Generalized Ordered Weighted Simplified Neutrosophic Cosine Similarity Measure for Multiple Attribute Group Decision Making

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ABSTRACT

The paper proposes a generalized ordered weighted simplified neutrosophic cosine similarity (GOWSNCS) measure by combining the cosine similarity measure of simplified neutrosophic sets (SNSs) with the generalized ordered weighted averaging (GOWA) operator and investigates its properties and special cases. Then, the author develops a simplified neutrosophic group decision-making method based on the GOWSNCS measure to handle multiple attribute group decision-making problems with simplified neutrosophic information. The prominent characteristics of the GOWSNCS measure are that it not only is a generalization of the cosine similarity measure but also considers the associated weights for attributes and decision makers in the aggregation of the cosine similarity measures of SNSs to alleviate the influence of unduly large or small similarities in the process of information aggregation. Finally, an illustrative example of investment alternatives is provided to demonstrate the application and effectiveness of the developed approach.

KEYWORDS

Cosine Similarity Measure, Generalized Ordered Weighted Simplified Neutrosophic Cosine Similarity (GOWSNCS) Measure, Group Decision Making, Simplified Neutrosophic Set

1. INTRODUCTION

In complex engineering, economics, and management, multiple attribute group decision making is a very important research topic (Zheng et al. 2018, Lin et al. 2018, Liu et al. 2019a and 2019b). Although fuzzy sets (Zadeh 1965), intuitionistic fuzzy sets (IFSs) (Atanassov 1986), and interval-valued intuitionistic fuzzy sets (IVIFSs) (Atanassov and Gargov 1989) have been developed in vague, incomplete, and uncertain setting, they cannot describe and deal with indeterminate and inconsistent information in various real problems. In this case, Smarandache (1999) proposed the concept of a neutrosophic set as a generalization of the concepts of the classic set, fuzzy set, IFS and IVIFS. In the neutrosophic set, a truth-membership $T(x)$, an indeterminacy-membership $I(x)$ and a falsity-membership $F(x)$ are represented independently and lie within the real standard or nonstandard unit interval $]^-0, 1^+[$. Then, the indeterminacy presented in the neutrosophic set is independent on the truth and falsity values and can include inconsistent information, while the incorporated uncertainty in the IFS is dependent on the degrees of belongingness and non-belongingness and cannot include inconsistent information. Hence, the neutrosophic set can better express incomplete, indeterminate and inconsistent information. However, the neutrosophic set is difficult to be applied in real-life situations due to the nonstandard unit interval $]^-0, 1^+[$ for the range of the three functions $T(x)$, $I(x)$ and $F(x)$. Thus, the range of the functions $T(x)$, $I(x)$ and $F(x)$ can be restrained to the real standard unit interval

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[0, 1] to be easily applied in real science and engineering problems. Consequently, a single-valued neutrosophic set (SVNS) (Wang et al. 2010), an interval neutrosophic set (INS) (Wang et al. 2005), and a simplified neutrosophic set (SNS) (Ye 2014a) were introduced by some researchers. Then, SNSs are the subclass of neutrosophic sets (Ye 2014a) and include the concepts of SVNSs and INSs.

In recent years, SNSs have been mainly applied to decision making and medical diagnosis problems. Ye (2013) presented a correlation coefficient of SVNSs and applied it to single-valued neutrosophic multiple attribute decision-making problems. Then, Ye (2014b) introduced the cross-entropy measure of SVNSs and its single-valued neutrosophic multiple attribute decision-making method. Further, Ye (2014c) put forward the distances-based similarity measures of INSs and their interval neutrosophic multicriteria decision-making method. Moreover, Chi and Liu (2013) proposed an extended TOPSIS method for interval neutrosophic multiple attribute decision making problems. Peng et al. (2014) introduced an outranking approach for multicriteria decision-making problems with simplified neutrosophic information. Zhang et al. (2014) developed the interval neutrosophic number weighted average (INNWA) and interval neutrosophic number weighted geometric (INNWG) operators and their interval neutrosophic multiple attribute decision-making method. Liu and Wang (2014) also developed single-valued neutrosophic normalized weighted Bonferroni mean operators for single-valued neutrosophic decision-making problems. Further, Liu et al. (2014) developed some generalized single-valued neutrosophic number Hamacher aggregation operators and their single-valued neutrosophic group decision-making method. Also, Ye (2014d) developed a multiple attribute group decision-making method with completely unknown weights based on similarity measures under single-valued neutrosophic environment. Ye (2014e) presented vector similarity measures of SNSs and their application in multicriteria decision making. Ye (2015) further proposed the improved cosine similarity measures of SNSs based on the cosine function to overcome some disadvantages of the cosine similarity measure of SNSs in vector space and applied them to medical diagnoses. Zhang et al. (2016) also introduced an outranking approach for multicriteria decision-making problems with interval neutrosophic information. Furthermore, Yang and Li (2016) introduced power aggregation operators of single-valued neutrosophic sets and used them for decision making. Then, Sahin and Liu (2017) presented possibility-induced simplified neutrosophic aggregation operators for group decision-making problems. Ye (2017) put forward simplified neutrosophic harmonic averaging projection method and applied it to multiple attribute decision making problems. Further, Tu et al. (2018) proposed simplified neutrosophic symmetry measures for decision making Problems.

However, in the aforementioned decision making methods based on similarity measures, they scarcely consider the importance of the ordered position of each similarity degree. In some cases, the important degree of the ordered positions of arguments is very important in the process of information aggregation (Yager 2004; Zhou et al 2014). Hence, we may need to consider the weights of the ordered position of arguments in the information aggregation. For example, in the diving contest of Olympic Games, generally one can take the average value of the remaining scores after removing the highest and lowest scores, i.e., one can assign that the weights of the highest and lowest scores are 0. Therefore, the positional weights are very important in some real group decision making problems. To alleviate the influence of unduly large or small similarities in the process of information aggregation, we should assign them specific weights. In such situations, the degrees of similarity can be rearranged in descending order, and then aggregated together with the weights of their ordered positions. Obviously, the existing decision-making methods based on similarity measures are unsuitable for dealing with such cases under simplified neutrosophic environment. Thus, we need to define ordered weighted aggregation operators for the cosine similarity measure of SNSs to handle the decision-making problems. Motivated by the generalized ordered weighted averaging (GOWA) operator (Yager 2004) and the intuitionistic fuzzy ordered weighted cosine similarity measure (Zhou et al 2014), the purposes of this paper are to develop a generalized ordered weighted simplified neutrosophic cosine similarity (GOWSNCS) measure by combining the simplified neutrosophic cosine similarity measure with the GOWA operator as an extension of the two major works in (Yager 2004 and Zhou et al 2014) and its group decision making method in SNS setting. It is obvious that

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