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Some New Results and Operations on Fuzzy Soft Matrices and Decision Making

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Abstract: *Here in this work we consider and introduce different type of matrices in fuzzy soft set theory. Then we define some important operations on fuzzy soft matrices. Using these operations we established new results on fuzzy soft matrices. Finally, using a suitable algorithm, a real world problem on decision making theory is solved and presented in detail in this paper.*
Keywords: *Fuzzy Soft Set, Fuzzy Soft Matrix, Production Matrix.*

I. Introduction :

We bear approaches that offer some type of flexible information processing capacity in order to handle real- life circumstances. To resolve similar issues, earlier(3) have defined different types of soft matrices lately(1) and(2) presented remarkable work on Fuzzy soft matrices grounded on soft set proposition(9) and(10). Some new results on fuzzy soft matrices are presented by (4) in detail.

In the time 1999, Molodtsov (7) first introduced soft set as a fully general fine instrument for modeling query. Experimenters choose the kind of parameters they need to simplify the decision- making process since there are nearly no limitations in characterizing the objects, which makes it more effective in the absence of deficient information. farther studies on soft set proposition, fuzzy soft set proposition, and related motifs have been conducted by Maji etal.(10, 11, 12). Maji etal.(10) also employ rough set proposition's notion of attributes reduction to minimize still, using this system, one can also gain an artificial optimal choice object. As a result, Chen etal.(5) demonstrated that the system of attributes reduction in rough set proposition can not be directly transferred to parameters reduction in soft set proposition, but he didn't expose the intricate procedure of parameters reduction in soft set proposition. The complete procedure for parameter reduction with the use of SQL(Structured Query Language), which Chambelin and Boyce (6) established, is handed by Zou etal. In (13). In addition, Zhi Kong etal.(15) have handed a new conception of fuzzy soft set normal parameter reduction and proposed an algorithm for it. also, Zou and Xiao's(14) data analysis styles for soft sets with partial data were handed. For reflecting factual countries of partial data in soft sets, the styles proposed in (14) are more. still, rough sets or fuzzy soft sets are generally used in the operations of soft set proposition to help break problems. A new soft set- grounded decision- making approach (uni-int decision- making system) (8) was developed by Cagman etal. and picks a set of ideal rudiments from the options. also, they handed a conception for soft matrices, which are just soft set representations. This definition has a number of benefits. In a computer, matrices and the soft sets they represent can be fluently stored and operated upon. also, Cagman etal.(8) have suggested an approach for handling situations involving soft sets and numerous operations. But the Cagman approach is exceedingly time- consuming and has a high computational complexity for soft set grounded decision making situations with further than two decision makers. We have the idea of a fuzzy soft matrix was put forth in this donation. also, after furnishing suitable exemplifications, we defined different types of fuzzy soft matrices. Then, we've also suggested the idea of a decision matrix connected to a fuzzy soft set. further presented some operations on choice matrices and fuzzy soft matrices. Eventually, we've handed a new method for working fuzzy soft set- grounded decision- making issues using these matrices and lately described operations of fuzzy soft matrices. The oneness of this new strategy is that it can readily answer any fuzzy soft- grounded decision- set forming problem involving a large number of decision- makers, and the computational process is fairly straightforward.

II. Preliminaries

Fuzzy Soft Set Matrix:

Let (F_A, E) be a fuzzy soft set over U. Then a subset of UxE is uniquely defined by $R_A = \{(u.e) : e\epsilon A, u\epsilon F_A(e)\}$ which is called a relation form of (F_A, E). Now the characteristic function of R_A is written by χ_{RA} : UXE → [0,1] s.t, if the $\chi_{RA}(u.e) = \mu(u.e)$ [where $\mu(u.e)$ is the membership value of the object u associated with the parameter e.]

Now if the set of universe U = {u_1, u_2,........……….....u_m) and the set of parameters E= {e_1,e_2,,..........e_n}, then R_A can be presented by a table as in the following form

	e_1	e_2	……….	e_n
u_1	$\chi_{RA}(u_1,e_1)$	$\chi_{RA}(u_1,e_2)$	……….	$\chi_{RA}(u_1,e_n)$
U_2	$\chi_{RA}(u_2,e_1)$	$\chi_{RA}(u_2,e_2)$	……….	$\chi_{RA}(u_2,e_n)$
…..	………..	…………	……….	………..
U_m	$\chi_{RA}(u_m,e_1)$	$\chi_{RA}(u_m,e_2)$	……….	$\chi_{RA}(u_m,e_n)$

which is called a fuzzy soft matrix of order mxn corresponding to the fuzzy soft set (F_A,E) over U. A fuzzy soft set (F_A.E) is uniquely characterized by the matrix $[a_{ij}]$mxn. Therefore we shall identify any fuzzy soft set with its fuzzy soft matrix and use these two concepts as interchangeable.

Example :
Suppose the initial universe set U contains five Institutes i_1, $i_{2,}$ $i_{3,}i_{4,i}h_5$ and parameter set
E = { costly, qualified faculty, Low ranking, comfortable, Big campus)= {e_1,e_2,.e_3,e_4,e_5).
A = {e_2,.e_3,e_4,e_5} C E
Let F:A→P(U) such that
F(e_1) = {i_1/0.8, i_2./0.3, i_3./0.6, i_4/0.5, i_5/0.2}.
F(e_2) = {i_1/0.8, i_2./0.2, i_3./0.5, i_4/0.4, i_5/0.1}.
F(e_3) = {i_1/0.3, i_2./0.7, i_3./0.5, i_4/0.4, i_5/0.9}
F(e_4)= {i_1/0.8, i_2./0.6, i_3./0.4, i_4/0.2, i_5/0.7}.
F(e_5)= {i_1/0.5, i_2./0.2, i_3./0.8, i_4/0.3, i_5/0.3}.

Then we write a fuzzy soft set describing the quality of the houses is given by,
(F, E) = {($e_{1,}${i_1/0.8, i_2./0.3, i_3./0.6, i_4/0.5, i_5/0.2}),
($e_{2,}$ {i_1/0.8, i_2./0.2, i_3./0.5, i_4/0.4, i_5/0.1}),
($e_{3,}$ {i_1/0.3, i_2./0.7, i_3./0.5, i_4/0.4, i_5/0.9}),
($e_{4,}$ {i_1/0.8, i_2./0.6, i_3./0.4, i_4/0.2, i_5/0.7}),
($e_{5,}${i_1/0.5, i_2./0.2, i_3./0.8, i_4/0.3, i_5/0.3})}.

and then the relation form of (F,A) is written by.
R_A = ({{i_1/0.8, i_2./0.3, i_3./0.6, i_4/0.5, i_5/0.2},e_1),
({i_1/0.8, i_2./0.2, i_3./0.5, i_4/0.4, i_5/0.1},e_2),.
{i_1/0.3, i_2./0.7, i_3./0.5, i_4/0.4, i_5/0.9},e_3),
{i_1/0.8, i_2./0.6, i_3./0.4, i_4/0.2, i_5/0.7},e_4),
{i_1/0.5, i_2./0.2, i_3./0.8, i_4/0.3, i_5/0.3},e_5).

Hence the fuzzy soft matrix ($a_{ij,}$) is written by

$$\begin{pmatrix} 0.8 & 0.8 & 0.3 & 0.8 & 0.5 \\ 0.3 & 0.2 & 0.7 & 0.6 & 0.2 \\ 0.5 & 0.5 & 0.4 & 0.8 & 0.6 \\ 0.5 & 0.4 & 0.4 & 0.2 & 0.3 \\ 0.2 & 0.1 & 0.9 & 0.7 & 0.3 \end{pmatrix}$$

III. Definitions:

Row-Fuzzy Soft Matrix: A fuzzy soft matrix of order 1xn i.e., with a single row is called a row-fuzzy soft matrix. Physically, a row-fuzzy soft matrix formally corresponds to a fuzzy soft set whose universal set contains only one object.

Column-Fuzzy Soft Matrix: A fuzzy soft matrix of order mx1 i.e., with a single column is called a column-fuzzy soft matrix. Physically, a column-fuzzy soft matrix formally corresponds to a fuzzy soft set whose parameter set contains only one parameter.

Square Fuzzy Soft Matrix:

fuzzy soft matrix of order mxn is said to be a **square fuzzy soft matrix** if m= n ie., the number of rows and the number of columns are equal. That means a square-fuzzy soft matrix is formally equal to a fuzzy soft set having the same number of objects and parameters.

Null Fuzzy Soft Matrix: A fuzzy soft matrix of order mxn is said to be a null fuzzy soft matrix or zero fuzzy soft matrix if all of it's a elements are zero. A null fuzzy soft matrix is denoted by Φ. Now the fuzzy soft set associated with a null fuzzy soft matrix must be a null fuzzy soft set.

Complete or Absolute Fuzzy Soft Matrix:
A fuzzy soft matrix of order mxn is said to be a **complete or absolute fuzzy soft matrix** if all of its elements are one. A complete or absolute fuzzy soft matrix is denoted by, C_A. Now the fuzzy soft set associated with an absolute fuzzy soft matrix must be an absolute fuzzy soft set.

Diagonal Fuzzy Soft Matrix: A square fuzzy soft matrix of order mxn is said to be a diagonal-fuzzy soft matrix if all of its non-diagonal elements are zero.

Transpose of a Fuzzy Soft Matrix: The transpose of a square fuzzy soft matrix (a_{ij}) of order mxn is another square fuzzy soft matrix of order nxm obtained from (a_{ij}) by interchanging its rows and columns. It is denoted by $(a_{ij})^T$. Therefore the fuzzy soft set associated with $(a_{ij})^T$ becomes a new fuzzy soft set over the same universe and over the same set of parameters.

Choice Matrix: It is a square matrix whose rows and columns both indicate parameters. If ξ is a choice matrix, then its element ξ(i, j) is defined as follows:

ξ(i, j) = 1 when i-th and j-th parameters are both choice parameters of the decision makers
= 0 otherwise, i.e. when atleast one of the i-th or j-th parameters is not under choice.

There are different types of choice matrices according to the number of decision makers. Like the choice matrices associated with a soft set based decision making problem; here also the choice matrices only contain the digits 0 and 1, the only difference is about the nature of the associated parameters. We may realize this by the following example.

Symmetric Fuzzy Soft Matrix:
A square fuzzy soft matrix A of order nxn is said to be a symmetric fuzzy soft matrix, if its transpose be equal to it, i.e., if $A^T = A$. Hence the fuzzy soft matrix (a_{ij}) is symmetric, if $a_{ij}=a_{ji}$.

IV. Operations on Fuzzy Soft Matrices:

Complement of a fuzzy soft matrix :
Let A= $(a_{ij})_{mxn}$ is a fuzzy soft matrix than complement of A is denoted by A*
Complement of a fuzzy soft matrix A= A*=(a_{ij})*mxn and is defined as (a_{ij})*mxn=(c_{ij})mxn where c_{ij}= 1-a_{ij}.

Example

$$\text{Let } A = \begin{pmatrix} 0.3 & 0.2 & 1 \\ 0.4 & 0 & 0.8 \\ 0.4 & 0.4 & 0.2 \end{pmatrix}$$

Then the complement of A is

$$A^* = \begin{pmatrix} 0.7 & 0.8 & 0.0 \\ 0.6 & 1 & 0.2 \\ 0.6 & 0.6 & 0.8 \end{pmatrix}$$

Addition of Fuzzy Soft Matrices:
Two fuzzy soft matrices A and B are said to be conformable for addition, if they be of the same order. The sum of two fuzzy soft matrices A and B of the same order is the fuzzy soft matrix whose elements are taken as the maximum element of the corresponding elements of the two fuzzy soft matrices A and B.

Therefore the addition of two fuzzy soft matrices (a_{ij}) and (b_{ij}) of order mxn is defined by,
$(a_{ij}) \oplus (b_{ij}) = (c_{ij})$, where (c_{ij}) is also an mxn fuzzy soft matrix and
$c_{ij} = \min\{1, a_{ij}+b_{ij}\}$ for every i,j.

Example.

$$\begin{bmatrix} 0.3 & 0.2 & 1 \\ 0.4 & 0 & 0.8 \\ 0.4 & 0.4 & 0.2 \end{bmatrix} \oplus \begin{bmatrix} 0.2 & 0.9 & 0.3 \\ 0.4 & 0.3 & 0.6 \\ 0.4 & 0.7 & 5 \end{bmatrix} = \begin{bmatrix} 0.5 & 1 & 1 \\ 0.8 & 0.3 & 1 \\ 0.8 & 1 & 0.7 \end{bmatrix}$$

Subtraction of Fuzzy Soft Matrices:
Two fuzzy soft matrices A and B are said to be conformable for subtraction, if they be of the same order. The subtraction of a fuzzy soft matrix B from a fuzzy soft matrix A is a fuzzy soft matrix.
Therefore for any two fuzzy soft matrices (a_{ij}) and (b_{ij}) of order mxn, the subtraction of (b_{ij}) from (a_{ij}) is defined as,
$(a_{ij}) - (b_{ij}) = (c_{ij})$, where $c_{ij} = \max\{0, a_{ij}+b_{ij}-1\}$ is also mxn fuzzy soft matrix for every i,j

Production of Two fuzzy soft matrices: Let A= (aij) and B=(bij) are two fuzzy soft matrices of orders mxn and nxp respectively then A and B are compatible for production and we def ine the production as follows:
$(a_{ij})_{mxn} \text{ X } (b_{ij})_{nxp} = (c_{ik})_{mxp}$
Where $(c_{ik})_{mxp}$ is a fuzzy soft matrix such that

$(c_{ik}) = \max\{a_{ij}.b_{jk}\}$, for j=1,2….n

Example

$$(a_{ij})_{3x2} = \begin{bmatrix} 0.4 & 0.3 \\ 0.3 & 0.2 \\ 0.5 & 0.6 \end{bmatrix} \text{ and } (b_{jk})_{2x3} = \begin{bmatrix} 0.4 & 0.3 & 0.5 \\ 0.9 & 0.4 & 0.2 \end{bmatrix}$$

Then we have

$$(a_{ij})_{3x2} \text{ x } (b_{jk})_{2x3} = \begin{bmatrix} 0.27 & 0.12 & 0.20 \\ 0.18 & 0.09 & 0.15 \\ 0.54 & 0.24 & 0.25 \end{bmatrix}$$

Product of a Fuzzy Soft Matrix with a Choice Matrix:
Let U be the set of universe and E be the set of parameters. Suppose that A be any fuzzy soft matrix and B be any choice matrix of a decision maker concerned with the same universe U and E. Now if the number of columns of the fuzzy soft matrix A be equal to the number of rows of the choice matrix B, then A and B

A and B are said to be conformable for the product (A $\otimes$ B) and $\otimes$product becomes a fuzzy soft matrix. We may denote the product by (A $\otimes$ B) or simply by AB.
If A = (aij)mxn and B = (bjk)nxp, then
[(cik) if 0≤cik≤1 for every , i=1,2,...,m, k=1,2,..., p

the normalized form of $(c_{ik})_{mxp}$ if $C_{ik}>1$ for at least one i(= 1,2,...,m) or,k(=1,2,..., p)
where $c_{ik} = \sum_{j=1}^{n}$ min{a,,b,) and normalize the array $(c_{ik})_{mxp}$ by dividing each entry of the array by the sum of the all entries of the array.

Example:
Let U be the set of four Paintings, given by, U
= $\{p_1, p_2, p_3, p_4\}$. Let E be the set of
parameters, given by, E
{ cheap, beautiful, comfortable, Attaractive } = $\{e_1,.e_2, .e_3,.e_4\}$
Suppose that the set of choice parameters of Mr Ram. be, A=$\{e_1,e_3,\}$. Now let
according to the choice parameters of Mr.X, we have the fuzzy soft set (F,A) which describes the worthfullness of the paintaings
and the fuzzy soft matrix of the fuzzy soft set (F,A) be,

$$(aij) = \begin{pmatrix} 0.8 & 0.2 & 0.7 & 0.3) \\ 0.3 & 0.7 & 0.4 & 0.8 \\ 0.7 & 0.4 & 0.5 & 0.6 \\ 0.5 & 0.1 & 0.9 & 0.2 \end{pmatrix}$$

Again the choice matrix of Mr. Ram is,

$$(\xi_{ij})_{(A)} = e_A \begin{pmatrix} & e_A & & \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

Since the number of columns of the fuzzy soft matrix (aij) is equal to the number of rows of the choice matrix $(\xi_{ij})_{(A)}$ they are conformable for the product.
Therefore

$$(aij) \otimes (\xi_{ij})_{(A} = \begin{pmatrix} 0.8 & 0.2 & 0.7 & 0.3) \\ 0.3 & 0.7 & 0.4 & 0.8 \\ 0.7 & 0.4 & 0.5 & 0.6 \\ 0.5 & 0.1 & 0.9 & 0.2 \end{pmatrix} \otimes$$

$$\begin{pmatrix} & e_A & & \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

- the normalized form of $\begin{pmatrix} 1.5 & 0 & 1.5 & 0 \\ 0.7 & 0 & 0.7 & 0 \\ 1.2 & 0 & 1.2 & 0 \\ 1.4 & 0 & 1.4 & 0 \end{pmatrix}$

$$= \begin{pmatrix} 1.5/9.6 & 0/9.6 & 1.5/9.6 & 0.9.6 \\ 0.7/9.6 & 0/9.6 & 0.7/9.6 & 0/9.6 \\ 1.2/9.6 & 0/9.6 & 1.2/9.6 & 0/9.6 \\ 1.4/9.6 & 0/9.6 & 1.4/9,6 & 0/9.6 \end{pmatrix}$$

Since 9.6 is the sum of all elements of the previous array]

$$= \begin{pmatrix} 0.16 & 0 & 0.16 & 0 \\ 0.07 & 0 & 0.07 & 0 \\ 0.13 & 0 & 0.13 & 0 \\ 0.15 & 0 & 0.15 & 0 \end{pmatrix}$$

V. Algorithm:

This new approach is specially based on operation of production of two fuzzy soft matrices. These matrices represent the parameters of the decision makers and also help us to solve the fuzzy soft matrix based decision making problems with least computational complexity. So by the help of these newly matrices and proposed the operations on them we are presenting the following algorithm:

Step-1: Input fuzzy soft set (F,E) and corresponding fuzzy soft matrix A.

Step-2: Input fuzzy soft set (F,E) and corresponding fuzzy soft matrix A..

Step-3: compute the production of fuzzy soft matrices A and B i.e. AXB
Step-4: Compute the Diognose Matrix $(C_{ij})_{mxl}$
Step-5: Find cit = max cij (for j= 1,2,….k)
The object having the highest value becomes the optimal gain object. If more than one object have the highest value then any one of them may be chosen as the optimal gain object.

To illustrate the basic idea of the algorithm, now we apply it to a fuzzy soft set based decision making problem.

VI. CASE STUDY: DECISION MAKING PROBLEM

Suppose that there are four students s_1, s_2, s_3, s_4 who participated in four exams E=(e_1, e_2,,e_3,e_4) For placing them into into four levels of education i.e. IIT, NIT, IIIT and others where L = (l_1,l_2,l_3,l_4) = (IIT,NIT,IIIT, others) denotes the level of education institutes.
Now suppose that (F,E) = {F,S_1)={(e_1,0.7,(e_2,0.8),(e_3,0.8,(e_4,0.9)},f(s_2)={(e_1,0.3,(e_2,0.4),(e_3,0.7, (e_4,0.69)},f(s_3)={(e_1,0.5,(e_2,0.3),(e_3,0.4,(e_4,0.8)}, f(s_4)={(e_1,0.9,(e_2,0.2),(e_3,0.7,(e_4,0.2)}}
Thus the student exams fuzzy soft matrix A is

$$A=\begin{array}{c} \\ s1 \\ s2 \\ S3 \\ S4 \end{array}\begin{array}{c} \begin{array}{cccc} e_1 & e_2 & e_3 & e_4 \end{array} \\ \begin{pmatrix} 0.7 & 0.8 & 0.2 & 0.9 \\ 0.3 & 0.4 & 0.7 & 0.6 \\ 0.5 & 0.3 & 0.4 & 0.8 \\ 0.9 & 0.2 & 0.7 & 0.2 \end{pmatrix} \end{array}$$

Also (G,L)={G(e1)= {(l_1,0.3,(l_2,0.6),(l_3,0.9,(l_4,04)},G(e_2)= {(l_1,0.5,(l_2,0.7),(l_3,0.3,(l_4,0.8)},G(e_3)={(l_1,0.9,(l_2,0.7),(l_3,0.6,(l_4,0.3)},G(e_4)={(l_1,0.1,(l_2,0.5),(l_3,0.3 ,(l_4,0.4)}}
Thus the syudent –exam fuzzy soft matrix B is

$$A=\begin{array}{c} \\ e_1 \\ e_2 \\ e_3 \\ e_4 \end{array}\begin{array}{c} \begin{array}{cccc} l_1 & l_2 & l_3 & l_4 \end{array} \\ \begin{pmatrix} 0.3 & 0.6 & 0.9 & 0.4 \\ 0.5 & 0.7 & 0.3 & 0.8 \\ 0.9 & 0.7 & 0.6 & 0.3 \\ 0.1 & 0.5 & 0.3 & 0.4 \end{pmatrix} \end{array}$$

Therefore by performing the production operation AXB, we have c= $(c_{ij})_{4x4}$

$$A=\begin{array}{c} \\ s1 \\ s2 \\ S3 \\ S4 \end{array}\begin{array}{c} \begin{array}{cccc} l_1 & l_2 & l_3 & l_4 \end{array} \\ \begin{pmatrix} 0.4 & 0.56 & 0.63 & \mathbf{0.64} \\ \mathbf{0.63} & 0.49 & 0.42 & 0.32 \\ 0.36 & 0.4 & \mathbf{0.45} & 0.32 \\ 0.63 & 0.54 & \mathbf{0.81} & 0.21 \end{pmatrix} \end{array}$$

Consequently , A_{14} = 0.64 is highest so student S_1 is qualified for merit of (l_4) others and student s_2 qualified for (l_1) i.e IIT. Student s_3 and s_4 qualified for IIIT.

VII. Conclusion:

In this paper first we have defined different types of fuzzy soft matrices and then introduced some operations on them. Finally we have presented a new algorithm using these matrices and newly proposed operations of fuzzy soft matrices to solve fuzzy soft set based decision making problems. We proposed that a real world problem can be solved by the idea of fuzzy set theory and its corresponding concept of fuzzy soft matrix by using proper algorithm. The specialty of this new method is that it may solve any fuzzy soft set based decision making problem involving huge number of decision makers easily along with a very simple computational procedure.

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