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Application of Generalized Triangular Fuzzy Soft Sets in Medical Diagnosis

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ABSTRACT*: *Fuzzy soft set which is the extension of soft set has become the most fruitful and interesting area of medicine and decision making problems. In this article, inspiring the concept of fuzzy soft set, we introduce the notion of generalized triangular fuzzy soft set, where the parameter set is generalized by a triangular fuzzy set. Finally, an application of generalized triangular fuzzy soft set in medical diagnosis problem is exhibited with a hypothetical case study.

Keywords: Fuzzy set; Soft set; Fuzzy soft set; Triangular fuzzy number; Triangular fuzzy soft set; Generalized triangular fuzzy soft set.

1. INTRODUCTION

In our real life, we often face various problems with uncertainties in which precise decision is very essential. But most of our traditional mathematical tools cannot solve these problems. For solving such problems, there are some theories such as theory of fuzzy sets [1], theory of rough sets [2], theory of vague sets [3], theory of intuitionistic fuzzy sets [4, 5], theory of interval mathematics [5, 6], and so on. However, all these theories have their intrinsic limitations as pointed out in [7]. To overcome these limitations in 1999, Molodtsov [7] initiated the idea of soft sets, which can be seen as an innovative mathematical tool for dealing with uncertainties. Later based on the concept of Molodtsov, some authors developed its theoretical aspects and applied them in different fields of science and engineering. Also the study of combined models involving soft sets with other mathematical structures is rising as a dynamic research topic of soft set theory. Roy and Maji [8] considered the concept of a fuzzy soft set and provided some of its properties. Later a host of

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researcher studied and applied the concept of fuzzy soft set in Decision making Problem [9-19], Image processing [20], Forecasting [21, 22], Medical diagnosis [23-27] . In above all the studies of fuzzy sets and the related topics the researchers are considered fuzzy membership values for the elements of the universal set, but fuzzyfing parameters may be play important role in case of decision making. To overcome these facts Zhang et al. [28] studied the concept of generalized trapezoidal fuzzy soft set and applied it in medical diagnosis problem. In this article, we developed the concept of generalized triangular fuzzy soft set. Then we have applied this generalized triangular fuzzy soft set in medical diagnosis problem with a theoretical case study. The article is organized as follows: In section 2, we describe some definitions which are essential to rest of the paper. In section 3, the generalized triangular fuzzy soft sets are described. In section 4, an application is illustrated by using the generalized triangular fuzzy soft sets. Finally, concluding remarks are given.

2. PRELIMINARIES

In this section, we recall some useful definitions which will be helpful in further pursuit of this study.

Definition 2.1: [1] Let X be a non-empty set and A be subset of X, then the characteristic function of A is defined as follows:

$$\mu(x) = \begin{cases} 1 & if\ x \in A \\ 0 & if\ x \notin A \end{cases}$$

That is, a classical set A can be defined as $\mu: A \to \{0,1\}$ where as a fuzzy set can be defined as $\mu: A \to [0,1]$, the usual interval of real number, where μ denote the membership function.We denote by I^X the set of all fuzzy sets of X.

Definition 2.2: [7] Suppose that U is an initial universe set and E is a set of parameters, let $P(U)$ denote the power set of U. A pair (F, E) is called a soft set of U where F is a mapping given by $F: E \to P(U)$. Clearly a soft set is a mapping from parameters to $P(U)$ and it is not a set, but a parameterized family of subsets of the universe.

Definition 2.3: [8] Let U be an initial universe set and E is a set of parameters. A pair (F, E) is called a fuzzy soft set of U where F is a mapping given by $F: E \to I^U$, where I^U denotes the collection of all fuzzy sets of U.

Definition 2.4: [29] A triangular fuzzy number $\tilde{a}$ can be defined as (a_1, a_2, a_3) shown in figure 1 which has the membership function $\mu_{\tilde{a}}(x)$ as follows:

$$\mu_{\tilde{a}}(x) = \begin{cases} 0 & , \ x < a_1 \\ \frac{x-a_1}{a_2-a_1} & , \ a_1 \leq x \leq a_2 \\ \frac{a_3-x}{a_3-a_2} & , \ a_2 \leq x \leq a_3 \\ 0 & , \ x > a_3 \end{cases}$$

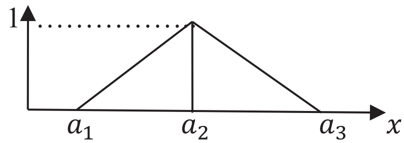

Figure 01: Triangular fuzzy number $\tilde{a}$.

For given two triangular fuzzy numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$, we define the maximum and minimum operations are as follows:

(i) $\tilde{a} \vee \tilde{b} = (a_1 \vee b_1, a_2 \vee b_2, a_3 \vee b_3)$;
(ii) $\tilde{a} \wedge \tilde{b} = (a_1 \wedge b_1, a_2 \wedge b_2, a_3 \wedge b_3)$.

Where $\vee$ and $\wedge$ denote maximum and minimum operators respectively.

Next we present a defuzzification technique of triangular fuzzy number. Take a triangular fuzzy number (a_1, a_2, a_3) as shown in the figure 1. Then the defuzzification value t of the fuzzy number is measured from the figure 1 as follows:

$$(t - a_2)(1) + \frac{1}{2}(a_2 - a_1)(1) = (a_2 - t)(1) + \frac{1}{2}(a_3 - a_2)(1)$$

$$\Rightarrow (t - a_2) + \frac{1}{2}(a_2 - a_1) = (a_2 - t) + \frac{1}{2}(a_3 - a_2)$$

$$\Rightarrow (t - a_2) - (a_2 - t) = \frac{1}{2}(a_3 - a_2) - \frac{1}{2}(a_2 - a_1)$$

$$\Rightarrow 2t = \frac{a_3 - a_2 - a_2 + a_1}{2} + a_2 + a_2$$

$$\Rightarrow 2t = \frac{a_3 + a_2 + a_2 + a_1}{2}$$

$$\Rightarrow t = \frac{a_1 + a_2 + a_2 + a_3}{4} \quad (1)$$

Definition 2.5: [14] A set which is consisted by triangular fuzzy numbers is called triangular fuzzy set it is denoted by (TFS). The membership function of a triangular fuzzy set can capture the vagueness of those linguistic terms as in figure 2. For example the linguistic term "medium high" can be represented by a triangular fuzzy set as $(0.5, 0.6, 0.7)$

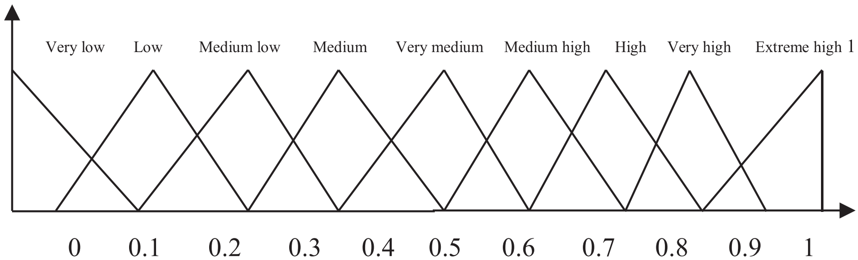

Figure 02: Linguistic terms for ratings.

and membership function is

$$\mu_{mediumhigh}(x) = \begin{cases} 0 & , \ x < 0.5 \\ \frac{x-0.5}{0.6-0.5} & , \ 0.5 \le x \le 0.6 \\ \frac{0.7-x}{0.7-0.6} & , \ 0.6 \le x \le 0.7 \\ 0 & , \ x > 0.7 \end{cases}$$

Definition 2.6: [14] Let $TFS(U)$ be the set of all triangular fuzzy sets in U. A pair (F, A) is called a triangular fuzzy soft set of U where F is a mapping given by $F: E \to TFS(U)$.

3. GENERALIZED TRIANGULAR FUZZY SOFT SETS

In this subsection, we generalize the idea of triangular fuzzy soft set by introducing the membership degree of parameters named as generalized triangular fuzzy soft set. We also developed some definitions regarding this generalized triangular fuzzy soft set.

Definition 3.1: Suppose that U is an initial universe set and E is a set of parameters. The pair (U, E) is called a soft universe. Suppose $F: E \to TFS(U)$ and f is a triangular fuzzy set of E, i.e., $f: E \to TFS$. We say that (F_f, E) is a generalized triangular fuzzy soft set of (U, E) if and only if F_f is a mapping defined by

$$F_f: E \to TFS(U) \times TFS,$$

where, $F_f(e) = (F(e), f(e))$, such that for all $e \in E, F(e) \in TFS(U)$ and $f(e) \in TFS$.

Here for each parameter e_i, $F_f(e_i) = (F(e_i), f(e_i))$ is not a triangular fuzzy set of U, but also the triangular fuzzy set E.

Also a generalized triangular fuzzy soft set (F_f, E) can be represented as a matrix such as:

$A_{m\times n} = [a_{ij}]$ $(i = 1, 2 \cdots\cdots m, j = 1, 2, \cdots\cdots n)$, where

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

Example 01: Suppose that $U = \{s_1, s_2, s_3, s_4\}$ is a set of cricket players and which may be characterized by a set of parameters $E = \{e_1, e_2, e_3\}$, where e_1, e_2 and e_3 stand for batting, bowling and fielding respectively.The linguistic variables for each player under these parameters are given in table 1.

Table 01: The ratings of four players under these parameters.

U	Batting (e_1)	Bowling(e_2)	Fielding(e_3)
s_1	Medium	Very medium	Very medium
s_2	Medium low	Very high	Medium
s_3	Low	Medium	Medium low
s_4	Very high	Low	Medium
f	High	Medium high	Medium

The generalized triangular fuzzy soft set (F_f, E) of the universe (U, E) through the rule of conversion between linguistic variables and numerical variables is

$$(F_f, E) = \left\{ \begin{array}{l} F_f(e_1) = \left(\left\{ \frac{s_1}{(0.3,0.4,0.5)}, \frac{s_2}{(0.2,0.3,0.4)}, \frac{s_3}{(0.1,0.2,0.3)}, \frac{s_4}{(0.7,0.8,0.9)} \right\}, (0.6, 0.7, 0.8) \right), \\ F_f(e_2) = \left(\left\{ \frac{s_1}{(0.4,0.5,0.6)}, \frac{s_2}{(0.7,0.8,0.9)}, \frac{s_3}{(0.3,0.4,0.5)}, \frac{s_4}{(0.1,0.2,0.3)} \right\}, (0.5, 0.6, 0.7) \right), \\ F_f(e_3) = \left(\left\{ \frac{s_1}{(0.4,0.5,0.6)}, \frac{s_2}{(0.3,0.4,0.5)}, \frac{s_3}{(0.2,0.3,0.4)}, \frac{s_4}{(0.3,0.4,0.5)} \right\}, (0.3, 0.4, 0.5) \right) \end{array} \right\}$$

.

This generalized triangular fuzzy soft set (F_f, E) can also be represented as matrix

$$A_{3\times 5} = \begin{bmatrix} 0.3, 0.4, 0.5 & 0.2, 0.3, 0.4 & 0.1, 0.2, 0.3 & 0.7, 0.8, 0.9 & 0.6, 0.7, 0.8 \\ 0.4, 0.5, 0.6 & 0.7, 0.8, 0.9 & 0.3, 0.4, 0.5 & 0.1, 0.2, 0.3 & 0.5, 0.6, 0.7 \\ 0.4, 0.5, 0.6 & 0.3, 0.4, 0.5 & 0.2, 0.3, 0.4 & 0.3, 0.4, 0.5 & 0.3, 0.4, 0.5 \end{bmatrix}.$$

Definition 3.2: A matrix which elements are generalized triangular fuzzy soft sets is called generalized triangular fuzzy soft matrix. Let $A = (a_{ik})$ and $B = (b_{kj})$ are two generalized triangular fuzzy soft matrices, then the max-min multiplication are defined as follows:

$$A \otimes B = max\ [Min(a_{ik}, b_{kj})].$$

4. APPLICATION

In this section, we have extended Sanchez's method [30] for medical diagnosis in generalized triangular fuzzy soft set. In medical some of the symptoms cannot represent in any numerical value in this case vagueness arise, for example a patient tells to the doctor that his headache is "very high" with linguistic assessments. In this case any numerical values cannot represent this patient's headache "very high" but we can characterize patient's headache by a triangular fuzzy number such as $(0.7, 0.8, 0.9)$. Hence we know that the membership function of triangularfuzzy number can state vagueness information. The methodology involves mainly the following three jobs:

1. Determination of symptoms.

2. Formulation of medical knowledge based on generalized triangular fuzzy soft sets.

3. Determination of diagnosis on the basis of composition of on generalized triangular fuzzy soft sets.

4.1. Procedure

Let $P = \{p_1, p_2, \cdots\cdots\cdots p_m\}$ be a set of m patients for medical diagnosis with a set of n symptoms $S = \{s_1, s_2, \cdots\cdots\cdots s_n\}$ and $D = \{d_1, d_2, \cdots\cdots\cdots d_k\}$ be a set of k diseases related of the symptoms. Now we build a triangular fuzzy soft set$(\tilde{F}, P)$ over S where $\tilde{F}$ is a mapping $\tilde{F}: P \to TFS(S)$. This triangular fuzzy soft set provides a matrix Q called patient-symptom matrix, where the entries are triangular fuzzy numbers$\tilde{a}_{ij} = (a_{ij}^1,\ a_{ij}^2, a_{ij}^3)$ for $1 \leq i \leq m$ and $1 \leq j \leq n$. The patient-symptom matrix Q is given as follows:

$$Q = \begin{matrix} & s_1 & s_2 & \cdots & s_n \\ p_1 \\ p_2 \\ \vdots \\ p_m \end{matrix} \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \cdots & \tilde{a}_{mn} \end{bmatrix}$$

Then, we create a generalized triangular fuzzy soft set $(\tilde{G}_{\tilde{g}}, S)$ over D, where $\tilde{G}_{\tilde{g}}$ is a mapping $\tilde{G}_g: S \to TFS(D) \times TFS$, this generalized fuzzy soft set presents also a matrix, say R called symptom-diseases matrix, where each element denote the weight of the symptoms for a certain diseases. These elements are also taken as generalized triangular fuzzy soft set. The symptom-diseases matrix R is given as follows:

$$R = \begin{matrix} & d_1 & d_2 & \cdots d_k & \tilde{g} \\ s_1 \\ s_2 \\ \vdots \\ s_n \end{matrix} \begin{bmatrix} \tilde{b}_{11} & \tilde{b}_{12} & \cdots & \tilde{b}_{1k} & \tilde{b}_{1k+1} \\ \tilde{b}_{21} & \tilde{b}_{22} & \cdots & \tilde{b}_{2k} & \tilde{b}_{2k+1} \\ \vdots & \vdots & & \cdots & \vdots \\ \tilde{b}_{n1} & \tilde{b}_{n2} & \cdots & \tilde{b}_{nk} & \tilde{b}_{nk+1} \end{bmatrix}$$

where the last column represents the values of $\tilde{g}$ which is a triangular fuzzy set on S.

Now executing the process $Q \otimes R$ we get the patient-diagnosis matrix D_1 as follows:

$$D_1 = \begin{matrix} & d_1 & d_2 & \cdots d_k & \tilde{g} \\ p_1 \\ p_2 \\ \vdots \\ p_m \end{matrix} \begin{bmatrix} \tilde{c}_{11} & \tilde{c}_{12} & \cdots & \tilde{c}_{1k} & \tilde{c}_{1k+1} \\ \tilde{c}_{21} & \tilde{c}_{22} & \cdots & \tilde{c}_{2k} & \tilde{c}_{2k+1} \\ \vdots & \vdots & & \cdots & \vdots \\ \tilde{c}_{m1} & \tilde{c}_{m2} & \cdots & \tilde{c}_{mk} & \tilde{c}_{mk+1} \end{bmatrix}$$

Then defuzzifying the matrix D_1 by (1) we get the classical diagnosis matrix as

$$D_2 = \begin{matrix} & d_1 & d_2 & \cdots d_k & \tilde{g} \\ p_1 \\ p_2 \\ \vdots \\ p_m \end{matrix} \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1k} & v_{1k+1} \\ v_{21} & v_{22} & \cdots & v_{2k} & v_{2k+1} \\ \vdots & \vdots & & \cdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mk} & v_{mk+1} \end{bmatrix}$$

Finally, $v_{il} \geq v_{ik+1}$for $1 \leq i \leq m$ and $1 \leq l \leq k$; then we terminate that the patient $p_i$is suffering from disease d_l.

4.2. Algorithm

Step I: Input the triangular fuzzy soft set $(\tilde{F}, P)$ to get the patient-symptom matrix Q.

Step II: Input the generalized triangular fuzzy soft set $(\tilde{G}_{\tilde{g}}, S)$ to get the symptom-disease matrix R.

Step III: Execute the operation $Q \otimes R$ to get the patient diagnosis matrix D_1.

Step IV: Defuzzify all the elements of the matrixD_1 by the equation (1) to get the matrix D_2 .

Step V: Find l for which $v_{il} \geq v_{i,k+1}$for $1 \leq i \leq m$ and $1 \leq l \leq k$; then we terminate that the patient p_i is suffering from disease d_l.

4.3. Case Study

In hospital, suppose there are three patients, Joni, Moni and Toni for medical diagnosis in the company of the symptoms: temperature, headache, cough, and muscle and joint painsand the possible diseases regarding to the above symptoms be Covid-19, typhoid, and Dengue. Let P be a set of three patients under consideration of a doctor to diagnose, which is denoted by $P = \{p_1, p_2, p_2\}$, where $p_1, p_2$and p_3 represents patient Joni, Moni and Toni respectively. Let $S = \{s_1, s_2, s_3, s_4\}$ be a set of symptoms, where s_1, s_2, s_3 and s_4 represent symptoms: temperature, headache, cough, and muscle and joint pains, respectively. Let $D = \{d_1, d_2, d_3\}$ be a set of diseases, where d_1, d_2 and d_3 represent the diseases: Covid-19, Typhoid, and Dengue, respectively. Observing the symptoms of three patients' doctor can construct the following table with their linguistic assessments.

Table 02: Linguistic assessments of three patients.

Q	s_1: Temparature	s_2: headache	s_3: cough	s_4:muscle and joint pains
p_1	High	Medium high	Medium high	Medium low
p_2	High	Very medium	Medium low	Medium high
p_3	Medium high	Very medium	Very medium	High

Now, we have a corresponding triangular fuzzy soft set$(\tilde{F}, P)$ over S according to the rule of conversion between linguistic terms and numerical values showed in figure 2. This triangular fuzzy soft set$(\tilde{F}, P)$ can be represented by the matrix Q, called patient-symptom matrix and is given as follows:

$$Q = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{cccc} s_1 & s_2 & s_3 & s_4 \end{array} \\ \begin{bmatrix} (0.6, 0.7, 0.8) & (0.5, 0.6, 0.7) & (0.5, 0.6, 0.7) & (0.2, 0.3, 0.4) \\ (0.6, 0.7, 0.8) & (0.4, 0.5, 0.6) & (0.2, 0.3, 0.4) & (0.5, 0.6, 0.7) \\ (0.5, 0.6, 0.7) & (0.4, 0.5, 0.6) & (0.4, 0.5, 0.6) & (0.6, 0.7, 0.8) \end{bmatrix} \end{array}$$

Now we make a generalized triangular fuzzy soft set $(\tilde{G}_{\tilde{g}}, S)$ over D, where $\tilde{G}_{\tilde{g}}$ is a mapping $\tilde{G}_{\tilde{g}}: S \to TFS(D) \times TFS$, which is determined from expert medical documentation. This matrix R is called symptom-diseases matrix and is given as follows:

$$R = \begin{array}{c} \\ s_1 \\ s_2 \\ s_3 \\ s_4 \end{array} \begin{array}{c} \begin{array}{cccc} d_1 & d_2 & d_3 & \tilde{g} \end{array} \\ \begin{bmatrix} (0.8, 0.9, 1.0) & (0.5, 0.6, 0.7) & (0.1, 0.2, 0.3) & (0.8, 0.9, 1.0) \\ (0.4, 0.5, 0.6) & (0.5, 0.6, 0.7) & (0.5, 0.6, 0.7) & (0.6, 0.7, 0.8) \\ (0.6, 0.7, 0.8) & (0.1, 0.2, 0.3) & (0.6, 0.7, 0.8) & (0.3, 0.4, 0.5) \\ (0.3, 0.4, 0.5) & (0.7, 0.8, 0.9) & (0.7, 0.8, 0.9) & (0.8, 0.9, 1.0) \end{bmatrix} \end{array}$$

Then, executing the operation $Q \otimes R$, we get the patient-diagnosis matrix D_1 as follows:

$$D_1 = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{cccc} d_1 & d_2 & d_3 & \tilde{g} \end{array} \\ \begin{bmatrix} (0.6, 0.7, 0.8) & (0.5, 0.6, 0.7) & (0.5, 0.6, 0.7) & (0.6, 0.7, 0.8) \\ (0.6, 0.7, 0.8) & (0.5, 0.6, 0.7) & (0.5, 0.6, 0.7) & (0.6, 0.7, 0.8) \\ (0.5, 0.6, 0.7) & (0.6, 0.7, 0.8) & (0.6, 0.7, 0.8) & (0.6, 0.7, 0.8) \end{bmatrix} \end{array}$$

Now, defuzzifying the matrix D_1 by the equation (1), we get the classical diagnosis matrix as

$$D_2 = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{cccc} d_1 & d_2 & d_3 & \tilde{g} \end{array} \\ \begin{bmatrix} 0.7 & 0.6 & 0.6 & 0.7 \\ 0.7, & 0.6 & 0.6 & 0.7 \\ 0.6 & 0.7 & 0.7 & 0.7 \end{bmatrix} \end{array}$$

From the matrix D_2 we conclude that Joni is suffering from the disease Covid-19, Moni is also suffering from Covid-19, Toni is suffering from two diseases typhoid and Dengue. This is a simple example more accurate result is possible if we can employ specialist about disease.

5. CONCLUSIONS

After the introduction of fuzzy set by Zadeh, it has become an important tool in modern sciences. On the other hand soft set which has been invented by Moldtsov is rapidly growing its application in many branches of science and engineering. In this article, we have studied the combined tool of fuzzy set and soft set by generalized triangular fuzzy soft set and applied it in medical diagnosis. We also have represented a case study. This research will be helpful for further study of fuzzy soft set and its application in many branches of mathematics and engineering sciences.

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