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Multiple criteria decision analysis using a likelihood-based outranking method based on interval-valued intuitionistic fuzzy sets

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ABSTRACT

The purpose of this paper is to develop a likelihood-based outranking method for handling multiple criteria decision analysis problems based on interval-valued intuitionistic fuzzy sets. Using the concept of likelihood of the interval-valued intuitionistic fuzzy preference relations, this paper determines certain generalized criteria and the corresponding likelihood-based preference functions. Based on some useful concepts of comprehensive preference indices, concordance indices, counter-likelihood-based preference functions, and discordance indices, this paper conducts a concordance–discordance analysis with concordance and discordance outranking relationships to determine a global Boolean matrix and acquire partial ranking orders of the alternatives. Alternatively, this paper determines complete ranking orders of the alternatives using the concepts of net concordance indices, net discordance indices, and mean outranking values. The feasibility and applicability of the proposed method are illustrated with a practical multiple criteria decision-making application concerning the selection of a suitable bridge construction method. Finally, comparative discussions with different decision-making methods are conducted to verify the effectiveness and advantages of the proposed method in aiding decision making.

1. Introduction

The outranking methods constitute one of the most fruitful approaches in multiple criteria decision analysis (MCDA) and have been applied to many real life problems [47]. According to the preferences of the decision maker among criteria and the performances of alternatives with respect to criteria, the outranking model establishes an outranking, binary relation defined by the set of alternatives. The outranking methodology determines a set of preference rankings that best satisfies certain measurements of concordance and discordance. The method of elimination and choice expressing reality (ELECTRE) [7,55] and the preference ranking organization method for enrichment evaluations (PROMETHEE) [9] are well-known and widely used outranking methods for handling MCDA problems. In addition to traditional non-fuzzy outranking methods, there are other fuzzy outranking methods that are interesting both from theoretical and operational points of view. For example, numerous extended ELECTRE methods, such as the application of triangular fuzzy numbers [38], trapezoidal fuzzy numbers [31], triangular interval-valued fuzzy numbers [57], and intuitionistic fuzzy sets [58], have been developed within a fuzzy

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environment. The PROMETHEE methodology has also been extended to a fuzzy context, such as the applications of triangular fuzzy numbers [56], trapezoidal fuzzy numbers [33], generalized fuzzy numbers [44], and interval type-2 fuzzy sets [19].

In contrast to the existing fuzzy outranking methods, this paper presents a new outranking method that works with interval-valued intuitionistic fuzzy (IVIF) data. IVIF sets, introduced by Atanassov and Gargov [5], are generalizations of intuitionistic fuzzy sets. Atanassov [1,2] introduced the concept of an intuitionistic fuzzy set, which is characterized by the degree of membership, the degree of non-membership, and the degree of non-determinacy [4]. 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 [52]. Consequently, the IVIF sets, characterized by a membership function and a non-membership function whose values are intervals rather than exact numbers, have received increasing attention because of their great ability to handle imprecise and ambiguous information in real-world applications [16,20,21,54]. IVIF sets have been applied productively in the multiple criteria decision-making field [14,16,22,28–30,32,37,42,43,45,46,49,53,61,65,75,76]. The theory of IVIF sets is valuable for addressing the uncertainty of multiple criteria evaluations and quantifying the ambiguous nature of subjective assessments in a convenient way. From this perspective, this paper attempts to establish the theoretical framework and outranking methodology for MCDA based on IVIF sets.

The purpose of this paper is to develop a likelihood-based outranking method based on likelihood-based preference functions for managing MCDA problems within the IVIF environment. The main feature of the proposed outranking method is to compare all feasible alternatives by pairs based on likelihood-based preference functions defined on IVIF sets, and then to exploit these preference functions using the measures of concordance and discordance to obtain partial and complete rankings of the alternatives. Based on the concept of likelihood of the IVIF preference relations, this paper determines certain likelihood-based preference functions, which originate from the PROMETHEE methods, within the environment of IVIF sets. Motivated by the ELECTRE methods, the proposed likelihood-based outranking method explicitly takes into account the reasons in favor of and against an outranking relation via a concordance–discordance analysis. Based on useful concepts of comprehensive preference indices, concordance indices, counter-likelihood-based preference functions, and discordance indices, this paper constructs Boolean matrices with concordance and discordance outranking relationships to determine a global Boolean matrix and acquire partial ranking orders of the alternatives. Additionally, complete ranking orders of the alternatives can be determined using the concepts of net concordance and discordance indices and mean outranking values.

The likelihood calculation method has been proposed in our previous work, which includes an IVIF linear programming technique for the multidimensional analysis of preference (LINMAP) method in Chen [17], an IVIF MCDA method using an inclusion comparison possibility approach under incomplete preference information in Chen [18], and an IVIF qualitative flexible multiple criteria method (QUALIFLEX) in Chen [20]. Although the likelihood calculation method has already been applied to address MCDA problems within the IVIF environment in previous work (e.g., inclusion comparison possibilities in Chen [17,18] and likelihood measures in Chen [20]), the proposed likelihood-based outranking method is different from these previous MCDA methods. Fig. 1 summarizes the differences between the contributions of the proposed method and the previous relevant literature.

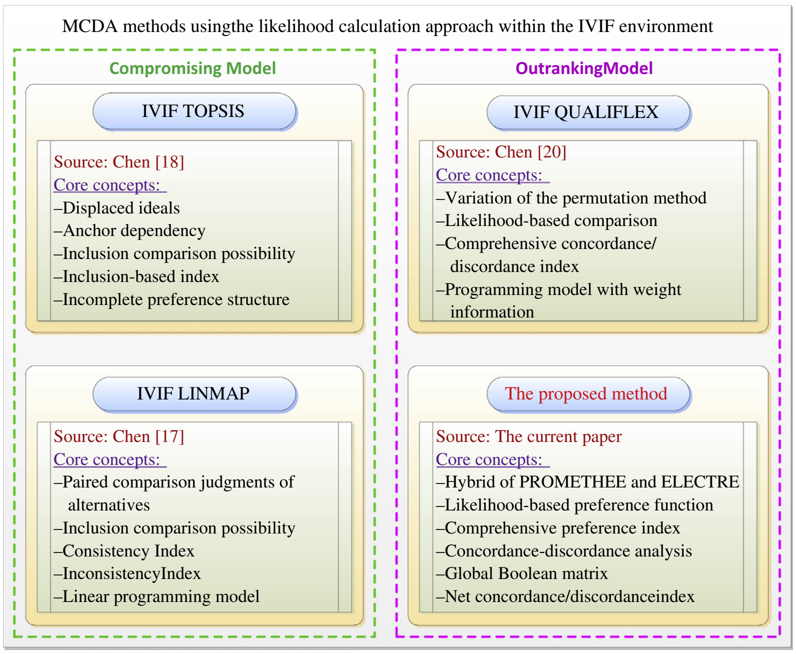

Fig. 1. Comparison of MCDA methods using the likelihood calculation approach.