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A method based on induced aggregation operators and distance measures to multiple attribute decision making under 2-tuple linguistic environment

Chunguang Li [a], Shouzhen Zeng [b,*], Tiejun Pan [b], Leina Zheng [c]

[a] *School of Business Administration, Zhejiang Gongshang University, Hangzhou, 310018, China*
[b] *College of Computer and Information, Zhejiang Wanli University, Ningbo, 315100, China*
[c] *Department of Business, Zhejiang Wanli University, Ningbo, 315100, China*

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ABSTRACT

We develop a new multiple attribute decision making approach for dealing with 2-tuple linguistic information, called the 2-tuple linguistic induced generalized ordered weighted averaging distance (2LIGOWAD) operator. This generalization includes a wide range of 2-tuple linguistic aggregation distance operators such as the 2-tuple linguistic induced ordered weighted averaging distance (2LIOWAD) and the 2-tuple linguistic induced Euclidean ordered weighted averaging distance (2LIEOWAD) operators. We study some of its main properties, and we further generalize the 2LIGOWAD operator by using the Quasi-arithmetic means. Finally we present an application of the developed operator to a group decision making problem about selection of strategies.

1. Introduction

A wide range of aggregation operators is found in the literature. One common aggregation method is the ordered weighted averaging (OWA) operator [38]. It provides a parameterized family of aggregation operators that include as special cases the maximum, the minimum and the average. In [41], Yager and Filev developed an extension of the OWA operator, called the induced ordered weighted averaging (IOWA) operator. The difference is that the reordering step is no longer determined only by the values of the arguments, but could be induced by another mechanism, such as the ordered position of the arguments; in other words, the reordering can depend on the values of their associated order-inducing variables. In the last few years, these two operators have received increasing attention, e.g., [1–6,10,11,14–19,21–25,27,28,33–40,43–45].

A further interesting extension is the one that uses the OWA and the IOWA operators in distance measures. Recently, motivated by the idea of the OWA operator, Xu and Chen [36] defined the ordered weighted distance (OWD) measure whose prominent characteristic is that they can alleviate (or intensify) the influence of unduly large (or small) deviations on the aggregation results by assigning them low (or high) weights. Merigó and Gil-Lafuente [22] presented the ordered weighted averaging distance (OWAD) operator by using the OWA operator to calculate the Hamming distance, and gave its application in the selection of financial products. Zeng and Su [43] developed the intuitionistic fuzzy ordered weighted distance (IFOWD) operator. On the basis of the idea of the IOWA operator, Merigó and Casanovas [17] presented the induced ordered weighted averaging distance (IOWAD) operator that extends the OWA operator by using distance measures

* Corresponding author.
E-mail addresses: lichunguang6817@163.com (C. Li), zszzxl@163.com (S. Zeng), Pantiejun@163.com (T. Pan), zhengleina@163.com (L. Zheng).

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and a reordering of arguments that depends on order-inducing variables. The IOWAD generalizes the OWAD operator and provides a parameterized family of distance aggregation operators between the maximum and the minimum distance. Then Merigó and Casanovas [18] presented the induced Euclidean ordered weighted averaging distance (IEOWAD) operator. Going a step further, Merigó and Casanovas [19] introduced the induced generalized OWA distance (IGOWAD) (also called the induced Minkowski OWA distance (IMOWAD) operator), which generalizes the OWD measure, the OWAD operator, the IOWAD operator, the IEOWAD operator and a lot of other particular cases. It is very useful for decision making problems because it can establish a comparison between an ideal, though unrealistic, alternative and available options in order to find the optimal choice. As such, the optimal choice is the alternative closest to the ideal one. The main advantage of the IGOWAD operator is that it is able to deal with complex attitudinal characters (or complex degrees of orness) in the aggregation process. Therefore, we are able to deal with more complex situations closer to the real world.

Usually, when using the above aggregation distance operators, such as the IOWAD and the IGOWAD operators, it is assumed that the available information is clearly known and can be assessed with exact numbers. However, in real life, there are many decision situations wherein the information cannot be assessed precisely in a quantitative form but may be in a qualitative one, for example, when evaluating the "comfort" or "design" of a car, terms like "good", "medium", "bad" are usually used, and evaluating a car's speed, terms like "very fast", "fast", "slow" can be used instead of numeric values [4]. Thus, in such situations, the use of linguistic approach is necessary. The use of the fuzzy linguistic approach [42] provides a direct way to manage the uncertainty and model the linguistic assessments by means of linguistic variables. In the literature, many aggregation operators and approaches have been developed to solve group decision making problems with linguistic information. In order to effectively avoid the loss and distortion of information in linguistic information processing process, Herrera and Herrera-Viedma [7] developed the 2-tuple arithmetic average (2TAA) operator, 2-tuple weighted average (2TWA) operator, 2-tuple ordered weighted average (2TOWA) operator and extended 2-tuple weighted average (ET-WA) operator. Herrera et al. [8] proposed a fuzzy linguistic methodology to deal with unbalanced linguistic term sets. Wang and Hao [26] presented a 2-tuple fuzzy linguistic evaluation model for selecting appropriate agile manufacturing system in relation to MC production. Wei [28] proposed a method for multiple attribute group decision-making based on the ET-WG and ET-OWG operators with 2-tuple linguistic information. Wei [30] proposed the GRA-based linear-programming methodology for multiple attribute group decision making with 2-tuple linguistic assessment information. Merigó et al. [20] developed the belief structure-linguistic ordered weighted averaging (BS-LOWA), the BS-linguistic hybrid averaging (BS-LHA) and a wide range of particular cases. Liu [12] presented an approach based on 2-tuple to solve the hybrid multiple attribute decision making problem with weight information unknown. Wei [29] extended the TOPSIS method for 2-tuple linguistic multiple attribute group decision making with incomplete weight information. Wei [31] utilized the gray relational analysis method for 2-tuple linguistic multiple attribute group decision making with incomplete weight information. Xu and Wang [33] developed some 2-tuple linguistic power aggregation operators.

From above analysis, we can see that 2-tuple linguistic variable is an effective tool to deal with uncertainty. More and more multiple attribute decision making theories and methods under 2-tuple linguistic environment have been developed. The aim of this paper is to develop a new multiple attribute decision making approach for dealing with 2-tuple linguistic variables based on induced aggregation operators and distance measures. For doing so, we present the 2-tuple linguistic induced generalized ordered weighted averaging distance (2LIGOWAD) operator, which is an extension of the IGOWAD operator with 2-tuple linguistic variables. Thus, the 2LIGOWAD uses the IOWA operator, distance measures and uncertain information represented in the form of 2-tuple linguistic variables. The 2LIGOWAD includes a wide range of distance operators such as the 2-tuple linguistic maximum distance, the 2-tuple linguistic minimum distance, the 2-tuple linguistic normalized generalized distance (2LNGD), the 2-tuple linguistic weighted generalized distance (LWGD), the 2-tuple linguistic generalized ordered weighted averaging distance (2LGOWAD) operator, the 2-tuple linguistic induced ordered weighted averaging distance (2LIOWAD) operator and the 2-tuple linguistic induced Euclidean ordered weighted averaging distance (2LIEOWAD) operator. We study some families of the 2LIGOWAD operators. The main advantage of the 2LIGOWAD is that it is able to deal with complex reordering processes that represent a wide range of factors in an uncertain environment that can be assessed with linguistic variables. Then, we can deal with the information in situations with high degree of uncertainty. Another advantage is that it is able to deal with complex attitudinal characters (or complex degrees of orness) in the decision process by using order-inducing variables. In addition, we generalize the 2LIGOWAD operator by using the Quasi-arithmetic means and obtaining the Quasi-arithmetic 2LIOWAD (Q2LIOWAD). The main advantage of this approach is that it includes the 2LIGOWAD as a special case and a lot of other cases. Thus, we get a more robust formulation of this model.

The remainder of this paper is set out as follows. In the next section, we introduce some basic concepts about the 2-tuple linguistic variables and some aggregation operators. Section 3 presents the 2LIGOWAD operator. Section 4 analyzes different families of 2LIGOWAD operators. Section 5 introduces the Quasi-2LIOWAD operator, whereas Section 6 develops a numerical example of the new approach. Finally, Section 7 draws the main conclusions of the paper.

2. Preliminaries

In this Section we briefly review the 2-tuple linguistic approach, the IOWA operator and the IGOWAD operator.