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QUALIFLEX based ranking system by using Interval Valued Hesitant Fuzzy Set and its application to rank the Diabetic patients

Pankaj Srivastava
Department of Mathematics
Motilal Nehru National Institute of Technology Allahabad
Prayagraj, Uttar Pradesh, India
pankajs@mnnit.ac.in

Rajkrishna Mondal
Department of Mathematics
Motilal Nehru National Institute of Technology Allahabad
Prayagraj, Uttar Pradesh, India
rajkrishna@mnnit.ac.in

***Abstract*—India has a high prevalence of Diabetes Mellitus and the numbers are increasing day by day at an alarming rate. According to Diabetes Care report prediction of Diabetes will be doubled globally from 2000 to 2030 with a maximum rate in India. It is reported that by 2030 diabetes mellitus may afflict up to 79.4 million people in India. Indians are becoming more prone to diabetes because of unhealthy living style and diet, also due to rapid migration to metropolitan cities for employment. In today's generation, it is required to take a proper management and right decision according to our current lifestyle. Generally, it is seen the health experts are most of the time hesitate to diagnose a Diabetic patient because Diabetes is a chronically disease, it depends on various kind of imprecise lifestyle factors. Interval-valued Hesitant fuzzy set(IVHFS) is the best mathematical tool for management and taking the right decisions for such kind of imprecise data. In this study, we have developed a ranking system based on QUALIFLEX (i.e., QUALItative FLEXible) by using IVHFS and as a case study, this ranking system is applied on Diabetic Patients according to their various imprecise category which is collected from our near health center. The output result is verified by the various medical experts in this field. This system is useful for developing a software which will be helpful for the rural areas patients where till now have not proper medical facilities.**

***Index Terms*—Decision Making, QUALIFLEX, Interval Valued Hesitant Fuzzy Set, Ranking System**

I. Introduction

A. Introduction of Diabetes

Diabetes is a medical disorder characterized by varying or persistent high blood sugar level, caused by either lack of or resistance to insulin. The treatment of diabetes focuses on controlling blood sugar levels to prevent various symptoms and complications through medicine, diet, and exercise. Management, as well as decision making, is an important part of our regular life to maintain diabetes [1].

In India near about 5%-15% are suffering from type 1, mainly it occurs at a young age before 30 years. On other in type 2 diabetes body still produces insulin but lack of resistance to dominant insulin, the body cannot produce calories from glucose, mainly it shows on adult people about 40. According to [2] in 2017 on South-East Asia(SEA) 962 million adults from 20-79 years aged i.e. about 8.5% is suffering from it and by 2045, the region is predicted to grow about 1.37 billion. They also show that India is home to the second-largest number of adults living with diabetes worldwide after China and contribute to the largest mortality in the SEA.

B. Real problem in today's Society

In such a dangerous situation we need to take proper action to prevent Diabetes and such kind of chronic diseases. It is only possible when we maintain a healthy lifestyle and take the right decisions in every step in our life. In the age of Artificial Intelligence, we are all directly or indirectly depended on technology. So using this technology if we build such kind of device or software which will help us for management a healthy lifestyle and help us to make the right decisions in our life [3], then it may be possible to control such kind of disease and hypertension, etc. But in nature human life totally depends on imprecise, uncertain, vague pieces of information. But the introduction of Hesitant Fuzzy Set(HFS) [4], [5] helps us to manage such kind of imprecise informations. The improvements of HFS developed Interval Valued Hesitant Fuzzy Set (IVHFS) [6] which is more closer to nature than HFS to make realistic decisions.

C. Objective of this study

In this present article, we have developed a ranking system based on QUALIFLEX (i.e., QUALItative FLEXible) by using IVHFS. And in the field of case study, we have applied this ranking system to our near health center for ranking various kind of Diabetic patients according to various imprecise category. The output result is verified by the various experts of this field.

D. Literature Review

In 2010, Torra [4], [5] introduced the concept of HFS and in 2013 Chen et. all [7] extended this to IVHFS and developed a group decision making system.In 2015, Zhang and Zu [8] developed Hesitant fuzzy QUALIFLEX approach for multi criteria decision anlysis and in 2017 Zhiming Zhang [9]

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developed using interval-valued hesitant fuzzy QUALIFLEX methods based on a likelihood-based comparison approach a multi-criteria decision making system. Simultaneously, various researchers like Wei et. all [6] using fuzzy aggregation operators on IVHFS developed multiple attribute decision making, Zhang et all [10] introduced the concept of Induced generalized hesitant fuzzy operators, using continuous hesitant fuzzy aggregation operators Peng et. all [11] developed decision making under interval-valued hesitant fuzzy setting, Park et al [12] extended the TOPSIS method for decision making problems under interval-valued intuitionistic fuzzy environment.

In 2006, Pandey et. all [13] analysis cardiac system using soft computing rule-based system. Further in 2012, Srivastava and Srivastava [14], [15] proposed soft computing risk assessment scheme for cardiac analysis and hypertension respectively. In 2014, Srivastava P. and Sharma N. designed a soft computing model for medical diagnosis [16]. Srivastava et. al. [17] developed Soft computing tools and it applied on classification criterion for hepatitis B. and also in [18] they describe a Soft Computing Diagnostic System for Diabetes diagnosis. Recently, [19]–[22] using the concept IVHFS they have solved various kind of real life problems.

E. Structure of this present article

In section 2, we have discussed about some preliminaries. Section 3 is discussed about required materials and methods of this study and designed the algorithm and flow chart. In Section 4 discussed about a case study from near health center. Section 5 is briefly discussed about Sensitivity Analysis and proof the validation of the output results. In section 5, draw a proper conclusion.

II. Preliminaries

A. Hesitant Fuzzy Set [4], [5]:

Let X be an universal set and $A \subset X$. Then Hesitant Fuzzy Set (HFS) of A is defined by

$$Hes(A) = \{< x, h_A(x) > | \; x \in X\} \tag{1}$$

where $h_A(x)$ is set of possible membership degrees of x in $[0, 1]$ to the set A.

Example 1: If $X = \{1, 2, 3, 4, 5\}$ and $A = \{1, 2, 3\}$ be a subset of X then

$$Hes(A) = \left\{ \begin{array}{c} < 1, \{0.2, 0.5, 0.7, 0.4\} > \\ < 2, \{0.4, 0.6, 0.9\} > \\ < 3, \{0.2, 0.9, 0.1, 0.8, 0.5\} > \end{array} \right\}$$

which is shown in figure 1.

B. Interval Valued Hesitant Fuzzy Set [7]:

Let $D([0, 1])$ be the set of all closed sub-intervals in $[0, 1]$. An Interval Valued Hesitant Fuzzy Set(IVHFS) $Hes(\tilde{A})$ is defined by

$$Hes(\tilde{A}) = \left\{ < x, \tilde{h}_A(x) > | \; x \in X, \tilde{h}_A(x) \in D([0, 1]) \right\} \tag{2}$$

where $\tilde{h}_A(x)$ is the set of possible membership degrees of x in $D([0, 1])$ to the set A.

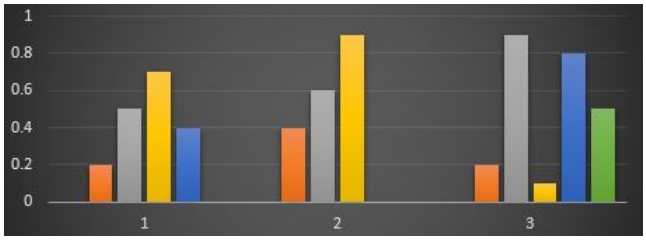

Fig. 1. Hesitant Fuzzy Set

Example 2: As on the previous example for X and A, here

$$Hes(\tilde{A}) = \left\{ \begin{array}{c} < 1, \{[0.6, 0.7], [0.3, 0.5]\} > \\ < 2, \{[0.2, 0.7], [0.3, 0.8], [0.2, 0.5]\} > \\ < 3, \{[0.4, 0.6]\} > \end{array} \right\}$$

C. Properties of IVHF Elements

1) Degree of Possibility [23]:: Let $\tilde{A}, \tilde{B} \in D[0, 1]$ where $\tilde{A} = [a^L, a^U], \tilde{B} = [b^L, b^U]$ and $l_{\tilde{A}} = a^U - a^L$, $l_{\tilde{B}} = b^U - b^L$ Then The degree of possibility of $\tilde{A} \succeq \tilde{B}$ is defined by

$$p(\tilde{A} \succeq \tilde{B}) = max \left\{ 1 - max \left(\frac{b^U - a^L}{l_{\tilde{A}} + l_{\tilde{B}}}, 0 \right), 0 \right\} \tag{3}$$

2) Likelihood preference relation:: If $\tilde{h}_\alpha = \{\tilde{a}_1, \tilde{a}_2, \ldots, \tilde{a}_m\}$and $\tilde{h}_\beta = \{\tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_n\}$ be two IVHF elements then The likelihood $L(\tilde{h}_\alpha \succeq \tilde{h}_\beta)$ is an IVHF preference relation from equation 3, is defined by

$$L(\tilde{h}_\alpha \succeq \tilde{h}_\beta) = \frac{1}{m.n} \sum_{i=1}^{m} \sum_{j=1}^{n} p(\tilde{a}_i \succeq \tilde{b}_j) \tag{4}$$

III. Materials and Methods

For an multi criteria decision making(MCDM) problem, suppose we have a set of alternatives $Z = \{z_1, z_2, \ldots, z_m\}$ and a set of criteria $C = \{c_1, c_2, \ldots, c_n\}$. Here we use IVHF element $\tilde{h}_{ij} = \left\{ \tilde{\gamma}_{ij}^1, \tilde{\gamma}_{ij}^2, \ldots, \tilde{\gamma}_{ij}^{l_{ij}} \right\}$ for rating the alternative $z_i \in Z$ corresponding to the criterion $c_j \in C$. So, the IVHF decision matrix can be written as

$$\tilde{H} = \left(\tilde{h}_{ij} \right)_{m \times n} = \begin{array}{c|cccc} & c_1 & c_2 & \cdots & c_n \\ z_1 & \tilde{h}_{11} & \tilde{h}_{12} & \cdots & \tilde{h}_{1n} \\ z_2 & \tilde{h}_{21} & \tilde{h}_{22} & \cdots & \tilde{h}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ z_m & \tilde{h}_{m1} & \tilde{h}_{m1} & \cdots & \tilde{h}_{mn} \end{array}$$

A. Concordance/Discordance Index (CDI):

If Z_α[1]$= \left\{ \tilde{h}_{\alpha 1}, \tilde{h}_{\alpha 2}, \ldots, \tilde{h}_{\alpha n} \right\}$ and $Z_\beta = \left\{ \tilde{h}_{\beta 1}, \ldots, \tilde{h}_{\beta n} \right\}$ be sets of IVHF elements for the alternative z_α and z_β respectively corresponding to the each criteria in C; $\alpha, \beta \in \{1, 2, \cdots, m\}$. Then CDI $\varphi_j(Z_\alpha, Z_\beta)$ for the jth criteria in $\tilde{H}$ is defined by

$$\varphi_j(Z_\alpha, Z_\beta) = L(\tilde{h}_{\alpha j} \succeq \tilde{h}_{\beta j}) - 0.5 \tag{5}$$

where $\varphi_j(Z_\alpha, Z_\beta) \in [-0.5, 0.5]; j \in \{1, 2, \cdots, n\}$.

[1]Here we denote the alternative $z_\alpha \in Z$ through the notation Z_α for collection of IVHF elements for all criteria in C

1. $\varphi_j(Z_\alpha, Z_\beta) > 0$, Z_α ranks over Z_β for jth criteria.
2. $\varphi_j(Z_\alpha, Z_\beta) < 0$, Z_β ranks over Z_α for jth criteria.
3. $\varphi_j(Z_\alpha, Z_\beta) = 0$, Z_α and Z_β have same rank for jth criteria.

B. Weighted Concordance/Discordance Index (WCDI):

If $\tilde{W}_j\,(\in D([0,1]))$ be corresponding weight of the jth criteria then WCDI for each pair of $(Z_\alpha, Z_\beta) \in Z \times Z$ is defined by

$$\varphi\left(Z_\alpha, Z_\beta\right) = \sum_{j=1}^{n} \left(\varphi_j(Z_\alpha, Z_\beta) \cdot L\left(\tilde{W}_j \succeq \{[0,1]\}\right)\right) \quad (6)$$

C. Comprehensive Concordance/Discordance Index (CCDI):

$\forall (Z_\alpha, Z_\beta) \in Z \times Z$ then CCDI is computed by

$$\varphi = \sum_{(Z_\alpha, Z_\beta) \in Z \times Z} \varphi\left(Z_\alpha, Z_\beta\right) \quad (7)$$

Using the above definitions and equations, the developed algorithm and graphical structure that has been shown in table I and figure 2 respectively.

IV. Case Studies

Set of data for three patients $(P1, P2, P3)$ for the three respective criteria c_1 =**Previous Medical Report (PMR),** c_2 =**Physical History (PH) and** c_3 =**Doctor's Suggestions (DrS)** developed decision matrix $\tilde{H}$ with the help of input 1 and 2 that has been shown in table II.

Now according to the step 2, in this case we have constructed $3! = 6$ different permutation for these 3 patients
$Permutation_1 = (P1, P2, P3)$
$Permutation_2 = (P1, P3, P2)$
$Permutation_3 = (P2, P1, P3)$
$Permutation_4 = (P2, P3, P1)$
$Permutation_5 = (P3, P1, P2)$
$Permutation_6 = (P3, P2, P1)$

Now as on step 3, Compute the likelihood values $L(\tilde{h}_{\alpha j} \succeq \tilde{h}_{\beta j})$ for each different pairs $(P_\alpha, P_\beta); \alpha \neq \beta$ corresponding to each criteria $c_j, j = 1, 2, 3$ which has been shown in table III.

According to the step 4, compute all possible CDI values for each permutation that has been shown in table IV.

Then calculate WCDI computational table with the help of input 3 as described in step 5 that has been shown in table V.

And finally compute CCDI values for each permutation (shown in table VI), as on step 6.

From the above table, we see that the largest CCDI value is 0.2174 for permutation 5 i.e. $(P3, P1, P2)$.
So, as on our decision making system, Physicians diagnose these group of diabetic patients as $patient_3 \succ patient_1 \succ patient_2$.

V. Sensitivity Analysis and Validation of the Result

A. Sensitivity Analysis

In this section we have discussed about sensitivity analysis of the proposed algorithm. It has been discussed into two parts. In 1st part, by changing the values of weighting vectors and in 2nd part, by changing the values of criteria vectors, how it effects into the output results.

Between $[0, 1]$, here we have taken 55 sub intervals which has been given below,
$\{[0, .1], [0, .2], [0, .3], [0, .4], [0, .5], [0, .6], [0, .7], [0, .8], [0, .9], [0, 1]\}$
$\{[.1, .2], [.1, .3], [.1, .4], [.1, .5], [.1, .6], [.1, .7], [.1, .8], [.1, .9], [.1, 1]\}$
$\{[.2, .3], [.2, .4], [.2, .5], [.2, .6], [.2, .7], [.2, .8], [.2, .9], [.2, 1]\}$
$\{[.3, .4], [.3, .5], [.3, .6], [.3, .7], [.3, .8], [.3, .9], [.3, 1]\}$
$\{[.4, .5], [.4, .6], [.4, .7], [.4, .8], [.4, .9], [.4, 1]\}$
$\{[.5, .6], [.5, .7], [.5, .8], [.5, .9], [.5, 1]\}$
$\{[.6, .7], [.6, .8], [.6, .9], [.6, 1]\}$
$\{[.7, .8], [.7, .9], [.7, 1]\}$
$\{[.8, .9], [.8, 1]\}$
$\{[.9, 1]\}$

1) Changing the weighting vectors: Here 1st changing the values of $\tilde{W}_1$ from $[0, .1]$ to $[.9, 1]$ and taking the remaining two are constant i.e. $\tilde{W}_2 = \{[0.2, 0.3], [0.3, 0.4]\}$ and $\tilde{W}_3 = \{[.7, .8]\}$, then taken the output result. Similarly, changes the values of $\tilde{W}_2$ from $[0, .1]$ to $[.9, 1]$ and $\tilde{W}_1 = \{[0.3, 0.5], [0.2, 0.4]\}, \tilde{W}_3 = \{[0.7, 0.8]\}$; same is done for $\tilde{W}_3$ also.

In figure 3, we have shown that how the output results changes when $\tilde{W}_1, \tilde{W}_2, \tilde{W}_3$ is changes from $[0, .1]$ to $[.9, 1]$ respectively and other two are constant.

In figure 4, has been shown that how the output variable changes when any two weighting vectors changes simultaneously i.e. $\tilde{W}_1\tilde{W}_2; \tilde{W}_1\tilde{W}_3; \tilde{W}_2\tilde{W}_3$ changes when $\tilde{W}_3, \tilde{W}_2, \tilde{W}_1$ are constant respectively.

2) Changing the Criteria vectors: Same as weighting vectors, here we changes the criteria vectors from $[0, .1]$ to $[.9, 1]$, first changes single criteria vector and other two has remain constant(shown in figure 5), then changes two vectors and remain one has constant(shown in figure 6).

B. Validation of the Result

From the Sensitivity Analysis we have seen that for the small changes of the weighting vectors and criterion vectors how the output results behaves for each patients.

In this section we have shown that actually this output result is valid with according to the Doctors analysis.

1st we consider the weighting vector case, if we look into the W_1 i.e. weighting value of the **Previous Medical Report**(C_1) when it is increases from $[0, .1]$ to $[.9, 1]$, the chances of diabetes increases from Patient 1 to Patient 3 because in decision matrix the C_1 values of Patient 3 is much

TABLE I
ALGORITHM: DIABETES DIAGNOSTIC MECHANISM USING IVHFS

INPUT:
1. Set of alternatives $Z = \{z_1, z_2, \ldots, z_m\}$ and corresponding set of criteria $C = \{c_1, c_2, \ldots, c_n\}$
2. IVHF elements $\tilde{h}_{ij}$ for each alternative $z_i, i \in \{1, 2, \cdots, m\}$ for corresponding criteria $c_j, j \in \{1, 2, \cdots, n\}$
3. IV weight vector $\tilde{W}_j = \left\{\tilde{w}_j^1, \tilde{w}_j^2, \ldots, \tilde{w}_j^{l_j}\right\}$ for each criteria $c_j, j \in \{1, 2, \cdots, n\}$

OUTPUT: Sequence wise alternatives ranking

METHODOLOGY

1: Construct IVHF decision matrix $\tilde{H} = \left(\tilde{h}_{ij}\right)_{m\times n}$ with the help of input 1 and 2 that has been shown in sec III.
2: Construct $m!$ permutation for m alternative set $z_i, i = 1, 2, \ldots, m$. Where $P_l = (\cdots, z_\alpha, \cdots, z_\beta, \cdots), l = 1, 2, \ldots, m!$ be the l th permutation.
3: Calculate likelihood value $L(\tilde{h}_{\alpha j} \succeq \tilde{h}_{\beta j})$ for each different pairwise alternatives $(Z_\alpha, Z_\beta) \in Z \times Z$ corresponding to each criteria $c_j, j \in \{1, 2, \cdots, n\}$ using the equation 4.
4: For each permutation $P_l, l \in \{1, 2, \cdots, m!\}$ compute CDI $\varphi_j^l(z_\alpha, z_\beta)$ for criteria $c_j \in C$ using equation 5.
5: With the help of input 3, calculate WCDI $\varphi^l(z_\alpha, z_\beta)$ between each pair (z_α, z_β) in $P_l, l \in \{1, 2, \cdots, m!\}$ using equation 6.
6: Finally compute CCDI φ^l for each permutation $P_l, l = 1, 2, \ldots, m!$ using equation 7.
7: According to the largest value of φ^l's,$l \in \{1, 2, \cdots, m!\}$, we decide optimal ranking of the alternatives as on the l th permutation.

TABLE II
IVHF DECISION MATRIX $\tilde{H}$

$\tilde{W}$	$\underbrace{\{[0.3, 0.5], [0.2, 0.4]\}}_{\tilde{W}_1}$	$\underbrace{\{[0.2, 0.3], [0.3, 0.4]\}}_{\tilde{W}_2}$	$\underbrace{\{[0.7, 0.8]\}}_{\tilde{W}_3}$
	PMR(c_1)	PH(c_2)	DrS(c_3)
P1	$\underbrace{\{[0.4, 0.6], [0.1, 0.3], [0.1, 0.2]\}}_{\tilde{h}_{11}}$	$\underbrace{\{[0.3, 0.5], [0.2, 0.3]\}}_{\tilde{h}_{12}}$	$\underbrace{\{[0.4, 0.6]\}}_{\tilde{h}_{13}}$
P2	$\underbrace{\{[0.4, 0.5], [0.2, 0.3]\}}_{\tilde{h}_{21}}$	$\underbrace{\{[0.5, 0.6]\}}_{\tilde{h}_{22}}$	$\underbrace{\{[0.2, 0.3], [0.3, .0.5]\}}_{\tilde{h}_{23}}$
P3	$\underbrace{\{[0.6, 0.8], [0.5, 0.8], [0.4, 0.6]\}}_{\tilde{h}_{31}}$	$\underbrace{\{[0.3, 0.4], [0.2, 0.6]\}}_{\tilde{h}_{32}}$	$\underbrace{\{[0.2, 0.5], [0.3, 0.5]\}}_{\tilde{h}_{33}}$

TABLE III
LIKELIHOOD VALUES FOR EACH PERMUTATIONS

	c_1	c_2	c_3
$L(\tilde{h}_{1j} \succeq \tilde{h}_{2j})$	0.3333	0.0000	0.8750
$L(\tilde{h}_{1j} \succeq \tilde{h}_{3j})$	0.0778	0.3417	0.7750
$L(\tilde{h}_{2j} \succeq \tilde{h}_{1j})$	0.6667	1.0000	0.1250
$L(\tilde{h}_{2j} \succeq \tilde{h}_{3j})$	0.0556	0.9000	0.3375
$L(\tilde{h}_{3j} \succeq \tilde{h}_{1j})$	0.9222	0.6583	0.2250
$L(\tilde{h}_{3j} \succeq \tilde{h}_{2j})$	0.9444	0.1000	0.6625

more than Patient 1. So, According the increasing of the weighting value of W_1 Patient 3 get more chances to be in Diabetes.

Similarly if we look into the W_3 vector i.e. weighting value of the **Doctor's Suggestions**(C_3) when it increases its value from $[0, .1]$ to $[.9, 1]$ then Patient 1 get more chances to be in diabetes than Patient 3 because in Decision Matrix the C_3 values of Patient 1 is much more than Patient 3. So, According the increasing of the weighting value of W_3 Patient 1 get more chances to be in Diabetes.

Similarly if we analyses the W_2 values we get the same kind of results as above.

Now we have look into the Criteria vectors, if we consider Patient 1 then according to increasing of the three criteria we have seen that Patient 1 get more chances to be in Diabetes than patient 3 because if we only change C_1 and C_2, C_3 as remain then as increasing of C_1 patient 1 get more priority than Patient 3, similarly for the case of C_2 and C_3.

So from the above two analysis of weighting vectors and criteria vectors we can confirm that the output result of our algorithms is near about correct according to the given data and this is results is also verified with various Doctors' decisions given in our Acknowledgment section.

VI. CONCLUSION

The designed soft computing information system using the concept of IVHFS and its performance has been cross verified by the medical experts and therefore we are of the view that the proposed diagnostic information system will be highly useful to the Health organizations as well as the health experts also. Using this algorithm if we developed a software or devises that will help the rural area people where have not proper medical services.

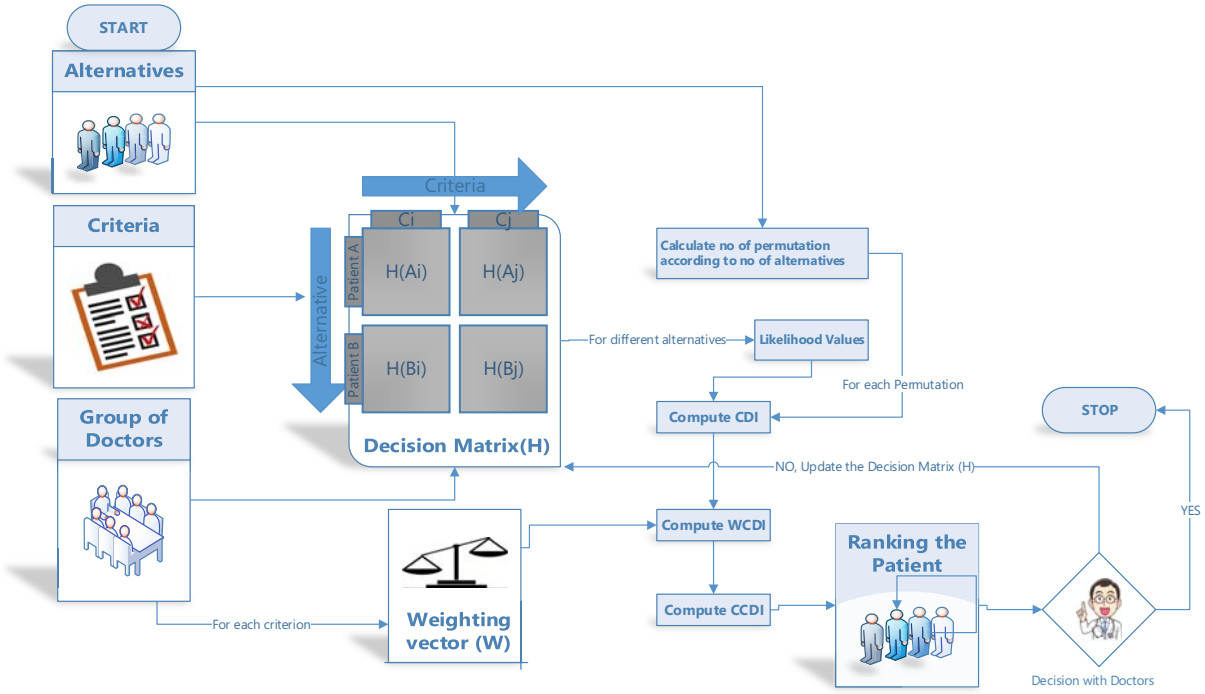

Fig. 2. Graphical structure of the entire study

TABLE IV
CDI COMPUTATIONAL TABLE

	c_1	c_2	c_3		c_1	c_2	c_3
Permutation 1				Permutation 4			
$\varphi_j^1(P1,P2)$	-0.1667	-0.5	0.3750	$\varphi_j^4(P2,P3)$	-0.4444	0.4000	-0.1625
$\varphi_j^1(P1,P3)$	-0.4222	-0.1583	0.2750	$\varphi_j^4(P2,P1)$	0.1667	0.5000	-0.3750
$\varphi_j^1(P2,P3)$	-0.4444	0.4000	-0.1625	$\varphi_j^4(P3,P1)$	0.4222	0.1583	-0.2750
Permutation 2				Permutation 5			
$\varphi_j^2(P1,P3)$	-0.4222	-0.1583	0.2750	$\varphi_j^5(P3,P1)$	0.4222	0.1583	-0.2750
$\varphi_j^1(P1,P2)$	-0.1667	-0.5	0.3750	$\varphi_j^5(P3,P2)$	0.4444	-0.4000	0.1625
$\varphi_j^1(P3,P2)$	0.4444	-0.4000	0.1625	$\varphi_j^5(P1,P2)$	-0.1667	-0.5	0.3750
Permutation 3				Permutation 6			
$\varphi_j^3(P2,P1)$	0.1667	0.5000	-0.3750	$\varphi_j^6(P3,P2)$	0.4444	-0.4000	0.1625
$\varphi_j^3(P2,P3)$	-0.4444	0.4000	-0.1625	$\varphi_j^6(P3,P1)$	0.4222	0.1583	-0.2750
$\varphi_j^3(P1,P3)$	-0.4222	-0.1583	0.2750	$\varphi_j^6(P2,P1)$	0.1667	0.5000	-0.3750

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REFERENCES

[1] A. D. Association *et al.*, "Introduction: standards of medical care in diabetes—2018," 2018.
[2] I. D. Federation, "Idf diabetes atlas, 8th edn," 2017. [Online]. Available: https://diabetesatlas.org/resources/2017-atlas.html
[3] T. J. Stewart, "A critical survey on the status of multiple criteria decision making theory and practice," *Omega*, vol. 20, no. 5-6, pp. 569–586, 1992.
[4] V. Torra, "Hesitant fuzzy sets," *International Journal of Intelligent Systems*, vol. 25, no. 6, pp. 529–539, 2010.
[5] V. Torra and Y. Narukawa, "On hesitant fuzzy sets and decision," in *2009 IEEE International Conference on Fuzzy Systems*. IEEE, 2009, pp. 1378–1382.
[6] G. Wei, X. Zhao, and R. Lin, "Some hesitant interval-valued fuzzy aggregation operators and their applications to multiple attribute decision making," *Knowledge-Based Systems*, vol. 46, pp. 43–53, 2013.
[7] N. Chen, Z. Xu, and M. Xia, "Interval-valued hesitant preference relations and their applications to group decision making," *Knowledge-based systems*, vol. 37, pp. 528–540, 2013.
[8] X. Zhang and Z. Xu, "Hesitant fuzzy qualiflex approach with a signed distance-based comparison method for multiple criteria decision analysis," *Expert systems with applications*, vol. 42, no. 2, pp. 873–884, 2015.
[9] Z. Zhang, "Multi-criteria decision-making using interval-valued hesitant fuzzy qualiflex methods based on a likelihood-based comparison ap-

TABLE V
WCDI COMPUTATIONAL TABLE

	c_1	c_2	c_3		c_1	c_2	c_3
Permutation 1				Permutation 4			
$\varphi_j^1(P1,P2).L_{\tilde{W}_j}$	-0.0625	-0.1591	0.2727	$\varphi_j^4(P2,P3).L_{\tilde{W}_j}$	-0.1667	0.1273	-0.1182
$\varphi_j^1(P1,P3).L_{\tilde{W}_j}$	-0.1583	-0.0504	0.2000	$\varphi_j^4(P2,P1).L_{\tilde{W}_j}$	0.0625	0.1591	-0.2727
$\varphi_j^1(P2,P3).L_{\tilde{W}_j}$	-0.1667	0.1273	-0.1182	$\varphi_j^4(P3,P1).L_{\tilde{W}_j}$	0.1583	0.0504	-0.2000
Permutation 2				Permutation 5			
$\varphi_j^2(P1,P3).L_{\tilde{W}_j}$	-0.1583	-0.0504	0.2000	$\varphi_j^5(P3,P1).L_{\tilde{W}_j}$	0.1583	0.0504	-0.2000
$\varphi_j^1(P1,P2).L_{\tilde{W}_j}$	-0.0625	-0.1591	0.2727	$\varphi_j^5(P3,P2).L_{\tilde{W}_j}$	0.1667	-0.1273	0.1182
$\varphi_j^1(P3,P2).L_{\tilde{W}_j}$	0.1667	-0.1273	0.1182	$\varphi_j^5(P1,P2).L_{\tilde{W}_j}$	-0.0625	-0.1591	0.2727
Permutation 3				Permutation 6			
$\varphi_j^3(P2,P1).L_{\tilde{W}_j}$	0.0625	0.1591	-0.2727	$\varphi_j^6(P3,P2).L_{\tilde{W}_j}$	0.1667	-0.1273	0.1182
$\varphi_j^3(P2,P3).L_{\tilde{W}_j}$	-0.1667	0.1273	-0.1182	$\varphi_j^6(P3,P1).L_{\tilde{W}_j}$	0.1583	0.0504	-0.2000
$\varphi_j^3(P1,P3).L_{\tilde{W}_j}$	-0.1583	-0.0504	0.2000	$\varphi_j^6(P2,P1).L_{\tilde{W}_j}$	0.0625	0.1591	-0.2727

Where $L_{\tilde{W}_j} = L(\tilde{W}_j \succeq \{[0,1]\}), L_{\tilde{W}_1} = 0.3750; L_{\tilde{W}_2} = 0.3182; L_{\tilde{W}_3} = 0.7237$

TABLE VI
CCDI VALUES FOR EACH PERMUTATIONS

	WCDI		WCDI
Permutation 1		Permutation 4	
$\varphi^1(P1,P2)$	0.0511	$\varphi^4(P2,P3)$	-0.1576
$\varphi^1(P1,P3)$	-0.0087	$\varphi^4(P2,P1)$	-0.0511
$\varphi^1(P2,P3)$	-0.1576	$\varphi^4(P3,P1)$	0.0087
CCDI (Per 1)	**-0.1152**	**CCDI (Per 4)**	**-0.2000**
Permutation 2		Permutation 5	
$\varphi^2(P1,P3)$	-0.0087	$\varphi^5(P3,P1)$	0.0087
$\varphi^1(P1,P2)$	0.0511	$\varphi^5(P3,P2)$	0.1576
$\varphi^1(P3,P2)$	0.1576	$\varphi^5(P1,P2)$	0.0511
CCDI (Per 2)	**0.2000**	**CCDI (Per 5)**	**0.2174**
Permutation 3		Permutation 6	
$\varphi^3(P2,P1)$	-0.0511	$\varphi^6(P3,P2)$	0.1576
$\varphi^3(P2,P3)$	-0.1576	$\varphi^6(P3,P1)$	0.0087
$\varphi^3(P1,P3)$	-0.0087	$\varphi^6(P2,P1)$	-0.0511
CCDI (Per 3)	**-0.2174**	**CCDI (Per 6)**	**0.1152**

proach," *Neural Computing and Applications*, vol. 28, no. 7, pp. 1835–1854, 2017.

[10] Z. Zhang, C. Wang, D. Tian, and K. Li, "Induced generalized hesitant fuzzy operators and their application to multiple attribute group decision making," *Computers & Industrial Engineering*, vol. 67, pp. 116–138, 2014.

[11] D.-H. Peng, T.-D. Wang, C.-Y. Gao, and H. Wang, "Continuous hesitant fuzzy aggregation operators and their application to decision making under interval-valued hesitant fuzzy setting," *The Scientific World Journal*, vol. 2014, 2014.

[12] J. H. Park, I. Y. Park, Y. C. Kwun, and X. Tan, "Extension of the topsis method for decision making problems under interval-valued intuitionistic fuzzy environment," *Applied Mathematical Modelling*, vol. 35, no. 5, pp. 2544–2556, 2011.

[13] D. Pandey, V. Mahajan, and P. Srivastava, "Rule-based system for cardiac analysis," *National Academy Science Letters*, vol. 29, no. 7-8, pp. 299–309, 2006.

[14] P. Srivastava and A. Srivastava, "A note on soft computing approach for cardiac analysis," *Journal of Basic and Applied Scientific Research*, vol. 2, no. 1, pp. 376–385, 2012.

[15] ——, "Spectrum of soft computing risk assessment scheme for hypertension," *International Journal of Computer Applications*, vol. 44, no. 17, pp. 23–30, 2012.

[16] P. Srivastava and N. Sharma, "A spectrum of soft computing model for medical diagnosis," *Applied Mathematics & Information Sciences*, vol. 8, no. 3, p. 1225, 2014.

[17] P. Srivastava, A. Srivastava, and R. Sirohi, "Soft computing tools and classification criterion for hepatitis b," *International Journal of Research and Reviews in Soft & Intelligent Computing*, vol. 2, no. 2, pp. 147–153, 2012.

[18] P. Srivastava and N. Sharma, "Soft computing diagnostic system for diabetes," *International Journal of Computer Applications*, vol. 47, no. 18, pp. 22–27, 2012.

[19] Z. Zhang and C. Wu, "Some interval-valued hesitant fuzzy aggregation operators based on archimedean t-norm and t-conorm with their application in multi-criteria decision making," *Journal of Intelligent & Fuzzy Systems*, vol. 27, no. 6, pp. 2737–2748, 2014.

[20] J. H. Paelinck, "Qualitative multiple criteria analysis, environmental protection and multiregional development," *Papers in Regional Science*, vol. 36, no. 1, pp. 59–74, 1976.

[21] ——, "Qualiflex: a flexible multiple-criteria method," *Economics Letters*, vol. 1, no. 3, pp. 193–197, 1978.

[22] J. Paelinck, "Qualitative multicriteria analysis: an application to airport location," *Environment and Planning A*, vol. 9, no. 8, pp. 883–895, 1977.

[23] Z. Xu and Q.-L. Da, "The uncertain owa operator," *International Journal of Intelligent Systems*, vol. 17, no. 6, pp. 569–575, 2002.

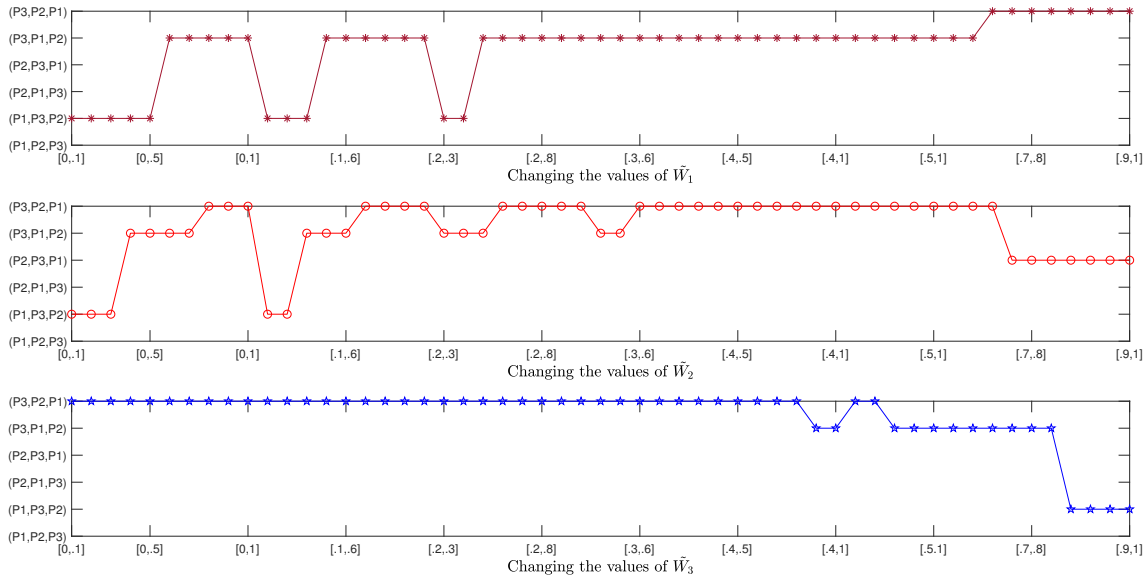

Fig. 3. Output of the Algorithm when Change $\tilde{W}_1, \tilde{W}_2, \tilde{W}_3$ respectively

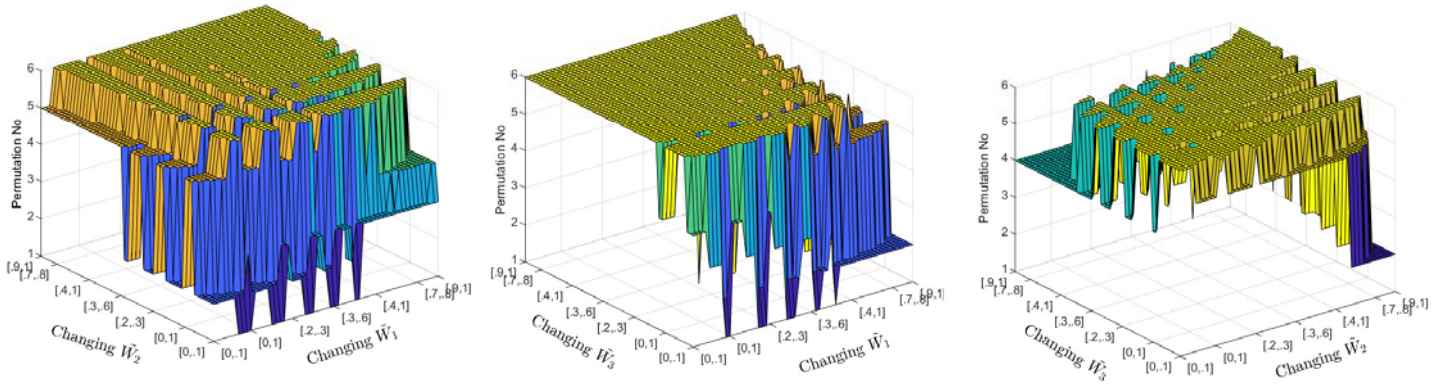

Fig. 4. Output of the Algorithm when Change $\tilde{W}_1\tilde{W}_2; \tilde{W}_1\tilde{W}_3; \tilde{W}_2\tilde{W}_3$ simultaneously

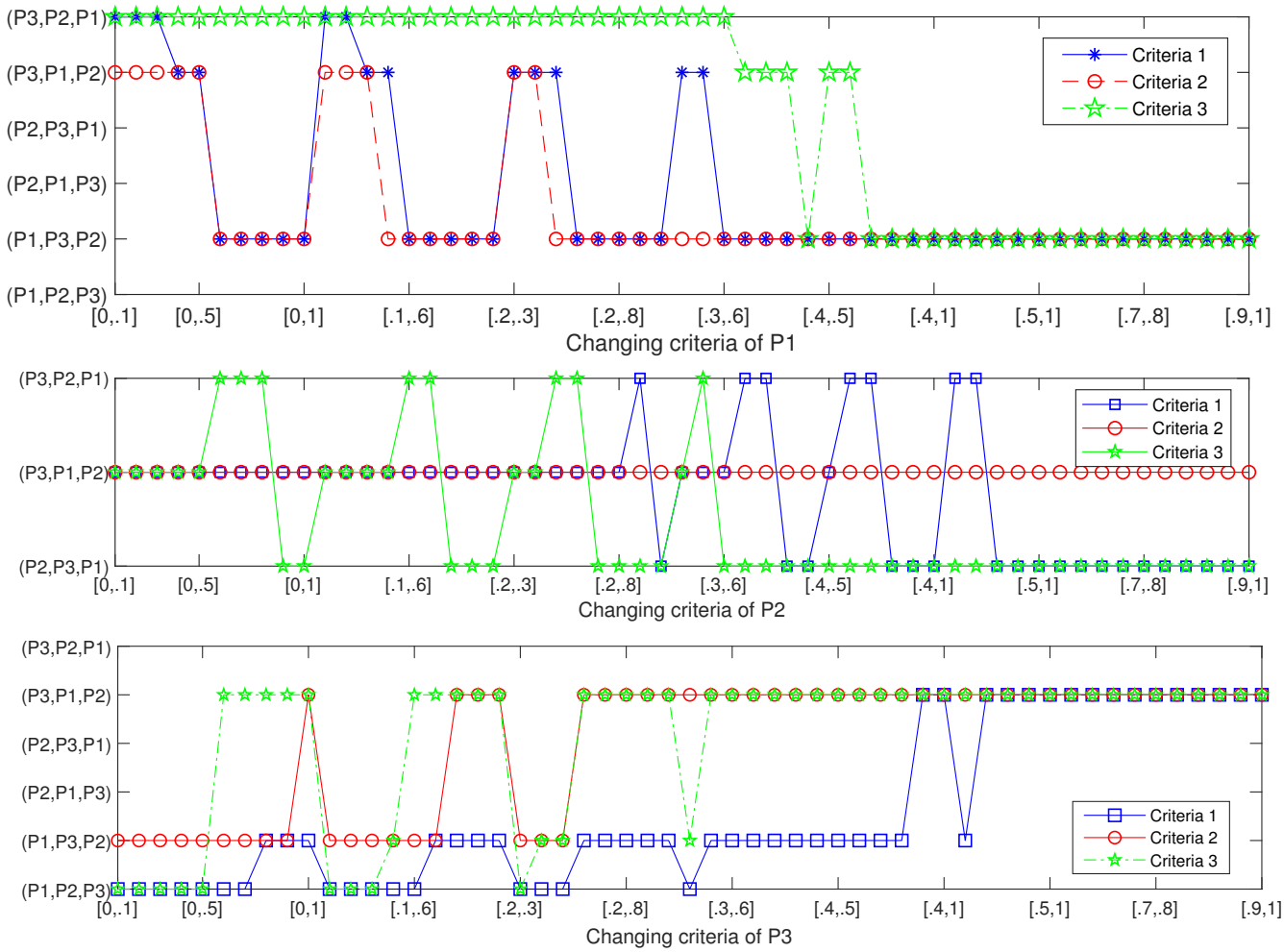

Fig. 5. Output of the algorithm when changing the criteria of the patients

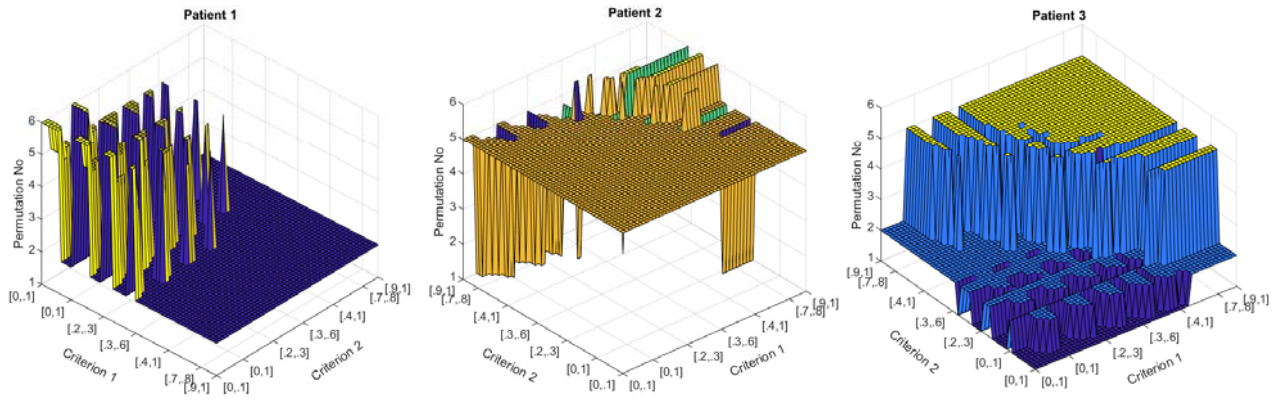

Fig. 6. Output of the algorithm when changing the criteria C_1C_2 simultaneously of the patients