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Neutrosophic Pythagorean Sets with Dependent Neutrosophic Pythagorean Components and its Improved Correlation Coefficients

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Abstract: The concept of Neutrosophic Pythagorean set [NPS] with dependent Neutrosophic Pythagorean components was introduced and discussed the relationship between dependent neutrosophic and neutrosophic pythagorean components. The correlation coefficient is a statistical measure which contributes in deciding the degree to which changes in one variable predict changes in another. In this article, we analyze the characteristics of neutrosophic pythagorean sets with improved correlation coefficients. We've also used the same approach in multiple attribute decision-making methodologies including one with a neutrosophic pythagorean environment. Finally, we implemented for above technique to the problem of multiple attribute group decision making.

Keywords: neutrosophic pythagorean sets, neutrosophic Sets, Improved correlation coefficient.

1. Introduction

Fuzzy sets were introduced by Zadeh [20] in 1965 that permits the membership perform valued within the interval [0,1] and set theory it's an extension of classical pure mathematics. Fuzzy set helps to deal the thought of uncertainty, unclearness and impreciseness that isn't attainable within the cantorian set. As Associate in Nursing extension of Zadeh's fuzzy set theory intuitionistic fuzzy set(IFS) was introduced by Atanassov [1] in 1986, that consists of degree of membership and degree of non membership and lies within the interval of [0,1]. IFS theory wide utilized in the areas of logic programming, decision making issues, medical diagnosis etc.

Florentine Smarandache [12] introduced the idea of Neutrosophic set in 1995 that provides the information of neutral thought by introducing the new issue referred to as uncertainty within the set. thus neutrosophic set was framed and it includes the parts of truth membership function(T), indeterminacy membership function(I), and falsity membership function(F) severally. Neutrosophic sets deals with non normal interval of]−0 1+[. Since neutrosophic set deals the indeterminateness effectively it plays an very important role in several applications areas embrace info technology, decision web, electronic database systems, diagnosis, multicriteria higher cognitive process issues etc.,

To method the unfinished data or imperfect data to unclearness a brand new mathematical approach i.e., To deal the important world issues, Wang [13](2010) introduced the idea of single valued neutrosophic sets(SVNS) that is additionally referred to as an extension of intuitionistic fuzzy sets and it became a really new hot analysis topic currently. The concept of neutrosophic pythagorean sets with dependent neutrosophic components was introduced by R. Jhansi and K. Mohana[6].

Further, R. Radha and A. Stanis Arul Mary[7] outlined a brand new hybrid model of Pentapartitioned Neutrosophic Pythagorean sets (PNPS) and Quadripartioned neutrosophic pythagorean sets in 2021.Correlation coefficient may be a effective mathematical tool to live the strength of the link between 2 variables. such a lot of researchers pay the attention to the idea of varied correlation coefficients of the various sets like fuzzy set, IFS, SVNS, QSVNS. In 1999 D.A Chiang and N.P. Lin [3] projected the correlation of fuzzy sets underneath fuzzy setting. Later D.H. Hong [4] (2006) outlined fuzzy measures for a coefficient of correlation of fuzzy numbers below Tw (the weakest t-norm) based mostly fuzzy arithmetic operations.

Correlation coefficients plays a very important role in several universe issues like multiple attribute cluster higher cognitive process, cluster analysis, pattern recognition, diagnosis etc., therefore several authors targeted the idea of shaping correlation coefficients to resolve the important world issues in significantly multicriteria decision making strategies. Jun Ye [19] outlined the improved correlation coefficients of single valued neutrosophic sets and interval neutrosophic sets for multiple attribute higher cognitive process to beat the drawbacks of the correlation coefficients of single valued neutrosophic sets (SVNSs) that is outlined in [17].

In this paper, we have applying improved correlation coefficient on Neutrosophic Pythagorean sets and studied with an example. In the third section, the idea of Neutrosophic Pythagorean set was initiated and in fourth section, the improved correlation coefficient was applied to neutrosophic pythagorean sets. Finally, the decision making under improved correlation was illustrated by an example in the last section

2 Preliminaries

2.1 Definition [12]

Let X be a universe. A Neutrosophic set A on X can be defined as follows:

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

Where T_A , $I_A, F_A: U \to [0,1]$ and $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$

Here, $T_A(x)$ is the degree of membership, $I_A(x)$ is the degree of inderminancy and $F_A(x)$ is the degree of non-membership.

He re, $T_A(x)$ and $F_A(x)$ are dependent neutrosophic components and $I_A(x)$ is an independent component.

2.2 Definition [6]

Let X be a universe. A Pythagorean Neutrosophic set A with T and F are dependent neutrosophic components and I as independent component for $A = \{< x, T_A, I_A, F_A >: x \in X\}$ on X is an object of the form

$$(T_A)^2 + (I_A)^2 + (F_A)^2 \leq 2$$

Here, $T_A(x)$ is the truth membership, $I_A(x)$ is indeterminancy membership and $F_A(x)$ is the false membership .

2.3 Definition [6]

The complement of a Pythagorean Neutrosophic set $A = \{< x, T_A, U_A, F_A >: r \in R\}$ with dependent Neutrosophic components is

$A^C = \{< x, F_A, U_A, T_A >: r \in R\}$.

2.4 Definition [6]

Let $A = \{< x, T_A, U_A, F_A >: r \in R\}$ and $B = \{< x, T_B, U_B, F_B >: r \in R\}$ are two Pythagorean Neutrosophic sets with dependent Neutrosophic components on the universe R. Then the union and intersection of two sets can be defined by

A $\cup B$ = {max (T_A, T_B), max (U_A, U_B),min (F_A, F_B)},

A $\cap B$ = {min (T_A, T_B), min (U_A, U_B),max (F_A, F_B)}.

3.Neutrosophic Pythagorean Set with Dependent Neutrosophic Pythagorean Components

3.1 Definition

Let R be a universe. A Neutrosophic pythagorean set A with T and F as dependent Neutrosophic Pythagorean components and U as independent component for A on R is an object of the form

$$A = \{< x, T_A, U_A, F_A >: r \in R\}$$

Where $(T_A)^2 + (F_A)^2 \leq 1$ and

$$(T_A)^2 + (U_A)^2 + (F_A)^2 \leq 2$$

Here, $T_A(x)$ is the truth membership, $U_A(x)$ is indeterminancy membership and $F_A(x)$ is the false membership .

Remark: When T and F as dependent Neutrosophic Components, then T + F ≤ 1.

3.2 Definition

The complement of a Neutrosophic Pythagorean set $A = \{< x, T_A, U_A, F_A >: r \in R\}$ with dependent Neutrosophic Pythagorean components is

$A^C = \{< x, F_A, 1 - U_A, T_A >: r \in R\}$.

3.3 Definition

Let $A = \{< x, T_A, U_A, F_A >: r \in R\}$ and $B = \{< x, T_B, U_B, F_B >: r \in R\}$ are two Neutrosophic Pythagorean sets with dependent Neutrosophic Pythagorean components on the universe R. Then the union and intersection of two sets can be defined by

A $\cup B$ = {max (T_A, T_B), min (U_A, U_B),min (F_A, F_B)},

A $\cap B$ = {min (T_A, T_B), max (U_A, U_B),max (F_A, F_B)}.

3.4 Example

Let R = {a, b} and A ={ (a, 0.4,0.3),(b,0.5,0.2)}.

Then τ = {0,1, A} is a topology on R. Then A is a Neutrosophic Pythagorean set.

3.5 Example

Let R = {a, b} and A ={ (a, 0.7,0.7),(b,0.7,0.7)}.

Then τ = {0,1, A} is a topology on R. Since $T_A + F_A > 1$,then A is a Neutrosophic Pythagorean set with dependent neutrosophic pythagorean components but not dependent neutrosophic components.

$But\ (T_A)^2 + (U_A)^2 + (F_A)^2 \leq 2$. Hence A is a Pythagorean Neutrosophic set.

3.6 Example

Let R = {a, b} and A ={ (a, 0.8,0.7),(b,0.7,0.7)}.

Then τ = {0,1, A} is a topology on R. Since $T_A + F_A > 1, (T_A)^2 + (F_A)^2 > 1$,then A is not a Neutrosophic Pythagorean set with dependent neutrosophic pythagorean components and dependent neutrosophic components.

$But\ (T_A)^2 + (U_A)^2 + (F_A)^2 \leq 2$. Hence A is a Pythagorean Neutrosophic set.

4. Improved Correlation Coefficients

Based on the concept of correlation coefficient of NPS s ,we have defined the improved correlation coefficients of NPS s in the following section.

4.1 Definition

Let P and Q be any two NPs s in the universe of discourse R = { $r_1, r_2, r_3, \ldots, r_n$ }, then the improved correlation coefficient between P and Q is defined as follows

$$K(P, Q) = \frac{1}{3n} \sum_{k=1}^{n} [\, \alpha_k(1 - \Delta T_k) + +\gamma_k(1 - \Delta U_k) + \mu_k(1 - \Delta F_k) \,] \quad (1)$$

Where

$$\alpha_k = \frac{2 - \Delta T_k - \Delta T_{max}}{2 - \Delta T_{min} - \Delta T_{max}},$$

$$\gamma_k = \frac{2 - \Delta U_k - \Delta U_{max}}{2 - \Delta U_{min} - \Delta U_{max}},$$

$$\mu_k = \frac{2 - \Delta F_k - \Delta F_{max}}{2 - \Delta F_{min} - \Delta F_{max}},$$

$$\Delta T_K = |T_P^2(r_k) - T_Q^2(r_k)\,|,$$

$$\Delta U_K = |U_P^2(r_k) - U_Q^2(r_k)\,|,$$

$$\Delta F_K = |F_P^2(r_k) - F_Q^2(r_k)\,|,$$

$$\Delta T_{min} = min_k |T_P^2(r_k) - T_Q^2(r_k)\,|,$$

$$\Delta U_{min} = min_k |U_P^2(r_k) - U_Q^2(r_k)|,$$

$$\Delta F_{min} = min_k |F_P^2(r_k) - F_Q^2(r_k)|,$$

$$\Delta T_{max} = max_k |T_P^2(r_k) - T_Q^2(r_k)|,$$

$$\Delta U_{max} = max_k |U_P^2(r_k) - U_Q^2(r_k)|,$$

$$\Delta F_{max} = max_k |F_P^2(r_k) - F_Q^2(r_k)|,$$

For any $r_k \in$ R and k = 1, 2, 3….. n.

4.2 Theorem

For any two NPS s P and Q in the universe of discourse R = { r_1, r_2, r_3 ,…, r_n}, the improved correlation coefficient K(P, Q) satisfies the following properties.

1) K (P, Q) = K (Q, P);
2) $0 \leq$ K (P, Q) ≤ 1 ;
3) K(P, Q) = 1 iff P =Q.

Proof

(1) It is obvious and straightforward.

(2) Here, $0 \leq \alpha_k \leq 1$, $0 \leq \gamma_k \leq 1$, $0 \leq \mu_k \leq 1$, $0 \leq 1 - \Delta T_k \leq 1$, $0 \leq 1 - \Delta U_k \leq 1$, $0 \leq 1 - \Delta F_k \leq 1$, Therefore the following inequation satisfies $0 \leq \alpha_k (1 - \Delta T_k) + +\gamma_k(1 - \Delta U_k) + \mu_k(1 - \Delta F_k) \leq 3$. Hence we have $0 \leq$ K (P, Q) ≤ 1

(3) If K (P, Q) = 1, then we get $\alpha_k (1 - \Delta T_k) + \gamma_k(1 - \Delta U_k) + \mu_k (1 - \Delta F_k) = 3$.

Since $0 \leq \alpha_k (1 - \Delta T_k) \leq 1$, $0 \leq \gamma_k(1 - \Delta U_k) \leq 1$ and $0 \leq \mu_k (1 - \Delta F_k) \leq 1$, there are

$\alpha_k (1 - \Delta T_k) = 1$, $\gamma_k(1 - \Delta U_k) = 1$ and $\mu_k (1 - \Delta F_k) = 1$. And also since $0 \leq \alpha_k \leq 1$, $0 \leq \gamma_k \leq 1$ and $0 \leq \mu_k \leq 1, 0 \leq 1 - \Delta T_k \leq 1$, $0 \leq 1 - \Delta U_k \leq 1$, $0 \leq 1 - \Delta F_k \leq 1$. We get $\alpha_k = = \gamma_k = \mu_k = 1$ and $1 - \Delta T_k = 1 - \Delta U_k = 1 - \Delta F_k = 1$. This implies, $\Delta T_k = \Delta T_{min} = \Delta T_{max} = 0$, $\Delta U_k = \Delta U_{min} = \Delta U_{max} = 0$, $\Delta F_k = \Delta F_{min} = \Delta F_{max} = 0$. Hence $T_P(r_k) = T_Q(r_k)$, $U_P(r_k) = U_Q(r_k)$ and $F_P(r_k) = F_Q(r_k)$ for any $r_k \in R$ and k = 1,2,3….n.Hence P = Q.

Conversely, assume that P = Q, this implies $T_P(r_k) = T_Q(r_k)$, $U_P(r_k) = U_Q(r_k)$ and $F_P(r_k) = F_Q(r_k)$ for any $r_k \in R$ and k = 1,2,3….n. Thus $\Delta T_k = \Delta T_{min} = \Delta T_{max} = 0$, $\Delta U_k = \Delta U_{min} = \Delta U_{max} = 0$, $\Delta F_k = \Delta F_{min} = \Delta F_{max} = 0$. Hence we get K (P, Q) = 1.

The improved correlation coefficient formula which is defined is correct and also satisfies these properties in the above theorem . When we use any constant $\varepsilon > 3$ in the following expressions

$$\alpha_k = \frac{\varepsilon - \Delta T_k - \Delta T_{max}}{\varepsilon - \Delta T_{min} - \Delta T_{max}},$$

$$\gamma_k = \frac{\varepsilon - \Delta U_k - \Delta U_{max}}{\varepsilon - \Delta U_{min} - \Delta U_{max}},$$

$$\mu_k = \frac{\varepsilon - \Delta F_k - \Delta F_{max}}{\varepsilon - \Delta F_{min} - \Delta F_{max}}$$

4.3 Example

Let A = { r, 0,0,0,0} and B = { r, 0.4,0.2,0.5} be any two NPS s in R. Therefore by equation (1) we get K(A, B) =0.15 . It shows that the above defined improved correlation coefficient overcome the disadvantages of the correlation coefficient .

In the following, we define a weighted correlation coefficient between NPS s since the differences in the elements are considered into an account,

Let w_k be the weight of each element r_k(k = 1,2…n), $w_k \in [0,1]$ and $\sum_{k=1}^{n} w_k = 1$, then the weighted correlation coefficient between the NPS s A and B

$$K_w(A, B) = \frac{1}{3} \sum_{k=1}^{n} w_k [\, \alpha_k(1 - \Delta T_k) + \gamma_k(1 - \Delta U_k) + \mu_k(1 - \Delta F_k) \,] \quad (2)$$

If $w = (1/n,1/n,1/n,\ldots.1/n)^T$, then equation (2) reduces to equation (1). K_w(A, B) also satisfies the three properties in the above theorem.

4.4 Theorem

Let w_k be the weight for each element r_k(k = 1,2,…n), $w_k \in [0,1]$ and $\sum_{k=1}^{n} w_k = 1$, then the weighted correlation coefficient between the NPS s A and B which is denoted by K_w(A, B) defined in equation (3.2) satisfies the following properties.

1) K_w(A, B) = K_w(B, A);
2) $0 \leq K_w(A, B) \leq 1$;
3) K_w(A, B) = 1 iff A = B.

It is similar to prove the properties in theorem 3.1

5 Decision Making using the improved correlation coefficient of NPS s

Multiple attribute decision making (MADM) problems refers to make decisions when several attributes are involved in real -life problem. For example one may buy a vehicle by analysing the attributes which is given in tems of price, style,safety, comfort etc.,

Here we consider a multiple attribute decision making problem with Neutrosophic pythagorean information and the characteristic of an alternative A_i(i = 1,2,…m) on an attribute C_j(j = 1,2…n) is represented by the following NPS s:

$A_i = \{(C_j, T_{A_i}(C_j), U_{A_i}(C_j), F_{A_i}(C_j) \setminus C_j \in C, j = 1,2, \ldots n\}$,

Where $T_{A_i}(C_j), U_{A_i}(C_j), F_{A_i}(C_j) \in [0,1]$ and

$0 \leq T_{A_j}^2(C_j) + +U_{A_j}^2(C_j) + F_{A_j}^2(C_j) \leq 2$ for $C_j \in C, j = 1,2, \ldots n$ and I = 1,2,…m.

$$d_{ij} = (t_{ij}, u_{ij}, f_{ij})(i = 1,2, \ldots m; j = 1,2 \ldots n).$$

Here the values of d_{ij} are usually derived from the evaluation of an alternative A_i with respect to a criteria C_j by the expert or decision maker. Therefore we got a Neutrosophic pythagorean decision matrix $D = (d_{ij})_{m\times n}$.

In the caseof ideal alternative A^* an ideal PNP can be defined by

$d_j^* = (t_j^*, u_j^*, f_j^*) = (1, 0,0)$(j = 1,2…n) in the decision making method,

Hence the wighted correlation coefficient between an alternative A_i(i=1,2….m) and the ideal alternative A^* is given by,

$$K_w(A_i, A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j[\alpha_k(1 - \Delta t_{ij}) + \gamma_{ij}(1 - \Delta u_{ij}) + \mu_k(1 - \Delta f_{ij})] \tag{3}$$

Where,

$$\alpha_k = \frac{2 - \Delta t_{ij} - \Delta t_{imax}}{2 - \Delta t_{imin} - \Delta t_{imax}},$$

$$\gamma_{ij} = \frac{2 - \Delta u_{ij} - \Delta u_{imax}}{2 - \Delta u_{imin} - \Delta u_{imax}},$$

$$\mu_k = \frac{2 - \Delta f_{ij} - \Delta f_{imax}}{2 - \Delta f_{imin} - \Delta f_{imax}},$$

$$\Delta t_{ij} = |t_{ij}^2 - t_j^*|,$$

$$\Delta u_{ij} = |u_{ij}^2 - u_j^*|,$$

$$\Delta f_{ij} = |f_{ij}^2 - f_j^*|,$$

$$\Delta t_{imin} = min_j\, |t_{ij}^2 - t_j^*|,$$

$$\Delta u_{imin} = min_j\, |u_{ij}^2 - u_j^*|,$$

$$\Delta f_{imin} = min_j\, |f_{ij}^2 - f_j^*|,$$

$$\Delta t_{imax} = max_j\, |t_{ij}^2 - t_j^*|,$$

$$\Delta u_{imax} = max_j\, |u_{ij}^2 - u_j^*|,$$

$$\Delta f_{imax} = max_j\, |f_{ij}^2 - f_j^*|,$$

For i = 1,2….m and j = 1,2….n.

By using the above weighted correlation coefficient We can derive the ranking order of all alternatives and we can choose the best one among those.

5.1 Example

This section deals the example for the multiple attribute decision making problem with the given alt ernatives corresponds to the criteria alloted under Neutrosophic pythagorean environment

For this example, the three potential alternatives are to be evaluated under the four different attributes. The types of intellectual property rights are the alternatives and the various cybercrimes are the attributes for this example. The three potential alternatives are A_1 − copyright, A_2 −patent right and A_3 − trademark and the four diffident attributes are C_1 − infringement, C_2 – piracy and C_3 − cybersquatting . For the evaluation of an alternative A_1 with respect to an attribute C_1 , it is obtained from the questionnaire of a domain expert. According to the attributes we will derive the ranking order of all alternatives and based on this ranking order customer will select the best one. The weight vector of the above attributes is given by w = (0.35,0.4,0.25),Here the alternatives are to be evaluated under the above three attributes by the form of NPS s, In general the evaluation of an alternative A_i with respect to the attributes C_j (i=1,2,3,j=1,2,3) will be done by the questionnaire of a domain expert. In particular, while asking the opinion about an alternative A_1 with respect to an attribute C_1 , the possibility he (or) she say that the statement true is 0.4 , the statement indeterminacy is 0.3 and the statement false is 0.4 . It can be denoted in neutrosophic notation as d_{11} = (0.4,0.3,0.4).

$A_i \setminus C_j$	C_1	C_2	C_3
A_1	[0.4,0.3,0.4]	[0.5.0.4,0.5]	[0.4,0.1,0.4]
A_2	[0.4,0.2,0.6]	[0.3,0.3,0.5]	[0.1,0.4,0.2]
A_3	[0.3,0.4,0.4]	[0.5,0.1,0.4]	[0.4,0.5,0.4]

Then by using the proposed method we will obtain the most desirable alternative. We can get the values of the improved correlation coefficient $M_w(A_i, A^*)$ (i = 1,2,3) by using Equation (3.3).

Hence $M_w(A_1, A^*)$ = 0.2069, $M_w(A_2, A^*)$ = 0.17738, $M_w(A_3, A^*)$ = 0.13516. Therefore

Thus ranking order of the three potential alternatives is $A_1 > A_2 > A_3$. Therefore we can say that A1 alternative copyright have more cyber problems subsists in original literary, dramatic, musical, artistic, cinematographic film, sound recording and computer programme as well than the other alternatives of intellectual property rights. The decision making method provided in this paper is more judicious and more vigorous.

6. Conclusion

In this paper, we've outlined the improved correlation coefficient of NP sets and this is often applicable for a few cases ,once the correlation coefficient of NP sets is undefined (or) unmeaningful and additionally studied its properties. Decision making could be a process that plays a significant role in real world issues. the most method in higher cognitive process is recognizing the matter (or) chance and deciding to deal with it. Here we've mentioned the decision making technique using the improved correlation of NP sets and in significantly an illustrative example is given in multiple attribute higher cognitive process issues that involves the many alternatives supported varied criteria. Therefore our projected improved correlation of NP sets helps to spot the foremost appropriate different to the client supported on the given criteria.

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