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A New Similarity Measure Based on Falsity Value between Single Valued Neutrosophic Sets Based on the Centroid Points of Transformed Single Valued Neutrosophic Numbers with Applications to Pattern Recognition

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Abstract. In this paper, we propose some transformations based on the centroid points between single valued neutrosophic numbers. We introduce these transformations according to truth, indeterminacy and falsity value of single valued neutrosophic numbers. We propose a new similarity measure based on falsity value between single valued neutrosophic sets. Then we prove some properties on new similarity measure based on falsity value between single valued neutrosophic sets. Furthermore, we propose similarity measure based on falsity value between single valued neutrosophic sets based on the centroid points of transformed single valued neutrosophic numbers. We also apply the proposed similarity measure between single valued neutrosophic sets to deal with pattern recognition problems.

Keywords: Neutrosophic sets, Single Valued Neutrosophic Numbers, Centroid Points.

1 Introduction

In [1] Atanassov introduced a concept of intuitionistic sets based on the concepts of fuzzy sets [2]. In [3] Smarandache introduced a concept of neutrosophic sets which is characterized by truth function, indeterminacy function and falsity function, where the functions are completely independent. Neutrosophic set has been a mathematical tool for handling problems involving imprecise, indeterminant and inconsistent data; such as cluster analysis, pattern recognition, medical diagnosis and decision making.In [4] Smarandache et.al introduced a concept of single valued neutrosophic sets. Recently few researchers have been dealing with single valued neutrosophic sets [5-10].

The concept of similarity is fundamentally important in almost every scientific field. Many methods have been proposed for measuring the degree of similarity between intuitionistic fuzzy sets [11-15]. Furthermore, in [13-15] methods have been proposed for measuring the degree of similarity between intuitionistic fuzzy sets based on transformed techniques for pattern recognition. But those methods are unsuitable for dealing with the similarity measures of neutrosophic sets since intuitionistic sets are characterized by only a membership function and a non-membership function. Few researchers dealt with similarity measures for neutrosophic sets [16-22]. Recently, Jun [18] discussed similarity measures on internalneutrosophic sets, Majumdar et al.[17] discussed similarity and entropy of neutrosophic sets, Broumi et.al.[16]discussed several similarity measures of neutrosophic sets, Ye [9] discussed single-valued neutrosophic similarity measures based on cotangent function and their application in the fault diagnosis of steam turbine, Deli et.al.[10] discussed multiple criteria decision making method on single valued bipolar neutrosophic set based on correlation coefficient similarity measure, Ulucay et.al. [21] discussed Jaccard vector similarity measure of bipolar neutrosophic set based on multi-criteria decision making and Ulucay et.al.[22] discussed similarity measure of bipolar neutrosophic sets and their application to multiple criteria decision making.

In this paper, we propose methods to transform between single valued neutrosophic numbers based on centroid points. Here, as single valued neutrosophic sets are made up of three functions, to make the transformation functions be applicable to all single valued neutrosophic numbers, we divide them into four according to their truth, indeterminacy and falsity values. While grouping according to the truth values, we take into account whether the truth values are greater or smaller than the indeterminancy and falsity values. Similarly, while grouping according to the indeterminancy/falsity values, we examine the indeterminancy/falsity values and their greatness or smallness with respect to their remaining two values. We also propose a new method to measure the degree of similarity based on falsity values between single valued neutrosophic sets. Then we prove some properties of new similarity measure based on falsity value between single valued neutrosophic sets. When we take this measure with respect to truth or indeterminancy we show that it does not satisfy one of the conditions of similarity measure. We also apply the proposed new similarity measures based on falsity value between single valued neutrosophic sets to deal with pattern recognition problems. Later, we define the method based on falsity value to measure the degree of similarity between single valued neutrosophic set based on centroid points of transformed single valued neutrosophic numbers and the similarity measure based on falsity value between single valued neutrosophic sets.

In section 2, we briefly review some concepts of single valued neutrosophic sets [4] and property of similarity measure between single valued neutrosophic sets. In section 3, we define transformations between the single valued neutrosophic numbers based on centroid points. In section 4, we define the new similarity measures based on falsity value between single valued neutrosophic sets and we prove some properties of new similarity measure between single valued neutroshopic sets. We also apply the proposed method to deal with pattern recognition problems. In section 5, we define the method to measure the degree of similarity based on falsity value between single valued neutrosophicset based on the centroid point of transformed single valued neutrosophic number and we apply the measure to deal with pattern recognition problems. Also we compare the traditional and new methods in pattern recognition problems.

2 Preliminaries

Definition 2.1[3] Let U be a universe of discourse. The neutrosophic set A is an object having the farm $A = \{\langle x: T_{A(x)}, I_{A(x)}, F_{A(x)}\rangle, x \in U\}$ where the functions $T, I, F: U \to]^{-}0, 1^{+}[$ respectively the degree of membership, the degree of indeterminacy and degree of non-membership of the element $x \in U$ to the set A with the condition:

$$0^{-} \leq T_{A(x)} + I_{A(x)} + F_{A(x)} \leq 3^{+}$$

Definition 2.2 [4] Let U be a universe of discourse.The single valued neutrosophic set $A$is an object having the farm $A = \{\langle x: T_{A(x)}, I_{A(x)}, F_{A(x)}\rangle, x \in U\}$ where the functions $T, I, F: U \to [0,1]$respectively the degree of membership, the degree of indeterminacy and degree of non-membership of the element $x \in U$ to the set A with the condition:

$$0 \leq T_{A(x)} + I_{A(x)} + F_{A(x)} \leq 3$$

For convenience we can simply use x = (T,I,F) to represent an element x in SVNS, and element x can be called a single valued neutrosophic number.

Definition 2.3 [4] A single valued neutrosophic set A is equal to another single valued neutrosophic set B, $A = B$ if$\forall x \in U$,

$$T_{A(x)} = T_{B(x)},\ I_{A(x)} = I_{B(x)},\ F_{A(x)} = F_{B(x)}.$$

Definition 2.4[4] A single valued neutrosophic set A is contained in another single valued neutrosophic set B , $A \subseteq B$ if $\forall x \in U$,

$$T_{A(x)} \leq T_{B(x)},\ I_{A(x)} \leq I_{B(x)},\ F_{A(x)} \geq F_{B(x)}.$$

Definition 2.5[16] (Axiom of similarity measure)

A mapping$S(A,B): NS_{(x)} \times NS_{(x)} \to [0,1]$, where $NS_{(x)}$ denotes the set of all NS in$x = \{x_1, \dots, x_n\}$,is said to be the degree of similarity between A and B if it satisfies the following conditions:

sP_1) $0 \leq S(A,B) \leq 1$

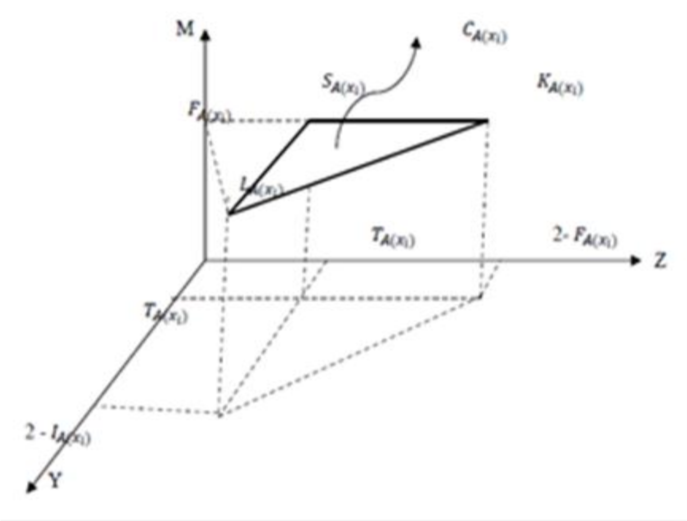
sp_2) $S(A,B) = 1$ if and only if $A = B$, $\forall\ A, B \in NS$

sP_3) $S(A,B) = S(B,A)$

sp_4) If $A \subseteq B \subseteq C$ for all $A, B, C \in NS$, then $S(A,B) \geq S(A,C)$and $S(B,C) \geq S(A,C)$.

3 The Transformation Techniques between Single Valued Neutrosophic Numbers

In this section, we propose transformation techniques between a single valued neutrosophic number $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ and a single valued neutrosophic number $C_{(x_i)}$. Here $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ denote the single valued neutrosophic numbers to represent an element x_i in the single valued neutrosophic set A, and $C_{A(x_i)}$ is the center of a triangle (SLK) which was obtained by the transformation on the three-dimensional $Z-Y-M$ plane.



First we transform single valued neutrosophic numbers according to their distinct T_A, I_A, F_A values in three parts.

3.1 Transformation According to the Truth Value

In this section, we group the single valued neutrosophic numbers after the examination of their truth values T_A's greatness or smallness against I_A and F_A values. We will shift the $T_{A(x_i)}$ and $F_{A(x_i)}$ values on the Z – axis and $T_{A(x_i)}$ and $I_{A(x_i)}$ values on the Y – axis onto each other. We take the $F_{A(x_i)}$ value on the M – axis. The shifting on the Z and Y planes are made such that we shift the smaller value to the difference of the greater value and 2, as shown in the below figures.

1. **First Group**

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if

$$T_{A(x_i)} \le F_{A(x_i)}$$

and

$$T_{A(x_i)} \le I_{A(x_i)},$$

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(T_{A(x_i)}, T_{A(x_i)}, F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(2-F_{A(x_i)},\ T_{A(x_i)},\ F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(T_{A(x_i)},\ 2-I_{A(x_i)},\ F_{A(x_i)}\right).$$

Here, as

$$T_{C_A(x_i)} = T_{A(x_i)} + \frac{\left(2-F_{A(x_i)}-T_{A(x_i)}\right)}{3} = \frac{2-F_{A(x_i)}+2T_{A(x_i)}}{3}$$

$$I_{C_A(x_i)} = T_{A(x_i)} + \frac{\left(2-I_{A(x_i)}-T_{A(x_i)}\right)}{3} = \frac{2-I_{A(x_i)}+2T_{A(x_i)}}{3}$$

and

$$F_{C_A(x_i)} = F_{A(x_i)},$$

we have

$$C_{A(x_i)} = \left(\frac{2-F_{A(x_i)}+2T_{A(x_i)}}{3}, \frac{2-I_{A(x_i)}+2T_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

2. **Second Group**

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if

$$T_{A(x_i)} \ge F_{A(x_i)}$$

and

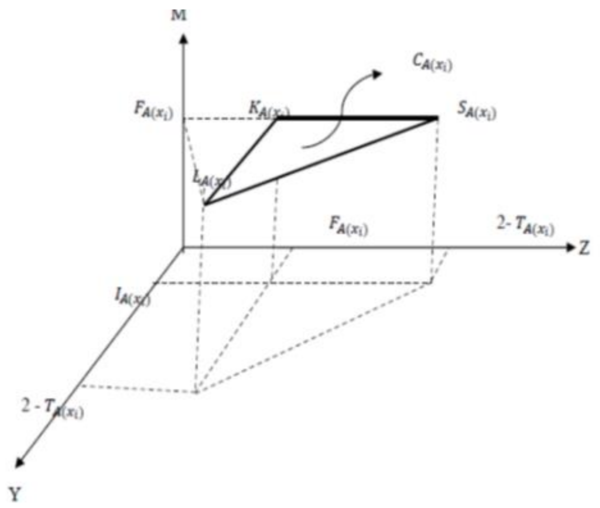
$$T_{A(x_i)} \ge I_{A(x_i)},$$

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$S_{A(x_i)} = \left(F_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\right)$

$\mathrm{L}_{A(x_i)} = \left(F_{A(x_i)}, 2 - T_{A(x_i)}, F_{A(x_i)}\right)$

$\mathrm{K}_{A(x_i)} = \left(2 - T_{A(x_i)}, I_{A(x_i)}, F_{a(x_i)}\right)$.



Here, as

$$T_{C_A(x_i)} = F_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - F_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2F_{A(x_i)}}{3}$$

$$I_{C_A(x_i)} = I_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2I_{A(x_i)}}{3}$$

and

$$F_{C_A(x_i)} = F_{A(x_i)},$$

we have

$$\mathrm{C}_{A(x_i)} = \left(\frac{2 - \mathrm{T}_{A(x_i)} + 2\,\mathrm{F}_{A(x_i)}}{3}, \frac{2 - \mathrm{T}_{A(x_i)} + 2\mathrm{I}_{A(x_i)}}{3}, \mathrm{F}_{A(x_i)}\right).$$

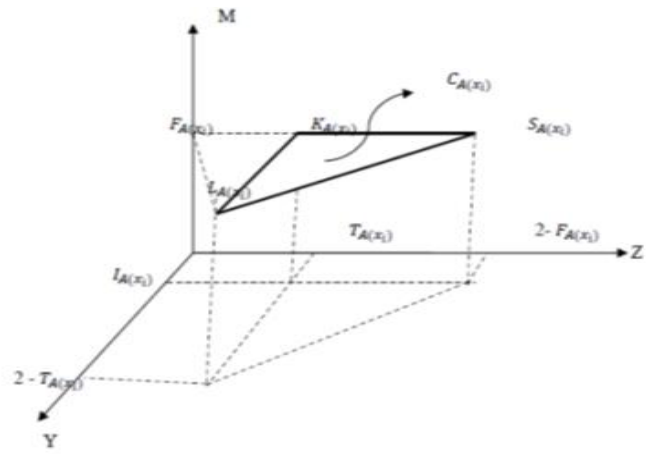
3. Third Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if $\mathrm{I}_{A(x_i)} \le \mathrm{T}_{A(x_i)} \le \mathrm{F}_{A(x_i)}$,as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$\mathrm{S}_{A(x_i)} = \left(\mathrm{T}_{A(x_i)}, \mathrm{I}_{A(x_i)}, \mathrm{F}_{A(x_i)}\right)$

$\mathrm{L}_{A(x_i)} = \left(\mathrm{T}_{A(x_i)}, 2 - \mathrm{T}_{A(x_i)}, \mathrm{F}_{A(x_i)}\right)$

$\mathrm{K}_{A(x_i)} = \left(2 - \mathrm{F}_{A(x_i)}, \mathrm{I}_{A(x_i)}, \mathrm{F}_{A(x_i)}\right)$.



Here, as

$$T_{C_A(x_i)} = T_{A(x_i)} + \frac{\left(2 - F_{A(x_i)} - T_{A(x_i)}\right)}{3} = \frac{2 - F_{A(x_i)} + 2T_{A(x_i)}}{3}$$

$$I_{C_A(x_i)} = I_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2I_{A(x_i)}}{3}$$

and

$$F_{C_A(x_i)} = F_{A(x_i)},$$

we have

$$\mathrm{C}_{A(x_i)} = \left(\frac{2 - \mathrm{F}_{A(x_i)} + 2\,\mathrm{T}_{A(x_i)}}{3}, \frac{2 - \mathrm{T}_{A(x_i)} + 2\mathrm{I}_{A(x_i)}}{3}, \mathrm{F}_{A(x_i)}\right).$$

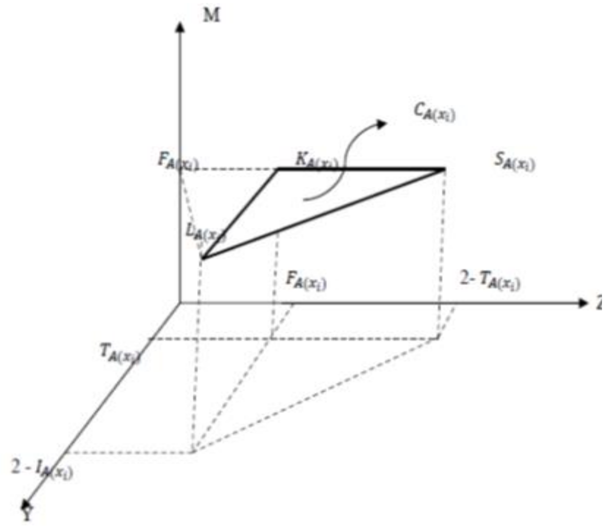
4. Fourth Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if $\mathrm{F}_{A(x_i)} \le \mathrm{T}_{A(x_i)} \le \mathrm{I}_{A(x_i)}$,as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{A(x_i)} = \left(F_{A(x_i)},\ T_{A(x_i)},\ F_{A(x_i)}\right)$$

$$L_{A(x_i)} = \left(F_{A(x_i)},\ 2 - T_{A(x_i)},\ F_{A(x_i)}\right)$$

$$K_{A(x_i)} = \left(2 - T_{A(x_i)},\ T_{A(x_i)},\ F_{A(x_i)}\right).$$



Example3.1.1 Transform the following single valued neutrosophic numbers according to their truth values.

$\langle 0.2,\ 0.5,\ 0.7\rangle$, $\langle 0.9,\ 0.4,\ 0.5\rangle$, $\langle 0.3,\ 0.2,\ 0.5\rangle$, $\langle 0.3,\ 0.2,\ 0.4\rangle$.

i. $\langle 0.2,\ 0.5,\ 0.7\rangle$ single valued neutrosophic number belongs to the first group.

The center is calculated by the formula, $C_{A(x_i)} = \left(\frac{2-F_{A(x_i)}+2\,T_{A(x_i)}}{3}, \frac{2-I_{A(x_i)}+2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right)$

and we have $C_{A(x)} = \langle 0.566,\ 0.633,\ 0.7\rangle$.

ii. $\langle 0.9,\ 0.4,\ 0.5\rangle$ single valued neutrosophic number is in the second group.

The center for the values of the second group is, $C_{A(x_i)} = \left(\frac{2-T_{A(x_i)}+2\,F_{A(x_i)}}{3}, \frac{2-T_{A(x_i)}+2I_{A(x_i)}}{3}, F_{A(x_i)}\right)$

and for $\langle 0.9,\ 0.4,\ 0.5\rangle$, $C_{A(x)} = \langle 0.7,\ 0.633,\ 0.5\rangle$.

iii. $\langle 0.3,\ 0.2,\ 0.5\rangle$ single valued neutrosophic number belongs to the third group.

The formula for the center of $\langle 0.3,\ 0.2,\ 0.5\rangle$ is $C_{A(x_i)} = \left(\frac{2-F_{A(x_i)}+2\,T_{A(x_i)}}{3}, \frac{2-T_{A(x_i)}+2I_{A(x_i)}}{3}, F_{A(x_i)}\right)$ and therefore we have $C_{A(x)} = \langle 0.7,\ 0.7,\ 0.5\rangle$.

iv. $\langle 0.3,\ 0.2,\ 0.4\rangle$ single valued neutrosophic number is in the third group and the center is calculated to be $C_{A(x)} = \langle 0.733,\ 0.7,\ 0.4\rangle$.

Corollary 3.1.2 The corners of the triangles obtained using the above method need not be single valued neutrosophic number but by definition, trivially their centers are.

Note 3.1.3 As for the single valued neutrosophic number$\langle 1,$ ber$\langle 1,\ 1,\ 1\rangle$ there does not exist any transformable triangle in the above four groups, we take its transformation equal to itself.

Corollary 3.1.4 If $F_{A(x_i)} = T_{A(x_i)} = I_{A(x_i)}$ the transformation gives the same center in all four groups. Also, if $T_{A(x_i)} = I_{A(x_i)} \le F_{A(x_i)}$, then the center in the first group is equal to the one in the third group and if $F_{A(x_i)} \le T_{A(x_i)} = I_{A(x_i)}$, the center in the second group is equal to the center in the fourth group. Similarly, if $T_{A(x_i)} = F_{A(x_i)} \le I_{A(x_i)}$, then the center in the first group is equal to the center in the fourth group and if $I_{A(x_i)} \le T_{A(x_i)} = F_{A(x_i)}$, the center in the second group is equal to the one in the third group.

3.2Transformation According to the Indeterminancy Value

In this section, we group the single valued neutrosophic numbers after the examination of their indeterminancy values I_A's greatness or smallness against T_A and$F_A$values. We will shift the $I_{A(x_i)}$ and $F_{A(x_i)}$ values on the Z – axis and $T_{A(x_i)}$ and $I_{A(x_i)}$values on the Y – axis onto each other. We take the $F_{A(x_i)}$value on the M – axis. The shifting on the Z and Y planes are made such that we shift the smaller value to the difference of the greater value and 2, as shown in the below figures.

1. **First Group**

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if

$$I_{A(x_i)} \leq F_{A(x_i)}$$

and

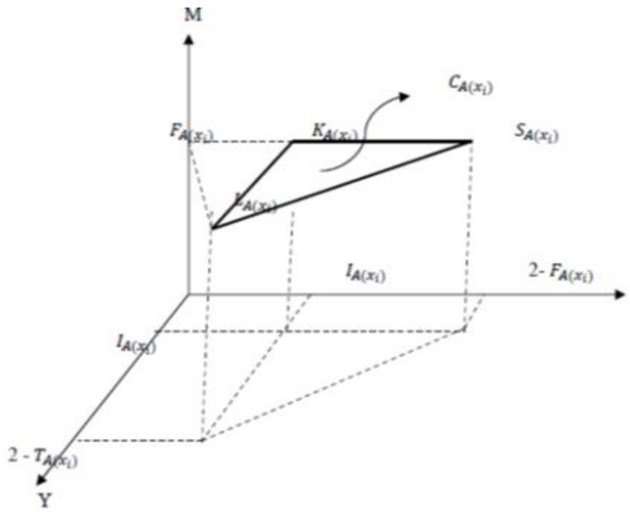
$$I_{A(x_i)} \leq F_{A(x_i)} ,$$

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(I_{A(x_i)}, \quad I_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(2 - F_{A(x_i)}, \; I_{A(x_i)}, \; F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(I_{A(x_i)}, \; 2 - T_{A(x_i)}, \; F_{A(x_i)}\right) .$$



We transformed the single valued neutrosophic number $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$into the center of the SKL triangle, namely $C_{A(x_i)}$. Here, as

$$T_{C_{A(x_i)}} = I_{A(x_i)} + \frac{\left(2 - F_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - F_{A(x_i)} + 2\, I_{A(x_i)}}{3}$$

$$I_{C_{A(x_i)}} = T_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2\, I_{A(x_i)}}{3}$$

and

$$F_{C_{A(x_i)}} = F_{A(x_i)} ,$$

we have

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\, I_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\, I_{A(x_i)}}{3}, F_{A(x_i)}\right) .$$

2. Second Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$, if

$$I_{A(x_i)} \geq F_{A(x_i)}$$

and

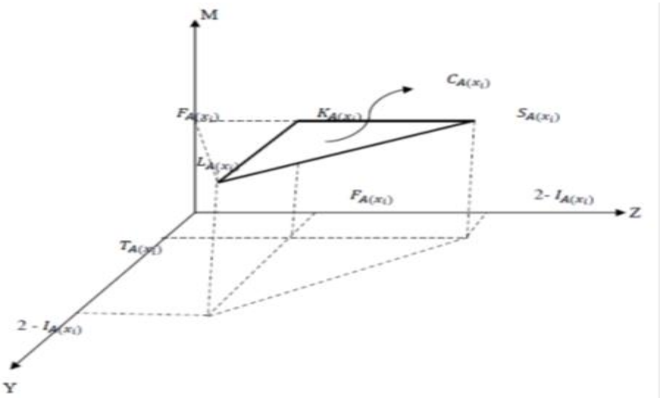
$$I_{A(x_i)} \geq F_{A(x_i)} ,$$

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(F_{A(x_i)}, \quad T_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(F_{A(x_i)}, 2 - I_{A(x_i)}, \; F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(2 - I_{A(x_i)}, \; T_{A(x_i)}, \; F_{A(x_i)}\right) .$$



Here, as

$$T_{C_{A(x_i)}} = F_{A(x_i)} + \frac{\left(2 - I_{A(x_i)} - F_{A(x_i)}\right)}{3} = \frac{2 - I_{A(x_i)} + 2\, F_{A(x_i)}}{3}$$

$$I_{C_{A(x_i)}} = T_{A(x_i)} + \frac{\left(2 - I_{A(x_i)} - T_{A(x_i)}\right)}{3} = \frac{2 - I_{A(x_i)} + 2\,T_{A(x_i)}}{3}$$

and

$$F_{C_{A(x_i)}} = F_{A(x_i)},$$

we have

$$C_{A(x_i)} = \left(\frac{2 - I_{A(x_i)} + 2\,F_{A(x_i)}}{3}, \frac{2 - I_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

3. Third Group

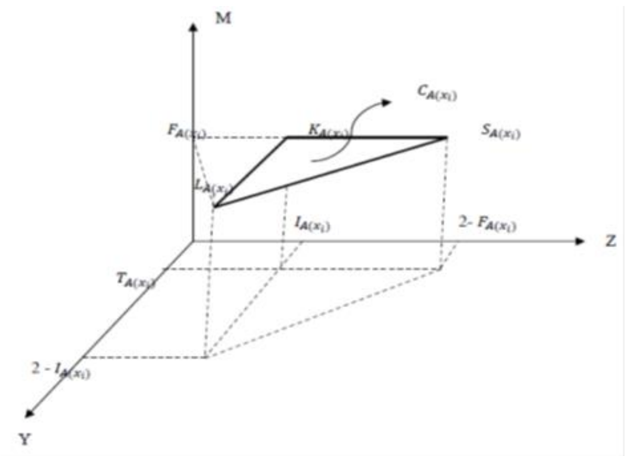
For the single valued neutrosophic number $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$, if $T_{A(x_i)} \le I_{A(x_i)} \le F_{A(x_i)}$,

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(I_{A(x_i)}, \quad T_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(I_{A(x_i)}, 2 - I_{A(x_i)}, F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(2 - F_{A(x_i)}, T_{A(x_i)}, F_{A(x_i)}\right).$$



Here as

$$T_{C_{A(x_i)}} = I_{A(x_i)} + \frac{\left(2 - F_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}$$

$$I_{C_{A(x_i)}} = T_{A(x_i)} + \frac{\left(2 - I_{A(x_i)} - T_{A(x_i)}\right)}{3} = \frac{2 - I_{A(x_i)} + 2\,T_{A(x_i)}}{3}$$

and

$$F_{C_{A(x_i)}} = F_{A(x_i)},$$

we have

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - I_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

4. Fourth Group

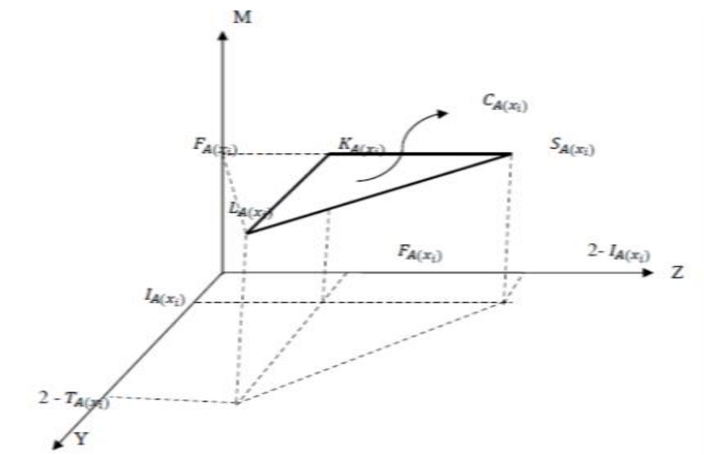
For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$, if $F_{A(x_i)} \le I_{A(x_i)} \le T_{A(x_i)}$,

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$ into the single valued neutrosophic numbers $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(F_{A(x_i)}, \quad I_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(F_{A(x_i)}, 2 - T_{A(x_i)}, F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(2 - I_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\right).$$



Here, as

$$T_{C_A(x_i)} = F_{A(x_i)} + \frac{\left(2 - I_{A(x_i)} - F_{A(x_i)}\right)}{3} = \frac{2 - I_{A(x_i)} + 2\,F_{A(x_i)}}{3}$$

$$I_{C_A(x_i)} = I_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2\,I_{A(x_i)}}{3}$$

and

$$F_{C_A(x_i)} = F_{A(x_i)},$$

we have

$$C_{A(x_i)} = \left(\frac{2 - I_{A(x_i)} + 2\,F_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\,I_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

Example3.2.1:Transform the single neutrosophic numbers of Example 3.1.3 ,

$\langle 0.2,\ 0.5,\ 0.7\rangle$, $\langle 0.9,\ 0.4,\ 0.5\rangle$, $\langle 0.3,\ 0.2,\ 0.5\rangle$, $\langle 0.3,\ 0.2,\ 0.4\rangle$according to their indeterminancy values.

$i.$ $\langle 0.2,\ 0.5,\ 0.7\rangle$ single valued neutrosophic number is in the third group. The center is given by the formula

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - I_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

and so $C_{A(x)} = \langle 0.766,\ 0.633,\ 0.7\rangle$.

$ii.$ $\langle 0.9,\ 0.4,\ 0.5\rangle$ single valued neutrosophic number is in the first group.

By

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\,I_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

we have $C_{A(x)} = \langle 0.733,\ 0.633,\ 0.5\rangle$.

$iii.$ $\langle 0.3,\ 0.2,\ 0.5\rangle$single valued neutrosophic number belongs to the first group and the center is

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\,I_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

so,$C_{A(x)} = \langle 0.633,\ 0.9,\ 0.5\rangle$.

$iv.$ $\langle 0.3,\ 0.2,\ 0.4\rangle$single valued neutrosophic number is in the first group.
Using

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\,I_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

we have $C_{A(x)} = \langle 0.666,\ 0.7,\ 0.4\rangle$.

Corollary 3.2.2 The corners of the triangles obtained using the above method need not be single valued neutrosophic numbers but by definition, trivially their centers are.

Note 3.2.3 As for the single valued neutrosophic number $\langle 1,\ 1,\ 1\rangle$ there does not exist any transformable triangle in the above four groups, we take its transformation equal to itself.

Corollary 3.2.4 If $F_{A(x_i)} = T_{A(x_i)} = I_{A(x_i)}$,the transformation gives the same center in all four groups. Also if $T_{A(x_i)} = I_{A(x_i)} \leq F_{A(x_i)}$, then the center in the first group is equal to the center in the third group, and if $F_{A(x_i)} \leq T_{A(x_i)} = I_{A(x_i)}$, then the center in the second group is the same as the one in the fiurth group. Similarly, if$F_{A(x_i)} = I_{A(x_i)} \leq T_{A(x_i)}$, then the center in the first group is equal to the one in the fourth and in the case that $T_{A(x_i)} \leq F_{A(x_i)} = I_{A(x_i)}$,the center in the second group is equal to the center in the third.

3.3 Transformation According to the Falsity Value

In this section, we group the single valued neutrosophic numbers after the examination of their indeterminancy values F_A's greatness or smallness against I_A and F_A values. We will shift the $I_{A(x_i)}$and $F_{A(x_i)}$values on the Z – axis and $T_{A(x_i)}$ and $F_{A(x_i)}$values on the Y – axis onto each other. We take the $F_{A(x_i)}$value on the M – axis. The shifting on the Z and Y planes are made such that we shift the smaller value to the difference of the greater value and 2, as shown in the below figures.

1. First Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$, if

$$F_{A(x_i)} \leq T_{A(x_i)}$$

and

$$F_{A(x_i)} \leq I_{A(x_i)} ,$$

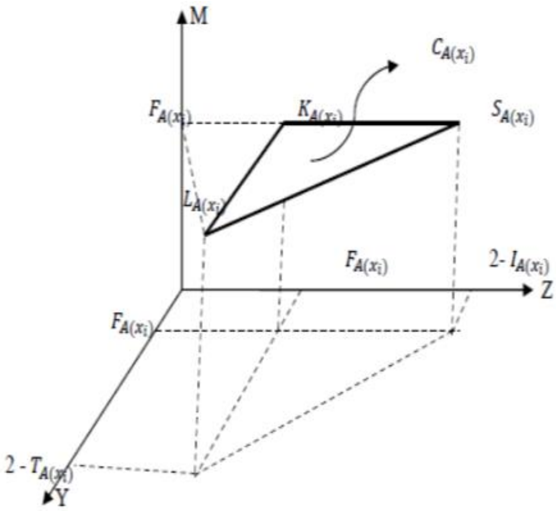
then

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$ into the single valued neutrosophic number $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(F_{A(x_i)}, \quad F_{A(x_i)} , \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(2 - I_{A(x_i)}, F_{A(x_i)}, \ F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(F_{A(x_i)}, \ 2 - T_{A(x_i)}, \ F_{A(x_i)}\right) .$$



Here, as

$$T_{C_A(x_i)} = F_{A(x_i)} + \frac{\left(2 - I_{A(x_i)} - F_{A(x_i)}\right)}{3} = \frac{2 - I_{A(x_i)} + 2 F_{A(x_i)}}{3}$$

$$I_{C_A(x_i)} = F_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - F_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2 F_{A(x_i)}}{3}$$

and

$$F_{C_A(x_i)} = F_{A(x_i)},$$

we get

$$C_{A(x_i)} = \left(\frac{2 - I_{A(x_i)} + 2 F_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2 F_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

2. Second Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$, if

$$F_{A(x_i)} \geq T_{A(x_i)}$$

and

$$F_{A(x_i)} \geq I_{A(x_i)} ,$$

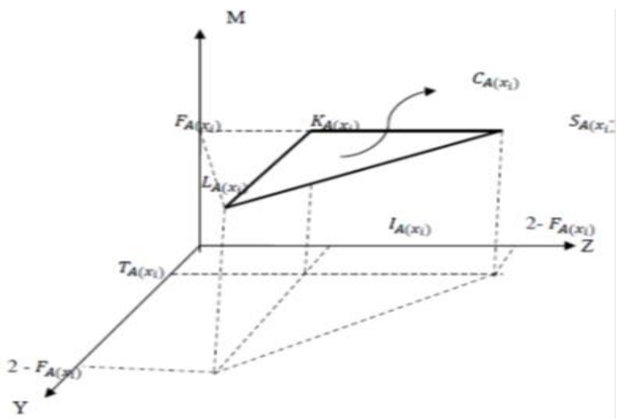
then

as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle$ into the single valued neutrosophic numbers $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(I_{A(x_i)}, \quad T_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(I_{A(x_i)}, 2 - F_{A(x_i)}, \ F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(2 - F_{A(x_i)}, \ T_{A(x_i)}, \ F_{A(x_i)}\right) .$$



Here, as

$$T_{C_A(x_i)} = I_{A(x_i)} + \frac{\left(2 - F_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - F_{A(x_i)} + 2 I_{A(x_i)}}{3}$$

$$I_{C_{A(x_i)}} = T_{A(x_i)} + \frac{\left(2 - F_{A(x_i)} - T_{A(x_i)}\right)}{3} = \frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}$$

and

$$F_{C_{A(x_i)}} = F_{A(x_i)},$$

we have

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, \frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

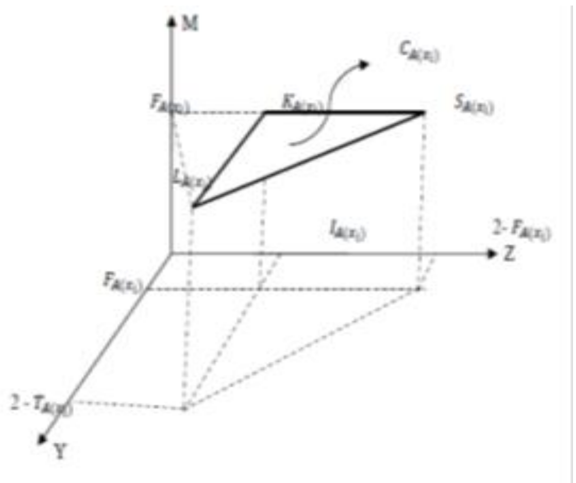
3. Third Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if $\mathrm{I}_{A(x_i)} \le \mathrm{F}_{A(x_i)} \le \mathrm{T}_{A(x_i)}$ then as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ into the single valued neutrosophic numbers $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(I_{A(x_i)}, \quad F_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(I_{A(x_i)}, 2 - T_{A(x_i)}, \ F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(2 - F_{A(x_i)}, \ F_{A(x_i)}, \ F_{A(x_i)}\right).$$



Here, as

$$T_{C_{A(x_i)}} = I_{A(x_i)} + \frac{\left(2 - F_{A(x_i)} - I_{A(x_i)}\right)}{3} = \frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}$$

$$I_{C_{A(x_i)}} = F_{A(x_i)} + \frac{\left(2 - T_{A(x_i)} - F_{A(x_i)}\right)}{3} = \frac{2 - T_{A(x_i)} + 2\,F_{A(x_i)}}{3}$$

and

$$F_{C_{A(x_i)}} = F_{A(x_i)},$$

we have

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\,F_{A(x_i)}}{3}, F_{A(x_i)}\right).$$

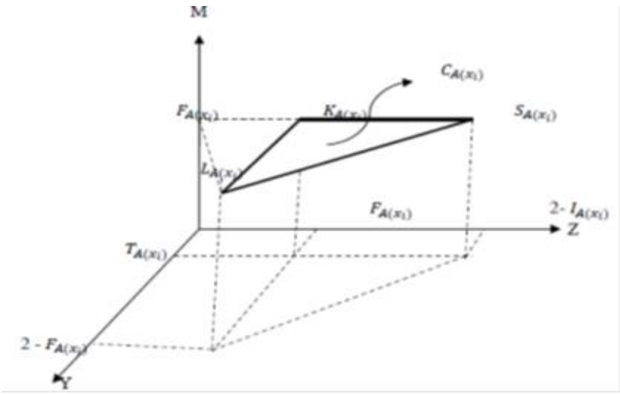
4. Fourth Group

For the single valued neutrosophic numbers $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$, if $\mathrm{T}_{A(x_i)} \le \mathrm{F}_{A(x_i)} \le \mathrm{I}_{A(x_i)}$, then as shown in the figure below, we transformed $\langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle$ into the single valued neutrosophic numbers $C_{A(x_i)}$, the center of the SKL triangle, where

$$S_{(Ax_i)} = \left(F_{A(x_i)}, \quad T_{A(x_i)}, \quad F_{A(x_i)}\right)$$

$$K_{(Ax_i)} = \left(F_{A(x_i)}, 2 - F_{A(x_i)}, \ F_{A(x_i)}\right)$$

$$L_{(Ax_i)} = \left(2 - I_{A(x_i)}, \ T_{A(x_i)}, \ F_{A(x_i)}\right).$$



Example 3.3.1: Transform the single neutrosophic numbers of Example 3.1.3.

$\langle 0.2,\ 0.5,\ 0.7\rangle$, $\langle 0.9,\ 0.4,\ 0.5\rangle$, $\langle 0.3,\ 0.2,\ 0.5\rangle$, $\langle 0.3,\ 0.2,\ 0.4\rangle$according to their falsity values.

$i.$ $\langle 0.2,\ 0.5,\ 0.7\rangle$ single valued neutrosophic number belongs to the second group. So, the center is

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, \frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

and we get $C_{A(x)} = \langle 0.766,\ 0.7,\ 0.7\rangle$.

$ii.$ $\langle 0.9,\ 0.4,\ 0.5\rangle$ single valued neutrosophic number is in the third group. Using the formula

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,I_{A(x_i)}}{3}, \frac{2 - T_{A(x_i)} + 2\,F_{A(x_i)}}{3}, F_{A(x_i)}\right)$$

we see that$C_{A(x)} = \langle 0.766,\ 0.7,\ 0.5\rangle$.

$iii.$ $\langle 0.3,\ 0.2,\ 0.5\rangle$single valued neutrosophic number is in the second group. As

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, \frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

the center of the triangle is $C_{A(x)} = \langle 0.633,\ 0.7,\ 0.5\rangle$.

$iv.$ $\langle 0.3,\ 0.2,\ 0.4\rangle$single valued neutrosophic number belongs to the second group.

$$C_{A(x_i)} = \left(\frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, \frac{2 - F_{A(x_i)} + 2\,T_{A(x_i)}}{3}, F_{A(x_i)}\right),$$

and so we have $C_{A(x)} = \langle 0.666,\ 0.733,\ 0.4\rangle$.

Corollary 3.3.2 The corners of the triangles obtained using the above method need not be single valued neutrosophic numbers but by definition, trivially their centers are single valued neutrosophic values.

Note 3.3.3 As for the single valued neutrosophic ber$\langle 1,\ 1,\ 1\rangle$ there does not exist any transformable triangle in the above four groups, we take its transformation equal to itself.

Corollary 3.3.4 If $F_{A(x_i)} = T_{A(x_i)} = I_{A(x_i)}$, the transformation gives the same center in all four groups. Also, if $T_{A(x_i)} = F_{A(x_i)} \leq I_{A(x_i)}$, then the center in the first group is equal to the one in the fourth group, and if $I_{A(x_i)} \leq T_{A(x_i)} = F_{A(x_i)}$, then the center in the second group is the same as the center in the third. Similarly, if $I_{A(x_i)} = F_{A(x_i)} \leq T_{A(x_i)}$, then the centers in the first and third groups are same and lastly, if $T_{A(x_i)} \leq I_{A(x_i)} = F_{A(x_i)}$, then the center in the second group is equal to the one in the fourth group.

4. A New Similarity Measure Based on Falsity Value Between Single Valued Neutrosophic Sets

In this section, we propose a new similarity measure based on falsity value between single valued neutrosophic sets.

Definition 4.1 Let A and B two single valued neutrosophic sets in $x = \{x_1, x_2, \ldots, x_n\}$.
Let $A = \{\langle x, T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle\}$

and

$B = \{\langle x, T_{B(x_i)}, I_{B(x_i)}, F_{B(x_i)}\rangle\}$.

The similarity measure based on falsity value between the neutrosophic numbers $A(x_i)$ and $B(x_i)$ is given by

$$S(A_{(x_i)}, B_{(x_i)}) = 1 - \left(\frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (T_{A(x_i)} - T_{B(x_i)})\right|}{9} + \frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (I_{A(x_i)} - I_{B(x_i)})\right|}{9} + \frac{3\left|(F_{A(x_i)} - F_{B(x_i)})\right|}{9}\right).$$

Here, we use the values

$$2\big(F_{A(x_i)} - F_{B(x_i)}\big) - \big(T_{A(x_i)} - T_{B(x_i)}\big),$$

$$2\big(F_{A(x_i)} - F_{B(x_i)}\big) - \big(I_{A(x_i)} - I_{B(x_i)}\big),$$

$$2\big(F_{A(x_i)} - F_{B(x_i)}\big) + \big(F_{A(x_i)} - F_{B(x_i)}\big) = 3\big(F_{A(x_i)} - F_{B(x_i)}\big).$$

Since we use the falsity values $F_{A(x_i)}$ in all these three values, we name this formula as “similarity measure based on falsity value between single valued neutrosophic numbers”.

Property4.2 :$0 \leq S\big(A_{(x_i)}, B_{(x_i)}\big) \leq 1$.

Proof: By the definition of Single valued neutrosophic numbers, as

$$0 \leq T_{A(x_i)}, T_{B(x_i)}, I_{A(x_i)}, I_{B(x_i)}, F_{A(x_i)}, F_{B(x_i)} \leq 1,$$

we have

$$0 \leq 2\left(F_{A(x_i)} - F_{B(x_i)}\right) - \left(T_{A(x_i)}, T_{B(x_i)}\right) \leq 3$$

$$0 \leq 2\left(F_{A(x_i)} - F_{B(x_i)}\right) - \left(I_{A(x_i)}, I_{B(x_i)}\right) \leq 3$$

and

$$0 \leq 3\left(F_{A(x_i)}, F_{B(x_i)}\right) \leq 3 .$$

So,

$$0 \leq 1 - \left(\frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (T_{A(x_i)} - T_{B(x_i)})\right|}{9} + \frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (I_{A(x_i)} - I_{B(x_i)})\right|}{9} + \frac{3\left|(F_{A(x_i)} - F_{B(x_i)})\right|}{9}\right) \leq 1 .$$

Therefore,$0 \leq S\left(A_{(x_i)}, B_{(x_i)}\right) \leq 1.$

Property 4.3:$S(A_{(x_i)}, B_{(x_i)}) = 1 \Leftrightarrow A_{(x_i)} = B_{(x_i)}$

Proof.i) First we show $A_{(xi)} = B_{(xi)}$ when $S\left(A_{(x_i)}, B_{(x_i)}\right) = 1$.

Let $\left(A_{(x_i)}, B_{(x_i)}\right) = 1$.

$$S\left(A_{(x_i)}, B_{(x_i)}\right) = 1 - \left(\frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (T_{A(x_i)} - T_{B(x_i)})\right|}{9} + \frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (I_{A(x_i)} - I_{B(x_i)})\right|}{9} + \frac{3\left|(F_{A(x_i)} - F_{B(x_i)})\right|}{9}\right)$$

$$= 1$$

and thus,

$$\left(\frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (T_{A(x_i)} - T_{B(x_i)})\right|}{9} + \frac{\left|2(F_{A(x_i)} - F_{B(x_i)}) - (I_{A(x_i)} - I_{B(x_i)})\right|}{9} + \frac{3\left|(F_{A(x_i)} - F_{B(x_i)})\right|}{9}\right) = 0$$

So,

$$\left|(F_{A(x_i)} - F_{B(x_i)})\right| = 0,$$

$$\left|2(F_{A(x_i)} - F_{B(x_i)}) - (T_{A(x_i)} - T_{B(x_i)})\right| = 0,$$

and

$$\left|2(F_{A(x_i)} - F_{B(x_i)}) - (I_{A(x_i)} - I_{B(x_i)})\right| = 0 .$$

As $\left|(F_{A(x_i)} - F_{B(x_i)})\right|$=0 , then $F_{A(x_i)} = F_{B(x_i)}$.

If $F_{A(x_i)} = F_{B(x_i)}$,

$$\left|2\left(F_{A(x_i)} - F_{B(x_i)}\right) - \left(T_{A(x_i)} - T_{B(x_i)}\right)\right| = 0$$

and

$$T_{A(x_i)} = T_{B(x_i)}.$$

When $F_{A(x_i)} = F_{B(x_i)}$,

$$\left|2(F_{A(x_i)} - F_{B(x_i)}) - (I_{A(x_i)} - I_{B(x_i)})\right| = 0$$

and

$$I_{A(x_i)} = I_{B(x_i)}$$

Therefore, if $\left(A_{(x_i)}, B_{(x_i)}\right) = 1$, then by Definition 2.3, $A_{(x_i)} = B_{(x_i)}$.

ii) Now we show if $A_{(x_i)} = B_{(x_i)}$, then$S\left(A_{(x_i)}, B_{(x_i)}\right) = 1$. Let $A_{(x_i)} = B_{(x_i)}$. By Definition 2.3 ,

$$T_{A(x_i)} = T_{B(x_i)},\ I_{A(x_i)} = I_{B(x_i)},\ F_{A(x_i)} = F_{B(x_i)}$$

and we have

$$T_{A(x_i)} - T_{B(x_i)} = 0,\ I_{A(x_i)} - I_{B(x_i)} = 0,\ F_{A(x_i)} - F_{B(x_i)} = 0 .$$

So,

$$S(A_{(x_i)},B_{(x_i)}) = 1-\left(\frac{|2(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})|}{9}+\frac{|2(F_{A(x_i)}-F_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})|}{9}+\frac{3|(F_{A(x_i)}-F_{B(x_i)})|}{9}\right)$$

$$=1-\frac{0}{9} = 1 .$$

Property4.4 :$S(A_{(x_i)},B_{(x_i)}) = S(B_{(x_i)},A_{(x_i)})$.

Proof:

$$S(A_{(x_i)},B_{(x_i)}) = 1-\left(\frac{|2(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})|}{9}+\frac{|2(F_{A(x_i)}-F_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})|}{9}+\frac{3|(F_{A(x_i)}-F_{B(x_i)})|}{9}\right)$$

$$=1-\left(\frac{|2(-(F_{A(x_i)}-F_{B(x_i)}))-(-(T_{A(x_i)}-T_{B(x_i)}))|}{9}+\frac{|2((-F_{A(x_i)}-F_{B(x_i)}))-(-(I_{A(x_i)}-I_{B(x_i)}))|}{9}+\frac{3|-(F_{A(x_i)}-F_{B(x_i)})|}{9}\right)$$

$$=1-\left(\frac{|2(F_{B(x_i)}-F_{A(x_i)})-(T_{B(x_i)}-T_{A(x_i)})|}{9}+\frac{|2(F_{B(x_i)}-F_{A(x_i)})-(I_{B(x_i)}-I_{A(x_i)})|}{9}+\frac{3|(F_{B(x_i)}-F_{A(x_i)})|}{9}\right.$$

$$=S(B_{(x_i)},A_{(x_i)}).$$

Property 4.5 : If $A\subseteq B\subseteq C$,

i) $S(A_{(x_i)},B_{(x_i)}) \ge S(A_{(x_i)},C_{(x_i)})$

ii) $S(B_{(x_i)},C_{(x_i)}) \ge S(A_{(x_i)},C_{(x_i)})$

Proof:

i)

By the single valued neutrosophic set property, if $A\subseteq B\subseteq C$, then

$$T_{A(x_i)} \le T_{B(x_i)} \le T_{C(x_i)},$$

$$I_{A(x_i)} \le I_{B(x_i)} \le I_{C(x_i)},$$

$$F_{A(x_i)} \ge F_{B(x_i)} \ge F_{C(x_i)} .$$

So,

$$T_{A(x_i)}-T_{B(x_i)} \le 0,$$

$$I_{A(x_i)}-I_{B(x_i)} \le 0,$$

$$F_{A(x_i)}-F_{B(x_i)} \ge 0 \qquad (1)$$

$$T_{A(x_i)}-T_{C(x_i)} \le 0,$$

$$I_{A(x_i)}-I_{C(x_i)} \le 0,$$

$$F_{A(x_i)}-F_{C(x_i)} \ge 0 \qquad (2)$$

$$T_{A(x_i)}-T_{B(x_i)} \ge T_{A(x_i)}-T_{C(x_i)},$$

$$I_{A(x_i)}-I_{B(x_i)} \ge I_{A(x_i)}-I_{C(x_i)},$$

$$F_{A(x_i)}-F_{B(x_i)} \le F_{A(x_i)}-F_{C(x_i)} \qquad (3)$$

Using (1), we have

$$2(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)}) \ge 0$$

$$2(F_{A(x_i)}-F_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)}) \ge 0$$

and

$$3(T_{A(x_i)}-T_{B(x_i)}) \ge 0 .$$

Thus, we get

$$S(A_{(x_i)},B_{(x_i)}) = 1-\left(\frac{|2(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})|}{9}+\frac{|2(F_{A(x_i)}-F_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})|}{9}+\frac{3|(F_{A(x_i)}-F_{B(x_i)})|}{9}\right)$$

$$=1-\frac{7(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})}{9}. \qquad (4)$$

Similarly, by (2), we have

$$S(A_{(x_i)},C_{(x_i)}) = 1-\left(\frac{|2(F_{A(x_i)}-F_{C(x_i)})-(T_{A(x_i)}-T_{C(x_i)})|}{9}+\frac{|2(F_{A(x_i)}-F_{C(x_i)})-(I_{A(x_i)}-I_{C(x_i)})|}{9}+\frac{3|(F_{A(x_i)}-F_{C(x_i)})|}{9}\right)$$

$$=1-\frac{7(F_{A(x_i)}-F_{C(x_i)})-(T_{A(x_i)}-T_{C(x_i)})-(I_{A(x_i)}-I_{C(x_i)})}{9}\ . (5)$$

Using (4) and (5) together, we get

$$S(A_{(x_i)},B_{(x_i)})-S(A_{(x_i)},C_{(x_i)})$$

$$=1-\frac{7(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})}{9}$$

$$-1+\frac{7(F_{A(x_i)}-F_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})}{9}$$

$$=\frac{7(F_{A(x_i)}-F_{B(x_i)})}{9}-\frac{(T_{A(x_i)}-T_{B(x_i)})}{9}-\frac{(I_{A(x_i)}-I_{B(x_i)})}{9}$$

$$+\frac{7(F_{A(x_i)}-F_{C(x_i)})}{9}-\frac{(T_{A(x_i)}-T_{C(x_i)})}{9}-\frac{(I_{A(x_i)}-I_{C(x_i)})}{9}$$

$$=\frac{7(F_{A(x_i)}-F_{B(x_i)})}{9}+\frac{7(F_{A(x_i)}-F_{C(x_i)})}{9}-\frac{(T_{A(x_i)}-T_{B(x_i)})}{9}$$

$$-\frac{(T_{A(x_i)}-T_{C(x_i)})}{9}-\frac{(I_{A(x_i)}-I_{B(x_i)})}{9}-\frac{(I_{A(x_i)}-I_{C(x_i)})}{9}$$

by (1) and (3),

$$\frac{7(F_{A(x_i)}-F_{B(x_i)})}{9}+\frac{7(F_{A(x_i)}-F_{C(x_i)})}{9}\geq 0,$$

$$-\frac{(T_{A(x_i)}-T_{B(x_i)})}{9}-\frac{(T_{A(x_i)}-T_{C(x_i)})}{9}\geq 0,$$

$$-\frac{(I_{A(x_i)}-I_{B(x_i)})}{9}-\frac{(I_{A(x_i)}-I_{C(x_i)})}{9}\geq 0$$

and therefore

$$S(A_{(x_i)},B_{(x_i)})-S(A_{(x_i)},C_{(x_i)})\geq 0$$

and

$$S(A_{(x_i)},B_{(x_i)})\geq S(A_{(x_i)},C_{(x_i)})\ .$$

ii. The proof of the latter part can be similarly done as the first part.

Corollary 4.6 : Suppose we make similar definitions to Definition 4.1, but this time based on truth values or indeterminancy values. If we define a truth based similarity measure, or namely,

$$S(A_{(x_i)},B_{(x_i)}) = 1-\left(\frac{|2(T_{A(x_i)}-T_{B(x_i)})-(F_{A(x_i)}-F_{B(x_i)})|}{9}+\frac{|2(T_{A(x_i)}-T_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})|}{9}+\frac{3|(T_{A(x_i)}-T_{B(x_i)})|}{9}\right),$$

or if we define a measure based on indeterminancy values like

$$S(A_{(x_i)},B_{(x_i)}) = 1-\left(\frac{|2(I_{A(x_i)}-I_{B(x_i)})-(T_{A(x_i)}-T_{B(x_i)})|}{9}+\frac{|2(I_{A(x_i)}-I_{B(x_i)})-(F_{A(x_i)}-F_{B(x_i)})|}{9}+\frac{3|(I_{A(x_i)}-I_{B(x_i)})|}{9}\right)$$

these two definitions don't provide the conditions of Property 4.5 . For instance, for the truth value

$$S(A_{(x_i)},B_{(x_i)}) = 1-\left(\frac{|2(T_{A(x_i)}-T_{B(x_i)})-(F_{A(x_i)}-F_{B(x_i)})|}{9}+\frac{|2(T_{A(x_i)}-T_{B(x_i)})-(I_{A(x_i)}-I_{B(x_i)})|}{9}+\frac{3|(T_{A(x_i)}-T_{B(x_i)})|}{9}\right),$$

when we take the single valued neutrosophic numbers $A_{(x)}=\langle 0,0.1,0\rangle$, $B_{(x)}=\langle 1,0.2,0\rangle$ and $C_{(x)}=\langle 1,0.3,0\rangle$, we see $S(A_{(x)},B_{(x)})=0.233$ and $S(A_{(x)},C_{(x)})=0.244$. This contradicts with the results of Property 4.5.

Similarly, for the indeterminancy values,

$$S(A_{(x_i)}, B_{(x_i)}) = 1 - \left(\frac{|2(\mathrm{I}_{\mathrm{A}(x_i)} - \mathrm{I}_{\mathrm{B}(x_i)}) - (\mathrm{T}_{\mathrm{A}(x_i)} - \mathrm{T}_{\mathrm{B}(x_i)})|}{9} + \frac{|2(\mathrm{I}_{\mathrm{A}(x_i)} - \mathrm{I}_{\mathrm{B}(x_i)}) - (\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)})|}{9} + \frac{3|(\mathrm{I}_{\mathrm{A}(x_i)} - \mathrm{I}_{\mathrm{B}(x_i)})|}{9}\right)$$

if we take the single valued neurosophic numbers $\mathrm{A}_{(x)} = \langle 0.1, 0, 1\rangle$, $\mathrm{B}_{(x)} = \langle 0.2, 1, 1\rangle$and $\mathrm{C}_{(x)} = \langle 0.3, 1, 1\rangle$, we have $S(A_{(x)}, B_{(x)}) = 0.233$ and $S(A_{(x)}, C_{(x)}) = 0.244$.

These results show that the definition 4.1 is only valid for the measure based on falsity values.

Defintion 4.7 As

$$S(A_{(x_i)}, B_{(x_i)}) = 1 - \left(\frac{|2(\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)}) - (\mathrm{T}_{\mathrm{A}(x_i)} - \mathrm{T}_{\mathrm{B}(x_i)})|}{9} + \frac{|2(\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)}) - (\mathrm{I}_{\mathrm{A}(x_i)} - \mathrm{I}_{\mathrm{B}(x_i)})|}{9} + \frac{3|(\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)})|}{9}\right),$$

The similarity measure based on the falsity value between two single valued neutrosophic sets *A* and *B* is;

$$\mathrm{S}_{\mathrm{NS}}(A, B) = \sum_{i=1}^{n} \left(w_i \times \mathrm{S}\left(\mathrm{A}_{(x_i)}, \mathrm{B}_{(x_i)}\right)\right).$$

Here,$\mathrm{S}_{\mathrm{NS}}(A, B) \in [0,1]$and w_i's are the weights of the x_i's with the property $\sum_{i=1}^{n} w_i = 1$. Also,

$$A = \{\langle x: T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)}\rangle\},$$

$$B = \{\langle x: T_{B(x_i)}, I_{B(x_i)}, F_{B(x_i)}\rangle\}.$$

Example4.8 Let us consider three patterns$\mathrm{P}_1, \mathrm{P}_2$, P_3 represerted by single valued neutrosophic sets $\widetilde{\mathrm{P}_1}$ and $\widetilde{\mathrm{P}_2}$in $X = \{x_1, x_2\}$ respectively, where $\widetilde{\mathrm{P}_1} = \{\langle \mathrm{x}_1, 0.2, 0.5, 0.7\rangle, \langle \mathrm{x}_2, 0.9, 0.4, 0.5\rangle\}$ and $\widetilde{\mathrm{P}_2} = \{\langle \mathrm{x}_1, 0.3, 0.2, 0.5\rangle, \langle \mathrm{x}_2, 0.3, 0.2, 0.4\rangle\}$. We want to classify an unknown pattern represented by a single valued neutrosophic set $\tilde{Q}$ in $X = \{x_1, x_2\}$ into one of the patterns $\widetilde{\mathrm{P}_1}$, $\widetilde{\mathrm{P}_2}$;where $\tilde{Q} = \{\langle \mathrm{x}_1, 0.4, 0.4, 0.1\rangle, \langle \mathrm{x}_2, 0.6, 0.2, 0.3\rangle\}$.

Let w_i be the weight of element w_i , where $w_i = \frac{1}{2}$ $1 \leq i \leq 2$,

$$\mathrm{S}_{\mathrm{NS}}(\widetilde{P_1}, \tilde{Q}) = 0.711$$

and

$$\mathrm{S}_{\mathrm{NS}}(\widetilde{P_1}, \tilde{Q}) = 0.772 .$$

We can see that $\mathrm{S}_{\mathrm{NS}}(\widetilde{P_2}, \tilde{Q})$is the largest value amongthe values of $\mathrm{S}_{\mathrm{NS}}(\widetilde{P_1}, \tilde{Q})$ and $\mathrm{S}_{\mathrm{NS}}(\widetilde{P_2}, \tilde{Q})$.

Therefore, the unknown pattern represented by single valued neutrosophic set$\tilde{Q}$ should be classified into the pattern P_2.

5. A New Similarity Measure Based on Falsity Measure Between Neutrosophic Sets Based on the Centroid Points of Transformed Single Valued Neutrosophic Numbers

In this section, we propose a new similarity measure based on falsity value between single valued neutrosophic sets based on the centroid points of transformed single valued neutrosophic numbers.

Definition5.1:

$$S(A_{(x_i)}, B_{(x_i)}) = 1 - \left(\frac{|2(\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)}) - (\mathrm{T}_{\mathrm{A}(x_i)} - \mathrm{T}_{\mathrm{B}(x_i)})|}{9} + \frac{|2(\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)}) - (\mathrm{I}_{\mathrm{A}(x_i)} - \mathrm{I}_{\mathrm{B}(x_i)})|}{9} + \frac{3|(\mathrm{F}_{\mathrm{A}(x_i)} - \mathrm{F}_{\mathrm{B}(x_i)})|}{9}\right),$$

Taking the similarity measure as defined in the fourth section, and letting $\mathrm{C}_{\mathrm{A}(x_i)}$ and$\mathrm{C}_{\mathrm{B}(x_i)}$be the centers of the triangles obtained by the transformation of $\mathrm{A}_{(x_i)}$and $\mathrm{B}_{(x_i)}$in the third section respectively,the similarity measure based on falsity value between single valued neutrosophic sets A and B based on the centroid points of transformed single valued neutrosophic numbers is

$$\mathrm{S}_{\mathrm{NSC}}(A, B) = \sum_{i=1}^{n} \left(w_i \mathrm{x} \mathrm{S}(\mathrm{C}_{\mathrm{A(xi)}}, \mathrm{C}_{\mathrm{B(xi)}})\right),$$

where

$$A = \{x: \langle T_{A(x_i)}, I_{A(x_i)}, F_{A(x_i)} \rangle\},$$
$$B = \{x: \langle T_{B(x_i)}, I_{B(x_i)}, F_{B(x_i)} \rangle\} .$$

Here again, w_i's are the weights of the x_i's with the property $\sum_{i=1}^{n} w_i = 1$.

Example5.2: Let us consider two patterns P_1 and P_2 represented by single valued neutrosophic sets $\widetilde{P_1}$, $\widetilde{P_2}$ in $X = \{x_1, x_2\}$respectively in Example 4.8,where

$$\widetilde{P_1} = \{\langle x_1, 0.2, 0.5, 0.7\rangle, \langle x_2, 0.9, 0.4, 0.5\rangle\}$$

and

$$\widetilde{P_2} = \{\langle x_1, 0.3, 0.2, 0.5\rangle, \langle x_2, 0.3, 0.2, 0.4\rangle\}.$$

We want to classify an unknown pattern represented by single valued neutrosophic set $\tilde{Q}$ in $X = \{x_1, x_2\}$ into one of the patterns $\widetilde{P_1}$, $\widetilde{P_2}$, where

$$\tilde{Q} = \{\langle x_1, 0.4, 0.4, 0.1\rangle, \langle x_2, 0.6, 0.2, 0.3\rangle\}.$$

We make the classification using the measure in Definition 5.1, namely

$$S_{NSC}(A, B) = \sum_{i=1}^{n} \left(w_i \times S\left(C_{A(xi)}, C_{B(xi)}\right)\right) .$$

Also we find the $C_{A(xi)}$, $C_{B(xi)}$ centers according to the truth values.

Let w_i be the weight of elementx_i, $w_i = \frac{1}{2}$; $1 \le i \le 2$.

$\widetilde{P_1}x_1 = \langle 0.2, 0.5, 0.7\rangle$transformed based on falsity value in Example 3.1.1

$$C_{\widetilde{P_1}x_1} = (0.566, 0.633, 0.7)$$

$\widetilde{P_1}x_2 = \langle 0.9, 0.4, 0.5\rangle$ transformed based on falsity value in Example 3.1.1

$$C_{\widetilde{P_1}x_2} = (0.7,0.633,0.5)$$

$\widetilde{P_2}x_1 = \langle 0.3, 0.2, 0.5\rangle$ transformed based on falsity value in Example 3.1.1

$$C_{\widetilde{P_2}x_1} = (0.7, 0.7,0.5)$$

$\widetilde{P_2}x_2 = \langle 0.3, 0.2, 0.4\rangle$ transformed based on falsity value in Example 3.1.1

$$C_{\widetilde{P_2}x_2} = (0.733, 0.7, 0.4)$$

$\tilde{Q}_{x_1} = \langle x_1, 0.4, 0.4, 0.1\rangle$ transformed based on falsity value in Section 3.1

$C_{\tilde{Q}x_1} = \langle 0.6, 0.8, 0.1\rangle$(second group)

$\tilde{Q}_{x_2} = \langle x_2, 0.6, 0.2, 0.3\rangle$transformed based on truth falsity in Section 3.1

$C_{\tilde{Q}x_2} = \langle 0.666, 0.6, 0.3\rangle$(second group)

$$S_{NSC}(\widetilde{P_1}, \tilde{Q}) = 0.67592$$

$$S_{NSC}(\widetilde{P_2}, \tilde{Q}) = 0.80927$$

Therefore, the unknown patternQ,represented by a single valued neutrosophic set based on truth value is classified into pattern P_2.

Example5.3 : Let us consider two patterns P_1 and P_2 of example 4.8, represented by single valued neutrosophic sets $\widetilde{P_1}$, $\widetilde{P_2}$, in $X = \{x_1, x_2\}$ respectively, where

$$\widetilde{P_1} = \{\langle x_1, 0.2, 0.5, 0.7\rangle, \langle x_2, 0.9, 0.4, 0.5\rangle\}$$

and

$$\widetilde{P_2} = \{\langle x_1, 0.3, 0.2, 0.5\rangle, \langle x_2, 0.3, 0.2, 0.4\rangle\}.$$

We want to classify an unknown pattern represented by the single valued neutrosophic set $\tilde{Q}$ in $X = \{x_1, x_2\}$ into one of the patterns $\widetilde{P_1}$, $\widetilde{P_2}$,where

$$\tilde{Q} = \{\langle x_1, 0.4, 0.4, 0.1\rangle, \langle x_2, 0.6, 0.2, 0.3\rangle\}.$$

We make the classification using the measure in Definition 5.1, namely

$$S_{NSC}(A, B) = \sum_{i=1}^{n} \left(w_i x S\left(C_{A(xi)}, C_{B(xi)}\right)\right).$$

Also we find the $C_{A(xi)}$, $C_{B(xi)}$ centers according to the indeterminacy values.

Let w_i be the weight of element$x_i, w_i = \frac{1}{2}$; $1 \le i \le 2$.

$\widetilde{P_1}x_1 = \langle 0.2, 0.5, 0.7\rangle$ transformed based on falsity value in Example 3.2.1

$$C_{\widetilde{P_1}x_1} = (0.766,0.633, 0.7)$$

$\widetilde{P_1}x_2 = \langle 0.9,\ 0.4,\ 0.5\rangle$ transformed based on falsity value in Example 3.2.1

$$C_{\widetilde{P_1}x_2} = (0.766, 0.633, 0.5)$$

$\widetilde{P_2}x_1 = \langle 0.3,\ 0.2,\ 0.5\rangle$ transformed based on falsity value in Example 3.2.1

$$C_{\widetilde{P_2}x_1} = (0.633, 0.9, 0.5)$$

$\widetilde{P_2}x_2 = \langle 0.3,\ 0.2,\ 0.4\rangle$ transformed based on falsity value in Example 3.2.1

$$C_{\widetilde{P_2}x_2} = (0.666, 0.7, 0.4)$$

$\tilde{Q}_{x_1} = \langle x_1, 0.4, 0.4, 0.1\rangle$ transformed based on falsity value in Section 3.2

$C_{\tilde{Q}x_1} = \langle 0.6,\ 0.8,\ 0.1\rangle$(second group)

$\tilde{Q}_{x_2} = \langle x_2, 0.6,\ 0.2,\ 0.3\rangle$transformed based on truth falsity in Section 3.2

$C_{\tilde{Q}x_2} = \langle 0.7,\ 0.666,\ 0.3\rangle$ (first group)

$$S_{NSC}(\widetilde{P_1}, \tilde{Q}) = 0.67592$$

$$S_{NSC}(\widetilde{P_2}, \tilde{Q}) = 0.80927$$

Therefore, the unknown patternQ, represented by a single valued neutrosophic set based on indeterminacy value is classified into pattern P_2.

Example5.4: Let us consider in example 4.8, two patterns P_1 and P_2 represented by single valued neutrosophic sets $\widetilde{P_1}$, $\widetilde{P_2}$ in $X = \{x_1, x_2\}$ respectively ,where

$$\widetilde{P_1} = \{\langle x_1, 0.2, 0.5, 0.7\rangle, \langle x_2, 0.9, 0.4, 0.5\rangle\}$$

and

$$\widetilde{P_2} = \{\langle x_1, 0.3, 0.2, 0.5\rangle, \langle x_2, 0.3, 0.2, 0.4\rangle\}.$$

We want to classify an unknown pattern represented by single valued neutrosophic set $\tilde{Q}$ in$x = \{x_1 , x_2\}$ into one of the patterns $\widetilde{P_1}$, $\widetilde{P_2}$, where

$$\tilde{Q} = \{\langle x_1, 0.4, 0.4, 0.1\rangle, \langle x_2, 0.6, 0.2, 0.3\rangle\}.$$

We make the classification using the measure in Definition 5.1, namely

$$S_{NSC}(A, B) = \sum_{i=1}^{n} \left(w_i x S(C_{A(xi)}, C_{B(xi)})\right).$$

Also we find the $C_{A(xi)}$, $C_{B(xi)}$ centers according to the falsity values.

Let w_i be the weight of elementx_i, $w_i = \frac{1}{2}$; $1 \le i \le 2$.

$\widetilde{P_1}x_1 = \langle 0.2,\ 0.5,\ 0.7\rangle$transformed based on falsity value in Example 3.3.1

$$C_{\widetilde{P_1}x_1} = (0.766,0.7,0.7)$$

$\widetilde{P_1}x_2 = \langle 0.9,\ 0.4,\ 0.5\rangle$ transformed based on falsity value in Example 3.3.1

$$C_{\widetilde{P_1}x_2} = (0.766, 0.7,0.5)$$

$\widetilde{P_2}x_1 = \langle 0.3,\ 0.2,\ 0.5\rangle$ transformed based on falsity value in Example 3.3.1

$$C_{\widetilde{P_2}x_1} = (0.633,0.7,0.5)$$

$\widetilde{P_2}x_2 = \langle 0.3,\ 0.2,\ 0.4\rangle$ transformed based on falsity value in Example 3.3.1

$$C_{\widetilde{P_2}x_2} = (0.666, 0.733, 0.4)$$

$\tilde{Q}_{x_1} = \langle x_1, 0.4, 0.4, 0.1\rangle$ transformed based on falsity value in Section 3.3

$C_{\tilde{Q}x_1} = \langle 0.6,\ 0.6,\ 0.1\rangle$(first group)

$\tilde{Q}_{x_2} = \langle x_2, 0.6,\ 0.2,\ 0.3\rangle$transformed based on truthfalsity in Section 3.3

$C_{\tilde{Q}x_2} = \langle 0.7,\ 0.666,\ 0.3\rangle$ (third group)

$$S_{NSC}(\widetilde{P_1}, \tilde{Q}) = 0.7091$$

$$S_{NSC}(\widetilde{P_2}, \tilde{Q}) = 0.8148$$

Therefore, the unknown pattern Q, represented by a single valued neutrosophic set based on falsity value is classified into pattern P_2.

In Example 5.2, Example 5.3 and Example 5.4, all measures according to truth, indeterminancy and falsity values give the same exact result.

Conclusion

In this study, we propose methods to transform between single valued neutrosophic numbers based on centroid points. We also propose a new method to measure the degree of similarity based on falsity values between single valued neutrosophic sets. Then we prove some properties of new similarity measure based on falsity value between single valued neutrosophic sets. When we take this measure with respect to truth or indeterminancy we show that it does not satisfy one of the conditions of similarity measure. We also apply the proposed new similarity measures based on falsity value between single valued neutrosophic sets to deal with pattern recognition problems.

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