Execution of N-Valued interval neutrosophic sets in medical diagnosis

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Abstract

In this paper, cosecant similarity measure among n-valued interval neutrosophic sets are proposed and some of its properties are discussed herein. Finally, an application of medical diagnosis is presented to find out the disease impacting the patient.

Keywords

N-valued interval neutrosophic set, cosecant similarity measure, medical diagnosis.

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 behaviour 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 some practical situations, there is the possibility of each element having different truth membership, indeterminate and false membership functions. The unique feature of n-valued interval neutrosophic 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 the best diagnosis. So, n-valued interval neutrosophic sets and their applications 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. De et al [4] presented an application of intuitionistic fuzzy set in medical diagnosis. Jun Ye [5] introduced the concept of cosine similarity measures for intuitionistic fuzzy sets. Tian Maoying [6] presented the cotangent similarity function for intuitionistic fuzzy sets. Later on, intuitionistic fuzzy sets were extended to the interval valued intuitionistic fuzzy sets. Intuitionistic fuzzy sets and interval valued intuitionistic fuzzy set scan 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 Florentin Smarandache [7] has capability to deal with uncertainty, imprecise, incomplete and inconsistent information which exists in real world from philosophical point of view. Wang *et al* [8] proposed the single valued neutrosophic set. Similarity and entropy between neutrosophic sets were proposed by Mamjumdar and Samanta [9]. Wang et al [10] proposed the set theoretic operations on an instance of neutrosophic set is called interval valued neutrosophic set which is more flexible and practical than neutrosophic set. Similarity measures between interval valued neutrosophic sets were proposed by Jun Ye [11]. Interval valued neutrosophic soft sets were introduced by Irfan Deli [12].

Sebastian and Ramakrishnan [13] studied a new concept called fuzzy multi sets (FMS), which is the generalization of multi sets. Shinoj and John [14] extended the concept of fuzzy multi sets by introducing intuitionistic fuzzy multi sets (IFMS). Rajarajeswari and Uma [15] proposed the normalized hamming similarity measure between them. However, the concepts of FMS & IFMS are not capable of dealing with indeterminacy. Shan Ye and Jun Ye[16]introduced the concept of single valued neutrosophic multi sets. Distance based similarity measures between them were introduced by Ye et al [17]. Florentin Smarandache [18] extended the classical neutrosophic logic to n-valued refined neutrosophic logic, by refining each neutrosophic component into respectively, $T_1, T_2, \ldots, T_m, I_1, I_2, \ldots, I_p \,\&\, F_1, F_2, \ldots, F_r$. Deli et al [19] studied a new concept called neutrosophic refined sets. Broumi and Deli [20] proposed the correlation measure between them. Broumi *et al* [20] generalize the concept of n-valued neutrosophic sets to the case of n-valued interval neutrosophic sets. Edward Samuel and Narmadhagnanam [21] proposed few novel methods in n-valued interval neutrosophic sets.

In this paper, using the notion of n-valued interval neutrosophic set it was provided an exemplary for medical diagnosis. In order to make this, a novel method was implemented.

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

II. PRELIMINARIES

A. Definition [10]

Let X be a space of points (objects), with a generic element in X denoted by x. An interval neutrosophic set (INS) A in X is characterized by the truth-membership function T_A, indeterminacy-membership function I_A and falsity-membership function F_A $T_A(x), I_A(x) \,\&\, F_A(x)$ are real standard or non-standard subsets of $]^-0,1^+[$. That is $T_A : X \to]^-0,1^+[$, $I_A : X \to]^-0,1^+[$, $F_A : X \to]^-0,1^+[$. There is no restriction on the sum of $T_A(x), I_A(x) \,\&\, F_A(x)$, so $^-0 \le T_A(x) + I_A(x) + F_A(x) \le 3^+$

B. Definition [20]

Let X be a universe, a n-valued interval neutrosophic set on X can be defined as follows:

$$A = \left\{ \begin{array}{l} x, \left(\left[\inf T_A^1(x), \sup T_A^1(x)\right], \left[\inf T_A^2(x), \sup T_A^2(x)\right], \ldots, \left[\inf T_A^p(x), \sup T_A^p(x)\right] \right), \\ \left(\left[\inf I_A^1(x), \sup I_A^1(x)\right], \left[\inf I_A^2(x), \sup I_A^2(x)\right], \ldots, \left[\inf I_A^p(x), \sup I_A^p(x)\right] \right), \\ \left(\left[\inf F_A^1(x), \sup F_A^1(x)\right], \left[\inf F_A^2(x), \sup F_A^2(x)\right], \ldots, \left[\inf F_A^p(x), \sup F_A^p(x)\right] \right) : x \in X \end{array} \right\}$$ where

$\inf T_A^1(x), \inf T_A^2(x), \ldots, \inf T_A^P(x), \inf I_A^1(x),$

$\inf I_A^2(x), \ldots, \inf I_A^P(x), \inf F_A^2(x), \inf F_A^2(x), \ldots, \inf F_A^P,$

$\sup T_A^1(x), \sup T_A^2(x), \ldots, \sup T_A^P(x), \sup I_A^1(x), \sup I_A^2(x), \ldots,$

$\sup I_A^P(x), \sup F_A^1(x), \sup F_A^2(x), \ldots, \sup F_A^P \in [0,1]$

such that

$0 \le \sup T_A^j(x) + \sup I_A^j(x) + \sup F_A^j(x) \le 3 \;\; \forall\, j = 1, 2, 3, \ldots, p$

C. Definition [20]

A n-valued interval neutrosophic set A is contained in the other n-valued interval neutrosophic set B , denoted by $A \subseteq B$, if and only if

$$\{\inf T_A^1(x) \le \inf T_B^1(x),\ \inf T_A^2(x) \le \inf T_B^2(x),\ \ldots, \inf T_A^p(x) \le \inf T_B^p(x),\ \sup T_A^1(x) \le \sup T_B^1(x),\ \sup T_A^2(x) \le \sup T_B^2(x), \ldots,$$
$$\sup T_A^p(x) \le \sup T_B^p(x),\ \inf I_A^1(x) \ge \inf I_B^1(x),\ \inf I_A^2(x) \ge \inf I_B^2(x), \ldots,\ \inf I_A^p(x) \ge \inf I_B^p(x),\ \sup I_A^1(x) \ge \sup I_B^1(x),$$
$$\sup I_A^2(x) \ge \sup I_B^2(x), \ldots,\ \sup I_A^p(x) \ge \sup I_B^p(x),\ \inf F_A^1(x) \ge \inf F_B^1(x),\ \inf F_A^2(x) \ge \inf F_B^2(x), \ldots,\ \inf F_A^p(x) \ge \inf F_B^p(x),$$
$$\sup F_A^1(x) \ge \sup F_B^1(x),\ \sup F_A^2(x) \ge \sup F_B^2(x), \ldots,\ \sup F_A^p(x) \ge \sup F_B^p(x) \forall x \in X\}$$

(1)

III.PROPOSED DEFINITION

A. Definition

Let $A = \left\{ \begin{array}{l} x, \left(\left[\inf T_A^1(x), \sup T_A^1(x)\right], \left[\inf T_A^2(x), \sup T_A^2(x)\right], \ldots, \left[\inf T_A^p(x), \sup T_A^p(x)\right]\right), \\ \left(\left[\inf I_A^1(x), \sup I_A^1(x)\right], \left[\inf I_A^2(x), \sup I_A^2(x)\right], \ldots, \left[\inf I_A^p(x), \sup I_A^p(x)\right]\right), \\ \left(\left[\inf F_A^1(x), \sup F_A^1(x)\right], \left[\inf F_A^2(x), \sup F_A^2(x)\right], \ldots, \left[\inf F_A^p(x), \sup F_A^p(x)\right]\right) : x \in X \end{array} \right\}$ &

$B = \left\{ \begin{array}{l} x, \left(\left[\inf T_B^1(x), \sup T_B^1(x)\right], \left[\inf T_B^2(x), \sup T_B^2(x)\right], \ldots, \left[\inf T_B^p(x), \sup T_B^p(x)\right]\right), \\ \left(\left[\inf I_B^1(x), \sup I_B^1(x)\right], \left[\inf I_B^2(x), \sup I_B^2(x)\right], \ldots, \left[\inf I_B^p(x), \sup I_B^p(x)\right]\right), \\ \left(\left[\inf F_B^1(x), \sup F_B^1(x)\right], \left[\inf F_B^2(x), \sup F_B^2(x)\right], \ldots, \left[\inf F_B^p(x), \sup F_B^p(x)\right]\right) : x \in X \end{array} \right\}$ be two n-valued interval neutrosophic sets then the cosecant similarity measure is defined as

$$CSM_{NVINS}(A, B) = \frac{1}{n+2}$$

$$\sum_{j=1}^{p}\left[\sum_{i=1}^{n}\frac{1}{10}\operatorname{cosec}\left[\frac{\pi}{24}\left[\begin{array}{l}1 + \left|\inf T_A^j(x_i) - \inf T_B^j(x_i)\right| + \left|\sup T_A^j(x_i) - \sup T_B^j(x_i)\right| + \left|\inf I_A^j(x_i) - \inf I_B^j(x_i)\right| + \\ \left|\sup I_A^j(x_i) - \sup I_B^j(x_i)\right| + \left|\inf F_A^j(x_i) - \inf F_B^j(x_i)\right| + \left|\sup F_A^j(x_i) - \sup F_B^j(x_i)\right|\end{array}\right]\right]\right] \quad (2)$$

Proposition 1

(i) $CSM_{NVINS}(A,B) > 0$

(ii) $CSM_{NVINS}(A,B) = CSM_{NVINS}(B,A)$

(iii)If $A \subseteq B \subseteq C$ then $\begin{array}{l} CSM_{NVINS}(A,C) \leq CSM_{NVINS}(A,B) \;\& \\ CSM_{NVINS}(A,C) \leq CSM_{NVINS}(B,C) \end{array}$

Proof

(i) The proof is straightforward.
(ii) The proof is straightforward
(iii) By (1),

$$\inf T_A^j(x_i) \leq \inf T_B^j(x_i) \leq \inf T_C^j(x_i)$$
$$\sup T_A^j(x_i) \leq \sup T_B^j(x_i) \leq \sup T_C^j(x_i)$$
$$\inf I_A^j(x_i) \geq \inf I_B^j(x_i) \geq \inf I_C^j(x_i)$$
$$\sup I_A^j(x_i) \geq \sup I_B^j(x_i) \geq \sup I_C^j(x_i)$$
$$\inf F_A^j(x_i) \geq \inf F_B^j(x_i) \geq \inf F_C^j(x_i)$$
$$\sup F_A^j(x_i) \geq \sup F_B^j(x_i) \geq \sup F_C^j(x_i)$$

Hence,

$$\left|\inf T_A^j(x_i) - \inf T_B^j(x_i)\right| \leq \left|\inf T_A^j(x_i) - \inf T_C^j(x_i)\right|$$
$$\left|\sup T_A^j(x_i) - \sup T_B^j(x_i)\right| \leq \left|\sup T_A^j(x_i) - \sup T_C^j(x_i)\right|$$
$$\left|\inf I_A^j(x_i) - \inf I_B^j(x_i)\right| \leq \left|\inf I_A^j(x_i) - \inf I_C^j(x_i)\right|$$
$$\left|\sup I_A^j(x_i) - \sup I_B^j(x_i)\right| \leq \left|\sup I_A^j(x_i) - \sup I_C^j(x_i)\right|$$
$$\left|\inf F_A^j(x_i) - \inf F_B^j(x_i)\right| \leq \left|\inf F_A^j(x_i) - \inf F_C^j(x_i)\right|$$
$$\left|\sup F_A^j(x_i) - \sup F_B^j(x_i)\right| \leq \left|\sup F_A^j(x_i) - \sup F_C^j(x_i)\right|$$
$$\left|\inf T_B^j(x_i) - \inf T_C^j(x_i)\right| \leq \left|\inf T_A^j(x_i) - \inf T_C^j(x_i)\right|$$
$$\left|\sup T_B^j(x_i) - \sup T_C^j(x_i)\right| \leq \left|\sup T_A^j(x_i) - \sup T_C^j(x_i)\right|$$
$$\left|\inf I_B^j(x_i) - \inf I_C^j(x_i)\right| \leq \left|\inf I_A^j(x_i) - \inf I_C^j(x_i)\right|$$
$$\left|\sup I_B^j(x_i) - \sup I_C^j(x_i)\right| \leq \left|\sup I_A^j(x_i) - \sup I_C^j(x_i)\right|$$

$$\left|\inf F_B^j(x_i) - \inf F_C^j(x_i)\right| \le \left|\inf F_A^j(x_i) - \inf F_C^j(x_i)\right|$$
$$\left|\sup F_B^j(x_i) - \sup F_C^j(x_i)\right| \le \left|\sup F_A^j(x_i) - \sup F_C^j(x_i)\right|$$

Here, the cosecant similarity measure is a decreasing function.

$\therefore CSM_{NVINS}(A,C) \le CSM_{NVINS}(A,B)$ & $CSM_{NVINS}(A,C) \le CSM_{NVINS}(B,C)$

IV. METHODOLOGY

In this section, it was presented an application of n-valued interval 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 n-valued interval neutrosophic relation from the set of patients to the symptoms. *i.e.*, $Q(P \to S)$ and R be an interval 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 n-valued interval neutrosophic sets & interval neutrosophic sets
3. Determination of diagnosis on the basis of new computation technique of n-valued interval neutrosophic sets.

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: The computation T of the relation of patients and diseases is found using (2) and are noted in Table 3.

Step 4: Finally, maximum value from Table 3 of each row were selected to find the 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 [20]

Let there be three patients $P = \langle P_1, P_2, P_3 \rangle$ and the set of symptoms S = { S_1 =Temperature, S_2 = Cough, S_3 = Throat pain, S_4 = Headache, S_5 = Body pain}.The n-valued interval neutrosophic relation $Q(P \to S)$ is given as in Table 1. Let the set of diseases D ={ D_1 =Viral fever, D_2 = Tuberculosis, D_3 =Typhoid, D_4 =Throat disease}.The interval neutrosophic relation $R(S \to D)$ is given as in Table 2.

Table 1:The relation between Patients and Symptoms (Using step1)

Q	Temperature	Cough	Throat pain	Headache	Body pain
P_1	[0.3,0.4],[0.4,0.5],[0.3,0.7] [0.0,0.3],[0.1,0.3],[0.0,0.5] [0.0,0.6],[0.4,0.5],[0.3,0.4]	[0.1,0.2],[0.3,0.6],[0.6,0.8] [0.0,0.5],[0.4,0.7],[0.4,0.5] [0.2,0.3],[0.0,0.5],[0.4,0.6]	[0.0,0.5],[0.2,0.6],[0.0,0.4] [0.3,0.4],[0.2,0.3],[0.3,0.4] [0.0,0.7],[0.3,0.7],[0.3,0.5]	[0.2,0.3],[0.3,0.5],[0.0,0.7] [0.4,0.5],[0.4,0.7],[0.3,0.6] [0.2,0.6],[0.0,0.6],[0.3,0.4]	[0.0,0.4],[0.6,0.7],[0.2,0.5] [0.2,0.4],[0.4,0.5],[0.1,0.2] [0.1,0.3],[0.1,0.3],[0.2,0.3]
P_2	[0.2,0.3],[0.4,0.5],[0.1,0.2] [0.4,0.5],[0.2,0.5],[0.0,0.3] [0.6,0.7],[0.4,0.5],[0.4,0.5]	[0.5,0.7],[0.0,0.4],[0.7,0.8] [0.6,0.7],[0.0,0.5],[0.4,0.5] [0.4,0.6],[0.2,0.7],[0.0,0.3]	[0.5,0.6],[0.0,0.6],[0.2,0.3] [0.4,0.7],[0.4,0.6],[0.3,0.4] [0.1,0.3],[0.2,0.3],[0.5,0.7]	[0.2,0.5],[0.5,0.6],[0.1,0.5] [0.2,0.3],[0.2,0.5],[0.5,0.6] [0.1,0.3],[0.3,0.4],[0.4,0.5]	[0.2,0.4],[0.4,0.6],[0.1,0.4] [0.0,0.5],[0.2,0.4],[0.5,0.6] [0.5,0.7],[0.0,0.7],[0.2,0.4]
P_3	[0.1,0.3],[0.0,0.5],[0.4,0.6] [0.1,0.2],[0.3,0.4],[0.2,0.5] [0.2,0.4],[0.4,0.5],[0.3,0.7]	[0.2,0.3],[0.0,0.7],[0.1,0.4] [0.5,0.6],[0.0,0.3],[0.3,0.5] [0.3,0.5],[0.2,0.5],[0.4,0.6]	[0.2,0.4],[0.3,0.6],[0.0,0.6] [0.4,0.5],[0.0,0.3],[0.3,0.4] [0.5,0.7],[0.4,0.6],[0.3,0.7]	[0.2,0.3],[0.5,0.6],[0.4,0.5] [0.2,0.4],[0.0,0.4],[0.2,0.7] [0.4,0.5],[0.2,0.3],[0.3,0.5]	[0.0,0.6],[0.4,0.7],[0.2,0.3] [0.2,0.3],[0.2,0.3],[0.1,0.2] [0.0,0.6],[0.2,0.4],[0.4,0.6]

Table 2:The relation among Symptoms and Diseases (Using step2)

R	Viral fever	Tuberculosis	Typhoid	Throat disease
Temperature	[0.2,0.4],[0.3,0.5],[0.3,0.7]	[0.1,0.4],[0.2,0.6],[0.6,0.7]	[0.0,0.3],[0.4,0.6],[0.0,0.2]	[0.3,0.4],[0.2,0.5],[0.0,0.6]
Cough	[0.2,0.4],[0.2,0.3],[0.0,0.5]	[0.3,0.4],[0.2,0.5],[0.7,0.8]	[0.3,0.4],[0.2,0.3],[0.1,0.2]	[0.4,0.5],[0.1,0.3],[0.0,0.5]
Throat pain	[0.0,0.4],[0.2,0.4],[0.2,0.4]	[0.0,0.2],[0.3,0.6],[0.6,0.7]	[0.1,0.2],[0.4,0.5],[0.3,0.4]	[0.2,0.4],[0.2,0.5],[0.3,0.7]
Headache	[0.4,0.7],[0.0,0.3],[0.3,0.5]	[0.1,0.2],[0.0,0.5],[0.0,0.6]	[0.3,0.4],[0.2,0.3],[0.2,0.5]	[0.0,0.3],[0.3,0.6], [0.2,0.5]
Body pain	[0.1,0.4],[0.2,0.5],[0.3,0.4]	[0.5,0.7],[0.4,0.5],[0.2,0.5]	[0.2,0.3],[0.2,0.4],[0.2,0.3]	[0.0,0.4],[0.1,0.2], [0.1,0.3]

Table 3: Cosecant similarity measure(Using step3 &step4)

T	Viral fever	Tuberculosis	Typhoid	Throat disease
P_1	**0.9054**	0.7879	0.8374	0.8514
P_2	0.7888	0.7596	0.8216	**0.8572**
P_3	**0.9243**	0.7847	0.8717	0.8929

From Table 3, it is obvious that if the doctor agrees, then P_1 & P_3 suffers from Viral fever and P_2 suffers from Throat disease.

VII. CONCLUSIONS

Our proposed method plays a vital role in handling medical diagnosis problems . In future, we will enhance these methods to other types of neutrosophic sets.

ACKNOWLEDGEMENT

We sincerely acknowledge the suggestions of the anonymous reviewers which improve the quality of this article. The input of the editor is highly appreciated.

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