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An Overview of Neutrosophic Theory in Medicine and Healthcare

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Abstract

Neutrosophic ranking studies are an important part of medicine that determines the ranks of tests, risk factors, attributes, and medical suppliers. Neutrosophic clustering in healthcare can split data into groups (called clusters) to determine usage patterns for purposes, in which objects within the same cluster have similar properties and objects of different clusters have different properties. Like neutrosophic clustering, neutrosophic classification studies are also a data mining technique. Neutrosophic pattern recognition is a machine learning process to decipher the underlying patterns in the concerned subjects. Neutrosophic time series analysis tries to find patterns and rules depending on time, neutrosophic recognition of medical images belongs to this type of study. This article comes as an attempt to review and shed light on almost all studies and subjects that used neutrosophic studies and algorithms related to medicine and healthcare for dozens of articles and authors.

Keywords: Neutrosophic logic, medical diagnosis, healthcare, neutrosophic sets, neutrosophic soft sets and lung disease diagnosis.

1. Introduction

Indeterminacy stems from real-world problems. It is well known that between the two colours white and black, there are unlimited grey colour gradients. It is the same as the infinite decimal numbers between zero and one. Also, between absolute truthiness and absolute falseness, there are many situations and logistic phrases can hold a percentage of truth with a percentage of false, as well as, when the concepts get mixed up, we will see the situation that should be true may be regarded as absolutely false and vice versa. The solver won't be able to meet all the requirements unless the solving tools are flexible and soft and cover the incompleteness, inconsistency, and indeterminate data to analyze them fairly without neglecting any part of the data.

In medicine, it is not applicable to describe medical concepts and relationships precisely. Consider the phrase (If the back pain is severe and the patient is old, then apply acupuncture to a certain point for a long time), aiming to program the above statement, we need to reformulate it as an If-Then loop regarded as a model in a computer system, so we need a mathematical interpretation for the following linguistic terms:

'' serve'', ''old'', ''certain point'', and ''long-time'', are all linguistic words that are vague and contain indeterminate boundaries. This is why the information on healthcare should be interpreted by neutrosophic methodologies.

Imperfect knowledge is unavoidable in medicine and the nature of medical data causes many uncertainties in medical decision-making, arising from a number of areas.

such as an incomplete understanding of biological mechanisms, imprecise test measurements, uncertainty about normal ranges for test results, the simultaneous presence of more than one condition, and missing information occurring in a large percentage of cases. The Romanian scholar Florentin Smarandache set up the neutrosophic sets, neutrosophic numbers, neutrosophic theory, neutrosophic logic, and neutrosophic probability in 1995 [1], he also presented hundreds of new unfathomable concepts, and theorems in neutrosophic calculus, neutrosophic probability and statistics, neutrosophic number theory, neutrosophic graph theory, neutrosophic geometry and so on, especially, in decision- making.

Maria et al. [2] used the concepts of single-valued neutrosophic sets (SVS) with a score function S of a single-valued neutrosophic function based on the truth-membership degree, indeterminacy-membership degree, and falsity membership degree, with neutrosophic statistic tool (i.e. neutrosophic frequency distribution) to development the assertive communication competencies that allow nursing professionals to keep a good relationship with their therapeutic team and the patient and avoid professional burnout.

Medicine is one of the fastest-growing fields when compared to other computer-aided technology. This fast growth, together with the vague nature the medicine, brings the need for different strategies and creative technologies such as neutrosophic logic or its combination with other artificial intelligence techniques.

All of us suffered from COVID-19, its propagation and virulence, which has constituted the second global pandemic of the XXI century, reasons why have generated social distancing as a preventive measure, Marylin et al [3] point out the uncertainties in discursive analysis using a qualitative research approach in line with the Smarandache proposal. Datamining tool orange was adapted to the neutrosophic environment, improves the social and emotional facilitated by parents strengthens the development of adaptive behaviour skills, and generates active and coherent of the special educational needs of students, strengthening their inclusive education.

Because of its ability to extend the classical Boolean logic (two-valued logic) of the computer applications, healthcare computer-aided applications employ neutrosophic logic to handle the semantics of the related domain. It compares, constraints, extends, and particularizes concepts as humans do in reasoning; it connects symbols and concepts.

This article is arranged as follows: the upcoming section (section two) has been dedicated to demonstrating neutrosophic logic, while section three is regarded as the main part entitled ʻʻ Neutrosophic Logic in Medical Domainʼʼ covering the common neutrosophic applications and techniques in medicine. As well as the uncertainty of medicine will be explained in detail in this section. The ending section will be the conclusion section.

2. Preliminaries of Neutrosophic Theory

As previously mentioned, the neutrosophic set has been presented in its current seemliness by Florentin Smarandache in 1995 [1], Huda et al [4] gave the differences between fuzzy logic and neutrosophic logic in the application of linear programming as follows:

In Fuzzy Linear Programming Problems (FLP), the optimal solution depends on a limited number of constraints, therefore, much of the information that should be collected and have a good impact on the solution is absent, this is exactly what Neutrosophic Linear Programming (NLP) provides.

Given the power of LP, one could have expected even more applications. This might be because LP requires many well-defined and precise data which involves high information costs. In real-world applications certainty, reliability, and precision of data are often illusory. Being able to deal with vague and imprecise data may greatly contribute to the diffusion and application of LP. Neutrosophic Linear Programming problems can reformulate the soft linear programming problems through three membership functions which are truth membership function, indeterminacy membership function, and falsity membership functions, while fuzzy linear programming deals with just one membership function.

We won't be unfair if we say that neutrosophic logic can be defined as the efforts of simulation of the human thinking model, which uses linguistic variables and concepts, into computer applications. In this way, digital computers can easily be able to handle linguistic variables and their degrees of membership, non-membership, and indeterminate membership rather than fuzzy or crisp systems.

2.1 Neutrosophic Sets

The neutrosophic set has a meaning that differs from the fuzzy set or intuitionistic fuzzy set, where the fuzzy set has members belonging to it partially, while the intuitionistic set has members partially belonging to it side by side with partially un-belonging to it. wherein any member can find a well belonging definition to any set in the perspective of neutrosophic theory, since any element either belongs partially to its truth membership function or belongs partially to its falsity membership function, there is another chance to belonging to an indeterminate membership function, the following examples can clearly determine the global comprehensive vision of neutrosophic thought:

Ex.1 [5]

Suppose 5 professors conduct PhD dissertations in neutrosophic statistics. Each professor has a number of graduate students, but some students are undecided about whether to pursue their dissertations in classical or neutrosophic statistics. The professors represent the clusters. One randomly selects 2 professors to interview their students about research in neutrosophic statistics. But, because some students are undecided (indeterminate) with respect to their research topic, we have a neutrosophic cluster sampling.

Ex.2 [5]

For example: tossing a coin on an irregular surface which has cracks, the coin can fall inside a crack on its edge, and thus one gets neither head, nor tail, but indeterminacy.

Ex. 3 [6]

A cloud is a neutrosophic set, because its borders are ambiguous, and each element (water drop) belongs with a neutrosophic probability to the set. (e.g. there are a kind of separated water drops, around a compact mass of water drops, that we don't know how to consider them: in or out of the cloud).

2.2 Why the Neutrosophic Set is an Essential Tool in Medical Diagnosis?

Neutrosophic sets suit the requirements of medical data representation. It is very rare that a doctor tends to diagnose/ judge the disease in definite environments. Imprecision could be due to the lack of confidence on the part of patients in reporting symptoms, or imperfection leads to doubt about the value of a variable, a decision to be taken or a conclusion to be drawn for the actual symptom. Multiple factors could lead to uncertainty like incomplete knowledge (ignorance of the patient, limited view of a system because of its complexity), stochasticity (the case of intrinsic imperfection where a typical and single value does not exist), or acquisition errors (intrinsically imperfect lab observations, the quantitative errors in measures). So, the neutrosophic technique would have indeterminate features and behaviors associated, and there would always be unanticipated happening conditions which are uncontrollable - we mean the indeterminacy plays a role as well [7].

2.3. Mathematical Representation of Neutrosophic Set

Definition2.3.1 [8]

Let X be a space of points (objects), with a generic element in X denoted by x. A neutrosophic set A in X is characterized by a truth-membership function T_A , an indeterminacy-membership function I_A and a falsity-membership function F_A. $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or non-standard subsets of $]0-,1+[$. That is:

$T_A: X \to]^{-}0, 1^{+}[$

$I_A: X \to]^{-}0, 1^{+}[$

$F_A: X \to]^{-}0, 1^{+}[$

Definition 2.3.2[8]

(Single Valued Neutrosophic Set). Let X be a space of points (objects), with a generic element in X denoted by x. A single valued neutrosophic set ($SVNS$) A in X is characterized by truth-membership function T_A, indeterminacy-membership function I_A and falsity-membership function F_A. For each point x in X, $T_A(x),\ I_A(x), F_A(x) \in [0,1]$.

2.4 Neutrosophic's Analytical Comparison to Other Logics [9]

Neutrosophic logic is a far better representation of real-world data/executions because of the following reasons:

a. Fuzzy logic though ensures multiple belongingness of a particular element to multiple classes with a varied degree but capturing of neutralities due to indeterminacy is missing, it is further limited by the fact that membership and non-membership value of an element to a particular class should sum up to 1.

b. Similarly other allied logics like Lukasiewicz logic considered three values (1, 1/2, 0), Post considered m values, etc., but all are handicapped with the constraint that values can vary between 0 and 1 only.

c. Intuitionistic fuzzy logic though deals with indeterminacy parameter related to a particular element, but this fact is still constrained with the condition that, for any element x , indeterminacy value (x) = 1 – [membership value(x) + non − membership value(x)]. There is no provision of distinguishing between relative and absolute truth/indeterminacy/falsity.

d. In a rough set, an element x on the boundary line cannot be classified as a member of a particular class nor of its complement with certainty; but can be very well described by neutrosophic logic, such that x (T, I, F) where T, I, F are standard or non-standard subsets of the nonstandard interval $]^{-}0, 1^{+}[$.

3. Neutrosophic Logic in Medical Domain

As shown below figure 1 displays the conceptual membership functions of blood sugar=normal, the neutrosophic logic would help in explicitly listing out three important components of the input values captured: truthiness, indeterminacy, and falsity.

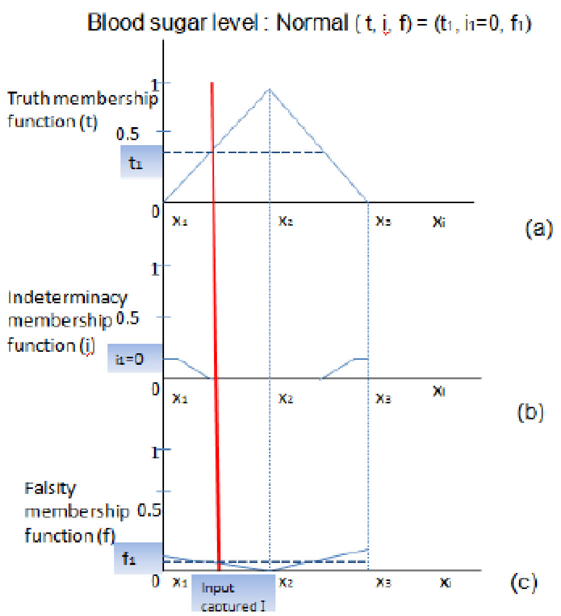

Figure 1: Neutrosophication of the input captured

Again, Figure 1 shows the conceptual membership functions of blood sugar level=normal; designed for capturing the truthiness, indeterminacy and falsity of the input record. The designing of these three membership functions would vary considerably for different parameters. Here in this figure, the captured input (I) is mapped onto the three membership functions, it is assumed that indeterminacy related to deciding whether the blood sugar is normal is high on the tapering ends of the truth membership functions designed and falsity membership function corresponds to the lab equipment error or degradation of equipment noticed which can give erroneous results. So as per Figure 1, the three-component values generated after neutrosophication of captured input I is $I(t_1, i_1 = 0, f_1)$. Figure 2 discusses the neutrosophication process applied to multiple parameters simultaneously. As it is very common in the medical domain to infer D, analysis of multiple parameters is required. Here in this figure, it is assumed that analysis of 4 input parameters is required to infer D. As clearly shown input parameter (I_1) lies in the indeterminacy zone (which could be possible due to lack of information or early onset of the disease during which input I_1 cannot be captured); input parameters (I_2 and I_3) lies in the truth zone indicating favor for D and the corresponding mapping shows I_3 favors strongly for D in comparison to I_2 as $t_1 > t_2$; input parameter I_4 contradicts the possibility of D by f_1 value.

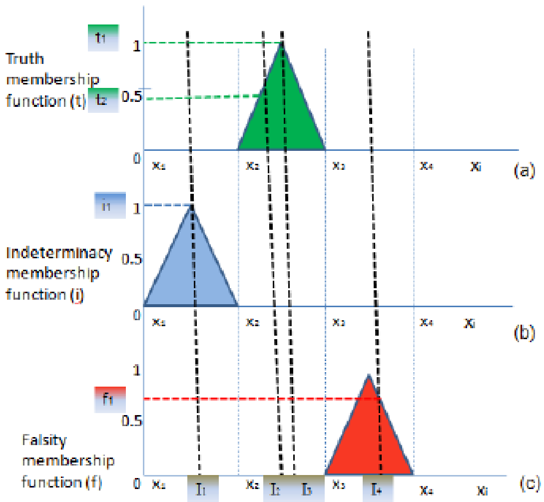

Figure 2: Neutrosophication involving multiple parameters

Fuzzy logic designs only the truth membership functions that give a description of the degree of membership value to a particular class. Contrary to fuzzy logic in which there is no provision of capturing indeterminacy corresponding to non-availability of information, or falsity functions to record the imprecision or degradation of the equipment with which input is captured, neutrosophic logic is a better representation of the medical data as it gives the clear insight of the truthiness, indeterminacy and falsity associated with the input captured. This should indeed be of considerable interest to the medical artificial intelligence community, because, as indicated above, medicine is essentially a continuous domain where the captured inputs could have uncertainty, indeterminacy and sometimes falsity associated [9].

The incorporation of neutrosophic logic in the medical models would retain the continuous behavior as displayed by the fuzzy logic. The medical domain is the field where there is indeterminacy, unknown, hidden parameters, imprecision, the high conflict between sources of information, and non-exhaustive or non-exclusive elements of the frame of discernment so neutrosophic could be applied. Similar to fuzzy systems, depending on the design of the rule base of the neutrosophic medical model, the output of such a system can be a continuous function (Sugeno model [10]) or it can be a single value output (Mamdani and Tsukamoto model [11], [12]). Generally, the continuous output function would be a better estimation of the modelled medical relationship than its underlying discrete specification. As suggested neutrosophic medical systems can be utilized for neutrosophic scores; continuous truth/indeterminate/falsity versions of conventional score schemes. The approach of incorporation of neutrosophic sets in the medical domain would lead to tabular or rule-based mapping from input to output variables effectively implementing a continuous control law. Neutrosophic qualitative simulation and, more generally, neutrosophic model-based diagnosis are promising candidates for future research. The proposed neutrosophic logic theory is not a substitute for existing fuzzy medical models, but an extension and enhancement of the classical AI approach. Due to the inherent advantages of neutrosophic sets, such systems would address medical problems more adequately as discussed in previous sections. What makes the inclusion of neutrosophic logic in the medical domain a powerful tool is its desirable properties of allowing continuity, gradation of reality, capturing of truthiness, indeterminacy, and falsity.

3.1 Miscellaneous Neutrosophic Works in Medicine

If we focused on the work of G. Shahzadi et al. [13] in medical diagnosis, we would find that they adapted and normalized the Hamming distance and Euclidean distance to be appropriate for medical diagnosis via distances between neutrosophic sets. They aimed to find an accurate diagnosis for three patients and gave the relation between neutrosophic sets for all symptoms of the $i-th$ patient from the $k-th$ diagnosis. the symptoms of the three patients were Temperature, Insulin, Blood pressure, Blood plates, Cough and finally, they were diagnosed with Diabetes, Dengue, and Tuberculosis. The readers can return to their article to see two algorithms with two different techniques, those two algorithms with fourteen tables of data enable the authors to identify that the first patient suffers from Dengue, the second patient suffers from Diabetes, and the last patient suffers from Tuberculosis. There are many other fields of the application area of neutrosophic logic in medicine, but not limited to, are as follows:

1. Managing malaria disease.
2. HIV infection cell determination.
3. Anaesthesia monitoring.
4. Image segmentation for tumours.
5. Lymph disease.
6. Monitoring and control in intensive care units.
7. Lung disease diagnosis.
8. Cancer risk prognosis.

The computer-based tools for medical decision-making help medical staff diagnose disease. One of these computer-based tools that ease medical decision-making is the neutrosophic expert system which has proven to be useful in the quantitative analysis and qualitative evaluation of medical data, by achieving the correctness of results.

The following Algorithm was used in the upcoming case study as an example published by M.N. Jafar et al [14],

Algorithm:

In the forthcoming steps, the authors describe a process used for medical diagnosis by neutrosophic soft sets (NSS), at the hypothesis that P° is a set of patients, $\check{S}$ is the set of symptoms, $D^{\sim}$ is the set of diseases.

The set of diseases related to their symptoms is obtained from the symptom-disease relation R_1.

The patient symptoms set has obtained the relation of the symptoms Q_1.

Evaluate their corresponding complement matrices $\widehat{R_2}$ and Q_2.

The relation between the patient symptoms and the disease matrices is T_1.

Compute relation T_2 called patient non-symptoms non-disease matrices.

Evaluate $\check{S}_{T_1}$ and $\check{S}_{T_2}$ neutrosophic soft sets by using the definition of (evaluation of neutrosophic soft sets).

Compute $\check{S}_k$, i.e. the higher value of the possibility of the patient suffering from that disease.

Using the above algorithm in the following case study:

Assume that the three patients P_1, P_2, P_3 in the hospital with symptoms of headache, temperature and severe pain are represented by c_1, c_2, c_3. Now consider $P^{\circ} = \{P_1, P_2, P_3\}$ represents the patients and $\check{S} = \{c_1, c_2, c_3.\}$ Shows the symptoms and $D^{\sim} = \{\tilde{d_1}, \tilde{d_2}, \tilde{d_3}\}$ shows the diseases: fever, typhoid, and malaria.

Solving the above case study using the mentioned algorithm, the authors conclude that there are the following possibilities for the patients suffering from the disease:

The patient P_1 has 0.85 possible suffering from fever, 0.9 suffering from typhoid, and 0.5 suffering from malaria. The patient P_2 has 0.9 possible suffering from fever, 0.8 possible suffering from typhoid, and 1 possible suffering from malaria which means the patient P_2 guaranteed suffering from malaria. The patient P_3 has 0.8 possible suffering from fever, 0.3 suffering from typhoid, and 0.7 suffering from malaria.

4. Conclusion

This article reviews the applications of the uncertainty mathematical tools/ neutrosophic logic in the medical domain. Dozens of papers and authors are interested in medical diagnosis, decision-making, pattern recognition studies, and performance comparison studies. The neutrosophic nature enables the computer programs' algorithms in medicine fields and healthcare to be flexible by taking into consideration all possible values including the indeterminate ones, and by making the process more robust when compared to traditional techniques with the feature of taking indeterminate data into consideration, and by efficiency by using more available data.

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