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Pi-Distance of Rough Neutrosophic Sets for Medical Diagnosis

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Abstract. The objective of the study is to find out the relationship between the disease and the symptoms seen with the patient and diagnose the disease that impacted the patient using rough neutrosophic set. Neoteric method [PI-distance] is devised in rough neutrosophic set. Utilization of medical diagnosis is commenced with using prescribed procedures to identify a person suffering from the disease for a considerable period. The result showed that the proposed method is free from shortcomings that affect the existing methods and found to be more accurate in diagnosing the diseases.

Keywords: Neutrosophic set, rough neutrosophic set, Pi-distance, medical diagnosis.

1. Introduction

Mathematical principles play a vital role in solving the real life problems in engineering, medical sciences, social sciences, economics and so on. These problems are having no definite data and they are mostly imprecise in character. We are therefore employing probability theory, fuzzy set theory, rough set theory *etc.*, in Mathematics to find solutions to these problems. In the same way, fuzzy logic techniques have been integrated with conventional clinical decision in healthcare industry. As clinicians find it hard to have a fool proof diagnosis, they are initiating certain steps without any guidance from the experts. Neutrosophic set which is a generalized set possesses all attributes necessary to encode medical knowledge base and capture medical inputs.

The law of average has been applied in Medical diagnosis combining the information of which most of them are quantifiable derived through various sources and the inconsistent data derived through intuitive thought and 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. Edward Samuel and Narmadhagnanam[4] proposed the tangent inverse distance and sine similarity measure of intuitionistic fuzzy sets and apply them in medical diagnosis.

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[5] has capability to deal with uncertainty, imprecise, incomplete and inconsistent information which exists in real world from philosophical point of view.

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.

SurapatiPramanik and KalyanMondal [8,9] introduced cosine and cotangent similarity measures of rough neutrosophic sets. Pramanik *et al* [10] introduced correlation coefficient of rough neutrosophic sets. Edward Samuel and Narmadhagnanam [11] proposed order function among roughneutrosophic sets. Pramanik *et al* [12] introduced several trigonometric Hamming similarity measures under interval rough neutrosophic environment. Pramanik *et al* [13] introduced Multi attribute decision making strategy on projection and bidirectional projection measures of interval rough neutrosophic sets. Mondal *et al* [14] examined TOPSIS in rough neutrosophic environment.

Mondal *et al* [15] proposed variational coefficient similarity measure under rough neutrosophic environment. Mondal *et al* [16] proposed several trigonometric Hamming similarity measures of rough neutrosophic sets. Mondal and Pramanik [17] proposed grey relational analysis among rough neutrosophic sets. Pramanik and Mondal [18] proposed some similarity measures among rough neutrosophic sets. Mondal *et al* [19] proposed aggregation operators among rough neutrosophic sets. Pramanik *et al* [20] introduced Multi criteria decision making based on projection and bidirectional projection measures of rough neutrosophic sets. Neutrosophic set is applied to different areas including decision making by many researchers[21-27]. Mohana and Mohanasundari [28] proposed similarity measures of single valued neutrosophic rough sets. Tuhin Bera and Nirmal KumarMahapatra[29] applied generalised single valued neutrosophic number in neutrosophic linear programming. Ulucay et al [30] proposed a new approach for multi-attribute decision-making problems in bipolar neutrosophic sets.Broumi et al [31] proposed single valued (2N+1) sided polygonal neutrosophic numbers and single valued (2N) sided polygonal neutrosophic numbers. Li et al [32] proposed slope stability assessment method using the arctangent and tangent similarity measure of neutrosophic numbers.

Rest of the article is structured as follows. In Section 2, we briefly present the basic definitions.Section 3 deals with proposed definition (PI distance) and some of its properties. Sections 4, 5 and 6 deal with methodology,algorithm and case study related to medical diagnosis respectively.Conclusion is given in Section 7.

2. Preliminaries

2.1 Definition [33]

Let X be a Universe of discourse, with a generic element in X denoted by x, the neutrosophic set(NS) A is an object having the form $A=\{\langle x:T_A(x),I_A(x),F_A(x)\rangle,x\in X\}$ where the functions define $T,I,F:X\to\,]^-0,1^+[$ respectively the degree of membership (or Truth), the degree of indeterminacy and the degree of non-membership(or Falsehood) of the element $x \in X$ to the set A with the conditio $^{-}0 \le T_A(x) + I_A(x) + F_A(x) \le 3^{+}$

2.2 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, $0 \le T_{\underline{N}(P)}(x) + I_{\underline{N}(P)}(x) + F_{\underline{N}(P)}(x) \le 3$ and $0 \le T_{\overline{N}(P)}(x) + I_{\overline{N}(P)}(x) + F_{\overline{N}(P)}(x) \le 3$, where $\vee$ and $\wedge$ mean "max" and "min" operators respectively, $T_P(y), I_P(y)$ *and* $F_P(y)$ are the membership, indeterminacy and non-membership of 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 $(\underline{N}(P), \overline{N}(P))$ is called the rough neutrosophic set in (U,R).

3 Proposed definitions

3.1. Pi-distance

Let $A = \left\langle \left(\underline{T}_A(x_i), \underline{I}_A(x_i), \underline{F}_A(x_i)\right), \left(\overline{T}_A(x_i), \overline{I}_A(x_i), \overline{F}_A(x_i)\right) \right\rangle$ and $B = \left\langle \left(\underline{T}_B(x_i), \underline{I}_B(x_i), \underline{F}_B(x_i)\right), \left(\overline{T}_B(x_i), \overline{I}_B(x_i), \overline{F}_B(x_i)\right) \right\rangle$ be two rough neutrosophic sets, then the Pi-distance is defined as

$$PI_{RNS}(A,B) = \sum_{i=1}^{n} \frac{\left[|\underline{T}_A(x_i) - \underline{T}_B(x_i)| + |\underline{I}_A(x_i) - \underline{I}_B(x_i)| + |\underline{F}_A(x_i) - \underline{F}_B(x_i)| + |\overline{T}_A(x_i) - \overline{T}_B(x_i)| + |\overline{I}_A(x_i) - \overline{I}_B(x_i)| + |\overline{F}_A(x_i) - \overline{F}_B(x_i)| \right]^2}{\pi + \left[\sqrt{\underline{T}_A(x_i) + \underline{T}_B(x_i) + \underline{I}_A(x_i) + \underline{I}_B(x_i) + \underline{F}_A(x_i) + \underline{F}_B(x_i)} \sqrt{\overline{T}_A(x_i) + \overline{T}_B(x_i) + \overline{I}_A(x_i) + \overline{I}_B(x_i) + \overline{F}_A(x_i) + \overline{F}_B(x_i)} \right]}$$

3.1.1. Boundedness

Let $A_i = \left\langle \left(\underline{T}_A(x_i), \underline{I}_A(x_i), \underline{F}_A(x_i)\right), \left(\overline{T}_A(x_i), \overline{I}_A(x_i), \overline{F}_A(x_i)\right) \right\rangle$ $(i = 1,2,\dots,n)$ be a collection of rough neutrosophic sets and

$$\bar{A} = \left\langle \left[\min_i [\underline{T}_A(x_i)], \min_i [\overline{T}_A(x_i)] \right], \left[\max_i [\underline{I}_A(x_i)], \max_i [\overline{I}_A(x_i)] \right], \left[\max_i [\underline{F}_A(x_i)], \max_i [\overline{F}_A(x_i)] \right] \right\rangle \; \&$$

$$\bar{A} = \left\langle \left[\min_i [\underline{T}_A(x_i)], \min_i [\overline{T}_A(x_i)] \right], \left[\max_i [\underline{I}_A(x_i)], \max_i [\overline{I}_A(x_i)] \right], \left[\max_i [\underline{F}_A(x_i)], \max_i [\overline{F}_A(x_i)] \right] \right\rangle$$

$$\overset{+}{A} = \left\langle \left[\max_i [\underline{T}_A(x_i)], \max_i [\overline{T}_A(x_i)] \right], \left[\min_i [\underline{I}_A(x_i)], \min_i [\overline{I}_A(x_i)] \right], \left[\min_i [\underline{F}_A(x_i)], \min_i [\overline{F}_A(x_i)] \right] \right\rangle$$

then $\bar{A} \le PI_{RNS}(A_1, A_2, \dots, A_n) \le \overset{+}{A}$

3.1.2. Proposition 1

(i) $PI_{RNS}(A,B)\geq 0$

(ii) $PI_{RNS}(A,B)=0$ if and only if $A=B$

(iii) $PI_{RNS}(A,B)=PI_{RNS}(B,A)$

(iv) If $A\subseteq B\subseteq C$ then $PI_{RNS}(A,C)\geq PI_{RNS}(A,B)$ & $PI_{RNS}(A,C)\geq PI_{RNS}(B,C)$

Proof

(i) We know that, the truth-membership function, indeterminacy –membership function and falsity–membership function in rough neutrosophic sets are within $[0,1]$. Hence $PI_{RNS}(A,B)\geq 0$

(ii) If $A=B$, then $\underline{T}_A(x_i)=\underline{T}_B(x_i), \underline{I}_A(x_i)=\underline{I}_B(x_i), \underline{F}_A(x_i)=\underline{F}_B(x_i), \overline{T}_A(x_i)=\overline{T}_B(x_i), \overline{I}_A(x_i)=\overline{I}_B(x_i) \& \overline{F}_A(x_i)=\overline{F}_B(x_i)$ for $i=1,2,\cdots,n \;\&\; x_i\in X$. Therefore, $PI_{RNS}(A,B)=0$. If $IHD_{RNS}(A,B)=0$, this implies

$$\left|\underline{T}_A(x_i)-\underline{T}_B(x_i)\right|=0;\quad \left|\underline{I}_A(x_i)-\underline{I}_B(x_i)\right|=0$$
$$\left|\underline{F}_A(x_i)-\underline{F}_B(x_i)\right|=0;\quad \left|\overline{T}_A(x_i)-\overline{T}_B(x_i)\right|=0$$
$$\left|\overline{I}_A(x_i)-\overline{I}_B(x_i)\right|=0;\quad \left|\overline{F}_A(x_i)-\overline{F}_B(x_i)\right|=0$$

Since its denominator is not equal to zero. Then,

$\underline{T}_A(x_i)=\underline{T}_B(x_i), \underline{I}_A(x_i)=\underline{I}_B(x_i), \underline{F}_A(x_i)=\underline{F}_B(x_i), \overline{T}_A(x_i)=\overline{T}_B(x_i), \overline{I}_A(x_i)=\overline{I}_B(x_i) \& \overline{F}_A(x_i)=\overline{F}_B(x_i)$ for $i=1,2,\cdots,n \;\&\; x_i\in X$. Hence $A=B$.

(iii) We know that,

$$\left|\underline{T}_A(x_i)-\underline{T}_B(x_i)\right|=\left|\underline{T}_B(x_i)-\underline{T}_A(x_i)\right|;\ \left|\underline{I}_A(x_i)-\underline{I}_B(x_i)\right|=\left|\underline{I}_B(x_i)-\underline{I}_A(x_i)\right|;\ \left|\underline{F}_A(x_i)-\underline{F}_B(x_i)\right|=\left|\underline{F}_B(x_i)-\underline{F}_A(x_i)\right|$$
$$\left|\overline{T}_A(x_i)-\overline{T}_B(x_i)\right|=\left|\overline{T}_B(x_i)-\overline{T}_A(x_i)\right|;\ \left|\overline{I}_A(x_i)-\overline{I}_B(x_i)\right|=\left|\overline{I}_B(x_i)-\overline{I}_A(x_i)\right|;\ \left|\overline{F}_A(x_i)-\overline{F}_B(x_i)\right|=\left|\overline{F}_B(x_i)-\overline{F}_A(x_i)\right|$$

Hence $PI_{RNS}(A,B)=PI_{RNS}(B,A)$.

(iv) We know that,

$$\underline{T}_A(x_i)\leq\underline{T}_B(x_i)\leq\underline{T}_C(x_i);\ \overline{T}_A(x_i)\leq\overline{T}_B(x_i)\leq\overline{T}_C(x_i)$$
$$\underline{I}_A(x_i)\geq\underline{I}_B(x_i)\geq\underline{I}_C(x_i);\ \overline{I}_A(x_i)\geq\overline{I}_B(x_i)\geq\overline{I}_C(x_i)$$
$$\underline{F}_A(x_i)\geq\underline{F}_B(x_i)\geq\underline{F}_C(x_i);\ \overline{F}_A(x_i)\geq\overline{F}_B(x_i)\geq\overline{F}_C(x_i)$$
$$[\because A\subseteq B\subseteq C]$$

Hence,

$$\left|\underline{T}_A(x_i)-\underline{T}_B(x_i)\right|\leq\left|\underline{T}_A(x_i)-\underline{T}_C(x_i)\right|;\ \left|\overline{T}_A(x_i)-\overline{T}_B(x_i)\right|\leq\left|\overline{T}_A(x_i)-\overline{T}_C(x_i)\right|$$
$$\left|\underline{I}_A(x_i)-\underline{I}_B(x_i)\right|\leq\left|\underline{I}_A(x_i)-\underline{I}_C(x_i)\right|;\ \left|\overline{I}_A(x_i)-\overline{I}_B(x_i)\right|\leq\left|\overline{I}_A(x_i)-\overline{I}_C(x_i)\right|$$
$$\left|\underline{F}_A(x_i)-\underline{F}_B(x_i)\right|\leq\left|\underline{F}_A(x_i)-\underline{F}_C(x_i)\right|;\ \left|\overline{F}_A(x_i)-\overline{F}_B(x_i)\right|\leq\left|\overline{F}_A(x_i)-\overline{F}_C(x_i)\right|$$
$$\left|\underline{T}_B(x_i)-\underline{T}_C(x_i)\right|\leq\left|\underline{T}_A(x_i)-\underline{T}_C(x_i)\right|;\ \left|\overline{T}_B(x_i)-\overline{T}_C(x_i)\right|\leq\left|\overline{T}_A(x_i)-\overline{T}_C(x_i)\right|$$
$$\left|\underline{I}_B(x_i)-\underline{I}_C(x_i)\right|\leq\left|\underline{I}_A(x_i)-\underline{I}_C(x_i)\right|;\ \left|\overline{I}_B(x_i)-\overline{I}_C(x_i)\right|\leq\left|\overline{I}_A(x_i)-\overline{I}_C(x_i)\right|$$
$$\left|\underline{F}_B(x_i)-\underline{F}_C(x_i)\right|\leq\left|\underline{F}_A(x_i)-\underline{F}_C(x_i)\right|;\ \left|\overline{F}_B(x_i)-\overline{F}_C(x_i)\right|\leq\left|\overline{F}_A(x_i)-\overline{F}_C(x_i)\right|$$

Here, the PI- distance is an increasing function

$\therefore\ PI_{RNS}(A,C)\geq PI_{RNS}(A,B) \& PI_{RNS}(A,C)\geq PI_{RNS}(B,C)$

4. Methodology

In this section, we present 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 of rough neutrosophic sets.

5. 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 : The Computation *T* (relation between patients and diseases) is found using (3.1) between Table 1 & Table 2 and are noted in Table 3

Step 4: Finally, we select the minimum value from Table 3 of each row for possibility of the patient affected with the respective disease and then we conclude that the patient P_k is suffering from the disease D_r.

6. Case study [8]

In this section, an example adapted from Surapati Pramanik and Kalyan Mondal (Cosine Similarity Measure of Rough Neutrosophic Sets and its application in medical diagnosis) is used. 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	Chestproblem
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: Pi-distance

T	Viral fever	Malaria	Stomach problem	Chest problem
P_1	**0.4115**	0.9147	1.2435	1.0821
P_2	**0.4963**	0.7953	1.3853	0.7419
P_3	**0.5233**	0.8466	1.3912	1.3189

7. Conclusion

This study discovers the relationship between the symptoms found with the patients and the set of diseases. This study will help the researcher to find out the diseases accurately that impacted the patients. This method is apt for handling the medical diagnosis problems and its efficiency and rationality have been proved without any doubt. The method employed is free from the limitations that are commonly found in other studies. Without such limitations, a new theory on image processing, cluster analysis etc., has been developed. In the same way it will grow and extend itself to other types of neutrosophic sets.

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