A COMPARATIVE STUDY OF FUZZY NEUTROSOPHIC SOFT MATRIX AND ITS DECISION MAKING

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Abstract:

In this paper, we presented fuzzy neutrosophic soft matrices[FNSM] and their operators which are representative of the fuzzy neutrosophic soft sets. The matrix is useful for solving a fuzzy neutrosophic soft set[FNSS] in computer memory which are very useful and applicable. Finally, based on some of the operations on sufficient methodology has been developed to solve FNSS based group decision making problems. Examples are illustrations to verify and compare the proposed algorithms.

Key words: Soft set, Neutrosophic set, Fuzzy neutrosophic soft set, optimal soft set, fuzzy neutrosophic soft matrix, Group decision making.

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1. Introduction: Maji [27], firstly proposed neutrosophic soft sets can handle the indeterminate information and inconsistent information which exists commonly in brief systems. In recent years a number of theories have been proposed to deal with uncertainty, imprecision, Vagueness and indeterminacy. Theory of Probability, fuzzy set theory [44], intuitionistic fuzzy sets [4], interval valued fuzzy sets [3], Vague sets [22], rough set theory [34], neutrosophic theory [37], interval neutrosophic theory [43],etc, are consistently being utilized as efficient tools for diverse types of Uncertainties and impression embedded in a system. However, each of these theories has its inherent difficulties as pointed out by Molodtsov [33], the reason for these difficulties is, possible, the inadequacy of parameterization tool of the theories. The theories has developed in many directions and applied to wide variety of fields such as on soft decision making [12], fuzzy soft decision making [16,17,24,36], on relation of fuzzy soft set [41,42], on relation on neutrosophic soft set [19], on relation on interval valued neutrosophic soft set [18] and so on.

Recently, Cagman et. al [12] introduced soft matrices and applied it in decision making problem. They also introduced fuzzy soft matrices [14], Chetia and Das [11] defined intuitionistic fuzzy soft matrices with different products and properties on these products. Further, Saikia et. al [38] defined generalized fuzzy soft matrices with four different product of generalized intuitionistic fuzzy soft matrices and presented on application in medical diagnosis. Next Broumi et. al [9] studied fuzzy soft matrix based on reference function and defined some new operations such fuzzy soft complement metrics, trace of fuzzy soft matrix based on reference function a new fuzzy soft matrix decision method on reference function is presented.

Recently, Mondal et.al [30,31,32] introduced fuzzy and intuitionistic fuzzy soft matrix and the multicriteria in decision making based on three basic theorem operators. Irfan Deli.et.al. [18] proposed the neutrosophic soft matrices based on decision making,

Our objective is to introduce the concept of FN soft matrices and its applications in decision making problem. The remaining part of this paper is organized us follows. Section 2 contains basic definitions and notations that are used in the remaining parts of the paper. We investigated and defined fuzzy neutrosophic soft set and some operations in Section 3. In section 4, we present group decision making method based on find-product of fuzzy soft neutrosophic matrix. Finally, conclusion is made in section 5.

2.Preliminaries

In this section, we give the basic definition and results of Neutrosophic theory (46) soft set theory (39) and soft matrix theory (13) that an useful subsequent discussions.

Definition 2.1: [37]Let W be a space of points (objects), with a generic element in w denote by u. A neutrosophic sets (N-sets) A in w is characterized by a truth-membership function T_A, a indeterminacy membership function I_A and a falsity-membership function F_A. $T_A(w)$; $I_A(w)$ and $F_A(w)$ are real standard and non-standard subsets of [0,1]. It can be written as A={w, < $T_A(w)$, $I_A(w)$, $F_A(w)$ >: w ϵ W, $T_A(w)$, $I_A(w)$, $F_A(w)$ ϵ [0,1] }, there is no restriction on the sum of $T_A(w)$, $I_A(w)$, and $F_A(w)$, so $0 \leq \text{Sup } T_A(w) + \text{Sup } I_A(w) + \text{Sup } F_A(w) \leq 3$.

Definition 2.2 :[33] Let W be a Universe, E be a set of parameters that are describe the elements of w, and A ⊆ E, then a soft set F_A over w is a set defined by a set valued function F_A representing a mapping $F_A : E \rightarrow P(U)$ such that $F_A(x) = \phi$ if x ϵ E where F_A is called approximate function of the soft set F_A.

Definition 2.3:**[18]** Let W = { $w_1, w_2, \ldots w_m$ } be an initial Universe and then $[c_{i\phi}] = [d_{ij}]$ as in the following way $opt_{[dii]}(w) = \{ u_i / \alpha_I : w_i \in W \}$, $d_i = \max\{s, y\}$ which is called an optimum fuzzy set on w. M_{mm} is called Max. min decision function.

Definition 2.4:**[18]** Let W be the Universe, N(w) be the set of all neutrosophic sets on W, E be the set of all paramenters that are describe the elements of W and A ⊆ E. then, a neutrosophic soft set N over W is a set defined by a set valued function F_N representing a mapping $F_N : A \rightarrow N(w)$ where F_N is called approximate function of the neutrosophic soft set N.

Let N_1 and N_2 be two neutrosophic soft sets over W.

1. N_1 is said to be neutrosophic soft subset of N_2 if A < B and $T_{FN1(x)}(w) \leq T_{FN2(x)}(w)$, $I_{FN1(x)}(w) \leq I_{FN2(x)}(w)$, $F_{FN1(x)}(w) \geq F_{FN2(x)}(w)$, for all x ϵ A, wϵW.

2. N_1 and N_2 are said to be equal if N_1 neutrosophic soft subset of N_2 and N_2 neutrosophic soft set of N_1.

Definition 2.5: A fuzzy subset of a nonempty set X is defined as a function $\mu : X \rightarrow [0,1]$.

Definition 2.6: Let W be the initial Universal set and E be a set of parameters. Let P(W) denote the set of all fuzzy neutrosophic set of W. Consider a non-empty set A, A $\subset$ E. The collection (F,A) is termed to be the 'fuzzy neutrosophic soft' set over W, where F:A→P(W). It is denoted by FNSS.

Let N_1 and N_2 be two fuzzy neutrosophic soft sets. Then

Complement $N_1^c = \{(x,\{<u,\ F_{FN1(x)}(w),\ I_{FN1(x)}(w),\ T_{FN1(x)}(w)>\ : x \in W, x \in E\}$.

Union $N1 \cup N2 = \{(x, \{w, T_{N1UN2}(w),\ I_{N1UN2}(w),\ F_{N1UN2}(w)> : x \in W, x \in E\}$

Intersection $N1 \cap N2 = \{(x, \{w, T_{N1 \cap N2}(w),\ I_{N1 \cap N2}(w),\ F_{N1 \cap N2}(w)> : x \in W, x \in E\}$.

Example :

Let $W = \{w_1,w_2,w_3,w_4\}$, $E = \{e_1,e_2,e_3\}$. N_1 and N_2 be two fuzzy neutrosophic soft sets as

N_1 = { (e_1, {<w_1, (0.4**I**, 0.5,0.8)>, <w_2, (0.2, 0.5**I**,0.1I)>, <w_3, (0.3, 0.1**I**,0.4)>, <w_4, (0.4,0.7, 0.7**I**)>}), e_2, {<w_1, (0.5**I**, 0.7,0.7)>, <w_2, (0.3, 0.6**I**,0.3)>, <w_3, (0.2**I**, 0.6,0.5)>, <w_4, (0.4, 0.5**I**,0.5)>}), {e_3, {<w_1, (0.7, 0.8**I**,0.6I)>, <w_2, (0.5I, 0.6,0.7I)>, <w_3, (0.7I, 0.5,0.8)>, <w_4, (0.2I, 0.8,0.5)>) }

N_2 = { (e_1, {<w_1, (0.7I, 0.6,0.7)>, <w_2, (0.4, 0.2I,0.8)>, <w_3, (0.9, 0.1,0.5I)>, <w_4, (0.4I,0.7, 0.7I)>}),{e_2, {<w_1, (0.5, 0.7I,0.8)>, <w_2, (0.5, 0.9**I**,0.3)>, <w_3, (0.5I, 0.6,0.8)>, <w_4, (0.5, 0.8I,0.5)>}), {e_3, {<w_1, (0.8I, 0.6,0.9I)>, <w_2, (0.5, 0.9I,0.9)>, <w_3, (0.7, 0.5I,0.4)>, <w_4, (0.3I, 0.5,0.6I)>) }

Then

N1UN2 ={(e_1, {<w_1, (0.7I, 0.5,0.7)>, <w_2, (0.4, 0.2I,0.1I)>, <w_3, (0.9, 0.1I,0.4)>, <w_4, (0.4I,0.2I, 0.5)>),(e_2, {<w_1, (0.5, 0.7,0.7)>, <w_2, (0.5, 0.2I,0.3)>, <w_3, (0.5I, 0.6,0.5)>, <w_4, (0.5,0.5I, 0.5)>),(e_3, {<w_1, (0.8I, 0.6,0.6I)>, <w_2, (, 0.6,0.7)>, <w_3, (0.7I, 0.5,0.4)>, <w_4, (0.3I,0.5, 0.5)>)}.

$N1 \cap N2$ =

{(e_1, {<w_1, (0.4I, 0.6,0.8)>, <w_2, (0.2, 0.5I,0.8)>, <w_3, (0.3, 0.1I,0.5I)>, <w_4, (0.4I,0.7, 0.7I)>),

(e_2, {<w_1, (0.5I, 0.7I,0.8)>, <w_2, (0.3, 0.9I,0.3)>, <w_3, (0.2I, 0.6,0.8)>, <w_4, (0.4,0.8I, 0.5)>),

(e_3, {<w_1, (0.7, 0.8I,0.9I)>, <w_2, (0.5 , 0.9I,0.9)>, <w_3, (0.7I, 0.5,0.8)>, <w_4, (0.3I,0.5, 0.5)>)}.

3 FUZZY NEUTROSOPHIC SOFT MATRICES

In this section, we have introduced fuzzy neutrosophic soft matrices (FNSM) and their operators which are more functional to make theoretical studies in the fuzzy neutrosophic soft set theory(FNSS). The matrix is useful for storing an FNSS in computer memory which are very useful and applicable. Some of its quoted from [1,2,13,20,26,37]. Throughout this section I is the indeterminable such that $I^2 = I$.

Definition 3.1: Let A be a matrix if it entries are from [0,1] and [0,1] then we call A to be a fuzzy neutrosophic soft matrix.

Example-1. Let W = { w_1,w_2,w_3 }, E = { x_1, x_2, x_3}. N be a fuzzy neutrosophic soft sets over neurosophic as N = { (x_1, {<w_1, (0.7,0.6I,0.7>, < w_2, (0.4I,0.2,0.8)>, <w_3, (0.9,0.1,0.5I)>},
{ (x_2, {<w_1, (0.5I,0.7,0.8>, < w_2, (0.5, 0.9I,0.3)>, (w_3, (0.5,0.6I,0.8)>},
{ (x_3,{<w_1,(0.8I, 0.6, 0.9>, < w_2,(0.5, 0.9I,0.9)>, (w_3,(0.7, 0.5. 0.4I) >} ,
the FNSS-matrix [aij] is written by

$$[aij] = \begin{bmatrix} (0.7,0.6I,0.7) & (0.4I, 0.2, 0.8) & (0.9,0.1,0.5I) \\ (0.5I,0.7,0.8) & (0.5, 0.9I, 0.3) & (0.5,0.6I,0.8) \\ (0.8I,0.6,0.9) & (0.5, 0.9I,0.9) & (0.7,0.5.0.4I) \end{bmatrix}$$

Definition 3.2: A fuzzy neutrosophic soft matrix FNSM of order 1×N . i.e., with a single row is called row fuzzy neutrosophic soft set matrix.

Example N ={ x_1, {<w_1, (0.3,0.4I,0.6)>}), {(x_2,< $w_{1,}$ (0.3I,0.2,0.3)>}, {(x_3,<w3,(0.7,0.6,0.9I)>}, then FNSM matrix [aij] is written by [aij] = [(0.3,0.4I, 0.6), (0.3I, 0.2, 0.3) , (0.7,0.6,0.9 I)]

Definition 3.3: A fuzzy neutrosophic soft matrix (FNSM) of order m × 1 i.e.) with a single column is called a column FNSM.

Example. In above example

$$[\ aij\ ] = \begin{pmatrix} (0.3, 0.4I, 0.6) \\ (0.3I, 0.2, 0.3) \\ (0.7, 0.6, 0.9I) \end{pmatrix}$$

Definition 3.4: A FNSM of order m × n is said to be a square FNSM if m = n. (i.e)., the number of rows and the number of columns are equal.

Example: Consider the example 1, Here since the FNSM contains three rows and three columns, so it is a square FNSM.

Definition 3.5: A square FNSM of order m × n is said to be a diagonal FNSM if all of its non-diagonal elements are (0,0,1).

Example:

$$[aij] = \begin{pmatrix} (0.7, 0.6I, 0.7) & (0.0, I.0, 1.0) & (0.0, 1.0, I.0) \\ (0.0, 1.0, I.0) & (0.0, I.0, 1.0) & (0.0, 1.0. I.0) \\ (0.0, I.0. 1.0) & (0.0, 1.0, I.0) & (0.7I, 0.5. 0.4) \end{pmatrix}$$

Definition 3.6: Let $[a_{ij}] \in N$, then $[a_{ij}]$ is called

(i) A Zero FNS-matrix, denoted by [ộ], if a_{ij} = (0,I,I) for all i and j.

(ii) A Universal FNS-matrix, denoted [Î], if a_{ij} = (I, 0, 0)for all I and j.

Example : Let W = { w_1, w_2, w_3 }, E = {x_1,x_2,x_3 }, then a Zero FNS-matrix $[a_{ij}]$is given by

$$[a_{ij}] = \begin{pmatrix} (0, I, I) & (0, I, I) & (0, I, I) \\ (0, I, I) & (0, I, I) & (0, I, I) \end{pmatrix}$$

(0, I, I) (0, I, I) (0, I, I) and a Universal FNS-matrix $[a_{ij}]$ is given by

$$[a_{ij}] = \begin{pmatrix} (I,0,0) & (I,0,0) & (I,0,0) \\ (I,0,0) & (I,0,0) & (I,0,0) \\ (I,0,0) & (I,0,0) & (I,0,0) \end{pmatrix}$$

Definition 3.7: Let $[a_{ij}]$, $[b_{ik}] \in N$, then And-product of $[a_{ij}]$ and $[b_{ik}]$ is defined by

$[a_{ij}] \wedge [b_{ik}] = [c_{ip}]$. Also max min product is defined by

$$[aij]o[bik] = \begin{pmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \end{pmatrix}$$

4.Decision making problem using And-Product of fuzzy Neutrosophic soft matrices

Algorithm-1(And-Product)

The algorithm for the solution is given below.

Step-1 Choose feasible subset of the set of parameters.

Step-2 Construct the fuzzy neutrosophic matrices for each parameter.

Step-3 Choose a And-product of the fuzzy neutrosophic matrices.

Step-4 Compare it and find the method min-max-max decision Fuzzy neutrosophic matrices.

Step-5 Find an optimum fuzzy set on X.

Case Study: Assume that a car dealer stores three different types of cars $W = \{ w_1, w_2, w_3 \}$ which may be characterize by the set of parameter $E = \{e_1, e_2, \}$ where e1 stands for costly, e_2 stands for fuel efficiency, then we consider the following example. Suppose a couple Mr. X and Mrs. X come to the dealer to buy a car before Durga Pooja. If each partner has to consider his/her own set of parameters., then we select the car on the basis of partner's parameters by using FNS-matrices as follows:

Step-1: First Mr. X and Mrs. X have to choose the sets of parameters A = $\{e_1, e_2\}$ and B= $\{e_1, e_2\}$ respectively.

Step-2: Then we construct the FNS-matrix [aij] and [bij] according to their set of parameters A and B respectively as follows:

$$[aij] = \begin{pmatrix} (0.2I, 0.3, 0.4) & (0.1, 0.4I, 0.5) \\ (0.3I, 0.5, 0.1) & (0.7, 0.6, 0.2I) \\ (0.1, 0.6I, 0.3) & (0.3, 0.2I, 0.6) \end{pmatrix}$$

and

$$[bij] = \begin{pmatrix} (0.5\ I, 0.6, 0.3) & (0.2, 0.5\ I, 0.3) \\ (0.2\ I, 0.7, 0.3) & (0.3, 0.5\ I, 0.2) \\ (0.3I, 0.7I, 0.2) & (0.3I, 0.6, 0.7) \end{pmatrix}$$

Step 3: Now, we can find the And-Product of the FNS-matrics $[a_{ij}]$ and $[b_{ij}]$ as follows:

$$[a_{ij}] \wedge [b_{ij}] = \begin{pmatrix} (0.2I, 0.6, 0.3) & (0.2, 0.5I, 0.3) & (0.1, 0.6, 0.3) & (0.1, 0.5I, 0.3) \\ (0.2I, 0.7, 0.1) & (0.3, 0.5I, 0.1) & (0.2I, 0.7, 0.2I) & (0.3, 0.6, 0.2I) \\ (0.1, 0.7I, 0.2) & (0.1, 0.6I, 0.3) & (0.3, 0.7I, 0.2) & (0.3I, 0.6, 0.6) \end{pmatrix}$$

Step4: To demonstrate, let us find d_{21} for i=2.

Since i =2 and k ϵ {1,2} so $d_{21} = \{a_{21}, b_{21}, c_{21}\}$.

Let $t_{2k} = \{t_{21}, t_{22}\}$, where $t_{2k} = \{a_{2p}, b_{2p}, c_{2p}\}$, then We have to find t_{2k} for all k ϵ {1,2}.

First to find t_{21}. $I_1 = \{p : 0 \le p \le 2\}$ for k=1 and n=2.

We have $t_{21} = (\min \{a_{2p}\}, \max (b_{2p}\}, \max \{c_{2p}\})$

[When p= 1,2] $= (\min \{a_{21}, a_{22}\}, \max \{b_{21}, b_{22}\}, \max \{c_{21}, c_{22}\})$

$= (\min \{0.2I, 0.3\}, \max \{0.7, 0.5I\}, \max \{0.1.0.1\})$

$= (0.2 I, 0.7, 0.1)$

[when p = 3,4] $t_{22} = (\min \{a_{22}, a_{24}\}, \max \{b_{23}, b_{24}\}, \max \{c_{23}, c_{24}\})$

$= (\min \{0.2I, 0.3\}, \max \{0.7, 0.6\}, \max \{0.1I, 0.2I\})$

$= (0.2 I, 0.7, 0.2 I)$

Similarly, we can find d_{11} and d_{31} as $d_{11} = (0.2I, 0.6, 0.3)$, $d_{31} = (0.1, 0.7 I, 0.3)$

Now, We calculate, for i = {1, 2, 3}

$$[dij] = \begin{pmatrix} a_{11} & b_{11} & c_{11} \\ a_{21} & b_{21} & c_{21} \\ a_{31} & b_{31} & c_{31} \end{pmatrix}$$

$$[dij] = \begin{pmatrix} (0.2\,I, 0.6, 0.3) \\ (0.2\,I, 0.7, 0.1) \\ (0.2\,I, 0.7, 0.2I) \end{pmatrix}$$

$$\text{Max } (S_i) = \begin{pmatrix} 0.02 \\ \mathbf{0.13} \\ 0.06I \end{pmatrix} \qquad \text{where } S_i = a_{11} \text{ ----------------} b_{11} \times c_{11}$$

Step 5: Finally, we can find an optimum fuzzy set on W as :

$OPT_{[dij]}$ (X) = {w_1/0.02 , **w_2/0.13**, w_3/0.06I} , Thus w_2 has the maximum value. Therefore the couple may decide to buy the **car w_2.**

The following max-min Product algorithm is also applicable to the above case study problems

Algorithm 2 : [max-min product]

Step1: Choose feasible subset of the set of parameter.

Step 2: Construct the fuzzy neutrosophic matrices for each parameter.

Step 3: Choose a max-min product of the Fuzzy neurosophic soft matrix.

Step 4: Compare it and find the method min-max-max decision fuzzy neutrosophic matrices.

Step 5: Find an optimum fuzzy set on X.

Step-1: First Mr. X and Mrs. X have to choose the sets of parameters A = {e_1, e_2} and B= {e_1, e_2} respectively.

Step-2: we construct the FNS-matrix [aij] and [bij] according to their set of parameters A and B respectively as follows:

$$[a_{ij}] = \begin{pmatrix} (0.2I, 0.3, 0.4) & (0.1, 0.4I, 0.5) & (0.3, 0.5I, 0.6) \\ (0.3I, 0.5, 0.1) & (0.7, 0.6, 0.2I) & (0.4I, 0.2, 0.1I) \\ (0.1, 0.6I, 0.3) & (0.3, 0.2I, 0.6) & (0.6I, 0.3, 0.7I) \end{pmatrix}$$

$$[b_{ij}] = \begin{pmatrix} (0.5I, 0.6, 0.3) & (0.2, 0.5I, 0.3) \\ (0.2I, 0.7, 0.3) & (0.3, 0.5I, 0.2) \\ (0.3, 0.7I, 0.2) & (0.3I, 0.6, 0.7) \end{pmatrix}$$

Step 3: Now, we can find the max-min product of the FNS-matrices $[a_{ij}]$ and $[b_{ij}]$ as follows

$$[a_{ij}] \circ [b_{ij}] = \begin{pmatrix} (0.3, 0.5I, 0.3) & (0.3, 0.5I, 0.6) \\ (0.3, 0.6, 0.2I) & (0.3, 0.5I, 0.2) \\ (0.3, 0.6I, 0.3) & (0.3, 0.5I, 0.7I) \end{pmatrix}$$

Step 4: min-max-max decision fuzzy neutrosophic soft matrix

$$[d_{ij}] = \begin{pmatrix} (0.3, 0.5I, 0.6) \\ (0.3, 0.6, 0.2I) \\ (0.3, 0.6I, 0.7I) \end{pmatrix}$$

$$\text{Max }(S_i) = \begin{pmatrix} 0.00 \\ \mathbf{0.18I} \\ -0.12I \end{pmatrix}$$ where $S_i = a_{11}$ ---------- $b_{11} \times c_{11}$

Step 5: Finally, we can find an optimum fuzzy set on W.

Thus W_2 has the maximum value, then for the couple my decide to buy the car W_2.

Among the above two different algorithms, they have the maximum value in the same position, but in second algorithm one value of the optimum fuzzy set is negative. So Algorithm -1 is most suitable than max-min product.

5.Conclusion: In this paper, we have introduced the notion of neutrosophic at in a new way and proposed the concept of FNS-matrix called max-min product and And – Product of matrix has been defined, then we discuss the group decision value problem under certain algorithm.

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