOWA) operator and the extended ordered weighted geometric (EOWG) operator [34]; the 2-tuple ordered weighted geometric (TOWG) operator [35]; the 2-tuple correlated averaging (TCA) operator, the 2-tuple correlated geometric (TCG) operator [36]; interval-valued 2-tuple weighted averaging operator (IVTWA) [37]; interval-valued 2-tuple weighted geometric (IVTWG) operator [38]; the dependent 2-tuple ordered weighted geometric (D2TOWG) operator [39]; the induced 2-tuple linguistic ordered weighted averaging (I-2TLOWA) operator [40], etc.

For the linguistic MCGDM problems with incomplete weight information, many approaches have been proposed for aggregating linguistic information up to now. Wei [41] proposed a method for 2-tuple linguistic multiple attribute group decision making with incomplete weight information based on the idea of grey relational analysis (GRA) method. Wei [42] developed a method for 2-tuple linguistic multiple attribute group decision making with incomplete weight information based on the idea of Technique for order performance by similarity to ideal solution (TOPSIS) method. Ju and Wang [43] proposed projection method for multiple criteria group decision making with incomplete weight information under linguistic setting. Xu and Da [44] proposed a method for multiple attribute decision making with incomplete weight information under uncertain linguistic environment. Zhang and Guo [45] proposed a method for multi-granularity uncertain linguistic group decision making with incomplete weight information. However, all these methods mentioned above assume that the criteria weight take the form of numerical values, and fail to solve the MCGDM problems with incomplete linguistic criteria weight information. Although Wang and Fan [46] extended the TOPSIS method to solve the MCGDM problems in which both the criteria values and criteria weights take the form of linguistic information, it fails to solve the MCGDM problems in which the linguistic criteria weights are partly known or completely unknown. Consequently, how to solve the MCGDM problems in which both the criteria values and criteria weights take the form of linguistic information, and the information about linguistic criteria weights is partly known or completely unknown is an interesting research topic. This is the motivation of our study.

MCGDM problem under linguistic environment is characterized by a set of decision makers (DMs) who are called to express their linguistic judgments on a predefined set of alternatives in order to select the best one(s). This needs to aggregate all individual linguistic decisions into a collective one. Therefore, the DMs' weights play an important role in the aggregating process since DMs have their different cultural, educational backgrounds, experiences, knowledge and abilities, etc. Recently, many methods have been proposed to determine the weights of DMs [43,47–49]. Ju and Wang [43] presented a method for determining weights of DMs by defining the degree of similarity of the individual decision matrix to the collective decision matrix under 2-tuple linguistic environment. Yue [47] developed a method for determining weights of DMs with interval numbers under group decision environment. Yue [48] proposed a method for determining weights of DMs by using projection method. Xu [49] gave some straightforward formulas to determine the weights of DMs. However, all these methods mentioned above assume that the DMs' weights are constant for all criteria. But in the real decision making process, DMs usually come from different research fields, and they are usually experts in some criteria but not in other criteria [50]. To get reasonable decision result, we should determine the weights of DMs with respect to each criterion. Chen and Yang [50] proposed a method for determining the DMs' weights with respect to each evaluation value under intuitionistic fuzzy environment. In that method, the weights of the DMs are derived from decision matrices, and the DM whose evaluation value is close to the average evaluation value has a big weight, while the DM whose evaluation value is far from the average evaluation value would have a small weight. But it fails to determine the DMs' weights under linguistic environment, i.e., the criteria values and criteria weights take the form of linguistic information. In this paper, we propose a method to determine the weights of DMs with respect to each criterion under linguistic environment by calculating the similarity degree between individual 2-tuple linguistic evaluation value and the mean given by all DMs.

The remainder of this paper is organized as follows. In Section 2, some basic concepts and operations related to 2-tuple are introduced briefly. In Section 3, we develop a new method to determine the DMs' weights with respect to each criterion under linguistic environment. In Section 4, we develop a new method to solve linguistic MCGDM problem with partly known or completely unknown linguistic criteria weights. In Section 5, a numerical example is used to demonstrate the calculation process of the proposed method. The paper is concluded in Section 6.

2. Preliminaries

In the following, we shall make a brief review of some concepts and operations of 2-tuples to facilitate the following discussion.

Let $S = \{s_0, s_1, s_2, \ldots, s_g\}$ is a finite and totally ordered discrete term set, where $g+1$ is the cardinality of S. Generally speaking, $g+1$ is an odd number. For example, when $g = 6$, the set S could be given as follows: $S = \{s_0, s_1, s_2, \ldots, s_6\}$ = {very unimportant; unimportant; slightly unimportant; middle; slightly important; important; very important}.