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Application of Intuitionistic Fuzzy Soft Matrices for Disease Diagnosis

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Abstract: Decision Making is the best procedure to choose a superlative alternative from all feasible alternatives. Almost in all other issues, the overall number of criteria because decision making the general alternatives is pervasive. Nowadays decision making is a critical problem in every field of life. In some cases, we must deliberate membership unbiassed as the non- membership values for the suitable representation of an object in uncertain and indeterminate conditions that could not be handled by fuzzy sets nor by interval-valued fuzzy sets. To overcome these difficulties the notion of Intuitionistic fuzzy sets has been presented. In this paper, we study some basic concepts of fuzzy sets, soft sets, fuzzy soft sets, intuitionistic fuzzy sets, intuitionistic soft sets, intuitionistic fuzzy soft sets (IFSS), and intuitionistic fuzzy soft matrices (IFSM). Finally, in this research, we use the IFSM for disease diagnoses in patients who suffer from different diseases such as stomach ulcer and typhoid by using hypothetical data we conclude that patient p_2 suffering stomach ulcer p_2 and p_3 patients suffering from typhoid.

Keywords: Fuzzy Set, Fuzzy Soft Set, Intuitionistic Soft Set, Intuitionistic Fuzzy Soft Set, Intuitionistic Fuzzy Soft Matrices

1. Introduction

Nowadays in every field of life, we face some uncertainties such as economics business, medical science, social science, etc. To handle these uncertainties different theories are presented like probability theory, fuzzy set, neutrosophic set, intuitionistic fuzzy set, rough set, etc. In 1999, Molodstov claimed that these theories have their challenges to overcome those challenges he proposed a new theory known as the soft set (SS) theory [1]. Many researchers used SS in decision making, medical diagnoses [2, 3]. In 2001, Maji et al. developed a new theory which is known as the fuzzy soft set (FSS) theory by combining the fuzzy set and SS [4]. They also proposed some basic operations and properties such as intersection, union, complement, and De Morgan laws. They also reviewed the SS theory which was given by (Molodtsov 1999) and used this theory for decision making in 2002 [5]. Maji et al. introduced different types of SS with examples and defined some operations such as And-operation, Or-operation, union, intersection, complement, etc on SS [6].

Some limitations were faced in the work of (Maji et al. 2002) which were attensonoid by constructing a new definition of parameterization reduction and applied this definition in decision making. Ali et al. worked on SS theory and proposed some new definitions on SS such as restricted union, restricted intersection, etc, they also proved that the De-Morgan laws are held according to new definitions of SS theory [7]. A further contribution of Ahmad and Kharal in the properties of FSS which were defined in the work of [4, 9, 10] with illustrations and counter illustrations and improved their work, they also extended the concept of FSS by defining some new definition such as the union of arbitrary FSS, the intersection of arbitrary FSS and proved De-Morgan inclusion on FSS [8]. Zulqarnain et al. used trapezoidal fuzzy numbers for disease identification [11]. The authors discussed FSS and constructed the fuzzy soft matrices with different properties and operations and used for decision making [12, 13]. Selim Eraslan studied the TOPSIS method on SS theory and used the newly developed method for decision making problems [14]. Zulqarnain et al also used the TOPSIS method for decision making by using SS [15-17]. The author's used the TOPSIS method for the prediction of diabetes patients in humans [18]. Many researchers studied the TOPSIS method on fuzzy sets and developed a fuzzy TOPSIS method and used this method for supplier selection, decision making, and medical diagnoses [19–22].

In 1984, Atanassov introduced intuitionistic fuzzy sets (IFS) with some basic operations and properties [23]. Many researchers studied IFS and used for decision making in different fields of life [24, 25]. Matrices play a very important role to solve our daily life problems such as decision making, medical and engineering, etc. but sometimes the classical matrices fail to resolve uncertain problems, to overcome these problems Chetia and Das developed the concept of IFSM with different operations and properties [26]. The authors developed a decision-making method known as the interval-valued fuzzy soft max-min decision-making method and used the interval-valued fuzzy soft matrices for decision making and medical diagnoses [27-29]. They also compared the results obtained by fuzzy soft matrices and interval-valued fuzzy soft matrices [30]. Deli and Cagman constructed the Intuitionistic fuzzy parameterized soft sets with properties and developed different operations, finally, they used Intuitionistic fuzzy parameterized soft sets for decision making. The author's discussed IFS with the TOPSIS method and used the Intuitionistic fuzzy TOPSIS method for decision making and medical diagnoses [31, 32]. Dayan and Zulqarnain used the generalized fuzzy soft set for ranking of different students, they also developed generalized interval-valued fuzzy soft matrices [35, 36].

In this article, we discuss some basic definitions of fuzzy sets, SS, FSS, IFS, IFSS, and IFSM with basic operation. IFSM is used for disease diagnoses in those patients who suffer from different diseases by using hypothetical data.

2. Preliminaries

In this sequel, we study some basic concepts of fuzzy set, SS, FSS, and IFSS.

Definition 2.1 [33]

If we identify a set A in X by its membership function μ_A: X → [0, 1], then a set A is called a fuzzy set.

Definition 2.2 [1]

Suppose U be a universe set and E be a set of values. Suppose P (U) indicates the power set of Us A ≤ E. A set (F_A, E) known as SS Under U in which F_A is processed by F_A: E → P (U) such as F_A (e)=φ if e ∉ A.

Definition 2.3 [4]

χ_A be an FSS over U which is defined by a function μ_A which is represented by a mapping

"μ_A: E → F (U) such that μ_A (t)=if t ∉ A.

Where μ_A is called the fuzzy approximate function of FSS, and the value of μ_A (t) is a set called the element of FSS for all t ∈ E. This FSS can be represented in ordered pair form such as

$$\chi_A=\{(t, \mu_A(t)): t \in E, \mu_A(t) \in F(U)\}. \quad (1)$$

Example 2.4

U and E are the universe and set of attributes respectively.

A={t_1, t_2, t_3} is any subset of E than

$\mu_A(t_1)=\{0.5/P_1, 0.3/P_4\}$, $\mu_A(t_2)=\{0.2/P_3, 0.6/P_4, 0.3/P_5\}$ and $\mu_A(t_3)$=U, than SS F_A is written as

$$F_A=\{(t_1, \{0.5/P_1, 0.3/P_4\}), (t_2, \{0.2/P_3, 0.6/P_4, 0.3/P_5\}), (t_3, U)\}$$

Note that FSS over U is denoted by FS (U).

Definition 2.5 [4]

Let χ_A, χ_B ∈ FS (U). Than χ_A is called a fuzzy soft subset of χ_B, if μ_A(t) is a subset of μ_B(t) for all t ∈ E., it is denoted as $\chi_A \subseteq \chi_B$.

Example 2.6

U and E are the universe and set of attributes respectively.

A={t_1, t_2, t_3} is any subset of E than

$\mu_A(t_1)=\{0.5/P_1, 0.3/P_4\}$, $\mu_A(t_2)=\{0.2/P_3, 0.6/P_4, 0.3/P_5\}$ and $\mu_A(t_3)$=U, than SS F_A is written as

$$F_A=\{(t_1, \{0.5/P_1, 0.3/P_4\}), (t_2, \{0.2/P_3, 0.6/P_4, 0.3/P_5\}), (t_3, U)\}$$

Note that FSS over U is denoted by FS (U).

Definition 2.7 [12]

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

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

$$a_{ij} = \begin{cases} \mu_j\left(y_j\right) if\ y_j \in A \\ 0\ if\ y_j \notin A \end{cases} \quad (2)$$

Definition 2.8 [23]

IFS A in a finite set X can be written as

$A = \{x, \mu_a(x), v_A(x): x\epsilon X\}$, where

$\mu_a(x), v_A(x): X \rightarrow$ [0, 1] are membership and non-membership functions respectively, such that

$$0 \leq \mu_a(x) + v_A(x) \leq 1.$$

Definition 2.9 [34]

Suppose S be a universal set and N be a collection of parameters suppose ≤ N then a set (F,) is called IFSS over S. Where F is a mapping from F: →Î where Î is the collection of all intuitionistic soft set.

Definition 2.10 [26]

Suppose S and N are universal set and set of parameters respectively and ≤ N and (F_A, N) be an IFSS over S. Than any subset of S × N is defined as follows $R_A = \{(s, n) \in F_A(n)\}$. The membership function and non-membership function of this relation can be written as follows

μ_{R_A}: S × N → [0, 1] and R_A: S × N → [0, 1], where μ_{R_A}(s, n) ∈ [0, 1] and R_A(s, n) ∈ [0, 1].

If (μ_{ij}, μ_{ij})=$\mu_{R_A}(s_i, n_j)$, $R_A(s_i, n_j)$, then it can be written in matrix form as follows

$$\left[\mu_{ij}, \mu_{ij}\right]_{m\times n} = \begin{bmatrix} (\mu_{11}, \mu_{11}) & (\mu_{12}, \mu_{12}) & \dots & (\mu_{1n}, \mu_{1n}) \\ (\mu_{21}, \mu_{21}) & (\mu_{22}, \mu_{22}) & \dots & (\mu_{2n}, \mu_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ (\mu_{m1}, \mu_{m1}) & (\mu_{m2}, \mu_{m2}) & \dots & (\mu_{mn}, \mu_{mn}) \end{bmatrix} \quad (3)$$

Definition 2.11 [26]

Assume S=$[a_{ij}]_{m\times n}$ and T=$[b_{ij}]_{n\times p}$ are two IFSM, then their product is defined as follows

S ∗ T=$[c_{ik}]_{m\times p}$={max-min (μ_{S_i}, μ_{T_j}), min-max (S_i, T_j)} for all i, j.

3. Effect of Stomach Ulcer and Typhoid in Medical Analysis

In this section, we study the different climates and environmental features causing several diseases. For the diagnosis of these diseases, several antibiotics and drugs are available. The stomach ulcer is caused by food poisoning and affects the different organs of our body such as the digestive system. The stomach plays a vital role in the second phase of the digestive system, it performs a chemical breakdown in humans and other animals due to enzymes and hydrochloric acid. Typhoid is a bacterial infection and caused by Salmonella typhi bacteria it is very dangerous for children especially in developing countries and affects almost 26 million peoples every year. In this research, we used intuitionistic fuzzy soft matrices for diagnoses of those people who are suffering from stomach ulcers and typhoid.

IFSM in Medical Analysis

Assume S be a set of symptoms of stomach ulcer and typhoid, D is the side effects of diseases associated to these signs, and P be a set of patients characterized the set of signs presenting in the set S, we can get an FSS (F_A, D) over S. Relation matrix A gets from the FSS ($F_{A,}$ D). we assign the matrix as symptoms diseases matrix. The complement of above FSS $(F_A, \mathrm{D})^c$ is also gives a relation matrix A^c which is known as no symptoms disease matrix. Similarly, we develop another FSS (F_B, S) over P which provides us, patients, disease signs relation matrix represented by B and its complement $(F_B, \mathrm{S})^c$ gives the non symptoms relation matrix B^c. Now we get two new relation matrices $M_1 = B \cdot A$ and $M_2 = B \cdot A^c$ known as symptoms patient disease and patient symptoms nondisease matrix appropriately. In the same way, we get the relation matrix $M_3 = B^c \cdot A$ and $M_4 = B^c \cdot A^c$ known the patient non-symptoms disease matrix and patient non-symptoms nondisease matrix respectively. Now

$$M_1 = B \cdot A, M_2 = B \cdot A^c \quad (4)$$

$$M_3 = B^c \cdot A, M_4 = B^c \cdot A^c \quad (5)$$

and use definition membership value

ZV (M_1), ZV (M_2), ZV (M_3), ZV (M_4)"

We compute the diagnosis score (S_{M_1}) and (S_{M_2}) for and against the diseases appropriately like

(S_{M_1})=$[\rho(M_1)\mathrm{kl}]_{p\times q}$, where $\rho(M_1)\mathrm{kl} = \delta(M_1)\mathrm{kl} - \delta(M_3)\mathrm{kl}$

an(

(S_{M_2})=$[\rho(M_2)\mathrm{kl}]_{p\times q}$, where $\rho(M_2)\mathrm{kl} = \delta(M_2)\mathrm{kl} - \delta(M_4)\mathrm{kl}$

Then if max(S_{M_1} (p_i, d_j) - S_{M_2} (p_i, d_k) appear for exactly (p_i, d_k) only.

Now we would be able to accept that diagnosis hypothesis for patient P_i is the disease d_k. Then in this way, there is a connection in which the hypothesis is repeated for patient p_i by assuming the symptoms.

4. Application of IFSM in Medical Diagnoses

Suppose $P = \{P_1, P_2, P_3\}$ are three patients who are suffering from a disease whose symptoms are fever, flu, the digestive problem represented as $S = \{s_1, s_2, s_3\}$ and the possible diseases related to the above symptoms may be stomach ulcer and typhoid represented by D=$\{d_1, d_2\}$. Let the FSS (F, D) over S, where is a mapping such that F: D → F (S), gives an approximation result of two disease and their symptoms.

(F_A, D)=$\{F_A(d_1)$=$\{(n_1$, 0.7, 0.2), (n_2, 0.4, 0.5),(n_3, 0.5, 0.3)}, $\{F_A(d_2)$=$\{(n_1$, 0.5, 0.3), (n_2, 0.3, 0.6),(n_3, 0.6, 0.2)}}

The complement of (F_A, D) is

$(F_A, D)^c$=$\{F_A(d_1)^c$=$\{(n_1$, 0.8, 0.7), (n_2, 0.5, 0.4),(n_3, 0.7, 0.5)}, $\{F_A(d_2)^c$=$\{(n_1$, 0.7, 0.5), (n_2, 0.4, 0.3), (n_3, 0.8, 0.6)}}

We are representing the FSS (F_A, D) and its complement $(F_A, D)^c$ in matrix form can be written as follows

$$A = \begin{array}{c} n_1 \\ n_2 \\ n_3 \end{array} \begin{bmatrix} (0.7, 0.2) & (0.5, 0.3) \\ (0.4, 0.5) & (0.3, 0.6) \\ (0.5, 0.3) & (0.6, 0.2) \end{bmatrix} \text{ and } A^c = \begin{array}{c} n_1 \\ n_2 \\ n_3 \end{array} \begin{bmatrix} (0.8, 0.7) & (0.7, 0.5) \\ (0.5, 0.4) & (0.4, 0.3) \\ (0.7, 0.5) & (0.8, 0.6) \end{bmatrix}$$

Let P=$\{P_1, P_2, P_3\}$ be a set of patients and $S = \{s_1, s_2, s_3\}$ be a set of symptoms. Than (F_B, S), where F_B is a mapping such that F_B: S → F (P) gives the collection of patients and their symptoms.

(F_B, S)=$\{F_B$ (n_1)=$\{(p_1$, 0.6, 0.3),(p_2, 0.7, 0.2),(p_3, 0.5, 0.4)$\}$, F_B (n_2)=$\{(p_1$, 0.3, 0.6), (p_2, 0.4, 0.5), (p_3, 0.2, 0.7)$\}$, F_B (n_3)=$\{(p_1$, 0.5, 0.4), (p_2, 0.6, 0.2), (p_3, 0.6, 0.3)$\}\}$

The complement of (F_B, S) is

$(F_B, S)^c$=$\{F_B$ $(n_1)^c$=$\{(p_1$, 0.7, 0.6),(p_2, 0.8, 0.7),(p_3, 0.6, 0.5)$\}$, F_B (n_2)=$\{(p_1$, 0.4, 0.3), (p_2, 0.5, 0.4), (p_3, 0.3, 0.2)$\}$, F_B (n_3)=$\{(p_1$, 0.6, 0.5), (p_2, 0.8, 0.6), (p_3, 0.7, 0.6)$\}\}$

$$B = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.6, 0.3) & (0.3, 0.6) & (0.5, 0.4) \\ (0.7, 0.2) & (0.4, 0.5) & (0.6, 0.2) \\ (0.5, 0.4) & (0.2, 0.7) & (0.6, 0.3) \end{bmatrix} \text{ and } B^c = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.7, 0.6) & (0.4, 0.3) & (0.6, 0.5) \\ (0.8, 0.7) & (0.5, 0.4) & (0.8, 0.6) \\ (0.6, 0.5) & (0.3, 0.2) & (0.7, 0.6) \end{bmatrix}$$

Where B and B^c represents the symptoms and non-symptoms patient matrix.
Thus we can get

$$M_1 = B \cdot A = \begin{bmatrix} (0.6, 0.3) & (0.3, 0.6) & (0.5, 0.4) \\ (0.7, 0.2) & (0.4, 0.5) & (0.6, 0.2) \\ (0.5, 0.4) & (0.2, 0.7) & (0.6, 0.3) \end{bmatrix} \begin{bmatrix} (0.7, 0.2) & (0.5, 0.3) \\ (0.4, 0.5) & (0.3, 0.6) \\ (0.5, 0.3) & (0.6, 0.2) \end{bmatrix}$$

By using definition 1.11 we get

$$M_1 = B \cdot A = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.6, 0.3) & (0.5, 0.3) \\ (0.7, 0.2) & (0.6, 0.2) \\ (0.5, 0.3) & (0.6, 0.3) \end{bmatrix}$$

Similarly, we can get

$$M_2 = B \cdot A^c = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.6, 0.5) & (0.6, 0.5) \\ (0.7, 0.5) & (0.7, 0.5) \\ (0.6, 0.5) & (0.6, 0.5) \end{bmatrix}$$

$$M_3 = B^c \cdot A = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.7, 0.5) & (0.6, 0.5) \\ (0.7, 0.5) & (0.6, 0.6) \\ (0.6, 0.5) & (0.6, 0.5) \end{bmatrix}$$

$$M_4 = B^c \cdot A^c = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.7, 0.4) & (0.7, 0.3) \\ (0.8, 0.4) & (0.8, 0.4) \\ (0.7, 0.4) & (0.7, 0.3) \end{bmatrix}$$

The membership of M_1, M_2, M_3 and M_4 is ZV(M_1), ZV(M_2), ZV(M_3), ZV(M_4) respectively

$$\text{ZV}(M_1) = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.6 - 0.3) & (0.5 - 0.3) \\ (0.7 - 0.2) & (0.6 - 0.2) \\ (0.5 - 0.3) & (0.6 - 0.3) \end{bmatrix} = \begin{bmatrix} 0.3 & 0.2 \\ 0.5 & 0.4 \\ 0.2 & 0.3 \end{bmatrix}$$

$$\text{ZV}(M_2) = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.6 - 0.5) & (0.6 - 0.5) \\ (0.7 - 0.5) & (0.7 - 0.5) \\ (0.6 - 0.5) & (0.6 - 0.5) \end{bmatrix} = \begin{bmatrix} 0.1 & 0.1 \\ 0.2 & 0.2 \\ 0.1 & 0.1 \end{bmatrix}$$

$$\text{ZV}(M_3) = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.7 - 0.5) & (0.6 - 0.5) \\ (0.7 - 0.5) & (0.6 - 0.6) \\ (0.6 - 0.5) & (0.6 - 0.5) \end{bmatrix} = \begin{bmatrix} 0.2 & 0.1 \\ 0.2 & 0.0 \\ 0.1 & 0.1 \end{bmatrix}$$

$$\text{ZV}(M_4) = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array} \begin{bmatrix} (0.7 - 0.4) & (0.7 - 0.3) \\ (0.8 - 0.4) & (0.8 - 0.4) \\ (0.7 - 0.4) & (0.7 - 0.3) \end{bmatrix} = \begin{bmatrix} 0.3 & 0.4 \\ 0.4 & 0.4 \\ 0.3 & 0.4 \end{bmatrix}$$

$$S_{M_1}=\mathrm{ZV}(M_1) - \mathrm{ZV}(M_3)=\begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array}\begin{bmatrix} 0.3-0.2 & 0.2-0.1 \\ 0.5-0.2 & 0.4-0.0 \\ 0.2-0.1 & 0.3-0.1 \end{bmatrix} = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array}\begin{bmatrix} 0.1 & 0.1 \\ 0.3 & 0.4 \\ 0.1 & 0.2 \end{bmatrix}$$

$$S_{M_2}=\mathrm{ZV}(M_2) - \mathrm{ZV}(M_4)=\begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array}\begin{bmatrix} 0.1-0.3 & 0.1-0.4 \\ 0.2-0.4 & 0.2-0.4 \\ 0.1-0.3 & 0.1-0.4 \end{bmatrix} = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array}\begin{bmatrix} -0.2 & -0.3 \\ -0.2 & -0.2 \\ -0.2 & -0.3 \end{bmatrix}$$

$$S_{KM} = S_{M_1} - S_{M_2} = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array}\begin{bmatrix} 0.1-(-0.2) & 0.1-(-0.3) \\ 0.3-(-0.2) & 0.4-(-0.2) \\ 0.1-(-0.2) & 0.2-(-0.3) \end{bmatrix} = \begin{array}{c} p_1 \\ p_2 \\ p_3 \end{array}\begin{bmatrix} 0.3 & 0.4 \\ 0.5 & 0.6 \\ 0.3 & 0.5 \end{bmatrix}$$

Table 1. *Ranking of Patients with disease.*

S_{KM}	d_1	d_2
p_1	0.3	0.4
p_2	0.7	0.6
p_3	0.2	0.4

5. Conclusion

In this article, we discuss some basic definitions of fuzzy sets, soft set, fuzzy soft set, Intuitionistic fuzzy set, Intuitionistic fuzzy soft set, and IFSM with some basic operation. We use the IFSM for disease diagnoses in patients who suffer from different diseases such as stomach ulcers and typhoid by using hypothetical data. We consider three patients who are suffering from a disease stomach ulcer or typhoid whose symptoms are fever, flu, the digestive problem. Finally, by using intuitionistic fuzzy soft matrix we conclude that patient p_2 suffering stomach ulcer p_1 and p_3 patients suffering from disease typhoid. In the future, we extend this technique for decision making in the neutrosophic set, interval neutrosophic set, neutrosophic soft set, and interval neutrosophic soft set, etc.

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