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Introduction to Image Processing via Neutrosophic Techniques

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Abstract. This paper is an attempt of proposing the processing approach of neutrosophic technique in image processing. As neutrosophic sets is a suitable tool to cope with imperfectly defined images, the properties, basic operations distance measure, entropy measures, of the neutrosophic sets method are presented here. İn this paper we, introduce the distances between neutrosophic sets: the Hamming distance, the normalized Hamming distance, the Euclidean distance and normalized Euclidean distance. We will extend the concepts of distances to the case of neutrosophic hesitancy degree. Entropy plays an important role in image processing. In our further considertions on entropy for neutrosophic sets the concept of cardinality of a neutrosophic set will also be useful. Possible applications to image processing are touched upon.

Keywords: Neutrosophic sets; Hamming distance; Euclidean distance; Normalized Euclidean distance; Image processing.

1. Introduction

Since the world is full of indeterminacy, the neutrosophics found their place into contemporary research. Smarandache [9, 10] and Salama et al [4, 5, 6, 7, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 45]. Entropy plays an important role in image processing. İn this paper we, introduce the distances between neutrosophic sets: the Hamming distance. İn this paper we, introduce the distances between neutrosophic sets: the Hamming distance, The normalized Hamming distance, the Euclidean distance and normalized Euclidean distance. We will extend the concepts of distances to the case of neutrosophic hesitancy degree. In our further considertions on entropy for neutrosophic sets the concept of cardinality of a neutrosophic set will also be useful.

2. Terminologies

Neutrosophy has laid the foundation for a whole family of new mathematical theories generalizing both their classical and fuzzy counterparts [1, 2, 3, 11, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 46] such as a neutrosophic set theory. We recollect some relevant basic preliminaries, and in particular, the work of Smarandache in [9, 10] and Salama et al. [4, 5, 6, 7, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 45]. Smarandache introduced the neutrosophic components T, I, F which represent the membership, indeterminacy, and non-membership values respectively, where $\left]0^-,1^+\right[$ is nonstandard unit interval. Salama et al. introduced the following:

Let X be a non-empty fixed set. A neutrosophic set A is an object having the form $A=\langle \mu_A(x),\sigma_A(x),\nu_A(x)\rangle$ where $\mu_A(x),\sigma_A(x)$ and $\nu_A(x)$ which represent the degree of member ship function (namely $\mu_A(x)$), the degree of indeterminacy (namely $\sigma_A(x)$), and the degree of non-member ship (namely $\nu_A(x)$) respectively of each element $x\in X$ to the set A where

$0^- \le \mu_A(x), \sigma_A(x), \nu_A(x) \le 1^+$ and

$0^- \le \mu_A(x) + \sigma_A(x) + \nu_A(x) \le 3^+$ .Smarandache introduced the following: Let T, I,F be real standard or nonstandard subsets of $\left]0^-,1^+\right[$, with

Sup_T=t_sup, inf_T=t_inf
Sup_I=i_sup, inf_I=i_inf
Sup_F=f_sup, inf_F=f_inf
n-sup=t_sup+i_sup+f_sup
n-inf=t_inf+i_inf+f_inf,
T, I, F are called neutrosophic components

3. Distances Betoween Neutrosophic Sets

We will now extend the concepts of distances presented in [11] to the case of neutrosophic sets.

Definition 3.1

Let $A = \{(\mu_A(x), \nu_A(x), \gamma_A(x)), x \in X\}$ and $B = \{(\mu_B(x), \nu_B(x), \gamma_B(x)), x \in X\}$ in $X = \{x_1, x_2, x_3, ..., x_n\}$ then

i) The Hamming distance is equal to

$$d_{Ns}(A,B) = \sum_{i=1}^{n} \left(\left|\mu_A(x_i) - \mu_B(x_i)\right| + \left|\nu_A(x_i) - \nu_B(x_i)\right| + \left|\gamma_A(x_i) - \gamma_B(x_i)\right| \right)$$
.

ii) The Euclidean distance is equal to

$$e_{Ns}(A,B) = \sqrt{\sum_{i=1}^{n} \left((\mu_A(x_i) - \mu_B(x_i))^2 + (\nu_A(x_i) - \nu_B(x_i))^2 + (\gamma_A(x_i) - \gamma_B(x_i))^2 \right)}$$

iii) The normalized Hamming distance is equal to

$$NH_{Ns}(A,B) = \frac{1}{2n} \sum_{i=1}^{n} \left(\left|\mu_A(x_i) - \mu_B(x_i)\right| + \left|\nu_A(x_i) - \nu_B(x_i)\right| + \left|\gamma_A(x_i) - \gamma_B(x_i)\right| \right)$$

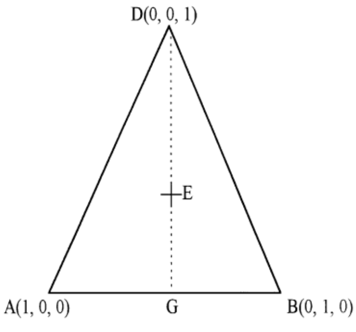
iv) The normalized Euclidean distance is equal to

$$NE_{Ns}(A,B) = \sqrt{\frac{1}{2n} \sum_{i=1}^{n} \left((\mu_A(x_i) - \mu_B(x_i))^2 + (\nu_A(x_i) - \nu_B(x_i))^2 + (\gamma_A(x_i) - \gamma_B(x_i))^2 \right)}$$

Example 3.1

Let us consider for simplicity degenrated neutrosophic sets A, B, D, G, F in $X = \{a\}$. A full description of each neutrosophic set i.e. $A = \{(\mu_A(x), \nu_A(x), \gamma_A(x)), a \in X\}$, may be exemplified by $A = \{\langle 1,0,0 \rangle, a \in X\}$, $B = \{\langle 0,1,0 \rangle, a \in X\}$,
$D = \{\langle 0,0,1 \rangle, a \in X\}$, $G = \{\langle 0.5,0.5,0 \rangle, a \in X\}$,
$E = \{\langle 0.25,0.25,0.0.5 \rangle, a \in X\}$, .

Let us calculate four distances between the above neutrosophic sets using i), ii), iii) and iv) formulas ,



(Fig.1) A geometrical interpretation of the neutrosophic considered in Example 5.1 .

We obtain $e_{Ns}(A,D) = \frac{1}{2}$, $e_{Ns}(B,D) = \frac{1}{2}$,
$e_{Ns}(A,B) = \frac{1}{2}$, $e_{Ns}(A,G) = \frac{1}{2}$, $e_{Ns}(B,G) = \frac{1}{2}$,
$e_{Ns}(E,G) = \frac{1}{4}$, $e_{Ns}(D,G) = \frac{1}{4}$, $NE_{Ns}(A,B) = 1$,
$NE_{Ns}(A,D) = 1$, $NE_{Ns}(B,D) = 1$, $NE_{Ns}(A,G) = \frac{1}{2}$,
$NE_{Ns}(B,G) = \frac{1}{2}$, $NE_{Ns}(B,G) = \frac{1}{2}$, $NE_{Ns}(E,G) = \frac{\sqrt{3}}{4}$, a
nd $NE_{Ns}(D,G) = \frac{\sqrt{3}}{2}$,

From the above results the triangle ABD (Fig.1) has edges equal to $\sqrt{2}$ and
$e_{Ns}(A,D) = e_{Ns}(B,D) = e_{Ns}(A,B) = \frac{1}{2}$ and
$NE_{Ns}(A,B) = NE_{Ns}(A,D) = NE_{Ns}(B,D) =$
$2NE_{Ns}(A,G) = 2NE_{Ns}(B,G) = 1$, and $NE_{Ns}(E,G)$ is equal to half of the height of triangle with all edges equal to $\sqrt{2}$ multiplied by, $\frac{1}{\sqrt{2}}$ i.e. $\frac{\sqrt{3}}{4}$.

Example 3.2

Let us consider the following neutrosophic sets A and B in $X = \{a, b, c, d, e\}$. ,

$A = \{\langle 0.5,0.3,0.2 \rangle, \langle 0.2,0.6,0.2 \rangle, \langle 0.3,0.2,0.5 \rangle, \langle 0.2,0.2,0.6 \rangle, \langle 1,0,0 \rangle\}$
$B = \{\langle 0.2,0.6,0.2 \rangle, \langle 0.3,0.2,0.5 \rangle, \langle 0.5,0.2,0.3 \rangle, \langle 0.9,0,0.1 \rangle, \langle 0,0,0 \rangle\}$

.Then
$d_{Ns}(A,B) = 3$, $NH_{Ns}(A,B) = 0.43$, $e_{Ns}(A,B) = 1.49$ and $NE_{Ns}(A,B) = 0.55$.

Remark 3.1

Clearly these distances satisfy the conditions of metric space.

Remark 3.2

It is easy to notice that for formulas i), ii), iii) and iv) the following is valid:

a) $0 \le d_{Ns}(A,B) \le n$
b) $0 \le NH_{Ns}(A,B) \le 1$
c) $0 \le e_{Ns}(A,B) \le \sqrt{n}$
d) $0 \le NE_{Ns}(A,B) \le 1$.

This representation of a neutrosophic set (Fig. 2) will be a point of departure for neutrosophic crisp distances, and entropy of neutrosophic sets.

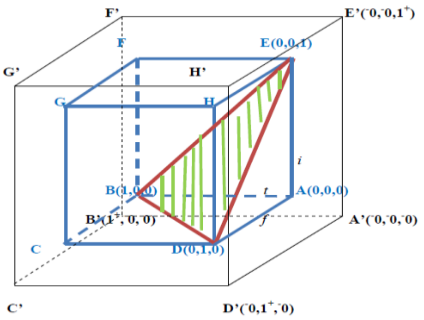


Fig. 2. A three-dimension representation of a neutrosophic set[9, 10].

4. Hesitancy Degree and Cardinality for Neutrosophic Sets

We will now extend the concepts of distances to the case of neutrosophic hesitancy degree. By taking into account the four parameters characterization of neutrosophic sets i.e. $A=\{<\mu_A(x),\nu_A(x),\gamma_A(x),\pi_A(x)>, x\in X\}$

Definition4.1

Let $A=\{(\mu_A(x),\nu_A(x),\gamma_A(x)), x\in X\}$ and $B=\{(\mu_B(x),\nu_B(x),\gamma_B(x)), x\in X\}$ on $X=\{x_1,x_2,x_3,...,x_n\}$

For a neutrosophic set $A=\{(\mu_A(x),\nu_A(x),\gamma_A(x)), x\in X\}$ in X, we call $\pi_A(x)=3-\mu_A(x)-\nu_A(x)-\gamma_A(x)$, the neutrosophic index of x in A. İt is a hesitancy degree of x to A it is obvtous that $0\le\pi_A(x)\le 3$.

Definition 4.2

Let $A=\{(\mu_A(x),\nu_A(x),\gamma_A(x)), x\in X\}$ and $B=\{(\mu_B(x),\nu_B(x),\gamma_B(x)), x\in X\}$ in $X=\{x_1,x_2,x_3,...,x_n\}$ then

i) The Hamming distance is equal to

$$d_{Ns}(A,B)=\sum_{i=1}^{n}\left(\left|\mu_A(x_i)-\mu_B(x_i)\right|+\left|\nu_A(x_i)-\nu_B(x_i)\right|+\left|\gamma_A(x_i)-\gamma_B(x_i)\right|+\left|\pi_A(x_i)-\pi_B(x_i)\right|\right)$$

. Taking into account that

$$\pi_A(x_i)=3-\mu_A(x_i)-\nu_A(x_i)-\gamma_A(x_i)$$ and

$$\pi_B(x_i)=3-\mu_B(x_i)-\nu_B(x_i)-\gamma_B(x_i)$$

we have

$$\left|\pi_A(x_i)-\pi_B(x_i)\right|=\left|3-\mu_A(x_i)-\nu_A(x_i)-\gamma_A(x_i)-3+\mu_A(x_i)+\nu_B(x_i)+\gamma_B(x_i)\right|$$
$$\le\left|\mu_B(x_i)-\mu_A(x_i)\right|+\left|\nu_B(x_i)-\nu_A(x_i)\right|+\left|\gamma_B(x_i)-\gamma_A(x_i)\right|$$

.

ii) The Euclidean distance is equal to

$$e_{Ns}(A,B)=\sqrt{\sum_{i=1}^{n}\left((\mu_A(x_i)-\mu_B(x_i))^2+(\nu_A(x_i)-\nu_B(x_i))^2+(\gamma_A(x_i)-\gamma_B(x_i))^2+(\pi_A(x_i)-\pi_B(x_i))^2\right)}$$

we have

$$(\pi_A(x_i)-\pi_B(x_i))^2=$$
$$(-\mu_A(x_i)-\nu_A(x_i)-\gamma_A(x_i)+\mu_B(x_i)+\nu_B(x_i)+\gamma_B(x_i))^2$$
$$=(\mu_B(x_i)-\mu_A(x_i))^2+(\nu_A(x_i)-\nu_B(x_i))^2+$$
$$(\gamma_A(x_i)-\gamma_B(x_i))^2$$
$$+2(\mu_B(x_i)-\mu_A(x_i)(\nu_A(x_i)-\nu_B(x_i))$$
$$(\gamma_B(x_i)-\gamma_A(x_i))$$

iii) The normalized Hamming distance is equal to

$$NH_{Ns}(A,B)=\frac{1}{2n}\sum_{i=1}^{n}\left(\left|\mu_A(x_i)-\mu_B(x_i)\right|+\left|\nu_A(x_i)-\nu_B(x_i)\right|+\left|\gamma_A(x_i)-\gamma_B(x_i)\right|+\left|\pi_A(x_i)-\pi_B(x_1)\right|\right)$$

iv) The normalized Euclidean distance is equal to

$$NE_{Ns}(A,B)=\sqrt{\frac{1}{2n}\sum_{i=1}^{n}\left((\mu_A(x_i)-\mu_B(x_i))^2+(\nu_A(x_i)-\nu_B(x_i))^2+(\gamma_A(x_i)-\gamma_B(x_i))^2+(\pi_A(x_i)-\pi_B(x_i))^2\right)}$$

5.2 Remark

It is easy to notice that for formulas i), ii), iii) and the following is valid:

a) $0\le d_{Ns}(A,B)\le 2n$

b) $0\le NH_{Ns}(A,B)\le 2$

c) $0\le e_{Ns}(A,B)\le\sqrt{2n}$

d) $0\le NE_{Ns}(A,B)\le\sqrt{2}$.

5. from Images to Neutrosophic Sets, and Entropy

Given the definitions of the previous section several possible contributions are discussed. Neutrosophic sets may be used to solve some of the problems of data causes problems in the classification of pixels. Hesitancy in images originates from various factors, which in their majority are due to the inherent weaknesses of the acquisition and the imaging mechanisms. Limitations of the acquisition chain, such as the quantization noise, the suppression of the dynamic range, or the nonlinear behavior of the mapping system, affect our certainty on deciding whether a pixel is "*gray*" or "*edgy*" and therefore introduce a degree of hesitancy associated with the corresponding pixel. Therefore, hesitancy should encapsulate the aforementioned sources of indeterminacy that characterize digital images. Defining the membership component of the A–NS that describes the brightness of pixels in an image, is a more straightforward task that can be carried out in a similar manner as in traditional fuzzy image processing systems. In the presented heuristic framework, we consider the membership value of a gray level *g* to be its normalized intensity level; that is $\mu_A(g) = \frac{g}{L-1_x}$ where $g \in \{0,..., L-1\}$.It should be mentioned that any other method for calculating $\mu_A(g)$ can also be applied.

In the image is A being (x, y) the coordinates of each pixel and the $g(x, y)$ be the gray level of the pixel (x, y) implies $0 \le g(x, y) \le L-1$. Each image pixel is associated with four numerical values:

- A value representing the membership $\mu_A(x)$, obtained by means of membership function associated with the set that represents the expert's knowledge of the image.
- A value representing the indeterminacy $\nu_A(x)$, obtained by means of the indeterminacy function associated with the set that represents the ignorance of the expert's decision.
- A value representing the non-membership $\gamma_A(x)$, obtained by means of the non -membership function associated with the set that represents the ignorance of the expert's decision.
- A value representing the hesitation measure $\pi_A(x)$, obtained by means of the $\pi_A(x) = 3 - \mu_A(x) - \nu_A(x) - \gamma_A(x)$.

Let an image A of size $M \times N$ pixels having L gray levels ranging between 0 and *L-1*. The image in the neutrosophic domain is considered as an array of neutrosophic singletons. Here, each element denoted the degree of the membership, indeterminacy and non-membership according to a pixel with respect to an image considered. An image A in neutrosophic set is $A = \{< \mu_A(g_{ij}), \nu_A(g_{ij}), \gamma_A(g_{ij}) >, g_{ij} \in \{0,..., L-1\}\}$ where $\mu_A(g_{ij}), \nu_A(g_{ij}), \gamma_A(g_{ij})$ denote the degrees of membership indeterminacy and non-membership of the $(i, j)-th$ pixel to the set A associated with an image property $\mu_A(g) = \frac{g - g_{\min}}{g - g_{\max}}$ where $g_{\min}$ and $g_{\max}$ are the minimum and the maximum gray levels of the image. Entropy plays an important role in image processing. In our further considertions on entropy for neutrosophic sets the concept of cardinality of a neutrosophic set will also be useful

Definition 5.1

Let $A = \langle(\mu_A(x), \nu_A(x), \gamma_A(x)), x \in X\rangle$ a neutrosophic set in X, first, we define two cardinalities of a neutrosophic set

- The least (sure) cadinality of A is equal to so is called segma-count, and is called here the

$$\min \sum cont(A) = \sum_{i=1} \mu_A(x_i) + \sum_{i=1} \nu_A(x_i)$$

- The bigesst cadinality of A , which is possible due to $\pi_A(x)$ is equal to

$$\max \sum cont(A) = \sum_{i=1} (\mu_A(x_i) + \pi_A(x_i)) + \sum_{i=1} \nu_A(x_i) + \pi_A(x_i))$$

and , clearly for A^c we have

$$\min \sum cont(A^c) = \sum_{i=1} \gamma_A(x_i) + \sum_{i=1} \nu_A(x_i),$$

$$\max \sum cont(A^c) = \sum_{i=1} (\gamma_A(x_i) + \pi_A(x_i)) + \sum_{i=1} \nu_A(x_i) + \pi_A(x_i))$$

. Then the cadinality of neutrosophic set is defined as the interval

$$Card(A) = [\min \sum Cont(A), \max \sum Cont(A)]$$

Definition 5.2

An entropy on $NS(X)$ is a real-valued functional $E : NS(X) \to [0,1]$, satisfying the following axiomatic requirements:

E_1: $E(A) = 0$ iff A is a neutrosophic crisp set; that is $\mu_A(x_i) = 0$ or $\mu_A(x_i) = 1$ for all $x_i \in X$.

E_2 : $E(A) = 1$ iff $\mu_A(x_i) = \nu_A(x_i) = \gamma_A(x_i)$ for all $x_i \in X$. that is $A = A^c$.

E_3: $E(A) \le E(B)$ if A refine B; i.e. $A \le B$.

E_4: $E(A) = E(A^c)$

Where a neutrosophic entropy measure be define as

$$E(A) = \frac{1}{n} \sum_{i=1}^{n} \frac{\max Count(A_i \cap A_i^c)}{\max Count(A_i \cup A_i^c)}$$ where

$n = Cardinal(X)$ and A_i denotes the single-element A–NS corresponding to the ith element of the universe X and is described as

$A_i = \{(\mu_A(x_i), \nu_A(x_i), \gamma_A(x_i)), x_i \in X\}$.

In other words, A_i is the ith "component" of A. Moreover, $\max Count(A)$ denotes the biggest cardinality of A and is given by :

$$\max \sum cont(A) = \sum_{i=1} (\mu_A(x_i) + \pi_A(x_i)) + \sum_{i=1} \nu_A(x_i) + \pi_A(x_i))$$

Conclusion

Some of the properties of the neutrosophic sets, Distance measures, Hesitancy Degree, Cardinality and Entropy measures are briefed in this paper. These measures can be used effectively in image processing and pattern recognition. The future work will cover the application of these measures.

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