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FUZZY NEUTROSOPHIC SOFT SET MEASURES

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Abstract

In this paper we propose the three types of similarity measures between fuzzy neutrosophic soft sets based on value matrix of fuzzy neutrosophic soft sets. Furthermore, we demonstrate the efficiency of the proposed similarity measures through the application in decision making.

Introduction:-

In 1999, [14] Molodtsov initiated the novel concept of soft set theory which is a completely new approach for modeling vagueness and uncertainty. In [6,7,8] Maji et al. initiated the concept of fuzzy soft sets ,intuitionistic fuzzy soft sets and Neutrosophic soft sets and the concept of Neutrosophic set was initiated by Smarandache [18] which a mathematical tool for handling problems involving imprecise, indeterminacy and inconsistent data. In several application it is often needed to compare two sets and we are interested to know whether two patterns or images are identical or approximately identical of atleast to what degree they are identical. Several researchers like Chen [2,3], Li and Xu[6], Hong and Kim[5] , and many authors has studied the problem of similarity measures between fuzzy sets, fuzzy numbers and vague sets. Recently P.Majumdar and S.K.Samanta [11] have studied the similarity measures of soft sets and intuitionistic fuzzy soft sets. In this paper we have introduced some new similarity measures and derived some of their properties. A decision making method based on the similarity measure is constructed.

Preliminaries:-

Definition 2.1:-

Suppose U is an universal set and E is a set of parameters, Let P(U) denote the power set of U. A pair (F, E) is called a soft set over U where F is a mapping given by F: E$\rightarrow$P(U). Clearly, a soft set is a mapping from parameters to P(U) and it is not a set, but a parameterized family of subsets of the universe.

Definition 2.2:-

A Fuzzy Neutrosophic set A on the universe of discourse X is defined as

A=$\langle x, T_A(x), I_A(x), F_A(x)\rangle, x \in X$ where $T, I, F: X \rightarrow$ [0, 1] and $0 \leq T_A(x)+I_A(x)+F_A(x) \leq 3$

Definition 2.3:-

Let U be the initial universe set and E be a set of parameters. Consider a non-empty set A, A $\subset$ E. Let P (U) denote the set of all fuzzy neutrosophic sets of U. The collection (F, A) is termed to be the fuzzy neutrosophic soft set over U, where F is a mapping given by F: A $\rightarrow$ P(U).

Definition 2.4:-
Let U = { c_1, c_2, ………… c_m} be the universal set and E be the set of parameters given by E = {e_1, e_2, ……. e_n}. Let A ⊆ E. A pair (F, A) be a Fuzzy Neutrosophic soft set over U. Then the subset of U x E is defined by R_A = { (u, e) ; e∈A, u ∈ f_A(e)} which is called a relation form of (f_A ,E). The membership function , indeterminacy membership function and non – membership function are written by $T_{R_A} : U \times E \to [0,1]$, $I_{R_A} : U \times E \to [0,1]$ and $F_{R_A} : U \times E \to [0,1]$ where $T_{R_A}(u,e) \in [0,1]$, $I_{R_A}(u,e) \in [0,1]$ and $F_{R_A}(u,e) \in [0,1]$ are the membership value, indeterminacy value and non membership value respectively of u ∈ U for each e∈E.

If [(T_{ij} , I_{ij} , F_{ij})] = (T_{ij}(u_i , e_j) , I_{ij}(u_i , e_j) , F_{ij}(u_i , e_j)) we can define a matrix

$$\left[\left(T_{ij}, I_{ij}, F_{ij}\right)\right]_{mxn} = \begin{bmatrix} \left(T_{11}, I_{11}, F_{11}\right) & \left(T_{12}, I_{12}, F_{12}\right) & \cdots\cdots & \left(T_{1n}, I_{1n}, F_{1n}\right) \\ \left(T_{21}, I_{21}, F_{21}\right) & \left(T_{22}, I_{22}, F_{22}\right) & \cdots\cdots & \left(T_{2n}, I_{2n}, F_{2n}\right) \\ \cdots\cdots & \cdots\cdots & \cdots\cdots & \cdots\cdots \\ \left(T_{m1}, I_{m1}, F_{m1}\right) & \left(T_{m2}, I_{m2}, F_{m2}\right) & \cdots\cdots & \left(T_{mn}, I_{mn}, F_{mn}\right) \end{bmatrix}$$

which is called an m x n Fuzzy Neutrosophic Soft Matrix of the FNSS (f_A , E) over U.

Definition 2.5:-
Let U = { c_1, c_2, ………… c_m} be the universal set and E be the set of parameters given by E = {e_1, e_2, ……. e_n}. Let A ⊆ E. A pair (F, A) be a fuzzy neutrosophic soft set. Then fuzzy neutrosophic soft set (F, A) in a matrix form as $A_{m \times n} = [a_{ij}]_{m \times n}$ or A = [a_{ij}] , i=1,2,….m, j = 1,2, ….. n where

$$a_{ij} = \begin{cases} \left(T_j(c_i), I_j(c_i), F_j(c_i)\right) & if \quad e_j \in A \\ (0,0,1) & if \quad e_j \notin A \end{cases},$$

where $T_j(c_i)$ represent the membership of (c_i) , $I_j(c_i)$ represent the indeterminacy of (c_i) and $F_j(c_i)$ represent the non-membership of (c_i) in the fuzzy neutrosophic set $F(e_j)$.

Note: Fuzzy Neutrosophic soft matrix is denoted by FNSM.

Similarity measures of fuzzy neutrosophic soft sets:-

Definition 3.1:-

If $\tilde{A}$ = [a_{ij}] ∈$FNSM_{m \times n}$, where [a_{ij}] = $\left(T_j(c_i), I_j(c_i), F_j(c_i)\right)$ then we define the value matrix of FNSM $\tilde{A}$ is V($\tilde{A}$) = [a_{ij}] = $\left(T_j(c_i) + (1 - I_j(c_i)) - F_j(c_i)\right)$; i= 1, 2, …..m and j = 1,2, ….n.

Example 3.2:-

Let U = {u_1, u_2, u_3, u_4} be the universal set and E = {e_1, e_2 , e_3} be a set of parameters. Let A⊆E. Consider A = {e_1, e_2} then fuzzy neutrosophic set is

(F,A) = {F(e_1) = {(u_1,0.8,0.4,0.1), (u_2,0.3,0.4,0.6), (u_3,0.8,0.6,0.2), (u_4,0.9,0.1,0.0)}

{F(e_2) = {(u_1,0.8,0.4,0.1), (u_2,0.9,0.6,0.1), (u_3,0.4,0.5,0.6), (u_4,0.3,0.5,0.6)}

The matrix representation for the above is given as

$$\tilde{A}=\begin{bmatrix}(0.8,0.4,0.1) & (0.8,0.4,0.1) & (0.0,0.0,1.0)\\ (0.3,0.4,0.6) & (0.9,0.6,0.1) & (0.0,0.0,1.0)\\ (0.8,0.6,0.2) & (0.4,0.5,0.6) & (0.0,0.0,1.0)\\ (0.9,0.1,0.0) & (0.3,0.5,0.6) & (0.0,0.0,1.0)\end{bmatrix} \text{ and } V(\tilde{A})=\begin{bmatrix}1.3 & 1.3 & 0\\ 0.3 & 1.2 & 0\\ 1 & 0.3 & 0\\ 1.8 & 0.2 & 0\end{bmatrix}$$

Here we denote a column of the value matrix by the vector $V(\tilde{A}_{e_i})$ and $V(\tilde{A}_{e_1})=(1.3 \quad 0.3 \quad 1 \quad 1.8)$.

Definition 3.3:-

Let (F,E) and (G,E) be two FNSS over U where F and G is a mapping given by F:E→P(U), G:E→P(U) , P(U) denotes the collection of all fuzzy neutrosophic subsets of U. Let $\tilde{A}$ and $\tilde{B}$ be FNSM of (F,E) and (G,E) respectively then we define similarity between (F,E) and (G,E) denoted by sim($\tilde{A}$, $\tilde{B}$) as

$$sim(\tilde{A},\tilde{B})=\frac{\sum_{i=1}^{n}\left[V(\tilde{A}_{e_i})\cdot V(\tilde{B}_{e_i})\right]}{\sum_{i=1}^{n}\max\left[V(\tilde{A}_{e_i})^2, V(\tilde{B}_{e_i})^2\right]}.$$

Example 3.4:-

Let U = {u_1, u_2, u_3, u_4} be the universal set and E = {e_1, e_2 , e_3} be a set of parameters.

We consider two FNSSs (F,E) and (G,E) such that the corresponding fuzzy neutrosophic soft matrices $\tilde{A}$ and $\tilde{B}$ are

$$\tilde{A}=\begin{array}{c} \\ u_1\\ u_2\\ u_3\\ u_4\end{array}\begin{array}{c} \begin{array}{ccc} e_1 & e_2 & e_3\end{array}\\ \begin{bmatrix}(0.5,0.5,0.5) & (0.4,0.7,0.6) & (0.2,0.4,0.7)\\ (0.4,0.5,0.5) & (0.2,0.6,0.7) & (0.1,0.3,0.9)\\ (0.7,0.4,0.2) & (0.2,0.6,0.8) & (0.5,0.4,0.4)\\ (0.8,0.1,0.4) & (0.2,0.6,0.7) & (0.7,0.4,0.2)\end{bmatrix}\end{array}$$

$$\tilde{B}=\begin{array}{c} \\ u_1\\ u_2\\ u_3\\ u_4\end{array}\begin{array}{c} \begin{array}{ccc} e_1 & e_2 & e_3\end{array}\\ \begin{bmatrix}(0.2,0.3,0.7) & (0.5,0.5,0.5) & (0.4,0.5,0.6)\\ (0.1,0.6,0.9) & (0.4,0.5,0.5) & (0.2,0.4,0.7)\\ (0.5,0.5,0.4) & (0.3,0.4,0.6) & (0.2,0.7,0.8)\\ (0.4,0.5,0.4) & (0.4,0.5,0.6) & (0.2,0.4,0.6)\end{bmatrix}\end{array}$$

Therefore the corresponding value matrices of $\tilde{A}$ and $\tilde{B}$ are

$$|V(\tilde{A})|=\begin{bmatrix}0.5 & 0.1 & 0.1\\ 0.4 & 0.1 & 0.1\\ 1.1 & 0.2 & 0.7\\ 1.3 & 0.1 & 1.1\end{bmatrix} ; \qquad |V(\tilde{B})|=\begin{bmatrix}0.2 & 0.5 & 0.3\\ 0.4 & 0.4 & 0.1\\ 0.6 & 0.3 & 0.3\\ 0.5 & 0.3 & 0.2\end{bmatrix}$$

Then $sim(\tilde{A},\tilde{B})=\frac{1.57+0.18+0.47}{5.7}=0.3895$.

Proposition 3.5:-

Let (F,E) , (G,E) and (H,E) be FNSS over U where F,G and H are mappings given by F:E→P(U), G:E→P(U) and H:E→P(U) respectively, P(U) denote the collection of all fuzzy neutrosophic subsets of U. Let $\tilde{A}$, $\tilde{B}$ and $\tilde{C}$ be FNSM of (F,E) , (G,E) and (H,E) respectively and similarity between (F,E) and (G,E) denoted by , then the following holds.

(i) $sim(\tilde{A},\tilde{B}) = sim(\tilde{B},\tilde{A})$

(ii) $0 \le sim(\tilde{A},\tilde{B}) \le 1$

(iii) $sim(\tilde{A},\tilde{A}) = 1$

(iv) If $\tilde{A} \subseteq \tilde{B} \subseteq \tilde{C}$ then $sim(\tilde{A},\tilde{C}) \le sim(\tilde{B},\tilde{C})$.

(v)

Similarity measures of fuzzy neutrosophic soft sets based on set theoretic approach:-

Definition 4.1:-

Let U = {u_1, u_2, …..u_m} be the universal set and E be the set of parameters given by E = {e_1, e_2,….e_n}. A pair (F,E) and (G,E) is called FNSS over U where F and G are mapping given by F:E→P(U), G:E→P(U) , P(U) denotes the collection of all fuzzy neutrosophic subsets of U. Let $\tilde{A}$ and $\tilde{B}$ be FNSM of (F,E) and (G,E) respectively. Then $\tilde{A} = \{F(e_i) \in P(U), e_i \in E\}$; $\tilde{B} = \{G(e_i) \in P(U), e_i \in E\}$ where $F(e_i)$ is called the e_i^{th} approximation of $\tilde{A}$ and $G(e_i)$ is called the e_i^{th} approximation of $\tilde{B}$.

Let $S_i(\tilde{A},\tilde{B})$ denote the similarity between the two e_i approximation $F(e_i)$ and $G(e_i)$ defined by $\tilde{S}_i(\tilde{A},\tilde{B}) = \dfrac{\sum_{i=1}^{n} \min\left[V(\tilde{A}_{e_i}), V(\tilde{B}_{e_i})\right]}{\sum_{i=1}^{n} \max\left[V(\tilde{A}_{e_i}), V(\tilde{B}_{e_i})\right]}$ where $V(\tilde{A}_{e_i})$ and $V(\tilde{B}_{e_i})$ are the value matrix of $\tilde{A}$ and $\tilde{B}$ respectively, $S(\tilde{A},\tilde{B})$ indicates the similarity between (F,E) and (G,E) then $S(\tilde{A},\tilde{B}) = \max S_i(\tilde{A},\tilde{B})$.

Example 4.2:-

Consider the FNSS given in example 3.4.

Now $S_1 = \frac{1.7}{3.3} = 0.515$, $S_2 = \frac{0.5}{1.5} = 0.333$ and $S_3 = \frac{0.7}{2.2} = 0.318$. Therefore $S(\tilde{A},\tilde{B}) = 0.515$.

Proposition 4.3 :-

Let (F,E) , (G,E) and (H,E) be FNSS over U where F,G and H are mappings given by F:E→P(U), G:E→P(U) and H:E→P(U) respectively, P(U) denote the collection of all fuzzy neutrosophic subsets of U. Let $\tilde{A}$, $\tilde{B}$ and $\tilde{C}$ be FNSM of (F,E) , (G,E) and (H,E) respectively and similarity between (F,E) and (G,E) denoted by , then the following holds.

(i) $S(\tilde{A},\tilde{B}) = S(\tilde{B},\tilde{A})$

(ii) $0 \le S(\tilde{A},\tilde{B}) \le 1$

(iii) $S(\tilde{A},\tilde{A}) = 1$

(iv) If $\tilde{A} \subseteq \tilde{B} \subseteq \tilde{C}$ then $S(\tilde{A},\tilde{C}) \le S(\tilde{B},\tilde{C})$.

5. Similarity measure of fuzzy neutrosophic soft sets based on distance measures.

Definition 5.1:

Let U = {u_1, u_2, …..u_n} be the universal set and E be the set of parameters given by E = {e_1, e_2,….e_m}. A pair (F,E) and (G,E) is called FNSS over U where F and G are mapping given by F:E→P(U), G:E→P(U) , P(U) denotes the collection of all fuzzy neutrosophic subsets of U. Let $\tilde{A}$ and $\tilde{B}$ be FNSM of (F,E) and (G,E) respectively. Then $\tilde{A} = \{F(e_i) \in P(U), e_i \in E\}$; $\tilde{B} = \{G(e_i) \in P(U), e_i \in E\}$ where $F(e_i)$ is called the e_i^{th} approximation of $\tilde{A}$ and $G(e_i)$ is called the e_i^{th} approximation of $\tilde{B}$.

Then we define the following distances between (F,E) and (G,E)

a) Hamming distance

$$d_H(\tilde{A},\tilde{B}) = \frac{1}{3m}\sum_{i=1}^{m}\sum_{j=1}^{n}\left\| V(\tilde{A}_{e_i}) \right| - \left| V(\tilde{B}_{e_i}) \right\|$$

b) Normalized hamming distance

$$d_{NH}(\tilde{A},\tilde{B}) = \frac{1}{3mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left\| V(\tilde{A}_{e_i}) \right| - \left| V(\tilde{B}_{e_i}) \right\|$$

c) Euclidean distance

$$d_E(\tilde{A},\tilde{B}) = \frac{1}{3m}\left[\sum_{i=1}^{m}\sum_{j=1}^{n}\left\| V(\tilde{A}_{e_i}) \right| - \left| V(\tilde{B}_{e_i}) \right\|^2\right]^{1/2}$$

Normalized hamming distance

d) $$d_{NE}(\tilde{A},\tilde{B}) = \frac{1}{3mn}\left[\sum_{i=1}^{m}\sum_{j=1}^{n}\left\| V(\tilde{A}_{e_i}) \right| - \left| V(\tilde{B}_{e_i}) \right\|^2\right]^{1/2}$$

Then the similarity measure between (F,E) and (G,E) denoted by $\mathrm{D}(\tilde{A},\tilde{B})$ is defined as $\mathrm{D}(\tilde{A},\tilde{B}) = \dfrac{1}{1+d_H(\tilde{A},\tilde{B})}$.

Example 5.2:-

Consider the FNSSs given in example 3.4. The hamming distance between (F,E) and (G,E) is $d_H(\tilde{A},\tilde{B}) = \frac{1}{9}(4.1) = 0.4556$ and $\mathrm{D}(\tilde{A},\tilde{B}) = \dfrac{1}{1+d_H(\tilde{A},\tilde{B})} = 0.5940$.

Proposition 5.3:-

Let (F,E) , (G,E) and (H,E) be FNSS over U where F,G and H are mappings given by F:E→P(U), G:E→P(U) and H:E→P(U) respectively, P(U) denote the collection of all fuzzy neutrosophic subsets of U. Let $\tilde{A}$, $\tilde{B}$ and $\tilde{C}$ be FNSM of (F,E) , (G,E) and (H,E) respectively and similarity between (F,E) and (G,E) denoted by , then the following holds.

(i) $\mathrm{D}(\tilde{A},\tilde{B}) = \mathrm{D}(\tilde{B},\tilde{A})$

(ii) $0 \le \mathrm{D}(\tilde{A},\tilde{B}) \le 1$

(iii) $\mathrm{D}(\tilde{A},\tilde{A}) = 1$

(iv) If $\tilde{A} \subseteq \tilde{B} \subseteq \tilde{C}$ then $\mathrm{D}(\tilde{A},\tilde{C}) \le \mathrm{D}(\tilde{B},\tilde{C})$.

(v)

Application of similarity measures of fuzzy neutrosophic soft sets in decision making

Algorithm:-

Step 1: Obtain the fuzzy neutrosophic soft sets (F,E) and (G,E) over the universe U and the fuzzy neutrosophic soft matrices $\tilde{A}$ and $\tilde{B}$ of (F,E) and (G,E) respectively

Step 2: Compute V($\tilde{A}$) and V($\tilde{B}$).

Step 3: Calculate the similarity measures of (F,E) and (G,E).

Step 4: Conclude the result by using similarity measure of (F,E) and (G,E).

A computer company attempts to predict the sale of three models of computer U = {c_1, c_2, c_3}in the location C by investigating the sale in the location A and B. And then make a reasonable marketing strategy. Let E = {e_1, e_2, e_3, e_4} be the parameters where e_1 = computing function, e_2 = storage capacity, e_3 = speed, and e_4 = prize. We characterize corresponding index values with fuzzy neutrosophic set.

The index values of location C:

(F_1,E)	e_1	e_2	e_3	e_4
c_1	(1.0,1.0,0.0)	(0.4,0.5,0.6)	(1.0,1.0,0.0)	(1.0,1.0,0.0)
c_2	(0.2,0.3,0.6)	(0.0,0.0,0.7)	(0.6,0.3,0.6)	(0.4,0.5,0.7)
c_3	(0.8,0.1,0.1)	(0.4,0.3,0.2)	(0.1,0.6,0.7)	(0.9,0.0,0.0)

The index values of location A:

(F_2,E)	e_1	e_2	e_3	e_4
c_1	(0.8,0.4,0.5)	(0.4,0.5,0.6)	(0.1,0.5,0.6)	(1.0,1.0,0.0)
c_2	(0.5,0.3,0.6)	(0.3,0.5,0.4)	(0.8,0.1,0.1)	(0.4,0.3,0.4)
c_3	(0.0,0.0,0.8)	(0.5,0.5,0.5)	(0.1,0.4,0.5)	(0.9,0.0,0.0)

The index values of location B:

(F_3,E)	e_1	e_2	e_3	e_4
c_1	(0.3,0.2,0.1)	(0.4,0.5,0.6)	(0.1,0.2,0.5)	(0.2,0.3,0.4)
c_2	(0.5,0.5,0.5)	(0.4,0.3,0.2)	(0.2,0.2,0.4)	(0.5,0.6,0.1)
c_3	(0.8,0.9,0.0)	(0.5,0.4,0.6)	(0.4,0.3,0.5)	(0.1,0.6,0.2)

$$\left|\tilde{F}_1\right| = \begin{bmatrix} 1.0 & 0.3 & 1.0 & 1.0 \\ 0.3 & 0.3 & 0.7 & 0.2 \\ 1.6 & 0.9 & 0.2 & 1.9 \end{bmatrix}, \left|\tilde{F}_2\right| = \begin{bmatrix} 0.9 & 0.3 & 0.0 & 1.0 \\ 0.6 & 0.4 & 1.6 & 0.7 \\ 0.2 & 0.5 & 0.2 & 1.9 \end{bmatrix}, \left|\tilde{F}_3\right| = \begin{bmatrix} 1.0 & 0.3 & 0.4 & 0.5 \\ 0.5 & 0.9 & 0.6 & 0.8 \\ 0.9 & 0.5 & 0.6 & 0.3 \end{bmatrix}$$

	S_1	S_2	S_3	S_4	**Max(S_i)**
$S(\tilde{F}_1,\tilde{F}_2)$	0.438	0.688	0.321	0.861	**0.861**
$S(\tilde{F}_1,\tilde{F}_3)$	0.710	0.524	0.522	0.270	**0.710**

Here we have $S(\tilde{F}_1,\tilde{F}_2) > S(\tilde{F}_1,\tilde{F}_3)$, which indicate C is more similar with A. Then we predict the sale in location C according to location A and make a reasonable marketing strategy.

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