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Spherical Fuzzy Binary Soft Sets

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ABSTRACT:

In this paper a connection between Spherical Fuzzy Soft Sets and Binary Soft Sets is introduced. This is clearly visible through a new concept Spherical Fuzzy Binary Soft Sets. A few necessary properties are also provided. Real-life application demands more flexible tools than a single rigid one. Three dimensional approach of a fuzzy set to analyse a situation through three different angles with two universal sets will be a more useful tool that can be reliable in day-to-day life.

Keywords: Spherical Fuzzy Set, Binary Soft Set, Spherical Fuzzy Soft Set, Spherical Binary Soft Set, Cardinal Set, Similarity Measure

2010 AMS Classification: 03E72,06D72

Notations: SFS – Spherical Fuzzy Set, SFSS – Spherical Fuzzy Soft Set, SFBSS – Spherical Fuzzy Binary Soft Set

1. Introduction

Lotfi Aliasker Zadeh [11] recognised that classical set theory was not suitable for representing uncertainties which is prevalent in many real world scenarios. So he developed fuzzy set theory in 1960. Fuzzy set theory has various applications across various fields such as decision making, intelligent data analysis, processing information, pattern recognition, optimisation including medical fields for diagnosing diseases and differentiating syndromes. Soft set is introduced by Molodtsov [16] in 1999, as an extension of Hard Sets. Molodtsov applied soft theory to different directions. Soft set theory has been applied to many different fields with great success. P. K. Maji [5, 14] presented the concept of fuzzy soft sets based on fuzzy sets. He worked on theoretical study of soft sets too and then applied soft set in the decision making problem using rough sets. In 2010, Feng [7] studied soft sets combined with fuzzy sets and rough sets. Based on the theory of soft sets Z. Xiao [19] gave a recognition for soft information. In 2001, Maji, Biswas and Roy [14] defined concept of a fuzzy soft set and an intuitionistic fuzzy soft set. Operations defined by Maji [13,14,15] on fuzzy soft sets and soft sets paved the way for more research. In 2003, Maji [13] studied the theoretical operations of the soft set theory. In 2009, Ali [2] investigated several operations on soft sets and defined some new notions such as the restricted union etc. In 2011, Shabir [3] introduced algebraic structures of soft sets via new notions. In 2011, Naz [18] defined some notions such as soft topological space, soft interior, soft closure etc. In 2018 S. Ashraf [19] proposed new structure by defining spherical fuzzy sets which enlarge the space of membership degrees. Spherical fuzzy set is a direct generalization of fuzzy set, Pythagorean fuzzy set and picture fuzzy set. Spherical fuzzy sets are characterised by a fuzzy membership function that extends in multiple dimension. A spherical fuzzy set is a type of fuzzy set where the membership function is defined based on the distance from a central point, with the elements closer to the centre having higher membership degrees. Central point represents the core and distance from this point determines the degree of membership.

Spherical fuzzy soft set is introduced by P.A. Perveen, Sunil Jacob John [8] which is a more advanced form of fuzzy soft set. Spherical fuzzy soft set is more realistic, practical and accurate which is a new variation of the picture fuzzy soft set. Spherical fuzzy soft sets have more capability in modelling vagueness and uncertainty while dealing with decision making problems. Spherical fuzzy soft set theory has tremendous applications in decision making problems.

In section 3, a small modification has done for union and intersection operation of spherical fuzzy soft sets. This paper aims a hybrid modelling for Spherical Fuzzy Soft Set and Binary Soft Sets. For the newly introduced set, a few operations like union and intersection are also provided. Some elementary properties are verified in 4^{th} section. In section 5, cardinal set for the new set is given. In section 6, similarity measure for spherical fuzzy binary soft sets are introduced with one real-life example.

2. Preliminaries

In this section some basic definition and properties that is used in this paper are provided

Definition 2.1(Fuzzy set) [9]: Let X be a space of points (Universe of Discourse) with generic element denoted by x such that $X = \{x\}$. A *fuzzy set* A in X is characterized by a membership value function f_A(x) which associates with each point in X, a real number in the interval [0,1] with the value of f_A (x) represents the "grade of membership" of x in A.

Definition 2.2 (Operation of Fuzzy Set) [9]:

(i) Fuzzy Union : $\mu_{A\cup B}(x) = max\{\mu_A(x),\mu_B(x)\}$

(ii) Fuzzy Intersection : $\mu_{A\cap B}(x) = min\{\mu_A(x),\mu_B(x)\}$

(iii) Fuzzy Complement : $\mu_{\underline{A}}(x) = 1-\mu_A(x)$

Definition 2.3 (Soft Set) [11]: A pair (F, A) is called a soft set over U where F is a mapping given by $: A \rightarrow P(U)$. That is, a soft set over U is a parameterized family of subsets of the universe U.

Definition 2.4 (Binary Soft Set) [1]: Let U_1,U_2 be two initial universe sets and E be a set of parameters. Let $P(U_1)$, $P(U_2)$ denote the power set of U_1, U_2, respectively. Also, let $A, B, C \subseteq E$. A pair(F, A) is said to be a binary soft set overU_1, U_2, where F is defined as below : F: A $\rightarrow P(U_1) \times P(U_2)$, $F(e) = (X, Y)$ for each e $\in$ A such that X $\subseteq U_1$, Y $\subseteq U_2$. F∈ (X, Y) for each e $\in A$ such that X $\subseteq U_1$, Y $\subseteq U_2$

Definition 2.5 (Fuzzy Soft Set) [4]: Let U be an initial universal set, E be a set of parameters, and I^U be the power set of fuzzy set of U. Let A⊆ E and (F, E) is a pair called a fuzzy soft set over U where F is a mapping given by F: A $\longrightarrow I^U$

Definition 2.6 (Fuzzy Binary Soft Set) [1]: Let U_1, U_2 be two universal sets and E be a set of parameters. Let (U_1) , $F(U_2)$ denotes the set of all fuzzy sets over U_1, U_2 respectively. Also let $A, B \subseteq E$. A pair (F, A) is said to be a fuzzy binary soft set over U_1, U_2 where F is a mapping given by $F: A \rightarrow F(U_1) \times F(U_2)$.

Definition 2.7 (Union of two binary soft sets) [1]: Union of two fuzzy binary soft sets (F, A) and (G, B) over the common U_1, U_2 is binary soft set *(H, C)*, where $C = A \cup B$ and for each e $\in C$,

$$H(e) = \begin{cases} (X_1, Y_1) \ ; \ e \in A - B \\ (X_2, Y_2) \ ; \ e \in B - A \\ (X_1 \cup X_2, Y_1 \cup Y_2) \ ; \ e \in A \cap B \end{cases}$$

such that $F(e) = (X_1, Y_1)$ for each $e \in A$ and $G(e) = (X_2, Y_2)$ for each $e \in B$. We denote it $(F, A) \,\tilde{\tilde{\cup}}\, (G, B) = (H, C)$

Definition 2.8 (Intersection of two binary soft sets) [1]: Intersection of two binary soft sets (F, A) and (G, B) over the common U_1, U_2 is the binary soft set (H, C), where $C = A \cap B$ and $H(e) = (X_1 \cap X_2, \ Y_1 \cap Y_2)$ for each $e \in C$ such that $F(e) = (X_2, Y_2)$ for each $e \in A$ and $G(e) = (X_2, Y_2)$ for each $e \in B$. We denote it by $(F, A) \,\tilde{\tilde{\cap}}\, (G, B) = (H, C)$.

Definition 2.9 (Spherical Fuzzy Set) [1]: Let U be a universe. Let A be a Spherical Fuzzy Set. Then A is defined by, $A = \{\langle(x, (\mu_A, \vartheta_A, \pi_A))\rangle \,/\, x \in U\}$. The triplet $(\mu_A, \vartheta_A, \pi_A)$ such that $(\mu_A^2 + \vartheta_A^2 + \pi_A^2) \leq 1$ is known as Spherical Fuzzy Number, where μ , ϑ , π in A are membership, non-membership and hesitancy degrees of x. Values of all these three will be in [0, 1].

Definition 2.10 (Union & Intersection of two Spherical Fuzzy Sets) [10]: Basic operators of Spherical Fuzzy Sets:

Union:

$$\tilde{A}_S \cup \tilde{B}_S = \left\{ \begin{matrix} max\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}, \\ min\{\vartheta_{\tilde{A}_S}, \vartheta_{\tilde{B}_S}\}, \\ min\left\{\left\{\left(1 - \left(\left(max\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}\right)^2 + \left(min\{\vartheta_{\tilde{A}_S}, \vartheta_{\tilde{B}_S}\}\right)^2\right)\right)^{\frac{1}{2}}, max\{\pi_{\tilde{A}_S}, \pi_{\tilde{B}_S}\}\right\}\right\} \end{matrix} \right\}$$

Intersection:

$$\tilde{A}_S \cap \tilde{B}_S = \begin{Bmatrix} min\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}, \\ min\{\vartheta_{\tilde{A}_S}, \vartheta_{\tilde{B}_S}\}, \\ max\left\{\left\{\left(1-\left(\left(min\{\mu_{\tilde{A}_S}, \mu_{\tilde{B}_S}\}\right)^2+\left(max\{\vartheta_{\tilde{A}_S}, \vartheta_{\tilde{B}_S}\}\right)^2\right)\right)^{\frac{1}{2}}, min\{\pi_{\tilde{A}_S}, \pi_{\tilde{B}_S}\}\right\}\right\} \end{Bmatrix}$$

Definition 2.11 (Spherical Fuzzy Soft Set) [7]: Let U be an initial universal set, E be a set of parameters and $A \subseteq E$. A pair $\langle F, A\rangle$ is called a spherical fuzzy soft set $(SFSS)$ over U, where F is a mapping given by $F : A \to SFS(U)$. Here, for any parameter $e \in E$, $F(e)$ can be written as a spherical fuzzy set such that $F(e) = \left\{\left(x, \mu_{F(e)}(x), \eta_{F(e)}(x), \vartheta_{F(e)}(x)\right) / x \in U\right\}$ where $\mu_{F(e)}(x)$ is the degree of positive membership, $\eta_{F(e)}(x)$ is the degree of neutral membership and $\vartheta_{F(e)}(x)$ is the degree of negative membership function respectively with the condition, $\mu^2_{F(e)}(x) + \mu^2_{F(e)}(x) + \mu^2_{F(e)}(x) \leq 1$.

Remark 2.1: In other words, it is a parametrized family of spherical fuzzy set.

Remark 2.2: Being an extension of fuzzy, pythagorean and picture fuzzy set its membership function can interpret as picture fuzzy set.

Definition 2.12 (Union of two Spherical Fuzzy Soft Sets) [7]: Union of two SFSSs $\langle F, A\rangle$ and $\langle G, B\rangle$ over a common universe U is a SFSS $\langle H, C\rangle$ where $C = A \cup B$ and $\forall\ e \in C$

$$H(e) = \begin{cases} F(e) & if \quad e \in A - B \\ G(e) & if \quad e \in B - A \\ F(e) \cup G(e) & if \quad e \in A \cap B \end{cases}$$

$\forall\ e \in A \cap B$,

$F(e) \cup G(e)$

$= \left\{x, max\{\mu_{F(e)}(x), \mu_{G(e)}(x)\}, min\{\eta_{F(e)}(x), \eta_{G(e)}(x)\}, min\{\vartheta_{F(e)}(x), \vartheta_{G(e)}(x) / x \in U\}\right\}$

This relation is denoted by $\langle F, A\rangle \cup \langle G, B\rangle = \langle H, C\rangle$.

Definition 2.13 (Intersection of two Spherical Fuzzy Soft Sets) [7]: The intersection of two SFSSs $\langle F, A\rangle$ and $\langle G, B\rangle$ over a common universe U is a SFSS $\langle H, C\rangle$ where $C = A \cup B$ and $\forall\ e \in C$

$$H(e) = \begin{cases} F(e) & if \quad e \in A - B \\ G(e) & if \quad e \in B - A \\ F(e) \cap G(e) & if \quad e \in A \cap B \end{cases}$$

That is, $\forall\ e \in A \cap B$, we have

$F(e) \cap G(e) =$

$\left\{x, min\{\mu_{F(e)}(x), \mu_{G(e)}(x)\}, min\{\eta_{F(e)}(x), \eta_{G(e)}(x)\}, max\{\vartheta_{F(e)}(x), \vartheta_{G(e)}(x) / x \in U\}\right\}$

This relation is denoted by $\langle F, A\rangle \cap (G, B) = \langle H, C\rangle$.

Definition 2.14 (Similarity Measure of Soft Set)[5] : If $E_1 = E_2$, then similarity between $(G_1, E_1)\ and (G_2, E_2)$ is defined by $S(G_1, G_2) = \frac{\sum_i G_1(e_1)\cdot G_2(e_2)}{\sum_i |G_1(e_1)^2 \vee G_2(e_2)^2|}$

Definition 2.15 (Similarity Measure of Spherical Fuzzy Set) [17]: For two *SFSs A* and *B* in *X*, a new similarity measures is defined between *A* and *B* as follows:

$$S_{SFS}(F, G) = \frac{\sum_{j=0}^{n}[\mu_A^2(x_j)\mu_B^2(x_j) + \vartheta_A^2(x_j)\vartheta_B^2(x_j) + \eta_A^2(x_j)\eta_B^2(x_j)]}{\sum_{i=0}^{n}[\{\mu_B^4(x_j) \vee \mu_B^4(x_j)\} + \{\vartheta_A^4(x_j) \vee \vartheta_B^4(x_j)\} + \eta_A^4(x_j) \vee \eta_B^4(x_j)]}$$

Definition 2.15 : (Similarity measure of Spherical Fuzzy Soft Set) [6] : Assume that there are two SFSSs $\langle F, E\rangle$ and $\langle G, E\rangle$ over the universe U = $\{x_1, x_2, \dots x_n\}$ with the parameter set E = $\{e_1, e_2, \dots e_n\}$. Then a similarity measure between the SFSS $\langle F, A\rangle$ and $\langle G, E\rangle$ can be defined as follows:

$$S_{SFSS}(F,G) = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{1-\frac{1}{2}\left[min\left\{\left|\mu^2_{F(e_i)}(x_j)-\mu^2_{G(e_i)}(x_j)\right|,\left|\vartheta^2_{F(e_i)}(x_j)-\vartheta^2_{G(e_i)}(x_j)\right|\right\}+\left|\eta^2_{F(e_i)}(x_j)-\eta^2_{G(e_i)}(x_j)\right|\right]}{1+\frac{1}{2}\left[max\left\{\left|\mu^2_{F(e_i)}(x_j)-\mu^2_{G(e_i)}(x_j)\right|,\left|\vartheta^2_{F(e_i)}(x_j)-\vartheta^2_{G(e_i)}(x_j)\right|\right\}+\left|\eta^2_{F(e_i)}(x_j)-\eta^2_{G(e_i)}(x_j)\right|\right]}$$

3. Modification of Union & Intersection operations of SFSS

In this section a novel concept Spherical Fuzzy Binary Soft Set is introduced.

Definition 3.1 (Union of two Spherical Fuzzy Soft Sets):
Union of two SFBSSs $\langle\langle F, A\rangle\rangle$ and $\langle\langle G, B\rangle\rangle$ over a common universe $\{U_1, U_2\}$ is a SFSS $\langle\langle H, C\rangle\rangle$ where $C = A \cup B$ and $\forall\ e \in C$

$$H(e) = \begin{cases} F(e) & if \quad e \in A - B \\ G(e) & if \quad e \in B - A \\ F(e) \cup G(e) & if \quad e \in A \cap B \end{cases}$$

where $\forall\ e \in A \cap B$,
$F(e) \cup G(e) =$

$$\left\{\left(e, \left(\begin{matrix} max\{\mu_{F(e)}(u_i), \mu_{G(e)}(u_j)\}, min\{\mu_{F(e)}(u_i), \mu_{G(e)}(u_j)\}, \\ min\left\{\begin{matrix}\left(1-\left(\left(max\{\mu_{F(e)}(u_i), \mu_{G(e)}(u_j)\}\right)^2+\left(min\{\vartheta_{F(e)}(u_i), \vartheta_{G(e)}(u_j)\}\right)^2\right)\right)^{\frac{1}{2}}, \\ max\{\pi_{F(e)}(u_i), \pi_{G(e)}(u_j)\}\end{matrix}\right\}\end{matrix}\right)\right)\right\}$$

This relation is denoted by $\langle\langle F, A\rangle\rangle \cup \langle\langle G, B\rangle\rangle = \langle\langle H, C\rangle\rangle$.

Example 3.1: Let U = $\{h_1, h_2, h_3, h_4, h_5\}$; $E = \{e_1, e_2, e_3, e_4, e_5, e_6, e_7\}$;
$A = \{e_1, e_2\}$; $B = \{e_2, e_3\}$
$\langle F, A\rangle = \left\{\left(e_1, \left\{\frac{(0.2,0.3,0.1)}{\{h_1,h_2\}}\right\}\right), \left(e_2, \left\{\frac{(0.5,0.3,0.4)}{\{h_2\}}\right\}\right)\right\}$
$\langle G, B\rangle = \left\{\left(e_2, \left\{\frac{(0.3,0.7,0.1)}{\{h_2,h_5\}},\right\}\right), \left(e_3, \left\{\frac{(0.5,0.8,0.1)}{\{h_4\}}\right\}\right)\right\}$
$\langle F, A\rangle \cup \langle G, B\rangle = \left\{\left(e_1, \frac{(0.2,0.3,0.1)}{\{h_1,h_2\}}\right), \left(e_2, \left\{\frac{(0.5,0.3,0.4)}{\{h_2,h_5\}}\right\}\right), \left(e_3, \frac{(0.5,0.8,0.1)}{h_4}\right)\right\}$

Definition 3.2 (Intersection of two Spherical Fuzzy Soft Sets) : Intersection of two SFBSSs $\langle\langle F, A\rangle\rangle$ and $\langle\langle G, B\rangle\rangle$ over a common universe $\{U_1, U_2\}$ is a SFSS $\langle\langle H, C\rangle\rangle$ where $C = A \cup B$ and $\forall\ e \in C$

$$H(e) = \begin{cases} F(e) & if \quad e \in A - B \\ G(e) & if \quad e \in B - A \\ F(e) \cap G(e) & if \quad e \in A \cap B \end{cases}$$

where $\forall e\ \epsilon\ A \cap B$,
$F(e) \cap G(e) =$

$$\left\{\left(e,\left(\begin{array}{c} min\{\mu_{F(e)}(u_i),\mu_{G(e)}(u_j)\}, min\{\vartheta_{F(e)}(u_i),\vartheta_{G(e)}(u_j)\}, \\ max\left\{\left\{\begin{array}{c}\left(1-\left(\left(min\{\mu_{F(e)}(u_i),\mu_{G(e)}(u_j)\}\right)^2+\left(max\{\vartheta_{F(e)}(u_i),\vartheta_{G(e)}(u_j)\}\right)^2\right)\right)^{\frac{1}{2}}, \\ min\{\pi_{F(e)}(u_i),\pi_{G(e)}(u_j)\}\end{array}\right\}\right\}\end{array}\right)\right)\right\}$$

This relation is denoted by $\langle\langle F,A\rangle\rangle \cup \langle\langle G,B\rangle\rangle = \langle\langle H,C\rangle\rangle$.

Example 3.2: Let U = $\{h_1,h_2,h_3,h_4,h_5\}$; $E = \{e_1,e_2,e_3,e_4,e_5,e_6,e_7\}$;

$A = \{e_1,e_2\}$; $B = \{e_2,e_3\}$

$\langle F,A\rangle = \left\{\left(e_1,\left\{\frac{(0.2,0.3,0.1)}{\{h_1,h_2\}}\right\}\right),\left(e_2,\left\{\frac{(0.5,0.3,0.4)}{\{h_2\}}\right\}\right)\right\}$

$\langle G,B\rangle = \left\{\left(e_2,\left\{\frac{(0.3,0.7,0.1)}{\{h_2,h_5\}},\right\}\right),\left(e_3,\left\{\frac{(0.5,0.8,0.1)}{\{h_4\}}\right\}\right)\right\}$

$\langle F,A\rangle \cap \langle G,B\rangle = \left\{\left(e_2,\left\{\frac{(0.3,0.3,0.6)}{h_2}\right\}\right)\right\}$

Remark 3.1: (i) *SFS (U)* denotes the set of all spherical fuzzy soft sets over U

(ii) *SFBSS* (U_1,U_2) denotes the set of all spherical fuzzy binary soft sets over $\{U_1,U_2\}$

4. Spherical Fuzzy Binary Soft Set & Properties

In this section a novel concept Spherical Fuzzy Binary Soft Set is introduced with its properties.

4. 1. Spherical Fuzzy Binary Soft Set

Definition 4.1.1 (Spherical Fuzzy Binary Soft Set): Let $\{U_1,U_2\}$ be the binary universe and E be a set of parameters. Let $S(U_1)$, $S(U_2)$ denote power sets of spherical fuzzy sets over U_1, U_2 respectively. Also let $A \subseteq$ E. A pair $\langle\langle F,A\rangle\rangle$ is said to be a spherical fuzzy binary soft set over $\{U_1,U_2\}$, where F is the mapping given by $F : A \to S(U_1)\times S(U_2)$; $\forall e \in A$,

$$F\text{ (e)} = \left\{\begin{array}{c}\frac{\left(\mu_{F(e)}(u_i),\vartheta_{F(e)}(u_i),\pi_{F(e)}(u_i)\right)}{u_i},\frac{\left(\mu_{F(e)}(u_j),\vartheta_{F(e)}(u_j),\pi_{F(e)}(u_j)\right)}{u_j}; \\ \forall u_i \in X \subseteq U_1, \forall u_j \in Y \subseteq U_2\end{array}\right\}$$

$$\langle\langle F,A\rangle\rangle = \{e \in A\ /\ (e,F(e))\}$$

$$= \left\{\begin{array}{c}\left(e,\left(\left\{\frac{\left(\mu_{F(e)}(u_i),\vartheta_{F(e)}(u_i),\pi_{F(e)}(u_i)\right)}{u_i}\right\},\left\{\frac{\left(\mu_{F(e)}(u_i),\vartheta_{F(e)}(u_i),\pi_{F(e)}(u_i)\right)}{u_j}\right\}\right)\right); \\ \forall u_i \in X \subseteq U_1, \forall u_j \in Y \subseteq U_2\end{array}\right\}$$

where

$$F\text{ (e)} = \left\{\begin{array}{c}\frac{\left(\mu_{F(e)}(u_i),\vartheta_{F(e)}(u_i),\pi_{F(e)}(u_i)\right),}{u_i},\frac{\left(\mu_{F(e)}(u_j),\vartheta_{F(e)}(u_j),\pi_{F(e)}(u_j)\right),}{u_j}; \\ \forall u_i \in X \subseteq U_1, \forall u_j \in Y \subseteq U_2\end{array}\right\}$$

Example 4.1.1: Let $U_1 = \{h_1, h_2\}$; $U_2 = \{f_1, f_2\}$; $E = \left\{\begin{array}{c} e_1 = expensive, \\ e_2 = urban, \\ e_3 = rural, \\ e_4 = cheap, \\ e_5 = medium, \\ e_6 = corporation, \\ e_{7=} \; metrocity, \\ e_8 = village \end{array}\right\}$;

$A = \{e_3, e_5, e_6, e_7\}$; $B = \{e_3, e_6\}$;

$$\langle\langle F, A\rangle\rangle = \left\{\begin{array}{c} \left(e_3, \left(\frac{(0.3,0.1,0.4)}{\{h_1,h_4\}}, \frac{(0.5,0.4,0.1)}{\{f_1\}}\right)\right), \\ \left(e_5, \left(\frac{(0.6,0.3,0.2)}{\{h_1,h_4\}}, \frac{(0.7,0.3,0.6)}{\{f_1\}}\right)\right)\left(e_6, \left(\frac{(0.8,0.3,0.1)}{\{h_1,h_4\}}, \frac{(0.4,0.6,0.2)}{\{f_1\}}\right)\right), \\ \left(e_7, \left(\frac{(0.6,0.5,0.1)}{\{h_1,h_4\}}, \frac{(0.2,0.8,0.3)}{\{f_1\}}\right)\right) \end{array}\right\}$$

with a different attribute set $B = \{e_2, e_6\}$ another spherical fuzzy soft set can be defined as below:

$$\langle\langle G, B\rangle\rangle = \left\{\begin{array}{c} \left(e_3, \left(\frac{(0.1,0.3,0.2)}{\{h_1,h_4\}}, \frac{(0.9,0.3,0.1)}{\{f_1\}}\right)\right), \\ \left(e_6, \left(\frac{(0.6,0.7,0.2)}{\{h_1,h_3\}}, \frac{(0.5,0.7,0.2)}{\{f_1\}}\right)\right) \end{array}\right\}$$

Definition 4.1.2 (Null & Absolute Spherical Fuzzy Binary Soft Set):

A Spherical Fuzzy Binary Soft Set $\langle\langle F, A\rangle\rangle$ is said to be null spherical fuzzy binary soft set if $\forall\ e \in A$, $(e) = \left(\frac{0,0,1}{X_1}, \frac{0,0,1}{Y_1}\right)$; $X_1 \subseteq U_1$ and $Y_1 \subseteq U_2$. It is denoted as $\langle\langle \emptyset, A\rangle\rangle$.

A Spherical Fuzzy Binary Soft Set $\langle\langle F, A\rangle\rangle$ is said to be Absolute spherical fuzzy binary soft set if $\forall\ e \in A$, $(e) = \left(\frac{1,0,0}{X_1}, \frac{1,0,0}{Y_1}\right)$; $X_1 \subseteq U_1$ and $Y_1 \subseteq U_2$. It is denoted as $\langle\langle U, A\rangle\rangle$.

Example 4.1.2: $U_1 = \{a_1, a_2, a_3, a_4\}$ **;** $U_2 = \{b_1, b_2, b_3\}$ **;** $E = \{e_1, e_2, e_3, e_4\}$ and $A = \{e_1, e_3\}$

Null Spherical Fuzzy Binary Soft Set

$$(\emptyset, A) = \left\{\begin{array}{c} \left(e_1, \left(\left\{\frac{(0,0,1)}{a_1}, \frac{(0,0,1)}{a_2}\right\}, \left\{\frac{(0,0,1)}{b_1}\right\}\right)\right), \\ \left(e_3 \left(\left\{\frac{(0,0,1)}{a_3}, \frac{(0,0,1)}{a_4}\right\}, \left\{\frac{(0,0,1)}{b_2}, \frac{(0,0,1)}{b_3}\right\}\right)\right) \end{array}\right\}$$

Absolute Spherical Fuzzy Binary Soft Set

$$(U, A) = \left\{\begin{array}{c} \left(e_1, \left(\left\{\frac{(1,0,0)}{a_1}, \frac{(1,0,0)}{a_2}\right\}, \left\{\frac{(1,0,0)}{b_1}, \frac{(1,0,0)}{b_2}\right\}\right)\right), \\ \left(e_3, \left(\left\{\frac{(1,0,0)}{a_1}, \frac{(1,0,0)}{a_2}\right\}, \left\{\frac{(1,0,0)}{b_1}, \frac{(1,0,0)}{b_2}\right\}\right)\right) \end{array}\right\}$$

4.2. Properties of Spherical Fuzzy Binary Soft Set

In this section some elementary properties of SFBSS is introduced with example.

Definition 4.2.1(Union of two Spherical Fuzzy Binary Soft Sets): Union of two SFBSSs $\langle\langle F,A\rangle\rangle$ and $\langle\langle G,B\rangle\rangle$ over a common universe $\{\mathrm{U}_1,\mathrm{U}_2\}$ is a SFSS $\langle\langle H,C\rangle\rangle$ where $C=A\cup B$ and $\forall\ e\in C$

$$H(e)=\begin{cases}F(e) & if \quad e\in A-B\\ G(e) & if \quad e\in B-A\\ F(e)\cup G(e) & if \quad e\in A\cap B\end{cases}$$

where $\forall\ e\in A\cap B$,

$F(e)\cup G(e)=$

$$\left\{\left(e,\left(\begin{array}{c}\left\{max\{\mu_{F(e)}(u_i),\mu_{G(e)}(u_i)\},max\{\mu_{F(e)}(u_j),\mu_{G(e)}(u_j)\}\right\}\\ \left\{min\{\mu_{F(e)}(u_i),\mu_{G(e)}(u_i)\},min\{\mu_{F(e)}(u_j),\mu_{G(e)}(u_j)\}\right\}\\ \left\{\begin{array}{c}\left(min\left\{\left\{\left(1-\left(\left(max\{\mu_{F(e)}(u_i),\mu_{G(e)}(u_i)\}\right)^2+\left(min\{\vartheta_{F(e)}(u_i),\vartheta_{G(e)}(u_i)\}\right)^2\right)\right)^{\frac{1}{2}},max\{\pi_{F(e)}(u_i),\pi_{G(e)}(u_i)\}\right\}\right\}\right)\\ \left(min\left\{\left\{\left(1-\left(\left(max\{\mu_{F(e)}(u_j),\mu_{G(e)}(u_j)\}\right)^2+\left(min\{\vartheta_{F(e)}(u_j),\vartheta_{G(e)}(u_j)\}\right)^2\right)\right)^{\frac{1}{2}},max\{\pi_{F(e)}(u_j),\pi_{G(e)}(u_j)\}\right\}\right\}\right)\end{array}\right\}\end{array}\right)\right)\right\}$$

This relation is denoted by $\langle\langle F,A\rangle\rangle\cup\langle\langle G,B\rangle\rangle=\langle\langle H,C\rangle\rangle$.

Example 4.2.1. Let $U_1=\{a,b,c,d\}$, $U_2=\{d,e,f\}$ be two universes common to a set of parameters

$E=\{e_1,e_2,e_3,e_4\}$, $A=\{e_1,e_2\}$, $B=\{e_2,e_3\}$, $A\cup B=\{e_1,e_2,e_3\}$

A Spherical Fuzzy Binary Soft Set is given by,

$$\langle\langle F,A\rangle\rangle=\left\{\left(e_1,\left(\frac{(0.4.0.5,0.3,)}{\{b,c\}},\frac{(0.6,0.1,0.2)}{\{e,f\}}\right)\right),\left(e_2,\left(\frac{(0.3.0.1,0.5)}{\{a,d\}},\frac{(0.7,0.2,0.5)}{\{d,f\}}\right)\right)\right\}$$

$$\langle\langle G,B\rangle\rangle=\left\{\left(e_2,\left(\frac{(0.2,0.1,0.4)}{\{a,b\}},\frac{(0.2,0.6,0.4)}{\{e,f\}}\right)\right),\left(e_3,\left(\frac{(0.3,0.2,0.1)}{\{b,c\}},\frac{(0.4,0.1,0.2)}{\{d,f\}}\right)\right)\right\}$$

$$\langle\langle F,A\rangle\rangle\cup\langle\langle G,B\rangle\rangle=\langle\langle H,C\rangle\rangle=\left\{\begin{array}{c}\left(e_1,\left(\frac{(0.4.0.5,0.3,)}{\{b,c\}},\frac{(0.6,0.1,0.2)}{\{e,f\}}\right)\right),\\ \left(e_2,\left(\frac{(0.3,0.1,0.5)}{\{a,b,d\}},\frac{(0.7,0.2,0.5)}{\{d,e,f\}}\right)\right),\\ \left(e_3,\left(\frac{(0.3,0.2,0.1)}{\{b,c\}},\frac{(0.4,0.1,0.2)}{\{d,f\}}\right)\right)\end{array}\right\}$$

Definition 4. 2. 2 (Spherical Fuzzy Binary Soft Set Intersection):

Union of two SFBSSs $\langle\langle F,A\rangle\rangle$ and $\langle\langle G,B\rangle\rangle$ over a common universe $\{\mathrm{U}_1,\mathrm{U}_2\}$ is a SFSS $\langle\langle H,C\rangle\rangle$ where $C=A\cap B$ and $\forall\ e\in C$

$$H(e)=\begin{cases}F(e) & if \quad e\in A-B\\ G(e) & if \quad e\in B-A\\ F(e)\cap G(e) & if \quad e\in A\cap B\end{cases}$$

where $\forall\ e \in A \cap B$,
$F(e) \cap G(e)$=

$$\left\{\left(e, \left(\begin{array}{c}\{min\{\mu_{F(e)}(u_i), \mu_{G(e)}(u_i)\}, min\{\mu_{F(e)}(u_j), \mu_{G(e)}(u_j)\}\} \\ \{min\{\mu_{F(e)}(u_i), \mu_{G(e)}(u_i)\}, min\{\mu_{F(e)}(u_j), \mu_{G(e)}(u_j)\}\} \\ \left\{\begin{array}{c}\left(max\left\{\left\{\left(1-\left((min\{\mu_{F(e)}(u_i), \mu_{G(e)}(u_i)\})^2 + (max\{\vartheta_{F(e)}(u_i), \vartheta_{G(e)}(u_i)\})^2\right)\right)^{\frac{1}{2}}, min\{\pi_{F(e)}(u_i), \pi_{G(e)}(u_i)\}\right\}\right\}\right) \\ \left(max\left\{\left\{\left(1-\left((min\{\mu_{F(e)}(u_j), \mu_{G(e)}(u_j)\})^2 + (max\{\vartheta_{F(e)}(u_j), \vartheta_{G(e)}(u_j)\})^2\right)\right)^{\frac{1}{2}}, min\{\pi_{F(e)}(u_j), \pi_{G(e)}(u_j)\}\right\}\right\}\right)\end{array}\right\}\end{array}\right)\right)\right\}$$

This relation is denoted by $\langle\langle F, A\rangle\rangle \cap \langle\langle G, B\rangle\rangle = \langle\langle H, C\rangle\rangle$.

Example 4. 2. 2 : In example 3.4, $A \cap B = \{e_2\}$

$\langle\langle F, A\rangle\rangle \cap \langle\langle G, B\rangle\rangle = \langle\langle H, C\rangle\rangle = \left\{\left(\left(e_2, \left(\frac{(0.2,0.1,0.9)}{\{a,b\}}, \frac{(0.2,0.2,0.8)}{\{e,f\}}\right)\right)\right)\right\}$

5. Cardinal Set of a Spherical Fuzzy Binary Soft Set

In this section cardinality of Spherical Fuzzy Soft set with example is given.

5.1. Cardinal Set of a Spherical Fuzzy Binary Soft Set

Definition 5. 1 : (Cardinality of a Spherical Fuzzy Soft Set) : Let $\Psi_A \in SFS\ (U_1, U_2)$. Cardinal Set of Ψ_A denoted by cΨ_A and defined by

c $\Psi_A = \left\{\left(\mu_{c\Psi_A}(u_i), \vartheta_{c\Psi_A}(u_i), \pi_{c\Psi_A}(u_i)\right):\ u_i \in U\right\}$ is a spherical fuzzy binary soft set over E.

Membership function $\mu_{c\Psi_A}$:E → $[0, 1]$, $\mu_{c\Psi_A} = \frac{|\Psi_A(x)|}{|U|}$

Non-Membership function $\vartheta_{c\Psi_A}: E \to [0, 1]$, $\vartheta_{c\Psi_A} = \frac{|\vartheta_A(x)|}{|U|}$

Hesitancy function $\pi_{c\Psi_A}: E \to [0, 1]$, $\mu_{c\Psi_A} = \frac{|\pi_A(x)|}{|U|}$

Example 5.1: Suppose the department of mathematics in a college is recruiting assistant professors post. The number of candidates for recruitment is $U = \{U_1, U_2, U_3, U_4\}$ .The set of parameters are

$E = \{e_1, e_2, e_3\}$,

where e_1 = Educational Qualification, e_2 = Experience, e_3 = NET/SLET, e_4 = Guide ship

The selected candidates are $A = \{x_2, , x_3, x_4\}$

Spherical Fuzzy Soft set over U is, $A_\beth = \left\{\begin{array}{c}\left(x_2, \left\{\frac{(0.2,0.07,0.3)}{u_1}, \frac{(0.3,0.1,0.5)}{u_2}, \frac{(0.5,0.3,0.2)}{u_3}\right\}\right) \\ \left(x_3, \left\{\frac{(0.2,0.1,0.4)}{u_2}, \frac{(0.5,0.02,0.4)}{u_3}, \frac{(0.1,0.05,0.4)}{u_4}\right\}\right)\end{array}\right\}$

The cardinal is calculated as, $\#A_{SFS} = \left\{\frac{(0.6,0.002,0.7)}{u_2}, \frac{(0.5,0.0001,0.8)}{u_3}\right\}$

The aggregate fuzzy soft set is found by,

$$\#B_{SFS} = \frac{1}{3}\begin{bmatrix}(0,0,0) & (0.2,0.07,0.3) & (0,0,0) \\ (0,0,0) & (0.3,0.1,0.5) & (0.2,0.1,0.4) \\ (0,0,0) & (0.5,0.3,0.2) & (0.5,0.02,0.4) \\ (0,0,0) & (0,0,0) & (0.1,0.05,0.4)\end{bmatrix} \times \begin{bmatrix}(0,0,0) \\ (0.6,0.002,0.7) \\ (0.5,0.0001,0.8)\end{bmatrix}$$

= $\begin{bmatrix} (0.05,0.03,0.8) \\ (0.1,0.2,0.6) \\ (0.2,0.2,0.7) \\ (0.02,0.06,0.8) \end{bmatrix}$

that means, $\#^{*}A_{SFS} = \left\{\frac{(0.05,0.03,0.8)}{u_1}, \frac{(0.1,0.2,0.6)}{u_2}, \frac{(0.2,0.2,0.7)}{u_3}, \frac{(0.02,0.06,0.8)}{u_4}\right\}$

The largest membership grade is chosen by, max $\#B_{SFS}(u) = (0.2,0.2,0.7)$

Definition 5. 2 : (Cardinality of a Spherical fuzzy Binary Soft Set) : Let $\Psi_A \in$ SFS (U_1, U_2). Cardinal Set of Ψ_A denoted by $c\Psi_A$ and defined by

$c\ \Psi_A = \left\{\left(\mu_{c\Psi_A}(u_i), \vartheta_{c\Psi_A}(u_i), \pi_{c\Psi_A}(u_i)\right), \left(\mu_{c\Psi_A}(u_j), \vartheta_{c\Psi_A}(u_j), \pi_{c\Psi_A}(u_j)\right);\ u_i \in U_1, u_j \in U_2\right\}$ is a spherical fuzzy binary soft set over E. Membership function $\mu_{c\Psi_A}$:E → $[0, 1]$,

$\mu_{c\Psi_A} = \frac{|\Psi_A(x)|}{|U_1 \cup U_2|}$

Non-Membership function $\vartheta_{c\Psi_A}$: E → $[0, 1]$, $\vartheta_{c\Psi_A} = \frac{|\vartheta_A(x)|}{|U_1 \cup U_2|}$.

Hesitancy function $\pi_{c\Psi_A}$: E → $[0, 1]$, $\mu_{c\Psi_A} = \frac{|\pi_A(x)|}{|U_1 \cup U_2|}$

6. Similarity Measure of SFBSS with an application

In section 6.1, similarity measure for SFBSS is introduced and in section 6.2 its application is provided.

6.1 Similarity Measure of SFBSS

In this section a formula for Similarity Measure of Spherical Fuzzy Binary Soft Set is provided.

Definition 6.1 (Similarity Measure of Spherical Fuzzy Binary Soft Set): Let $\{U_1, U_2\}$ be a common universe with a parameter set E having $A \subseteq E$.

A mapping *M: SFSS*(U_1, U_2)× *SFSS*(U_1, U_2) → *[0,1]* is a mapping. Let $\langle\langle F, A\rangle\rangle, \langle\langle G, B\rangle\rangle$ be two SFBSS's such that $\langle\langle F, A\rangle\rangle, \langle\langle G, B\rangle\rangle \in$ *SFBSS* (U_1, U_2). Then $M(\langle\langle F, A\rangle, \langle G, B\rangle\rangle)$, is called a similarity measure of SFBSS's if it satisfies the following conditions:

1. $0 \le S(\langle\langle F, A\rangle\rangle, \langle\langle G, A\rangle\rangle) \le 1$
2. $S(\langle\langle F, A\rangle\rangle, \langle\langle G, A\rangle\rangle) = S(\langle\langle G, A\rangle\rangle, \langle\langle F, A\rangle\rangle)$;
3. $S(\langle\langle F, A\rangle\rangle, \langle\langle G, A\rangle\rangle) = 1$ *if and only if* $\langle\langle F, A\rangle\rangle = \langle\langle G, A\rangle\rangle$
4. *Let* $\langle\langle H, A\rangle\rangle$ *be a SFBSS, if* $\langle\langle F, A\rangle\rangle \subseteq \langle\langle G, B\rangle\rangle$ *and* $\langle\langle G, A\rangle\rangle \subseteq \langle H, A\rangle$,

then $S(\langle\langle F, A\rangle, \langle H, A\rangle) \le S(\langle\langle F, A\rangle\rangle, \langle G, A\rangle)$ and $S(\langle\langle F, A\rangle\rangle, \langle\langle H, A\rangle\rangle) \le S(\langle\langle G, A\rangle\rangle, \langle\langle H, A\rangle\rangle)$.

Proof

Obvious

Definition 6.1 (Similarity Measure of SFBSS): Let $\langle\langle F, A\rangle\rangle$ and $\langle\langle G, A\rangle\rangle$ be two SFBSS's defined on a binary universe $\{U_1, U_2\}$ with a parameter set $A \subseteq E = \{e_1, e_2, ---, e_m\}$. Similarity measure between $\langle\langle F, A\rangle\rangle$ and $\langle\langle G, A\rangle\rangle$ can be defined as follows:

$M_{SFBSS}(\langle\langle F, A\rangle\rangle, \langle\langle G, A\rangle\rangle) =$

$$\frac{1}{m(n_1+n_2)}\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{1-\frac{1}{2}\left[\left\{\begin{matrix} min\left(\left|\mu^2_{F(e_i)}(u_i)-\mu^2_{G(e_i)}(u_i)\right| \wedge \left|\mu^2_{F(e_i)}(u_j)-\mu^2_{G(e_i)}(u_j)\right|\right), \\ \left(\left|\vartheta^2_{F(e_i)}(u_i)-\vartheta^2_{G(e_i)}(u_i)\right| \wedge \left|\vartheta^2_{F(e_i)}(u_j)-\vartheta^2_{G(e_i)}(u_j)\right|\right)+\left(\left|\eta^2_{F(e_i)}(u_i)-\eta^2_{G(e_i)}(u_i)\right| \wedge \left|\eta^2_{F(e_i)}(u_j)-\eta^2_{G(e_i)}(u_j)\right|\right)\end{matrix}\right\}\right]}{1+\frac{1}{2}\left[\left\{\begin{matrix} max\left(\left|\mu^2_{F(e_i)}(u_i)-\mu^2_{G(e_i)}(u_i)\right| \vee \left|\mu^2_{F(e_i)}(u_j)-\mu^2_{G(e_i)}(u_j)\right|\right), \\ \left(\left|\vartheta^2_{F(e_i)}(u_i)-\vartheta^2_{G(e_i)}(u_i)\right| \vee \left|\vartheta^2_{F(e_i)}(u_j)-\vartheta^2_{G(e_i)}(u_j)\right|\right)+\left(\left|\eta^2_{F(e_i)}(u_i)-\eta^2_{G(e_i)}(u_i)\right| \vee \left|\eta^2_{F(e_i)}(u_j)-\eta^2_{G(e_i)}(u_j)\right|\right)\end{matrix}\right\}\right]}$$

Definition 6.2 (Application of Similarity Measure of SFBSS)
A survey has conducted among 800 people in Muthuvara & Mattampuram, villages of Thrissur district, Kerala State, to know the negative impact of Main Stream Medias and Online Medias among society, especially on youths.
$U_1 = \{S_1, S_2, S_3, S_4, S_5, S_6\}$; U_1 = Main stream medias
$U_2 = \{T_1, T_2, T_3, T_4, T_5, T_6\}$; U_2 = Online medias
$X_1 = \{S_1, S_2\} \subseteq U_1$; $Y_1 = \{T_1, T_4\} \subseteq U_2$
$X_2 = \{S_3, S_4\} \subseteq U_1$; $Y_2 = \{T_2, T_5\} \subseteq U_2$
$X_3 = \{S_5, S_6\} \subseteq U_1$; $Y_3 = \{T_3, T_6\} \subseteq U_2$

$$E = \left\{\begin{matrix} e_1 = cyberbullying, \\ e_2 = spread\ of\ hate, \\ e_3 = misleading, \\ e_4 = spread\ of\ misinformation\ to\ promote\ rating, \\ e_5 = depression\ and\ anxiety \end{matrix}\right\}$$

$$A = \{e_1 = cyberbullying, e_3 = misleading, e_5 = depression \ \&\ anxiety\} \subseteq E$$

$$\langle\langle F, A\rangle\rangle = \left\{\begin{matrix} \left(e_1, \left(\frac{(0,0,1)}{\{S_1,S_2\}}, \frac{(0,0,1)}{\{T_1,T_4\}}\right)\right), \\ \left(e_3, \left(\frac{(0,0,1)}{\{S_3,S_4\}}, \frac{(0,0,1)}{\{T_2,T_5\}}\right)\right), \\ \left(e_5, \left(\frac{(0,0,1)}{\{S_5,S_6\}}, \frac{(0,0,1)}{\{T_3,T_6\}}\right)\right) \end{matrix}\right\}$$

$\langle\langle M_1, \mathrm{A}\rangle\rangle$: *SFBSS* framed on the survey conducted in Muthuvara village, Thrissur District, Kerala State.

$(X, Y) \subseteq (U_1, U_2)$	e_1	e_3	e_5
$\{S_1, S_2\}, \{T_1, T_4\}$	$((0.41,0.22,0.13), (0.78,0.32,0.1))$	$((0.21,0.16,0.1), (0.85,0.3,0.1))$	$((0.72,0.45,0.2), (0.81,0.46,0.16))$
$\{S_3, S_4\}, \{T_2, T_5\}$	$((0.36,0.19,0.11), (0.83,0.04,0.12))$	$((0.39,0.3,0.18), (0.78,0.2,0.13))$	$((0.7,0.38,0.16), (0.83,0.41,0.11))$
$\{S_5, S_6\}, \{T_3, T_6\}$	$((0.4,0.12,0), (0.75,0.21,0.13))$	$((0.4,0.12,0), (0.82,0.21,0.12))$	$((0.68,0.32,0.14), (0.85,0.38,0.12))$

$\langle\langle \mathrm{M}_2, \mathrm{A}\rangle\rangle$: SFBSS framed on the survey conducted in Mattampuram village, Thrissur District, Kerala State.

$(X, Y) \subseteq (U_1, U_2)$	e_1	e_3	e_5
$\{S_1, S_2\}, \{T_1, T_4\}$	$((0.32,0.2,0.1), (0.75,0.31,0.12))$	$((0.2,0.1,0), (0.66,0.3,0.12))$	$((0.75,0.22,0.1), (0.86,0.4,0.15))$
$\{S_3, S_4\}, \{T_2, T_5\}$	$((0.44,0.25,0.15), (0.81,0.2,0.15))$	$((0.44,0.2,0.12), (0.86,.38,0.1))$	$((0.62,0.32,0.1), (0.84,0.3,0.14))$
$\{S_5, S_6\}, \{T_3, T_6\}$	$((0.56,0.33,0.1), (0.56,0.33,0.1))$	$((0.31,0.15,0.1), (0.85,0.3,0.1))$	$((0.72,0.31,0.12), (0.82,0.2,0.1))$

$M_{SFBSS}(\langle\langle \mathrm{F}, \mathrm{A}\rangle\rangle, \langle\langle M_1, \mathrm{A}\rangle\rangle) = 0.195 < 0.75$; $M_{SFBSS}(\langle\langle \mathrm{F}, \mathrm{A}\rangle\rangle, \langle\langle M_2, \mathrm{A}\rangle\rangle) = 0.20075 < 0.75$
From both the result, it is clear that, both the Medias affecting young generations in a dangerous level, according to the parameters chosen. Parents should take care of their children seriously and have to monitor them to avoid the situation of a victim or prey.

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7. Conclusion

Soft set theory is a recently emerging area used as a tool for mathematical applications. In this paper two universes are simultaneously applied in Spherical Fuzzy Soft Set environment with some of its properties. Real –life situation demands more than one universes in certain situation. Tool introduced in this theory will assist such situations to draw a combined effect. Cardinal Set for Spherical Fuzzy Soft Set and Spherical Fuzzy Binary Soft Set are discussed. Similarity Measure for Spherical Fuzzy Binary Soft Sets with one application is provided. These concepts can be make use for higher dimensions and to the other branches of mathematics.

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