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ASSIGNMENT PROBLEM BASED ON NEW SIMILARITY MEASURES OF INTUITIONISTIC FUZZY SETS

B. POTHIRAJ[1] AND S. RAJARAM[2]

[1]Assistant Professor, Department of Mathematics,
Sri S. R. N. M. College, Sattur-626203, Virudhunagar (Dt.), Tamil Nadu, India.

[2]Associate Professor, Department of Mathematics,
Sri S. R. N. M. College, Sattur-626203, Virudhunagar (Dt.), Tamil Nadu, India.

E-mail: komburani@gmail.com[1] and rajaram_srnm@yahoo.co.in[2]

ABSTRACT

In this paper we introduce some new similarity measures of intuitionistic fuzzy sets. These similarity measures can be applied in models of multi-attribute decision. We propose an assignment model based on similarity measures of intuitionistic fuzzy sets. A numerical example is given to clarify the developed approach under intuitionistic fuzzy environment.

AMS Mathematics subject classification: *90C08, 90C70.*

Keywords – *Intuitionistic fuzzy set; Similarity measures; Assignment model.*

1. INTRODUCTION

In decision-making situations we have to assign tasks to machines, workers to jobs, salesmen to regions, drivers to trucks, trucks to routes requirements to suppliers etc are mainly tackled with the help of Assignment Problems. In day to day problems various calculations should be solved with uncertainty and inexactness accuracy, errors in computation leads to uncertainty and in exactness. In order to deal with this uncertainty we use fuzzy assignment problems instead of classical assignment problems. The measures of distance and similarity are used to estimate the degree of closeness between two sets. In the model of multi-attribute decision, the distance and the similarity between two IFS is very important.

Szmidt and Kacprzyk [20], Hung and Yang [10] showed several measures for the distance between two IFS and the way of associated similarity measure is constructed. Li Qin and Olson [13] made a comparative analysis of different defined measures of similarity between two IFS. Xu [22] developed some similarity measures of IFS and define the notions of positive and negative ideals IFS.

In 1952 Votaw and Orden [21] first proposed the assignment problem. Lin and Wen [14] concentrate on the assignment problem where costs are not deterministic numbers but imprecise ones. Huang and Zhang [16] proposed a mathematical model for the fuzzy assignment problem with restriction on qualification. Chen [6] introduced a fuzzy assignment model that considers all individuals have same skills. Kuhn [12] developed the Hungarian algorithm for the assignment problem. Balinski and Gomory [4] introduced a labeling algorithm for solving assignment problem. Aggarwal *et al.* [1] developed an algorithm for bottleneck assignment problem. Liu and Gao [15] introduced fuzzy weighted equilibrium multi-job assignment problem and genetic algorithm. Yang and Liu [24] proposed a multi – objective fuzzy assignment problem. Mukherjee and Basu [17] proposed intuitionistic fuzzy assignment problem using similarity measures and score functions. Sakawa *et al.* [19] dealt with problems on production and work force assignment in a firm.

2. PRELIMINARIES ON INTUITIONISTIC FUZZY SETS

This section presents the basic concepts related to Intuitionistic Fuzzy Set, which was originally introduced by Attanassov and Gargov.

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2.1. Intuitionistic Fuzzy Sets (IFS)

Let $X = \{x_1, x_2, \ldots, x_n\}$ be a universe of discourse. A fuzzy set $A = \{\langle x_j, \mu_A(x_j)\rangle | x_j \in X\}$ defined by Zadeh [25] is characterized by a membership function $\mu_A: X \to [0,1]$ where $\mu_A(x_j)$ denotes the degree of membership of the element x_j to the set A.

Atanassov [3] introduced a generalized fuzzy set called IFS as follows:
An Intuitionistic Fuzzy Set (IFS) A in X is an object having the form: $A = \{\langle x_j, \mu_A(x_j), \vartheta_A(x_j)\rangle | x_j \in X\}$which is characterized by a membership function μ_A and a nonmembership function ϑ_A where $\mu_A: X \to [0,1]$, $\vartheta_A: X \to [0,1]$ with the condition $\mu_A(x_j) + \vartheta_A(x_j) \le 1$ for all $x_j \in X$. Attanassov defined $\pi_A(x_j) = 1 - \mu_A(x_j) - \vartheta_A(x_j)$, for all $x_j \in X$ as the degree of indeterminacy or hesitancy of x_j to A where A is an IFS in X. Especially, if
$\pi_A(x_j) = 1 - \mu_A(x_j) - \vartheta_A(x_j) = 0$ for each $x_j \in X$ then the IFS A is reduced to a fuzzy set.

2.2 Intuitionistic Fuzzy Number (IFN)

An Intuitionistic fuzzy number A is defined as follows:

(i) intuitionistic fuzzy sub set of the real line.
(ii) normal i.e. there is any $x_0 \in \mathbb{R}$ such that $\mu_A(x_0) = 1$ (so $\vartheta_A(x_0) = 0$)
(iii) a convex set for the membership function $\mu_A(x)$
i.e $\mu_A(\lambda x_1 + (1-\lambda)x_2) \ge \min(\mu_A(x_1), \mu_A(x_2))$ for all $x_1, x_2 \in \mathbb{R}, \lambda \in [0,1]$
(iv) a concave set for the non membership function $\vartheta_A(x)$
i.e $\vartheta_A(\lambda x_1 + (1-\lambda)x_2) \le \max(\vartheta_A(x_1), \vartheta_A(x_2))$ for all $x_1, x_2 \in \mathbb{R}, \lambda \in [0,1]$

2.3 Ranking of Intuitionistic Fuzzy Number

Let $a = (\mu_1, \vartheta_1)$ be an intuitionistic fuzzy number. Chen T.Y [8] introduced a score function S of an intuitionistic fuzzy value, which is represented as follows:

$$S(a) = \mu_1 - \pi_1\vartheta_1 \text{ where } S(a) \in [-1,1]. \tag{1}$$

2.4 Similarity Measures of Intuitionistic Fuzzy sets [23]

Let $\Phi(X)$ be the set of all IFSs of X. Let $S : \Phi(X)^2 \to [0,1]$, then the degree of similarity between $A \in \Phi(X)$ and $B \in \Phi(X)$ is defined as $S(A,B)$, which satisfies the following properties:

1. $0 \le S(A,B) \le 1$;
2. $S(A,B) = 1 \; iff \; A = B$
3. $S(A,B) = S(B,A)$;
4. $S(A,C) \le S(A,B) \; and \; S(A,C) \le S(B,C)$, if $\subseteq B \subseteq C$, $C \in \Phi(X)$.

2.5 New similarity measures

The new similarity measures are defined by

$$S_{B1}(A,B) = 1 - \frac{1}{3n}\sum_{i=0}^{n}\begin{pmatrix} |(\text{Max. of } \mu_A \text{and } \mu_B) - (\text{A.M of } \mu_A \text{and } \mu_B)\,| + \\ |(\text{Max. of } \vartheta_A \text{and } \vartheta_B) - (\text{G.M of } \vartheta_A \text{and } \vartheta_B)| + \\ |(\text{Max. of } \pi_A \text{and } \pi_B) - (\text{H.M of } \pi_A \text{and } \pi_B)|. \end{pmatrix} \tag{2}$$

$$S_{B2}(A,B) = 1 - \frac{1}{3n}\sum_{i=0}^{n}\begin{pmatrix} |(\text{Max. of } \mu_A \text{and } \mu_B) - (\text{A.M of } \mu_A \text{and } \mu_B)\,| + \\ |(\text{Max. of } \vartheta_A \text{and } \vartheta_B) - (\text{A.M of } \vartheta_A \text{and } \vartheta_B)| + \\ |(\text{Max. of } \pi_A \text{and } \pi_B) - (\text{A.M of } \pi_A \text{and } \pi_B)|. \end{pmatrix} \tag{3}$$

$$S_{B3}(A,B) = 1 - \frac{1}{3n}\sum_{i=0}^{n}\begin{pmatrix} |(\text{Max. of } \mu_A \text{and } \mu_B) - (\text{G.M of } \mu_A \text{and } \mu_B)\,| + \\ |(\text{Max. of } \vartheta_A \text{and } \vartheta_B) - (\text{G.M of } \vartheta_A \text{and } \vartheta_B)| + \\ |(\text{Max. of } \pi_A \text{and } \pi_B) - (\text{G.M of } \pi_A \text{and } \pi_B)|. \end{pmatrix} \tag{4}$$

$$S_{B4}(A,B) = 1 - \frac{1}{3n}\sum_{i=0}^{n}\begin{pmatrix} |(\text{Max. of } \mu_A \text{and } \mu_B) - (\text{H.M of } \mu_A \text{and } \mu_B)\,| + \\ |(\text{Max. of } \vartheta_A \text{and } \vartheta_B) - (\text{H.M of } \vartheta_A \text{and } \vartheta_B)| + \\ |(\text{Max. of } \pi_A \text{and } \pi_B) - (\text{H.M of } \pi_A \text{and } \pi_B)|. \end{pmatrix} \tag{5}$$

3. MATHEMATICAL MODEL OF INTUITIONISTIC FUZZY ASSIGNMENT PROBLEM

An assignment problem is a special type of transporation problem which can be stated in the form of $n \times n$ cost matrix $[\tilde{c}_{ij}]$ of intuitionistic fuzzy numbers as follows:

Table-1: Cost matrix of an assignment problem

Person \ Job	1	2	...	n
1	$\tilde{c}_{11}$	$\tilde{c}_{12}$	...	$\tilde{c}_{1n}$
2	$\tilde{c}_{21}$	$\tilde{c}_{22}$	...	$\tilde{c}_{2n}$
⋮	⋮	⋮	⋮	⋮
n	$\tilde{c}_{n1}$	$\tilde{c}_{n2}$	...	$\tilde{c}_{nn}$

The objective is to assign a number of origins to an equal number of destinations at a minimum cost or maximum profit. Each job must be done by exactly one person and one person can do, at most one job. Mathematically assignment problem can be denoted as

Min $Z = \sum_{i=1}^{n}\sum_{j=1}^{n}\tilde{c}_{ij}x_{ij}$

subject to

$$\sum_{j=1}^{n} x_{ij} = 1,\ i = 1,2,\dots,n \tag{6}$$

$$\sum_{i=1}^{n} x_{ij} = 1,\ j = 1,2,\dots,n \tag{7}$$

where x_{ij} is the decision variable defined as

$$x_{ij} = \begin{cases} 1, if\ the\ i^{th}\ person\ is\ assigned\ to\ the\ j^{th}\ job; \ where\ i,j = 1,2,\dots,n. \\ 0, otherwise \end{cases}$$

The cost of a person i doing the job j is considered as an intuitionistic fuzzy number

$\tilde{c}_{ij} = \{(\mu_{ij}, \vartheta_{ij}), i,j = 1,2,\dots,n\}$ where μ_{ij}denotes the degree of acceptance and ϑ_{ij} denotes the degree of rejection.

As our objective is to minimize the cost and maximize the profit, we should go for maximize the acceptance degree μ_{ij} and minimize the rejection degree ϑ_{ij}.

Then the objective function becomes a multi-objective function as

$Max\ z_1 = \sum_{i=1}^{n}\sum_{j=1}^{n}\mu_{ij}\,x_{ij}$ and

$$Min\ z_2 = \sum_{i=1}^{n}\sum_{j=1}^{n}\vartheta_{ij}\,x_{ij}$$

subject to $(\mu_{ij} + \vartheta_{ij} - 1)x_{ij} \le 0$ (8)

$\mu_{ij}x_{ij} \ge \vartheta_{ij}x_{ij}$ (9)

$\vartheta_{ij}x_{ij} \ge 0$ (10)

Thus the model becomes

max $Z = \sum_{i=1}^{n}\sum_{j=1}^{n}(\mu_{ij} - \vartheta_{ij})x_{ij}$.

subject to the conditions (6), (7), (8), (9) and (10).

5. SOLUTION PROCEDURE

Algorithm 1:

Step-1: Determine the positive-ideal and negative-ideal solution based on intuitionistic fuzzy numbers, defined as follows

$$A^+ = \{\langle\mu_{A^+}(C), \vartheta_{A^+}(C)\rangle\} \tag{11}$$

$$A^- = \{\langle\mu_{A^-}(C), \vartheta_{A^-}(C)\rangle\} \tag{12}$$

where $\mu_{A^+}(C) = \max\{\mu_{A_i}(C_{ij})\}$,$\vartheta_{A^+}(C) = \min\{(\vartheta_{A_i}(C_{ij})\}$ and $\pi_{A^+}(C) = 1 - \mu_{A^+}(C) - \vartheta_{A^+}(C)$ (13)

$\mu_{A^-}(C) = \min\{\mu_{A_i}(C_{ij})\}$, $\vartheta_{A^-}(C) = \max\{(\vartheta_{A_i}(C)\}$ and $\pi_{A^-}(C) = 1 - \mu_{A^-}(C) - \vartheta_{A^-}(C)$ (14)

Step-2: Based on the equation (2), the following similarity measures of IFSs have been defined. Calculate the degree of similarity of positive ideal IFS A^+ and the alternative A_i, and the degree of similarity of negative ideal IFS A^- and the alternative A_i, using the following equations respectively. The degree of similarity of each alternative A_i and the positive ideal IFS A^+ is defined as:

$$S_{B1}(A^+, A_i) = 1 - \frac{1}{3}\begin{pmatrix} \left|\left(Max.of\ \mu_{A^+}and\ \mu_{A_i}\right) - (A.M\ of\ \mu_{A^+}and\ \mu_{A_i})\ \right| + \\ \left|\left(Max.of\ \vartheta_{A^+}and\ \vartheta_{A_i}\right) - \left(G.M\ of\ \vartheta_{A^+}and\ \vartheta_{A_i}\right)\right| + \\ \left|\left(Max.of\ \pi_{A^+}and\ \pi_{A_i}\right) - \left(H.M\ of\ \pi_{A^+}and\ \pi_{A_i}\right)\right|. \end{pmatrix} \tag{15}$$

$i = 1,2,3,\dots n; j = 1,2,3,\dots,n$

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Similarly, degree of similarity of each alternative A_i and the negative ideal IFS A^- is defined as:

$$S_{B1}(A^-,A_i) = 1 - \frac{1}{3}\begin{pmatrix} \left|\left(Max.of\ \mu_{A^-} and\ \mu_{A_i}\right) - \left(A.M\ of\ \mu_{A^-} and\ \mu_{A_i}\right)\right| + \\ \left|\left(Max.of\ \vartheta_{A^-} and\ \vartheta_{A_i}\right) - \left(G.M\ of\ \vartheta_{A^-} and\ \vartheta_{A_i}\right)\right| + \\ \left|\left(Max.of\ \pi_{A^-} and\ \pi_{A_i}\right) - \left(H.M\ of\ \pi_{A^-} and\ \pi_{A_i}\right)\right|. \end{pmatrix} \tag{16}$$

$i = 1,2,3,\dots n; j = 1,2,3,\dots,n$. similarly to calculate positive and negative ideals for equations (3) (4) and (5).

Step-3: Using (15) and (16) calculate the relative similarity measure d_i corresponding to the alternative A_i as

$$d_i = \frac{S_{B1}(A^+,A_i)}{S_{B1}(A^+,A_i)+S_{B1}(A^-,A_i)},\ i = 1,2,3,\dots,n. \tag{17}$$

Step-4: Then considering the relative similarity matrix as the initial table for an assignment problem in the maximization type and we solved by Hungarian method or by any standard software to find the optimal assignment.

Algorithm 2:

Step-1: Find the score function matrix of the given cost matrix with data in the form of IFN by using (1).

Step-2: Considering this score function matrix as the maximization form and solve Hungarian method or standard software to find the optimal assignment.

6. ILLUSTRATIVE EXAMPLE

Let us consider an Intuitionistic fuzzy assignment problem having three persons and three jobs where the cost matrix contains intuitionistic fuzzy elements denoting time for completing the jth job by the ith person. The cost matrix is given in Table 2. It is required to find the optimal assignment of jobs to machines.

Table-2: Intuitionistic fuzzy cost matrix

	J_1	J_2	J_3
P_1	(0.4, 0.5)	(0.6, 0.2)	(0.5, 0.2)
P_2	(0.2, 0.7)	(0.8, 0.1)	(0.6, 0.3)
P_3	(0.7, 0.1)	(0.3, 0.6)	(0.4, 0.3)

Similarity measure for $\mathbf{S_{B1}(A,B)}$

Apply Algorithm1 in table 2. The positive-ideal and negative-ideal by using (15) and (16) are as in table 3 and table 4.

Table-3: Positive ideal

$\boldsymbol{S_{B1}(A^+,A_i)}$	J_1	J_2	J_3
P_1	0.841	0.925	0.88
P_2	0.755	1	0.924
P_3	0.961	0.798	0.841

Table-4: Negative ideals

$\boldsymbol{S_{B1}(A^-,A_i)}$	J_1	J_2	J_3
P_1	0.931	0.802	0.791
P_2	1	0.755	0.853
P_3	0.749	0.966	0.836

To calculate Relative similarity by using (17) we get

Table-5: Relative similarity

d_i	J_1	J_2	J_3
P_1	0.475	0.536	0.527
P_2	0.43	0.57	0.52
P_3	0.562	0.452	0.501

By using step4 and we calculate optimal assignment for Table 5.

The optimal assignment is
1st job is assigned to the 2nd person.
2nd job is assigned to the 3rd person.
3rd job is assigned to the 1st person.

Similarity measure for $\mathbf{S_{B2}(A, B)}$
Apply Algorithm1 in table 2. The positive-ideal and negative-ideal by using $S_{B2}(A^{+}, A_i)$ and $S_{B2}(A^{-}, A_i)$ we get

Table 6: Positive ideal

$\boldsymbol{S_{B2}(A^{+}, A_i)}$	J_1	J_2	J_3
P_1	0.85	0.95	0.917
P_2	0.783	0.983	0.917
P_3	0.983	0.817	0.833

Table-7: Negative ideal

$\boldsymbol{S_{B2}}(A^{-}, \boldsymbol{A_i})$	J_1	J_2	J_3
P_1	0.933	0.833	0.833
P_2	1	0.8	0.867
P_3	0.8	0.967	0.867

To calculate Relative similarity by using (17) we get

Table-8: Relative similarity

d_i	J_1	J_2	J_3
P_1	0.477	0.533	0.524
P_2	0.439	0.551	0.514
P_3	0.551	0.458	0.505

By using step4 and we calculate optimal assignment for Table 8.

The optimal assignment is
1st job is assigned to the 2nd person.
2nd job is assigned to the 3rd person.
3rd job is assigned to the 1st person.

Similarity measure for $\mathbf{S_{B3}(A, B)}$
Apply Algorithm1 in table 2. The positive-ideal and negative-ideal by using $S_{B3}(A^{+}, A_i)$ and $S_{B3}(A^{-}, A_i)$ we get

Table-9: Positive ideal

$\boldsymbol{S_{B3}(A^{+}, A_i)}$	J_1	J_2	J_3
P_1	0.83	0.925	0.882
P_2	0.722	1	0.922
P_3	0.963	0.778	0.837

Table-10: Negative ideal

$\boldsymbol{S_{B3}}(A^{-}, \boldsymbol{A_i})$	J_1	J_2	J_3
P_1	0.925	0.787	0.788
P_2	1	0.722	0.835
P_3	0.727	0.964	0.838

To calculate Relative similarity by using (17) we get

Table-11: Relative similarity

d_i	J_1	J_2	J_3
P_1	0.473	0.54	0.528
P_2	0.419	0.581	0.525
P_3	0.57	0.477	0.5

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By using step4 and we calculate optimal assignment for Table 11

The optimal assignment is
1st job is assigned to the 2nd person.
2nd job is assigned to the 3rd person.
3rd job is assigned to the 1st person.

Similarity measure for $\mathbf{S_{B4}(A,B)}$
Apply Algorithm1 in table 2. The positive-ideal and negative-ideal by using $S_{B4}(A^{+},A_i)$ and $S_{B4}(A^{-},A_i)$ we get

Table-12: Positive ideal

$\boldsymbol{S_{B4}(A^{+},A_i)}$	J_1	J_2	J_3
P_1	0.8	0.917	0.866
P_2	0.665	1	0.912
P_3	0.96	0.736	0.811

Table-13: Negative ideal

$\boldsymbol{S_{B4}}(A^{-},\boldsymbol{A_i})$	J_1	J_2	J_3
P_1	0.917	0.748	0.749
P_2	1	0.665	0.807
P_3	0.673	0.962	0.812

To calculate Relative similarity by using (17) we get

Table-14: Relative similarity

d_i	J_1	J_2	J_3
P_1	0.466	0.551	0.536
P_2	0.399	0.601	0.531
P_3	0.588	0.433	0.5

By using step4 and we calculate optimal assignment for Table 14

The optimal assignment is
1st job is assigned to the 2nd person.
2nd job is assigned to the 3rd person.
3rd job is assigned to the 1st person.

Hungarian method
By using score function (1) for given table then we get

Table-14: Score value

	J_1	J_2	J_3
P_1	0.35	0.56	0.44
P_2	0.13	0.79	0.57
P_3	0.68	0.24	0.31

Apply Algorithm 2 for the above table we get the following optimal assignment.

The optimal assignment is
1st job is assigned to the 2nd person.
2nd job is assigned to the 3rd person.
3rd job is assigned to the 1st person.

7. CONCLUSION

In this paper a real life intuitionistic fuzzy assignment model with new similarity measure is proposed. The procedure for solving IFAP has been described which uses the concept of relative degree of similarity under intuitionistic fuzzy environment. Even though different similarity measures are defined, the result obtained by the proposed method is validated with the same result obtained by solving the IFAP considering the score function matrix as the profit matrix.

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