Review Article

Application of Interval Valued Fuzzy Soft Max-Min Decision Making Method in Medical Diagnosis

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ABSTRACT

In this paper, we study some basic concepts of fuzzy sets, soft sets, fuzzy soft sets, and interval-valued fuzzy soft sets. Secondly, a graphical model developed by using an Interval-valued fuzzy soft max-min decision-making function known as Interval-valued fuzzy soft max-min decision making (IVFSMmDM) method. Finally, we used IVFSMmDM for the identification of patients who need medical diagnoses urgently.

Keywords: Fuzzy set, soft set, interval-valued fuzzy soft set, IVFSMmDM function.

INTRODUCTION

Zadeh was the first mathematician who reformed the Mathematical approach to respond to the complications and uncertainties with the concept of the fuzzy set (FS) in 1965 [1]. After this revolution many other concepts such as Hesitant fuzzy sets, Intuitionistic fuzzy sets, Neutrosophic Sets, Linguistic Term Sets, and Hesitant Fuzzy Linguistic term sets, etc. This stream of knowledge grew when Molodstov expressed the concept of soft set (SS) in 1999 [2]. This idea of SS was channelized by many other Mathematicians who took further actions to establish the foundations. In [3] Maji et al in 2003 defined the ideas such as subset, superset, equality of SSs, union, intersection AND, and OR operations of SSs. Pei and Miao also contributed to redefining these ideas in a study[4]. In a study[5] some more operations were also defined by Ali et al. Cagman and Enginoglu[6] developed the concept of the soft matrix with different properties and operations.

In these days, mathematician plays a vital role in the SS fuzzification. A new perception of the fuzzy soft set (FSS) was introduced in a study[7] after the fuzzification of SS with different types and properties. They also reviewed the SS theory which was given by Molodtsov and used this theory for decision making in a study[8]. The work on FSS theory was extended and introduced a new concept from FSS which is known as a fuzzy soft aggregation operator and its cardinal set[9]. They introduced the cardinal matrix of the cardinal set also construct a decision algorithm and used this method in decision making successfully. Some limitations were faced in the work of Maji et al. which were attensonoid by Chen *et al.,*[10] by constructing a new definition of parameterization reduction and applied this definition in decision making. Ahmad and Kharal [11] extended the work of Maji *et al.,*[7,12] with illustrations and counter illustrations and improved their work, also they extended the concept of FSS by defining some new

definitions such as the union of arbitrary FSS, the intersection of arbitrary FSS and proved De-Morgan inclusion on FSS.

In a study[13], the author's generalized the concept of FSS and proposed a new theory of generalized FSS with some properties and used generalized FSS for decision-making problem, also use this theory for the diagnosis of Pneumonia. Dayan et al. also used this theory for decision making in a study[14]. In a study[15] fuzzy soft set theory used for medical diagnosis through Sanchez's approach by using fuzzy arithmetic operations. Many researchers extend the concept of studied FS and SS and developed TOPSIS models for fuzzy sets and soft sets and used for decision making and medical diagnoses[16-20]. The work on fuzzy soft matrices (FSM) was extended by Borah *et al.,*[21], they forwarded the FSM theory with some definitions and properties; they proposed a special type of product of FSMs which is known as the T-product of FSMs and used this product in decision-making problem after construct algorithm.

The theory of interval-valued fuzzy set (IVFS) was forwarded by Yushi in 2010 and discussed the properties of IVFS [22]. He proposed a new concept on IVFS which is known as a cut set of IVFS with some properties and introduced three decomposition theorems of IVFS. A most important topic of fuzzy algebra is the fuzzy matrix (FM) in this matrix elements are belonging to the unit interval [0, 1]. FM becomes the interval-valued fuzzy matrix (IVFM) when we generalized the FM elements in subintervals of [0, 1]. The membership value of rows and columns is crisp in IVFM, but there are many challenges are faced in real-life problems. To solve those challenges Pal [23] presented the idea of IVFM with the help of interval-valued fuzzy rows and columns and defined some basic definitions with some binary operators. He also defined complement and density of interval-valued fuzzy rows and columns with verification of few important properties.

Yang *et al.,* [24] worked on IVFS and SS and proposed a new theory which is known as interval-valued fuzzy soft set (IVFSS) with different types and properties. They define different operations on IVFSS such as complement, AND-operation, and OR-operation on IVFSS with examples also prove the De-Morgan laws, associative laws, and distributive laws on IVFSS and successfully used this theory in decision making to show the validity of IVFSS. In a study[25] an algorithm developed on IVFSS and used for medical diagnoses by extending Sanchez's approach. The author's studied the fuzzy set theory and used the trapezoidal fuzzy numbers for disease identification by using Sanchez's approach[26]. The work on IVFSS was extended by Shawkat and Abdul in a study[27], they introduced generalized IVFSS with basic operations such as union, intersection, and complement also proved some properties related to these operations. They also proposed AND-operation, OR-operation similarity measure on generalized IVFSS, and use this similarity measure in medical diagnoses for decision making. Dayan and Zulqarnain studied the interval-valued fuzzy soft matrix (IVFSM) and developed some new operations and properties on IVFSM in a study[28].

Rajarajeswari and Dhanalakshmi worked on IVFSM and proposed new definitions on IVFSM with examples and properties in a study[29]. A decision-making method on IVFSM developed in a study[30] which is known as the "Interval Valued fuzzy soft max-min decision-making method" and used the developed method for decision making. They introduced some new operations on IVFSM such as arithmetic mean, weighted arithmetic mean, geometric mean, weighted geometric mean, harmonic mean, and weighted harmonic mean with some properties of IVFS-matrices in decision making. In a study[31] Sarala and Prabharathi worked on IVFSS and extended Sanchez`s approach for medical diagnoses by using IVFSM with illustrations. They proposed some new definitions on IVFSM such as union and intersection of IVFSM with their examples. They also proved the commutative laws, associative laws, and construct an algorithm for medical diagnoses. The author's used IVFSM for decision making in a study[32,33]. The author's defined some new operations on IVFSM and used for decision making [34].

In this research, we study fuzzy sets, soft sets, fuzzy soft sets, and interval-valued fuzzy soft matrices. We constructed a graphical model for the IVFSMmDM method by using the IVFSMmDM function. Finally, we use this for medical diagnoses.

PRELIMINARIES

Definition 2.1 [1]

If we identify a set A in X by its membership function $\mu_A : X \rightarrow [0, 1]$. Then a set A is called an FS. Indeed, A = {(x, μ_A(x)): x∈X}. A real number $\mu_A(x)$ represents a grade of membership of a fuzzy set A defined over a universe.

Definition 2.2 [2]

A pair (F, A) is called an SS over M if A is any subset of E, and there exists a mapping from A to P (M) is F, P (M) is the parameterized family of subsets of the M but not a set.

Definition 2.3 [6]

Suppose X and E are universe set and set of attributes respectively and A ⊆ E. Let (f_A, E) be a SS over X. Then a subset R_A of X×E, uniquely defined as R_A ={(g, t): t∈A, g∈f_A (t)}, is called a relation form of the SS (f_A, E).

The characteristic function χ_{R_A} of R_A is defined as χ_{R_A}: X×E→{0,1} where

$$\chi_{R_A}(g, t) = \begin{cases} 1, & (g, t) \in R_A \\ 0, & (g, t) \notin R_A \end{cases}$$

Now if X= $\{g_1, g_2, g_3, \ldots, g_m\}$ and E=$\{t_1, t_2, t_3, \ldots, t_n\}$ then the SS (f_A, E) can be represented by a matrix $[a_{ij}]_{m \times n}$ called a " SM" of SS (f_A, E) over X as follows

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

Where $a_{ij} = \chi_{R_A}(g_i, t_i)$

In other words, an SS is uniquely represented by its corresponding SM. So, we can define a function ρ which maps SS to SM i.e. $\rho: R_A \rightarrow [a_{ij}]$ Where $a_{ij} = \chi_{R_A}(g_i, t_i)$

Definition 2.4 [7]

A pair (F, A) is called FSS over M, and there exists a mapping from A to P (M) is F, P (M) is the collection of fuzzy subsets of M.

Definition 2.5 [35]

A pair (F, A) is called FSS in the fuzzy soft class (M, E). Then (F, A) is represented in a matrix form such as

$A_{m \times n}$ = $[a_{ij}]_{m \times n}$ or A = $[a_{ij}]$ (i = 1→ m), (j = 1 → n)

Where

$$a_{ij} = \begin{cases} \mu_j(b_j) & if \ b_j \in A \\ 0 & if \ b_j \notin A \end{cases}$$

Definition 2.6 [22]

Let A be a set and U be a universal set than IVFS in A over U is defined as

A = {(p, [$\mu_{AL}(p), \mu_{AU}(p)$]): p ∈ U},

Where $\mu_{AL}(p)$ and $\mu_{AU}(p)$ are a fuzzy subset of U and $\mu_{AL}(p) \leq \mu_{AU}(p)$ for all i, j.

Definition 2.7 [22]

Let A = [$\mu_{AL}(p), \mu_{AU}(p)$] and B = [$\mu_{BL}(p), \mu_{BU}(p)$] are two IVFS over U, then A is said to be IVF-subset of B if $\mu_{AL}(p) \leq \mu_{BL}(p)$ and $\mu_{AU}(p) \leq \mu_{BU}(p)$ for all p ∈ U., it is represented as A ⊆ B.

Definition 2.8 [24]

A pair (F, A) is called IVFSS over M where F is a mapping such that

F: $A \rightarrow I^M$

Where I^M represent the all interval-valued fuzzy subsets (IVFSbS) of M

Definition 2.9 [24]

A pair (F, A) is called IVFSS over M, where F is a mapping such that

F: $A \rightarrow I^M$, where I^M represent the all IVFSbS of M. Then the IVFSS can be expressed in matrix form as

$A_{m \times n} = [a_{ij}]_{m \times n}$

Or

A= $[a_{ij}]$ (i = 1 → m), (j = 1→ n)

Where

$a_{ij} = \begin{cases} [\mu_{jL}(b_i), \mu_{jU}(b_i)] & If\ b_i \in A \\ [0, 0] & If\ b_i \notin A \end{cases}$

Where $[\mu_{jL}(b_i), \mu_{jU}(b_i)]$ represents the membership of b_i in the IVFS.

Definition 2.10 [34]

Let A= $[a_{ij}]$ and B= $[b_{ij}]$ are two IVFS-matrices of order m×n and n×p respectively than their product defined as

A∗B = $[c_{ik}]_{m \times p}$ = [max min (μ_{AL_j}, μ_{BL_j}), max min (μ_{AU_j}, μ_{BU_j})] ∀ i, j, k.

Definition 2.11 [34]

Let A = $[a_{ij}]$ and B = $[b_{ij}]$ are two IVFS-matrices of order m×n and n×p respectively than their product defined as

A∗B = $[c_{ik}]_{m \times p}$ = [max (μ_{AL_j}, μ_{BL_j}), max (μ_{AU_j}, μ_{BU_j})] ∀ i, j, k.

OR

A∗B = $c_{ij} = \sum_{k=1}^{n} (a_{ik} * b_{ik})$, i = 1, 2… m and j = 1, 2… p

A∗B = $[c_{ik}]_{m \times p}$ = $[\sum_{k=1}^{n} (a_{ikL} * b_{ikL}), \sum_{k=1}^{n} (a_{ikU} * b_{ikU})]$, i = 1, 2… m and k = 1, 2… p ∀ i, j, k.

Definition 2.12 [34]

A = $[a_{ij}]$ and B = $[a_{ik}]$ are two IVFS-matrices of same order m×n then Or-product is defined as

V: A×B $\rightarrow C_{m \times n^2}$, $[a_{ij}]_{m \times n} \vee [b_{ik}]_{m \times n} = [c_{ip}]_{m \times n^2}$ where

c_{ip} = [max (μ_{AL_j}, μ_{BL_j}), max (μ_{AU_j}, μ_{BU_j})] ∀ i, j, k. such that p = n(j −1) + k.

Interval Valued Fuzzy Soft Max-Min Decision Making Method

In this section, we present the "Interval Valued Fuzzy Soft Max-min Decision Making (IVFSMmDM)" function and construct a graphical model for decision making by using the IVFSMmDM function.

Definition 3.1 [30]

Let $[c_{ip}] \in IVFSM_{m \times n^2}$, I_k = {P: $c_{ip} \neq 0$, (k-1) n < P ≤ kn} for all k ∈ {1,2,3,….,n} and IVFS-max-min decision function define as follows

Mm: $IVFSM_{m \times n^2} \rightarrow IVFSM_{m \times 1}$

Mm: $[c_{ip}]$ = $[d_{i1}]$ = $[\max\{t_{ik}\}]$ where t_{ik} = $\begin{cases} min_{p \in I_k}\{c_{ip}\} & If\ I_k \neq o \\ [0.0, 0.0] & If\ I_k = o \end{cases}$ and

c_{ip} = [min(μ_{AL_j}, μ_{BL_j}), min(μ_{AU_j}, μ_{BU_j})] ∀ i, j, k and p = n (j - 1) + k is known as IVFSMmDM function.

Definition 3.2 [30]

Let M = $\{m_1, m_2, m_3, …., m_n\}$ be a universal set and max-min $[c_{ip}]$ = $[d_{i1}]$, then optimum IVFS on M is defined as follows

Opt $[d_{i1}]$ (M) = $\{d_{i1}/m_i: m_i \in M, d_{i1} \neq 0\}$
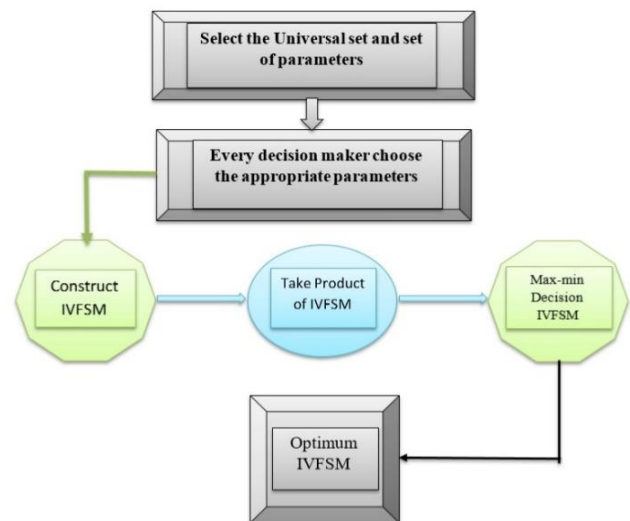

Figure 1: Graphical Model for IVFSMmDM

Application IVFSMMDM Method for Medical Diagnoses

Let P = $\{P_1, P_2, P_3, P_4\}$ be a set of patients suffering from different diseases and E = $\{j_1, j_2, j_3, j_4\}$ be a set of symptoms for the selection of patient who must need diagnoses as soon as possible represents fever, flu, headache and chest infection respectively. The medical supredent of hospital hire a medical board for the selection of patient who need treatment on urgent bases which consist on two members represent as follows C = $\{M_1, M_2\}$.

Step 1: Both board members choose the parameters for selection of faculty member

$M_1 = \{j_2, j_3, j_4\}$ and $M_2 = \{j_1, j_2, j_4\}$

Step 2: We construct the IVFSMs of both medical board members according to their selected parameters.

$$M_1 = [m_{ij}] = \begin{bmatrix} [0.0, 0.0] & [0.8, 0.9] & [0.9, 1.0] & [0.7, 0.8] \\ [0.0, 0.0] & [0.5, 0.6] & [0.3, 0.4] & [0.4, 0.5] \\ [0.0, 0.0] & [0.9, 1.0] & [0.7, 0.8] & [0.8, 0.9] \\ [0.0, 0.0] & [0.7, 0.8] & [0.6, 0.7] & [0.8, 0.9] \end{bmatrix} \quad M_2 = [n_{ik}] = \begin{bmatrix} [0.5, 0.6] & [0.9\ 1.0] & [0.0, 0.0] & [0.6, 0.7] \\ [0.8, 0.9] & [0.4, 0.5] & [0.0, 0.0] & [0.8, 0.9] \\ [0.3, 0.4] & [0.6, 0.7] & [0.0, 0.0] & [0.4, 0.5] \\ [0.6, 0.7] & [0.9, 1.0] & [0.0, 0.0] & [0.9, 1.0] \end{bmatrix}$$

Step 3: Take And-product of both developed IVFSMs

$$[m_{ij}] \wedge [n_{ik}] = \begin{bmatrix} [0.0, 0.0] & [0.8, 0.9] & [0.9, 1.0] & [0.7, 0.8] \\ [0.0, 0.0] & [0.5, 0.6] & [0.3, 0.4] & [0.4, 0.5] \\ [0.0, 0.0] & [0.9, 1.0] & [0.7, 0.8] & [0.8, 0.9] \\ [0.0, 0.0] & [0.7, 0.8] & [0.6, 0.7] & [0.8, 0.9] \end{bmatrix} \wedge \begin{bmatrix} [0.5, 0.6] & [0.9\ 1.0] & [0.0, 0.0] & [0.6, 0.7] \\ [0.8, 0.9] & [0.4, 0.5] & [0.0, 0.0] & [0.8, 0.9] \\ [0.3, 0.4] & [0.6, 0.7] & [0.0, 0.0] & [0.4, 0.5] \\ [0.6, 0.7] & [0.9, 1.0] & [0.0, 0.0] & [0.9, 1.0] \end{bmatrix}$$

$$[m_{ij}] \wedge [n_{ik}] = \begin{bmatrix} [.0,.0] & [.0,.0] & [.0,.0] & [.0,.0] & [.5,.6] & [.8,.9] & [.0,.0] & [.6,.7] & [.5,.6] & [.9,1] & [.0,.0] & [.6,.7] & [.5,.6] & [.7,.8] & [.0,.0] & [.6,.7] \\ [.0,.0] & [.0,.0] & [.0,.0] & [.0,.0] & [.5,.6] & [.4,.5] & [.0,.0] & [.5,.6] & [.3,.4] & [.3,.4] & [.0,.0] & [.3,.4] & [.4,.5] & [.4,.5] & [.0,.0] & [.4,.5] \\ [.0,.0] & [.0,.0] & [.0,.0] & [.0,.0] & [.3,.4] & [.6,.7] & [.0,.0] & [.4,.5] & [.3,.4] & [.6,.7] & [.0,.0] & [.4,.5] & [.3,.4] & [.6,.7] & [.0,.0] & [.4,.5] \\ [.0,.0] & [.0,.0] & [.0,.0] & [.0,.0] & [.6,.7] & [.7,.8] & [.0,.0] & [.7,.8] & [.6,.7] & [.6,.7] & [.0,.0] & [.6,.7] & [.6,.7] & [.8,.9] & [.0,.0] & [.8,.9] \end{bmatrix}$$

Step 4: Calculate $Mm([m_{ij}] \wedge [n_{ik}]) = d_{i1}$ where $i = 1, 2, 3, 4$. First, we find d_{11}, for this

$d_{11} = \max\{t_{1k}\} = \max\{t_{11}, t_{12}, t_{13}, t_{14}\}$, to find d_{11} we need to find t_{1k} for every $k = 1, 2, 3, 4$.

If $k = 1$ and $n = 4$, t_{11} is $I_1 = \{P: c_{ip} \neq 0, 0 < P \leq 4\}$, then

$t_{11} = [0.0, 0.0]$

If $k = 2$ and $n = 4$, t_{12} is $I_2 = \{P: c_{ip} \neq 0, 4 < P \leq 8\}$, then

$t_{12} = \min\{c_{15}, c_{16}, c_{18}\} = \min\{[0.5, 0.6], [0.8, 0.9], [0.6, 0.7]\} = [0.5, 0.6]$

If $k = 3$ and $n = 4$, t_{13} is $I_3 = \{P: c_{ip} \neq 0, 8 < P \leq 12\}$, then

$t_{13} = \min\{c_{19}, c_{110}, c_{112}\} = \min\{[0.5, 0.6], [0.9, 1.0], [0.6, 0.7]\} = [0.5, 0.6]$

If $k = 4$ and $n = 4$, t_{14} is $I_4 = \{P: c_{ip} \neq 0, 12 < P \leq 16\}$, then

$t_{14} = \min\{c_{113}, c_{114}, c_{116}\} = \min\{[0.5, 0.6], [0.7, 0.8], [0.6, 0.7]\} = [0.5, 0.6]$

So $d_{11} = \max\{t_{1k}\} = \max\{t_{11}, t_{12}, t_{13}, t_{14}\} = \max\{[0.0, 0.0], [0.5, 0.6], [0.5, 0.6], [0.5, 0.6]\}$ $d_{11} = [0.5, 0.6]$

Similarly, we can find d_{21}, d_{31}, d_{41}

$d_{21} = [0.4, 0.5]$

$d_{31} = [0.3, 0.4]$

$d_{41} = [0.6, 0.7]$

We get IVFSM by using IVFSMmDM as follows

$$Mm([m_{ij}] \wedge [n_{ik}]) = d_{i1} = \begin{bmatrix} d_{11} \\ d_{21} \\ d_{31} \\ d_{41} \end{bmatrix} = \begin{bmatrix} [0.5, 0.6] \\ [0.4, 0.5] \\ [0.3, 0.4] \\ [0.6, 0.7] \end{bmatrix}$$

According to the above matrix, we get optimum IVFSM on P.

Opt $Mm([m_{ij}] \wedge [n_{ik}])$ (P) = $\{[0.5, 0.6]/ P_1, [0.4, 0.5]/ P_2, [0.3, 0.4]/ P_3, [0.6, 0.7]/ P_4\}$. So P_4 is a patient who needs treatment on urgent bases.

CONCLUSION

The concepts of fuzzy sets, soft sets, fuzzy soft sets, and interval-valued fuzzy soft sets are presented in this work with some properties and operations. By using the IVFSMmDM function we develop a graphical model known as the IVFSMmDM method. Finally, we use the proposed model for the selection of patients who need medical treatment on urgent bases according to given symptoms.

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