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A MODEL FOR MEDICAL DIAGNOSIS VIA FUZZY NEUTROSOPHIC SOFT SETS

YILDIRAY ÇELİK[1*]

[1]Department of Mathematics, Ordu University, 52200, Ordu, Turkey.

AUTHOR'S CONTRIBUTION

This work was carried out by author. Author YÇ designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Author read and approved the final manuscript.

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ABSTRACT

The concept of neutrosophic soft set is a new mathematical tool for dealing with uncertainties that is free from the difficulties affecting existing methods. The theory has rich potential for applications in several directions. In this paper, a new approach is proposed to construct the decision method for medical diagnosis by using fuzzy neutrosophic soft sets. Also, we develop a technique to diagnose which patient is suffering from what disease. Our data with respect to the case study has been provided by the a medical center in Ordu, Turkey.

Keywords: Soft set; fuzzy neutrosophic soft set.

1 Introduction

A number of real life problems in engineering, medical sciences, social sciences, economics etc. involve imprecise data and their solution involves the use of mathematical principles based on uncertainty and imprecision. Such uncertainties are being dealt with the help of topics like probability theory, fuzzy set theory [1], rough set theory [2] etc. However, Molodtsov [3] has shown that each of the above topics has some inherent difficulties due to the inadequacy of their parameterization tools. Then he initiated a different concept called soft set theory as a new mathematical tool for dealing with uncertainties which is free from the limitations of the above topics. Soft set theory has a rich potential for applications in several directions, few of which had been explained by Molodtsov in his pioneer work [3]. Later on Maji et al. [4] initiated the concept of fuzzy soft sets with some properties regarding fuzzy soft union, intersection, complement of a fuzzy soft set, De Morgan's Law etc. Neog and Sut [5] have reintroduced the notion of fuzzy soft sets and redefined the complement of a fuzzy soft set accordingly. They have shown that the modified definition of complement of a fuzzy soft set meets all the requirements that complement of a set in classical sense really does. De et al. [6] gave an application of intuitionistic fuzzy sets in medical diagnosis. Çelik and Yamak [7] applied the fuzzy soft set theory through well-known Sanchezs approach for medical diagnosis using fuzzy

**Corresponding author: E-mail: ycelik61@gmail.com*

arithmetic operations. Zhang et al. [8] defined generalized trapezoidal fuzzy soft sets and also they showed applications of generalized fuzzy soft sets in medical diagnosis problem. Shanmugasundaram et al. [9] proposed a new approach to construct the decision method for medical diagnosis by using intuitionistic fuzzy soft matrices. Sarala and Probhavathi [10] extended Sanchez's approach for medical diagnosis using the representation of an interval valued fuzzy soft matrices. Sarala and Rajkumari [11] proposed fuzzy soft matrix theory and also extended their approach with regard to fuzzy soft matrices based on reference function in medical diagnosis. Applications of Fuzzy Soft Set Theory in many disciplines and real life situations have been studied by many researchers.

Neutrosophic Logic was proposed by Florentine Smarandache ([12], [13]) which is based on non-standard analysis that was given by Abraham Robinson in 1960. Neutrosophic Logic has been developed to represent mathematical model of uncertainty, vagueness, ambiguity, imprecision un-defined, incompleteness, inconsistency, redundancy contradiction. The neutrosophic logic is a formal frame to measure truth, indeterminacy and falsehood. In Neutrosophic set, indeterminacy is quantified explicitly whereas the truth membership, indeterminacy membership and falsity membership are independent. This assumption is very important in a lot of situations such as information fusion when we try to combine the data from different sensors. And neutrosophy by its virtue of handling inconsistent and incomplete information seems to be a better choice for modeling medical knowledge base, because it is often not possible to have all of information at hand while making decision. From philosophical point of view, the neutrosophic set takes value from real standard or non standard subset of]-0, 1+[. But in real life application in scientific and engineering problems it is difficult to use neutrosophic set with value from real standard or non standard subset of]-0, 1+[. Hence we consider the fuzzy neutrosophic set which takes the value from the subset of [0,1].

In this paper, by using the notion of fuzzy neutrosophic soft set, we give a model for medical diagnosis. In order to make this, union, intersection and the composition of a fuzzy neutrosophic soft sets are applied. The data set used in this work is 4 patients who appealed to a medical center in Ordu, Turkey for some complaints.

2 Preliminaries

In this section, we recall some definitions and properties related to soft set, fuzzy soft set and fuzzy neutrosophic soft set which wiil be used in the rest of the paper.

Definition 2.1. [3] Let U be an inital universe set and E be a set of parameters. The power set of U is denoted by $\mathcal{P}(U)$ and A is a subset of E. A pair (F, A) is called a *soft set* over U, where F is a mapping given by $F : A \to \mathcal{P}(U)$.

Definition 2.2. [1] A *fuzzy subset* μ of U is defined as a map from U to $[0, 1]$. The family of all fuzzy subsets of U is denoted by $\mathcal{F}(U)$. Let $\mu, \nu \in \mathcal{F}(U)$ and $x \in U$. Then the union and intersection of μ and ν are defined following way:

$$\begin{aligned} (\mu \cup \nu)(x) &= \mu(x) \vee \nu(x) \\ (\mu \cap \nu)(x) &= \mu(x) \wedge \nu(x) \end{aligned}$$

$\mu \subseteq \nu$ if and only if $\mu(x) \leq \nu(x)$ for all $x \in U$.

Definition 2.3. [4] Let U be a common universe, E be a set of parameters and $A \subseteq E$. Then a pair (F, A) is called a *fuzzy soft set* over U, where F is a mapping given by $F : A \to \mathcal{F}(U)$.

Definition 2.4. [4] For two fuzzy soft sets (F, A) and (G, B) over a common universe U , we say that (F, A) is a *fuzzy soft subset* of (G, B) if

(i) $A \subseteq B$

(ii) $F(a) \leq G(a)$ for all $a \in A$.

In this case, we write $(F, A)\widetilde{\subseteq}(G, B)$.

Definition 2.5. [14] A fuzzy neutrosophic set A on the universe of discourse X is defined as A=$< x, T_A(x), I_A(x), F_A(x) >$ for all $x \in X$, where $T, I, F : X \to [0, 1]$ and $0 \leq T_A(x)+I_A(x)+F_A(x) \leq 3$.

All fuzzy neutrosophic sets of X is denoted $F_N(X)$.

Definition 2.6. [14] Let U be a common universe, E be a set of parameters and $A \subseteq E$. Then a pair (F, A) is called a *fuzzy neutrosophic soft set* over U, where F is a mapping given by $F : A \to F_N(X)$.

Definition 2.7. [14] A fuzzy neutrosophic soft set A is contained in another neutrosophic soft set B if $A \subseteq B$ and $T_A(x) \leq T_B(x)$, $I_A(x) \leq I_B(x)$, $F_A(x) \geq F_B(x)$ for all $x \in X$.

Definition 2.8. [14] The *complement* of fuzzy neutrosophic soft set is defined as the fuzzy neutrosophic soft set $(F^c, \neg A)$, where $F^c : \neg A \to F_N(X)$, and $F^c(a) =< x, T_{F^c}(x) = F_F(x), I_{F^c}(x) = 1 - I_F(x), F_{F^c}(x) = T_F(x) >$ for all $a \in A$, $x \in X$

Definition 2.9. [14] Let X be a non empty set and
$A =< x, T_A(x), I_A(x), F_A(x) >$, $B =< x, T_B(x), I_B(x), F_B(x) >$ are fuzzy neutrosophic sets. Then

$$A \vee B =< x, \max(T_A(x), T_B(x)), \max(I_A(x), I_B(x)), \min(F_A(x), F_B(x)) >$$
$$A \wedge B =< x, \min(T_A(x), T_B(x)), \min(I_A(x), I_B(x)), \max(F_A(x), F_B(x)) >$$

Definition 2.10. [14]

(i) A fuzzy neutrosophic soft set (F, A) is said to be *empty fuzzy neutrosophic soft set* over U, denoted by $\widetilde{0}_N$, if $T_{F(a)} = 0$, $I_{F(a)} = 0$, $F_{F(a)} = 1$ for all $a \in A$.

(ii) A fuzzy neutrosophic soft set (F, A) is said to be *universe fuzzy neutrosophic soft set* over U, denoted by $\widetilde{1}_N$, if $T_{F(a)} = 1$, $I_{F(a)} = 1$, $F_{F(a)} = 0$ for all $a \in A$.

Definition 2.11. Let (F, A) and (G, B) be two fuzzy neutrosophic soft sets over a common universe U. Then,

(1) The *union* of fuzzy neutrosophic soft sets (F, A) and (G, B) is defined as the fuzzy neutrosophic soft set $(H, C) = (F, A)\widetilde{\cup}(G, B)$ over U, where $C = A \cup B$ and

$$H(c) = \begin{cases} F(c) & \text{if} \quad c \in A\backslash B \\ G(c) & \text{if} \quad c \in B\backslash A \\ F(c) \vee G(c) & \text{if} \quad c \in A \cap B \end{cases}$$

for all $c \in C$.

(2) The *intersection* of fuzzy neutrosophic soft sets (F, A) and (G, B) is defined as the fuzzy neutrosophic soft set $(H, C) = (F, A)\widetilde{\cap}(G, B)$ over U, where $C = A \cap B$, and $H(c) = F(c) \wedge G(c)$ for all $c \in C$.

2.1 Relations on fuzzy neutrosophic soft sets

Definition 2.12. Let $K \subseteq A \times B$. Then a fuzzy neutrosophic soft relation $\widetilde{R}$ between two fuzzy neutrosophic soft sets (F, A) and (G, B) is defined as $\widetilde{R}(a, b) = F(a) \wedge G(b)$ for all $a \in A$, $b \in B$, where $\widetilde{R} : K \to F_N(U)$.

Definition 2.13. Let (F, A), (G, B) and (H, C) be fuzzy neutrosophic soft sets over a common universe U. Let $\widetilde{R_1}$ be a fuzzy neutrosophic soft relation from (F, A) to (G, B) and $\widetilde{R_2}$ be a fuzzy neutrosophic soft relation from (G, B) to (H, C). Then the composition of two fuzzy neutrosophic soft relation $\widetilde{R_1}$ and $\widetilde{R_2}$ is defined by $(\widetilde{R_1 \circ R_2})(a, c) = \widetilde{R_1}(a, b) \wedge \widetilde{R_2}(b, c)$ for all $a \in A$, $b \in B$, $c \in C$.

Definition 2.14 The union and intersection of the relations $\widetilde{R}_1$ and $\widetilde{R}_2$ of the fuzzy neutrosophic soft set (F, A) and (G,B) over a common universe U respectively is defined as

$$(\widetilde{R}_1 \cup \widetilde{R}_2)(a, b) = \max(\widetilde{R_1}(a, b), \widetilde{R_2}(a, b))$$
$$(\widetilde{R}_1 \cap \widetilde{R}_2)(a, b) = \min(\widetilde{R_1}(a, b), \widetilde{R_2}(a, b)).$$

Definition 2.15 Let A be a fuzzy neutrosophic set in X. Let R be the relation from X to Y. Then max-min-max composition of fuzzy neutrosophic set with A is another fuzzy neutrosophic set B of Y which is denoted by $R \circ A$. Then the membership function, indeterminate function and non-membership function of B is defined as

$$T_{R \circ A}(y) = \vee_x [T_A(x) \wedge T_A(x, y)],$$
$$I_{R \circ A}(y) = \vee_x [I_A(x) \wedge I_A(x, y)],$$
$$F_{R \circ A}(y) = \wedge_x [F_A(x) \vee F_A(x, y)].$$

Definition 2.16 Let (F, A) be fuzzy neutrosophic soft set . Then the value function of (F, A) is defined as

$V(F, A) = T_A + (1 - I_A) - F_A$, where T_A, I_A and F_A denotes the truth value, indeterministic value and false value of (F, A) respectively.

Definition 2.17 Let (F, A) and (G, B) be two fuzzy neutrosophic soft set . Then the score function of (F, A) and (G, B) defined as $S_1 = V(F, A) - V(G, B)$.

Definition 2.18 Let (F, A) be fuzzy neutrosophic soft set. Then the score function of (F, A) is defined as $S_2 = T_j - I_j.F_j$.

3 Methodology and Algorithm

In this section we present a method for medical diagnosis using fuzzy neutrosophic soft sets. Assume that there is a set of patients P with a set of symptoms S related to a set of diseases D.

We apply fuzzy neutrosophic soft set theory to develop a technique for diagnosis which patient is suffering from what disease.

Algorithm

Step I: The symptoms of the patients are given to obtain the patient-symptom relation Q and are noted in Table 1.

Step II: The medical knowledge relating the symptoms with the set of disease under consideration are given to obtain the symptom-disease relation R and are noted in Table 2.

Step III: The composition T of the relation of patients and diseases is found using the definition 2.15 and is noted Table 3.

Step IV: The complement of Table 1 is obtained and is noted in Table 4.

Step V: The complement of Table 2 is obtained and is noted in Table 5.

Step VI: For the values of Table 4 and Table 5, the definition 2.15 is applied, and is noted in Table 6.

Step VII: The value function is calculated for Table 3 and Table 6, and is given in Table 7 and Table 8 respectively.

Step VIII: The score function for the values in Table 7 and 8 is found using definition 2.17, and is noted in Table 9.

Step IX: Another score function for the table 3 is applied using the definition 2.18, and it is given Table 10.

Step X: Find the higher score for possibility of the patient affected with the respective disease.

4 Case Study

There are four patients who appealed to a medical center in Ordu, Turkey with symptoms vomiting, stomach ache, temperature problem. Let the possible diseases relating to these symptoms be intestinal obstruction, inguinal hernia, appendicitis and ureteric colic. Now take $P = \{p_1, p_2, p_3\, p_4\}$ as the universal set where p_1, p_2, p_3 and p_4 represents patients. Next consider the set $S = \{s_1, s_2, s_3, s_4\}$ as universal set where s_1, s_2, s_3, s_4 represents symptoms vomiting, stomach ache, temperature problem respectively and the set $D = \{d_1, d_2, d_3, d_4\}$, where d_1, d_2, d_3 and d_4 represent the diseases intestinal obstruction, inguinal hernia, appendicitis and ureteric colic respectively.

By using our data, we construct patient-symptom relation and symptom-disease relation as follows.

$F(p_1) = \{s_1/(0.7, 0.4, 0.1), s_2/(0.8, 0.6, 0.7), s_3/(0.4, 0.8, 0.5)\}$,
$F(p_2) = \{s_1/(0.6, 0.5, 0.3), s_2/(0.6, 0.5, 0.2), s_3/(0.7, 0.9, 0.0)\}$,
$F(p_3) = \{s_1/(0.8, 0.4, 0.2), s_2/(0.5, 0.1, 0.5), s_3/(1.0, 0.5, 1.0)\}$,
$F(p_4) = \{s_1/(0.4, 0.6, 0.3), s_2/(0.5, 0.4, 0.8), s_3/(0.5, 0.6, 0.9)\}$.

Then the fuzzy neutrosophic soft set (F, P) is a parameterized family of all fuzzy subsets over S and gives a collection of approximate description of the patient-symptoms in the medical center. This fuzzy neutrosophic soft set (F, P) represents the patient-symptom relation Q and is given by

Table 1

Q	Vomiting	Stomach ache	Temperature
Patient 1	(0.7,0.4,0.1)	(0.8,0.6,0.7)	(0.4,0.8,0.5)
Patient 2	(0.6,0.5,0.3)	(0.6,0.5,0.2)	(0.7,0.9,0.0)
Patient 3	(0.8,0.4,0.2)	(0.5,0.1,0.5)	(1.0,0.5,1.0)
Patient 4	(0.4,0.6,0.3)	(0.5,0.4,0.8)	(0.5,0.6,0.9)

Next,
$G(s_1) = \{d_1/(0.9, 0.6, 0.7), d_2/(0.9, 1.0, 0.5), d_3/(0.9, 0.2, 0.8), d_4/(0.6.0.2, 0.3)\}$,
$G(s_2) = \{d_1/(0.5, 0.3, 0.3), d_2/(0.4, 0.6, 0.6), d_3/(0.4, 0.5, 0.3), d_4/(0.9, 0.5, 0.8)\}$,
$G(s_4) = \{d_1/(0.8, 0.8, 0.9), d_2/(0.7, 0.8, 0.3), d_3/(0.8, 0.1, 0.8), d_4/(0.3, 0.4, 0.5)\}$.

Then the fuzzy neutrosophic soft set (G, S) is a parameterized family $\{G(s_1), G(s_2), G(s_3)\}$ of all fuzzy subsets over the set S where $G : S \to F_N(D)$ and is determined from expert medical documentation. Thus the fuzzy neutrosophic soft set (G, S) gives an approximate description of the four diseases and their symptoms. This fuzzy soft set is represented by a relation matrix (symptom-disease matrix) R and is given by

Table 2

R	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Vomiting	(0.9,0.6,0.7)	(0.9,1.0,0.5)	(0.9,0.2,0.8)	(0.6.0.2,0.3)
Stomach ache	(0.5,0.3,0.3)	(0.4,0.6,0.6)	(0.4,0.5,0.3)	(0.9,0.5,0.8)
Temperature	(0.8,0.8,0.9)	(0.7,0.8,0.3)	(0.8,0.1,0.8)	(0.3,0.4,0.5)

Then performing the transformation operation $Q \circ R$ we get the patient-disease relation T as

Table 3

T	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Patient 1	(0.7,0.8,0.7)	(0.7,0.8,0.5)	(0.7,0.5,0.7)	(0.8.0.5,0.3)
Patient 2	(0.7,0.8,0.3)	(0.7,0.8,0.3)	(0.7,0.5,0.3)	(0.6,0.5,0.3)
Patient 3	(0.8,0.5,0.5)	(0.8,0.5,0.5)	(0.8,0.1,0.5)	(0.5,0.4,0.3)
Patient 4	(0.5,0.6,0.7)	(0.5,0.6,0.5)	(0.5,0.4,0.8)	(0.5,0.4,0.3)

From the complement of Q and R, we get

Table 4

Q’	Vomiting	Stomach ache	Temperature
Patient 1	(0.1,0.6,0.7)	(0.7,0.4,0.8)	(0.5,0.2,0.4)
Patient 2	(0.3,0.5,0.6)	(0.2,0.5,0.6)	(0.0,0.1,0.7)
Patient 3	(0.2,0.6,0.8)	(0.5,0.9,0.5)	(1.0,0.5,1.0)
Patient 4	(0.3,0.4,0.4)	(0.8,0.6,0.5)	(0.9,0.4,0.5)

Table 5

R’	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Vomiting	(0.7,0.4,0.9)	(0.5,0.0,0.9)	(0.8,0.8,0.9)	(0.3.0.8,0.6)
Stomach ache	(0.3,0.7,0.5)	(0.6,0.4,0.4)	(0.3,0.5,0.4)	(0.8,0.5,0.9)
Temperature	(0.9,0.2,0.8)	(0.3,0.2,0.7)	(0.8,0.9,0.8)	(0.5,0.6,0.3)

The composition values of Table 4 and Table 5 are calculated as

Table 6

T'	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Patient 1	(0.5,0.4,0.8)	(0.6,0.4,0.7)	(0.5,0.6,0.8)	(0.7.0.6,0.4)
Patient 2	(0.3,0.5,0.6)	(0.3,0.4,0.6)	(0.3,0.5,0.6)	(0.3,0.5,0.6)
Patient 3	(0.9,0.7,0.5)	(0.5,0.5,0.5)	(0.8,0.6,0.5)	(0.5,0.6,0.8)
Patient 4	(0.9,0.6,0.5)	(0.6,0.4,0.5)	(0.9,0.5,0.5)	(0.8,0.5,0.5)

The value function for Table 3 and Table 6 is calculated as

Table 7

Value function	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Patient 1	0.2	0.4	0.5	1
Patient 2	0.6	0.6	0.9	0.8
Patient 3	0.8	0.8	1.2	0.6
Patient 4	0.2	0.4	0.3	0.8

Table 8

Value function	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Patient 1	0.3	0.5	0.1	0.7
Patient 2	0.2	0.3	0.2	0.2
Patient 3	0.7	0.5	0.7	0.1
Patient 4	0.8	0.7	0.7	0.8

Score function for the values in Table 7 and 8 is calculated as

Table 9

Score function	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Patient 1	-.01	-0.1	-.04	**0.3**
Patient 2	0.4	0.3	**0.7**	0.6
Patient 3	0.1	0.3	**0.5**	**0.5**
Patient 4	-0.7	-.03	-.04	**0**

Another score function for the table 3 is given as

Table 10

Score function	Intestinal obstruction	Inguinal hernia	Appendicitis	Ureteric colic
Patient 1	0.14	0.3	0.35	**0.65**
Patient 2	0.46	0.46	**0.55**	0.45
Patient 3	0.55	0.55	**0.75**	0.38
Patient 4	0.08	0.2	0.18	**0.38**

It is clear from Table 9 and Table 10 that patient 1 and patient 4 are suffering from ureteric colic, and patient 2 and patient 3 both are suffering from appendicitis.

5 Conclusion

We have applied the notion of fuzzy neutrosophic soft sets to medical diagnosis. The results are obtained based on the higher score value in the score function. Also, we develop a technique to diagnose which patient is suffering from what disease. To extend this work, one could study the properties of fuzzy neutrosophic soft sets in other decision making problems such as game theory.

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Competing Interests

The author declares that no competing interest exist.

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