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An intuitionistic fuzzy multiplicative best-worst method for multi-criteria group decision making

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ABSTRACT

In order to extend the best-worst method (BWM) to uncertain circumstances, in this paper, we propose an intuitionistic fuzzy multiplicative best-worst method (IFMBWM) with intuitionistic fuzzy multiplicative preference relations (IFMPRs) for multi-criteria group decision making. First of all, we aggregate individual IFMPRs provided by the decision makers to a collective one by using the intuitionistic fuzzy multiplicative weighted geometric aggregation (IFMWGA) operator. Afterwards, we design an algorithm to rank the criteria according to the membership degrees of the intuitionistic fuzzy assessments, which can be used to identify the best and worst criteria by calculating the out-degrees and in-degrees of the directed network about the collective IFMPR. Furthermore, based on the new definition of the multiplicative consistent IFMPR, we develop several max-min programming models to derive the weights of criteria, and then propose a consistency ratio to check the reliability of the derived results. The procedure of the IFMBWM is provided for the convenience of practical applications. Finally, a numerical example concerning the evaluation of the severity of pulmonary emphysema is given to illustrate the proposed method.

1. Introduction

The analytic hierarchy process (AHP) [32], as one of the most important decision making tools, has been applied to solve various decision making problems over the last decades, such as priority analysis for localization equipment in a thermal power plant [44], urban land-use planning [27], healthcare decision making [7], water transfer compensation classification [13], and the prediction of potential agro waste fibers for sustainable automotive industry [2]. In most cases, the decision making procedure is based on pairwise comparisons. Nevertheless, with the rapid development of modern economy and society, uncertainty and fuzziness can always be found in modern decision making problems, and the classical AHP is not competent in solving uncertain and vague problems. Hence, some researchers have combined the classical AHP with several innovative theories, such as fuzzy set theory [46], intuitionistic fuzzy set theory [5], and hesitant fuzzy set theory [35], and consequently developed a succession of extended methods under uncertain circumstances, which include the fuzzy AHP [1,8,36], the intuitionistic fuzzy AHP [19,40,41] and the hesitant fuzzy AHP [47]. In the fuzzy decision making processes, these innovative AHP methods provide more comprehensive structures than the classical AHP because they combine both quantitative and qualitative criteria.

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Intuitionistic fuzzy multiplicative preference relations (IFMPR), as a useful decision making technique, was first introduced by Xia et al. [38] to express the preferences over alternatives based on the Saaty's 1/9–9 scale (see Table 1). For a pair of alternatives, an IFMPR gives the degrees of both membership and non-membership that show an alternative is prior to the other. In contrast to the fuzzy preference relation (FPR) [9–11] and the intuitionistic fuzzy preference relation (IFPR) [40], the IFMPR uses unsymmetrical scale to express the preference between two alternatives instead of the symmetrical scale in IFPR and FPR, and thus can reflect our perceptions and preferences more intuitively and objectively. Since it was proposed, the IFMPR has received lots of attention, and many fruitful results have been achieved. For example, Xia et al. [39] proposed some operators to aggregate the intuitionistic fuzzy multiplicative preference information. Based on the normalized Manhattan distance between any two intuitionistic fuzzy multiplicative numbers (IFMNs) under the Saaty's 1/9–9 scale, Jiang et al. [16] proposed a novel method to rank the IFMNs, which can overcome the disadvantages of the existing methods [39] using the score and accuracy functions to rank the IFMNs. After introducing the concept of incomplete IFMPR, Jiang et al. [17] studied the consistency and the acceptable consistency of an IFMPR, and proposed an approach to complement the missing elements of the incomplete IFMPRs. By introducing the expected IFMPR and the left and right error matrices, Xu [42] developed an approach to derive the priority weight intervals from an IFMPR through the geometric aggregation operator and the error propagation formula. Some other approaches have been developed to help decision making based on IFMPRs [30].

The world is essentially granular as well as fuzzy. The fuzzy granulation is an intrinsic method of human ideology to some degree. Practices have proven that granular computing (GC), as one of the emerging and active information disposal tools, has become a novel and interdisciplinary subject. It has gradually formed its unique research system and contents [12,20–23,33,34,37,43]. Many researchers have been attracted by GC and have achieved abundant research results [3,4,29,45]. Pedrycz and Chen [28] overviewed the approaches in GC, the plethora of algorithmic developments and a rich and diversified slew of application studies. GC is one of the important mainstream styles for solving the large-scale decision making problems, and there are still a number of open and intriguing issues worth pursuing in spite of the ongoing research and a long list of accomplishments [28]. In particular, there is a genuine need to come to grip as to the dominant aspects of the methodology and resulting technology along with their systematic and coherent usage [18,26]. The growing roles of GC, information granules and type-2 fuzzy sets as well as computing with words (CWW), have been fully reflected in the literature [14,24,25]. A number of contributions have been directly devoted to this subject either by offering some methodological insights or presenting interesting applications [23,38–44].

Recently, Rezaei [31] proposed a novel best-worst method (BWM) for multi-criteria decision making (MCDM) problems, which can be taken as an enhancement of the traditional AHP method. With the BWM, the decision makers do not need to conduct pairwise comparisons between all criteria as they do in the traditional AHP. They only need to identify the most and least desirable criteria, and then make pairwise comparisons between the best/worst criterion and the other criteria. A max-min mathematical model is constructed to determine the weights of different criteria, and a new definition of consistency ratio is established to check the reliability of the method. In the BWM, however, it is not easy to determine which criterion is the best or worst when the number of criteria is very large. Hence, it is necessary to give a specific procedure to identify the best or worst criterion. In addition, the BWM is improper under uncertain circumstances, which further restricts the limited application scope of the BWM. The BWM, however, brings some inspirations and enlightenments from the following two aspects: one is that with the help of diagrams, charts, tables and other direct tools, the method of diagram can be used widely in thinking and analyzing; the other is that the decision makers first identify the best and worst criteria, and then conduct pairwise comparisons between each of these two criteria (best and worst) and the other criteria, which can simplify computations compared with conducting all preference information in the criterion set. Thus, in this paper, we shall make efforts to extend the BWM through the following attempts: giving a specific algorithm to help the decision maker rank the criteria; extending the application scope of the BWM to uncertain situations; and applying the extended BWM method to solve some decision making problems.

The specific novelties of the paper are as follows:

(1) Stimulated by the idea of Ref. [31], and combined with the graph theory as well as some greedy algorithms, we propose a novel algorithm to rank the criteria and obtain the ordered criterion set after aggregating the individual IFMPRs into a collective one by using the intuitionistic fuzzy multiplicative weighted geometric aggregation (IFMWGA) operator. In this paper, we take advantage of an efficient tool, the directed network of the collective IFMPR, to reflect the relationship of the criteria. It makes the IFMBWM more intuitive and vivid than the BWM.
(2) After discussing the disadvantage of the BWM within the context that all the assessments are expressed as IFMNs, a new definition of the multiplicative consistent IFMPR is given, which can not only check the consistency of the IFMPR, but also provide the theoretical basis of mathematical modeling in the next sections.
(3) We build some programming models to produce the weights of criteria according to the new definition of the multiplicative consistent IFMPR. The elicited weight vector is composed of several IFMNs by combining those optimal solutions in the corresponding models. Furthermore, the effectiveness and the reliability of the weights are measured by the consistency ratio.
(4) We develop a procedure for group decision making (GDM) with IFMPRs, which can help us make decisions easily by following the procedure step by step. A numerical example concerning the evaluation of the severity of pulmonary emphysema is provided to illustrate our method.