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Jointly Organized by

Department of Biological Science, Physical Science and Computational Science

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A nations's growth is in proportion to education and intelligence spread among the masses. Having this idealistic vision, two great philanthropists late. S.P. Nallamuthu Gounder and Late. Arutchelver Padmabhushan Dr.N.Mahalingam formed an organization called Pollachi Kalvi Kazhagam, which started NGM College in 1957, to impart holistic education with an objective to cater to the higher educational needs of those who wish to aspire for excellence in knowledge and values. The College has achieved greater academic distinctions with the introduction of autonomous system from the academic year 1987-88. The college has been Re-Accredited by NAAC and it is ISO 9001 : 2015 Certified Institution. The total student strength is around 6000. Having celebrated its Diamond Jubilee in 2017, the college has blossomed into a premier Post-Graduate and Research Institution, offering 26 UG, 12 PG, 13 M.Phil and 10 Ph.D Programmes, apart from Diploma and Certificate Courses. The college has been ranked within Top 100 (72nd Rank) in India by NIRF 2021.

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Solving Intuitionistic Fuzzy Multi-Criteria Decision Making Problems a Centroid Based Approach

Dr.K.Arun Prakash [1] – Dr.M.Suresh [2]

ABSTRACT: The concept of an intuitionistic fuzzy number (IFN) is of importance for representing an uncertainty. Ranking of intuitionistic fuzzy numbers is a challenging role in decision making and linear programming problems. In this paper ranking of intuitionistic fuzzy number by means of centroid is applied for solving intuitionistic fuzzy multi-criteria decision making problems. Finally numerical example was illustrated to express the proposed method.
KEYWORDS: Intuitionistic fuzzy sets, intuitionistic fuzzy numbers, trapezoidal intuitionistic fuzzy numbers, magnitude of intuitionistic fuzzy number, intuitionistic fuzzy multi-criteria decision making.

1. INTRODUCTION

In our day today life, so many decisions are being made from various criteria's, so the decision can be made by providing weights to different criteria's and all the weights are obtain from expert groups. It is important to determine the structure of the problem and explicitly evaluate multi criteria. There are not only very complex issues involving multi criteria, some criteria may have effect toward some problem, but over all to have an optimum solution, all the alternatives must have common criteria which clearly lead to more informed and better decisions.

The classical decision making methods generally assume that all criteria and their respective weights are expressed in crisp values and, thus, that the rating and the ranking of the alternatives can be carried out without any problem. In a real-world decision situation, the application of the classical decision making method may face serious practical constraints from the criteria perhaps containing imprecision in the information. In many cases, performance of the criteria can only be expressed qualitatively or by using linguistic terms, which certainly demands a more appropriate method. The most preferable situation for a decision making problem is when all ratings of the criteria and their degree of importance are known precisely, which makes it possible to arrange them in a crisp ranking. However, many of the decision making problems in the real world take place in an environment in which the goals, the constraints, and the consequences of possible actions are not known precisely. As a result, the best condition for a classic decision making problem may not be satisfied, when the decision situation involves both fuzzy and crisp data. The classical decision making methods cannot handle such problems effectively, because they are only suitable

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for dealing with problems in which all performances of the criteria are represented by crisp numbers. The application of the fuzzy set theory in the field of decision making is justified when the intended goals or their attainment cannot be defined or judged crisply but only as fuzzy sets.

The fuzzy multi criteria techniques have been applied in various fields such as Banking sectors, issues such as urban distribution centers, water shed allocation, safety assessment, and performance evolution of business organizations. The use of fuzzy is to analyze the quantitative and qualitative data for any application. The different methods under FMCDM help us to perform may subtasks between where evaluation and ranking are done by different methods. Each method has its own uniqueness. Many methods exist to handle fuzzy multi-criteria decision making problems.

In many real world problems, due to insufficiency in the information available, the evaluation of membership values is not possible up to our satisfaction. Also the evaluation of non –membership values is not always possible and there remains an indeterministic part in which hesitation survives. Atanassov [1986] introduced the concept of intuitionistic fuzzy sets (IFS) which is a generalization of the concept of fuzzy set. In IFS the degree of non-membership denoting the non-belonging of an element to a set is explicitly specified along with the degree of membership.

Multiple attribute decision making (MADM) has been one of the fastest growing areas during the last decades depending on the changing in the business sector. Chen and Tan [5] developed an approach to intuitionistic fuzzy multiattribute decision making by utilizing the minimum and maximum operations and the score function. Later, Hong and Choi [6] improved Chen and Tan’s [5] technique through adding an accuracy function. Considering that the minimum and maximum operations adopted in these two papers may produce the loss of considerable decision information, Xu and Yager [7] proposed some geometric mean operators to aggregate intuitionistic fuzzy information and applied them to develop a procedure for multiattribute decision making with intuitionistic fuzzy information. Motivated by the well-known technique for order preference by similarity to ideal solution (TOPSIS), Boran et al. [8] suggested a method to select the appropriate supplier in intuitionistic fuzzy group decision-making environments, in which the intuitionistic fuzzy weighted averaging operator was utilized to aggregate individual opinions of decision makers for rating the importance of attributes and alternatives. Zhao [9] also used the intuitionistic fuzzy weighted averaging operator to establish an evaluation model for intellectual capital with intuitionistic fuzzy information. Zhao et al. [9] introduced the generalized intuitionistic fuzzy weighted aggregation operator, the generalized intuitionistic fuzzy ordered weighted aggregation operator, and the generalized intuitionistic fuzzy hybrid aggregation operator, and gave their applications to intuitionistic fuzzy multiattribute decision making. Motivated by the correlation properties of the traditional Choquet integral, Xu [7] proposed the intuitionistic fuzzy correlated averaging operators and the intuitionistic fuzzy correlated geometric operators, whose characteristic is that they cannot only consider the importance of the elements or their ordered positions, but reflect the correlations of the elements or their ordered positions as well. The developed operators were, then, applied to a practical decision-making problem involving the prioritization of information technology improvement projects.

Tan and Chen [12] also studied the desirable characteristics of the intuitionistic fuzzy correlated averaging operators, and based on this, they gave an approach for multiattribute decision making with intuitionistic fuzzy information and applied it to solve a practical decision-making problem where a manufacturing company wants to select the best global supplier according to the core competencies of potential suppliers. Wei [14] introduced an induced intuitionistic fuzzy ordered weighted geometric operator and gave a corresponding technique for multiattribute group decision making. Combining the order-induced aggregation and the generalized aggregation, Xu and Xia [15] developed some new types of aggregation operators, including the induced generalized intuitionistic fuzzy Choquet integral operators and the induced generalized intuitionistic fuzzy Dempster-Shafer operators, and used them to financial decision making under intuitionistic fuzzy environments. Xu and Yager [16] applied the weighted intuitionistic fuzzy Bonferroni mean to multiattribute decision making, which can also reflect the interrelationship of the individual attributes and, thus, can take the decision information into account as much as possible. Li [17] developed a nonlinear programming methodology that is based on the TOPSIS to solve multiattribute decision-making problems with both the ratings of alternatives on attributes and the weights of attributes expressed with interval-valued intuitionistic fuzzy sets (A-IVIFS).

Xu [18] first established an optimization model by which a straightforward formula to derive attribute weights can be obtained, and then, on the basis of information theory, the intuitionistic fuzzy hybrid aggregation operator, the intuitionistic fuzzy weighted averaging operator, the score function, and the accuracy function, he developed an approach to intuitionistic fuzzy group decision making. Xu and Cai [19] established several nonlinear optimization models to determine the weights of experts and attributes and utilized the simple additive weighting method to aggregate all the intuitionistic fuzzy information to rank and select the alternatives. Li et al. [20] developed a linear programming methodology to solve multiattribute group decision-making problems using intuitionistic fuzzy sets, in which the attribute weights are estimated using a new auxiliary linear programming model, which minimizes the group inconsistency index under some constraints, and the distances of the alternatives from the intuitionistic fuzzy positive ideal solution are calculated to determine their ranking order.

Li [21] constructed some linear programming models to generate the optimal weights for attributes and proposed the corresponding multiattribute decision-making methods using intuitionistic fuzzy sets. For more general situations where the information about attribute weights is partially known, which may be constructed by various forms, such as weak rankings, strict rankings, rankings with multiples, interval forms, and rankings of differences, Xu [22] established a linear programming model, a multiobjective optimization model, and a single-objective optimization model to determine the optimal attribute weights. Based on this, he used the intuitionistic fuzzy weighted geometric aggregation operator, the intuitionistic fuzzy hybrid geometric aggregation operator, the score function, and the accuracy function to develop an approach to intuitionistic fuzzy multiattribute group decision making and gave its application to search the best global supplier for one of a manufacturing company’s most.

Boran [24] has applied the intuitionistic fuzzy preference relation to derive the weights of criteria and intuitionistic fuzzy TOPSIS method has been used to rank alternative. Wang et.al. [25] based on intuitionistic interval fuzzy information, developed a method is to handle the problems in MCGDM. By applying the knowledge level of the experts to the decision making problem, the model of maximizing comprehensive membership coefficient is constructed to determine the weights of decision makers. By calculating the distances to the ideal and negative ideal solutions, the comprehensive attribute values and the rank of the alternatives can be obtained.

2. PRELIMINARIES

Definition 2.1 [Atanassov 1986] An IFS A in X is given by $A = \{(x, \mu_A(x), \nu_A(x)), x \in X\}$ where the functions $\mu_A(x)$: $X \to [0,1]$ and $\nu_A(x)$: $X \to [0,1]$define respectively, the degree of membership and degree of non-membership of the element $x \in X$ to the set A, which is a subset of X, and for every $x \in X$, $0 \le \mu_A(x) + \nu_A(x) \le 1$.

Obviously, every fuzzy set has the form $\{(x, \mu_A(x), \mu_{A^c}(x)), x \in X\}$

For each IFS A in X, we will call $\Pi_A(x) = 1 - \mu(x) - \nu(x)$ the intuitionistic fuzzy index of x in A. It is obvious that $0 \le \Pi_A(x) \le 1, \forall x \in X$.

Definition 2.2 [Nehi 2010] An Intuitionistic Fuzzy Set (IFS) $A = \{(x, \mu_A(x), \gamma_A(x) | x \in X)\}$ is called IF-normal, if there exist at least two points $x_0, x_1 \in X$ such that $\mu_A(x_0) = 1, \gamma_A(x_1) = 1$, It is easily seen that given intuitionistic fuzzy set A is IF-normal if there is at least one point that surely belongs to A and atleast one point which does not belong to A.

Definition 2.3 [Nehi 2010] An Intuitionistic Fuzzy Set (IFS) $A = \{(x, \mu_A(x), \gamma_A(x) | x \in X)\}$ of the real line is called IF-convex, if $\forall x_1, x_2 \in \mathbb{R}, \forall \lambda \in [0,1]$

$$\mu_A(\lambda x_1 + (1-\lambda)x_2) \ge \mu_A(x_1) \wedge \mu_A(x_2)$$
$$\gamma_A(\lambda x_1 + (1-\lambda)x_2) \ge \gamma_A(x_1) \wedge \gamma_A(x_2)$$

Thus A is IF –convex if its membership function is fuzzy convex and its non membership function is fuzzy concave.

Definition 2.4 [Nehi 2010] An IFS $A = \{(x, \mu_A(x), \gamma_A(x) | x \in X)\}$of the real line is called an intuitionistic fuzzy number (IFN) if

(i) A is IF-normal,

(ii) A is IF-convex,

(iii) μ_A is upper semicontinuous and γ_A is lower semicontinuous,

(iv) $A = \{(x \in X \mid \gamma_A(x) < 1\}$ is bounded.

Definition 2.5 [Nehi 2010] A is a trapezoidal intuitionistic fuzzy number with parameters $b_1 \le a_1 \le b_2 \le a_2 \le a_3 \le b_3 \le a_4 \le b_4$ and denoted by $A = (b_1, a_1, b_2, a_2, a_3, b_3, a_4, b_4)$. In this case we will give

$$\mu_A(x) = \begin{cases} 0 & ; x < a_{1,} \\ \dfrac{x - a_1}{a_2 - a_1} & ;\ a_1 \le x \le a_2 \\ 1 & ; a_2 \le x \le a_3 \\ \dfrac{x - a_4}{a_3 - a_4} & ; a_3 \le x \le a_4 \\ 0 & ; a_4 < x \end{cases}$$

$$\gamma_A(x) = \begin{cases} 0 & ; x < b_{1,} \\ \dfrac{x - b_2}{b_1 - b_2} & ;\ b_1 \le x \le b_2 \\ 1 & ; b_2 \le x \le b_3 \\ \dfrac{x - b_3}{b_4 - b_3} & ; b_3 \le x \le b_4 \\ 0 & ; b_4 < x \end{cases}$$

In the above definition, if we let $b_2 = b_3$ ($and\ hence\ a_2 = a_3$), then we will get a triangular intuitionistic fuzzy number with parameters $b_1 \le a_1 \le (b_2 = a_2 = a_3 = b_{3)} \le a_4 \le b_4$ and denoted by $A = (b_1, a_1, b_2, a_4, b_4)$.

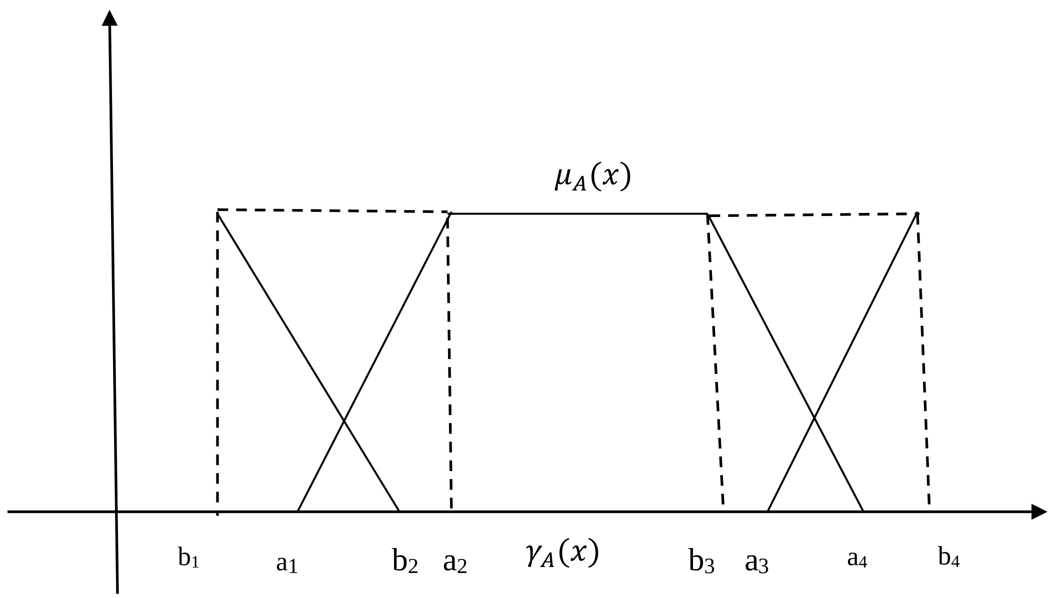

Fig.I. Trapezoidal Intuitionistic fuzzy number

Definition 2.6 **[23]** Let $A = (b_1, a_1, b_2, a_2, a_3, b_3, a_4, b_4)$ be a Trapezoidal intuitionistic fuzzy number we define the ranking function of trapezoidal (triangular) intuitionistic fuzzy number A is defined by ,

$$\Re(A) = \sqrt{\frac{1}{2}\left(\left[\tilde{x}_{\mu}(A) - \tilde{y}_{\mu}(A)\right]^2 + \left[\tilde{x}_{\upsilon}(A) - \tilde{y}_{\upsilon}(A)\right]^2\right)}$$

Where,

$$\tilde{x}_{\mu}(A) = \frac{1}{3}\left[\frac{a_3{}^2 + a_4{}^2 - a_1{}^2 - a_2{}^2 - a_1 a_2 + a_3 a_4}{a_4 + a_3 - a_2 - a_1}\right]$$

$$\tilde{x}_{\upsilon}(A) = \frac{1}{3}\left[\frac{2b_4^2 - 2b_1^2 + 2b_2^2 + 2b_3^2 + b_1 b_2 - b_3 b_4}{b_3 + b_4 - b_1 - b_2}\right]$$

$$\tilde{y}_{\mu}(A) = \frac{1}{3}\left(\frac{a_1 + 2a_2 - 2a_3 - a_4}{a_1 + a_2 - a_3 - a_4}\right)$$

$$\tilde{y}_{\upsilon}(A) = \frac{1}{3}\left(\frac{2b_1 + b_2 - b_3 - 2b_4}{b_1 + b_2 - b_3 - b_4}\right)$$

which is the Euclidean distance .

It is obvious that the proposed ranking function satisfies the properties A1;A2;A3;A4;A5 and A6 of [23]. We list these properties below for the completeness of the section. Let S be the set of fuzzy quantities, and M be an ordering approach.

A1: For an arbitrary finite subset A of S , , by M on A.

A2: For an arbitrary finite subset A of S and and by M on A, we should have by M on A.

A3: For an arbitrary finite subset A of S and and by M on A, we should have by M on A.

A4: For an arbitrary finite subset A of S and ((a,)˜ b˜)∈A^2,inf〖supp(a˜)〗≽sup〖supp(b˜ 〗), we should have by M on A.

A4': For an arbitrary finite subset A of S and ((a,)˜ b˜)∈A^2,inf〖supp(a˜)〗≻sup〖supp(b˜ 〗), we should have by M on A.

A5: Let S and S' be two arbitrary finite sets of fuzzy quantities in which M can be applied and and are in :We obtain the ranking order by M on S' iff by M on S.

A6: Let be elements of S. If by M on ,then by M on

A6': Let be elements of S. If by M on ,then by M on

A7: Let be elements of S. If by M on ,then by M on

3. MULTI-CRITERIA DECISION MAKING BASED ON RANKING OF INTUITIONISTIC FUZZY NUMBERS A CENTROID BASED APPROACH

In this section we will apply the centriod based ranking of intuitionistic fuzzy numbers to solve multi-criteria decision making problems. We consider the alternatives in terms of intuitionistic fuzzy umbers which should be rated to select best alternative.

Let $A = \{A_1, A_2, \ldots\ldots, A_m\}$ be a set of alternatives and $C = \{C_1, C_2, \ldots., C_n\}$ be the set of attributes (or) criterions. There are 'm' alternatives which are to be assessed on the basis of 'n' attributes. Assume that the rating of alternative A_i on the attribute C_j is represented in terms of trapezoidal intuitionistic fuzzy number namely,

$$\widetilde{a_{ij}} = \langle (b_{ij1}, a_{ij1}, b_{ij2}, a_{ij2}, a_{ij3}, b_{ij3}, a_{ij4}, b_{ij4}) \rangle.$$

Thus MCDM problem can be expressed as a matrix $D = \left(\widetilde{a_{ij}}\right)_{m \times n}$consisting of trapezoidal intuitionistic fuzzy numbers. Let $w_j (j = 1,2, \ldots n)$ be the relative weight corresponding to the attribute $C_j (j = 1,2, \ldots n)$, satisfying the conditions $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$. Let $W = (w_1, w_2, \ldots., w_n)$ be the relative weight vector.

The following algorithm explains the process of intuitionistic fuzzy multi-criteria decision making based on trapezoidal intuitionistic fuzzy information using magnitude based ranking approach.

Step 1: Construct the weighted trapezoidal intuitionistic fuzzy number decision matrix by using the equation

$$\widetilde{\boldsymbol{w}_{ij}} = \boldsymbol{w}_j \widetilde{a_{ij}}$$

Step 2: Calculate the weighted comprehensive values of the alternatives $A_i(i = 1,2,,\dots.m)$ as follows $\tilde{C}_i = \sum_{j=1}^{n} \widetilde{\boldsymbol{w}_{ij}}$

Step 3: Apply the centriod based ranking for $\tilde{C}_i(i = 1,2,\dots,m)$using the equation given in (1)

Step 4: Rank the alternatives according to the non increasing order of trapezoidal intuitionistic fuzzy numbers $\tilde{C}_i(i = 1,2,\dots,m)$

4.ILLUSTRATIVE EXAMPLE

In this section, an illustrative example for a multi-criteria decision making involving trapezoidal intuitionistic fuzzy numbers based on ranking using magnitude is given. For this we consider the investment problem as follows.

There are four alternatives namely (1) A_1 is a car company; (2) A_2 is a food company; (3) A_3 is a computer company; (4) A_4 is a television company. The investment company must take a decision according to the following criteria: (1) C_1 is the risk analysis; (2) C_2 is the growth analysis; (3) C_3 is the environmental impact analysis. The four possible alternatives are to be evaluated under the above three criteria.

Preference values of alternatives and criteria weights given in the following table

	C_1	**C_2**	**C_3**
A_1	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>
A_2	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>
A_3	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>
A_4	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>	<(0.2,0.3.0.4,0.4,0.5,0.5,0.6,0.7)>

Step 1: The weighted trapezoidal intuitionistic fuzzy number decision matrix is

$$D = \begin{bmatrix} \langle(0.064,0.096,0.128,0.128,0.16,0.16,0.192,0.224)\rangle & \langle(0.112,0.168,0.224,0.224,0.28,0.28,0.336,0.392)\rangle & \langle(0,0.022,0.04 \\ \langle(0.128,0.16,0.192,0.192,0.224,0.224,0.256,0.288)\rangle & \langle(0.224,0.28,0.336,0.336,0.392,0.392,0.448,0.504)\rangle & \langle(0.044,0.066,0. \\ \langle(0.064,0.096,0.128,0.128,0.16,0.16,0.192,0.224)\rangle & \langle(0.224,0.28,0.336,0.336,0.392,0.392,0.448,0.504)\rangle & \langle(0.044,0.066,0 \\ \langle(0.224,0.224,0.256,0.256,0.288,0.288,0.32,0.32)\rangle & \langle(0.224,0.28,0.336,0.336,0.392,0.392,0.448,0.504)\rangle & \langle(0,0.022,0.044 \end{bmatrix}$$

Step 2: The weighted comprehensive values of the alternatives A_1, A_2, A_3 and A_4 are

$$\widetilde{C_1} = \langle(0.176,0.286,0.396,0.396,0.506,0.506,0.616,0.726)\rangle$$

$$\widetilde{C_2} = \langle(0.176,0.506,0.616,0.616,0.726,0.726,0.836,0.946)\rangle$$

$$\widetilde{C_3} = \langle(0.332,0.442,0.552,,0.552,0.662,0.662,0.772,0.946)\rangle$$

$$\widetilde{C_4} = \langle(0.448,0.526,0.636,0.636,0.746,0.746,0.856,0.934)\rangle$$

Step 3: Calculate the centroid based Euclidean distance values for the above obtained weighted comprehensive values $\widetilde{C_1}, \widetilde{C_2}, \widetilde{C_3}$ and $\widetilde{C_4}$

$$\mathcal{R}(\widetilde{C_1}) = 0.451, \mathcal{R}(\widetilde{C_2}) = 0.671, \mathcal{R}(\widetilde{C_3}) = 0.607 \text{ and } \mathcal{R}(\widetilde{C_4}) = 0.691.$$

Step 4: Ranking the alternatives we get $\widetilde{C_4} > \widetilde{C_2} > \widetilde{C_3} > \widetilde{C_1}$.

Hence $A_4 > A_2 > A_3 > A_1$.

Thus the most desirable alternative is A_4 (i.e.) the television company is more suitable for investment based on the three criterions.

5.CONCLUSIONS

In many of the existing ranking methods, ranking is done either by considering the membership or non-membership values only. But in the newly proposed method the ranking is done directly by taking both membership and non-membership values in a single formula. This ranking procedure is very simple and time consuming compared to the existing methods. We also illustrated the advantages of our method by means of suitable examples. The proposed ranking technique can be applied to multi-criteria decision making problems, linear programming problems, assignment problems, transportation, some management problems and industrial problems which are our future research works.

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