RESEARCH PAPER

SINE LOGARITHMIC DISTANCE OF NEUTROSOPHIC REFINED SETS IN MEDICAL DIAGNOSIS

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Abstract: In this paper, sine logarithmic distance among neutrosophic refined sets is proposed and some of its properties are discussed herein. The concept of the above method is an essential tool for dealing with uncertainties and shortcomings that affect the existing methods. Implementation of medical diagnosis is presented to find out the disease impacting the patient**.**

Keywords:*Neutrosophic set, neutrosophic refined set, sine logarithmic distance, medical diagnosis.*

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.Suchuncertainties are being dealt with the help of topics like probability theory,fuzzy set theory[15],rough set theory [8] 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. Neutrosophicset 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 person consistency. So contradictions, inconsistency, indeterminacy and fuzziness should be accepted as unavoidable as it is 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 set of symptoms under a single name of disease becomes difficult.In some practical situations, there is the possibility of each element having different truth membership, indeterminate and false membership functions.The unique feature of neutrosophic refined set is that it contains multi truth membership, indeterminate and false membership.By taking one time inspection, there may be error in diagnosis.Hence, multi time inspection, by taking the samples of the same patient at different times gives thebest diagnosis.So, neutrosophic refined sets and their applications play a vital role in medical diagnosis.

In 1965, Fuzzy set theory was firstly given by Zadeh[15] which is applied in many real applications to handle uncertainty.Then interval valued fuzzy set, intuitionistic fuzzy set theory and interval valued intuitionistic fuzzy set were introduced by Turksen, Atanassov and Atanassov&Gargov respectively.These theories can only handle incomplete information not the indeterminate information and inconsistent information which exists commonly in belief systems. So, Neutrosophicset(generalization of fuzzy sets, intuitionistic fuzzy sets and so on) defined by FlorentinSmarandache[2] has capability to deal with uncertainty, imprecise, incomplete and inconsistent information which exists in real world from philosophical point of view. Ye[5] proposed the vector similarity measures of simplified neutrosophic sets..

Yager[14] introduced the notion of multisets which is the generalization of the concept of set theory.Sebastian and Ramakrishnan[11]studied a new concept called fuzzymultisets(FMS), which is the generalization of multisets.Since then, Sebastian and Ramakrishnan[12] established more properties on fuzzy multisets.Shinoj T.K &John S.J [13]extended the concept of fuzzy multi sets by introducing intuitionistic fuzzy multisets(IFMS).An element of a multi fuzzy sets can occur more than once with possibly the same or different membership values, whereas an element of a intuitionisticmulti fuzzy sets is capable of having repeated occurrences of membership and non-membership values.However, the concepts ofFMS & IFMS are not capable of dealing with indeterminacy.In 2013,FlorentinSmarandache[3] 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 $F_1,F_2,..,F_r$. Recently,Deli and Broumi introduced the concept of neutrosophic refined sets and studied some of their basic properties.The concept of neutrosophicrefined sets(NRS) is a generalization of fuzzy multisets and intuitionistic fuzzy multisets.In 2014,Broumi and Smarandache[9] proposed the cosine similarity measure of neutrosophic refined sets.Mondal and Pramanik[6] proposed the cotangent similarity measure of neutrosophic refined sets.Edward Samuel and Narmadhagnanam[1] proposed the cosecant similarity measure of neutrosophic refined sets.

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

Rest of the article was structured as follows.In Section 2, the basic definitions werebriefly presented.Section 3 deals with proposed definition and some of its properties. Section 4 contains medical diagnosis .Conclusion was given in Section 5.

PRELIMINARIES

2.1 Definition[10]

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) ofthe element $x\in X$ to the set A with the condition $^-0\le T_A(x)+I_A(x)+F_A(x)\le 3^+$

2.2 Definition[10]

Let X be a Universe, a neutrosophic refinedset on X can be defined as follows:

$$A=\{\langle x,(T_A^1(x),T_A^2(x),\ldots,T_A^p(x)),(I_A^1(x),I_A^2(x),\ldots,I_A^p(x)),(F_A^1(x),F_A^2(x),\ldots,F_A^p(x))\rangle : x\in X\}$$

where $T_A^1(x),T_A^2(x),\ldots,T_A^p(x):X\to[0,1]$ $I_A^1(x),I_A^2(x),\ldots,I_A^p(x):X\to[0,1]$ and $F_A^1(x),F_A^2(x),\ldots,F_A^p(x):X\to[0,1]$ such that $0\le T_A^j(x)+I_A^j(x)+F_A^j(x)\le 3$ for $j=1,2,\ldots,p$ for any $x\in X$, $(T_A^1(x),T_A^2(x),\ldots,T_A^p(x)),(I_A^1(x),I_A^2(x),\ldots,I_A^p(x))$ & $(F_A^1(x),F_A^2(x),\ldots,F_A^p(x))$ is the truth-membership sequence, indeterminate-membership sequence &falsity-membership sequence ofthe element x, respectively.Also, p is called the dimension of neutrosophic refined set(NRS) A.

2.3 Definition[4]

Let $A=\{\langle x,(T_A^1(x),T_A^2(x),\ldots,T_A^p(x)),(I_A^1(x),I_A^2(x),\ldots,I_A^p(x)),(F_A^1(x),F_A^2(x),\ldots,F_A^p(x))\rangle : x\in X\}$ and $B=\{\langle x,(T_B^1(x),T_B^2(x),\ldots,T_B^p(x)),(I_B^1(x),I_B^2(x),\ldots,I_B^p(x)),(F_B^1(x),F_B^2(x),\ldots,F_B^p(x))\rangle : x\in X\}$ be two neutrosophicrefined sets then $A\subseteq B\Rightarrow T_A^j(x)\le T_B^j(x), I_A^j(x)\ge I_B^j(x)$ & $F_A^j(x)\ge F_B^j(x)$ (1) for all $x\in X$

PROPOSED DEFINITION

3.1Definition

Let $A=\{\langle x,(T_A^1(x),T_A^2(x),\ldots,T_A^p(x)),(I_A^1(x),I_A^2(x),\ldots,I_A^p(x)),(F_A^1(x),F_A^2(x),\ldots,F_A^p(x))\rangle : x\in X\}$ and $B=\{\langle x,(T_B^1(x),T_B^2(x),\ldots,T_B^p(x)),(I_B^1(x),I_B^2(x),\ldots,I_B^p(x)),(F_B^1(x),F_B^2(x),\ldots,F_B^p(x))\rangle : x\in X\}$ be two neutrosophic refined sets. Then the sine logarithmic distance is defined as

$$SLD_{NRS}(A,B)=\frac{1}{p}\sum_{j=1}^{p}\left[\sum_{i=1}^{n}\sin\left(\log\left(1+\left|T_A^j(x_i)-T_B^j(x_i)\right|+\left|I_A^j(x_i)-I_B^j(x_i)\right|+\left|F_A^j(x_i)-F_B^j(x_i)\right|\right)\right)\right] \quad (2)$$

Proposition 1

(i) $SLD_{NRS}(A,B)\ge 0$

(ii) $SLD_{NRS}(A,B)=0$ if and only if $A=B$

(iii) $SLD_{NRS}(A,B)=SLD_{NRS}(B,A)$

(iv)If $A\subseteq B\subseteq C$ then $SLD_{NRS}(A,C)\ge SLD_{NRS}(A,B)$ & $SLD_{NRS}(A,C)\ge SLD_{NRS}(B,C)$

Proof

(i) The proof is straightforward

(ii) The proof is straightforward

(iii) We know that,

$$\left|T_A^j(x_i)-T_B^j(x_i)\right|=\left|T_B^j(x_i)-T_A^j(x_i)\right|$$

$$\left|I_A^j(x_i)-I_B^j(x_i)\right|=\left|I_B^j(x_i)-I_A^j(x_i)\right|$$

$$\left|F_A^j(x_i)-F_B^j(x_i)\right|=\left|F_B^j(x_i)-F_A^j(x_i)\right|$$

$$\therefore SLD_{NRS}(A,B)=\frac{1}{p}\sum_{j=1}^{p}\left[\sum_{i=1}^{n}\sin\left(\log\left(1+\left|T_A^j(x_i)-T_B^j(x_i)\right|+\left|I_A^j(x_i)-I_B^j(x_i)\right|+\left|F_A^j(x_i)-F_B^j(x_i)\right|\right)\right)\right]$$

$$=\frac{1}{p}\sum_{j=1}^{p}\left[\sum_{i=1}^{n}\sin\left(\log\left(1+\left|T_B^j(x_i)-T_A^j(x_i)\right|+\left|I_B^j(x_i)-I_A^j(x_i)\right|+\left|F_B^j(x_i)-F_A^j(x_i)\right|\right)\right)\right]$$

$$=SLD_{NRS}(B,A)$$

(iv)By (1),

$T_A^j(x_i) \le T_B^j(x_i) \le T_C^j(x_i)$

$I_A^j(x_i) \ge I_B^j(x_i) \ge I_C^j(x_i)$

$F_A^j(x_i) \ge F_B^j(x_i) \ge F_C^j(x_i)$

$(\because A \subseteq B \subseteq C)$

Hence,

$|T_A^j(x_i) - T_B^j(x_i)| \le |T_A^j(x_i) - T_C^j(x_i)|$

$|T_B^j(x_i) - T_C^j(x_i)| \le |T_A^j(x_i) - T_C^j(x_i)|$

$|I_A^j(x_i) - I_B^j(x_i)| \le |I_A^j(x_i) - I_C^j(x_i)|$

$|I_B^j(x_i) - I_C^j(x_i)| \le |I_A^j(x_i) - I_C^j(x_i)|$

$|F_A^j(x_i) - F_B^j(x_i)| \le |F_A^j(x_i) - F_C^j(x_i)|$

$|F_B^j(x_i) - F_C^j(x_i)| \le |F_A^j(x_i) - F_C^j(x_i)|$

Here, our sine logarithmic distance is an increasing function

$\therefore SLD_{NRS}(A,C) \ge SLD_{NRS}(A,B)$ & $SLD_{NRS}(A,C) \ge SLD_{NRS}(B,C)$

MEDICAL DIAGNOSIS

4.1 Medical diagnosis under neutrosophic refined environment

The steps involved in medical diagnosis problem are as follows:

Step 1: Determination of relation between patients and symptoms

Table I. Patient – Symptom relation

Q	S_1	S_2	$\cdots$	S_m
P_1	$\left\{[T_{11}^1, I_{11}^1, F_{11}^1], [T_{11}^2, I_{11}^2, F_{11}^2], \ldots, [T_{11}^p, I_{11}^p, F_{11}^p]\right\}$	$\left\{[T_{12}^1, I_{12}^1, F_{12}^1], [T_{12}^2, I_{12}^2, F_{12}^2], \ldots, [T_{12}^p, I_{12}^p, F_{12}^p]\right\}$	$\cdots$	$\left\{[T_{1m}^1, I_{1m}^1, F_{1m}^1], [T_{1m}^2, I_{1m}^2, F_{1m}^2], \ldots, [T_{1m}^p, I_{1m}^p, F_{1m}^p]\right\}$
P_2	$\left\{[T_{21}^1, I_{21}^1, F_{21}^1], [T_{21}^2, I_{21}^2, F_{21}^2], \ldots, [T_{21}^p, I_{21}^p, F_{21}^p]\right\}$	$\left\{[T_{22}^1, I_{22}^1, F_{22}^1], [T_{22}^2, I_{22}^2, F_{22}^2], \ldots, [T_{22}^p, I_{22}^p, F_{22}^p]\right\}$	$\cdots$	$\left\{[T_{2m}^1, I_{2m}^1, F_{2m}^1], [T_{2m}^2, I_{2m}^2, F_{2m}^2], \ldots, [T_{2m}^p, I_{2m}^p, F_{2m}^p]\right\}$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
P_n	$\left\{[T_{n1}^1, I_{n1}^1, F_{n1}^1], [T_{n1}^2, I_{n1}^2, F_{n1}^2], \ldots, [T_{n1}^p, I_{n1}^p, F_{n1}^p]\right\}$	$\left\{[T_{n2}^1, I_{n2}^1, F_{n2}^1], [T_{n2}^2, I_{n2}^2, F_{n2}^2], \ldots, [T_{n2}^p, I_{n2}^p, F_{n2}^p]\right\}$	$\cdots$	$\left\{[T_{nm}^1, I_{nm}^1, F_{nm}^1], [T_{nm}^2, I_{nm}^2, F_{nm}^2], \ldots, [T_{nm}^p, I_{nm}^p, F_{nm}^p]\right\}$

Step 2:Determination of relation between symptoms and diseases

Table II. Symptom – Diseaserelation

R	D_1	D_2	$\cdots$	D_p
S_1	$\langle T_{11}, I_{11}, F_{11}\rangle$	$\langle T_{12}, I_{12}, F_{12}\rangle$	$\cdots$	$\langle T_{1p}, I_{1p}, F_{1p}\rangle$
S_2	$\langle T_{21}, I_{21}, F_{21}\rangle$	$\langle T_{22}, I_{22}, F_{22}\rangle$	$\cdots$	$\langle T_{2p}, I_{2p}, F_{2p}\rangle$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
S_m	$\langle T_{m1}, I_{m1}, F_{m1}\rangle$	$\langle T_{m2}, I_{m2}, F_{m2}\rangle$	$\cdots$	$\langle T_{mp}, I_{mp}, F_{mp}\rangle$

Step 3:Determination of relation between patients and diseases

Determine the sine logarithmic distance

$$SLD_{NRS}(A,B)=\frac{1}{p}\sum_{j=1}^{p}\left[\sum_{i=1}^{n}\sin\left(\log\left(1+\left|T_A^j(x_i)-T_B^j(x_i)\right|+\left|I_A^j(x_i)-I_B^j(x_i)\right|+\left|F_A^j(x_i)-F_B^j(x_i)\right|\right)\right)\right]$$ between Table 1& Table 2

Step 4: Ranking the alternatives

Rank the alternatives in ascending order of sine logarithmic distance. Lowest value indicates the disease affecting the patient.

Step 5:End

4.2 Example on medical diagnosis [7]

Let there be four patients P={P_1, P_2, P_3, P_4} and the set of symptoms S={Temperature,Headache, Stomach pain,Cough,Chest pain}.The NeutrosophicRefined Relation $Q(P \rightarrow S)$ is given as in Table 1.Let the set of diseases D = {Viral fever, Malaria, Typhoid, Stomach problem, Chest problem}.The Neutrosophic Relation $R(S \rightarrow D)$ is given as in Table 2.

Table I. Patient-Symptom relation

Q	Temperature	Headache	Stomach pain	Cough	Chest pain
P_1	(0.8,0.1,0.1) (0.6,0.3,0.3) (0.6,0.3,0.1)	(0.6,0.1,0.3) (0.5,0.2,0.4) (0.5,0.1,0.2)	(0.2,0.8,0.0) (0.3,0.5,0.2) (0.2,0.3,0.4)	(0.6,0.1,0.3) (0.4,0.4,0.4) (0.4,0.3,0.3)	(0.1,0.6,0.3) (0.3,0.4,0.5) (0.2,0.5,0.4)
P_2	(0.0,0.8,0.2) (0.2,0.6,0.4) (0.1,0.6,0.4)	(0.4,0.4,0.2) (0.5,0.4,0.1) (0.4,0.6,0.3)	(0.6,0.1,0.3) (0.4,0.2,0.5) (0.3,0.2,0.4)	(0.1,0.7,0.2) (0.2,0.7,0.5) (0.3,0.5,0.4)	(0.1,0.8,0.1) (0.3,0.6,0.4) (0.3,0.6,0.3)
P_3	(0.8,0.1,0.1) (0.6,0.4,0.1) (0.5,0.3,0.3)	(0.8,0.1,0.1) (0.6,0.2,0.4) (0.6,0.1,0.3)	(0.0,0.6,0.4) (0.2,0.5,0.5) (0.3,0.4,0.6)	(0.2,0.7,0.1) (0.2,0.5,0.5) (0.1,0.6,0.3)	(0.0,0.5,0.5) (0.2,0.5,0.3) (0.3,0.3,0.4)
P_4	(0.6,0.1,0.3) (0.4,0.3,0.2) (0.5,0.2,0.3)	(0.5,0.4,0.1) (0.4,0.4,0.4) (0.5,0.2,0.4)	(0.3,0.4,0.3) (0.2,0.4,0.5) (0.1,0.5,0.4)	(0.7,0.2,0.1) (0.5,0.2,0.4) (0.6,0.4,0.1)	(0.3,0.4,0.3) (0.4,0.3,0.4) (0.3,0.5,0.5)

Table II. Symptom-Disease relation

R	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
Temperature	(0.6,0.3,0.3)	(0.2,0.5,0.3)	(0.2,0.6,0.4)	(0.1,0.6,0.6)	(0.1,0.6,0.4)
Headache	(0.4,0.5,0.3)	(0.2,0.6,0.4)	(0.1,0.5,0.4)	(0.2,0.4,0.6)	(0.1,0.6,0.4)
Stomach pain	(0.1,0.6,0.3)	(0.0,0.6,0.4)	(0.2,0.5,0.5)	(0.8,0.2,0.2)	(0.1,0.7,0.1)
Cough	(0.4,0.4,0.4)	(0.4,0.1,0.5)	(0.2,0.5,0.5)	(0.1,0.7,0.4)	(0.4,0.5,0.4)
Chest pain	(0.1,0.7,0.4)	(0.1,0.6,0.3)	(0.1,0.6,0.4)	(0.1,0.7,0.4)	(0.8,0.2,0.2)

Table III. Sine logarithmic distance

T	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
P_1	**0.6875**	0.9914	1.0644	1.3316	1.2460
P_2	0.9560	0.9774	**0.7498**	0.8051	1.0935
P_3	**0.8690**	1.0985	0.9348	1.2859	1.3411
P_4	**0.7537**	0.9679	1.0108	1.3557	1.2079

From Table 3, it is obvious that, if the doctor agrees, then P_1 , P_3&P_4suffers from Viral fever and P_2suffers from Typhoid.

CONCLUSION

Our proposed method is most decisive to hold the problems related to medical diagnosis quiet comfortably. In future, we will enhance this method to other types of neutrosophic sets.

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