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A prioritized aggregation operator-based approach to multiple criteria decision making using interval-valued intuitionistic fuzzy sets: A comparative perspective

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ABSTRACT

Within the environment of interval-valued intuitionistic fuzzy (IVIF) sets, this paper develops a prioritized aggregation operator-based approach to handling multiple criteria decision analysis (MCDA) problems in which there exists a prioritization relationship over evaluative criteria. The prioritization between the criteria is modeled by assessing the IVIF weights that are associated with criteria dependence on the satisfaction of the higher priority criteria. Then, a new IVIF prioritized aggregation operator is presented to aggregate the IVIF ratings of the alternatives with respect to the prioritized criteria. Based on synthetic evaluations given by the IVIF prioritized aggregation operator, the ranking order of the alternatives can be determined according to the overall evaluation values. The feasibility and applicability of the proposed method are illustrated by the practical problem of watershed site selection. Moreover, a comparative analysis with other relevant methods is conducted to validate the effectiveness. The comparative results show that our proposed prioritized aggregation operator-based method is appropriate and effective for managing MCDA problems when there are uncertainties expressed by the IVIF sets.

1. Introduction

Uncertain and imprecise assessment information is usually present in many practical multiple criteria decision analysis (MCDA) situations because decision makers might not easily express their subjective judgments with exact and crisp values. Interval-valued intuitionistic fuzzy (IVIF) sets, introduced by Atanassov and Gargov [5], are useful for modeling impressions and for quantifying the ambiguous nature of the subjective judgments in a convenient way. The concept of an IVIF set is characterized by a membership function, a non-membership function, and a hesitancy function, whose values are intervals rather than exact numbers. In general, it is not completely justifiable or technically sound to quantify grades of membership and non-membership in terms of a single numeric value in human cognitive and decision-making activities [29]. Accordingly, the theory of intuitionistic fuzzy sets, especially IVIF sets with interval-valued membership and non-membership functions, has received increasing attention [6,11–13,32,34,36]. At present, IVIF sets have been applied productively in the MCDA field, and numerous and valuable techniques have been developed to handle MCDA problems with IVIF sets [10–14,18,19,24,27,28,30,35,37,50,52].

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However, most of the existing MCDA methods within the IVIF environment assume that all of the criteria are at the same priority level. This type of matching prioritization relationship among the criteria might be infeasible in numerous real-world decision-making problems. Yager [42,43] indicated that the relationship between safety and cost is a typical problem for prioritized criteria. When parents select a bicycle for their children based on the criteria of safety and cost, they must not allow the benefit with respect to the cost to compensate for a loss in safety. Thus, safety has a higher priority than cost. Because we want to consider the satisfaction of higher-priority criteria, such as the safety criterion above, it is no longer appropriate to employ the existing MCDA methods with IVIF sets.

Yager [41,42] introduced the concept of prioritized aggregation operators to address an aggregation problem in which there exists a prioritization relationship among the criteria. Yager [43] used importance weights to enforce this prioritization imperative and applied the developed priority-based importance weights to a case in which the scope of the criteria aggregation was an ordered weighted averaging (OWA) type of aggregation. Yager et al. [44] researched prioritized "and" and "or" operators and employed them to the aggregation problems that have prioritization relationships between the aggregated arguments. Xu et al. [40] proposed an intuitionistic fuzzy prioritized OWA operator to provide a novel method for prioritized MCDA problems. Yu [46] developed a generalized intuitionistic fuzzy prioritized weighted geometric operator based on the Archimedean t-conorm and t-norm and proposed a multiple criteria group decision-making method using this operator. Yu and Xu [48] introduced the concepts of a prioritized intuitionistic fuzzy aggregation (PIFA) operator and a prioritized intuitionistic fuzzy OWA operator. Li and He [25] developed intuitionistic fuzzy prioritized "and" and "or" operators and utilized them to aggregate intuitionistic fuzzy information when the criteria are in different priority levels.

Nevertheless, the aforementioned studies regarding prioritized aggregation operators were based on intuitionistic fuzzy sets, not in a setting of IVIF sets. IVIF sets are generalizations of the intuitionistic fuzzy sets [1,2]. Thus, the above intuitionistic fuzzy prioritized aggregation operators cannot be directly employed within the IVIF environment. Yu et al. [47] proposed some prioritized aggregation operators in the context of IVIF sets, specifically the IVIF prioritized weighted average (IVIFPWA) operator and the IVIF prioritized weighted geometric operator, and applied them to group decision making. However, they assumed that only one criterion exists at each priority level. In addition, the concept of score functions was employed to determine the scalar weight for each priority level in the early stage of their method. The application of score functions might lead to the insufficient utilization of uncertain and ambiguous information that is intrinsically possessed by IVIF sets.

The use of IVIF sets can address more imprecise or uncertain decision information in fields that require MCDA, especially with respect to a lack of knowledge or experience, intangible or non-monetary criteria, or a complex and uncertain environment. Therefore, this paper aims to develop a new IVIF prioritized aggregation operator on the premise of possessing complete IVIF information. In this paper, we investigate the MCDA problems with prioritized criteria in the context of IVIF sets. Consider situations in which a relationship between the criteria exists so that a lack of satisfaction by the higher priority criteria cannot be readily compensated for by satisfaction by the satisfaction of lower priority criteria. This paper introduces an IVIF prioritized aggregation operator to address the problem of criteria aggregation in this environment. To demonstrate the feasibility of the developed operator, we provide an MCDA method using IVIF prioritized aggregation operators and apply it to a practical problem of watershed site selection for watershed planning. Furthermore, some comparisons with other approaches are conducted to illustrate the advantages of the proposed method. Because we intend to investigate weighted averaging type aggregation in the IVIF framework, we select the IVIFPWA operator introduced by Yu et al. [47] as a comparative method. Additionally, we extend the PIFA operator developed by Yu and Xu [48] to the decision environment of the IVIF sets to conduct a comparative analysis.

The purpose of this paper is to develop a prioritized aggregation operator-based approach with IVIF information to solve an MCDA problem. Within the IVIF environment, we determine IVIF weights for distinct priority levels according to a prioritization of evaluative criteria. This paper provides a useful approach via the concept of IVIF prioritized aggregation operators to aggregate IVIF ratings of decision alternatives with respect to prioritized criteria. We utilize score functions to compare synthetic evaluations of the alternatives and then present an algorithmic procedure of the prioritized aggregation operator-based method in the context of IVIF sets. This paper illustrates an executive process using the proposed IVIF prioritized aggregation operator-based method by applying it to the problem of selecting a suitable watershed site. Additionally, some comparisons are provided to illustrate the advantages of the proposed methods. The most well-known and widely used simple additive weighting (SAW) method is extended to the IVIF environment to facilitate a comparative analysis. Considering the results yielded by the extended SAW method as a comparative benchmark, we examine the effectiveness of the proposed method with Yu and Xu's PIFA operator-based approach [48] and Yu et al.'s IVIFPWA operator-based approach [47].

This paper is organized as follows. Section 2 briefly reviews the concept of IVIF sets. Section 3 formulates an MCDA problem within the IVIF environment and develops an IVIF prioritized aggregation operator to handle IVIF MCDA problems. Section 4 illustrates the feasibility and applicability of the proposed method by applying it to the problem of watershed site selection. Section 5 demonstrates the effectiveness of the proposed methods via a comparative analysis with the extended SAW method, the PIFA operator-based approach, and the IVIFPWA operator-based approach. Section 6 presents the conclusions.

2. Basic concepts and operations

Several relevant definitions and operations of IVIF sets introduced by Atanassov [1] are briefly reviewed in this section. These important concepts were further published in an extended form in Atanassov [4].