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A FUZZY VAM- DIAGONAL OPTIMAL ALGORITHM TO SOLVE FUZZY ASSIGNMENT PROBLEM

S. Dhanasekar
School of Advanced Sciences-Mathematics Division,
VIT, Chennai Campus – 600 127

A. Manivannan
School of Advanced Sciences-Mathematics Division,
VIT, Chennai Campus – 600 127

V. Parthiban
School of Advanced Sciences-Mathematics Division,
VIT, Chennai Campus – 600 127

A.David Maxim Gururaj
School of Advanced Sciences-Mathematics Division,
VIT, Chennai Campus – 600 127

ABSTRACT

In this article we proposed a new algorithm called fuzzy Vogel approximation (VAM) method - Diagonal optimal algorithm for solving Fuzzy Assignment problem. An example is given to illustrate the fuzzy Vogel approximation - diagonal optimal algorithm and result is validated with the existing methods.

Keywords: Fuzzy number, triangular fuzzy number, trapezoidal fuzzy number, fuzzy arithmetic

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1. INTRODUCTION

Zadeh [20] introduced the fuzzy set theory in the year 1965. Recently, researchers paid much attention in the field of fuzzy theory. It has wide applications fields, like, operations research, control theory, neural networks, management science, finance etc. To minimize the assignment cost is the objective of the assignment problem. The assumptions in the assignment problem are one machine assigned to exactly one job and each machine can do exactly one job. As a special case, this article presents the solution of assignment problem using fuzzy parameters is investigated.

Assignment problem with fuzzy costs have been studied by many authors. Balinski and Gomory[2] discussed assignment and transportation problems. Chanas and Kuchta[3] solved the transportation with fuzzy cost problem. Lin and Wen [11] discussed the labelling algorithm with fuzzy assignment problem. Dubois and Fortemps [7] deveoped a flexible assignment problem, which is the combination of fuzzy theory, multiple criteria decision making and constrain-directed methodology. Fuzzy assignment problem is interesting one and researchers are giving much attention on it. Chen [4] proved some theorem and proposed a fuzzy assignment model that considers all individuals to have same skills. Wang [15] considered a fuzzy assignment problem in which the cost depends on the quality of the job and solved it. Mukherjee and Basu [12] converted the given fuzzy assignment problem in to crisp problem and solved it. Amit kumar and Anilgupta[1] proposed methods for solving fuzzy assignment problems and fuzzy travelling salesman problem with LR fuzzy numbers. Huang and Xu [8] developed a solution procedure for the assignment problems with constrains in qualification. Dhanasekar et al. [6] solved fuzzy assignment problem using Haar ranking. Khalid et al. [10] proposed diagonal optimal approach to solve crisp assignment problem.

Ramakrishnan [13] discussed Goyal's modification of VAM for the unbalanced transportation problem. He showed that how it can be improved by subtracting or adding suitable constants to the rows and columns of the cost matrix. Share [14] discussed the transportation problem with VAM and he showed that VAM method is the easiest method to solve transportation problem. In this paper, the Yager's ranking technique [18] is applied to order the fuzzy numbers. In the existing literature, there were no results on fuzzy VAM for assignment problem. This idea motivates the authors and proposed this method. In section 1 the basic definitions are given. Section 2 discusses the proposed new algorithm. An example is given in Section 3. Conclusion is given in Section 4.

1.2. Section-1

Definition

The fuzzy set is an ordered tuple $\langle x, \mu_{\tilde{A}}(x) \rangle$ where $\mu_{\tilde{A}}(x); A \to [0,1]$.

Definition

The fuzzy number $\widetilde{A}$ is a fuzzy set whose membership function $\mu_{\widetilde{A}}(x)$ is piecewise continuous, convex and normal.

Definition:

A fuzzy number with membership function of the form

$$\mu_{\widetilde{A}}(x) = \begin{cases} \frac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \frac{d-x}{d-c} & c \le x \le d \\ 0 & \text{otherwise} \end{cases}$$

is called a Trapezoidal fuzzy number $\widetilde{A}$= (a, b,c,d). If b=c, then it is called Triangular fuzzy number.

Operations on trapezoidal number and triangular number:

Addition:

$(a_1, b_1, c_1, d_1) + (a_2, b_2, c_2, d_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2)$

$(a_1, b_1, c_1) + (a_2, b_2, c_2,) = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$

Subtraction:

$(a_1, b_1, c_1, d_1) - (a_2, b_2, c_2, d_2) = (a_1 - d_2, b_1 - c_2, c_1 - b_2, d_1 - a_2)$

$(a_1, b_1, c_1) - (a_2, b_2, c_2,) = (a_1 - c_2, b_1 - b_2, c_1 - a_2)$

Definition

Yager's Ranking $Y(\tilde{a}) = \int_0^1 .5(a_U^\alpha + a_L^\alpha)d\alpha$ where $a_L^\alpha = Lower\alpha - cut$, $a_U^\alpha = Upper\alpha - cut$.

Fuzzy assignment problem:

The Matrix representation is given as follows

$$\begin{array}{c} \\ \text{person1} \\ \text{person2} \\ \text{person3} \\ . \\ \text{personN} \end{array} \begin{array}{c} \begin{array}{ccccc} \text{job1} & \text{job2} & . & & \text{jobN} \end{array} \\ \begin{pmatrix} \widetilde{C_{11}} & \widetilde{C_{12}} & . & . & \widetilde{C_{1N}} \\ \widetilde{C_{21}} & \widetilde{C_{22}} & . & . & \widetilde{C_{2N}} \\ \widetilde{C_{31}} & \widetilde{C_{32}} & . & . & \widetilde{C_{3N}} \\ . & . & . & . & . \\ \widetilde{C_{N1}} & \widetilde{C_{N2}} & . & . & \widetilde{C_{NN}} \end{pmatrix} \end{array}$$

Mathematically it can be represented as

$$\text{minimize } \tilde{Z} = \sum_{i=1}^{n} \sum_{j=1}^{n} \widetilde{C_{ij}}\, x_{ij}$$

$$\text{subject to } \sum_{i=1}^{n} x_{ij} = 1, \sum_{j=1}^{n} x_{ij} = 1,$$

$$\text{where } \begin{cases} x_{ij} = 1 & if\ i^{th} person\ is\ assigned\ to\ the\ j^{th} job \\ 0 & otherwise \end{cases}$$

1.3. Section-2

Fuzzy VAM –Diagonal optimal algorithm

1. Apply the Vogel's Approximation method to get the allocations.
2. Apply diagonal optimal algorithm to get the optimal assignment.

1.4. Section-3

Example 1

Consider the following assignment problem [10]

$$\begin{pmatrix} \langle 10\ 11\ 12 \rangle & \langle 16\ 17\ 18 \rangle & \langle 7\ 8\ 9 \rangle & \langle 15\ 16\ 17 \rangle & \langle 19\ 20\ 21 \rangle \\ \langle 8\ 9\ 10 \rangle & \langle 6\ 7\ 8 \rangle & \langle 11\ 12\ 13 \rangle & \langle 5\ 6\ 7 \rangle & \langle 14\ 15\ 16 \rangle \\ \langle 12\ 13\ 14 \rangle & \langle 15\ 16\ 17 \rangle & \langle 14\ 15\ 16 \rangle & \langle 11\ 12\ 13 \rangle & \langle 15\ 16\ 17 \rangle \\ \langle 20\ 21\ 22 \rangle & \langle 23\ 24\ 25 \rangle & \langle 16\ 17\ 18 \rangle & \langle 27\ 28\ 29 \rangle & \langle 25\ 26\ 27 \rangle \\ \langle 13\ 14\ 15 \rangle & \langle 9\ 10\ 11 \rangle & \langle 11\ 12\ 13 \rangle & \langle 10\ 11\ 12 \rangle & \langle 12\ 13\ 14 \rangle \end{pmatrix}$$

Applying the proposed algorithm

$$\begin{array}{r} \\ \\ \\ \\ \\ fuzzy\ penalty \end{array}\begin{pmatrix} \langle 10\ 11\ 12\rangle & \langle 16\ 17\ 18\rangle & \langle 7\ 8\ 9\rangle & \langle 15\ 16\ 17\rangle & \langle 19\ 20\ 21\rangle \\ \langle 8\ 9\ 10\rangle & \langle 6\ 7\ 8\rangle & \langle 11\ 12\ 13\rangle & \mathbf{\langle 5\ 6\ 7\rangle} & \langle 14\ 15\ 16\rangle \\ \langle 12\ 13\ 14\rangle & \langle 15\ 16\ 17\rangle & \langle 14\ 15\ 16\rangle & \langle 11\ 12\ 13\rangle & \langle 15\ 16\ 17\rangle \\ \langle 20\ 21\ 22\rangle & \langle 23\ 24\ 25\rangle & \langle 16\ 17\ 18\rangle & \langle 27\ 28\ 29\rangle & \langle 25\ 26\ 27\rangle \\ \langle 13\ 14\ 15\rangle & \langle 9\ 10\ 11\rangle & \langle 11\ 12\ 13\rangle & \langle 10\ 11\ 12\rangle & \langle 12\ 13\ 14\rangle \\ \langle 0\ 2\ 4\rangle & \langle 1\ 3\ 5\rangle & \langle 2\ 4\ 6\rangle & \langle 3\ 5\ 7\rangle\uparrow & \langle 0\ 2\ 4\rangle \end{pmatrix}\begin{array}{c} fuzzy\ penalty \\ \langle 1\ 3\ 5\rangle \\ \langle -1\ 1\ 3\rangle \\ \langle -1\ 1\ 3\rangle \\ \langle 2\ 4\ 6\rangle \\ \langle -1\ 1\ 3\rangle \end{array}$$

$$\begin{array}{r} \\ \\ \\ \\ fuzzy\ penalty \end{array}\begin{pmatrix} \langle 10\ 11\ 12\rangle & \langle 16\ 17\ 18\rangle & \langle 7\ 8\ 9\rangle & \langle 19\ 20\ 21\rangle \\ \langle 12\ 13\ 14\rangle & \langle 15\ 16\ 17\rangle & \langle 14\ 15\ 16\rangle & \langle 15\ 16\ 17\rangle \\ \langle 20\ 21\ 22\rangle & \langle 23\ 24\ 25\rangle & \langle 16\ 17\ 18\rangle & \langle 25\ 26\ 27\rangle \\ \langle 13\ 14\ 15\rangle & \mathbf{\langle 9\ 10\ 11\rangle} & \langle 11\ 12\ 13\rangle & \langle 12\ 13\ 14\rangle \\ \langle 0\ 2\ 4\rangle & \langle 4\ 6\ 8\rangle\uparrow & \langle 2\ 4\rangle 6 & \langle 1\ 3\ 5\rangle \end{pmatrix}\begin{array}{c} fuzzy\ penalty \\ \langle 1\ 3\ 5\rangle \\ \langle 0\ 2\ 4\rangle \\ \langle 2\ 4\ 6\rangle \\ \langle 0\ 2\ 4\rangle \end{array}$$

$$\begin{array}{r} \\ \\ \\ fuzzy\ penalty \end{array}\begin{pmatrix} \langle 10\ 11\ 12\rangle & \mathbf{\langle 7\ 8\ 9\rangle} & \langle 19\ 20\ 21\rangle \\ \langle 12\ 13\ 14\rangle & \langle 14\ 15\ 16\rangle & \langle 15\ 16\ 17\rangle \\ \langle 20\ 21\ 22\rangle & \langle 16\ 17\ 18\rangle & \langle 25\ 26\ 27\rangle \\ \langle 0\ 2\ 4\rangle & \langle 5\ 7\ 9\rangle\uparrow & \langle 2\ 4\ 6\rangle \end{pmatrix}\begin{array}{c} fuzzy\ penalty \\ \langle 1\ 3\ 5\rangle \\ \langle 0\ 2\ 4\rangle \\ \langle 2\ 4\ 6\rangle \end{array}$$

$$\begin{pmatrix} \langle 12\ 13\ 14\rangle & \mathbf{\langle 15\ 16\ 17\rangle} \\ \mathbf{\langle 20\ 21\ 22\rangle} & \langle 25\ 26\ 27\rangle \\ \langle 6\ 8\ 10\rangle & \langle 8\ 10\ 12\rangle\uparrow \end{pmatrix}\begin{array}{c} fuzzy\ penalty \\ \langle 1\ 3\ 5\rangle \\ \langle 3\ 5\ 7\rangle \end{array}$$

$fuzzy\ penalty$

The initial solution is

$$\begin{pmatrix} \langle 10\ 11\ 12\rangle & \langle 16\ 17\ 18\rangle & \mathbf{\langle 7\ 8\ 9\rangle} & \langle 15\ 16\ 17\rangle & \langle 19\ 20\ 21\rangle \\ \langle 8\ 9\ 10\rangle & \langle 6\ 7\ 8\rangle & \langle 11\ 12\ 13\rangle & \mathbf{\langle 5\ 6\ 7\rangle} & \langle 14\ 15\ 16\rangle \\ \langle 12\ 13\ 14\rangle & \langle 15\ 16\ 17\rangle & \langle 14\ 15\ 16\rangle & \langle 11\ 12\ 13\rangle & \mathbf{\langle 15\ 16\ 17\rangle} \\ \mathbf{\langle 20\ 21\ 22\rangle} & \langle 23\ 24\ 25\rangle & \langle 16\ 17\ 18\rangle & \langle 27\ 28\ 29\rangle & \langle 25\ 26\ 27\rangle \\ \langle 13\ 14\ 15\rangle & \mathbf{\langle 9\ 10\ 11\rangle} & \langle 11\ 12\ 13\rangle & \langle 10\ 11\ 12\rangle & \langle 12\ 13\ 14\rangle \end{pmatrix}$$

The optimal solution is given by

$$\langle 20\ 21\ 22\rangle \quad \langle 9\ 10\ 11\rangle \quad \langle 7\ 8\ 9\rangle \quad \langle 5\ 6\ 7\rangle \quad \langle 15\ 16\ 17\rangle$$

$$\begin{pmatrix} \langle 10\ 11\ 12\rangle & \langle 16\ 17\ 18\rangle & \langle 7\ 8\ 9\rangle & \langle 15\ 16\ 17\rangle & \langle 19\ 20\ 21\rangle \\ \langle 8\ 9\ 10\rangle & \langle 6\ 7\ 8\rangle & \langle 11\ 12\ 13\rangle & \langle 5\ 6\ 7\rangle & \langle 14\ 15\ 16\rangle \\ \langle 12\ 13\ 14\rangle & \langle 15\ 16\ 17\rangle & \langle 14\ 15\ 16\rangle & \langle 11\ 12\ 13\rangle & \langle 15\ 16\ 17\rangle \\ \langle 20\ 21\ 22\rangle & \langle 23\ 24\ 25\rangle & \langle 16\ 17\ 18\rangle & \langle 27\ 28\ 29\rangle & \langle 25\ 26\ 27\rangle \\ \langle 13\ 14\ 15\rangle & \langle 9\ 10\ 11\rangle & \langle 11\ 12\ 13\rangle & \langle 10\ 11\ 12\rangle & \langle 12\ 13\ 14\rangle \end{pmatrix}$$

$$\begin{pmatrix} \langle -12-10-8\rangle & \langle 5\ 7\ 9\rangle & \langle -2\ 0\ 2\rangle & \langle 8\ 10\ 12\rangle & \langle 2\ 4\ 6\rangle \\ \langle -14-13-10\rangle & \langle -5-3-1\rangle & \langle 2\ 4\ 6\rangle & \langle -2\ 0\ 2\rangle & \langle -3-1\ 1\rangle \\ \langle -10-8-6\rangle & \langle 4\ 6\ 8\rangle & \langle 5\ 7\ 9\rangle & \langle 4\ 6\ 8\rangle & \langle -2\ 0\ 2\rangle \\ \langle -2\ 0\ 2\rangle & \langle 12\ 14\ 16\rangle & \langle 7\ 9\ 11\rangle & \langle 20\ 22\ 24\rangle & \langle 8\ 10\ 12\rangle \\ \langle -9-7-5\rangle & \langle -2\ 0\ 2\rangle & \langle 2\ 4\ 6\rangle & \langle 3\ 5\ 7\rangle & \langle -5-3-1\rangle \end{pmatrix}$$

$$\tilde{d}_{11}\begin{array}{cc} \langle -12-10-8\rangle & \langle -2\ 0\ 2\rangle \\ \langle -2\ 0\ 2\rangle & \langle 7\ 9\ 11\rangle \end{array}\ \langle -12-10-8\rangle + \langle 7\ 9\ 11\rangle = \langle -5-1\ 3\rangle\ \ \tilde{d}_{11}\ \pi\ \tilde{0}$$

$$\tilde{d}_{21}\begin{array}{cc} \langle -14-13-10\rangle & \langle -2\ 0\ 2\rangle \\ \langle -2\ 0\ 2\rangle & \langle 20\ \ 22\ \ 24\rangle \end{array}\ \langle -14-13-10\rangle + \langle 20\ \ 22\ \ 24\rangle = \langle 6\ 9\ 14\rangle\ \ \tilde{d}_{21}\ \phi\ \tilde{0}$$

$$\tilde{d}_{22}\begin{array}{cc} \langle -5\ -3\ -1\rangle & \langle -2\ 0\ 2\rangle \\ \langle -2\ 0\ 2\rangle & \langle 3\ 5\ \ 7\rangle \end{array}\ \langle -5-3\ -1\rangle + \langle 3\ 5\ 7\rangle = \langle -2\ 2\ 6\rangle\ \ \tilde{d}_{22}\ \phi\ \tilde{0}$$

$$\tilde{d}_{25}\begin{array}{cc} \langle -2\ 0\ 2\rangle & \langle -3-1\ \ 1\rangle \\ \langle 4\ 6\ 8\rangle & \langle -2\ 0\ 2\rangle \end{array}\ \langle -3\ -1\ \ 1\rangle + \langle 4\ \ 6\ \ 8\rangle = \langle 1\ \ 5\ \ 9\rangle\ \ \tilde{d}_{25}\ \phi\ \tilde{0}$$

$$\tilde{d}_{31} \begin{matrix} \langle -10\ -8-6\rangle & \langle -2\ 0\ 2\rangle \\ \langle -2\ 0\ 2\rangle & \langle 8\ \ 10\ \ 12\rangle \end{matrix}\ \langle -10-8-6\rangle + \langle 8\ 10\ \ 12\rangle = \langle -2\ 2\ \ 6\rangle\ \ \tilde{d}_{31} \succ \tilde{0}$$

$$\tilde{d}_{51} \begin{matrix} \langle -2\ 0\ 2\rangle & \langle 12\ 14\ 16\rangle \\ \langle -9\ \ -7\ \ -5\rangle & \langle -2\ 0\ 2\rangle \end{matrix}\ \langle -9-7\ \ -5\rangle + \langle 12\ \ 14\ \ 16\rangle = \langle 3\ 7\ \ 11\rangle\ \ \tilde{d}_{51} \succ \tilde{0}$$

$$\tilde{d}_{55} \begin{matrix} \langle 4\ 6\ 8\rangle & \langle -2\ 0\ 2\rangle \\ \langle -2\ 0\ 2\rangle & \langle -5-3-1\rangle \end{matrix}\ \langle 4\ \ 6\ \ 8\rangle + \langle -5\ \ -3\ \ -1\rangle = \langle -1\ \ 3\ \ 7\rangle\ \ \tilde{d}_{55} \succ \tilde{0}$$

Out of all unassigned cells $\tilde{d}_{11} \prec \tilde{0}$. We replace the allocation $\tilde{d}_{41}$ in the first column to $\tilde{d}_{11}$ and the allocation $\tilde{d}_{13}$ in the third column to $\tilde{d}_{43}$.

$$\begin{matrix} \langle 10\ 11\ 12\rangle & \langle 9\ 10\ 11\rangle & \langle 16\ \ 17\ \ 18\rangle & \langle 5\ 6\ 7\rangle & \langle 15\ 16\ 17\rangle \end{matrix}$$

$$\begin{pmatrix} \langle 10\ 11\ 12\rangle & \langle 16\ 17\ 18\rangle & \langle 7\ 8\ 9\rangle & \langle 15\ 16\ 17\rangle & \langle 19\ 20\ 21\rangle \\ \langle 8\ 9\ 10\rangle & \langle 6\ 7\ 8\rangle & \langle 11\ 12\ 13\rangle & \langle 5\ 6\ 7\rangle & \langle 14\ 15\ 16\rangle \\ \langle 12\ 13\ 14\rangle & \langle 15\ 16\ 17\rangle & \langle 14\ 15\ 16\rangle & \langle 11\ 12\ 13\rangle & \langle 15\ 16\ 17\rangle \\ \langle 20\ 21\ 22\rangle & \langle 23\ 24\ 25\rangle & \langle 16\ 17\ 18\rangle & \langle 27\ 28\ 29\rangle & \langle 25\ 26\ 27\rangle \\ \langle 13\ 14\ 15\rangle & \langle 9\ 10\ 11\rangle & \langle 11\ 12\ 13\rangle & \langle 10\ 11\ 12\rangle & \langle 12\ 13\ 14\rangle \end{pmatrix}$$

Repeating the same process

$$\begin{pmatrix} \langle -2\ 0\ 2\rangle & \langle 5\ 7\ 9\rangle & \langle -11-9-5\rangle & \langle 8\ 10\ \ 12\rangle & \langle 2\ 4\ 6\rangle \\ \langle -4-2\ 0\rangle & \langle -5-3-1\rangle & \langle -7\ \ -5-3\rangle & \langle -2\ 0\ 2\rangle & \langle -3-1\ 1\rangle \\ \langle 0\ \ 2\ \ 4\rangle & \langle 4\ 6\ 8\rangle & \langle -4-2\ \ 0\rangle & \langle 4\ 6\ 8\rangle & \langle -2\ 0\ 2\rangle \\ \langle 8\ 10\ \ 12\rangle & \langle 12\ \ 14\ 16\rangle & \langle -2\ 0\ 2\rangle & \langle 20\ 22\ 24\rangle & \langle 8\ 10\ 12\rangle \\ \langle 1\ \ 3\ 5\rangle & \langle -2\ 0\ 2\rangle & \langle -7\ \ -5\ \ -3\rangle & \langle 3\ 5\ 7\rangle & \langle -5-3-1\rangle \end{pmatrix}$$

$$\tilde{d}_{13} \approx \langle 1\ 1\ 1\rangle \succ \tilde{0}, \tilde{d}_{21} \approx \langle 4\ 8\ \ 12\rangle \succ \tilde{0},\ \tilde{d}_{22} \approx \langle -2\ \ 2\ 6\rangle \succ \tilde{0},\ \tilde{d}_{23} \approx \langle 13\ \ 17\ \ 21\rangle \succ \tilde{0},$$

$$\tilde{d}_{25} \approx \langle 1\ 5\ 9\rangle \succ \tilde{0}$$

$\tilde{d}_{33} \approx \langle 4\ \ 8\ \ 12\rangle \succ \tilde{0}$, $\tilde{d}_{53} \approx \langle 5\ \ 9\ \ 13\rangle \succ \tilde{0}, \tilde{d}_{55} \approx \langle -1\ 3\ 7\rangle \succ \tilde{0}$. Since all $\tilde{d}_{ij} \succ \tilde{0}$, the obtained solution is optimal. The optimal solution is $\langle 10\ 11\ 12\rangle + \langle 9\ 10\ 11\rangle + \langle 16\ \ 17\ \ 18\rangle + \langle 5\ 6\ 7\rangle + \langle 15\ 16\ 17\rangle = \langle 55\ 60\ 65\rangle$ which the same is in [10 (Example 1 result)].

1.5. Section-4

2. CONCLUSION

Fuzzy VAM-diagonal opitmal algorithm is proposed for solving fuzzy assignment problem. This method is efficient to solve all kinds of fuzzy assignment problems. Numerical example is given to validate the algorithm.

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