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A Method for Solving Balanced Intuitionistic Fuzzy Assignment Problem

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Abstract
In this paper, we investigate an assignment problem in which cost coefficients are triangular intuitionistic fuzzy numbers. In conventional assignment problem, cost is always certain. This paper develops an approach to solve an intuitionistic fuzzy assignment problem where cost is not deterministic numbers but imprecise ones. Here, the elements of the costs (profits) matrix of the assignment problem are triangular intuitionistic fuzzy numbers. Then its triangular shaped membership and non-membership functions are defined. A new ranking procedure which can be found in [4] and is used to compare the intuitionistic fuzzy numbers so that an Intuitionistic Fuzzy Hungarian method may be applied to solve the intuitionistic fuzzy assignment problem. Numerical examples show that an intuitionistic fuzzy ranking method offers an effective tool for handling an intuitionistic fuzzy assignment problem.
Keywords: Intuitionistic Fuzzy Set, Triangular Fuzzy Number, Triangular Intuitionistic Fuzzy Number, Intuitionistic Fuzzy Assignment Problem, Optimal Solution.

I. Introduction

Assignment Problem(AP) is used worldwide in solving real world problems. An assignment problem plays an important role in an assigning of persons to jobs, or classes to rooms, operators to machines, drivers to trucks, trucks to routes, or problems to research teams, etc. The assignment problem is a special type of linear programming problem (LPP) in which our objective is to assign n number of jobs to n number of machines (persons) at a minimum cost. To find solution to assignment problems, various algorithm such as linear programming [8,9,13,17], Hungarian algorithm [15], neural network [12], genetic algorithm [6] have been developed.

However, in real life situations, the parameters of assignment problem are imprecise numbers instead of fixed real numbers because time/cost for doing a job by a facility (machine/persion) might vary due to different reasons. The theory of fuzzy set introduced by Zadeh[21] in 1965 has achieved successful applications in various fields. In 1970, Belmann and Zadeh introduce the concepts of fuzzy set theory into the decision-making problems involving uncertainty and imprecision. Amit Kumar et al investigated Assignment and Travelling Salesman Problems with cost coefficients as LR fuzzy parameters[1], Fuzzy linear programming approach for solving fuzzy transportation problems with transshipment[2], Method for solving fully fuzzy assignment problems using triangular fuzzy numbers[3]. In [18], Sathi Mukherjee et al presented an Application of fuzzy ranking method for solving assignment problems with fuzzy costs. Lin and Wen [16] proposed an efficient algorithm based an labeling method for solving the linear fractional programming case. Y.L.P.Thorani and N.Ravi Sankar did Fuzzy assignment problem with generalized fuzzy numbers [19].Different kinds of fuzzy assignment problems are solved in the papers [1, 3, 10, 11, 12, 20].

The concept of Intuitionistic Fuzzy Sets (IFSs) proposed by Atanassov[5] in 1986 is found to be highly useful to deal with vagueness. In [14], Jahir Hussian et all presented An Optimal More-for-Less Solution of Mixed Constrains Intuitionistic Fuzzy Transportation Problems. Here we investigate a more realistic problem, namely intuitionistic fuzzy assignment problem. Let $\tilde{c}_{ij}^{I}$ be the intuitionistic fuzzy cost of assigning the j^{th} job to the i^{th} machine. We assume that one machine can be assigned exactly one job; also each machine can do at most one job. The problem is to find an optimal assignment so that the total intuitionistic fuzzy cost of performing all jobs is minimum or the total intuitionistic fuzzy profit is maximum. In this paper, ranking procedure of Annie Varghese and Sunny Kuriakose [4] is used to compare the intuitionistic fuzzy numbers. Finally an Intuitionistic Fuzzy Hungarian method may be applied to solve an IFAP.

This paper is organized as follows: Section 2 deals with some basic terminology and ranking of triangular intuitionistic fuzzy numbers, In section 3, provides not only the definition of intuitionistic fuzzy assignment problem but also its mathematical formulation and Fundamental Theorems of an Intuitionistic Fuzzy

Assignment Problem. Section 4 describes the solution procedure of an intuitionistic fuzzy assignment problem, In section 5, to illustrate the proposed method a numerical example with results and discussion is discussed and followed by the conclusions are given in Section 6.

II. Preliminaries

Definition 2.1 Let A be a classical set, $\mu_A(x)$ be a function from A to [0,1]. A fuzzy set A^* with the membership function $\mu_A(x)$ is defined by

$$A^* = \{(x, \mu_A(x)); x \in A \text{ and } \mu_A(x) \in [0,1]\}.$$

Definition 2.2 Let X be denote a universe of discourse, then an intuitionistic fuzzy set A in X is given by a set of ordered triples,

$\tilde{A}^I = \{< x, \mu_A(x), \vartheta_A(x) >; x \in X\}$

Where$\mu_A, \vartheta_A: X \to [0,1]$, are functions such that $0 \le \mu_A(x) + \vartheta_A(x) \le 1, \forall x \in X.$ For each x the membership $\mu_A(x)$ *and* $\vartheta_A(x)$ represent the degree of membership and the degree of non – membership of the element $x \in X$ to $A \subset X$ respectively.

Definition 2.3 A fuzzy number A is defined to be a triangular fuzzy number if its membership functions μ_A:ℝ→ [0, 1] is equal to

$$\mu_A(\mathrm{x}) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} & if\ x \in [a_1, a_2] \\ \dfrac{a_3 - x}{a_3 - a_2} & if\ x \in [a_2, a_3] \\ 0 & otherwise \end{cases}$$

where $a_1 \le a_2 \le a_3$. This fuzzy number is denoted by (a_1, a_2, a_3).

Definition 2.4 A Triangular Intuitionistic Fuzzy Number ($\tilde{A}^I$ is an intuitionistic fuzzy set in R with the following membership function μ_A(x) and non membership function ϑ_A(x):)

$$\mu_A(\mathrm{x}) = \begin{cases} 0 & for\ x < a_1 \\ \dfrac{x - a_1}{a_2 - a_1} & for\ a_1 \le x \le a_2 \\ 1 & for\ x = a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & for\ a_2 \le x \le a_3 \\ 0 & for\ x > a_3 \end{cases} \qquad \vartheta_A(\mathrm{x}) = \begin{cases} 1 & for\ x < a_1' \\ \dfrac{a_2 - x}{a_2 - a_1'} & for\ a_1' \le x \le a_2 \\ 0 & for\ x = a_2 \\ \dfrac{x - a_2}{a_3' - a_2} & for\ a_2 \le x \le a_3' \\ 1 & for\quad x > a_3' \end{cases}$$

Where $a_1{}' \le a_1 \le a_2 \le a_3 \le a_3{}'$ and $\mu_A(\mathrm{x}), \vartheta_A(\mathrm{x}) \le 0.5$ for $\mu_A(\mathrm{x}) = \vartheta_A(\mathrm{x})\ \forall x \in R$. This TrIFN is denoted by $\tilde{A}^I = (a_1, a_2, a_3)(\ a_1{}', a_2, a_3{}')$

Particular Cases

Let $\tilde{A}^I = (a_1, a_2, a_3)(\ a_1{}', a_2, a_3{}')$ be a TrIFN. Then the following cases arise

Case 1: If $a_1{}' = a_1$, $a_3{}' = a_3$, then $\tilde{A}^I$ represent Tringular Fuzzy Number(TFN).
It is denoted by $\tilde{A} = (a_1, a_2, a_3)$.

Case 2: If $a_1{}' = a_1 = a_2 = a_3 = a_3{}' = m$, then $\tilde{A}^I$ represent a real number m.

Definition 2.5 Let $\tilde{A}^I$ and $\tilde{B}^I$ be two TrIFNs. The ranking of $\tilde{A}^I$ and $\tilde{B}^I$ by the $\Re$ (.) on E, the set of TrIFNs is defined as follows:

i. $\Re(\tilde{A}^I) > \Re(\tilde{B}^I)$ iff $\tilde{A}^I \succ \tilde{B}^I$
ii. $\Re(\tilde{A}^I) < \Re(\tilde{B}^I)$ iff $\tilde{A}^I \prec \tilde{B}^I$
iii. $\Re(\tilde{A}^I) = \Re(\tilde{B}^I)$ iff $\tilde{A}^I \approx \tilde{B}^I$
iv. $\Re(\tilde{A}^I + \tilde{B}^I) = \Re(\tilde{A}^I) + \Re(\tilde{B}^I)$
v. $\Re(\tilde{A}^I - \tilde{B}^I) = \Re(\tilde{A}^I) - \Re(\tilde{B}^I)$

Arithmetic Operations

Let $\tilde{A}^I = (a_1, a_2, a_3)(\,a_1{}', a_2, a_3{}')$ and $\tilde{B}^I = (b_1, b_2, b_3)(\,b_1{}', b_2, b_3{}')$be any two TrIFNs then the arithmetic operations as follows:

Addition: $\tilde{A}^I \oplus \tilde{B}^I$=$(a_1 + b_1, a_2 + b_2, a_3 + b_3)(a_1' + b_1', a_2 + b_2, a_3'+b_3')$

Subtraction: $\tilde{A}^I \ominus \tilde{B}^I$ =$(a_1 - b_3, a_2 - b_2, a_3 - b_1)(a_1' - b_3', a_2 - b_2, a_3' - b_1')$

Ranking of triangular intuitionistic fuzzy numbers

The Ranking of a triangular intuitionistic fuzzy number $\tilde{A}^I = (a_1, a_2, a_3)(\,a_1{}', a_2, a_3{}')$ is defined by [4]

$$R(\tilde{A}^I) = \frac{1}{3}\left[\frac{(a_3' - a_1')(a_2 - 2a_3' - 2a_1') + (a_3 - a_1)(a_1 + a_2 + a_3) + 3(a_3'^2 - a_1'^2)}{a_3' - a_1' + a_3 - a_1}\right]$$

The ranking technique [4] is:

If $\Re(\tilde{A}^I) \le \Re(\tilde{B}^I)$, then $\tilde{A}^I \le \tilde{B}^I$ i.e., min $\{\tilde{A}^I, \tilde{B}^I\} = \tilde{A}^I$

Example: Let $\tilde{A}^I = (8,10,12)(6,10,14)$ and $\tilde{B}^I = (3,5,8)(1,5,10)$ be any two TrIFN, then its rank is defined by $\Re(\tilde{A}^I) = 10$, $\Re(\tilde{B}^I) = 5.33$ this implies $\tilde{A}^I \succ \tilde{B}^I$

III. Intuitionistic Fuzzy Assignment Problem

Consider the situation of assigning n machines to n jobs and each machine is capable of doing any job at different costs. Let $\tilde{c}_{ij}^I$ be an intuitionistic fuzzy cost of assigning the jth job to the ith machine. Let x_{ij} be the decision variable denoting the assignment of the machine i to the job j. The objective is to minimize the total intuitionistic fuzzy cost of assigning all the jobs to the available machines (one machine per job) at the least total cost. This situation is known as balanced intuitionistic fuzzy assignment problem.

(IFAP)Minimize $\tilde{Z}^I = \sum_{i=i}^{n}\sum_{j=1}^{n} \tilde{c}_{ij}^I x_{ij}$

Subject to,

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

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

$$x_{ij} \in \{0,1\} \qquad Where\ x_{ij} = \begin{cases} 1, & if\ the\ \text{i}^{\text{th}}\ machine\ is\ assigned\ to\ j^{th}\ job \\ 0, & if\ \text{i}^{\text{th}}\ machine\ is\ not\ assigned\ to\ j^{th}\ job \end{cases}$$

$$\tilde{c}_{ij}^I = (c_{ij}^1, c_{ij}^2, c_{ij}^3)(c_{ij}^{1'}, c_{ij}^2, c_{ij}^{3'})$$

3.1 Fundamental Theorems of an Intuitionistic Fuzzy Assignment Problem

The solution of an intuitionistic fuzzy assignment problem is fundamentally based on the following two theorems.

Theorem 1:

In an intuitionistic fuzzy assignment problem, if we add or subtract an intuitionistic fuzzy number to every element of any row(or column) of the intuitionistic fuzzy cost matrix $[\tilde{c}_{ij}^I]$, then an assignment that minimizes the total intuitionistic fuzzy cost on one matrix also minimizes the total intuitionistic fuzzy cost on the other matrix. In other words if $x_{ij} = x_{ij}^*$ minimizes,

$\tilde{Z}^I = \sum_{i=i}^{n}\sum_{j=1}^{n} \tilde{c}_{ij}^I x_{ij}$ with $\sum_{i=1}^{n} x_{ij} = 1$, $\sum_{j=1}^{n} x_{ij} = 1$, $x_{ij} = 0\ or\ 1$ then x_{ij}^* also minimizes $\tilde{Z}^{I*} = \sum_{i=i}^{n}\sum_{j=1}^{n} \tilde{c}_{ij}^{I*} x_{ij}$, where $\tilde{c}_{ij}^{I*} = \tilde{c}_{ij}^I - \tilde{u}_i^I - \tilde{v}_j^I$ for all i,j=1,2,…n and $\tilde{u}_i^I, \tilde{v}_j^I$ are some real triangular intuitionistic intuitionistic fuzzy numbers.

Proof: Now, $\tilde{Z}^{I*} = \sum_{i=i}^{n}\sum_{j=1}^{n} \tilde{c}_{ij}^{I*} x_{ij}$

$=\sum_{i=i}^{n}\sum_{j=1}^{n} (\tilde{c}_{ij}^I - \tilde{u}_i^I - \tilde{v}_j^I) x_{ij}$

$=\sum_{i=i}^{n}\sum_{j=1}^{n} \tilde{c}_{ij}^I x_{ij} - \sum_{i=i}^{n} \tilde{u}_i^I \sum_{j=1}^{n} x_{ij} - \sum_{i=i}^{n} x_{ij} \sum_{j=1}^{n} \tilde{v}_j^I$

$= \tilde{Z}^I - \sum_{i=i}^{n} \tilde{u}_i^I - \sum_{j=1}^{n} \tilde{v}_j^I$

Since $\sum_{i=1}^{n} x_{ij} = \sum_{j=1}^{n} x_{ij} = 1$ This shows that the minimization of the new objective function $\tilde{Z}^{I*}$ yields the same solution as the minimization of original objective function $\tilde{Z}^I$ because $\sum_{i=i}^{n} \tilde{u}_i^I\ and\ \sum_{j=1}^{n} \tilde{v}_j^I$ are independent of x_{ij}

Theorem 2:

In an intuitionistic fuzzy assignment problem with cost $[\tilde{c}^I_{ij}]$, if all $[\tilde{c}^I_{ij}] \geq \tilde{0}^I$ then a feasible solution x_{ij} which satisfies$\sum_{i=i}^{n}\sum_{j=1}^{n}\tilde{c}^I_{ij}\,x_{ij} = \tilde{0}^I$, is optimal for the problem.

Proof: Since all $[\tilde{c}^I_{ij}] \geq \tilde{0}^I$ and all $[x_{ij}] \geq 0$,

The objective function $\tilde{Z}^I = \sum_{i=i}^{n}\sum_{j=1}^{n}\tilde{c}^I_{ij}\,x_{ij}$ can not be negative. The minimum possible value that $\tilde{Z}^I$ can attain $\tilde{0}^I$.

Thus, any feasible solution $[x_{ij}]$ that satisfies $\sum_{i=i}^{n}\sum_{j=1}^{n}\tilde{c}^I_{ij}\,x_{ij} = \tilde{0}^I$, will be an optimal.

IV. The Computational Procedure for Intuitionistic Fuzzy Assignment Problem.

Step 1. In the given intuitionistic fuzzy cost matrix, subtract the smallest element in each row from every element of that row by using ranking procedure as mentioned in section II.

Step 2. In the reduced intuitionistic fuzzy cost matrix, subtract the smallest element in each column from every element of that column by using ranking procedure as mentioned in section II.

Step 3. Make the assignment for the reduced intuitionistic fuzzy cost matrix obtained from Step 2 in the following way:

i. Examine the rows successively until a row with exactly one unmarked intuitionistic fuzzy zero is found. Enclose this intuitionistic fuzzy zero in a box ( ) as an assignment will be made there and cross (×) all other intuitionistic fuzzy zeros appearing in the corresponding column as they will not be considered for further assignment. Proceed in this way until all the rows have been examined.

ii. After examining all the rows completely, examine the columns successively until a column with exactly one unmarked intuitionistic fuzzy zero is found. Make an assignment to this single intuitionistic fuzzy zero by putting a box ( ) and cross out (×) all other intuitionistic fuzzy zeros in the corresponding row. Proceed in this way until all columns have been examined.

iii. Repeat the operation (i) and (ii) until all the intuitionistic fuzzy zeros are either marked ( ) or crossed (×).

Step 4. If there is exactly one assignment in each row and in each column then the optimum assignment policy for the given problem is obtained. Otherwise go to Step-5.

Step 5. Draw minimum number of vertical and horizontal lines necessary to cover all the intuitionistic fuzzy zeros in the reduced intuitionistic fuzzy cost matrix obtained from Step-3 by inspection or by adopting the following procedure

i. Mark (✓) all rows that do not have assignment
ii. Mark (✓) all columns (not already marked) which have intuitionistic fuzzy zeros in the marked rows
iii. Mark (✓) all rows (not already marked) that have assignments in marked columns,
iv. Repeat steps 5(ii) and 5(iii) until no more rows or columns can be marked.
v. Draw straight lines through all unmarked rows and marked columns.

Step 6. Select the smallest element among all the uncovered elements. Subtract this least element from all the uncovered elements and add it to the element which lies at the intersection of any two lines. Thus, we obtain the modified matrix. Go to Step 3 and repeat the procedure.

V. Numerical Examples:

Example: Let us consider an intuitionistic fuzzy assignment problem with rows representing 3 machines M_1, M_2, M_3 and columns representing the 3 jobs J_1, J_2, J_3. The cost matrix $[\tilde{c}^I]$ is given whose elements are TrIFN. The problem is to find the optimal assignment so that the total cost of job assignment becomes minimum

	J_1	J_2	J_3
M_1	(7,21,29)(2,21,34)	(7,20,57)(3,20,61)	(12,25,56)(8,25,60)
M_2	(8,9,16)(2,9,22)	(4,12,35)(1,12,38)	(6,14,28)(3,14,31)
M_3	(5,9,22)(2,9,25)	(10,15,20)(5,15,25)	(4,16,19)(1,16,22)

Solution: The above intuitionistic fuzzy assignment problem can be formulated in the following mathematical programming form

Min[(7,21,29)(2,21,34)x_{11}+(7,20,57)(3,20,61) x_{12}+(12,25,56)(8,25,60) x_{13}+(8,9,16)(2,9,22) x_{21}+(4,12,35)(1,12,38) x_{22}+(6,14,28)(3,14,31) x_{23}+(5,9,22)(2,9,25) x_{31}+(10,15,20)(5,15,25) x_{32}+(4,16,19)(1,16,22) x_{33}

Subject to $x_{11} + x_{12} + x_{13} = 1, x_{11} + x_{21} + x_{31} = 1,$

$x_{21} + x_{22} + x_{23} = 1, x_{12} + x_{22} + x_{32} = 1,$

$x_{31} + x_{32} + x_{33} = 1, x_{13} + x_{23} + x_{33} = 1,$

$x_{ij} \in \{0,1\}.$

Now, using the Step 1 of the intuitionistic fuzzy Hungarian assignment method, we have the following reduced intuitionistic fuzzy assignment table.

	J_1	J_2	J_3
M_1	(-22,0,22)(-32,0,32)	(-22,-1,50)(-31,-1,59)	(-17,4,49)(-26,4,58)
M_2	(-8,0,8)(-20,0,20)	(-12,3,27)(-21,3,36)	(-10,5,20)(-19,5,29)
M_3	(-17,0,17)(-23,0,23)	(-12,6, 15)(-20,6,23)	(-18,7,14)(-24,7,20)

Now, using the Step 2 of the intuitionistic fuzzy Hungarian assignment method, we have the following reduced intuitionistic fuzzy assignment table.

	J_1	J_2	J_3
M_1	(-22,0,22)(-32,0,32)	(-37,-7,62)(-54,-7,79)	(-31,-3,67)(-46,-3,82)
M_2	(-8,0,8)(-20,0,20)	(-27,-3,39)(-44,-3,56)	(-24,-2,38)(-39,-2,53)
M_3	(-17,0,17)(-23,0,23)	(-27,0,27)(-43,0,43)	(-32,0,32)(-44,0,44)

Now, using the Step 3 to the Step 6 of the intuitionistic fuzzy Hungarian assignment method, we have the following reduced intuitionistic fuzzy assignment table.

	J_1	J_2	J_3
M_1	(-22,0,22)(-32,0,32)	(-76,-4,89)(-110,-4,123)	(-70,0,94)(-102,0,126)
M_2	(-8,0,8)(-20,0,20)	(-66,0,66)(-100,0,100)	(-63,1,65)(-95,1,97)
M_3	(-27,-3,39)(-44,-3,56)	(-27,0,27)(-43,0,43)	(-32,0,32)(-44,0,44)

The optimal solution is

$$x_{11}^* = x_{22}^* = x_{33}^* = 1, \qquad x_{12}^* = x_{13}^* = x_{21}^* = x_{23}^* = x_{31}^* = x_{32}^* = 0,$$

With the optimal objective value $\Re(\tilde{Z}^{I*}) = 49$ which represents the optimal total cost. In other words the optimal assignment is

$M_1 \to J_1, M_2 \to J_2, M_3 \to J_3$

The intuitionistic fuzzy minimum total cost is calculated as

$\tilde{c}_{11}^I + \tilde{c}_{22}^I + \tilde{c}_{33}^I = (7,21,29)(2,21,34) + (4,12,35)(1,12,38) +$

$(4,16,19)(1,16,22)$= $(15,49,83)(4,49,94)$

Also we find that $\Re(\tilde{Z}^{I*}) = \Re(15,49,83)(4,49,94) = \text{Rs.}\, 49$

In the above example it has been shown that the total optimal cost obtained by our method remains same as that obtained by converting the total intuitionistic fuzzy cost by applying the ranking method [4].

Results and discussion:

The minimum total intuitionistic fuzzy assignment cost is

$\tilde{Z}^I$ = (15, 49, 83) (4, 49, 94) ………… (1)

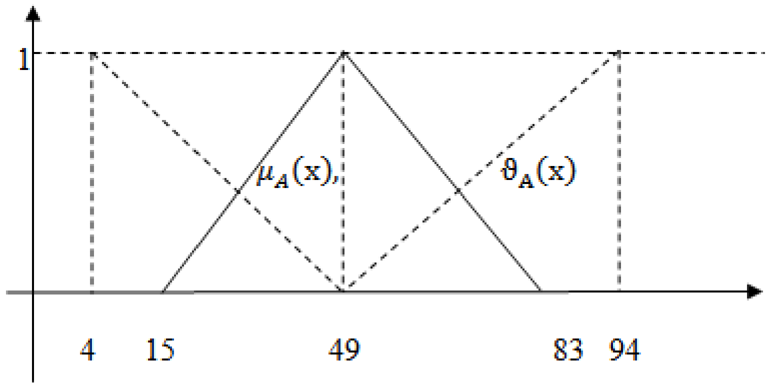

Figure1 Graphical Representation of IFAC

The result in (1) can be explained (Refer to figure1) as follows:

(a) Assignment cost lies in [15, 83].

(b) 100% expect are in favour that an assignment cost is 49 as $\mu_{\tilde{Z}^I}(x) = 1, x = 49$.

(c) Assuming that m is a membership value and n is a non-membership value at c. Then $100m\%$ experts are in favour and $100n\%$ experts are opposing but $100(1 - m - n)\%$ are in confusion that an assignment cost is c.

Values of $\mu_{\tilde{Z}^I}(c)$ and $\vartheta_{\tilde{Z}^I}(c)$ at different values of c can be determined using equations given below.

$$\mu_Z(\mathrm{x}) = \begin{cases} 0 & for\ x < 15 \\ \dfrac{x-15}{34} & for\ 15 \le x \le 49 \\ 1 & for\ x = 49 \\ \dfrac{83-x}{34} & for\ 49 \le x \le 83 \\ 0 & for\ x > 83 \end{cases} \qquad \vartheta_Z(\mathrm{x}) = \begin{cases} 1 & for\ x < 4 \\ \dfrac{49-x}{45} & for\ 4 \le x \le 49 \\ 0 & for\ x = 49 \\ \dfrac{x-49}{45} & for\ 49 \le x \le 94 \\ 1 & for\ x > 94 \end{cases}$$

VI.Conclusion

In this paper, we discussed finding a solution of an assignment problem in which cost coefficients are triangular intuitionistic fuzzy numbers. The total optimal cost obtained by our method remains same as that obtained by converting the total intuitionistic fuzzy cost by applying the ranking method [4].Also the membership and non-membership values of the intuitionistic fuzzy costs are derived. This technique can also be used in solving other types of problems like, project schedules, transportation problems and network flow problems.

References

[1] Amit Kumar and Anila Gupta, Assignment and Travelling Salesman Problems with Coefficients as LR Fuzzy Parameters, International Journal of Applied Science and Engineering 2012.10,3:155-170.

[2] Amit Kumar, Amarpreet Kaur, Anila Gupta, Fuzzy Linear Programming Approach for Solving Fuzzy Transportation probles with Transshipment, J Math Model Algor (2011) 10:163-180.

[3] Amit Kumar, Anila Gupta and Amarpreet Kumar,Method for Solving Fully Fuzzy Assignment Problems Using Triangular Fuzzy Numbers, International Journal of Computer and Information Engineering 3:4 2009.

[4] Annie Varghese and Sunny Kuriakose, Notes on Intuitionistic Fuzzy Sets Vol.18, 2012, No.1, 19-24.

[5] K.T.Atanassov, Intuitionistic fuzzy sets, fuzzy sets and systems, Vol.20, no.1.pp.87- 96, 1986.

[6] D.Avis, L.Devroye, An analysis of a decomposition heuristic for the assignment problem, Oper.Res.Lett., 3(6) (1985), 279-283.

[7] R.Bellman, L.A.Zadeh, Decision making in a fuzzy environment, management sci.17 (B)(1970)141-164.
[8] M.L.Balinski, A Competitive (dual) simplex method for the assignment problem, Math.Program,34(2) (1986), 125-141.
[9] R.S.Barr, F.Glover, D.Klingman, The alternating basis algorithm for assignment problems, Math.Program, 13(1) (1977), 1-13.
[10] M.S.Chen, On a Fuzzy Assignment Problem, Tamkang Journal 22(1985),407-411.
[11] P.K.De and Bharti Yadav, A General Approach for Solving Assignment Problems Involving with Fuzzy Costs Coefficients, Modern Applied Science Vol.6,No.3; March 2012.
[12] S.P.Eberhardt, T.Duad, A.Kerns, T.X.Brown, A.S.Thakoor, Competitive neural architecture for hardware solution to the assignment problem, Neural Networks, 4(4) (1991), 431-442.
[13] M.S.Hung, W.O.Rom, Solving the assignment problem by relaxation, Oper.Res., 24(4) (1980), 969-982.
[14] R.Jahir Hussain, P.Senthil Kumar, An Optimal More-for-Less Solution of Mixed Constrains Intuitionistic Fuzzy Transportation Problems, Int.J. Contemp.Math.Sciences, Vol.8, 2013.no.12, 565-576.doi.10.12988/ijcms.
[15] H.W.Kuhn , The Hungarian method for the assignment problem, Novel Research Logistic Quarterly, 2(1955) 83-97.
[16] Lin Chi-Jen, Wen Ue-Pyng, An Labeling Algorithm for the fuzzy assignment problem, Fuzzy Sets and Systems 142(2004), 373-391.
[17] L.F.McGinnis, Implementation and testing of a primal-dual algorithm for the assignment problem, Oper.Res.,31(2) (1983), 277-291.
[18] Sathi Mukherjee and Kajla Basu, Application of Fuzzy Ranking Method for Solving Assignment Problems with Fuzzy Costs, Int.Jour.Comp and Appl. Mathematics, Vol 5 Number 3(2010), pp.359-368.
[19] Y.L.P.Thorani and N.Ravi Sankar, Fuzzy Assignment Problem with Generalized Fuzzy Numbers, App. Math.Sci,Vol.7,2013,no.71,3511-3537.
[20] X.Wang, Fuzzy Optimal Assignment Problem. Fuzzy Math., 3(1987) 101-108.
[21] L.A. Zadeh, Fuzzy sets, Information and computation, vol.8, pp.338-353, 1965.