Sine Exponential Measure of Single Valued Neutrosophic Sets in 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 single valued neutrosophic set. Innovative method [sine exponential measure] is devised in single valued neutrosophic set and some of its properties are discussed herein. Utilization of medical diagnosis was commenced with using prescribed procedures to identify a person suffering from the disease for a considerable period. The result showed that the proposed method was free from shortcomings that affect the existing methods and found to be more accurate in diagnosing the diseases. It was concluded that the technique adopted in this study were more reliable and easier to handle medical diagnosis problems.

Keywords: Sine Exponential; Neutrosophic; Medical Diagnosis; Single Valued Neutrosophic

1 Introduction

Kumbakonam is a thickly populated town. Although underground drainage system is available here, it is yet to cover all the houses in the town. So, open drainage system continues to be in practice in different places of the town. Further this town is racing fast towards total sanitation in all spheres. As a result, Kumbakonam continues to be a repository of all new kinds of diseases. This created an urge to carry out research in the medical field. By introducing innovative methods in the research, the diseases can be diagnosed instantly and infallibly.

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.

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[2] introduced the intuitionistic fuzzy sets which consider both truth-membership and falsity-membership. Edward Samuel and Narmadhagnanam[3] proposed the tangent inverse distance and sine similarity measure of intuitionistic fuzzy sets and apply them in medical diagnosis.Kozae *et al* [4]applied intuitionistic fuzzy sets in corona covid-19 determination.Rajkalpana *et al* [5]applied intuitionistic fuzzy set and its operators in medical diagnosis.Shinoj and John [6] extended the concept of fuzzy multi sets by introducing intuitionistic fuzzy multi sets. Rajarajeswari and Uma [7,8] proposed few methods among intuitionistic fuzzy multi sets. Edward Samuel and Narmadhagnanam[9] proposed sine inverse distance of intuitionistic fuzzy multi 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[10] has capability to deal with uncertainty, imprecise, incomplete and inconsistent information which exists in real world from philosophical point of view.In 1982, Pawlak[11] introduced the concept of rough set, 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 [12] examined fuzzy rough sets. Broumi *et al* [13] introduced rough neutrosophic sets. SurapatiPramanik and KalyanMondal [14,15] introduced cosine and cotangent similarity measures of rough neutrosophic sets. Pramanik *et al* [16] introduced correlation coefficient of rough neutrosophic sets. Edward Samuel and Narmadhagnanam [17-20] proposed few methods among rough neutrosophic sets and applied it in medical diagnosis.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. Wang *et al*[31] proposed the single valued neutrosophic set.PinakiMajumdar and S.K.Samanta [32]proposed the similarity and entropy of neutrosophic sets. Jun Ye[33] proposed the cotangent similarity measure of single valued neutrosophic sets.

Broumi et al[34] proposed single valued (2N+1) sided polygonal neutrosophic numbers and single valued (2N) sided polygonal neutrosophic numbers. Li et al [35] Slope stability assessment method using the arctangent and tangent similarity measure of neutrosophic numbers. Edward Samuel and Narmadhagnanam [36,37] introduced cosine logarithmic distance and tangent inverse similarity measure among single valued neutrosophic sets and applied it in medical diagnosis.. Harish Garg and Nancy[38] proposed new distance measure of single valued neutrosophic sets. Chai *et al*[39]proposed new similarity measures of single valued neutrosophic sets. Shan Ye and Jun Ye [40] introduced the concept of single valued neutrosophic multi sets. Edward Samuel and Narmadhagnanam [41] introduced cosine exponential distance among single valued neutrosophic multi sets and applied it in medical diagnosis. In 2013[42], Florentin Smarandache extended the classical neutrosophic logic to n-valued refined neutrosophic logic, by refining each neutrosophic component T,I,F into respectively, $T_1,T_2,..,T_m,I_1,I_2,...,I_p$ and $F_1,F_2,..,F_r$. The concept of neutrosophic refined sets is a generalization of fuzzy multisets and intuitionistic fuzzy multi sets. In 2014,Broumi and Smarandache[43] extended the improved cosine similarity of single valued neutrosophic set proposed by Ye[44] to the case of neutrosophic refined sets. Edward Samuel and Narmadhagnanam [45-47] introduced few methods in neutrosophic refined sets and applied it in medical diagnosis. Broumi *et al* [48] generalise the concept of n-valued neutrosophic sets to the case of n-valued interval neutrosophic sets. Edward Samuel and Narmadhagnanam [49-51] introduced many methods in n-valued interval neutrosophic sets and applied it in medical diagnosis. The proposed method had more accuracy than the others and they could handle the limitations and drawbacks of the previous works well. This study discovers the relationship between the symptoms found within patients and set of diseases. This study will help the researcher to find out the diseases accurately that impacted the patients. The method employed is free from the limitations that are commonly found in other studies. Without such limitations, in this study a new theory on image processing, cluster analysis etc., has been developed.

Rest of the article is structured as follows. In Section 2, we briefly present the basic definitions. Section 3 deals with proposed definition 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[52]

Let X be a Universe of discourse,with a generic element in X denoted by x, the neutrosophicset(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 $T,I,F: X\rightarrow\,]^{-}0,1^{+}[$ respectively the degree of membership(or Truth), the degree of indeterminacy and the degree of non-membership(or Falsehood) ofthe element $x\in X$ to the set A with the condition

$^{-}0\leq T_A(x)+I_A(x)+F_A(x)\leq 3^{+}$

2.2 Definition[31]

Let X be a space of points (objects) with a generic element in X denoted by x. A single valued neutrosophic set A in X is characterized by truth membership function T_A, indeterminacy function I_A and falsity membership function F_A .For each point x in X,

$T_A(x), I_A(x), F_A(x)\in[0,1]$

When X is continuous, a SVNS A can be written as

$A=\int_x\langle T(x), I(x), F(x)\rangle / x, x\in X$

When X is discrete, a SVNS A can be written as

$A=\sum_{i=1}^{n}\langle T(x_i), I(x_i), F(x_i)\rangle / x_i, x_i\in X$

3 Proposed definition

3.1 Definition

Let $A=\sum_{i=1}^{n}\frac{x_i}{\langle T_A(x_i), I_A(x_i), F_A(x_i)\rangle}$ and $B=\sum_{i=1}^{n}\frac{x_i}{\langle T_B(x_i), I_B(x_i), F_B(x_i)\rangle}$ be two single valued neutrosophic sets in $X=\{x_1,x_2,...,x_n\}$, then the sine exponential measure is defined as

$$SEM_{SVNS}(A,B)=\frac{1}{n}\sum_{i=1}^{q}\left[\sum_{j=1}^{n}\sin e^{-[|T_A(x_i)-T_B(x_i)|+|I_A(x_i)-I_B(x_i)|+|F_A(x_i)-F_B(x_i)|]}\right] \tag{1}$$

Proposition 1

(i) $SEM_{SVNS}(A,B)>0$

(ii) $SEM_{SVNS}(A,B)=SEM_{SVNS}(B,A)$

(iii)If $A\subseteq B\subseteq C$ then $SEM_{SVNS}(A,C)\leq SEM_{SVNS}(A,B)$ & $SEM_{SVNS}(A,C)\leq SEM_{SVNS}(B,C)$

Proof

(i) We know that, the truth-membership function, indeterminacy –membership function and falsity–membership function in single valued neutrosophic sets are within $[0,1]$.

Hence $SEM_{SVNS}(A,B)>0$

(ii)We know that,

$$\left|T_A(x_i)-T_B(x_i)\right| = \left|T_B(x_i)-T_A(x_i)\right|$$
$$\left|I_A(x_i)-I_B(x_i)\right| = \left|I_B(x_i)-I_A(x_i)\right|$$
$$\left|F_A(x_i)-F_B(x_i)\right| = \left|F_B(x_i)-F_A(x_i)\right|$$

Hence $SEM_{SVNS}(A,B) = SEM_{SVNS}(B,A)$

(iii) We know that,

$$T_A(x_i) \le T_B(x_i) \le T_C(x_i)$$
$$I_A(x_i) \ge I_B(x_i) \ge I_C(x_i)$$
$$F_A(x_i) \ge F_B(x_i) \ge F_C(x_i)$$
$$\because A \subseteq B \subseteq C$$

Hence,

$$\left|T_A(x_i)-T_B(x_i)\right| \le \left|T_A(x_i)-T_C(x_i)\right|$$
$$\left|I_A(x_i)-I_B(x_i)\right| \le \left|I_A(x_i)-I_C(x_i)\right|$$
$$\left|F_A(x_i)-F_B(x_i)\right| \le \left|F_A(x_i)-F_C(x_i)\right|$$
$$\left|T_B(x_i)-T_C(x_i)\right| \le \left|T_A(x_i)-T_C(x_i)\right|$$
$$\left|I_B(x_i)-I_C(x_i)\right| \le \left|I_A(x_i)-I_C(x_i)\right|$$
$$\left|F_B(x_i)-F_C(x_i)\right| \le \left|F_A(x_i)-F_C(x_i)\right|$$

Here, the sine exponential measure is a decreasing function

$\therefore \quad SEM_{SVNS}(A,C) \le SEM_{SVNS}(A,B)$ & $SEM_{SVNS}(A,C) \le SEM_{SVNS}(B,C)$

4. Methodology

In this section, we present an application of single valued 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 single valued neutrosophic relation from the set of patients to the symptoms.i.e., $Q(P \rightarrow S)$ and R be a single valued neutrosophic relation from the set of symptoms to the diseases i.e., $R(S \rightarrow D)$ and then the methodology involves three main jobs:

1. Determination of symptoms.
2. Formulation of medical knowledge based on single valued neutrosophic sets.
3. Determination of diagnosis on the basis of new computation technique of single valued 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 (1) between Table 1 & Table 2 and are noted in Table 3

Step 4: Finally, we select the maximum 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 [53]

In this section, an example adapted from Gulfam Shahzadi,Muhammad Akram and Arsham Borumand Saied (An application of single valued neutrosophic sets in medical diagnosis) is used.

Let there be three patients P=(Ali,Hamza,Imran) and the set of symptoms S={Temperature,Insulin, Blood Pressure, Blood Platelets, Cough}.The Single valued neutrosophic relation $Q(P \rightarrow S)$ is given as in Table 1.Let the set of diseases D = {Diabetes, Dengue, Tuberculosis}.The Single valued neutrosophic relation$R(S \rightarrow D)$ is given as in Table 2.

Q	Temperature	Insulin	Blood Pressure	Blood Platelets	Cough
Ali	(0.8,0.1,0.1)	(0.2,0.2,0.6)	(0.4,0.2,0.4)	(0.8,0.1,0.1)	(0.3,0.3,0.4)
Hamza	(0.6,0.2,0.2)	(0.9,0.0,0.1)	(0.1,0.1,0.8)	(0.2,0.1,0.7)	(0.5,0.1,0.4)
Imran	(0.4,0.2,0.4)	(0.2,0.1,0.7)	(0.1,0.2,0.7)	(0.3,0.1,0.6)	(0.8,0.0,0.2)

Table 1:Patient-symptom relation(using step 1)

R	Diabetes	Dengue	Tuberculosis
Temperature	(0.2,0.0,0.8)	(0.9,0.0,0.1)	(0.6,0.2,0.2)
Insulin	(0.9,0.0,0.1)	(0.0,0.2,0.8)	(0.0,0.1,0.9)
Blood Pressure	(0.1,0.1,0.8)	(0.8,0.1,0.1)	(0.4,0.2,0.4)
Blood Platelets	(0.1,0.1,0.8)	(0.9,0.0,0.1)	(0.0,0.2,0.8)
Cough	(0.1,0.1,0.8)	(0.1,0.1,0.8)	(0.9,0.0,0.1)

Table 2: Symptom-Disease relation (Using step 2)

T	Diabetes	Dengue	Tuberculosis
Ali	0.3201	**0.5900**	0.4962
Hamza	**0.6287**	0.3217	0.4991
Imran	0.4547	0.3531	**0.6031**

Table 3: Sine exponential measure(Using step 3 and step 4)

7 Conclusion

Our propounded techniques are most decisive to hold the problems related to medical diagnosis competently. The proposed approaches can find more implementation in other areas such as decision making, cluster analysis etc.

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