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New Possibility Soft Sets with Gender Equality Application in Early Childhood Children

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Abstract. In this study, we introduce the theory of possibility Fermatean fuzzy soft set and describe various associated operations, such as complement, union, intersection, AND, and OR. Then, for dealing with decision issues, a similarity measure is devised to compare two possiblity Fermatean fuzzy soft sets. Finally, a practical example with respect to gender equality in early childhood children is given to demonstrate the applicability of this similarity measure in decision-making situations.

Keywords. Early childhood, gender equality, possibility Fermatean fuzy soft set, similarity measure

1. Introduction

Uncertainty may be found in almost all real-world issues. Many uncertain theories, such as fuzzy sets [1], intuitionistic fuzzy sets [2], and Pythagorean fuzzy sets [3], have been proposed to deal with uncertainty. According to Zadeh's fuzzy set, decision-makers should solve unclear situations by considering only the membership degree. Atanassov introduced the idea of an intuitionistic fuzzy set in [2] which is defined by a membership degree and a non-membership degree that meet the requirement that the total of its membership degree and non-membership is equal to or less than 1. However, throughout the decision-making process, we may encounter a circumstance in which the total degree of membership and nonmembership of a certain characteristic is more than 1. Yager developed the notion of Pythagorean fuzzy sets to expand intuitionistic fuzzy sets, which are defined by a membership degree and a nonmembership degree that meet the requirement that the square sum of their membership degree and nonmembership degree is equal to or less than 1. The notion of soft sets, introduced by Molodtsov [4], is well recognized as a parameterization tool for dealing with uncertainty. As compared to the

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other uncertain theories discussed above, the theory of soft sets better captures the objectivity and complexity of decision-making concerns in real-world circumstances.

The Fermatean fuzzy set is ascribed to Senapati and Yager [5]. The FFS's MD and ND accomplish the property XX. When it comes to recognizing uncertainties, the FFS, a fresh notion in the literature, outperforms the IFS and PFS. [5] provides some of the FFS properties, such as score and accuracy. The TOPSIS technique, which is extensively used to handle Multi-Criteria Decision Making (MCDM) challenges, was used to address the FFS problem. Furthermore, Senapati and Yager say that FFS was performed using the TOPSIS approach, which is commonly used to solve MCDM problems. Senapati and Yager [5] go on to say that the TOPSIS approach, which is commonly utilized in MCDM difficulties, was applied for FFS.

Gender equality is an important concept for the healthy structuring of an individual's perception of gender. Gender equality is the construction of an understanding-thought-life world that centers on biological genders. This construction process is based on early childhood, which is one of the most critical periods in which personality is formed. The individual observing his environment from infancy creates cognitive schemes by associating different behaviors with people. Children need sufficient and objective experience to construct these schemas correctly. Thanks to children's thinking skills, correct schemas regarding gender equality can be formed. Visual, auditory, and tactile stimuli that reach early childhood children are effective in forming their perceptions of gender equality. A cognitive structure that becomes concrete with the images, sounds, and tactile elements it encounters in family and social life, starting from its own body, becomes evident over time.

The goal of this paper is to broaden the concept of the Fermatean fuzzy soft set by introducing the possibility of each element in the universe that is associated with the parameterization of Fermatean fuzzy sets while defining a Fermatean fuzzy soft set from which we can obtain a possibility Fermatean fuzzy soft set model. Furthermore, we will build a similarity-measure technique based on this model. To exemplify the efficacy of the suggested strategy, an example of a real-life situation relating to children's understanding of gender equality in early childhood teachings is provided. Based on the results of the experiments, it was determined that the novel strategy proposed in the FFS environment may meet the real-life decision-making problem with its aims.

2. Preliminaries

Definition 2.1.[6] Let U be a universe of discourse. A Pythagorean fuzzy set(PFS) is an object having the following form: $A = \{(x, m_A(x), n_A(x)) : x \in U\}$, where $m_A : U \to [0,1]$ is a degree of membership and $n_A : U \to [0,1]$ is a degree of non- membership of element $x \in U$ to the set A, respectively, and for any $x \in U$, it holds that $0 \leq (m_A(x))^2 + (n_A(x))^2 \leq 1$. The degree of indeterminacy is given as $h_A(x) = \sqrt{1 - (m_A(x))^2 - (n_A(x))^2}$, where $m_A, n_A \in [0,1]$.

Definition 2.2. [7] Given an initial universe set U and a universe set of parameters E. F_f is referred to as a Pythagorean fuzzy soft set(PFSS) on U if $A \subseteq E$ and $F : A \to G(U)$, where G(U) is the family of all PF subsets of U.

Definition 2.3. [8] Given that U is a universal set of elements and E is a set of parameters then U_E is called a soft universe. Suppose that $F : A \to G(U)$, where G(U) is the collection of all PF subsets of U. If $F_f : E \to G(U) \times G(U)$ is a function defined as $F_f(e) = (F(e)(x), f(e)(x))$, $x \in U$, then F_f is referred to as a possibility PFSS(PPFSS) on U_E.

Further, $F_f(e)$ can be written as: $F_f(e) = \{\langle x, (m_{F(e)}(x),\ n_{F(e)}(x)), (m_{f(e)}(x),\ n_{f(e)}(x))\rangle : x \in U\}$.

Definition 2.4.[5] The Fermatean fuzzy set(FFS) F in U is an object having the form $F = \{(x, m_F(x), n_F(x)) : x \in U\}$, where $m_F, n_F \in [0,1]$, including the condition $0 \leq (m_F(x))^3 + (n_F(x))^3 \leq 1$. The degree of indeterminacy is given as $h_F(x) = \sqrt[3]{1 - (m_F(x))^3 - (n_F(x))^3}$.

Definition 2.5.[9] Let U be a universal set and E be a parameter set. Let $A \subseteq E$. F_f is a Fermatean fuzzy soft set(FFSS) over U, where $F: A \to G(U)$, where G(U) is the family of all FF subsets of U.

A FFS on U is a family of parameters formed by some Fermatean fuzzy subsets on U. For any parameter $\varepsilon \in A$, $F(\varepsilon)$ is a FSS associated with $\varepsilon \in U$. Then, it is called Fermatean fuzzy value set of parameter ε.

3. New Possibility Fuzzy Sets

Definition 3.1. Given that U is a universal set of elements and E is a set of parameters, then U_E is called a soft universe. Suppose that $F: E \to G(U)$, and f is a Fermatean fuzzy subset of e, i.e. $f: E \to G(U)$, where $G(U)$ denotes the collection of all Fermatean fuzzy subsets of U. If $F_f: E \to G(U) \times G(U)$ is a function defined as $F_f(e) = (F(e)(x), f(e)(x))$, $x \in U$, then F_f is referred to as a Possibility Fermatean Fuzzy Soft Set(PFFSS) on U_E.

It's worth noting that for each parameter e, $F_f(e)$ can be written as:

$$F_f(e) = \{\langle x, (m_{F(e)}(x),\ n_{F(e)}(x)), (m_{f(e)}(x),\ n_{f(e)}(x))\rangle : x \in U\}.$$

Example 1. Given that $U = \{u_1, u_2, u_3\}$ is a set of three diseases under consideration of an expert. Let $E = \{e_1, e_2, e_3\}$ be a set of symptoms. $F_f: E \to G(U) \times G(U)$ is given as follows:

$$F_f(e_1) = \{(u_1/(0.8, 0.6), (0.7,0.6)), (u_2/(0.6, 0.7), (0.5,0.8)), (u_3/(0.9, 0.4), (0.8,0.4))\},$$
$$F_f(e_2) = \{(u_1/(0.6, 0.5), (0.9,0.5)), (u_2/(0.7, 0.5), (0.4,0.8)), (u_3/(0.9, 0.2), (0.8,0.6))\},$$
$$F_f(e_3) = \{(u_1/(0.6, 0.6), (0.7,0.4)), (u_2/(0.9, 0.3), (0.8,0.4)), (u_3/(0.3, 0.9), (0.4,0.7))\}.$$

It matrix form it can be expressed as

$$F_f = \begin{bmatrix} (0.8, 0.6), (0.7,0.6) & (0.6, 0.7), (0.5,0.8) & (0.9, 0.4), (0.8,0.4) \\ (0.6, 0.5), (0.9,0.5) & (0.7, 0.5), (0.4,0.8) & (0.9, 0.2), (0.8,0.6) \\ (0.6, 0.6), (0.7,0.4) & (0.9, 0.3), (0.8,0.4) & (0.3, 0.9), (0.4,0.7) \end{bmatrix}$$

Definition 3.2. Given a universal set of elements U and a set of parameters E. Suppose that F_f and G_g are two PFFSSs over U_E. Now, F_f is referred to as a possibility Fermatean fuzzy soft subset of G_g if and only in

(i.) $g(e)(x) \subseteq f(e)(x)$ if $m_{f(e)}(x) \geq m_{g(e)}(x)$, $n_{q(e)}(x) \leq n_{f(e)}(x)$,

(ii.) $G(e)(x) \subseteq F(e)(x)$ if $m_{F(e)}(x) \geq m_{G(e)}(x)$, $n_{G(e)}(x) \leq n_{F(e)}(x)$, $\forall e \in E$.

This relationship is denoted as $G_g \subseteq F_f$.

Example 2. Consider the PFFSS F_f over U_E given in Example 1. Let G_g be another PFFSS over U_E defined as follows:

$$G_g(e_1) = \{(u_1/(0.7, 0.7), (0.5,0.8)), (u_2/(0.5, 0.8), (0.3,0.9)), (u_3/(0.8, 0.6), (0.7,0.5))\},$$
$$G_g(e_2) = \{(u_1/(0.4, 0.6), (0.7,0.7)), (u_2/(0.6, 0.7), (0.3,0.9)), (u_3/(0.8, 0.3), (0.6,0.7))\},$$
$$G_g(e_3) = \{(u_1/(0.5, 0.6), (0.6,0.5)), (u_2/(0.8, 0.5), (0.7,0.6)), (u_3/(0.2, 0.9), (0.3,0.8))\}$$

Clearly, we have $G_g \subseteq F_f$.

Definition 3.3. Given a universal set of elements U and a set of parameters E. Suppose that F_f and G_g are two PFFSSs over U_E. Now, F_f and G_g are referred to as a possibility Fermatean fuzzy soft equal if and only if

(i.) $F_f \subseteq G_g$,

(ii.) $G_g \subseteq F_f$,

which can be denoted by $G_g = F_f$.

Now, some operations of SFDSs will be defined and some of their features will be mentioned.

Definition 3.4. Given a universal set of elements U and a set of parameters E. Let F_f be a PFFSS over U_E. The complement of F_f, denoted by F_f^c is defined by $F_f^c = \langle F^c(e)(x),\ f^c(e)(x)\rangle$, where $F^c(e)(x) = \langle n_{F(e)}(x), m_{F(e)}(x)\rangle$ and $f^c(e)(x) = \langle n_{f(e)}(x), m_{f(e)}(x)\rangle$.

It can easily be seen that $\left(F_f^c\right)^c = F$ from the definition of the complement of a set.

Definition 3.5. Given a universal set of elements U and a set of parameters E. Let F_f and G_g are two PFFSSs over U_E. The union and intersection operations on two PFFSSs F_f and G_g over U_E denoted by $F_f \cup U_E$ and $F_f \cap U_E$ is respectively defined by two mappings as follows:

$$B_b: E \to G(U) \times G(U) \quad and \quad K_k: E \to G(U) \times G(U)$$

such that for all $x \in U$,

$$B_b(e)(x) = (B(e)(x), b(e)(x)) \quad and \quad K_k(e)(x) = (K(e)(x), k(e)(x)),$$

where $B(e)(x) = F(e)(x) \cup G(e)(x)$ and $b(e)(x) = f(e)(x) \cup g(e)(x)$; $K(e)(x) = F(e)(x) \cap G(e)(x)$ and $k(e)(x) = f(e)(x) \cap g(e)(x)$.

Example 3. Assume that F_f and G_g are two PFFSSs over U_E given in Example 1 and Example 2.

$$F_f \cup G_g = \begin{bmatrix} (0.8, 0.6), (0.7,0.8) & (0.6, 0.7), (0.5,0.8) & (0.9, 0.4), (0.8,0.4) \\ (0.6, 0.5), (0.9,0.5) & (0.7, 0.5), (0.4,0.8) & (0.9, 0.2), (0.8,0.6) \\ (0.6, 0.6), (0.7,0.4) & (0.9, 0.3), (0.8,0.4) & (0.3, 0.9), (0.4,0.7) \end{bmatrix}$$

and

$$F_f \cap G_g = \begin{bmatrix} (0.7, 0.7), (0.5,0.8) & (0.5, 0.8), (0.3,0.9) & (0.8, 0.6), (0.7,0.5) \\ (0.4, 0.6), (0.7,0.7) & (0.6, 0.7), (0.3,0.9) & (0.8, 0.3), (0.6,0.7) \\ (0.5, 0.6), (0.4,0.5) & (0.8, 0.5), (0.7,0.6) & (0.2, 0.9), (0.3,0.8) \end{bmatrix}$$

Definition 3.6. If $\emptyset_\theta: E \to G(U) \times G(U)$ is a function defined as $\emptyset(e)(x) = (0,1)$ and $\theta(e)(x) = (0,1)$, $\forall\, x \in U$, then $\emptyset_\theta(e)(x) = \langle \emptyset(e)(x),\ \theta(e)(x)\rangle$ is said to a possibility null Fermatean fuzzy soft set.

If $\Omega_\Lambda: E \rightarrow G(U) \times G(U)$ is a function defined as $\Omega(e)(x) = (1,0)$ and $\Lambda(e)(x) = (1,0)$, $\forall\, x \in U$, then $\Omega_\Lambda(e)(x) = \langle \Omega(e)(x), \Lambda(e)(x) \rangle$ is said to a possibility absolute Fermatean fuzzy soft set.

Theorem 3.1. Let F_f be a PFFSS over U_E. Then,
(i.) $F_f = F_f \cup F_f, \quad F_f = F_f \cap F_f,$
(ii.) $F_f \subseteq F_f \cup F_f, \quad F_f \subseteq F_f \cap F_f,$
(iii.) $F_f \cup \emptyset_\theta = F_f, \quad F_f \cap \emptyset_\theta = \emptyset_\theta,$
(iv.) $F_f \cup \Omega_\Lambda = F_f, \quad F_f \cap \Omega_\Lambda = F_f.$

Theorem 3.2. Let F_f, G_g, H_h be three PFFSS over U_E. Then,
(i.) $F_f \cup G_g = G_g \cup F_f,$
(ii.) $F_f \cap G_g = G_g \cap F_f,$
(iii.) $F_f \cup (G_g \cup H_h) = (F_f \cup G_g) \cup H_h,$
(iv.) $F_f \cap (G_g \cap H_h) = (F_f \cap G_g) \cap H_h.$

Theorem 3.3. Let F_f, G_g, H_h be three PFFSS over U_E. Then,
(i.) $(F_f \cup G_g)^c = F_f^c \cap G_g^c,$
(ii.) $(F_f \cap G_g)^c = F_f^c \cup G_g^c,$
(iii.) $(F_f \cup G_g) \cap F_f = F_f,$
(iv.) $(F_f \cap G_g) \cup F_f = F_f,$
(v.) $F_f \cup (G_g \cap H_h) = (F_f \cup G_g) \cap (F_f \cup H_h),$
(vi.) $F_f \cap (G_g \cup H_h) = (F_f \cap G_g) \cup (F_f \cap H_h).$

3.1. Similarity Measure

The conditions to be used in the new definition of similarity measure are listed below:

$$\Gamma(F(e)(x), G(e)(x)) = \frac{\sum_{i=1}^{n}\left(m_{F(e_i)}(x).m_{G(e_i)}(x)\right)}{\sum_{i=1}^{n}\left(1-\sqrt[3]{\left[1-m_{F(e_i)}^3(x)\right]\left[1-m_{G(e_i)}^3(x)\right]}\right)} \quad (1)$$

$$\Lambda(F(e)(x), G(e)(x)) = \sqrt[3]{1-\frac{\sum_{i=1}^{n}\left|n_{F(e_i)}^3(x)-n_{G(e_i)}^3(x)\right|}{\sum_{i=1}^{n}\left(1+n_{F(e_i)}^3(x).n_{G(e_i)}^3(x)\right)}} \quad (2)$$

$$\sigma_i = \frac{m_{f(e_i)}^3(x)}{m_{f(e_i)}^3(x)+n_{f(e_i)}^3(x)} \quad (3)$$

$$\tau_i = \frac{m_{g(e_i)}^3(x)}{m_{g(e_i)}^3(x)+n_{g(e_i)}^3(x)} \quad (4)$$

$$\Phi(F,G) = \frac{\Gamma(F(e)(x),G(e)(x))+\Lambda(F(e)(x),G(e)(x))}{2} \quad (5)$$

$$\Psi(f,g) = 1-\frac{\sum|\sigma_i-\tau_i|}{\sum|\sigma_i+\tau_i|} \quad (6)$$

Definition 4.1. Let F_f and G_g are two PFFSSs over U_E. Using the Equations (1)-(6), the similarity measures between F_f and G_g is defined as follows:

$$B(F_f, G_g) = \Phi(F,G).\Psi(f,g).$$

Theorem 4.1. Let F_f, G_g and H_h are three PFFSSs over U_E. Then, we have

(i.) $B(F_f, G_g) = B(G_g, F_f)$,

(ii.) $0 \leq B(F_f, G_g) \leq 1$,

(iii.) $F_f = G_g \Rightarrow B(F_f, G_g) = 1$,

(iv.) $F_f \subseteq G_g \subseteq H_h \Rightarrow B(F_f, G_g) \leq B(G_g, H_h)$,

(v.) $F_f \cap G_g = \emptyset \Rightarrow B(F_f, G_g) = 0$.

The proof of this theorem is immediately obtained from Definition 4.1.

Example 4. Let's use the two PFFSSs F_f and G_g over U_E given in Example 3. Compute the similarity between two PFFSSs F_f and G_g. The first disease u_1 and the set of symptom can be respectively, defined as follows:

$$F_f = \begin{bmatrix} (0.8, 0.6) & (0.7, 0.6) \\ (0.6, 0.5) & (0.9, 0.5) \\ (0.6, 0.6) & (0.7, 0.4) \end{bmatrix} \quad and \quad G_g = \begin{bmatrix} (0.7, 0.7) & (0.5, 0.8) \\ (0.4, 0.6) & (0.7, 0.7) \\ (0.5, 0.6) & (0.6, 0.5) \end{bmatrix}$$

$\Gamma(F(e)(x), G(e)(x)) = 0.483$, $\Lambda(F(e)(x), G(e)(x)) = 0.932$ and so $\Phi(F, G) = 0.6465$. Further, $\Psi(f, g) = 0.26$. Therefore, $B(F_f, G_g) = \Phi(F, G).\Psi(f, g) = 0.1681$.

4. New Method with Gender Equality Application

5.1 Scenario

This idea was formed according to the answers received by the early childhood experts from the questions they asked the children during their lessons. When responding to the questions, the kids were instructed to use one or more of the phrases "men can do," "women can do," or "both can do." The questions asked were analyzed in three dimensions: E1, Perceptions of personal rights and preferences; E2, perceptions of household responsibilities; E3, perceptions of responsibilities related to professions. Under these headings, answers to the following types of questions were sought: Can anyone cook at home? Can anyone do the cleaning at home? Can anyone do home repairs? Can everyone in the house do the daily shopping? Can every man and woman who wants to be an educator be one? Can everyone be a security force? Can all men and women be tradesmen? Can any male or female worker be a worker? Can anyone grow and dye their hair? Can everyone play with whatever toy they want? Can everyone wear whatever they want? Can anyone make it up?

5.2 Application

Young children aged 5 to 6 make up the target demographic. The ability to articulate their feelings and thoughts as they perceive them is still developing in children of this age range. The perception of gender equality in children will depend on a variety of elements, including their individual differences, their parents' attitudes and interactions with them, the attitudes of other adults in their environment, their interests, the intensity of the stimuli they are exposed to, and their impulsivity. Three experts evaluated the answers they have been received from the children. Early childhood experts determined the expected values according to the idea of gender equality before the children responded (Table 1). Early childhood teachers gave information to students about gender equality and implemented activities in their classes. Afterward, they asked questions to measure what children understood about gender equality.

Table 1. Expected criteria values Gender Equality

	E_1	E_2	E_3
$K(e)(x)$	(1,0)	(0.9, 0.1)	(0.9, 0.2)
$k(e)(x)$	(1, 0)	(1, 0)	(1, 0)

Table 2. First expert evaluation values

	E_1	E_2	E_3
$G(e)(x)$	(0.4, 0.9)	(0.9, 0.4)	(0.9, 0.3)
$g(e)(x)$	(0.8, 0.3)	(0.5, 0.6)	(0.9, 0.3)

Table 3. Second expert evaluation values

	E_1	E_2	E_3
$F(e)(x)$	(0.7, 0.5)	(0.4, 0.5)	(0.8, 0.3)
$f(e)(x)$	(0.2, 0.7)	(0.8, 0.5)	(0.9, 0.4)

Table 4. Third expert evaluation values

	E_1	E_2	E_3
$F(e)(x)$	(0.4, 0.9)	(0.8, 0.6)	(0.9, 0.2)
$f(e)(x)$	(0.6, 0.7)	(0.5, 0.6)	(0.5, 0.8)

We should calculate the similarity measure of the PFFSSs in Table 2-4 with Table 1, based on Definition 4.1, in order to choose the one closest to the ideal values determined by the experts on the ideas of the children of Early childhood on gender equality.

Calculating the similarity measure for the experts as follows: For the first expert evaluation, $\Gamma(K,F)=0.782$, $\Lambda(K,F)=0.913 \Rightarrow \Phi(K,F)=0.8475$; $\sigma_{1,2,3,4}=1$, $\tau_1=0.913$, $\tau_2=0.343$, $\tau_3=0.978$, $\tau_4=0.992$, $\Rightarrow \Psi(k,f)=0.9$ and so $B(K_k,F_f)=\Phi(K,F).\Psi(k,f)=0.76275$.

For second expert evaluation, $\Gamma(K,G)=0.992$, $\Lambda(K,G)=0.9 \Rightarrow \Phi(K,G)=0.946$; $\sigma_{1,2,3,4}=1$, $\tau_1=0.5$, $\tau_2=0.64$, $\tau_3=0.94$, $\tau_4=0.84$, $\Rightarrow \Psi(k,g)=0.844$ and so $B(K_k,G_g)=\Phi(K,G).\Psi(k,g)=0.8$.

For third expert evaluation, $\Gamma(K,H)=0.77$, $\Lambda(K,H)=0.231 \Rightarrow \Phi(K,H)=0.5005$; $\sigma_{1,2,3,4}=1$, $\tau_1=0.5$, $\tau_2=0.276$, $\tau_3=0.184$, $\tau_4=0.65$, $\Rightarrow \Psi(k,h)=0.574$ and so $B(K_k,H_h)=\Phi(K,H).\Psi(k,h)=0.2873$.

From the above results, we find that the second expert evaluation is closest to the ideal values in gender equality with the highest value of the similarity measure as 0.8. The first expert and the third expert with the values of similarity measured as 0.76275 and 0.2873 follow the second expert.

6. Conclusion

The primary goal of this research is to demonstrate the using possibility Fermatean fuzzy soft set to handle decision-making phenomena in which the cubic sum of membership and non-membership are bigger than one by taking into account the possibility of belongingness of components in the universe. We've also discussed a few operational properties, such as complement, union, and intersection. A similarity metric is developed to compare two possibility Fermatean fuzzy soft sets in order to handle choice challenges. Finally, the possibility Fermatean fuzzy soft sets may be employed for decision-making concerns to establish the validity of this similarity measure.

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