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Role of Fermatean Neutrosophic Sets in Determination of Career Planning

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Abstract

Fermatean Neutrosophic sets that combine membership degrees of Pythagorean fuzzy sets and neutrosophic sets provide a more effective means of representing uncertainty, vagueness, and indeterminacy. These type of sets are commonly utilized across various disciplines which offers a structure for addressing intrinsic uncertainties that inherits in real life situations, for example, when making decisions about career options, pattern identification, work-life equilibrium and entrepreneurship. This study mainly examines Fermatean neutrosophic sets, the various distance measures of Fermatean neutrosophic sets and the associated properties. The characteristics of these features are also investigated. In a Fermatean neutrosophic environment, distance measures play a very important role. These are used extensively in pattern recognition, medical diagnosis and decision making. The literature on neutrosophic theory has offered a variety of distance measurements over time, each with specific benefits and drawbacks. The common metrics used are Hamming, Euclidean and Hausdroff distances which are calculated element wise across the sets. Taking into consideration of the existing ambiguities, a new distance metric is introduced here for dealing with Fermatean neutrosophic sets. This method provides more comprehensive and reliable possibilities which can be helpful for prospective candidates to assess complex career options. Decision-making is aided by an approach described here for both people and organizations. Furthermore, an application based on Fermatean neutrosophic sets is shown to demonstrate the method's functionality.

Keywords: Fuzzy sets, Intuitionistic fuzzy sets, Pythagorean fuzzy sets, Fermatean fuzzy sets, Neutrosophic sets, Pythagorean neutrosophic sets, Fermatean neutrosophic sets

Introduction

The shortcomings of classical set theory paved the way for fuzzy sets by Zadeh [1] to deal with unreliability and unpredictability in real world problems faced by the existing theories. Gradually it was realized that only the membership function in fuzzy set was not sufficient to grasp the existing uncertainties which in turn resulted in the introduction of intuitionistic fuzzy set by Atanassav [2].This is undoubtedly a generalization of fuzzy sets which is represented by the degree of membership and the degree of non-membership together with the condition that their sum lies in the interval [0,1]. But in due course of time, it was again realized that intuitionistic fuzzy sets can only handle incomplete information not the indeterminate information and inconsistent information which exists commonly in belief system. There arise many situations where the sum of grades of membership and non-membership becomes greater than 1 which violates the condition of intuitionistic fuzzy set. These limitations led to derive a new concept called Pythagorean fuzzy set, Yager [5].

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Pythagorean fuzzy set was considered as an effective tool for handling situation characterized by imprecision and indeterminacies. Gradually it was realized that there may be the presence of some cases when the sum of the squares of values of membership and non-membership values is greater than 1. There are some situations which cannot be explained with intuitionistic fuzzy sets or Pythagorean fuzzy sets and hence Fermatean fuzzy sets was introduced by Senapati.et.al [6] to deal with such situations. But as in other cases of uncertainties, in Fermatean fuzzy sets also there exists some restrictions on in the form of the total of the third powers of the membership grades and non-membership grades should be less than one.

Neutrosophic sets was introduced by Smarandache [3, 4] as an extension of fuzzy sets and intuitionistic fuzzy sets which plays a vital role in handling uncertainties, imprecision and ambiguities that occur in day-to-day life. Gradually different kinds of neutrosophic sets took place depending upon the types of uncertainties.

Jansi.et.al [7], extended the concept of Pythagorean fuzzy sets to define Pythagorean neutrosophic sets and discussed some application areas as well. It can be observed that in the case of Pythagorean neutrosophic sets, sum of the square of the membership and the non-membership grades is less than or equal to 1 and the square of the indeterminancy value is less than or equal to 1.

Subsequently, Sweety et al. [9] proposed the novel concept of Fermatean Neutrosophic sets, integrating the membership degree of Pythagorean fuzzy sets and neutrosophic sets, facilitating a more effective representation of uncertainty, vagueness, and indecisiveness. Fermatean neutrosophic sets can be considered a relatively novel idea within the field of neutrosophic set theory. This somewhat sophisticated concept includes three functions that denote the levels of membership, non-membership, and indeterminacy, each elevated to the power of three. The requirements for a Fermatean neutrosophic set state that the total of the cubed values of membership and non-membership degrees is limited to 1, and the cubed indeterminacy degree is similarly restricted within the interval [0,1]. This guarantees an equal representation of all three elements of uncertainty. Fermatean neutrosophic sets are specific types of neutrosophic sets have found real applications under uncertainty in decision-making ([10]-[13]), graph theory ([14]–[17]) and so on.

Furthermore, the measuring distance among neutrosophic sets plays a very key role in various fields of study, several researchers are investigating it from various perspective. Normalized hamming and Euclidean distance for neutrosophic sets were developed by Majumdar.et.al [18]. More works in this direction can be found in ([18] - [27]). In this particular work, various distance measure between two Fermatean neutrosophic sets are discussed and then these measures are applied in selection of career from various probable opportunities.

The paper is organized as follows: Section 1 deals with literature reviews, Section 2 deals with some existing definitions which are subsequently used, Section 3 deals with various distance measures of neutrosophic sets, Section 4 deals with various new distance measures of Fermatean neutrosophic sets, Section 5 deals Fermatean neutrosophic set model in career planning and finally Section 6 deals with conclusions.

Preliminaries

In this section some definitions are provided which are subsequently used in later parts of the article.

Definition 2.1: Neutrosophic set ([3], [4])

Let the universe of discourse be Π. Then the neutrosophic set Υ_1 is an object having the form $A=\{(q,\varepsilon_A(q),\phi_A(q),\varphi_A(q))/q\in\Pi\}$,where functions $\varepsilon_A(q),\phi_A(q),\varphi_A(q):\Pi\rightarrow\,]^{-}0,1^{+}[$, define respectively the degree of membership $\varepsilon_A(q)$, the degree of indeterminacy $\phi_A(q)$ and the degree of non-membership $\varphi_A(q)$ respectively of the element $q\in\Pi$ to the set A with the condition $0\le\varepsilon_A(q)+\phi_A(q)+\varphi_A(q)\le 3^{+}$.

Definition 2.2: Pythagorean Fuzzy Set [5]

Let Π be the universe of discourse. Then a Pythagorean fuzzy set A set on Π is defined as $A=\{(q,\varepsilon_A(q),\varphi_A(q))/q\in\Pi\}$ where $\varepsilon_A(q):\Pi\rightarrow[0,1]$, and $\varphi_A(q):\Pi\rightarrow[0,1]$ denote membership degree and non-membership degree having the condition $0 \le (\varepsilon_A(q))^2 + (\varphi_A(q))^2 \le 1$ for $\forall q \in \Pi$. Pythogorean fuzzy set is a generalization of intuitionistic fuzzy set.

Definition 2.3: Fermatean Fuzzy Set [6]

A Fermatean fuzzy set on the universe of discourse Π is defined as $A = \{(q, \varepsilon_A(q), \varphi_A(q)) / q \in \Pi\}$, where $\varepsilon_A(q): \Pi \to [0,1]$ and $\varphi_A(q): \Pi \to [0,1]$ denotes the degree of membership and degree of non-membership having the condition $0 \le (\varepsilon_A(q))^3 + (\varphi_A(q))^3 \le 1$ for $\forall q \in \Pi$. Here the numbers $\varepsilon_A(q)$ and $\varphi_A(q)$ represents respectively the membership degree and non-membership degree of the element q in the set Π.

Definition 2.4: Pythagorean Neutrosophic Set ([7], [8])

Let Π be the universe of discourse. Then a Pythagorean neutrosophic set Υ_1 on $\aleph$ is defined as $A = \{(q, \varepsilon_A(q), \phi_A(q), \varphi_A(q)) / q \in \Pi\}$ where $\varepsilon_A(q): \Pi \to [0,1]$, $\phi_A(q): \Pi \to [0,1]$ and $\varphi_A(q): \Pi \to [0,1]$, $\eta_A(x): \aleph \to [0,1]$ and denote the degree of membership and degree indeterminacy and the degree of non-membership having the condition $0 \le (\varepsilon_A(q))^2 + (\varphi_A(q))^2 \le 1$ and $0 \le (\phi_A(q))^2 \le 1$ for $q \in \Pi$. Then other condition is obviously $0 \le (\varepsilon_A(q))^2 + (\phi_A(q))^2 + (\varphi_A(q))^2 \le 2$.

Definition 2.5: Fermatean Neutrosophic Set [9]

Let Π be the universe of discourse containing neutrosophic elements. Then a Fermatean neutrosophic set A is defined as $A = \{(q, \varepsilon_A(q), \phi_A(q), \varphi_A(q)) / q \in \Pi\}$ over the space Π with the condition that $\chi_A(x), \eta_A(x), \xi_A(x)) \in [0,1]$, $0 \le (\varepsilon_A(q))^3 + (\varphi_A(q))^3 \le 1$ and $0 \le (\phi_A(q))^3 \le 1$ so that $0 \le (\varepsilon_A(q))^3 + (\phi_A(q))^3 + (\varphi_A(q))^3 \le 2$ for all $q \in \Pi$. Here $\varepsilon_A(q)$ is the degree of membership, $\phi_A(q)$ is the degree of indeterminacy and $\varphi_A(q)$ represents the degree of non-membership respectively. This concept is illustrated with the help of a numerical example in the form when membership degree = 0.7 and non-membership degree = 0.6. Here it can be visualized that $(0.7)^2 + (0.9)^2 > 1$ and hence the condition of Pythagorean neutrosophic set is not satisfied because according to Pythagorean set it must be less than 1. That is it should have been $0 \le (\varepsilon_A(q))^2 + (\varphi_A(q))^2 \le 1$ and $0 \le (\phi_A(q))^2 \le 1$. But in this particular case it can be seen that $(0.7)^3 + (0.9)^3 \le 1$ which in fact implies that Fermatean neutrosophic set can handle such situations quite nicely.

Various Distance Measure of Neutrosophic Sets [28]

Let $A = \{(q, \varepsilon_A(q), \phi_A(q), \varphi_A(q)) / q \in \Pi\}$ and $B = \{(q, \varepsilon_B(q), \phi_B(q), \varphi_B(q)) / q \in \Pi\}$ be two Neutrosophic sets. Then the various existing distance measures are discussed in the following manner:

i. Hamming Distance

$$D_H(\mathrm{A,B}) = \frac{1}{3}\sum_{i=1}^{n}(|\varepsilon_A(q_i) - \varepsilon_A(q_i)| + |\phi_A(q_i) - \phi_A(q_i)| + |\varphi_A(q_i) - \varphi_A(q_i)|$$

ii. Euclidean Distance

$$D_E(\mathrm{A,B}) = \sqrt{\frac{1}{3}\sum_{i=1}^{n}[(\varepsilon_A(q_i) - \varepsilon_A(q_i))^2 + (\phi_A(q_i) - \phi_A(q_i))^2 + (\varphi_A(q_i) - \varphi_A(q_i))^2]}$$

iii. Normalized Hamming Distance

$$D_{nH}(\mathrm{A,B}) = \frac{1}{3n}\sum_{i=1}^{n}(|\varepsilon_A(q_i) - \varepsilon_A(q_i)| + |\phi_A(q_i) - \phi_A(q_i)| + |\varphi_A(q_i) - \varphi_A(q_i)|$$

iv. Normalized Euclidean Distance

$$D_{nE}(\mathrm{A,B}) = \sqrt{\frac{1}{3n}\sum_{i=1}^{n}[(\varepsilon_A(q_i) - \varepsilon_A(q_i))^2 + (\phi_A(q_i) - \phi_A(q_i))^2 + (\varphi_A(q_i) - \varphi_A(q_i))^2]}$$

New Distance Measures of Fermatean Neutrosophic Sets

Let $A = \{(q, \varepsilon_A(q), \phi_A(q), \varphi_A(q)) / q \in \Pi\}$ and $B = \{(q, \varepsilon_B(q), \phi_B(q), \varphi_B(q)) / q \in \Pi\}$ be two Fermatean Neutrosophic sets. Then the various distance measures are discussed in the following manner:

i. Hamming Distance

$$D_H(\mathrm{A},\mathrm{B}) = \frac{1}{3}\sum_{i=1}^{n}(\left|(\varepsilon_A(q_i))^3 - (\varepsilon_A(q_i))^3\right| + \left|(\phi_A(q_i))^3 - (\phi_A(q_i))^3\right| + \left|(\varphi_A(q_i))^3 - (\varphi_A(q_i))^3\right|$$

ii. Euclidean Distance

$$D_E(\mathrm{A},\mathrm{B}) = \sqrt{\frac{1}{3}\sum_{i=1}^{n}[\{(\varepsilon_A(q_i))^3 - (\varepsilon_A(q_i))^3)^2\} + \{(\phi_A(q_i))^3 - (\phi_A(q_i))^3)^2\} + \{(\varphi_A(q_i))^3 - (\varphi_A(q_i))^3)^2\}]}$$

iii. Normalized Hamming Distance

$$D_{nH}(\mathrm{A},\mathrm{B}) = \frac{1}{3n}\sum_{i=1}^{n}(\left|(\varepsilon_A(q_i))^3 - (\varepsilon_A(q_i))^3\right| + \left|(\phi_A(q_i))^3 - (\phi_A(q_i))^3\right| + \left|(\varphi_A(q_i))^3 - (\varphi_A(q_i))^3\right|$$

iv. Normalized Euclidean Distance

$$D_{nE}(\mathrm{A},\mathrm{B}) = \sqrt{\frac{1}{3n}\sum_{i=1}^{n}[\{(\varepsilon_A(q_i))^3 - (\varepsilon_A(q_i))^3)^2\} + \{(\phi_A(q_i))^3 - (\phi_A(q_i))^3)^2\} + \{(\varphi_A(q_i))^3 - (\varphi_A(q_i))^3)^2\}]}$$

Fermatean Neutrosophic Set Model in Selection of Career

The importance of giving students sufficient information for making informed career choices cannot be understated. This is crucial because the various issues of insufficient career guidance encountered by students significantly impact their career decisions and effectiveness. Consequently, it is important that students receive ample information regarding career selection to facilitate proper planning, preparation and skill development. Among the factors that shape a career, including academic success, personality traits etc (Table 1 and 2).

In this article Fermatean neutrosophic sets are used as it seems incorporating the membership degree (i.e., the marks of questions answered by the student), the indeterminancy degree (which is the mark allocated to the questions the student do not attempt) and the non-membership degree (i.e., the marks allocated to the questions the student failed).

Let the set of students be noted as A_{Students}={Student1, Student2, Student3, Student4} ,the set of career options be A_{Career}={ Medicine(M), Pharmacy(P), Surgery(S), Anatomy(A) } and the related set of subjects to career choices be A_{Subject} ={ Physics, Chemistry, Mathematics, Biology, Information Technology}. It is supposed that the students mentioned above going for examinations on the subjects mentioned for selection of their career options. The table below shows careers and related subjects requirements in terms of the values of Fermatean neutrosophic sets.

Table 1: Students Vs Subjects

	Physics	Chemistry	Mathematics	Biology	IT
Student 1	(0.9, 0.1, .45)	(0.8, 0.3, .66)	(0.9, 0.2, 0.5)	(.81, 0.1, .63)	(.76, 0.2, .67)
Student 2	(0.9, 0.2, 0.5)	(0.8, 0.4, .66)	(0.9, 0.31, .47)	(0.8,.27, .66)	(.79, .35, .65)
Student 3	(0.8, 0.3, .65)	(.77, 0.25, .69)	(.86, 0.2, .55)	(0.9,.15, 0.3)	(.82, 0.3, .63)
Student 4	(.82, .35, .65)	(.76, .25, .69)	(.83, 0.35, .64)	(.86, 0.3, .53)	(.87, 0.3, .52)

Table 2: Career Vs Subjects

	Physics	Chemistry	Mathematics	Biology	IT
M	(0.78, 0.2, .66)	(0.81, 0.3, .64)	(0.9, 0.25, 0.5)	(.82, .25, .63)	(.75, 0.35, .67)
P	(0.78, 0.3, 0.65)	(0.8, 0.3, .65)	(0.9, 0.3, .46)	(0.8,.25, .65)	(.77, .25, .65)
S	(0.8, 0.25, .62)	(.75, 0.2, .69)	(.85, 0.2, .55)	(0.9,0.1, 0.3)	(0.8, 0.2, .63)
A	(0.8, 0.4, .63)	(.75, .25, .69)	(.81, 0.3, .64)	(0.9, 0.3, .45)	(0.8, 0.3, .64)

In order to calculate the distance between each student and each career, normalized Eucledean distance measure is taken into account.

$$\partial(Student1, M) = \sqrt{\frac{1}{3.5}\begin{bmatrix} \{(0.9)^3-(0.78)^3\}^2+\{(0.1)^3-(0.2)^3\}^2+\{(.45)^3-(.66)^3\}^2+\{(0.8)^3-(.81)^3\}^2+\{(0.3)^3-(0.3)^3\}^2+\{(.66)^3-(.64)^3\}^2 \\ +\{(0.9)^3-(0.9)^3\}^2+\{(0.2)^3-(0.25)^3\}^2+\{(0.5)^3-(0.5)^3\}^2+\{(.81)^3-(.82)^3\}^2+\{(.1)^3-(.25)^3\}^2+\{(.63)^3-(.63)^3\}^2 \\ +\{(.76)^3-(.75)^3\}^2+\{(.2)^3-(.35)^3\}^2+\{(.67)^3-(.67)^3\}^2 \end{bmatrix}}$$

$$= \sqrt{\frac{1}{15}\times 0.106552857} = 0.0842824$$

$$\partial(Student1, P) = \sqrt{\frac{1}{3.5}\begin{bmatrix} \{(0.9)^3-(0.78)^3\}^2+\{(0.1)^3-(0.3)^3\}^2+\{(.45)^3-(.65)^3\}^2+\{(0.8)^3-(.8)^3\}^2+\{(0.3)^3-(0.3)^3\}^2+\{(.66)^3-(.65)^3\}^2 \\ +\{(0.9)^3-(0.9)^3\}^2+\{(0.2)^3-(0.3)^3\}^2+\{(0.5)^3-(0.46)^3\}^2+\{(.81)^3-(0.8)^3\}^2+\{(.1)^3-(.25)^3\}^2+\{(.63)^3-(.65)^3\}^2 \\ +\{(.76)^3-(.77)^3\}^2+\{(.2)^3-(.25)^3\}^2+\{(.67)^3-(.65)^3\}^2 \end{bmatrix}}$$

$$= \sqrt{\frac{1}{15}\times 0.103088625} = 0.092686$$

$$\partial(Student1, A) = \sqrt{\frac{1}{3.5}\begin{bmatrix} \{(0.9)^3-(0.8)^3\}^2+\{(0.1)^3-(0.4)^3\}^2+\{(.45)^3-(.63)^3\}^2+\{(0.8)^3-(.75)^3\}^2+\{(0.3)^3-(0.25)^3\}^2+\{(.66)^3-(.69)^3\}^2 \\ +\{(0.9)^3-(0.81)^3\}^2+\{(0.2)^3-(0.3)^3\}^2+\{(0.5)^3-(0.55)^3\}^2+\{(.81)^3-(0.9)^3\}^2+\{(.1)^3-(.3)^3\}^2+\{(.63)^3-(.45)^3\}^2 \\ +\{(.76)^3-(.8)^3\}^2+\{(.2)^3-(.3)^3\}^2+\{(.67)^3-(.64)^3\}^2 \end{bmatrix}}$$

$$= \sqrt{\frac{1}{15}\times 0.1907294} = 0.1127621$$

$$\partial(Student1, S) = \sqrt{\frac{1}{3.5}\begin{bmatrix} \{(0.9)^3-(0.8)^3\}^2+\{(0.1)^3-(0.25)^3\}^2+\{(.45)^3-(.62)^3\}^2+\{(0.8)^3-(.75)^3\}^2+\{(0.3)^3-(0.2)^3\}^2+\{(.66)^3-(.69)^3\}^2 \\ +\{(0.9)^3-(0.85)^3\}^2+\{(0.2)^3-(0.2)^3\}^2+\{(0.5)^3-(0.55)^3\}^2+\{(.81)^3-(0.9)^3\}^2+\{(.1)^3-(.1)^3\}^2+\{(.63)^3-(.3)^3\}^2 \\ +\{(.76)^3-(.8)^3\}^2+\{(.2)^3-(.2)^3\}^2+\{(.67)^3-(.63)^3\}^2 \end{bmatrix}}$$

$$= \sqrt{\frac{1}{15}\times 0.189017601} = 0.1122549$$

Similarly

$$\partial(Student2, M) === \sqrt{\frac{1}{15}\times 0.10290379} = 0.0842824$$

$$\partial(Student2, P) == \sqrt{\frac{1}{15}\times 0.09133433} = 0.0780317$$

$$\partial(Student2, S) == \sqrt{\frac{1}{15}\times 0.2079909} = 0.117754$$

$$\partial(Student2, A) == \sqrt{\frac{1}{15}\times 0.2285807} = 0.1234452$$

$$\partial(Student3, M) == \sqrt{\frac{1}{15}\times 0.1519361} = 0.10064329$$

$$\partial(Student3, P) == \sqrt{\frac{1}{15}\times 0.1726526} = 0.1072854$$

$$\partial(Student3, S) == \sqrt{\frac{1}{15}\times 0.0513995} = 0.0585375$$

$$\partial(Student3, A) == \sqrt{\frac{1}{15}\times 0.07204998} = 0.0693061$$

$$\partial(Student4, M) == \sqrt{\frac{1}{15}\times 0.140864203} = 0.09690689$$

$$\partial(Student4, P) == \sqrt{\frac{1}{15}\times 0.1395049} = 0.096438$$

$$\partial(Student4, S) == \sqrt{\frac{1}{15}\times 0.6213365} = 0.2035250$$

$$\partial(Student4, A) == \sqrt{\frac{1}{15}\times 0.05018635} = 0.0578425$$

As a result, the following table is obtained:

Table 3: Students Vs Career

	M	P	S	A
Student 1	0.0842824	0.092686	0.1122549	0.1127621
Student 2	0.0828266	0.0780317	0.117754	0.1234452
Student 3	0.10064329	0.1072854	0.0585375	0.0693061
Student 4	0.09690689	0.096438	0.2035250	0.0578425

The above table is obtained with the help of normalized Euclidean distance measure for calculating the distance between students and careers on the basis of subjects.

For choosing a proper career, from the above table the shortest distance is chosen to indicate what career is suitable for whom. Accordingly, Student 1 preferably to opt for M(Medicine), Student 2 to opt for P(Pharmacist), Student 3 to opt for S (Surgery) and Student 4 to opt for A (Anatomy).

Conclusion

This paper various distance measures of Fermatean neutrosophic sets are discussed. Thereafter an appropriate model is prepared for selecting suitable career opportunities using normalized Euclidean distance. This is done to find the distance of each student from each career with respect to the required specification of subjects. The various distances obtained thereby indicates how far or how near the student is from choosing the most suitable career path. The solution obtained on the basis of the smallest distance found between each student and career. The shortest distance indicates that the students are to choose that career. In future, the aim will be to utilize these distance measures in finding solutions on the issues that may arise in decision making problems. This method of finding the distance is limited to Fermatean neutrosophic sets only.

Ethics approval

Not required.

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Competing interests

There is no conflict of interest.

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Declaration of artificial intelligence use

It is hereby confirmed that no artificial intelligence (AI) tools or methodologies were utilized in any stage of this study, including during data collection, analysis, visualization or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

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