E-ISSN: 2717-3453 | P-ISSN: 2783-1442

Journal of Fuzzy Extension and Applications

www.journal-fea.com

J. Fuzzy. Ext. Appl. Vol. 4, No. 3 (2023) 207–216.

Paper Type: Research Paper

A New Approach to MCDM Problems by Fuzzy Binary Soft Sets

P G Patil[1,*], Vyshakha Elluru[1], S Shivashankar[2]

[1] Department of Mathematics, Karnatak University, Dharwad-580003, Karnataka, India; pgpatil@kud.ac.in; vyshakh2720@gmail.com.
[2] Department of Computer Science, Karnatak University, Dharwad-580003, Karnataka, India; shivashankars@kud.ac.in.

Citation:

Patil, P. G., Vyshakha, E., & Shivashankar, S. (2023). A new approach to MCDM problems by fuzzy binary soft sets. *Journal of fuzzy extension and applications*, 4(3), 207-216.

Received: 16/01/2023 Reviewed: 20/02/2023 Revised: 11/04/2023 Accepted: 01/05/2023

Abstract

Many real-world problems face strenuous in making decisions. Many theories have evolved for dealing with such problems. The present paper deals with Fuzzy Binary Soft Sets and their applications to Multi Criteria Decision Making (MCDM) problems. Then introduced an expanded matrix representation of Fuzzy Binary Soft Sets, an extended resultant matrix, and operator, and an algorithm to solve a proposed problem.

Keywords: Fuzzy binary soft set, Matrix representation, Expanded matrix representation.

1 | Introduction

Nowadays, many real-world problems face strenuous in making decisions. Some problems can be solved by human vision and human thinking, but in some of the problems, making decisions looks hard because the data that exist with the problems are difficult to analyze. In such cases, mathematical principals can be used to solve such problems.

Many theories have evolved for dealing with such problems. Zadeh [1] introduced the concept of fuzzy sets, which assign membership value to each set element. The real-world applications can also be solved by the concepts of Fuzzy differential equations and fuzzy linear programming [2]–[9]. The main application of fuzzy sets is Multi Criteria Decision Making (MCDM) Problem which has a large domain to solve. Many researchers solve the different types of MCDM problems [10]–[14]. But if we have some criteria to deal with, then fuzzy sets are inefficient for such problems. Molodtsov [15] introduced the concept of soft sets, which deal with parameter problems. The concept of soft sets solves many applications, but soft sets won't assign the membership value to the members of the universal set. In some cases, soft sets may not efficiently deal with real-time applications.

Roy and Maji [16] discussed the MCDM problems using fuzzy soft sets, which deal with a universal set with parameters and assign the membership value to the elements of the universal set using a comparison matrix. Kong et al. [17] discussed the fuzzy soft sets and their applications in the MCDM

Corresponding Author: pgpatil@kud.ac.in

https://doi.org/10.22105/jfea.2023.390059.1257

problem by the resultant matrix. Using a comparison matrix, Snekaa et al. [18] solved the MCDM problems by combining a fuzzy analytic hirachy process with a fuzzy soft set.

The concept of fuzzy soft sets deals with the problems associated with one universal set. Ahu Acikgoz et al. [19] defined and studied some of the properties of binary soft sets, which deal with the two universal sets and a parameter set. Binary soft sets may solve some applications that are not solved by soft sets, but it doesn't assign the membership value to the elements of universal sets. In some cases, it may also be insufficient to solve real-time problems as it won't rank the elements of universal sets. The concept of a Fuzzy Binary Soft Set for problems involving two universal sets and a parameter set with a membership value is very useful.

Fuzzy Binary Soft Sets are efficient in solving problems containing two universal sets; it also solves the data that exist with the problems that binary soft sets cannot solve. Metilda and Subhashini [20] discussed the MCDM problem using a Fuzzy Binary Soft Set that deals with two universal sets and a parameter set; it also assigns the membership value to the elements of universal sets according to the parameters. This method ranks the elements of universal sets separately. However, they don't relate each element of one universal set to another universal set.

In some situations, real-time applications involve two universal sets, and we may need to compare the two independent sets and rank the pair. In such cases, fuzzy binary soft may help to solve such applications. This paper discussed the MCDM problem by Fuzzy Binary Soft Set. We defined an algorithm that relates each element of one universal set to another universal set and ranks them accordingly.

2 | Preliminaries

Definition 1 ([1]). Let X be a universal set and A be a function defined by

$$A: X \to [0,1] \text{ or } \mu_A: X \to [0,1].$$

Then A is called a Fuzzy set of X.

Definition 2 ([1]). Let A and B be two Fuzzy sets of X; then, their union and intersection are given by

$$A \vee B = max\{A(x), B(x)\},$$

and

$$A \wedge B = min\{A(x), B(x)\}.$$

Definition 3 ([15]). Let X be an initial universal set, E be a set of parameters, and $A \subseteq E$, and F be a function defined by

$$F: A \to P(X).$$

Then (F, A) is called Soft Set over X.

Definition 4 ([21]). Let X be a universal set, E be a set of parameters, and $A \subseteq E$ and F be a mapping,

$$F: A \to \tilde{P}(X),$$

where $\tilde{P}(X)$ is a set of all fuzzy subsets of X. Then (F, A) is called fuzzy soft set over X.

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Definition 5 ([22]). Let X be a universal set, E be a set of parameters, and (F, A) and (G, B) be two fuzzy soft sets over X, then their union (H, C) where $C = A \cup B$ is defined by

$$(H, C) = \begin{cases} F(e), & \text{if } e \in A - B, \\ G(e), & \text{if } e \in B - A, \\ F(e)\ \tilde{\vee}\ G(e), & \text{if } e \in A \cap B. \end{cases}$$

Definition 6 ([22]). Let X be a universal set, E be the set of parameters, and (F, A) and (G, B) be two fuzzy soft sets over X, then their intersection (J, C) where $C = A \cap B$ is defined by

$$(J, C) = \begin{cases} F(e), & \text{if } e \in A - B, \\ G(e), & \text{if } e \in B - A,. \\ A(e)\ \tilde{\wedge}\ B(e), & \text{if } e \in A \cap B. \end{cases}$$

Definition 7 ([19]). Let U_1 and U_2 be two universal sets. E be a set of parameters, $A \subseteq E$. Let F be a function defined by

$$F: A \rightarrow P(U_1) \times P(U_2).$$

Then the set (F, A) is called Binary Soft Set over U_1 and U_2.

Definition 8 ([17]). Resultant matrix is a square matrix (c_{ij}) in which object names of universal set label rows and columns, and the entries are $c_{ij} = \sum_{k=1}^{m} \propto_{ik} - \propto_{jk}$ where $\propto_{ik}$ is the membership value of the i^{th} object and k^{th} parameter.

3 | Fuzzy Binary Soft Sets

Definition 9. Let U_1 and U_2 be two universal sets, E be the set of parameters, and $A \subseteq E$. Let F be a function defined by

$$F: A \rightarrow \tilde{P}(U_1) \times \tilde{P}(U_2),$$

where $\tilde{P}(U_1)$ and $\tilde{P}(U_2)$ are a set of all fuzzy sets of U_1 and U_2, respectively. Then (F, A) is called Fuzzy Binary Soft Set over U_1 and U_2.

Example 1. Let $U_1 = \{u_1, u_2, u_3\}$ be set of badminton players from city X, and $U_2 = \{v_1, v_2, v_3\}$ be set of badminton players from city Y.

$E = \{e_1(strength), e_2(fitness), e_3(Power), e_4(Defence)\}$ be a set of parameters. Let $A = \{e_1, e_2, e_3\}$, and F be a function,

$$F: A \rightarrow \tilde{P}(U_1) \times \tilde{P}(U_2).$$

Defined by

$$F(e_1) = (\{\frac{0.9}{u_1}, \frac{0.4}{u_2}, \frac{0.7}{u_3}\}, \{\frac{0.2}{v_1}, \frac{0.2}{v_2}, \frac{0.8}{v_3}\},$$

$$F(e_2) = (\{\frac{0.4}{u_1}, \frac{0.3}{u_2}, \frac{0.6}{u_3}\}, \{\frac{0.1}{v_1}, \frac{0.5}{v_2}, \frac{0.6}{v_3}\},$$

$$F(e_3) = (\{\frac{0.6}{u_1}, \frac{0.5}{u_2}, \frac{0.7}{u_3}\}, \{\frac{0.3}{v_1}, \frac{0.8}{v_2}, \frac{0.9}{v_3}\},$$

$$\text{i.e., } (F, A) = \{(e_1, \{\frac{0.9}{u_1}, \frac{0.4}{u_2}, \frac{0.7}{u_3}\}, \{\frac{0.2}{v_1}, \frac{0.2}{v_2}, \frac{0.8}{v_3}\}), (e_2\{\frac{0.4}{u_1}, \frac{0.3}{u_2}, \frac{0.6}{u_3}\}, \{\frac{0.1}{v_1}, \frac{0.5}{v_2}, \frac{0.6}{v_3}\}),$$

$(e_3,\{\frac{0.6}{u_1},\frac{0.5}{u_2},\frac{0.7}{u_3}\},\{\frac{0.3}{v_1},\frac{0.8}{v_2},\frac{0.9}{v_3}\}$.

Then (F, A) is a Fuzzy Binary Soft Set.

3.1 | Matrix Representation of Fuzzy Binary Soft Sets

Fuzzy Binary Soft Sets can be represented systematically in the form of a matrix. This section gives the matrix representation of the Fuzzy Binary Soft Sets. Rows of the matrix are labeled with parameters, and columns are labeled with elements of universal sets. The matrix representation of the Fuzzy Binary Soft Set discussed in *Example 1* is given as follows:

$$M(F,A)=\begin{array}{c} \\ e_1\\ e_2\\ e_3\end{array}\begin{array}{c}\begin{array}{cccccc} u_1 & u_2 & u_3 & v_1 & v_2 & v_3\end{array}\\ \begin{bmatrix}0.9 & 0.4 & 0.7 & 0.2 & 0.2 & 0.8\\ 0.4 & 0.3 & 0.6 & 0.1 & 0.5 & 0.6\\ 0.6 & 0.5 & 0.7 & 0.3 & 0.8 & 0.9\end{bmatrix}\end{array}.$$

3.2 | Expanded Matrix Representation of Fuzzy Binary Soft Sets

After representing the Fuzzy Binary Soft Sets in the form of the matrix, we can split the matrix into two matrices according to two universal sets. The expanded matrix representation of Fuzzy Binary Soft Set discussed in *Example 1* is given by

$$M_1(F,A)=\begin{array}{c} \\ e_1\\ e_2\\ e_3\end{array}\begin{array}{c}\begin{array}{ccc} u_1 & u_2 & u_3\end{array}\\ \begin{bmatrix}0.9 & 0.4 & 0.7\\ 0.4 & 0.3 & 0.6\\ 0.6 & 0.5 & 0.7\end{bmatrix}\end{array},$$

$$M_2(F,A)=\begin{array}{c} \\ e_1\\ e_2\\ e_3\end{array}\begin{array}{c}\begin{array}{ccc} v_1 & v_2 & v_3\end{array}\\ \begin{bmatrix}0.2 & 0.2 & 0.8\\ 0.1 & 0.5 & 0.6\\ 0.3 & 0.8 & 0.9\end{bmatrix}\end{array},$$

where $M_1(F, A)$ is the matrix corresponding to the first universal set and $M_2(F, A)$ is the matrix corresponding to the second universal set.

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Definition 10. Let (F, A) be Fuzzy Binary Soft Set over U_1 and U_2. Let $M_1(F, A)$ and $M_2(F, A)$ be Expanded Matrices of (F, A) then the AND operator of $M_1(F, A)$ and $M_2(F, A)$ with respect to the parameter, e is denoted by $P_e^*(F, A)$ and defined by

$$(P_e^*(F,A))(x,y)=(M_1(F,A))(x)\wedge(M_2(F,A))(y)).$$

Example 2. Consider expanded matrices of a Fuzzy Binary Soft Set defined in *Example 1*, then AND operator is given by

$$P^*=\begin{array}{c}\begin{array}{ccccccccc}(u_1,v_1) & (u_1,v_2) & (u_1,v_3) & (u_2,v_1) & (u_2,v_2) & (u_2,v_3) & (u_3,v_1) & (u_3,v_2) & (u_3,v_3)\end{array}\\ \begin{bmatrix}0.2 & 0.2 & 0.8 & 0.2 & 0.2 & 0.4 & 0.2 & 0.2 & 0.7\\ 0.1 & 0.4 & 0.4 & 0.1 & 0.3 & 0.3 & 0.1 & 0.5 & 0.6\\ 0.3 & 0.6 & 0.6 & 0.3 & 0.5 & 0.5 & 0.3 & 0.7 & 0.7\end{bmatrix}\end{array}$$

Definition 11. Let $M_1(F, A)$ and $M_2(F, A)$ be expanded matrices of Fuzzy Binary Soft Set (F, A) over U_1 and U_2. An extended resultant matrix is a resultant matrix in which rows and columns are labeled with order pair elements of U_1 and U_2.

4 | Application of Fuzzy Binary Soft Sets in MCDM Problem

Mr. V wants to choose the best course in city X's college. He has a choice of 4 colleges and four subjects. Let $U_1 = \{u_1, u_2, u_3, u_4\}$ be a set of his choice of colleges in X and $U_2 = \{v_1, v_2, v_3, v_4\}$ be a set of courses to be selected by Mr. V with respect to some parameters $A = \{e_1, e_2, e_3, e_4\}$. With the available data, we must choose the best course in a good college. The data we have is given by

$$(F, A) = \{(e_1, \left\{\frac{0.2}{u_1}, \frac{0.4}{u_2}, \frac{0.7}{u_3}, \frac{0.1}{u_4}\right\}, \left\{\frac{0.3}{v_1}, \frac{0.2}{v_2}, \frac{0.8}{v_3}, \frac{0.7}{v_4}\right\}), (e_2, \left\{\frac{0.1}{u_1}, \frac{0.3}{u_2}, \frac{0.9}{u_3}, \frac{0.7}{u_4}\right\}, \left\{\frac{0.3}{v_1}, \frac{0.2}{v_2}, \frac{0.1}{v_3}, \frac{0.8}{v_4}\right\}),$$
$$(e_3, \left\{\frac{0.4}{u_1}, \frac{0.5}{u_2}, \frac{0.8}{u_3}, \frac{0.2}{u_4}\right\}, \left\{\frac{0.7}{v_1}, \frac{0.3}{v_2}, \frac{0.2}{v_3}, \frac{0.8}{v_4}\right\}), (e_4, \left\{\frac{0.6}{u_1}, \frac{0.8}{u_2}, \frac{0.4}{u_3}, \frac{0.2}{u_4}\right\}, \left\{\frac{0.4}{v_1}, \frac{0.1}{v_2}, \frac{0.8}{v_3}, \frac{0.5}{v_4}\right\}).$$

We define an algorithm to solve the given problem as follows:

Step 1. Write given data in a Fuzzy Binary Soft Set and represent it in a matrix form.

Step 2. Convert the given Fuzzy Binary Soft Set into an expanded matrix form.

Step 3. Apply and operator defined in *Definition 10* for expanded matrices obtained in *Step 1*.

Step 4. Find the extended resultant matrix (*Definition 11*).

Step 5. Find the row sum of all the rows of the extended resultant matrix.

Step 6. Highest row sum is given the rank 1.

For the problem stated above, we apply the algorithm and discuss the result as follows:

Step 1. Representing the given Fuzzy Binary Soft Set data in matrix form:

$$\begin{matrix} \cdot \\ e_1 \\ e_2 \\ e_3 \\ e_4 \end{matrix}\begin{bmatrix} u_1 & u_2 & u_3 & u_4 & v_1 & v_2 & v_3 & v_4 \\ 0.2 & 0.4 & 0.7 & 0.1 & 0.3 & 0.2 & 0.8 & 0.7 \\ 0.1 & 0.3 & 0.9 & 0.7 & 0.3 & 0.2 & 0.1 & 0.8 \\ 0.4 & 0.5 & 0.8 & 0.2 & 0.7 & 0.3 & 0.2 & 0.8 \\ 0.6 & 0.8 & 0.4 & 0.2 & 0.4 & 0.1 & 0.8 & 0.5 \end{bmatrix}.$$

Step 2. Expanded matrix representation.

$$\begin{matrix} \cdot \\ e_1 \\ e_2 \\ e_3 \\ e_4 \end{matrix}\begin{bmatrix} u_1 & u_2 & u_3 & u_4 \\ 0.2 & 0.4 & 0.7 & 0.1 \\ 0.1 & 0.3 & 0.9 & 0.7 \\ 0.4 & 0.5 & 0.8 & 0.2 \\ 0.6 & 0.8 & 0.4 & 0.2 \end{bmatrix}, \quad \begin{matrix} \cdot \\ e_1 \\ e_2 \\ e_3 \\ e_4 \end{matrix}\begin{bmatrix} v_1 & v_2 & v_3 & v_4 \\ 0.3 & 0.2 & 0.8 & 0.7 \\ 0.3 & 0.2 & 0.1 & 0.8 \\ 0.7 & 0.3 & 0.2 & 0.8 \\ 0.4 & 0.1 & 0.8 & 0.5 \end{bmatrix}.$$

Step 3. Applying AND operator.

Table 1. Matrix after AND product.

*	(u_1,v_1)	(u_1,v_2)	(u_1,v_3)	(u_1,v_4)	(u_2,v_1)	(u_2,v_2)	(u_2,v_3)	(u_2,v_4)	(u_3,v_1)	(u_3,v_2)	(u_3,v_3)	(u_3,v_4)	(u_4,v_1)	(u_4,v_2)	(u_4,v_3)	(u_4,v_4)
e_1	0.2	0.2	0.2	0.2	0.3	0.2	0.4	0.4	0.3	0.2	0.7	0.7	0.1	0.1	0.1	0.1
e_2	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.3	0.3	0.2	0.1	0.8	0.3	0.2	0.1	0.7
e_3	0.4	0.3	0.2	0.4	0.5	0.3	0.2	0.5	0.7	0.3	0.2	0.8	0.2	0.2	0.2	0.2
e_4	0.4	0.1	0.6	0.5	0.4	0.1	0.8	0.5	0.4	0.1	0.4	0.4	0.2	0.1	0.2	0.2

Step 4. Expanded resultant matrix.

Table 2. Extended resultant matrix.

(u_1,v_1)	0	0.4	0	−0.1	−0.4	0.3	−0.4	−0.6	−0.6	0.3	−0.3	−1.6	0.3	0.5	0.5	−0.1
(u_1,v_2)	−0.4	0	−0.4	−0.5	−0.8	−0.1	−0.8	−1	−1	−0.1	−0.7	−2	−0.1	0.1	0.1	−0.5
(u_1,v_3)	0	0.4	0	−0.1	−0.4	0.3	−0.4	−0.6	−0.6	0.3	−0.3	−1.6	0.3	0.5	0.5	−0.1
(u_1,v_4)	0.1	0.5	0.1	0	0.3	0.4	−0.3	−0.5	−0.5	0.4	−0.2	−1.5	0.4	0.6	0.6	0
(u_2,v_1)	0.4	0.8	0.4	0.3	0	0.7	0	−0.2	−0.2	−0.7	0.1	−1.2	0.7	0.9	0.9	0.3
(u_2,v_2)	−0.3	0.1	−0.3	−0.4	−0.7	0	−0.7	−0.9	−0.9	0	−0.6	−1.9	0	0.2	0.2	−0.4
(u_2,v_3)	0.4	0.8	0.4	0.3	0	0.7	0	−0.2	−0.2	−0.7	0.1	−1.2	0.7	0.9	0.9	0.3
(u_2,v_4)	0.6	1	0.6	0.5	0.2	0.9	0.2	0	0	0.9	0.3	−1	0.9	1.1	1.1	0.5
(u_3,v_1)	0.6	1	0.6	0.5	0.2	0.9	0.2	0	0	0.9	0.3	−1	0.9	1.1	1.1	0.5
(u_3,v_2)	−0.3	0.1	−0.3	−0.4	−0.7	0	−0.7	−0.9	−0.9	0	−0.6	−1.9	0	0.2	0.2	−0.4
(u_3,v_3)	0.3	0.7	0.3	0.2	−0.1	0.6	−0.1	−0.3	−0.3	1.3	0	−1.3	0.6	0.8	0.8	0.2
(u_3,v_4)	1.6	2	1.6	1.5	1.2	1.9	1.2	1	1	1.9	1.3	0	1.9	2.1	2.1	1.5
(u_4,v_1)	−0.3	0.1	−0.3	−0.4	−0.7	0	−0.7	−0.9	−0.9	0	−0.6	−1.9	0	0.2	0.2	−0.4
(u_4,v_2)	−0.5	−0.1	−0.5	−0.6	−0.9	−0.2	−0.9	−1.1	−1.1	−0.2	−0.8	−2.1	−0.2	0	0	−0.6
(u_4,v_3)	−0.5	−0.1	−0.5	−0.6	−0.9	−0.2	−0.9	−1.1	−1.1	−0.2	−0.8	−2.1	−0.2	0	0	−0.6
(u_4,v_4)	0.1	0.5	0.1	0	0.3	0.4	−0.3	−0.5	−0.5	0.4	−0.2	−1.5	0.4	0.6	0.6	0

Step 5. Let R_i be the row sum of the i[th] row. Then

R_1 =	-1.8	(u_1, v_1)
R_2 =	-8.2	(u_1, v_2)
R_3 =	-1.8	(u_1, v_3)
R_4 =	0.4	(u_1, v_4)
R_5 =	3.2	(u_2, v_1)
R_6 =	-6.6	(u_2, v_2)
R_7 =	3.2	(u_2, v_3)
R_8 =	7.8	(u_2, v_4)
R_9 =	7.8	(u_3, v_1)
R_{10} =	-6.6	(u_3, v_2)
R_{11} =	3.7	(u_3, v_3)
R_{12} =	23.8	(u_3, v_4)
R_{13} =	-6.6	(u_4, v_1)
R_{14} =	-9.8	(u_4, v_2)
R_{15} =	-9.8	(u_4, v_3)
R_{16} =	0.4	(u_4, v_4).

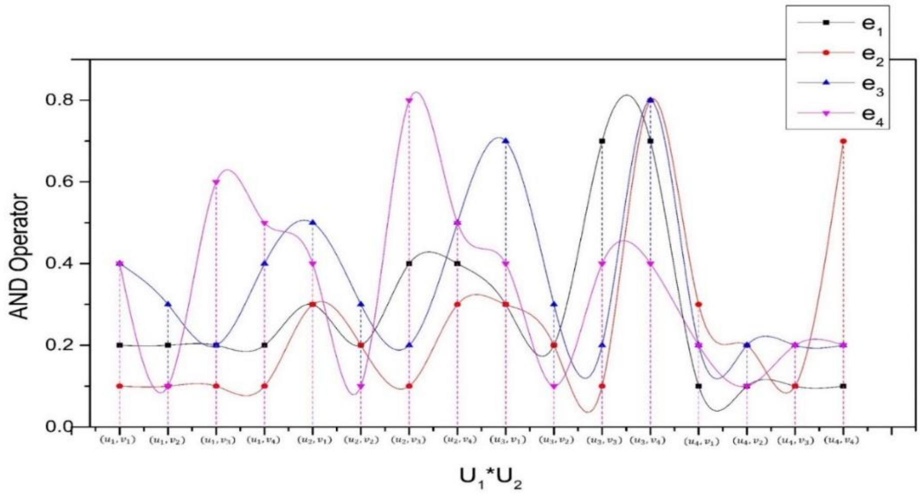

Fig. 1. Parameter graph.

Note: The parameter graph is a graph that is drawn by associating the value of (u_i, v_i) for $i = 1,2,3,4$ obtained after applying the and product corresponding to each parameter.

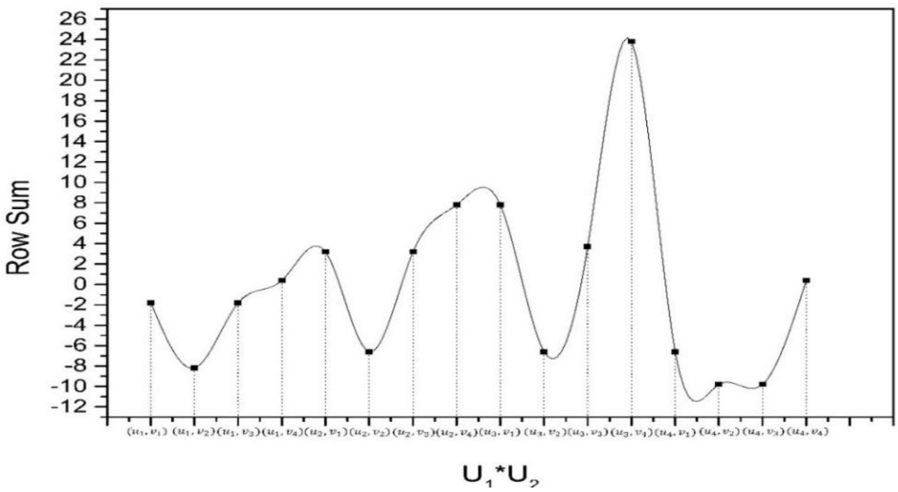

Fig. 2. Resultant graph.

Note: The resultant graph is a graph obtained by plotting the values of (u_i, v_i) for $i = 1,2,3,4$ corresponding to their row sum obtained after *Step 5*.

5 | Result and Discussion

The main aim of our paper is to relate one universal set to another universal set of a Fuzzy Binary Soft Set. In our problem, we must decide which course is best in u_1, u_2, u_3 and u_4 college and which college is better for v_1, v_2, v_3 and v_4 course. For this, we discuss the Fuzzy Binary Soft Set, matrix representation of the Fuzzy Binary Soft Set, and expanded matrix representation of the Fuzzy Binary Soft Set. Matrix representation of Fuzzy Binary Soft Sets gives the simple representation of the given data, and we can easily analyze the data in the matrix representation. After that, the new representation of the Fuzzy Binary Soft Set is defined and called an expanded matrix representation; it is represented by separating the data of universal sets. This expanded matrix is useful for relating one universal set to the other universal set by the operator (*Definition 11*).

Further, construct an algorithm to conclude the problem. The first step reduces the given data into a Fuzzy Binary Soft Set and represents it in a matrix form; this step will help to reduce the matrix into expanded matrix form, *Step 2*. In *Step 3*, apply and operator defined in *Definition 10* to get an extended resultant matrix (*Definition 11*). An expanded matrix will help to relate one universal set to another universal set which can be obtained by an extended resultant matrix, which is the next step of our algorithm. In *Step 5*, after obtaining an extended resultant matrix, take a row sum in which we can get some information.

Considering row sums, we can rank the colleges u_i, for $i = 1,2,3,4$ for courses v_i, for $i = 1,2,3,4$. Similarly, we can rank the courses v_i for $i = 1,2,3,4$ in colleges u_i for $i = 1,2,3,4$. This can be obtained by fixing u_i for $i = 1,2,3,4$ and varying v_i fo $i = 1,2,3,4$r. In the same way, fixing v_i for $i = 1,2,3,4$ and varying u_i for $i = 1,2,3,4$.

Clearly, we can see that for u_1, v_4 got the highest row sum and v_1 and v_3 got the same row rank. This can also be seen in *Fig. 2*. In *Fig. 2*, consider the curve regarding the element u_1 i.e., $(u_1, v_1), (u_1, v_2), (u_1, v_3)$ and (u_1, v_4) we can see that (u_1, v_4) Reaches the highest peak among them. (u_1, v_1) and (u_1, v_3) are at the same height. We can analyze the parameter graph (*Fig. 1*) in such same rank cases to conclude which is best. In *Fig. 1*, we can see that (u_1, v_3) reaches a maximum value corresponding to the parameter e_4. So, between v_1 and v_3, v_3 is our choice. By *Fig. 1*, the decision also be taken by preferring the parameter. If we prefer e_3 over e_4, then (u_1, v_1) reaches the maximum peak. So, in that case v_1 will be the better choice. In the same way, we can see that the course v_4 is the better choice among all the colleges.

Suppose Mr. V wants to choose the better college for a particular course; we fix the course v_i for $i = 1,2,3,4$ and vary u_i for $i = 1,2,3,4$.

For the course v_1, (u_3, v_1) has the highest row sum, and in the graph, (u_3, v_1) reaches the maximum corresponding to v_1. So, u_3 is the best choice for v_1 course. In the same way, we can conclude that, for v_2, v_2 andv_4, the college u_3 is the best choice.

From the resultant graph (*Fig. 2*), we can conclude which pair is best by seeing the highest peak and the worst pair by seeing the lowest peak. So, by *Fig. 1* (u_3, v_4) is the best pair. The pairs (u_4, v_2) and (u_4, v_3) are the worst pairs.

Some pairs got the same row sum; in such cases, it is difficult to decide which is best by just analyzing the resultant graph; in that case, the parameter graph (*Fig. 1*) gives the result. (u_1, v_1) and (u_1, v_3) are at the same position in the resultant graph, but in the parameter graph, we can see that (u_1, v_3) reaches a maximum value corresponding to the parameter e_4. So, we choose (u_1, v_3) over (u_1, v_1).

From the resultant matrix, clearly, the 12th row has the highest row sum, which corresponds to (u_3, v_4). The resultant graph can also decide this by seeing the highest peak, which corresponds to (u_3, v_4). So,

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v_4 the course is best in u_3 college. Metlida and Subhashini [20] discussed the application of Fuzzy Binary Soft Sets, but their method fails to relate one universal set's element to another. The current work gives better results than Metlida and Subhashini [20] as the proposed method relates the elements of both the universal sets and gives the result.

6 | Conclusion

This paper discusses the problem involving two universal sets and a parameter set that assigns the membership values to universal sets. This method can solve a problem involving two universal sets that want a simultaneous solution. This method can be utilized for a parameter set that contains a finite number of parameters. If two rows got the same row sum, then we can conclude by plotting a parameter graph.

Conflicts of Interest

All co-authors have seen and agree with the manuscript's contents, and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Acknowledgment

The authors thank the referees for their helpful comments and suggestions.

References

[1] Zadeh, L. A. (1965). Fuzzy sets. *Information and control*, *8*(3), 338–353.

[2] Alamin, A., Rahaman, M., Mondal, S. P., Chatterjee, B., & Alam, S. (2022). Discrete system insights of logistic quota harvesting model: A fuzzy difference equation approach. *Journal of uncertain systems*, *15*(02), 2250007. https://www.worldscientific.com/doi/abs/10.1142/S1752890922500076

[3] Das, S. K., & Mandal, T. (2017). A MOLFP method for solving linear fractional programming under fuzzy environment. *International journal of research in industrial engineering*, *6*(3), 202–213.

[4] Halder, P. K., Karmarker, C. L., Kundu, B., & Daniel, T. (2018). Evaluation of factors affecting the productivity of RMG in Bangladesh: A fuzzy AHP approach. *International journal of research in industrial engineering*, *7*(1), 51–60.

[5] Mahmoudi, F., & Nasseri, S. H. (2019). A new approach to solve fully fuzzy linear programming problem. *Journal of applied research on industrial engineering*, *6*(2), 139–149.

[6] Rahaman, M., Maity, S., De, S. K., Mondal, S. P., & Alam, S. (2021). Solution of an Economic production quantity model using the generalized Hukuhara derivative approach. *Scientia Iranica,* 1-37. https://scientiairanica.sharif.edu/article_22582.html

[7] Rahaman, M., Mondal, S. P., Chatterjee, B., & Alam, S. (2022). The solution techniques for linear and quadratic equations with coefficients as Cauchy neutrosphic numbers. *Granular computing*, 1–19. https://link.springer.com/article/10.1007/s41066-021-00276-0

[8] Rahaman, M., Mondal, S. P., Alam, S., De, S. K., & Ahmadian, A. (2022). Study of a fuzzy production inventory model with deterioration under Marxian principle. *International journal of fuzzy systems*, *24*(4), 2092–2106.

[9] Tudu, S., Gazi, K. H., Rahaman, M., Mondal, S. P., Chatterjee, B., & Alam, S. (2023). Type-2 fuzzy differential inclusion for solving type-2 fuzzy differential equation. *Annals of fuzzy mathematics and informatics*, *25*(1), 33–53.

[10] Alzahrani, F. A., Ghorui, N., Gazi, K. H., Giri, B. C., Ghosh, A., & Mondal, S. P. (2023). Optimal site selection for women university using neutrosophic multi-criteria decision making approach. *Buildings*, *13*(1), 152. https://doi.org/10.3390/buildings13010152

[11] Gazi, K. H., Mondal, S. P., Chatterjee, B., Ghorui, N., Ghosh, A., & De, D. (2023). A new synergistic strategy for ranking restaurant locations: A decision-making approach based on the hexagonal fuzzy numbers. *RAIRO-operations research*, *57*(2), 571–608.

[12] Ghorui, N., Mondal, S. P., Chatterjee, B., Ghosh, A., Pal, A., De, D., & Giri, B. C. (2023). Selection of cloud service providers using MCDM methodology under intuitionistic fuzzy uncertainty. *Soft computing*, *27*(5), 2403–2423.

[13] Momena, A. F., Mandal, S., Gazi, K. H., Giri, B. C., & Mondal, S. P. (2023). Prediagnosis of disease based on symptoms by generalized dual hesitant hexagonal fuzzy multi-criteria decision-making techniques. *Systems*, *11*(5), 231. https://www.mdpi.com/2079-8954/11/5/231

[14] Nandi, S., Granata, G., Jana, S., Ghorui, N., Mondal, S. P., & Bhaumik, M. (2023). Evaluation of the treatment options for COVID-19 patients using generalized hesitant fuzzy-multi criteria decision making techniques. *Socio-economic planning sciences*, *88*, 101614. https://www.sciencedirect.com/science/article/pii/S0038012123001143

[15] Molodtsov, D. (1999). Soft set theory—first results. *Computers & mathematics with applications*, *37*(4–5), 19–31.

[16] Roy, A. R., & Maji, P. K. (2007). A fuzzy soft set theoretic approach to decision making problems. *Journal of computational and applied mathematics*, *203*(2), 412–418.

[17] Kong, Z., Gao, L., & Wang, L. (2009). Comment on "A fuzzy soft set theoretic approach to decision making problems". *Journal of computational and applied mathematics*, *223*(2), 540–542.

[18] Snekaa, B., Dorathy, C., & Porchelvi, R. S. (2020). A combination of FAHP and fuzzy soft set theory method for solving MCDM problem in sports application. *Malaya journal of matematik (MJM)*, *8*(4), 1577–1579.

[19] Acikgoz, A., & Tas, N. (2016). Binary soft set theory. *European journal of pure and applied mathematics*, *9*(4), 452–463.

[20] Metilda, P. G., & Subhashini, J. (2021). An application of fuzzy binary soft set in decision making problems. *Webology (ISSN: 1735-188x)*, *18*(6), 3672-3680.

[21] Cagman, N., Enginoglu, S., & Citak, F. (2011). Fuzzy soft set theory and its applications. *Iranian journal of fuzzy systems*, *8*(3), 137–147.

[22] Kharal, A., & Ahmad, B. (2009). On fuzzy soft sets. *Advances in fuzzy systems*, 586507. https://ksascholar.dri.sa/en/publications/on-fuzzy-soft-sets-2