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Ranking of Trapezoidal Intuitionistic Fuzzy Sets based on Improved Accuracy Function and solving Fuzzy MCDM Problems Using TOPSIS method

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Abstract This research paper offers an improved accuracy function for the adequate ranking order of trapezoidal intuitionistic fuzzy sets and by using trapezoidal intuitionistic fuzzy TOPSIS method to solve the multicriteria decision-making problems .The alternatives can be ranked on the basis of the values of the closeness coefficients and the most enviable one(s) can be chosen in the decision-making process.In the end, some illustrative examples are given to show the potency of the proposed method.

Keywords Interval valued intuitionistic fuzzy sets ,Trapezoidal Intuitionistic Fuzzy Number,Accuracy Function,TOPSIS Method,Fuzzy Multi Criteria Decision Making.

1.Introduction

In order to find the most suitable alternative among a set of executable alternatives, decision-making is the procedure for it. Hwang and Yoon [1], developed an eminent method for multicriteria decision-making. On the basis of fuzzy arithmetic operations, Triantaphyllou and Lin [2], developed the fuzzy edition of the TOPSIS access by leading to a fuzzy relative closeness for every alternatives.Between any two fuzzy numbers Chen [3] defined a crisp Euclidean distance in order to stretch out the TOPSIS approach to fuzzy group decision-making circumstances. Fuzzy multicriteria decision-making problem converted into a crisp one by Tsaur et al. [4]. Nowadays, numerous researchers have paid nice care to interval-valued fuzzy sets (IVFSs) [5, 6], intuitionistic fuzzy sets (IFSs)/vague sets (VSs) [7,8] and interval-valued intuitionistic fuzzy sets (IVIFSs) [9], which are all the generalization of the fuzzy set proposed by Zadeh [10], and applied them in decision-making (DM) problems. For our purpose, we extended these IVIFN into TrIFN. Ashtiani et al. [11] has given an interval-valued fuzzy technique for order preference by similarity to an ideal solution (TOPSIS) for solving multi-criteria decision-making problems. Li [12] has given multi-attribute decision-making models and methods using IFSs, and then Li [13] extended the generalized-ordered, weighted, averaging operators to look into multi attribute decision-making problems using the accuracy function and the score function to rank the IFSs. Then, Ye [15] conferred a multicriteria decision-making technique using an improved accuracy function of VSs. Chen [16] constituted versatile algorithms with SAW and TOPSIS strategies by taking into account of each subjective and objective data to work out best multicriteria choices. Rudvan Sahin [17] developed an improved accuracy function for interval-valued intuitionistic fuzzy [18] sets to solve fuzzy MCDM problems. The basic characteristic of the IVIFS is that the values of its membership function and nonmembership function are intervals instead of precise numbers. So as to create correlations between two IVIFSs, some metric strategies were proposed by accuracy functions and score functions [15, 19,20] and were applied to multicriteria decision-making (MCDM)problems.

However, our studies proclaimed that these functions make some important defect in some places.Therefore, during this paper; we have a tendency to propose an improved accuracy function and developed trapezoidal intuitionistic fuzzy TOPSIS methodology supported the improved accuracy function to resolve multicriteria decision-making problems within which the performance rating values are expressed by TrIFSs.

The rest of this paper is unionized as follows. In Section 2, we succinctly introduce TrIFSs and its accuracy functions and score functions. Section 3 proposes an improved accuracy function of TrIFSs and makes comparisons with existing functions.Section 4 develops a TOPSIS method based on the improved accuracy function to solve trapezoidal intuitionistic fuzzy MCDM problems. Section 5 investigates two illustrative examples to show the potency of the proposed method. In Section 6, the paper is consummated.

2. Preliminaries

Definition 2.1 [9] Let the set of all closed subintervals of the interval [0, 1] be expression of an IVIFS in X is given by $=\{ ,( ), ( ): \in \}$, where with the condition $0 < ( ) + ( ) \leq 1$ [0, 1]. Let $(\neq \emptyset)$ be a given set.An : $\rightarrow [0, 1]$, : $\rightarrow [0, 1]$ set A are denoted by ( ) and ( )

The degree of belongingness and non-belongingness of the element x to the respectively.

Thus we denote A by A = { , [( ), ( )], [( ), ( )] | ∈ } where 0 < ( ) + ( ) ≤ 1 , ( ) ≥ 0, ( ) ≥ 0.

The unknown degree (hesitancy degree) for each ∈ in A defined as follows ( ) = 1 − ( ) − ( ) =[1 − ( ) − ( ) , 1 − ( ) − ( )].

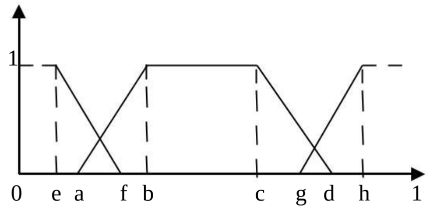
Let IVIFS( ) denotes the set of all IVIFSs in .An IVIFS value is denoted by = ([,], [,]) and the degree of indeterminacy by [,] = [1 − − , 1 − −] for convenience.And we will denote Trapezoidal Intuitionistic Fuzzy Number by = ([, , ,], [, , , h]) where [, , ,] denotes the degree of membership and [, , , h] denotes degree of nonmembership.

Definition 2.2 [9] Let P, Q ∈ IVIFS( ). A subset relation is defined by ⊂ if and only if ( ) ≤ ( ), ( ) ≤ (x) and ( ) ≥ ( ), ( ) ≥ ( ), for all ∈ .

Definition 2.3 [9] The complement of is defined by = { , ( ), ( ) : ∈ X }.

Definition 2.4 [20] Let = ([1, 1, 1, 1], [1, 1, 1, h1]) and = ([2, 2, 2, 2], [2, 2, 2, h2]) are two TrIFN. A subset relation is defined by ⊆ if and only if 1 ≤ 2, 1 ≤ 2, 1 ≤ 2, 1 ≤ 2 and 1 ≥ 2, 1 ≥ 2, 1 ≥ 2, h1 ≥ h2 respectively.

Definition 2.5 Let = ([, , ,], [, , , h]) be a trapezoidal intuitionistic fuzzy number.Then the and cuts of the membership and non membership functions are defined by [(−) + , (−) +] and [(−) + , (h −) +]



Definition 2.6 [19] Let = ([,], [,]) be an IVIFN. The accuracy function H is defined by

We can extend this accuracy function for TrIFN by the following proposition.

Proposition 2.6.1 Let = ([, , ,], [, , , h]) be a TrIFN. The accuracy function H_T is defined from H(A) as follows

$$H_T(A) \quad \frac{1}{2}\int_0^1 [\ (b\ \ a)\ \ a(c\ \ d)\ \ d(e\ \ f)\ \ f(h\ \ g)\ \ g]d$$

Hence, ( ) =

Definition 2.7 [15] Let = ([,], [,]) be an IVIFN. The novel accuracy function M is defined by

( ) = −(1− −)+ −(1− −) = + − 1 + +

We can extend this novel accuracy function for TrIFN by the following proposition.

Proposition 2.7.1 Let = ([, , ,], [, , , h]) be a TrIFN. The novel accuracy function M_T is defined from M(A) as follows

$$M_T(A) \quad \int_0^1 [\ (b\ \ a)\ \ a(c\ \ d)\ \ d\ \ 1]d \qquad \frac{1}{2}\int_0^1 [\ (e\ \ f)\ \ f(h\ \ g)\ \ g]d$$

Hence, ( ) = − 1 +

Definition 2.8 [18] Let = ([,], [,]) be an IVIFN. The new novel accuracy function L is defined by

We can extend this new novel accuracy function for TrIFN by the following proposition.

Proposition 2.8.1 Let = ([, , ,], [, , , h]) be a TrIFN. The new novel accuracy function L_T is defined from L(A) as follows

$$L_T(A) \quad \frac{1}{2}\int_0^1 [\ (b\ a)\ a\ \ (c\ \ d)\ \ d\ \ (\ (e\ \ f)\ \ f\ \ (h\ \ g)\ \ g)\ \ ((\ (b\ \ a)\ \ a)(\ (e\ \ f)\ \ f)\ \ (\ (c\ \ d)\ \ d)(\ (h\ \ g)\ \ g))]d$$

Hence, ( ) = − + +

3. Ranking by Improved Accuracy function for TrIFN

Consider that the socioeconomic environment becomes more complex,the membership and nonmembership values gathered from the information may be intervals rather than exact numbers.Also that interval may be of the trapezoidal intuitionistic fuzzy number form.So in order to solve decision problem when the given information is of TrIFNs,we introduce the improved accuracy function to rank the alternatives.

Example 3.1 Let A_1 = ([0.1, 0.2, 0.2, 0.4], [0.2, 0.2, 0.3, 0.3]) and A_2 = ([0.1, 0.1, 0.3, 0.4], [0.1, 0.2, 0.3, 0.4]) be two trapezoidal intuitionistic fuzzy values for two alternatives.

By applying Proposition 2.6.1 we obtain $H_T(A_1) = 0.475$ and $H_T(A_2) = 0.475$.

By applying Proposition 2.7.1 we obtain $M_T(A_1) = -0.3$ and $M_T(A_2) = -0.3$.

In both the above two Proposition 2.6.1 and Proposition 2.7.1,we have noticed that the novel accuracy function and the accuracy function are inversely proportional to the hesitation.Since we came to know that both are directly proportional to membership and nonmembership values, respectively. In order to overcome this illogical concept the new improved accuracy function is defined as follows

Definition 3.1.1 Let = ([, , ,], [, , , h]) be a TrIFN, the improved accuracy function K_T of a TrIF value, based on the hesitancy degree is defined from K(A) [17] as follows

Since ( ) = + (1 − −) + (1 −)

$$\frac{1}{2}\int_0^1 [((b-a)\alpha+a)+((c-d)\alpha+d)+((c-d)\alpha+d)(1-((b-a)\alpha+a)-((e-f)\alpha+f))-((b-a)\alpha+a)(1-((c-d)\alpha+d)-((h-g)\alpha+g))]d\alpha$$

Hence, ( ) = $\frac{+++}{2}$ $\frac{-+}{3}$ $\frac{-+++++h}{6}$ $\frac{-h++}{12}$ ....(1)

Note:

- If we put b = a , c = d and f = e ,g = h, we can define the improved accuracy function for an IVIFN.[17]

By applying Definition 3.1.1 to Example 3.1,we obtain $K_T(A_1) = 0.3542$ and $K_T(A_2) = 0.3708$

Example 3.2 Let A_1 = ([0.2, 0.3, 0.4, 0.4], [0.1, 0.2, 0.3, 0.5]) and A_2 = ([0.1, 0.3, 0.4, 0.5], [0.2, 0.2, 0.3, 0.4]) be two trapezoidal intuitionistic fuzzy values for two alternatives.If our intention is to choose the best alternative, according to the accuracy function H_T , we got $H_T(A_1) = 0.6$ and $H_T(A_2) = 0.6$.And according to the noval accuracy function M_T , we got $M_T(A_1) = -0.075$ and $M_T(A_2) = -0.075$.And according to the new noval accuracy function L_T , $L_T(A_1) = 0.1733$ and $L_T(A_2) = 0.1733$.

So we cannot say which alternative is better for these cases.But when we apply Definition 3.1.1 we can obtain $K_T(A_1) = 0.4692$ and $K_T(A_2) = 0.4808$.Thus the alternative A_2 is more suitable than the alternative A_1.But other functions which we derived from the existing functions cannot rank properly and so, we tend to do not recognize that which alternative is more good.Therefore, we will say that our proposed function for TrIFN is more practical and more sensible than the others.

Proposition 3.1.1 For any trapezoidal intuitionistic fuzzy subset A = ([a, b, c, d], [e, f, g, h]), the improved accuracy function ( ) ∈ [0, 1].

Proposition 3.1.2 For a fuzzy subset A = a = ([a, a, a, a] , [1 − a, 1 – a ,1 – a , 1 - a]) , the improved accuracy function is $K_T(A) = a$.

In particular

If A = ([1, 1, 1, 1], [0, 0, 0, 0]), $K_T(A) = 1$

If A = ([0, 0, 0, 0], [1, 1, 1, 1]), $K_T(A) = 0$

Theorem 3.1.1 For any two TrIFSs , , if ⊆ then ( ) ≤ ( ).

Proof ( ) − ( ) =

$$\frac{a_1-a_2+b_1-b_2+c_1-c_2+d_1-d_2}{2}+\frac{a_2d_2-a_1d_1+b_2c_2-b_1c_1}{3}+\frac{a_2c_2-a_1c_1+b_2d_2-b_1d_1-c_2e_2+c_1e_1-d_2f_2+d_1f_1-a_2g_2+a_1g_1-b_2h_2+b_1h_1}{6}+\frac{a_2h_2-a_1h_1+b_2g_2-b_1g_1-c_2f_2+c_1f_1-d_2e_2+d_1e_1}{12}$$

≥ 0

Hence, ( ) ≤ ( ).

Theorem 3.1.2 Let A = ([a, b, c, d], [e, f, g, h]) be a TrIFN.
Then $K_T(A) + K_T(A^c) \leq 1$.

4.TOPSIS Method Based on the Improved Accuracy Function for TrIFN

In this section by using TOPSIS method we are going to solve Fuzzy MCDM problems in which all precedence data gathered by decision makers is expressed as TrIF decision matrix, where every entry is distinguished by TrIFN value, and the data about standard weights is known. In order to ascertain the relative closeness coefficients we apply the improved accuracy function to compute the separation measures of every alternative from the positive and negative ideal solutions.

In a MCDM problem,if there exist a set of alternatives $A = \{ A_1, A_2, \ldots, A_m \}$.Every alternative is measured on n criteria,which are indicated by $C = \{ C_1, C_2, \ldots, C_n \}$.The characteristics of an alternative A_i with respect to a criterion C_j can be represented by an TrIFN $x_{ij} = ([a_{ij}, b_{ij}, c_{ij}, d_{ij}], [e_{ij}, f_{ij}, g_{ij}, h_{ij}])$(I = 1,2,….,m ; j = 1,2.…,n) which denotes the membership and nonmembership degree of the alternative $A_i \in A$ with respect to the criterion $C_j \in C$ .The TrIF decision matrix $D_{m \times n}(x_{ij})$ is defined as follows

$$D_{mxn}(x_{ij}) = \begin{pmatrix} \langle [a_{11},b_{11},c_{11},d_{11}],[e_{11},f_{11},g_{11},h_{11}] \rangle & \langle [a_{12},b_{12},c_{12},d_{12}],[e_{12},f_{12},g_{12},h_{12}] \rangle & \cdots & \langle [a_{1n},b_{1n},c_{1n},d_{1n}],[e_{1n},f_{1n},g_{1n},h_{1n}] \rangle \\ \langle [a_{21},b_{21},c_{21},d_{21}],[e_{21},f_{21},g_{21},h_{21}] \rangle & \langle [a_{22},b_{22},c_{22},d_{22}],[e_{22},f_{22},g_{22},h_{22}] \rangle & \cdots & \langle [a_{2n},b_{2n},c_{2n},d_{2n}],[e_{2n},f_{2n},g_{2n},h_{2n}] \rangle \\ \vdots & \vdots & & \vdots \\ \langle [a_{m1},b_{m1},c_{m1},d_{m1}],[e_{m1},f_{m1},g_{m1},h_{m1}] \rangle & \langle [a_{m2},b_{m2},c_{m2},d_{m2}],[e_{m2},f_{m2},g_{m2},h_{m2}] \rangle & \cdots & \langle [a_{mn},b_{mn},c_{mn},d_{mn}],[e_{mn},f_{mn},g_{mn},h_{mn}] \rangle \end{pmatrix}$$

Now we convert the TrIF decision matrix $D_{m \times n}(x_{ij})$ into the following accuracy matrix $R_{mxn}(K_{T_{ij}}(x_{ij}))$ using the improved accuracy function K_T

$$R_{m \times n}(K_{T_{ij}}(x_{ij})) = \begin{pmatrix} K_{T_{11}}(x_{11}) & K_{T_{12}}(x_{12}) & \cdots & K_{T_{1n}}(x_{1n}) \\ K_{T_{21}}(x_{21}) & K_{T_{22}}(x_{22}) & \cdots & K_{T_{2n}}(x_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ K_{T_{m1}}(x_{m1}) & K_{T_{m2}}(x_{m2}) & \cdots & K_{T_{mn}}(x_{mn}) \end{pmatrix}$$

Let us take the weight of the criterion C_j (j = 1,2,…,n), is w_j, $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$

Then the positive and negative ideal solutions of the alternatives are denoted by $A^+ = \{ (C_j,[1,1],[0,0]) / C_j \in C \}$, j = 1,2,….,n and $A^- = \{ (C_j,[0,0],[1,1]) / C_j \in C \}$, j = 1,2,…,n respectively.Thus the improved accuracy function based separation measures $d_i(A^-, A_i)$ and $d_i(A^+, A_i)$ of every alternative from the negative and positive ideal solutions respectively are obtained from

$$d_i(A^-, A_i) = \sqrt{\sum_{j=1}^{n} [w_j K_{T_{ij}}(x_{ij})]^2} \quad \text{and} \quad d_i(A^+, A_i) = \sqrt{\sum_{j=1}^{n} [w_j (1 - K_{T_{ij}}(x_{ij}))]^2} \qquad \text{….(2)}$$

Hence, the relative closeness of an alternative A_i with respect to the positive ideal solution A^+ is defined as the following general formula

$$C_i(A_i) = \frac{d_i(A^-, A_i)}{d_i(A^+, A_i) + d_i(A^-, A_i)} \quad \text{where } C_i(A_i) \ (i = 1,2,\ldots,m) \qquad \text{…. (3)}$$

is the relative closeness coefficient of A_i with respect to the positive ideal solution A^+ and $0 \leq C_i(A_i) \leq 1$.Then according to the descending order of $C_i(A_i)$,the alternatives can be ranked.Ultimately the highest value of $C_i(A_i)$ will be the preferable one amongst the alternatives.

5.Numerical Examples

In order to show the potency of the improved accuracy function, the following two examples are used as a demonstration

Example 5.1 A leading company has to select one among four candidates for their company for the HR post ,according to the following three criteria: (1) C_1 is the Academic Records.(2) C_2 is his/her IQ .(3) C_3 is the Fluency in English.The criterion weight is given by **W =** (0.35,0.25,0.40) .The alternatives A_i (i =1,2,3,4) is to be assessed using the TrIFN by the decision maker under the above three criteria as listed in the following DM , D_{4x3} (x_{ij})

.2,.3,.3,.4,.4,4,5,5,.4,4,.4,.5 , .4,.5,.5,.5 , .1,.2,.4.43,2.21.2.23,3.234.5 .3,.4,.4.4,.23,3.44,5.55, 3,3.44.1.13,3,.2.24,4.12,3,3,.22,.4,.4 .3,.4,.4.5,.23,4.42,3.44, 3,4.45.4.44,5,.3.34,4.34,5.5,.3.3,.4,.4

$D_{4\ 3}(x_{ij})$

Then we use the proposed approach to select the most enviable one(s).Then the accuracy matrix R_{4x3} (( )) is obtained by using (1).

$R_{4\ 3}\ K_T\ (x_{ij})$

0.4367	0.4983	0.5167
0.6075	0.5600	0.4233
0.5650	0.3200	0.5225
0.5608	0.3450	0.5300

We can determine the values of positive and negative ideal solutions by using (2) as follows

$d_1(A, A_1)$ 0.3033, $d_2(A, A_2)$ 0.2902, $d_3(A, A_3)$ 0.2977, $d(A, A_4)$ 0.2928

$d_1(A, A_1)$ 0.2857, $d_2(A, A_2)$ 0.3057, $d_3(A, A_3)$ 0.2986, $d(A, A_4)$ 0.3014

We can get the closeness coefficient $C_i(A_i)$ (i =1,2,3,4) by using (3): $C_1(A_1)$ =0.4851 , $C_2(A_2)$ =0.5130 , $C_3(A_3)$ =0.5008 , $C_4(A_4)$ =0.5072

Thus the four alternatives are ranked as follows A_2, A_4, A_3 and A_1.So clearly A_2 is preferable amongst them.

Example 5.2 let us take the same problem as in [18] and make another example.The alternative A_i (i= 1,2,…,5)the appropriate criterian C_j(j= 1,2,..,6) and the criterion weight is given by **W =** (0.2, 0.1, 0.25, 0.1, 0.15, 0.2) .The alternatives A_i (i =1,2,3,4,5) is to be assessed using the TrIFN by the decision maker under the above six criteria as listed in the following DM, D_{5x6} (x_{ij})

$D_{5\ 6}(x_{ij})$

.2,.2,.3,.3 , .4,.4,.5,.5	.6,.6,.7,.7 , .2,.2,.3,.3	.4,.4,.5,.5 , .2,.2,.4,.4	.7,.7,.8,.8 , .1,.1,.2,.2	.1,.1,.3,.3 , .5,.5,.6,.6	.5,.5,.7,.7 , .2,.2,.3,.3
.6,.6,.7,.7 , .2,.2,.3,.3	.5,.5,.6,.6 , .1,.1,.3,.3	.6,.6,.7,.7 , .2,.2,.3,.3	.6,.6,.7,.7 , .1,.1,.2,.2	.3,.3,.4,.4 , .5,.5,.6,.6	.4,.4,.7,.7 , .1,.1,.2,.2
.4,.4,.5,.5 , .3,.3,.4,.4	.7,.7,.8,.8 , .1,.1,.2,.2	.5,.5,.6,.6 , .3,.3,.4,.4	.6,.6,.7,.7 , .1,.1,.3,.3	.4,.4,.5,.5 , .3,.3,.4,.4	.3,.3,.5,.5 , .1,.1,.3,.3
.6,.6,.7,.7 , .2,.2,.3,.3	.5,.5,.7,.7 , .1,.1,.3,.3	.7,.7,.8,.8 , .1,.2,.2,.2	.3,.3,.4,.4 , .1,.1,.2,.2	.5,.5,.6,.6 , .1,.1,.3,.3	.7,.7,.8,.8 , .1,.1,.2,.2
.5,.5,.6,.6 , .3,.3,.4,.4	.3,.3,.4,.4 , .3,.3,.5,.5	.6,.6,.7,.7 , .1,.1,.3,.3	.6,.6,.8,.8 , .1,.1,.2,.2	.6,.6,.7,.7 , .2,.2,.3,.3	.5,.5,.6,.6 , .2,.2,.4,.4

Then we use the proposed approach to get the most desirable alternative(s).Then the accuracy matrix R_{5x6} (( )) is obtained by using (1).

$R_{5\ 6}\ K_{Tij}\ (x_{ij})$

0.3300	0.7200	0.5700	0.8300	0.2650	0.7050
0.7200	0.6950	0.7200	0.7850	0.3900	0.7450
0.5450	0.8300	0.6100	0.7550	0.5450	0.5800
0.7200	0.7400	0.8100	0.5300	0.6950	0.8475
0.6100	0.4450	0.7550	0.8200	0.7200	0.6400

We can determine the values of positive and negative ideal solutions by using (2) as follows

$d_1(A, A_1)$ 0.2154, $d_2(A, A_2)$ 0.1428, $d_3(A, A_3)$ 0.1745, $d_4(A, A_4)$ 0.1064, $d_5(A, A_5)$ 0.1424

$d_1(A, A_1)$ 0.2414, $d_2(A, A_2)$ 0.2995, $d_3(A, A_3)$ 0.2607, $d_4(A, A_4)$ 0.3311, $d_5(A, A_5)$ 0.2954

We can get the closeness coefficient $C_i(A_i)$ (i =1,2,3,4) by using (3): $C_1(A_1)$ =0.5285 , $C_2(A_2)$ =0.6771 , $C_3(A_3)$ =0.5990 , $C_4(A_4)$ =0.7568 , $C_5(A_5)$ =0.6747

Thus the five alternatives are ranked as A_4, A_2, A_5,A_3 and A_1.So clearly A_4 is preferable amongst them.

6. Conclusion

In this paper we have extended the improved accuracy function for IVIFSs into improved accuracy function for TrIFSs.And a Trapezoidal intuitionistic fuzzy TOPSIS method based on the proposed accuracy function is applied to rank the alternatives and the most suitable one(s) can be chosen in the DM process. In the end of this paper for giving the applications and the potency of the developed approach, two illustrative examples are illustrated .In the future we will continue functioning on the application of our proposed technique to different domains.

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