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AN EXTENSION OF THE WASPAS METHOD FOR DECISION-MAKING PROBLEMS WITH INTUITIONISTIC FUZZY NUMBERS: A CASE OF WEBSITE EVALUATION

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Abstract: *The use of fuzzy sets in classical multiple criteria decision-making methods has led to forming fuzzy multiple criteria decision-making that has enabled solving of a significantly larger number of decision-making problems. However, the membership function introduced in the fuzzy set theory has some limitations. Unlike the fuzzy set theory, the intuitionistic fuzzy set theory introduces non-membership function. Therefore, the intuitionistic fuzzy set theory, as an extension of the fuzzy set theory, can provide for some advantages in solving complex decision-making problems. The WASPAS method is a newly-proposed, widely-used multiple criteria decision-making method for which numerous extensions have already been proposed. In order to enable the use of the WASPAS method for solving a significantly larger number of decision-making problems, a new extension based on the use of intuitionistic fuzzy numbers is proposed in this article. Compared to similar extensions, the proposed extension is based on the use of the Hamming distance for the purpose of ranking alternatives. Efficiency and usability of the proposed approach are considered on the example of website evaluation. Based on the successfully conducted numerical example of the website evaluation it can be concluded that the proposed extension of the WASPAS method based on the use of single-valued intuitionistic fuzzy sets and of the Hamming distance has proven to be very effective and applicable when it comes to website evaluation. Besides, usability of the proposed extension is demonstrated on the example of website evaluation. In doing so, the same order ranking order of the considered alternatives is obtained using the proposed ranking procedure and the procedure based on the score function, which confirms the correctness of the proposed procedure.*

Key Words: *WASPAS, Intuitionistic Fuzzy Set, Single-valued Intuitionistic Fuzzy Number, Hamming Distance, Website Evaluation*

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1. Introduction

In recent decades, the Multiple Criteria Decision Making (MCDM) has successfully been applied for the purpose of solving numerous decision-making problems. Significant progress in the MCDM was made after Zadeh (1965) had proposed his fuzzy sets theory on the basis of which Bellman and Zadeh (1970) also proposed the Fuzzy Multiple Criteria Decision Making, thus enabling the solving of many real-world problems in a much more adequate manner.

Evident progress was also made after Atanasov (1986) had proposed the Intuitionistic Fuzzy Sets (IFS) theory as an extension of the fuzzy sets theory, which additionally introduces not belonging to a given set. Up to now, the IFS has been successfully used to solve many decision-making problems such as: Szmidt and Kacprzyk (1996), Atanassov *et al*. (2002, 2017), Wei (2011), Xu (2011), Shen *et al*. (2015), Xu and Liao (2015), Oztaysi *et al.* (2017); besides, it has also got significant extensions.

Moreover, there is a number of MCDM methods adapted for the use of IFS such as TOPSIS (Tan, 2011), VIKOR (Devi, 2011).), PROMETHEE (Krishankumar *et al*. 2017), WASPAS (Zavadskas, 2014), and so on.

The weighted aggregated sum product assessment (WASPAS) method was proposed by Zavadskas *et al*. (2012) for solving different problems such as: contractor selection (Zavadskas *et al*. 2015), construction site selection (Stević *et al.* 2018; Turskis *et al.* 2015), supplier selection (Stojić *et al*. 2018; Keshavarz Ghorabaee *et al.* 2016), logistics (Sremac *et al*. 2018; Keshavarz Ghorabaee *et al*. 2017), garage location selection (Bausys, Juodagalviene, 2017), telecommunications (Mishra *et al*. 2018; Peng, Dai, 2017) manufacturing decision-making (Chakraborty, Zavadskas 2014; Jahan, 2018), personnel selection (Urosevic *et al.* 2017) and so on. Also, a systematic and comprehensive review of the application of the WASPAS method is given by Mardani *et al*. (2017).

A number of extensions of the WASPAS method have also been proposed. For example, Zavadskas *et al*. (2015a, 2015b) have proposed neutrosophic and grey extensions of the WASPAS method. Zavadskas *et al*. (2014) also proposed an extension that allows the use of interval-valued intuitionistic fuzzy numbers.

In order to enable the use of the WASPAS method for solving a significantly larger number of decision-making problems, an extension based on the use of intuitionistic fuzzy numbers is proposed in this article. Compared to similar extensions, the proposed extension is based on the use of the Hamming distance for the purpose of ranking alternatives. On the other hand, websites could have a very important role in modern companies; that is why their evaluation is chosen to demonstrate efficiency and usability of the proposed approach. Because of their growing importance, there has been an increasing attention paid to evaluation of their quality. One of the increasingly used methods for evaluating their quality is the approach based on the use of the MCDM method. Some of those approaches can be mentioned here, such as: Pamučar *et al*. (2018), Abdel-Basset *et al*. (2018), Chou *et al*. (2012), and Bilsel *et al*. (2016).

Therefore, this paper is organized as follows: In Section 2 some basic elements of the IFSs theory as well as some elements relevant to the proposed approach are discussed. In Section 3, the WASPAS method is presented and one extension adapted for use IFSs is proposed, and in Section 4, efficiency and usability of the proposed approach are considered on an example of a website evaluation problem. Finally, the conclusions are given.

2. Preliminaries

In this section some basic definitions and notations relevant for the proposed approach are discussed.

2.1 The basic concepts of intuitionistic fuzzy sets

Atanassov *Intuitionistic Fuzzy Sets*. An IFS $\tilde{A}$ in X can be defined as follows:

$$\tilde{A} = \left\{ \langle x, \mu_A(x), \nu_A(x) \rangle \middle| x \in X \right\} \tag{1}$$

where: $\mu_A(x)$ and $\nu_A(x)$ denote the degree of the membership and the degree of the non-membership of the element *x* to set *A*, respectively; $\mu_A : X \to [0,1]$ and $\nu_A : X \to [0,1]$, with the following condition

$$0 \le \mu_A(x) + \nu_A(x) \le 1. \tag{2}$$

2. 2 Intuitionistic Fuzzy Numbers

The IFSs theory proposes several shapes of Intuitionistic Fuzzy Numbers (IFNs). Triangular and trapezoidal shapes can be mentioned as significant ones.

In addition to the above mentioned shapes, the singleton (single-valued) shape can be pointed out as a characteristic one. A single-valued IFN $\tilde{A}$, $\tilde{A} = \langle a, a' \rangle$, shown in Fig. 1, is defined with membership $\mu_A(x)$ and non-membership $\nu_A(x)$ function, respectively, as follows:

$$\mu(x) = \begin{cases} 1 & x = a, \\ 0 & otherwise; \end{cases} \tag{2}$$

$$\nu(x) = \begin{cases} 1 & x = a' \\ 0 & otherwise; \end{cases} \tag{3}$$

where: parameter *a* indicates the most promising value that describes belonging to a set, parameter *a′* indicates the most promising value that describes not-belonging to a set

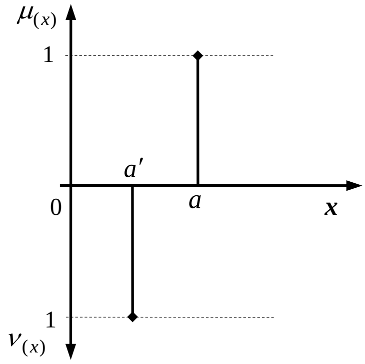

Fig. 1 A singleton IFN

Basic operations on IFNs. Let $\tilde{A} = \langle a, a' \rangle$ and $\tilde{B} = \langle b, b' \rangle$ be two IFNs. The operations of addition and multiplication on IFNs are as follows (Atanassov 1994):

$$\tilde{A} + \tilde{B} = \langle a + b - ab, a'b' \rangle \tag{4}$$

$$\tilde{A} \cdot \tilde{B} = \langle ab, a' + b' - a'b' \rangle \tag{5}$$

$$\lambda \tilde{A} = \left\langle 1 - (1-a)^{\lambda}, a'^{\lambda} \right\rangle \tag{6}$$

$$\tilde{A}^{\lambda} = \left\langle a^{\lambda}, 1 - (1-a')^{\lambda} \right\rangle \tag{7}$$

Score function of IFNs. Let be a single-valued IFN. Then, the score is as follows

$$S_{\tilde{A}} = a - a', \tag{8}$$

where $S_{\tilde{A}} \in [-1,\ 1]$.

The Hamming distance of IVIFNs. Let $\tilde{A} = \langle a, a' \rangle$ and $\tilde{B} = \langle b, b' \rangle$ be two IFNs. Then, the Hamming distance d_H is as follows

$$d_H(\tilde{A}, \tilde{B}) = \frac{1}{2}(|a - b| + |a' - b'|) \tag{9}$$

Intuitionistic Weighted Arithmetic Mean operator of single-valued IFNs. Let $\tilde{A}_j = \langle a_j, a'_j \rangle$ be a collection of n single valued IFNs. Then, the Intuitionistic Weighted Arithmetic Mean (IWAM) operator is as follows (Tikhonenko-Kędziak, Kurkowski, 2016):

$$IWAM = \left\langle 1 - \prod_{j=1}^{n} (1 - a_j)^{w_j}, \prod_{j=1}^{n} (a'_j)^{w_j} \right\rangle \tag{10}$$

where: w_j denote weight of *j*-th element of collection, $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$.

Intuitionistic Fuzzy Weighted Geometric operator of IFSs. Let $\tilde{A}_j = \langle a_j, a'_j \rangle$ be a collection of *n* single-valued IFNs. Then, the Intuitionistic Fuzzy Weighted Geometric (IFWG) operator is as follows (Tikhonenko-Kędziak, Kurkowski, 2016):

$$IFWG = \left\langle \prod_{j=1}^{n} (a_j)^{w_j}, 1 - \prod_{j=1}^{n} (1 - a'_j)^{w_j} \right\rangle \tag{11}$$

where: w_j denote weight of *j*-th element of collection, $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$.

3. WASPAS method

The basic idea of the WASPAS method is that it integrates two well-known approaches: weighted sum (WS) and weighted product (WP). The computational procedure of the WASPAS method for a decision-making problem involving only the beneficial criteria can be presented as follows:

Step 1 Determine the optimal performance rating for each criterion as follows:

$$x_{0j} = \max_i x_{ij} \tag{12}$$

where x_{0j} denotes the optimal performance rating of *j*-th criterion, x_{ij} denotes the performance rating of *i*-th alternative in relation to the *j*-th criterion.

Step 2 Construct the normalized decision matrix, as follows:

$$r_{ij} = \frac{x_{ij}}{x_{0j}} \tag{13}$$

where r_{ij} denotes the normalized performance rating of *i*-th alternative in relation to the *j*-th criterion.

Step 3 Calculate the importance of each alternative based on WS method Q_i^{ws} as follows:

$$Q_i^{ws} = \sum_{j=1}^{n} w_j \, r_{ij} \tag{14}$$

Step 4 Calculate the importance of each alternative based on WP method Q_i^{wp} as follows:

$$Q_i^{wp} = \prod_{j=1}^{n} r_{ij}^{\,w_j} \tag{15}$$

Step 5 Calculate the overall importance of each alternative Q_i as follows:

$$Q_i = 0.5(Q_i^{ws} + Q_i^{wp}) \tag{16}$$

3.1 An extension of WASPAS method based on the application of IFN and group decision-making

One extension of the WASPAS method proposed with the aim to enable the use of IFN in a group environment is presented in this section.

At the very beginning, it can be said that normalization is not necessary in this approach. The normalization process, in MCDM methods, is used for the following reasons:

- to transform performance ratings in the interval (0,1], and
- to transform performance ratings of cost criteria into adequate beneficial criteria.

However, as has already been stated, the values of IFN already belong to [0, 1] interval, which makes no need for normalization in this extension of the WASPAS method. Therefore, the procedure of the proposed extension could be precisely presented by using the following steps:

Step 1 Form a group decision-making matrix based on individual decision-making matrices, which can be carried out using Eq. (10).

Step 2 Determine the group criteria weights. In the scientific literature, a number of methods for determining criteria weights are proposed, and each of them can be used in this approach.

Step 3 Calculate the importance based on the WS approach, for each alternative, by using Eq. (10).

Step 4 Calculate the importance based on the WP approach, for each alternative, by using Eq. (11).

Step 5 Calculate the overall importance of each alternative $\tilde{Q}_i$. In this step, $\tilde{Q}_i$ is calculated by using Eq (5). However, taking into account that the values of $\tilde{Q}_i^{ws}$ and $\tilde{Q}_i^{wp}$ are IFNs, the calculation must be carried out by using Eqs. (4) and (7).

Step 6 Rank the alternatives and select the most acceptable one. Ranking of IFNs can be done based on the value of their score functions, which is an often used approach. However, the use of the Hamming distance is recommended in this approach, where the distance of each alternate is determined in relation to the ideal point <1, 0>.

Finally, the alternative that has the least distance from the ideal point is the most acceptable one.

4. A Numerical Example

In order to provide for a detailed explanation of the proposed approach an example of websites evaluation, borrowed from Stanujkic et al. (2015), is considered. In this example, three websites are evaluated based on the following criteria:

- Environment (E),
- Content (C),
- Graphics (G), and
- Authority (A).

The ratings obtained from three respondents are shown in Tables 1, 2 and 3.

Table 1 Ratings obtained from the first of three respondents

Criteria Alternatives	En	Co	Gr	Au
A_1	<0.625,0.125>	<0.625,0.375>	<0.625,0.250>	<0.375,0.250>
A_2	<0.625,0.375>	<0.750,0.125>	<0.625,0.125>	<0.500,0.250>
A_3	<0.750,0.125>	<0.500,0.125>	<0.625,0.375>	<0.375,0.125>

Table 2 Ratings obtained from the second of three respondents

Criteria Alternatives	En	Co	Gr	Au
A_1	<0.875,0.125>	<0.625,0.375>	<0.625,0.250>	<0.375,0.250>
A_2	<0.750,0.250>	<0.750,0.250>	<0.625,0.125>	<0.500,0.250>
A_3	<0.750,0.125>	<0.500,0.125>	<0.500,0.250>	<0.375,0.125>

Table 3 Ratings obtained from the third of three respondents

Criteria Alternatives	En	Co	Gr	Au
A_1	<0.625,0.125>	<0.625,0.375>	<0.500,0.250>	<0.375,0.250>
A_2	<0.250,0.375>	<0.750,0.125>	<0.500,0.125>	<0.500,0.250>
A_3	<0.625,0.250>	<0.500,0.125>	<0.625,0.375>	<0.250,0.375>

The group ratings, determined by using Eq. (10), and criteria weights are shown in Table 4. In this calculation, the following weights were assigned to the respondents: 0.35, 0.34, 0.31. The importance of the considered alternatives based on the WS approach, calculated by using Eq. (10), are shown in Table 5. The importance of the considered alternatives based on the WP approach, calculated by using Eq. (11), are also shown in Table 5.

Table 4 Group ratings and criteria weights

Criteria	En	Co	Gr	Au
Weights Alternatives	0.28	0.25	0.24	0.23
A_1	<0.742,0.125>	<0.625,0.375>	<0.590,0.250>	<0.375,0.250>
A_2	<0.595,0.327>	<0.750,0.158>	<0.590,0.125>	<0.500,0.250>
A_3	<0.717,0.155>	<0.500,0.125>	<0.586,0.327>	<0.339,0.176>

Table 5 Overall ratings and ranking order of alternatives

	WS	WP	$\tilde{Q}_i$	H_d	Rank
A_1	<0.609,0.229>	<0.572,0.253>	<0.591,0.241>	0.325	3
A_2	<0.622,0.202>	<0.604,0.222>	<0.613,0.212>	0.300	1
A_3	<0.562,0.181>	<0.522,0.198>	<0.543,0.190>	0.323	2

The overall importance of the considered alternatives, calculated by using Eqs. (4) and (7), as well as ranking order of the considered alternatives, are also shown in Table 5.

As can be seen from Table 5, the most appropriate alternative is alternative denoted as A_2.

For the purpose of verifying the proposed approach, the result of ranking alternatives based on the use of score function is shown in Table 6.

Table 6 Values of the score function and the ranking order of alternatives

	S_i	Rank
A_1	0.190	3
A_2	0.210	1
A_3	0.190	2

As can be seen from Table 6, the results obtained by using the Hamming distance and the score function are identical, which confirms accuracy of the proposed approach.

5. Conclusions

In this article, an extension of the WASPAS method that allows the use of single-valued intuitionistic fuzzy numbers and the Hamming distance is proposed. Due to the use of intuitionistic numbers, the proposed extension allows the formation of multiple criteria decision-making models using a smaller number of criteria, which can be more appropriate in some cases.

In numerous extensions of many multiple criteria decision-making methods, the ranking of intuitionistic fuzzy numbers is mainly based on the use of the score function. Therefore, a ranking based on the Hamming distance is suggested in the proposed extension of the WASPAS method.

Usability of the proposed extension is demonstrated on an example of website evaluation. In doing so, the same order ranking order of the considered alternatives was obtained using the proposed ranking procedure and the procedure based on the score function, which confirms the correctness of the proposed procedure.

The proposed approach is based on the Intuitionistic Set theory, which is a generalization of the fuzzy logic. Therefore, there are currently no significant limitations in the application of the proposed approach. The only real limitation that is observed is the gathering of the interviewees' realistic attitudes, which can be overcome by preparing interviewees or by using interactive questionnaires. On the other hand, with the adjusted set of evaluation criteria, the proposed model can be applied to solving similar problems.

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