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# Fuzzy multiattribute decision making based on transformation techniques of intuitionistic fuzzy values and intuitionistic fuzzy geometric averaging operators

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ABSTRACT

In this paper, we propose a new method for fuzzy multiattribute decision making based on the proposed transformation techniques between intuitionistic fuzzy values and right-angled triangular fuzzy numbers and the proposed intuitionistic fuzzy geometric averaging operators of intuitionistic fuzzy values. First, we propose a new multiplication operator between intuitionistic fuzzy values and propose a new power operator of intuitionistic fuzzy values based on the proposed transformation techniques between intuitionistic fuzzy values and right-angled triangular fuzzy numbers. Then, we propose the intuitionistic fuzzy weighted geometric averaging (IFWGA) operator, the intuitionistic fuzzy ordered weighted geometric averaging (IFOWGA) operator and the intuitionistic fuzzy hybrid geometric averaging (IFHGA) operator for aggregating intuitionistic fuzzy values. Then, we propose a new method for fuzzy multiattribute decision making based on the proposed IFWGA operator, the proposed IFOWGA operator and the proposed IFHGA operator of intuitionistic fuzzy values. The experimental results show that the proposed method can overcome the drawbacks of the existing methods for multiattribute decision making in intuitionistic fuzzy environments.



## 1. Introduction

Atanassov [1,2] proposed the concept of intuitionistic fuzzy sets characterized by a membership function and a non-membership function, which is a generalization of the concept of fuzzy sets [30]. Atanassov [3] defined some operators between intuitionistic fuzzy sets. An intuitionistic fuzzy set Ã in the universe of discourse $X = \{x_1, x_2, \ldots, x_n\}$ is represented by $\tilde{A} = \{\langle x_j,\ \mu_{\tilde{A}}(x_j),\ \upsilon_{\tilde{A}}(x_j)\rangle | x_j \in X\}$, where $\mu_{\tilde{A}}(x_j)$ and $\upsilon_{\tilde{A}}(x_j)$ denote the degree of membership and the degree of non-membership of element $x_j$ belonging to the intuitionistic fuzzy set $\tilde{A}$, respectively, $\mu_{\tilde{A}}(x_j) \in [0,\ 1]$, $\upsilon_{\tilde{A}}(x_j) \in [0,\ 1]$, $0 \le \mu_{\tilde{A}}(x_j) + \upsilon_{\tilde{A}}(x_j) \le 1$ and $1 \le j \le n$. The degree of indeterminacy of element $x_j$ belonging to the intuitionistic fuzzy set $\tilde{A}$ is denoted by $\pi_{\tilde{A}}(x_j)$, where $\pi_{\tilde{A}}(x_j) = 1 - \mu_{\tilde{A}}(x_j) - \upsilon_{\tilde{A}}(x_j)$ and $1 \le j \le n$. The intuitionistic fuzzy value of element $x_j$ belonging to the intuitionistic fuzzy set $\tilde{A}$ can be represented as $\langle \mu_{\tilde{A}}(x_j), \upsilon_{\tilde{A}}(x_j)\rangle$, where $1 \le j \le n$. In recent years, some methods [5–14,16,17,19–25,27–29,31–33] have been presented to deal with multiattribute decision making problems based on intuitionistic fuzzy sets. Chen and Chang [5] presented a similarity measure between intuitionistic fuzzy sets based on transformation techniques with applications to pattern recognition. Chen and Tan [7] presented a method for handling multicriteria

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fuzzy decision making problems based on vague sets [10], where Bustince and Burillo [4] pointed out that vague sets are intuitionistic fuzzy sets. Chen [8] presented bivariate models of optimism and pessimism in multicriteria decision making based on intuitionistic fuzzy sets. Chen [9] made a comparative analysis of score functions for multicriteria decision making in intuitionistic fuzzy environments. Guo and Li [11] presented an attitudinal-based method for constructing intuitionistic fuzzy information according to the attribute values expressed in different data types for hybrid multiattribute decision making. He et al. [13] presented the intuitionistic fuzzy weighted geometric interaction averaging (IFWGIA) operator, the intuitionistic fuzzy ordered weighted geometric interaction averaging (IFOWGIA) operator, and the intuitionistic fuzzy hybrid geometric interaction averaging (IFHGIA) operator for multiattribute decision making. Huang [14] presented intuitionistic fuzzy Hamacher aggregation operators for multiple attribute decision making. Lin et al. [16] presented the fuzzy number intuitionistic fuzzy prioritized weighted average (FNIFPWA) operator and the fuzzy number intuitionistic fuzzy prioritized weighted geometric (FNIFPWG) operator for multiple attribute decision making. Liu [17] presented the technique for order performance by similarity to ideal solution (TOPSIS) method for multiple attribute decision making under the trapezoidal intuitionistic fuzzy environment. Wang and Liu [20] defined some operators of intuitionistic fuzzy sets, such as the Einstein sum operator, the Einstein product operator and the Einstein scalar multiplication operator. They also presented the intuitionistic fuzzy Einstein weighted geometric operator ($IFWG^{\varepsilon}$) and the intuitionistic fuzzy Einstein ordered weighted geometric ($IFOWG^{\varepsilon}$) operator for multiattribute decision making. Wang and Zhang [21] presented a method for dealing with multicriteria decision making based on intuitionistic fuzzy sets with incomplete certain information on weights. Xu et al. [22] presented a multiattribute decision making method for air target threat evaluation based on intuitionistic fuzzy sets. Xu [23] presented the intuitionistic fuzzy weighted averaging (IFWA) operator, the intuitionistic fuzzy ordered weighted averaging (IFOWA) operator and the intuitionistic fuzzy hybrid aggregation (IFHA) operator for aggregating intuitionistic fuzzy values and established various properties of these operators. Xu [24] used Choquet integrals to propose intuitionistic fuzzy aggregation operators and applied them to deal with multiattribute decision making problems. Xu [25] presented an interactive method for multiattribute decision making with intuitionistic fuzzy information. Xu and Yager [27] presented the intuitionistic fuzzy weighted geometric (IFWG) operator, the intuitionistic fuzzy ordered weighted geometric (IFOWG) operator and the intuitionistic fuzzy hybrid (IFGH) operator for multiattribute decision making. Yager [28] presented ordered weighted averaging aggregation operators for multicriteria decision making. Yu and Zhang [29] presented an algorithmic method to extend TOPSIS for multiple attribute decision making under the intuitionistic fuzzy setting. Zhao et al. [31] presented the generalized intuitionistic fuzzy weighted averaging (GIFWA) operator, the generalized intuitionistic fuzzy ordered weighted averaging (GIFOWA) operator and the generalized intuitionistic fuzzy hybrid averaging (GIFHA) operator, where they apply them to multiple attribute decision making with intuitionistic fuzzy information. Moreover, they also presented the generalized interval-valued intuitionistic fuzzy weighted averaging (GIIFWA) operator, the generalized interval-valued intuitionistic fuzzy ordered weighted averaging (GIIFOWA) operator and the generalized interval-valued intuitionistic fuzzy hybrid average (GIIFHA) operator, where they apply them to multiple attribute decision making with interval-valued intuitionistic fuzzy information. Zhang and Yu [32] presented the Einstein based intuitionistic fuzzy Choquet geometric (EIFCG) operator and the Einstein based interval-valued intuitionistic fuzzy Choquet geometric (EIIFCG) operator using Einstein operations for multicriteria decision making under the intuitionistic fuzzy environment. Zhou and Chang [33] presented an approach to multiple attribute decision making based on the Hamacher operation with fuzzy number intuitionistic fuzzy information. However, He et al.'s method [13], Wang and Liu's method [20] and Xu and Yager's method [27] for intuitionistic fuzzy multiattribute decision making have the drawbacks that they get incorrect preference orders of alternatives in some situations. In order to overcome the drawbacks of He et al.'s method [13], Wang and Liu's method [20], and Xu and Yager's method [27], we need to develop a new intuitionistic fuzzy multiattribute decision making method.

In this paper, we propose a new method for fuzzy multiattribute decision making based on the proposed transformation techniques between intuitionistic fuzzy values and right-angled triangular fuzzy numbers and the proposed intuitionistic fuzzy geometric averaging operators of intuitionistic fuzzy values. First, we propose a new multiplication operator between intuitionistic fuzzy values and propose a new power operator of intuitionistic fuzzy values based on the proposed transformation techniques between intuitionistic fuzzy values and right-angled triangular fuzzy numbers. Then, we propose the intuitionistic fuzzy weighted geometric averaging (IFWGA) operator, the intuitionistic fuzzy ordered weighted geometric averaging (IFOWGA) operator and the intuitionistic fuzzy hybrid geometric averaging (IFHGA) operator for aggregating intuitionistic fuzzy values. Then, we propose a new method for intuitionistic fuzzy multiattribute decision making based on the proposed IFWGA operator, the proposed IFOWGA operator and the proposed IFHGA operator of intuitionistic fuzzy values. The experimental results show that the proposed fuzzy multiattribute decision making method can overcome the drawbacks of He et al.'s method [13], Wang and Liu's method [20] and Xu and Yager's method [27] for multiattribute decision making in intuitionistic fuzzy environments. The innovative aspects of this paper are that we propose a new method for fuzzy multiattribute decision making based on the proposed transformation techniques between intuitionistic fuzzy values and right-angled triangular fuzzy numbers and the proposed intuitionistic fuzzy geometric averaging operators of intuitionistic fuzzy values. The proposed method can overcome the drawbacks of the methods presented in [13,20] and [27] for multiattribute decision making in intuitionistic fuzzy environments.

The rest of this paper is organized as follows. In Section 2, we briefly review basic concepts of fuzzy sets [30] and intuitionistic fuzzy sets [1], the score function [7] of intuitionistic fuzzy values, the accuracy function [12] of intuitionistic fuzzy values, and the comparison law [27] of intuitionistic fuzzy values. In Section 3, we analyze the drawbacks of the existing intuitionistic fuzzy aggregation operators [13,20,27]. In Section 4, we propose a new multiplication operator between