Improved Correlation Coefficients of Fermatean Quadripartitioned Neutrosophic Sets for MADM

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Abstract

A correlation coefficient is a statistical measure, which contributes measure, whichhe degree to which changes in one variable predict changes in another. In this article, we analyze the characteristics of Fermatean Quadripartitioned Neutrosophic sets with improved correlation coefficients. We have also used the same approach in multiple attribute decision-making methodologies including one with a Fermatean Quadripartitioned Neutrosophic environment. Finally, we implemented for above technique to the problem of multiple attribute group decision making.

Keywords: Fermatean quadripartitioned neutrosophic sets; Neutrosophic Sets; Improved correlation coefficient

1. Introduction

Fuzzy sets were introduced by Zadeh in 1965 that permits the membership perform valued within the interval [0,1] and set theory it's an extension of classical pure mathematics [14]. Fuzzy set helps to deal the thought of uncertainty, unclearness and impreciseness that is not attainable within the cantorial set. As Associate in Nursing extension of Zadeh's fuzzy set theory intuitionistic fuzzy set(IFS) was introduced by Atanasov [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 [15].

Florentin Smarandache [11] 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 minateness effectively it plays an very important role in several applications areas embrace info technology, decision web, multicriteria decision making, 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 [10](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. Rama Malik., et al [8] projected the idea of pent partitioned single valued neutrosophic sets that relies on Belnap's five-valued logic and Smarandache's five numerical valued logic. In (PSVNS) indeterminacy is splitted into 3 functions referred to as 'Contradiction' (both true and false) and 'Ignorance' (neither true nor false) and an 'unknown' membership in order that PSVNS has five parts, T,C,U,F,G that additionally lies within the non normal unit interval]−0 1+[. Further, M. Ramya et al [7] outlined a brand new hybrid model of Fermatean quadripartitioned Neutrosophic sets (FQNS) in 2022.Correlation coefficient may be

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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, and 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. Radha introduced the concept of tetra neutrosophic sets and its topological spaces.

Correlation coefficients plays a very important role in several universe issues like multiple attribute cluster higher cognitive process, cluster analysis, decision making problems, 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 [13] outlined the improved correlation coefficients of single valued neutrosophic sets and interval neutrosophicsets multiple attribute higher cognitive process to beat the drawbacks of the correlation coefficients of single valued neutrosophic sets (SVNSs) that is outlined in [12]. In this paper, we have applying improved correlation coefficient on fermatean quadripartitioned neutrosophic sets and studied with an example.

2. Preliminaries

2.1 Definition [2]

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 $0 \le T_A(x) + I_A(x) + F_A\,(x) \le 3$

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.

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

2.2 Definition [5]

Let X be a universe. A Fermatean quadripartitioned neutrosophic [FQN] A on X is an object of the form

$$A = \{< x, T_A, C_A, U_A, F_A >: x \in X\}$$

$$(T_A)^3 + (C_A)^3 + (U_A)^3 + (F_A\,)^3 \le 2$$

2.3 Definition [6]

Let P be a non-empty set. A Pentapartitioned neutrosophic set A over P characterizes each element p in P a truth -membership function T_A , a contradiction membership function C_A, an ignorance membership function G_A, unknown membership function U_A and a false membership function F_A , such that for each p in P

$$T_A + C_A + G_A + U_A + F_A \le 5$$

3. Improved Correlation Coefficients

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

3.1 Definition [9]

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

K (P, Q) = $\frac{1}{4n}\sum_{k=1}^{n}$ [$\varphi_k(1 - \Delta \mathrm{T}_k) + \mu_k(1 - \Delta C_k)$ $+\vartheta_k(1 - \Delta U_k)$ $+\gamma_k(1 - \Delta F_k)$]

(3.1)

Where

$$\varphi_k = \frac{2 - \Delta \mathrm{T}_k - \Delta \mathrm{T}_{max}}{2 - \Delta \mathrm{T}_{min} - \Delta \mathrm{T}_{max}},$$

$$\mu_k = \frac{2 - \Delta \mathrm{C}_k - \Delta \mathrm{C}_{max}}{2 - \Delta \mathrm{C}_{min} - \Delta \mathrm{C}_{max}},$$

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

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

$\Delta T_K = |T_P^3(r_k) - T_Q^3(r_k)|$,

$\Delta C_K = |C_P^3(r_k) - C_Q^3(r_k)|$,

$\Delta U_K = |U_P^3(r_k) - U_Q^3(r_k)|$,

$\Delta F_K = |F_P^3(r_k) - F_Q^3(r_k)|$,

$\Delta T_{min} = min_k|T_P^3(r_k) - T_Q^3(r_k)|$,

$\Delta C_{min} = min_k|C_P^3(r_k) - C_Q^3(r_k)|$,

$\Delta U_{min} = min_k|U_P^3(r_k) - U_Q^3(r_k)|$,

$\Delta F_{min} = min_k|F_P^3(r_k) - F_Q^3(r_k)|$,

$\Delta T_{max} = max_k|T_P^3(r_k) - T_Q^3(r_k)|$,

$\Delta C_{max} = max_k|C_P^3(r_k) - C_Q^3(r_k)|$,

$\Delta U_{max} = max_k|U_P^3(r_k) - U_Q^3(r_k)|$,

$\Delta F_{max} = max_k|F_P^3(r_k) - F_Q^3(r_k)|$,

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

3.2 Theorem

For any two FQNS 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, $0 \leq \varphi_k \leq 1, 0 \leq \mu_k \leq 1, 0 \leq \vartheta_k \leq 1, 0 \leq \gamma_k \leq 1$, $0 \leq 1-\Delta T_k \leq 1, 0 \leq 1-\Delta C_k \leq 1$, $0 \leq 1-\Delta U_k \leq 1$, $0 \leq 1-\Delta F_k \leq 1$, Therefore the following inequation satisfies

$0 \leq \varphi_k (1-\Delta T_k) + \mu_k (1 - \Delta C_k) + \vartheta_k(1 - \Delta U_k) + \gamma_k (1 - \Delta F_k) \leq 4$. Hence we have $0 \leq$ K (P, Q) ≤ 1

(3) If K (P, Q) = 1, then we get $\mu_k (1-\Delta T_k) + \varphi_k(1 - \Delta C_k + \vartheta_k(1 - \Delta U_k) + \gamma_k(1 - \Delta F_k) = 4$. Since $0 \leq \varphi_k (1-\Delta T_k) \leq 1$, $0 \leq \vartheta_k(1 - \Delta C_k) \leq 1$, $0 \leq \gamma_k(1 - \Delta U_k) \leq 1$ and $0 \leq \vartheta_k (1 - \Delta F_k) \leq 1$, there are $\mu_k (1-\Delta T_k) = 1$, $\varphi_k(1 - \Delta C_k) = 1$, $\vartheta_k 1 - \Delta U_k) = 1$ and $\gamma_k (1 - \Delta F_k) = 1$. And also since $0 \leq \varphi_k \leq 1$, $0 \leq \mu_k \leq 1$, $0 \leq \vartheta_k \leq 1$ and $0 \leq \gamma_k \leq 1, 0 \leq 1-\Delta T_k \leq 1$, $0 \leq 1 - \Delta C_k \leq 1$, $0 \leq 1 - \Delta U_k \leq 1, 0 \leq 1 - \Delta F_k \leq 1$. We get $\mu_k = \varphi_k = \gamma_k = \vartheta_k = 1$ and $1 - \Delta T_k = 1 - \Delta C_k = 1 - \Delta U_k = 1 - \Delta F_k = 1$. This implies, $\Delta T_k = \Delta T_{min} = \Delta T_{max} = 0$, $\Delta C_k = \Delta C_{min} = \Delta C_{max} = 0$, $\Delta U_k = \Delta U_{min} = \Delta U_{max} = 0$, $\Delta F_k = \Delta F_{min} = \Delta F_{max} = 0$. Hence $T_P(r_k) = T_Q(r_k), C_P(r_k) = C_Q(r_k), U_P(r_k) = U_Q(r_k)$ and $F_P(r_k) = F_Q(r_k)$ for any $r_k \in R$ and k = 1,2,3….n.Hence P = Q.

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

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

$$\mu_k = \frac{\varepsilon - \Delta C_k - \Delta C_{max}}{\varepsilon - \Delta C_{min} - \Delta C_{max}},$$

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

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

3.3 Example

Let A = { r, 0,0,0,0} and B = { r, 0.4,0.2,0.1,0.2} be any two FQNS s in R. Therefore by equation (3.1) we get K(A, B) =0.871.56 . 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 FQNS 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 FQNS s A and B

K_w(A, B) = $\frac{1}{4}\sum_{k=1}^{n} w_k[\, \varphi_k(1 - \Delta T_k) + \mu_k(1 - \Delta C_k) + \vartheta_k(1 - \Delta U_k) + \gamma_k(1 - \Delta F_k)\,]$

(3.2)

If w = (1/n,1/n,1/n,….1/n) ^{T} , then euation (3.1) reduces to equation (3.2). K_w(A, B) also satisfies the three properties in the above theorem.

3.4 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 FQNS s A and B which is denoted by K_w(A, B) defined in equation ( ) 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.

4 Decision Making using the improved correlation coefficient of FQNS 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 fermatean quadripartiitoned neutrosophic information and the characteristic .f an alternative A_i(i = 1,2,…m) on an attribute C_j(j = 1,2…n) is represented by the following FQNS s:

A_i = $\{(C_j, T_{A_i}(C_j), C_{A_i}(C_j), U_{A_i}(C_j), F_{A_i}(C_j) \backslash C_j \in C, j = 1,2, \dots n\}$

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

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$0 \leq T_{A_j}^3(C_j) + C_{A_j}^3(C_j) + U_{A_j}^3(C_j) + F_{A_j}^3(C_j) \leq 2$ for $C_j \in C, j = 1,2, \ldots n$ and I = 1,2,…m.

To make it convenient, we are considering the following five functions $T_{A_i}(C_j), C_{A_i}(C_j), U_{A_i}(C_j), F_{A_i}(C_j)$ in terms of fermatean quadripartitioned neutrosophic value (FQNV)

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

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 fermatean quadripartitioned neutrosophic decision matrix $D = (d_{ij})_{m \times n}$.

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

$d_j^* = (t_j^*, c_j^*, u_j^*, f_j^*)$ = (1,1,0,0,0)(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,

$$K_w(A_i, A^*) = \frac{1}{4}\sum_{j=1}^{n} w_j[\varphi_{ij}(1 - \Delta t_{ij}) + \mu_{ij}(1 - \Delta c_{ij}) + \vartheta_{ij}(1 - \Delta u_{ij}) + (1 - \Delta f_{ij})]$$

(3.3)

Where,

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

$\mu_{ij} = \frac{3 - \Delta c_{ij} - \Delta c_{imax}}{3 - \Delta c_{imin} - \Delta c_{imax}}$,

$\vartheta_{ij} = \frac{3 - \Delta u_{ij} - \Delta u_{imax}}{3 - \Delta u_{imin} - \Delta u_{imax}}$,

$\gamma_{ij} = \frac{3 - \Delta f_{ij} - \Delta f_{imax}}{3 - \Delta f_{imin} - \Delta f_{imax}}$,

$\Delta t_{ij} = |t_{ij}^3 - t_j^*|$,

$\Delta c_{ij} = |c_{ij}^3 - c_j^*|$,

$\Delta u_{ij} = |u_{ij}^3 - u_j^*|$,

$\Delta f_{ij} = |f_{ij}^3 - f_j^*|$,

$\Delta t_{imin} = min_j |t_{ij}^3 - t_j^*|$,

$\Delta c_{imin} = min_j |c_{ij}^3 - c_j^*|$,

$\Delta u_{imin} = min_j |u_{ij}^3 - u_j^*|$,

$\Delta f_{imin} = min_j |f_{ij}^3 - f_j^*|$,

$\Delta t_{imax} = max_j |t_{ij}^3 - t_j^*|$,

$\Delta c_{imax} = max_j |c_{ij}^3 - c_j^*|$,

$\Delta u_{imax} = max_j |u_{ij}^3 - u_j^*|$,

$\Delta f_{imax} = max_j |f_{ij}^3 - f_j^*|$,

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.

4.1 Example

This section deals the example for the multiple attribute decision making problem with the given alternatives corresponds to the criteria alloted under fermatean quadripartitioned neutrosophic environment

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For this example, the three potential alternatives are to be evaluated under the four diffident 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, $C_3 -$ cybersquatting and $C_4 -$ hacking. 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.

By assigning the weight vector of the above attributes is given by w = (0.2,0.35,0.25,0.2), Here the alternatives are to be evaluated under the above four attributes by the form of FQNS s, In general the evaluation of an alternative A_i with respect to the attributes C_j (i=1,2,3,j=1,2,3,4) 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 both true and false is 0.3, the statement neither true nor false is 0.2 and the statement false is 0.1 .It can be denoted in neutrosophic notation as d_{11} = (0.4,0.3,0.2,0.1).

Table 1: The alternatives are to be evaluated under the above four attributes by the form of FQNS s

$A_i \setminus C_j$	C_1	C_2	C_3	C_4
A_1	[0.5,0.3,0.4,0.2]	[0.5.0.4, 0.3,0.2]	[0.4,0.1, 0.1,0.1]	[0.6,0.2,0.3,0.2]
A_2	[0.4,0.3,0.2,0.4]	[0.3,0.3, 0.2,0.1]	[0.1,0.4,0.2,0.3,0.2]	[0.5,0.3,0.1,0.1]
A_3	[0.3,0.4,0.3,0.4]	[0.5,0.1,0.2,0.1]	[0.4,0.5,0.4,0.3,0.2]	[0.3,0.2,0.2,0.2]

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

Hence $M_w(A_1, A^*)$ = 0.678, $M_w(A_2, A^*)$ = 0.6540, $M_w(A_3, A^*)$ = 0.*66921*. Therefore, ranking order of the three potential alternatives is A1>A3>A2. 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.

5. Conclusion

In this paper, we have outlined the improved correlation coefficient of FQNS s and this is often applicable for a few cases once the correlation coefficient of FQNS s 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 have mentioned the decision-making technique using the improved correlation of FQNS s and in significantly an illustrative example is given in multiple attribute higher process issues that involves the many alternatives supported varied criteria. Therefore our projected improved correlation of FQNS s helps to spot the foremost appropriate different to the client supported on the given criteria.

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