International Journal of Fuzzy Mathematics and Systems.
ISSN 2248-9940 Volume 12, Number 1 (2022), pp. 1-12

http://www.ripublication.com

Fuzzy Soft set Operations and Priority Decision Making with Fuzzy soft Set Relation Operator

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ABSTRACT

Generally in our day to day life we come across the real life situations when right decision making becomes difficult. In different fields like economics, social science, medical science, environment, where such complicacy arises and involves uncertainties. The conventional mathematical methods are unsuitable to solve such problems. To solve this problem, we are to find the various parameters related to the problem to use them to get the accurate result. So fuzzy soft set theory is the best mathematical tool for solving such problems using different techniques. In this research paper, we have defined some fundamental definitions and fuzzy soft operations along with a specific fuzzy soft operator i.e. Fuzzy soft relation operator with application in real life decision making problem.

Keywords: Fuzzy set; fuzzy soft set; fuzzy soft relation operator.

1. INTRODUCTION

In the fields of engineering, economics, social science, medical science, environment, etc. many complicated problems arise “involving uncertainties, classical methods are found to be inadequate in recent times”. To deal with this uncertainty, in 1965 Zadeh [1] developed the theory of fuzzy sets. Molodtsov [2] pointed out that existing theories, namely Probability Theory, Intuitionistic Fuzzy Set Theory, Fuzzy Set Theory, Rough Set Theory etc. have their own limitations for solving problems regarding uncertainties. He also explained that there are some limitation for solution due to the inadequacy of the parameterization tool of the fuzzy set theory, as such problems have multi-criteria in objects. He initiated the novel concept of Soft Set in 1999 as a new mathematical tool to deal with this problem. This soft set theory can be merged with previous theories. Scholars have proposed Probabilistic soft sets (Fatimah et al. [3]), Fuzzy soft sets (Maji et al. [4]), etc. In this paper, we are defining fuzzy set, fuzzy soft set and operations on soft sets and fuzzy soft sets. We have taken a specific fuzzy soft set relation operator defined by Kalaichelavi et al. [28] and applied this operation for priority decision making in real life problem.

2. MATHEMATICAL BACKGROUND

This new soft set theory found to be very useful in different fields using different techniques and showed great success. Molodtsov [2,5,6,7] applied this theory with different techniques formulating as the notions of soft number, soft integral and soft derivative etc. Maji et al. [8,9] studied it in detail and applied in decision making problems. Pawlak [10] proposed the reduction of rough sets, while Kong et al. [11] presented the normal parameterization reduction of soft sets and Chen et al. [12] gave parameterization reduction of soft sets. Zhan et al. [13] did a comprehensive study of that problem.

To obtain a better result in a more justified manner, many researchers used parameters through a different mathematical approach. Xiao et al. [14] formulated synthetic evaluation method, and gave a recognition for soft information based on the theory of soft sets [15]. Mushrif et al. [16] developed the algorithm based on the notions of soft set theory. Pei and Miao [17] worked on the soft sets to show a class of special information system, while Zou and Xiao [18] presented data analysis approaches of soft sets. Kovkov DV et al. [19] worked on optimization problems, whereas Majumdar and Samanta [20] worked on the similarity of soft sets and Ali et al. [21] presented a few new operations in soft set theory.

Many scholars around the globe presented their work with different novel concepts in interesting way to obtain more accurate result. Maji et al. [4] presented the concept of fuzzy soft sets by embedding the idea of fuzzy sets, whereas Roy and Maji [22] presented a different application of fs sets. Som [23] defined fuzzy soft relations and soft set relations. Krishna G et al. [24] worked on fuzzy soft set and Bhardwaj et al. [25] used Reduct soft set for real life decision making problems. Alcantud et al. [26] presented a concept of Partial Valuation Fuzzy Soft Set (PVFSS) and introduced the application of data filling in PVFSS. Irkin [27] generated the sensory score and presented a fuzzy soft set modeling in his study to find the maximum score. Kalaichelavi et al. [28], Karaca and Tas [29] presented notions of soft set and fuzzy soft sets. Ozgur and Tas [30] introduce a new method to include the notion of period using soft set and matrix form theories for solving investment decision making problem. Tas et al. [31] applied soft set theory and fuzzy soft set theory for the effective measurement of stock-out situations.

Maji et al. [4,9] defined the fundamental definitions of soft sets and fs sets which are used as an important basic operation. But Chen D, et al. [12], Pei and Miao [17], Kong et al. [32] and Ali et al. [21] pointed out some weak points of earlier work. Cogman and Enginoglu [33] redefined the operations of soft sets to develop the theory which became more functional for improving the approach and results. Cogman and Enginoglu [34] later came up with a soft matrix theory. Cagman et al. [35] defined a fuzzy parameterized soft set theory and its application.

3. BASIC DEFINITIONS[37].:

In this section, we present the basic definitions of fuzzy set theory [1] and soft set theory [2] that are useful for subsequent discussions. Throughout this work, U refers to an initial universe, E is a set of parameters, P(U) is the power set of U, and $A \subseteq E$.

Let us recall the notation of Fuzzy Set as follows:

3.1. Fuzzy Set: A fuzzy set X over a universal set U is a set defined by a function μ_X performing a mapping

$$\mu_x : U \rightarrow [0, 1]$$

here, this μ_x is the membership function of X, and the value $\mu_X(u)$ will be the grade of membership of $u \in U$. The value shows the degree of u belongingness to the fuzzy set X. So, a fuzzy set X over U can be defined as follows:

$$X = \{(\mu_X(u)/u), u \in U, \mu_X(u) \in [0, 1]\}.$$

The set of all the fuzzy sets over U will be denoted by F(U).

3.2 Soft set: Let X be a universe of discourse, E be set of parameters and $A \subseteq E$, then (F,A) is called a soft set over X, where F is a mapping given by $F:A \rightarrow P(X)$, P(X) is the power set of X, i.e. for $e \in A$ represents the set of all e-approximate members of the soft set (F,A).

for example Let $X=\{p_1,p_2,p_3\}$ be the set of three products and $E=\{e_1$(good looking), e_2(cheaper) ,e_3(Durable)} be the set of parameters and $A=\{e_1,e_3) \subset E$ then $(F,A)=\{F(e_1)=\{p_1,p_2\},F(e_3)=\{p_1,p_3\}\}$ is a soft set over X.

A soft set F_A over U is a set defined by a function f_A representing a mapping

$$f_A : E \rightarrow P(U) \text{ such that } f_A(x) = \emptyset \text{ ; if } x \notin A$$

Here, f_A is called approximate function of the soft set F_A, and the value $f_A(x)$ is a set called x-element of the soft set for all $x \in E$. The sets $f_A(x)$ may be empty, arbitrary or have nonempty intersection. So a soft set [F,A] $F_A = \{(x, f_A(x)) : x \in E, f_A(x) \in P(U)\}$over a universal set U can be shown as the set of ordered pairs such that

$$F_A=\{(x,F_A(x)): x \in E, F_A(x) \in P(U)$$

the set S(U) is the set of all soft sets over U.

Example: Let U = $\{u_1, u_2, u_3, u_4, u_5\}$ be a universal set and E = $\{x_1, x_2, x_3, x_4\}$ be a set of parameters. If A = $\{x_1, x_2, x_4\} \subseteq E$, $f_A(x_1) = \{u_2, u_4\}$, $f_A(x_2) = U$ and $f_A(x_4) = \{u_1, u_3, u_5\}$, this soft set F_A is written by

$F_A = \{(x_1, \{u_2, u_4\}), (x_2, U), (x_4, \{u_1, u_3, u_5\})\}$.

In the soft sets, the approximate functions and the parameter sets are crisp. But in the fs-sets, while the parameters sets are crisp, the approximate functions are fuzzy subsets of U. From now on, we will use Γ_A, Γ_B, Γ_C ,..., etc. for fs-sets and γ_A, γ_B, γ_C, etc. for their fuzzy approximate functions, respectively.

3.3 Fuzzy Soft Set: Let X be a universal set, E be set of parameters and $A \subset E$, We can represent the pair (F,A) as fuzzy soft set over X where F is a mapping given by $F:A \to I^X$, Where I^X denote the set of all fuzzy subsets of X.

for example Let $X=\{p_1,p_2,p_3\}$ be the set of three products and $E=\{e_1$(good looking), e_2(cheaper), e_3(Durable)$\}$ be the set of parameters and $A=\{e_1,e_3\} \subset E$ then $(F,A)=\{F(e_1)=\{(p_1,0.3,(p_2,0.5)\}, F(e_3)=\{p_1,0.3),(p_3,0.7)\}\}$ is a fuzzy soft set over X**.**

or fs Set: An fs-set Γ_A over U is a set defined by a function γ_A representing a function

$\gamma_A: E \to F(U)$ such that $\gamma_A(x) = \emptyset$; if $x \notin A$:

Here, γ_A is called fuzzy approximate function of the fs-set Γ_A, and the value $\gamma_A(x)$ is a set called x-element of the fs-set for all x€ E. Thus, an fs-set Γ_A over U can be represented by the set of ordered pairs

$\Gamma_{A=} \{(x, \gamma_A(x)) : x \in E; \gamma_A(x) \in F(U)\}$:

Note that the set of all fs-sets over U will be denoted by FS(U).

Example. Let U = $\{u_1, u_2, u_3, u_4, u_5\}$ be a universal set and E = $\{x_1, x_2, x_3, x_4\}$ be a set of parameters. If A = $\{x_1, x_2, x_4\}$ and $A \subseteq E$, $\gamma_A(x_1) = \{0.8/u_2, 0.4/u_4\}$, $\gamma_A(x_2) = U$, and $\gamma_A(x_4) = \{0.3/u_1, 0.5/u_3, 0.7/u_5\}$ then the soft set F_A is written by

$F_A = \{(x_1, \{0.8/u_2, 0.4/u_4\}), (x_2; U), (x_4, \{0.3/u_1, 0.5/u_3, 0.7/u_5\})\}$.

3.4. Empty fs-set: Let $\Gamma_A \in FS(U)$. If $\gamma_A(x) = \emptyset$; for all $x \in E$, then Γ_A is called an empty fs-set, denoted by $\Gamma\Phi$.

3.5. Universal fs-set: Suppose $\Gamma_A \in FS(U)$ and If $\gamma_A(x) = U$ for all $x \in A$, then Γ_A is called A-universal fs-set If A = E, then the A-universal fs-set is called universal fs-set, denoted by $\Gamma \tilde{E}$.

Example. Assume that U = $\{u_1, u_2, u_3, u_4, u_5\}$ is a universal set and E = $\{x_1, x_2, x_3, x_4\}$ is a set of all parameters.

If A = $\{x_2, x_3, x_4\}$, $\gamma_A(x_2) = \{0.4/u_2, 0.8/u_4\}$, $\gamma_A(x_3) = \emptyset$; and $\gamma_A(x_4)= U$, then the fs-set Γ_A is written by $\Gamma_A = \{(x_2, \{0.4/u_2, 0.8/u_4\}), (x_4, U)\}$.

If B = {x_1, x_3}, and $\gamma_B(x_1)$ = Ø, $\gamma_B(x_3)$ =Ø, then the fs-set Γ_B is an empty fs-set, i.e. $\Gamma_B = \Gamma\Phi$.

If C = {x_1, x_2}, γ_C (x_1) = U, and γ_C (x_2) = U, then the fs-set Γ_C is a C-universal fs-set, i.e., $\Gamma C = \Gamma_{\tilde{C}}$.

If D = E, and $\gamma_D(x_i)$ = U for all $x_i \in E$, where i =1,2,3,4, then the fs-set Γ_D is a universal fs-set, i.e., $\Gamma D = \Gamma \tilde{E}$.

4. OPERATIONS ON SOFT SETS AND FUZZY SOFT SETS [36]:

Let (F,A) and (G,B) be two soft set over common universe X where A,B⊂E, then

(i) (F,A) is a sub soft set of (G,B) written as (F,A) ⊆(G,B) if A⊂B and F(e)=G(e), $\forall e \in A$

(ii) (F,A)=(G,B) if (F,A) ⊆ (G,B) and (G,B) ⊆ (F,A)

(iii) The compliment of a soft set (F,A) denoted by $(F,A)^c=(F^c,A)$, where $F^c:A\rightarrow 2^X$ such that $F^c(e)=X-F(e)$, $\forall e \in A$

(iv) A soft set (F,A) is said to be a null soft set if $\forall e \in A$, F(e)=ϕ where ϕ is the null set of X.

(v) AND operation of two soft sets

“(F,A)AND((G,B)” denoted by (H, A×B)==(F,A)∧(G,B), is defined as $H(\alpha,\beta)=F(\alpha)\cap G(B)$, $\forall(\alpha,\beta) \in A\times B$

(vi) OR operation of two soft sets

“(F,A)OR((G,B)” denoted by (O, A×B)==(F,A)∨(G,B), is defined as $O(\alpha,\beta)=F(\alpha)\cup G(B)$, $\forall(\alpha,\beta) \in A\times B$.

(vii) Intersection of two soft sets (F,A) and (G,B) over the common universe X is the soft set (I,C)=(F,A) ∩(G,B), where C=A∩B and $I:C\rightarrow 2^X$ such that I(e)=F(e) or G(e), $\forall e \in C$

(viii) Union of two soft sets (F,A) and (G,B) over the common universe X is the soft set (U,C)=(F,A) ∪ (G,B), where C=A∪B and $U:C\rightarrow 2^X$ such that $\forall e \in C$

$$U(e)=\begin{cases} F(e),\ e \in A \sim B \\ G(e),\ e \in B \sim A \\ F(e)\cup G(e), e \in A\cap B \end{cases}$$

The definitions of sub fuzzy soft set, null fuzzy soft set and operations of intersection, union for fuzzy soft set are similar to those defined for soft sets.

5. PROPOSITION ON SOFT SETS (OR FUZZY SOFT SETS)[36]:

If (F,A) and (G,B) are two soft sets (or fuzzy soft sets) then

(i) $(F,A)\cup(F,A)=(F,A)$

(ii) $(F,A)\cap(F,A)=(F,A)$

(iii) $(F,A)\cup \phi= \phi$

(iv) $(F,A)\cap \phi= \phi$

(v) $\{(F,A)\cup(G,B)\}^C=(F,A)^C\cup(G,B)^C$

(vi) $\{(F,A)\cap(G,B)\}^C=(F,A)^C\cap(G,B)^C$

6. DECISION MAKING IN REAL LIFE PROBLEM:

(A) Fuzzy soft Set Relation Operator

Let (F, A) and (G, B) be two fuzzy soft sets over a common Universal set. Then a relation R of (F, A) on (G, B) may be defined as a mapping R: AXB $\rightarrow$P (U^2) such that for each $e_i \in A$, $e_j \in B$ for all $\mu_l \in F(e_i)$, $\mu_k \in G(e_j)$.

The relation R is characterized by the following membership function

$\mu_R (\mu_l , \mu_k)= \mu_F(e_i) (u_l)$ X $\mu_G(e_j) (\mu_k)$, where $u_l \in F(e_i)$, $u_k \in G(e_j)$

(B) **Application:**

A company wants to establish his new office in a state. The company gave the demand for the survey data based on various parameters of the cities in the state to the three different agencies viz. A_1. A_2 A_3. The set of alternatives of four cities in the state is U={ c_1,c_2,c_3,c_4}. The various parameters of the study of these cities are population of the city, distance from Airport & Railway Station, Available skilled man power in the city, Distance from the capital of the state and Crime rate in the city. They give different weights to the parameters in terms of fuzzy set to each city. Thus the set of parameters is E= $\{x_1,x_2,x_3,x_4,x_5\}$

where

$x_{1=}$ Population of the city

$x_{2=}$ Distance from Airport & Railway Station

$x_{3=}$, Available skilled man power in the city

$x_{4=}$, Distance from the capital of the state

$x_{5=}$ Crime rate in the city

Step 1: The data provided by the Survey agencies forms the fuzzy soft sets ΓA_1, ΓA_2, ΓA_3 over U as fallows:

ΓA_1	x1	x2	x3	x4	x5
c_1	0.8	0.6	0.4	0.6	0.4
c_2	0.7	0.6	0.4	0.6	0.7
c_3	0.6	0.5	0.4	0.6	0.5
c_4	0.9	0.6	0.3	0.9	0.5

ΓA_2	x1	x2	x3	x4	x5
c_1	0.6	0.5	0.2	0.8	0.5
c_2	0.6	0.5	0.5	0.4	0.6
c_3	0.4	0.6	0.4	0.5	0.7
c_4	0.8	0.4	0.2	0.7	0.5

ΓA_3	x1	x2	x3	x4	x5
c_1	0.7	0.4	0.3	0.7	0.6
c_2	0.5	0.7	0.3	0.5	0.5
c_3	0.5	0.7	0.4	0.4	0.6
c_4	0.7	0.5	0.4	0.8	0.5

So taking the average of the above three soft sets ΓA_1, ΓA_2, ΓA_3 we get the performance fs-set ΓA over U.

Step 2.: Construct an fs-set ΓA over U as given in the following table

ΓA	x1	x2	x3	x4	x5
c_1	0.7	0.5	0.3	0.7	0.5
c_2	0.6	0.6	0.4	0.5	0.6
c_3	0.5	0.6	0.4	0.5	0.6
c_4	0.8	0.5	0.3	0.8	0.5

Then $[aij]_{mxn}$ is called an *m x n* fs-matrix of fs-set ΓA over U as given below.

$$[aij]mxn = \begin{bmatrix} 0.7 & 0.5 & 0.3 & 0.7 & 0.5 \\ 0.6 & 0.6 & 0.4 & 0.5 & 0.6 \\ 0.5 & 0.6 & 0.4 & 0.5 & 0.6 \\ 0.8 & 0.5 & 0.3 & 0.8 & 0.5 \end{bmatrix}$$

Step 3: Here we have applied Fuzzy soft Relation Operator for the study of different cities in the state for making right decision for establishing the new office in a best suitable city taking their desired parameters.

1. So selection of a city based on parameters

   $x_{1=}$ Population of the city

   And $x_{3=}$, Available skilled man power in the city

   $(R_1, C_1) = \{c_1/0.21, c_2/0.24, c_3/0.20, c_4/0.24\}$

   Here two cities c_2 and c_4 get equal largest membership grade so company can opt for either of the city.

2. So selection of a city based on parameters

   $x_{1=}$ Population of the city

   $x_{3=}$ Available skilled man power in the city

   and $x_{5=}$ Crime rate in the city we get

   (R_2,C_2) ={c_1/0.105, c_2/0.144, c_3/0.120, C_4/0.120}

   Here city c_2 get largest membership grade i.e. 0.144 so city c2 is the best suitable based on these three parameters.

3. So selection of a city based on parameters x_2= Distance from Airport & Railway Station

   And $x_{4=}$, Distance from the capital of the state

   (R_3,C_3) ={c_1/0.35, c_2/0.30, c_3/0.30, C_4/0.40}

   Here city c_4 get largest membership grade i.e. 0.40 so city c4 is the best suitable based on these two parameters.

4. Now selection of the city based on all the five parameters
   $x_{1=}$ Population of the city

   $x_{2=}$ Distance from Airport & Railway Station

   $x_{3=}$, Available skilled man power in the city

   $x_{4=}$, Distance from the capital of the state

   $x_{5=}$ Crime rate in the city

   (R_4,C_4) = ={c_1/0.03675, c_2/0.0432, c_3/0.0360, C_4/0.0480}

   here, the city c_4 has the largest membership grade (0.0480) based on all five parameters taking together.

7. CONCLUSION

Here in this paper for using fuzzy soft relation operator, we first explained basic concepts of fuzzy soft set theory and operations. Here we have taken a real life problem for fixing the priority of the city based on selected parameters of our choice. This method is more useful and convenient over to other selection decision method that we can use the parameters as per our limited choice while in other methods, generally we get final result taking all the parameters together[37]. So this fuzzy soft set relation operator method can be extended for different type of classical real life problems in decision making.

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