New Entropy Measure Concept for Single Value Neutrosophic Sets with Application in Medical Diagnosis

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Abstract

This study aims to propose a new entropy weight on the distance measure of single value neutrosophic set (SVNS) to analyse medical diagnosis patient's risk. Four distance measures will be integrated with three entropy weight concepts and applied to medical diagnosis. A new entropy weight measure integrated with the four distance measures are calculated using the medical data of one patient with five symptoms and five diseases. The calculated new entropy and its associated distance measures give consistent finding with the existing entropy weight measures. However, all the values are even smaller showing that the relation between patient A and disease are stronger. This evaluation and diagnosis approach is applicable to a wide variety of other resources and medical problems.

Keywords: Distance measure; Entropy; Medical diagnosis; Single value neutrosophic set

1 Introduction

Neutrosophic sets (NSS) which is a generalization of fuzzy sets and intuitionistic fuzzy set, is a very good tool in overcoming incomplete, uncertain and inconsistent information which exist in the real world [1]. NSS are characterized by membership functions of truth (T), indeterminacy (I) and falsity (F). According to [2], neutrosophic theory was recently proposed as a better alternative where fuzzy sets and fuzzy logic cannot express false membership information and intuitionistic fuzzy sets and intuitionistic fuzzy logic cannot handle information indeterminacy. This is due to the ambiguity and impreciseness of the information, which always includes opposing and neutral information. An extension of the neutrosophic sets is the SVNS. Because of the imperfection of knowledge that humans receive or observe from the outside world, all of the factors described by the SVNS are very suitable for human thinking.

The neutrosophic sets can be used in medical settings to help with decision-making. In medical diagnosis decision making, [3] used algebraic neutrosophic measures to propose a novel neutrosophic recommender system . In neutrosophic clinical decision-making system for cardiovascular illnesses have been introduced by [4] by utilizing reasonable artificial intelligence approach. The framework assists clinical specialists with early diagnosis to distinguish the danger of cardiovascular diseases where careful steps can be taken earlier. This neutrosophic system had modelled an algorithm to be used for the decision-making process and designed the time complexity in understanding way. [5] furthered the study using distance based similarity measure in order to determine the relation between patient and disease.

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Furthermore, in multi-criteria decision-making issues, the distance measure is a useful tool in order to determine the strength of relation between patient symptoms and the diseases. [6] claimed that the generalized distance and its two proposed similarity measures were proposed to demonstrate the efficacy of the existing measure methods in medical diagnosis. It is obvious that medical specialists need sufficient amount of information in making correct medical diagnosis. Unfortunately, it is common to them being provided with vast amount of information which contains unclear, inconsistent, and indeterminate information. An association between a symptom and a disease is frequently defined based on this ambiguous and contradictory data, which leads to making inaccurate medical diagnosis. Based on [6], the use of distance measure of SVNS in decision making is applied not only in medical diagnosis but as well as pattern recognition and machine learning which also include clustering analysis in uncertainty environment. Neutrosophic sets aim to improve diagnostic precision in the presence of ambiguous data, where it helps physicians in determining whether or not a patient has any diseases. The decision in diagnosing a patient as having a certain disease is a challenging task due to the difficulty in classifying diseases by varieties set of symptoms. In the past few years, the distance, similarity, inclusion, and information entropy measures for SVNSs became very important topics to discuss. Therefore, there are a large number of researchers who gave focus on their studies considering all the mentioned measures. [7] discussed numerical example in demonstrating the efficacy of using distance based similarity measure. Meanwhile, Hausdorff distance, Hamming distance and Euclidean distance are found to be widely used distance measures in many areas including medical image segmentation methods [8].

Nowadays, researchers recognized the importance of entropy integrated with the distance or similarity measures in application of real world problem. [9, 10] introduced some entropy concepts and integrated them with distance similarity measures for SVNS and interval-valued neutrosophic sets (IVNS), respectively. However, many entropy measures for SVNS are very complicated and unacceptable in the intuitive sense. In order to overcome this weakness in the existing entropy measures, Qin and Wang [11] discussed an applications in multi-attribute decision making using SVNS similarity and entropy measures. They introduced an axiomatic definitions of similarity and entropy for single-valued neutrosophic values (SVNV) with respect to a new type of inclusion relation between SVNV.

The distance and entropy measure are very important in calculating the degree of relation and fuzziness of a neutrosophic set, and a lot of work as mentioned above has been contributed to the literature by various researchers.Therefore, motivated by the advantages of the entropy measures of different extensions of neutrosophic sets, in this paper we propose a new entropy measure integrated with four distance measures for SVNSs. In this approach, we first put forward a useful entropy measure for SVNSs which is completely different from the existing ones and then propose an entropy measure formula based on four existing distance measures which are Euclidean distance, Hamming distance, Hausdroff distance and [5]. Furthermore, a useful comparison of the proposed entropy measure with the existing entropy measures formulae is performed to avoid any inconsistency in the proposed approach. In order to ensure the practicality and effectiveness of the proposed approach, we finally apply this approach to be solved in medical problem. Obviously, weight entropy concept is an important technique because it can capture the implied interactions among patients and symptoms, and indicate the grade of each symptoms.

2 Preliminaries

Some of the preliminary notions that require to be understand for fully assist from this article is recall in this section.

2.1 Single Valued Neutrosophic Set

A neutrosophic set that is particularly suitable for use in real scientific and engineering problems is known as the (SVNS).

Definition 2.1.1 [12]. Let X be a points space with a generic element in X denoted by x. A SVNS A in X is characterized by a membership functions of truth $T_A(x)$, indeterminacy, $I_A(x)$, and falsity $F_A(x)$. Here $[T_A(x), I_A(x), F_A(x)]$ are real subsets of $[0, 1]$.

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$$A = \{<x, T_A(x), I_A(x), F_A(x)>|x \in X\} \tag{1}$$

2.2 Distance Measure of Neutrosophic set

Definition 2.2.1 [13]. Normalized Hamming distance measure $d_{M1}(A,B)$ operator between neutrosophic set A and B is defined as:

$$d_{M1}(A,B) = |T_A(x_i) - T_B(x_i)| + |I_A(x_i) - I_B(x_i)| + |F_A(x_I) - F_B(x_i)|$$

$$d_M(A,B) = 1/3n \sum_{i=1}^{n} d_{M1}(A,B) \tag{2}$$

Definition 2.2.2 [13]. Normalized Euclidean distance measured $d_{E1}(A,B)$ operator between neutrosophic set A and B is defined as follows:

$$d_{E1}(A,B) = ((T_A(x_i) - T_B(x_i))^2 + (I_A(x_i) - I_B(x_i))^2 + (F_A(x_i) - F_B(x_i))^2)$$

$$d_E(A,B) = \sqrt{1/3n \sum_{i=1}^{n} d_{E1}(A,B)} \tag{3}$$

Definition 2.2.3 [13]. An extended Hausdorff Distance $d_{H1}(A,B)$ operator between neutrosophic set A and B is defined as follows:

$$d_{H1}(A,B) = \max[|T_A(x_i) - T_B(x_i)|, |I_A(x_i) - I_B(x_i)|, |F_A(x_I) - F_B(x_i)|$$

$$d_H(A,B) = 1/n \sum_{i=1}^{n} d_{H1}(A,B) \tag{4}$$

Definition 2.2.4 [5]. Mustapha et al [5] proposed a distance measure $d_{N1}(A,B)$ between neutrosophic set A and B is defined as follows:

$$d_{N1}(A,B) = \sum_{i=1}^{n} \frac{sin\{\frac{\pi}{10}|T_A(x_i) - T_B(x_i)|\} + sin\{\frac{\pi}{10}|I_A(x_i) - I_B(x_i)|\} + sin\{\frac{\pi}{10}|F_A(x_i) - F_B(x_i)|\}}{1 + sin\{\frac{\pi}{10}|T_A(x_i) - T_B(x_i)|\} + sin\{\frac{\pi}{10}|I_A(x_i) - I_B(x_i)|\} + sin\{\frac{\pi}{10}|F_A(x_i) - F_B(x_i)|\}}$$

$$d_N(A,B) = \frac{2}{n} \sum_{i=1}^{n} d_{N1}(A,B) \tag{5}$$

Proposition 1: The distance measures for neutrosophic set $d(A,B)$ in equations (2-5) satisfies the following properties:

(C1) $0 \leq d(A,B) \leq 1$;
(C2) $d(A,B) = 0$ if and only if $A = B$; $d_N(A,B) = 1$ if and only if for $A = B$;
(C3) $d(A,B) = d(B,A)$;
(C4) $d(A,C) \leq d(A,B)$ and $d(A,C) \leq d(B,C)$ if C is neutrosophic set in X and $A \subseteq B \subseteq C$.
All the proof of the proposition are shown in [12-13].

3 Entropy Weight Measure Concept of SVNS

The weight of an index is essential for the multi-index comprehensive evaluation model. The entropy weight method could fully use the inherent information of indexes and avoid subjectivity effectively using the expert scoring method, resulting in more objective outcomes [13].

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3.1 Existing entropy measures

Definition 3.1.1 Entropy measures introduced by Thao and Smarandache [9]

$$E_T(A) = 1 - \frac{1}{n}\sum_{i=1}^{n} \frac{|T_A(x_i) - 0.5| + |F_A(x_i) - 0.5| + I_A(x_i) - 0.5| + |I_A^c(x_i) - 0.5|}{2} \tag{6}$$

where $I_A^c(x_i) = (1 - I_A(x_i))$.

Definition 3.1.2 Entropy measures introduced bu Ye and Du [10]

$$E_Y(A) = 1 - 2\{\frac{1}{3n}\sum_{i=1}^{n} |T_A(x_i) - 0.5|^2 + |I_A(x_i) - 0.5|^2 + |F_A(x_i) - 0.5|^2\}^{\frac{1}{2}}. \tag{7}$$

Proposition 2: An entropy on SVNS(X) is a function $E(A) : SVNS(X) \in [0, 1]$ satisfying the following conditions:
(C1) $E(A) = 0$ if A is a crisp set, i.e. $A_i = (T_A(x_i), I_A(x_i), F_A(x_i)) = (1, 0, 0)$ or $A_i = (T_A(x_i), I_A(x_i), F_A(x_i)) = (0, 0, 1)$ for all $x_i \in X$;
(C2) $E(A) = 1$ if $A = \{(x_i, 0.5, 0.5, 0.5)|x_i \in X\}$
(C3) $E(A) = E(A^C)$, for all $A \in SVNS(X)$;
(C4) $E(A) \leq E(B)$ if either $T_A(x_i) \leq T_B(x_i), I_A(x_i) \leq I_B(x_i), F_A(x_i) \leq F_B(x_i)$ when max$(T_B(x_i), I_B(x_i), F_B(x_i)) \leq 0.5$ or
$T_A(x_i) \geq T_B(x_i), I_A(x_i) \geq I_B(x_i), F_A(x_i) \geq F_B(x_i)$ when min$(T_B(x_i), I_B(x_i), F_B(x_i)) \geq 0.5$.

3.2 New Entropy Measure Concept

In this section, we will introduce the new entropy measure concept of a SVNS.

Definition 3.2.1 Let $A = \{A_i = (T_A(x_i), I_A(x_i), F_A(x_i))|x_i \in X\}$ be a SVNS set on X. We define

$$E_s(A) = \frac{4}{n}\sum_{i=1}^{n} \frac{\min(T_A(x_i), F_A(x_i)), I_A(x_i), I_A^c(x_i))}{(T_A + F_A)(|I_A - I_A^c| + 2)} \tag{8}$$

where $I_A^c(x_i) = (1 - I_A(x_i))$.

Proof
(C1) If $(T_A(x_i), I_A(x_i), F_A(x_i)) \in [0, 1]$ for all $i = 1, 2, ..., n$, then
min$(T_A(x_i), I_A(x_i), F_A(x_i), I_A^C(x_i)) = 0 \rightarrow min(\mathrm{T}_A(x_i), I_A(x_i), F_A(x_i), 1 - I_A(x_i)) = 0$.
It implies that $E_s(A) = 0$ for all $i = 1, 2, ..., n$.
So that

$$E_s(A) = \frac{4}{n}\sum_{i=1}^{n} \frac{\min(T_A(x_i), F_A(x_i)), I_A(x_i), I_A^c(x_i))}{(T_A + F_A)(|I_A - I_A^c| + 2)} = 0.$$

(C2) If $A = (x_i, 0.5, 0.5, 0.5)|x_i \in X$ then $E(A) = 1$.
It implies that

$$E_s(A) = \frac{4}{n}\sum_{i=1}^{n} \frac{\min(T_A(x_i), F_A(x_i)), I_A(x_i), I_A^c(x_i))}{(T_A + F_A)(|I_A - I_A^c| + 2)} = 1$$

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(C3) It is easy to verify that $E_s(A) = E_s(A^C)$, for all $A \in SVNS(X)$;
$E_s(A^C) = E_s(A)$, for all $A \in SVNS(X)$;

$$\begin{aligned} E_s(A^C) &= \frac{4}{n}\sum_{i=1}^{n} \frac{\min(T_{A^C}(x_i), F_{A^C}(x_i)), I_{A^C}(x_i), I_A(x_i))}{(T_{A^C} + F_{A^C})(|I_{A^C} - I_A| + 2)} \\ &= \frac{4}{n}\sum_{i=1}^{n} \frac{\min(F_A(x_i), T_A(x_i)), (1 - I_A(x_i)), I_A(x_i))}{(T_A + F_A)(|(1 - I_A) - I_A| + 2)} \\ &= \frac{4}{n}\sum_{i=1}^{n} \frac{\min(T_A(x_i), F_A(x_i)), I_A(x_i), I_A^c(x_i))}{(T_A + F_A)(|I_A - I_{A^c}| + 2)} \end{aligned}$$

(C4) For all $i = 1, 2, ..., n$ $E_s(A) \leq E_s(B)$, we have:
If $T_A(x_i) \geq T_B(x_i), I_A(x_i) \geq I_B(x_i), F_A(x_i) \geq F_B(x_i)$ when $\min(T_B(x_i), I_B(x_i), F_B(x_i)) \geq 0.5$, then $I_{A^C}(x_i) \leq I_{B^C}(x_i) \leq 0.5$.
So that $\min(T_A(x_i), I_A(x_i), F_A(x_i), I_{A^C}(x_i)) \leq \min(T_B(x_i), I_B(x_i), F_B(x_i), I_{B^C}(x_i))$ and $(T_A + F_A)(I_A + I_{A^C}) \geq (T_B + F_B)(I_B + I_{B^C})$. We get $E_s(A) \leq E_s(B)$.

4 Solution Procedures

In this study, there are several steps to analyze the medical diagnosis by using two existing entropy [9-10] and new entropy measure as in equation (8) integrated with four exisiting distance measures (equations (3-5)). The steps below are taken to achieve the objective.

4.1 STEP 1 : Formulate entropy measure; $E(A)$

Two existing entropy [9-10] and the new entropy measure as given in equation (8) are used to formulate the entropy measure for diseases and symptoms relation as shown in table (2).

4.2 STEP 2 : Data collection

This study uses secondary data as reported in [14]. Consider a medical diagnosis decision-making dilemma; suppose a set of diagnoses exists such that Q = [Q_1 (viral fever), Q_2 (malaria), Q_3 (typhoid), Q_4 (gastritis), Q_5 (stenocardia)] and a set of symptoms S = [S_1 (fever), S_2 (headache), S_3 (stomach pain), S_4 (cough), S_5 (chest pain)]. Assume that Patient A has all the symptoms in the process of diagnosis. The SVNS data are given in table 1 and table 2.

Table 1: The relation between patient and the symptoms for SVNS decision information

Q_1	Q_2	Q_3	Q_4	Q_5
(0.8, 0.2, 0.1)	(0.6,0.3,0.1)	(0.2,0.1,0.8)	(0.6,0.5,0.1)	(0.1,0.4,0.6)

Table 2: The relation between diagnosis and the symptoms for SVNS decision information

	Q_1	Q_2	Q_3	Q_4	Q_5
$S1$	(0.4,0.6,0.0)	(0.3,0.2,0.5)	(0.1,0.3,0.7)	(0.4,0.3,0.3)	(0.1,0.2,0.7)
$S2$	(0.7,0.3,0.0)	(0.2,0.2,0.6)	(0.0,0.1,0.9)	(0.7,0.3,0.0)	(0.1,0.1,0.8)
$S3$	(0.3,0.4,0.3)	(0.6,0.3,0.1)	(0.2,0.1,0.7)	(0.2,0.2,0.6)	(0.1,0.0,0.9)
$S4$	(0.1,0.2,0.7)	(0.2,0.4,0.4)	(0.8,0.2,0.0)	(0.2,0.1,0.7)	(0.2,0.1,0.7)
$S5$	(0.1,0.1,0.8)	(0.0,0.2,0.8)	(0.2,0.0,0.8)	(0.2,0.0,0.8)	(0.8,0.1,0.1)

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4.3 STEP 3: Apply distance measure

The four distance measures as defined in equations (2-5) are calculated in determining the distance measures of the association between symptoms and diseases, patients and symptoms using the data collected in step 2.

4.4 STEP 4: Compute Entropy Weight Based on Four Distance Measures

Next, calculate the value of distance multiplied by weight to determine the entropy weight as discussed in step 1. The results are compared with the existing entropy weight formula.

It is also noticed that $E_s \in [0,1]$ and the entropy weight of the jth attribute w_j is expressed as follow:

$$w_j = \frac{1 - E_s}{\sum_{j=1}^{n} 1 - E_s} \tag{9}$$

The entropy weight of distance measure for the four distances are shown as below.

Entropy weight of Hausdorff distance:

$$d_{Hj} = 1/n \sum_{j=1}^{n} w_j d_{H1} \tag{10}$$

Entropy weight of Hamming distance:

$$d_{Mj} = 1/3n \sum_{j=1}^{n} w_j d_{M1} \tag{11}$$

Entropy weight of Euclidean distance:

$$d_{Ej} = \sqrt{\sum_{j=1}^{n} w_j d_{E1}} \tag{12}$$

Entropy weight of Mustapha et al[5] distance:

$$d_{Nj} = \sum_{j=1}^{n} w_j d_N \tag{13}$$

Then, we able to determine whether the patients' symptoms are close to the diseases based on the results in steps 3 and 4. If the distance measure is less than 0.5, the patient is thought to be suffering from the disease; if the distance value is greater than 0.5, the patient is thought not to be suffering from the illness.

5 Results and Discussion

This section presents the findings based on a case study of patient A with five symptoms of a medical ailments. The entropy weight method is a weighting method that is commonly used in decision-making to measure dispersion value. A small entropy weight value indicates that the patient is more likely to be diagnosed with that condition.

Table 3 depicts the results of comparison between the existing weight entropy values of SVNS with the new entropy. As can be seen in table 3, the highest weight entropy values for these three formulae are $S3$ which is

Table 3: Various Weight Entropy values of SVNS

SYMPTOM	Thao & Smarandache [9]	Ye & Du [10]	Present Study
$S1$	0.270833333	0.236932076	0.201247453
$S2$	0.1875	0.186206162	0.19952122
$S3$	**0.29166667**	**0.236932076**	**0.201969333**
$S4$	0.104166667	0.167536278	0.198297163
$S5$	0.14583333	0.172393408	0.19896483

Table 4: Comparative Results of Various Entropy with Distance Measure for Patient A

Entropy	DISEASE	HAMMING DISTANCE	HAUSDORFF DISTANCE	EUCLIDEAN DISTANCE	Mustapha et al[5] DISTANCE
Without entropy measure	$Q1$	0.2	0.28	0.233809	0.310704
	$Q2$	**0.166667**	**0.26**	**0.2144761**	**0.263165**
	$Q3$	0.193333	0.3	0.2695676	0.28143
	$Q4$	0.366667	0.56	0.4404543	0.499153
	$Q5$	0.4066667	0.58	0.4892171	0.522241
Thao & Smarandache [9]	$Q1$	0.04111	0.05833	0.108141	0.063522
	$Q2$	**0.03139**	**0.04875**	**0.091894**	0.049821
	$Q3$	0.03139	0.055	0.109798	**0.049264**
	$Q4$	0.07722	0.120833	0.209828	0.104068
	$Q5$	0.07222	0.105	0.207699	0.093383
Ye & Du [10]	$Q1$	0.04061	0.05693	0.106314	0.062924
	$Q2$	**0.03211**	**0.04988**	**0.09296**	**0.0509144**
	$Q3$	0.03724	0.05898	0.117593	0.054451
	$Q4$	0.07554	0.11642	0.203633	0.1022391
	$Q5$	0.07776	0.11157	0.214622	0.100076
New entropy measure	Q1	0.04001	0.05603	0.1046	0.062156
	$Q2$	**0.03329**	**0.05193**	**0.0958**	**0.052566**
	$Q3$	0.03857	0.05991	0.1204	0.056159
	$Q4$	0.07342	0.11218	0.1973	0.099924
	$Q5$	0.08114	0.11576	0.2185	0.104214

stomach problem. Hence, it is considered as the main symptom influencing the disease. The results are also consistent with the existing entropy.

The four distance measures integrated with new entropy concepts discussed in section 4 are calculated and displayed in table 4. A higher weight entropy value will influence the values of distance measure between patients and diseases. Table 4 depicts the comparative results of new entropy for distance measure for a patient. The data is collected from [14]. The results indicate that the patient is more likely to be suffering from a specific condition especially for the closest value to zero. It shows consistent results with [14].

As can be seen from table 4, the results of distance measures without and with entropy determine the same disease for a patient A which is malaria. Meanwhile, the values of distance measure are smaller and closer to zero for the existing and new entropy. This indicates that when the values of distance close to zero, the relation between patient and disease are very strong. All the distance values shown in table 4 are then being displayed in figure 1 for better illustration.

In figure 1, the use of entropy weight gives more consistent results because persistent distance values are observed evidently. Further, an irrefutable conclusion can be made as the lowest distance value for each distance measure in all the four figures is identified as malaria disease. Hence, with high degree of certainty, we can conclude that patient A was likely to suffer from malaria disease.

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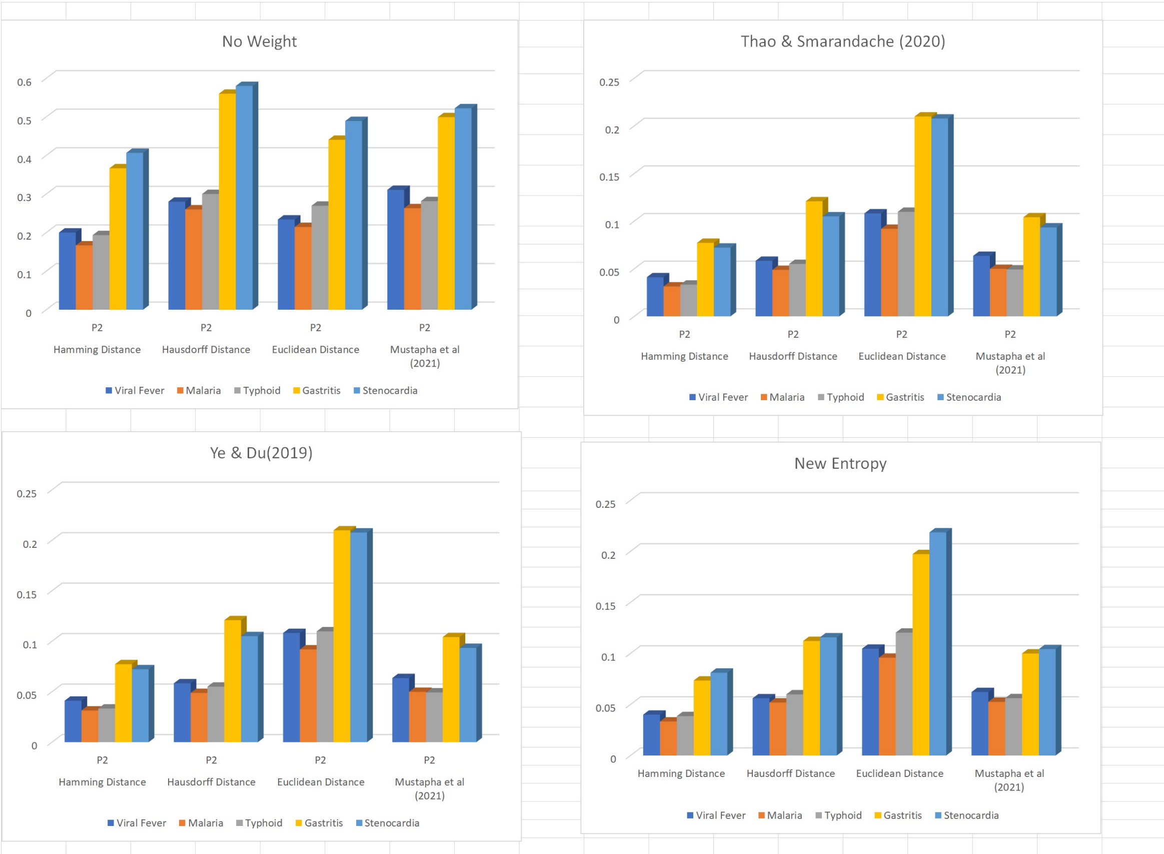

Figure 1: Distance Measure for a Patient of Medical Diagnosis with and without Entropy Weight

6 Conclusions

The distance measure is generally utilized in different models of decision-making issues and reliable with the associated similarity measure for the existing distance measures. To achieve more accurate results, we use the entropy weight method to measure the dispersion value in making decision. The entropy is highlighted as an important tool in reducing the fuzziness on data set. The higher level of differentiation and the more information can be obtained when the level of dispersion is greater. This study proposed a new entropy formula that can help in finding the distance measures between patients and diseases. We implement the weight entropy with Hamming, Hausdorff, Euclidean and Mustapha et al[5] distance measures for single value neutrosophic sets in medical diagnosis. Based on results obtained, we can conclude that the model with entropy weight is more consistent and accurate in making decision. In a future study, it is suggested that additional significant symptoms and other distance or similarity measures can be considered to increase the accuracy level in diagnosing a patient with any related medical diagnosis. Furthermore, it is suggested that using entropy of distance measures of other neutrosophic set such as multiset and refined neutrosophic sets can be used to overcome the limitation of distance measures.

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