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Utilization of Rough Neutrosophic Sets In Medical Diagnosis

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Abstract: *Rough neutrosophic set is an essential tool for dealing with uncertainties and shortcomings that affect the existing methods.In this paper, a new method (order function)is proposed and some of its properties are discussed herein. Execution of medicaldiagnosis is presented to find out the disease impacting the patient.*

Keywords -*Medical diagnosis, order function, rough neutrosophic set, single valued neutrosophic set.*

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I. 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*., Healthcare industry has been trying to complement the services offered by conventional clinical decision making systems with the integration of fuzzy logic techniques in them. As it is not an easy task for a clinician to derive a fool proof diagnosis, it is advantageous to automate few initial steps of diagnosis which would not require intervention from an expert doctor. Neutrosophic set which is a generalized set possesses all attributes necessary to encode medical knowledge base and capture medical inputs.

As medical diagnosis demands large amount of information processing, large portion of which is quantifiable, also intuitive thought process involve rapid unconscious data processing and combines available information by law of average, the whole process offers low intra and inter personal consistency. So contradictions, inconsistency, indeterminacy and fuzziness should be accepted as unavoidable as they are integrated in the behavior of biological systems as well as in their characterization. To model an expert doctor it is imperative that it should not disallow uncertainty as it would be then inapt to capture fuzzy or incomplete knowledge that might lead to the danger of fallacies due to misplaced precision.

As medical diagnosis contains lots of uncertainties and increased volume of information available to physicians from new medical technologies, the process of classifying different sets of symptoms under a single name of disease becomes difficult. The main advantage of rough set theory is that it does not need any preliminary or additional information about data(like the probability in statistics, the value of possibility in fuzzy set theory *etc*.,).So, rough neutrosophic sets play a vital role in medical diagnosis.

In 1965, Fuzzy set theory was firstly given by Zadeh[1] which is applied in many real applications to handle uncertainty. Sometimes membership function itself is uncertain and hard to be defined by a crisp value. So the concept of interval valued fuzzy sets was proposed to capture the uncertainty of grade of membership. In 1986, Atanassov[3] introduced the intuitionistic fuzzy sets which consider both truth-membership and falsity-membership. Later on, intuitionistic fuzzy sets were extended to the interval valued intuitionistic fuzzy sets. Intuitionistic fuzzy sets and interval valued intuitionistic fuzzy sets can only handle incomplete information not the indeterminate information and inconsistent information which exists commonly in belief systems. So, Neutrosophic set (generalization of fuzzy sets, intuitionistic fuzzy sets and so on) defined by FlorentinSmarandache[4] has capability to deal with uncertainty, imprecise, incomplete and inconsistent information which exists in real world from philosophical point of view. Wang *et al* [5] proposed the single valued neutrosophic set.

In 1982, Pawlak[2] introduced the concept of rough set (RS), as a formal tool for modeling and processing incomplete information in information systems. There are two basic elements in rough set theory, crisp set and equivalence relation, which constitute the mathematical basis of rough sets. The basic idea of rough set is based upon the approximation of sets by a pair of sets known as the lower approximation and the upper approximation of a set. Here, the lower and upper approximation operators are based on equivalence relation. Nanda and Majumdar [6] examined fuzzy rough sets. Broumi *et al* [7] introduced rough neutrosophic sets.

Surapati Pramanik and Kalyan Mondal [8,9] introduced cosine and cotangent similarity measures of rough neutrosophic sets. Edward Samuel and Narmadhagnanam [10] proposed tangent logarithmic distance and cosecant similarity measure of rough neutrosophic sets. Pramanik *et al* [11] introduced correlation coefficient of rough neutrosophic sets.

In this paper, by using the notion of rough neutrosophic set, it was provided an exemplary for medical diagnosis. In order to make this, a novel method was executed.

Rest of the article is structured as follows. In Section 2, the basic definitions were briefly presented. Section 3 deals with proposed definition and some of its properties. Sections 4, 5 & 6 contain methodology, algorithm and case study related to medical diagnosis respectively. Conclusion is given in Section 7.

II. Preliminaries

2.1 Definition [5]

Let H be a universal space of points (objects) with a generic element of H denoted by x. A single valued neutrosophic set S is characterized by a truth membership function $T_N(x)$, a falsity membership function $F_N(x)$ and an indeterminacy function $I_N(x)$ with $T_N(x)$, $F_N(x)$, $I_N(x) \in H$ for all x in H.

When H is continuous, a SVNS S can be written as follows:

$$S = \int_x \langle T_S(x), F_S(x), I_S(x) \rangle / x, \forall x \in H$$

and when H is discrete, a SVNS S can be written as follows:

$$S = \sum \langle T_S(x), F_S(x), I_S(x) \rangle / x, \forall x \in H$$

It should be observed that for SNVS S

$$0 \le \sup T_S(x) + \sup I_S(x) + \sup F_S(x) \le 3, \forall x \in H$$

2.2 Definition [12]

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

$$\left.\begin{aligned} T_{R\circ A}(y) &= \vee_x \left[T_A(x) \wedge T_A(x,y)\right] \\ I_{R\circ A}(y) &= \vee_x \left[I_A(x) \wedge I_A(x,y)\right] \\ F_{R\circ A}(y) &= \wedge_x \left[F_A(x) \vee F_A(x,y)\right] \end{aligned}\right\} \quad (1)$$

2.3 Definition [7]

Let U be a non-null set and R be an equivalence relation on U. Let P be neutrosophic set in U with the membership function T_P, indeterminacy function I_P and non-membership function F_P. The lower and the upper approximations of P in the approximation (U,R) denoted by $\underline{N}(P)$ & $\overline{N}(P)$ are respectively defined as follows:

$$\underline{N}(P) = \left\langle \left\langle x, T_{\underline{N}(P)}(x), I_{\underline{N}(P)}(x), F_{\underline{N}(P)}(x) \right\rangle / y \in [x]_R, x \in U \right\rangle$$

$$\overline{N}(P) = \left\langle \left\langle x, T_{\overline{N}(P)}(x), I_{\overline{N}(P)}(x), F_{\overline{N}(P)}(x) \right\rangle / y \in [x]_R, x \in U \right\rangle$$

where

$$T_{\underline{N}(P)}(x) = \wedge_{y \in [x]_R} T_P(y)$$

$$I_{\underline{N}(P)}(x) = \vee_{y \in [x]_R} I_P(y)$$

$$F_{\underline{N}(P)}(x) = \vee_{y \in [x]_R} F_P(y)$$

$$T_{\overline{N}(P)}(x) = \vee_{y \in [x]_R} T_P(y),$$

$$I_{\overline{N}(P)}(x) = \wedge_{y \in [x]_R} I_P(y),$$

$$F_{\overline{N}(P)}(x) = \wedge_{y \in [x]_R} F_P(y).$$

So, $0 \le T_{\underline{N}(P)}(x) + I_{\underline{N}(P)}(x) + F_{\underline{N}(P)}(x) \le 3 \,\&\, 0 \le T_{\overline{N}(P)}(x) + I_{\overline{N}(P)}(x) + F_{\overline{N}(P)}(x) \le 3$

where $\vee$ and $\wedge$ mean "max" and "min" operators respectively, $T_P(y), I_P(y) \,\&\, F_P(y)$ are the membership, indeterminacy and non-membership of y with respect to P. It is easy to see that $\underline{N}(P) \,\&\, \overline{N}(P)$ are two neutrosophic sets in U ,thus the NS mappings $\underline{N}, \overline{N} : N(U) \to N(U)$ are respectively, referred to as the lower and upper rough neutrosophic set approximation operators, and the pair $\left(\underline{N}(P), \overline{N}(P)\right)$ is called the rough neutrosophic set in (U, R).

III. Proposed Definition

3.1 Definition

Let $A = (a, b, c)$ be a single valued neutrosophic number, an order function R of a single valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsity-membership degree is defined as :

$$R(A) = \frac{11\left[1 + \log\left[\frac{1-a}{3} + b + \frac{1+c}{3}\right]\right]}{e^{3[c+[1-b]+a]}} \tag{2}$$

3.1.1 Proposition

$R(A) > 0$

Proof

The proof is straightforward

3.1.2 Theorem

Let $A = (a_1, b_1, c_1)$ and $B = (a_2, b_2, c_2)$ be two single valued neutrosophic numbers. If $A \subseteq B$ then $R(A) \ge R(B)$

Proof

By (2) ,

$$R(A) = \frac{11\left[1 + \log\left[\frac{1-a_1}{3} + b_1 + \frac{1+c_1}{3}\right]\right]}{e^{3[c_1+[1-b_1]+a_1]}} \,\&\, R(B) = \frac{11\left[1 + \log\left[\frac{1-a_2}{3} + b_2 + \frac{1+c_2}{3}\right]\right]}{e^{3[c_2+[1-b_2]+a_2]}}$$

Since $A \subseteq B, a_1 \le a_2$, $b_1 \ge b_2$ & $c_1 \ge c_2$.

$\therefore (a_2 - a_1) \ge 0$, $(b_1 - b_2) \ge 0 \,\&\, (c_1 - c_2) \ge 0$.

Hence $R(A) - R(B) \ge 0$

IV. Methodology

In this section, it was presented an application of rough neutrosophic set in medical diagnosis. In a given pathology, suppose S is a set of symptoms, D is a set of diseases and P is a set of patients and let Q be a rough neutrosophic relation from the set of patients to the symptoms. i.e., $Q(P \to S)$ and R be a rough neutrosophic relation from the set of symptoms to the diseases. i.e., $R(S \to D)$ and then the methodology involves three main jobs:

1. Determination of symptoms
2. Formulation of medical knowledge based on rough neutrosophic sets
3. Determination of diagnosis on the basis of new computation technique

V. Algorithm

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

Step 2 : The medical knowledge relating the symptoms with the set of diseases under consideration are given to obtain the symptom - disease relation *R* and are noted in "Table 2".
Step 3 : "Table 3" is obtained by calculating average values of "Table 1".
Step 4 : "Table 4" is obtained by calculating average values of "Table 2".
Step 5 : "Table 5" is obtained by applying (1) between "Table 3" &"Table 4".
Step 6 : The Computation *T* of the relation of patients and diseases is found using (2) in "Table 5" and are noted in "Table 6".
Step 7 : Finally, the minimum value from "Table 6" of each row are selected for possibility of the patient affected with the respective disease and then it was concluded that the patient $P_k(k=1,2,3)$ was suffering from the disease $D_r(r=1,2,3,4)$

VI. Case study [8]

Let there be three patients $P=\{P_1,P_2,P_3\}$ and the set of symptoms S = {Temperature, Headache, Stomach pain, Cough, Chest pain}.The rough neutrosophic relation $Q(P \to S)$ is given as in "Table 1".Let the set of diseases D = {Viral fever, Malaria, Stomach problem, Chest problem}.The rough neutrosophic relation $R(S \to D)$is given as in "Table 2".

Table 1 Patient – Symptom relation (using step 1)

Q	Temperature	Headache	Stomach pain	Cough	Chest pain
P_1	$\langle(0.6,0.4,0.3),(0.8,0.2,0.1)\rangle$	$\langle(0.4,0.4,0.4),(0.6,0.2,0.2)\rangle$	$\langle(0.5,0.3,0.2),(0.7,0.1,0.2)\rangle$	$\langle(0.6,0.2,0.4),(0.8,0.0,0.2)\rangle$	$\langle(0.4,0.4,0.4),(0.6,0.2,0.2)\rangle$
P_2	$\langle(0.5,0.3,0.4),(0.7,0.3,0.2)\rangle$	$\langle(0.5,0.5,0.3),(0.7,0.3,0.3)\rangle$	$\langle(0.5,0.3,0.4),(0.7,0.1,0.4)\rangle$	$\langle(0.5,0.3,0.3),(0.9,0.1,0.3)\rangle$	$\langle(0.5,0.3,0.3),(0.7,0.1,0.3)\rangle$
P_3	$\langle(0.6,0.4,0.4),(0.8,0.2,0.2)\rangle$	$\langle(0.5,0.2,0.3),(0.7,0.0,0.1)\rangle$	$\langle(0.4,0.3,0.4),(0.8,0.1,0.2)\rangle$	$\langle(0.6,0.1,0.4),(0.8,0.1,0.2)\rangle$	$\langle(0.5,0.3,0.3),(0.7,0.1,0.1)\rangle$

Table 2 Symptom – Disease relation (using step 2)

R	Viral fever	Malaria	Stomach Problem	Chest problem
Temperature	$\langle(0.6,0.5,0.4),(0.8,0.3,0.2)\rangle$	$\langle(0.1,0.4,0.4),(0.5,0.2,0.2)\rangle$	$\langle(0.3,0.4,0.4),(0.5,0.2,0.2)\rangle$	$\langle(0.2,0.4,0.6),(0.4,0.4,0.4)\rangle$
Headache	$\langle(0.5,0.3,0.4),(0.7,0.3,0.2)\rangle$	$\langle(0.2,0.3,0.4),(0.6,0.3,0.2)\rangle$	$\langle(0.2,0.3,0.3),(0.4,0.1,0.1)\rangle$	$\langle(0.1,0.5,0.5),(0.5,0.3,0.3)\rangle$
Stomach pain	$\langle(0.2,0.3,0.4),(0.4,0.3,0.2)\rangle$	$\langle(0.1,0.4,0.4),(0.3,0.2,0.2)\rangle$	$\langle(0.4,0.3,0.4),(0.6,0.1,0.2)\rangle$	$\langle(0.1,0.4,0.6),(0.3,0.2,0.4)\rangle$
Cough	$\langle(0.4,0.3,0.3),(0.6,0.1,0.1)\rangle$	$\langle(0.3,0.3,0.3),(0.5,0.1,0.3)\rangle$	$\langle(0.1,0.6,0.6),(0.3,0.4,0.4)\rangle$	$\langle(0.5,0.3,0.4),(0.7,0.1,0.2)\rangle$
Chest pain	$\langle(0.2,0.4,0.4),(0.4,0.2,0.2)\rangle$	$\langle(0.1,0.3,0.3),(0.3,0.1,0.1)\rangle$	$\langle(0.1,0.4,0.4),(0.3,0.2,0.2)\rangle$	$\langle(0.4,0.4,0.4),(0.6,0.2,0.2)\rangle$

Table 3 Average (using step 3)

Q	Temperature	Headache	Stomach pain	Cough	Chest pain
P_1	$[0.7,0.3,0.2]$	$[0.5,0.3,0.3]$	$[0.6,0.2,0.2]$	$[0.7,0.1,0.3]$	$[0.5,0.3,0.3]$
P_2	$[0.6,0.3,0.3]$	$[0.6,0.4,0.3]$	$[0.6,0.2,0.4]$	$[0.7,0.2,0.3]$	$[0.6,0.2,0.3]$
P_3	$[0.7,0.3,0.3]$	$[0.6,0.1,0.2]$	$[0.6,0.2,0.3]$	$[0.7,0.1,0.3]$	$[0.6,0.2,0.2]$

Table 4 Average (Using step 4)

R	Viral fever	Malaria	Stomach problem	Chestproblem
Temperature	[0.7 ,0.4 ,0.3]	[0.3 ,0.3 ,0.3]	[0.4 ,0.3,0.3]	[0.3 ,0.4 ,0.5]
Headache	[0.6 ,0.3 ,0.3]	[0.4 ,0.3 ,0.3]	[0.3 ,0.2 ,0.2]	[0.3 ,0.4 ,0.4]
Stomach pain	[0.3 ,0.3 ,0.3]	[0.2 ,0.3 ,0.3]	[0.5 ,0.2 ,0.3]	[0.2 ,0.3 ,0.5]
Cough	[0.5 ,0.2 ,0.2]	[0.4 ,0.2 ,0.3]	[0.2 ,0.5 ,0. 5]	[0.6 ,0.2 ,0.3]
Chest pain	[0.3 ,0.3 ,0.3]	[0.2 ,0.2 ,0.2]	[0.2 ,0.3 ,0.3]	[0.5 ,0.3,0.3]

Table 5 Max-Min composition (using step 5)

T	Viral fever	Malaria	Stomach problem	Chest problem
P_1	[0.7 ,0.3 ,0.3]	[0.4 ,0.3 ,0.3]	[0.5 ,0.3 ,0. 3]	[0.6 ,0.3 ,0.3]
P_2	[0.6 ,0.3 ,0.3]	[0.4 ,0.3 ,0.3]	[0.5 ,0.3 ,0.3]	[0.6 ,0.4 ,0. 3]
P_3	[0.7 ,0.3 ,0.3]	[0.4 ,0.3 ,0.2]	[0.5 ,0.3 ,0.2]	[0.6 ,0.3 ,0.3]

Table 6 Order function (using step 6 & step 7)

T	Viral fever	Malaria	Stomach problem	Chest problem
P_1	**0.2966**	0.3794	0.3483	0.3210
P_2	**0.3210**	0.3794	0.3483	0.3597
P_3	**0.2966**	0.4019	0.3668	0.3210

From Table 6,it is obvious that, if the doctor agrees, then P_1 , P_2 & P_3 suffers from viral fever.

VII. Conclusion

In this paper, it was analyzed the relationship between the set of symptoms found with the patients and the set of diseases and employed a novel method (order function) to find out the disease possibly affected the patient. The techniques considered in this study were more reliable to handle medical diagnosis problems quiet comfortably. In future, these methods can be enhanced to other types of neutrosophic sets also.

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