

“APPLICATION OF fs-AGGREGATE ALGORITHM FOR MULTI-CRITERIA DECISION MAKING IN REAL LIFE PROBLEM”

Abstract: Generally in our day to day life we face some problems in which the right decision making becomes confusing. In many complicated problems arising in the fields of social science, economics, environment, medical science etc involving uncertainties. Classical methods are found to be inadequate in recent times for solving such problems. To obtain the best feasible solution of these problems we have to consider various parameters relating to the solution. For this we can use the best mathematical tool called Fuzzy soft set theory. In this paper we have taken a multi-criteria real life problem and successfully applied the fs-aggregation algorithm in decision making for selecting a suitable city which suits the best conditions as per the given parameters.

Keywords:

Fuzzy set, Fuzzy Soft set, fs-aggregation

I. INTRODUCTION:

In many complicated problems arising in the fields of engineering, social science, economics, environment, medical science etc involving uncertainties. Classical methods are found to be inadequate in recent times. The most appropriate theory for dealing with uncertainty is the theory of fuzzy sets developed by Zedah [24] in 1965. Then after some time, Molodtsov [13] pointed out that the important existing theories viz. Probability Theory, Fuzzy Set Theory, Intuitionistic Fuzzy Set Theory, Rough Set Theory etc. which can be considered as mathematical tools for dealing with uncertainties, have their own difficulties. He further pointed out that the reason for these difficulties is, possibly, the inadequacy of the parameterization tool of the theory. In 1999 he initiated the novel concept of Soft Set as a new mathematical tool for dealing with uncertainties. Soft Set Theory, initiated by Molodtsov [13], is free of the difficulties present in these theories.

Molodtsov applied this theory to several directions [13], [14], [15], and then formulated the notions of soft number, soft derivative, soft integral, etc. in [16]. The soft set theory has been applied to many different fields with great success. Maji et al. [11] worked on theoretical study of soft sets in detail, and [10] presented an application of soft set in the decision making problem using the reduction of rough sets [18]. Chen et al. [5] proposed parameterization reduction of soft sets, and then Kong et al. [7] presented the normal parameterization reduction of soft sets.

Recently, many scholars study the properties and applications on the soft set theory. Xiao et al. [22] studied synthetically evaluating method for business competitive capacity and also Xiao et al.[23] gave recognition for soft information based on the theory of soft sets. Pei and Miao [19] showed that the soft sets are a class of special information systems. Mushrif et al. [17] presented a new algorithm based on the notions of soft set theory for classification of the natural textures. Kovkov et al. [8] considered the optimization problems in the framework of the theory of soft sets which is directed to formalization of the concept of approximate object description. Zou and Xiao [25] presented data analysis approaches of soft sets under incomplete information. Majumdar and Samanta [12] studied the similarity measure of soft sets. Ali et al. [1] introduced the analysis of several operations on soft sets.

Maji et al. [9] presented the concept of the fuzzy soft sets (fs-sets) by embedding the ideas of fuzzy sets [24]. By using this definition of fs-sets many interesting applications of soft set

theory have been expanded by some researchers. Roy and Maji [20] gave some applications of fs-sets. Som [21] defined soft relation and fuzzy soft relation on the theory of soft sets. Krishna Gogoi et al [27] applied fuzzy soft set and Bhardwaj et al. [28] used Reduct soft set for real life decision making problems.

The operations of the fs-sets and soft sets defined by Maji et al. [9],[11] are used in all the works mentioned above. But, Chen et al. [5], Pei and Miao [19], Kong et al. [6] and Ali et al. [1] pointed out that these works have some weak points. Therefore, to develop the theory, Cagman and Enginoglu [2] redefined operations of the soft sets which are more functional for improving several new results. By using these new operations, Cagman and Enginoglu [3] presented a soft matrix theory. Cagman et al. [4] defined a fuzzy parameterized soft set theory and its decision making method.

In this paper author is defining fuzzy soft set and applying fuzzy soft set aggregation algorithm to solve decision making problems. The fs-aggregation algorithm is well defined by Cagman et al. [26] for decision making. We finally give an example which shows that the method can be successfully applied to many problems containing uncertainties.

II. PRELIMINARIES:

In this section, we present the basic definitions of soft set theory [13] and fuzzy set theory [24] 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:

2.1. Let U be a universe. A fuzzy set X over U is a set defined by a function μ_X representing a mapping

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

μ_X is called the membership function of X , and the value $\mu_X(u)$ is called the grade of membership of $u \in U$. The value represents the degree of u belonging to the fuzzy set X .

Thus, a fuzzy set X over U can be represented as follows:

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

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

2.2. 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 $x \in E$. It is worth noting that the sets $f_A(x)$ may be arbitrary, empty, or have nonempty intersection. Thus a soft set over U can be represented by the set of ordered pairs

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

the set of all soft sets over U will be denoted by $S(U)$.

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 $f_A(x_4) = \{u_1, u_3, u_5\}$, then the 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 parameter sets and the approximate functions 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 $\Gamma_A, \Gamma_B, \Gamma_C, \dots$, etc. for fs-sets and $\gamma_A, \gamma_B, \gamma_C, \dots$, etc. for their fuzzy approximate functions, respectively.

2.3. An fs-set Γ_A over U is a set defined by a function γ_A representing a mapping $\gamma_A: E \rightarrow F(U)$ 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 $x \in E$. Thus, an fs-set Γ_A over U can be represented by the set of ordered pairs

$$\Gamma_A = \{(x, \gamma_A(x)) : x \in E; \gamma_A(x) \subseteq F(U)\}.$$

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 $A = \{x_1, x_2, x_4\} \subseteq E$, $\gamma_A(x_1) = \{0.9/u_2, 0.5/u_4\}$, $\gamma_A(x_2) = U$, and $\gamma_A(x_4) = \{0.2/u_1, 0.4/u_3, 0.8/u_5\}$ then the soft set F_A is written by

$$F_A = \{(x_1, \{0.9/u_2, 0.5/u_4\}), (x_2, U), (x_4, \{0.2/u_1, 0.4/u_3, 0.8/u_5\})\}.$$

2.4. Let $\Gamma_A \subseteq FS(U)$. If $\gamma_A(x) = \emptyset$; for all $x \in E$, then Γ_A is called an empty fs-set, denoted by $\Gamma_\emptyset$.

2.5. Let $\Gamma_A \subseteq FS(U)$. If $\gamma_A(x) = U$ for all $x \in A$, then Γ_A is called A -universal fs-set, denoted by $\Gamma_{\bar{A}}$.

If $A = E$, then the A -universal fs-set is called universal fs-set, denoted by $\Gamma_{\bar{E}}$.

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 $A = \{x_2, x_3, x_4\}$, $\gamma_A(x_2) = \{0.5/u_2, 0.9/u_4\}$, $\gamma_A(x_3) = \emptyset$; and $\gamma_A(x_4) = U$, then the fs-set Γ_A is written by $\Gamma_A = \{(x_2, \{0.5/u_2, 0.9/u_4\}), (x_4, U)\}$.

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

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

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., $\Gamma_D = \Gamma_{\bar{E}}$.

III. FS-AGGREGATION ALGORITHM :

Herein we introduced a new concept in which three different fs-sets are generated. Finally we define an fs-aggregation operator that produces an aggregate fuzzy set from an fs-set and its cardinal set. The approximate functions of an fs-set are fuzzy. An fs-aggregation operator on the fuzzy sets is an operation by which several approximate functions of an fs-set are combined to produce a single fuzzy set which is the aggregate fuzzy set of the fs-set. Once an aggregate fuzzy set has been arrived at, it may be necessary to choose the best single crisp alternative from this set.

Therefore, we can make a decision by the following algorithm.

Step 1: Construct different fs-sets $\Gamma_{A_1}, \Gamma_{A_2}, \Gamma_{A_3}$ over U .

Step 1: Construct an average fs-set Γ_A over U .

Step 2. Find the cardinal set $c\Gamma_A$ of Γ_A .

Step 3: Find the aggregate fuzzy set Γ_A^* of Γ_A . Step 4: Find the best alternative from this set that has the largest member-ship grade by $\max \Gamma_A^*(u)$.

A. Step 1:

Let $\Gamma_A \in FS(U)$. Assume that $U = \{u_1; u_2; \dots; u_m\}$, $E = \{x_1; x_2; \dots; x_n\}$ and $A \subseteq E$, then different fs-sets $\Gamma_{A_1}, \Gamma_{A_2}, \Gamma_{A_3}, \dots, \Gamma_{A_n}$ over U can be presented as per the following table.

Γ_{A_1}	X_1	X_2	.	X_n
u_1	$\mu\gamma_A(x_1)(u_1)$	$\mu\gamma_A(x_2)(u_1)$	.	$\mu\gamma_A(x_n)(u_1)$
u_2	$\mu\gamma_A(x_1)(u_2)$	$\mu\gamma_A(x_2)(u_2)$	.	$\mu\gamma_A(x_n)(u_2)$
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180	u_m	$\mu_{\Gamma A}(x_1)(u_m)$	$\mu_{\Gamma A}(x_2)(u_m)$	$\mu_{\Gamma A}(x_n)(u_m)$

Similarly we can generate ΓA_2 and $\Gamma A_3, \dots, \Gamma A_n$

B. Step 2:

So taking the average of the above all soft sets $\Gamma A_1, \Gamma A_2, \Gamma A_3, \dots, \Gamma A_n$ we get the performance fs-set ΓA over U

Let $\Gamma A \in FS(U)$. Assume that $U = \{u_1, u_2, \dots, u_m\}$, $E = \{x_1, x_2, \dots, x_n\}$ and $A \subseteq E$, then the ΓA can be presented by the following table.

ΓA	X_1	X_2	$\dots$	X_n
u_1	$\mu_{\Gamma A}(x_1)(u_1)$	$\mu_{\Gamma A}(x_2)(u_1)$	$\dots$	$\mu_{\Gamma A}(x_n)(u_1)$
u_2	$\mu_{\Gamma A}(x_1)(u_2)$	$\mu_{\Gamma A}(x_2)(u_2)$	$\dots$	$\mu_{\Gamma A}(x_n)(u_2)$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
u_m	$\mu_{\Gamma A}(x_1)(u_m)$	$\mu_{\Gamma A}(x_2)(u_m)$	$\dots$	$\mu_{\Gamma A}(x_n)(u_m)$

Where $a_{ij} = \mu_{\Gamma A}(x_j)(u_i)$ is the membership function of ΓA . If $a_{ij} = \mu_{\Gamma A}(x_j)(u_i)$ for $i=1,2,\dots,m$ and $j=1,2,\dots,n$ then the fs-set ΓA is uniquely characterized by the matrix

$$[a_{ij}]_{m \times n} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}$$

This matrix is called an $m \times n$ fs-matrix of the fs-set ΓA over U .

C. Step 3:

Let $\Gamma A \in FS(U)$ then the cardinal set ΓA denoted by $c\Gamma A$ and defined by $c\Gamma A = \{\mu_{\Gamma A}(x)/x : x \in E\}$ is a fuzzy set over E . The membership function $\mu_{c\Gamma A}$ of $c\Gamma A$ is defined by

$$\mu_{c\Gamma A} : E \rightarrow [0,1], \mu_{c\Gamma A}(x) = \frac{\sum_{i=1}^m \mu_{\Gamma A}(x)(u_i)}{|U|}$$

where $|U|$ is the cardinality of universe U .

And $|\gamma_A(x)|$ is the scalar cardinality of fuzzy set $\gamma_A(x)$. The set of all cardinal sets of the fs-sets over U will be denoted by $cFS(U) \subseteq F(E)$.
Now let $\Gamma_A \in FS(U)$ and $c\Gamma_A \in cFS(U)$. Assume that $E = \{x_1, x_2, \dots, x_n\}$ and $A \subseteq E$, then

$c\Gamma_A$ can be presented by the following table

E	x_1	x_2		x_n
$\mu_{c\Gamma_A}$	$\mu_{c\Gamma_A}(x_1)$	$\mu_{c\Gamma_A}(x_2)$		$\mu_{c\Gamma_A}(x_n)$

If $a_{ij} = \mu_{c\Gamma_A}(x_j)$ for $j=1, 2, \dots, n$, then the cardinal set $c\Gamma_A$ is uniquely characterized by a matrix,

$$[a_{ij}]_{1 \times n} = [a_{11}, a_{12}, \dots, a_{1n}]$$

Which is called the cardinal matrix of the cardinal set $c\Gamma_A$ over E .

D. Step 4

let $\Gamma_A \in FS(U)$ and $c\Gamma_A \in cFS(U)$. then fs-aggregation operator, denoted by $FSagg$, is defined by

$$FSagg : cFS(U) \times FS(U) \rightarrow F(U), FSagg(c\Gamma_A, \Gamma_A) = \Gamma^*_A$$

Where $\Gamma^*_A = \{ \mu_{\Gamma^*_A}(u) / u : u \in U \}$ is a fuzzy set over U . Γ^*_A is called the aggregate fuzzy set of the fs-set Γ_A . The membership function $\mu_{\Gamma^*_A}$ of Γ^*_A is denoted as follows:

$$\mu_{\Gamma^*_A} : U \rightarrow [0, 1], \mu_{\Gamma^*_A}(u) = \frac{1}{|E|} \sum_{x \in E} \mu_{c\Gamma_A}(x) \mu_{\Gamma_A}(x)(u)$$

where $|E|$ is the cardinality of E .

Now assume that $U = \{u_1, u_2, \dots, u_m\}$, then the Γ^*_A can be presented by the following table.

Γ_A	$\mu_{\Gamma^*_A}$
u_1	$\mu_{\Gamma^*_A}(u_1)$
u_2	$\mu_{\Gamma^*_A}(u_2)$
$\vdots$	$\vdots$
u_m	$\mu_{\Gamma^*_A}(u_m)$

If $a_{i1} = \mu_{\Gamma^*_A}(u_i)$ for $i=1, 2, \dots, m$ then Γ^*_A is uniquely characterized by the matrix

$$\begin{bmatrix} a_{11} \\ a_{21} \\ \vdots \\ a_{m1} \end{bmatrix}$$

$$[a_{i1}]_{m \times 1} =$$

Which is called the aggregate matrix of Γ^*A over U .

If $M\Gamma A$, $Mc\Gamma A$, $M\Gamma^*A$ are representation matrices of ΓA , $c\Gamma A$ and Γ^*A , respectively then

$$IEI \times M\Gamma^*A = M\Gamma A \times M^T \Gamma A$$

$$M\Gamma^*A = \frac{1}{IEI} M\Gamma A \times M^T \Gamma A$$

Where $M^T \Gamma A$ is the transposition of $M \Gamma A$ and IEI is the cardinality of E .

E. Step 5

Find the best alternative from this aggregate fuzzy set Γ^*A that has the largest membership grade by $\max \Gamma^*A(u)$.

IV. 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

Here we have applied fs-Aggregation algorithm for the study of different cities in the state for making right decision for establishing the new office in a best suitable city.

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

ΓA_1	x_1	x_2	x_3	x_4	x_5
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	x_1	x_2	x_3	x_4	x_5
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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 $\Gamma A_1, \Gamma A_2, \Gamma A_3$ 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 $[a_{ij}]_{m \times n}$ is called an $m \times n$ fs-matrix of the fs-set ΓA over U as given below.

$$[a_{ij}]_{m \times n} = \begin{bmatrix} 0.7 & 0.5 & 0.3 & 0.7 & 0.5 \\ 0.6 & 0.6 & 0.4 & 0.5 & 0.6 \\ 0.5 & 0.6 & 0.4 & 0.5 & 0.6 \\ 0.8 & 0.5 & 0.3 & 0.8 & 0.5 \end{bmatrix}$$

Step 3: The cardinal set $c\Gamma A$ of ΓA is computed as follows:

$$\mu_{c\Gamma A}(x_1) = (0.7+0.6+0.5+0.8)/4=0.65$$

$$\mu_{c\Gamma A}(x_2) = (0.5+0.6+0.6+0.5+)/4=0.55$$

$$\mu_{c\Gamma A}(x_3) = (0.3+0.4+0.4+0.3)/4=0.35$$

$$\mu_{c\Gamma A}(x_4) = (0.7+0.5+0.5+0.8)/4=0.625$$

$$\mu_{c\Gamma A}(x_5) = (0.5+0.6+0.6+0.5)/4=0.55$$

So cardinal set $c\Gamma A = \{0.65/x_1, 0.55/x_2, 0.35/x_3, 0.625/x_4, 0.55/x_5\}$

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Step 4: The aggregate fuzzy set $M\Gamma * A$ is computed as follows:

$$M\Gamma * A = \frac{1}{5} \begin{bmatrix} 0.7 & 0.5 & 0.3 & 0.7 & 0.5 \\ 0.6 & 0.6 & 0.4 & 0.5 & 0.6 \\ 0.5 & 0.6 & 0.4 & 0.5 & 0.6 \\ 0.8 & 0.5 & 0.3 & 0.8 & 0.5 \end{bmatrix} = \begin{bmatrix} 0.65 \\ 0.55 \\ 0.35 \\ 0.625 \\ 0.55 \end{bmatrix} = \begin{bmatrix} 0.310 \\ 0.301 \\ 0.288 \\ 0.335 \end{bmatrix}$$

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That means,

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$$\Gamma * A = \{0.310/c_1, 0.301/c_2, 0.288/c_3, 0.355/c_4\}$$

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Step 5: Finally the largest membership grade is chosen by $\max \mu_{\Gamma * A}(u) = 0.355$

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Which means that the city c_4 has the largest membership grade, hence c_4 is the best suitable city which has the parameters as $x_1=0.8$, $x_2=0.5$, $x_3=0.3$, $x_4=0.8$ and $x_5=0.5$. and we may also grading the cities on the basis on membership grade that c_4, c_1, c_2 and c_3 are in decreasing grade on the basis of given parameters.

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V. CONCLUSION:

Here in this paper for using fs-aggregation method we first explained some basic concepts of fuzzy soft set theory and its operations. Here we have taken a multi-criteria real life problem to apply the extended application of fs-aggregation algorithm. We developed fs-aggregation algorithm in more simplified and precisely analytic than the existed methods for the application point of view. Finally, we explained the successful application and output of this method. Our aim is that we can apply the fs-aggregation algorithm for such extended problems which contains multi-criteria in the real life situations. The method can be extended for the multi-faceted applications for the subsequent studies.

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