Ratio Mathematica Volume 46, 2023

Intuitionistic Robust fuzzy matrix for the diagnosis of stress, anxiety and hypertension

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Abstract

The mathematical model given here attempts to improve precision in the diagnosis of stress, anxiety, and hypertension using Intuitionistic robust fuzzy matrix (IRFM). In practice, the imprecise nature of medical documentation and the uncertainty of patient information frequently do not provide the appropriate level of confidence in the diagnosis. To that purpose, a novel method based on distinct fuzzy matrices and fuzzy relations is devised, which makes use of the capabilities of fuzzy logic in describing, understanding, and exploiting facts and information that are unclear and lack clarity. With the assistance of 30 doctors, a medical knowledge base is created during the procedure. The model obtained 95.55%t accuracy in the diagnosis, demonstrating its utility.

Keywords: Fuzzy logic; fuzzy matrices; max-min principles; Robust; Intuitionistics.
2020 AMS subject classifications: 03B52, 62F35, 70H30, 20N25 [1]

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[1]Received on September 15, 2022. Accepted on December 15, 2022. Published on March 20, 2023. DOI: 10.23755/rm.v46i0.1087. ISSN: 1592-7415. eISSN: 2282-8214.

1 Introduction

The computer scientist Zadeh was the first to utilize fuzzy logic as a scientific notion. Medicine is one subject where the use of fuzzy logic was recognized as early as the mid-1970s. The ambiguity encountered during the illness diagnostic process has repeatedly been the subject of application of fuzzy set theory in this sector. The greatest and most helpful explanations of clinical symptoms frequently include language concepts that are inevitably ambiguousAdlassing [1986].
Fuzzy mathematics seeks to derive exact meaning from erroneous information by capturing ambiguity in real life. It is a valuable tool for decision-making systems. Using the fuzzy set paradigm, several ways have been created to imitate medical diagnostic procedures. The basic principle behind a medical diagnosis is to associate a patient's symptoms or signals with potential illnesses based on the expert's medical knowledge. According to Sanchez [1979], Meenakshi and M [2011], Elizabeth and Sujatha.L [2013], Ravi.J [2022] and Raich and Dalal [2009] is approach demonstrates the doctor's medical skill as a blurry association between symptoms and illnesses. The method to medical diagnostics by employing an interval-valued fuzzy matrix as a representation. The another approach of medical diagnosis by utilising a triangular fuzzy membership matrix representation. Saravanan and Prasanna [2016] presented a fuzzy matrices application for use in medicine that utilised the idea network and concept matrices. Raich and Dalal [2009] employed fuzzy matrices for the first time in diabetes research.
In this study, we employed IRFM to improve medical diagnostic accuracy Klir and Yuan [1995]. This mathematical model produces diagnoses based on the expertise and experience of the 30 doctors. We created a differentiating strategy for studying indication relationships for diagnosis, which can be described as non-symptom indication non-occurrence indication conformability indication Gupta [1976]. Our method is reasonably accurate, as evidenced by a 95% confidence between the genuine diagnoses supplied by physicians and the diagnostic conclusion produced by our algorithm.

2 Research method

This section shows the consists of the following elements:

2.1 Medical terms:

The expertise of physicians is depicted as a hazy relationship between symptoms and illnesses. There are two kinds of hazy relationships between symptoms and diseases:

(i). **An incidence relation** r_i

It describes the possibility or proclivity of a symptom manifesting when a specific condition is present, i.e., how frequently does the symptom I occur with disease p.

(ii). **A comfortability relation** r_j

It denotes how well the symptoms differentiate between diseases, or how strongly symptom I verifies disease j.

The distinction between occurrence and conformability is significant because, whereas a symptom is present in many diseases, its occurrence and conformability differ depending on the condition.The above-mentioned correlations were discovered using medical records from an expert.

2.2 Intuitionistic robust fuzzy matrices (IRFM)

Then the membership function of A and B is defined as,

$$A\blacksquare B = \left\{max\left[min\left(\frac{\sigma_{ij}\left(r_1\right)+\sigma_{jk}\left(r_1\right)}{2}\right)\right], max\left[min\left(\frac{s_{ij}\left(r_2\right)+s_{jk}\left(r_2\right)}{2}\right)\right]\right\}$$

If $s_{ij}\left(r_2\right)$ = $s_{jk}\left(r_2\right)$ = 0 for all I,j,k then,

$$A\blacksquare B = \left\{max\left[min\left(\frac{\sigma_{ij}\left(r_1\right)+\sigma_{jk}\left(r_1\right)}{2}\right)\right], 0\right\}$$

$$A\blacksquare B = \left\{max\left[min\left(\frac{a_1+b_1}{2}\right), \left(\frac{a_2+b_2}{2}\right), \left(\frac{a_3+b_3}{2}\right), \ldots, \left(\frac{a_n+b_n}{2}\right)\right], 0\right\}$$

Let D represent a grouping of specific illnesses, S represent a grouping of symptoms, and P represent a grouping of persons in need of a diagnosis. According to the fuzzy relation rs(p, s) (where pm, sn) membership grades, the set PS is supposed to indicate the degree to which the symptom s is present in the patient p. On the set S, D, the fuzzy relation ri (s, d) = ri (m, n) is defined, where sS, dD denotes the recurrence frequency of symptoms s with sickness d. The same set defines the fuzzy relation rj, which shows how strongly a symptom (s) predicts the presence of an illness (d). A fuzzy relation rj is also formed on the same set, where *rj (p, d)= r2(n,p)* denotes the strength with which a symptom (s) supports the occurrence of an illness (d). Using relations rs, ri, and rj, the following four alternative indicator relations supplied on set P×D are computed:

(i).Relationship between the two $r_1 = r_s \blacksquare r_i$

(ii).Conformability indication relation $r_2 = r_s \blacksquare r_j$

$$r_s = \begin{array}{c} \\ p_1 \\ p_2 \end{array} \begin{array}{c} \begin{array}{ccc} s_1 & s_2 & s_3 \end{array} \\ \begin{bmatrix} 0.2 & 0.4 & 0.1 \\ 0.5 & 0.2 & 0.1 \end{bmatrix} \end{array} \qquad r_1 = \begin{array}{c} \\ s_1 \\ s_2 \\ s_3 \end{array} \begin{array}{c} \begin{array}{cc} d_1 & d_2 \end{array} \\ \begin{bmatrix} 0.1 & 0.3 \\ 0.7 & 0.3 \\ 0.2 & 0.7 \end{bmatrix} \end{array}$$

$$R_1 = \begin{array}{c} \\ p_1 \\ p_2 \end{array} \begin{array}{c} \begin{array}{cc} d_1 & d_2 \end{array} \\ \begin{bmatrix} 0.2 & 0.15 \\ 0.1 & 0.15 \end{bmatrix} \end{array}$$

(iii). Non-occurrence Occurrence indication relation indication relation $r_3 = r_s \blacksquare (1 - r_i)$
(iv). Non-symptom indication relation $r_4 = r_i \blacksquare (1 - r_j)$
The max-min product of fuzzy matrices is used to compose fuzzy relations.
Example 1
Let D= $\{d_1, d_2\}$, S= $\{s_1, s_2, s_3\}$, P= $\{p_1, p_2\}$
Let r*1 = rs* ■ *ri* So for every i=1, 2 and j= 1, 2, r_1(pi, dj) = max{min{ Rs(p_i, s), r_1(s, dj)}}**sϵS**
Example 2
Let $r_1(p_1,d_1)$ = max{min{0.2,0.1}/2, min{0.4,0.7}/2, min{0.1,0.2}/2} = max{0.05, 0.2, 0.15} = 0.2. Similarly, $r_1(p_i, d_j)$ for every *i* and *j*. Hence, we get Other indication relations are calculated in the same way.

2.3 Hypertension overview

A blood pressure reading of 120/80 mmHg or less is considered normal. You may aim to keep your blood pressure in a healthy range every day, regardless of your age. One of the most dangerous elements of high blood pressure is that you may be unaware of it. In reality, one-third of persons with high blood pressure are unaware of their condition. This is because indications of high blood pressure are uncommon until blood pressure is quite high. Regular blood pressure checks are the best way to discover if your blood pressure is too high. You may also monitor your blood pressure at home. This is especially important if someone in your family has high blood pressure. I regularly suffer from headaches. Headaches and nosebleeds are not always signs of high blood pressure. This is feasible when blood pressure increases above 180/120, as it does during a hypertensive crisis.
2.3.1 There are two kinds of hypertension.

(i). The primary (essential) hypertension The most patient instances of high blood pressure have no known cause. Primary (essential) hypertension is a form of high blood pressure that appears gradually over time.
(ii). Secondary hypertension Some people develop high blood pressure as a result of a more serious condition. Secondary hypertension, a more severe variant of primary hypertension, is a kind of high blood pressure that develops suddenly. Secondary hypertension can be caused by a variety of medical conditions and medications, including obstructive sleep apnea, kidney disease, adrenal cancer, and thyroid problems. Since birth, your body has had certain blood vessel anomalies. Drugs include birth control pills, allergy and cold treatments, decongestants, over-the-counter pain relievers, and some prescription prescriptions. Illicit drugs include amphetamines and cocaine.

Disease *1: Heart attack or stroke or Heart failure.*

Atherosclerosis, or artery hardening and thickening, can lead to heart attacks, strokes, and other complications. To pump blood against the increased pressure in your veins, your heart must work harder. As a result, the walls of the heart's pumping chamber thicken (left ventricular hypertrophy) (left ventricular hypertrophy). Heart failure may occur if the developing muscle is unable to pump enough blood to meet your body's demands.

Disease *2: Aneurysm is a weakening and narrowing of the blood arteries in your kidneys.*

High blood pressure can weaken and bulge your blood vessels, resulting in an aneurysm. A ruptured aneurysm can endanger one's life.

Disease *3: Eye blood vessel enlargement, constriction, or rupture; metabolic syndrome; memory or cognitive problems; dementia*

As a result, several organs may be unable to operate effectively. This might result in vision loss. This syndrome is characterised by a larger waist, greater triglyceride levels, lower HDL cholesterol (the "good" cholesterol), higher blood pressure, and higher insulin levels. All of these disorders raise your chances of acquiring diabetes, heart disease, or stroke. Uncontrolled high blood pressure may impair your ability to think, remember, and learn. Patients with high blood pressure have difficulty grasping and recalling their ideas. One type of dementia is caused by clogged or restricted arteries, which limit the quantity of blood that can reach the brain. A stroke can cause vascular dementia by cutting off blood supply to the brain.

2.3.2 Symptoms of Severe High Blood Pressure

If your blood pressure is really high, you should be aware of the following symptoms:

Symptom S_1: Severe headaches
Symptom S_2: Nosebleed
Symptom S_3: Fatigue or confusion

Symptom S_4: Vision problems
Symptom S_5: Chest pain
Symptom S_6: Difficulty breathing
Symptom S_7: Irregular heartbeat
Symptom S_8: Blood in the urine
Symptom S_9: Pounding in your chest, neck, or ears.
People sometimes feel that other symptoms may be related to high blood pressure, however it is possible that they are not:
Symptom S_{10}: Dizziness
Symptom S_{11}: Nervousness
Symptom S_{12}: Sweating
Symptom S_{13}: Trouble sleeping
Symptom S_{14}: Facial flushing
S represents the collection of all symptoms.
S=$(s_1,s_2,s_3,s_4,s_5,s_6,s_7,s_8,s_9,s_{10},s_{11},s_{12},s_{13},s_{14}\}$
Let D represent the whole collection of illnesses, D=$(d_1,d_2,d_3\}$.
Let P represent the precise universal set of all Patients, D=$(p_1,p_2,p_3\}$.

3 Experimental study

As a case study, we picked a serious condition with three types of symptoms, such as hypertension. These ailments were chosen because, according to WHO (World Health Organization) figures, they are the most frequent in India. According to WHO data from 2016, the adult prevalence of hypertension in India is 24%. Following the selection of the three illnesses, we chose 14 symptoms that are commonly found in people with those ailments.Then, with the help of medical specialists, we constructed a medical knowledge base. We looked at the prevalence of a symptom in a linked sickness and the confirmation of a disease from a connected symptom as we built the database.The phrase ”symptom emergence in the setting of the associated sickness” is related to the question ”How frequently does a symptom appear in the presence of a disease?” When a certain sickness is present, the average or frequency of symptom presentation is high. It alludes to the question, ”To what degree do symptoms strongly confirm disease d?” A symptom's discriminating power in confirming the presence of an illness is defined by its ability to confirm the presence of a disease based on its own observations. We distributed blank charts (Appendix) to 30 randomly selected specialist doctors in Namakkal district, Tamilnadu, India, in order to build a knowledge base that includes the presence of a symptom in the linked illness and confirmation of a disease based on a specific symptom. We asked the clinicians to keep track of how many patients with the relevant disease exhibited each symptom out of 100.

For example, if a doctor checks 100 diabetic patients and finds ”severe thirst” in 80 of them, he or she must document 90 cases of excessive thirst in hypertension. To determine the presence of a disease, we asked the doctors to specify the percentage of the time that they detect the relevant symptom in the patient. These statistics should be multiplied by 100 such that they fall between [0, 1] and indicate an 80% chance of anaemia. As shown in table 1, we calculated the mean of the information obtained to estimate the data’s central tendency. We awarded membership ratings to each of the 14 fuzzification symptoms based on the severity or frequency of the patient’s condition. The following are the grades:

Table 1: A patient’s symptoms according to their frequency or intensity

Sr. No.	**Symptom**	**Cont.severe**	**Cont.mild**	**Occa.**	**Rare**	**No**
1.	Severe headaches	1.0	0.75	0.50	0.25	0.00
2.	Nosebleed	1.0	0.75	0.50	0.25	0.00
3.	Fatigue or confusion	1.0	0.75	0.50	0.25	0.00
4.	Vision problems	1.0	0.75	0.50	0.25	0.00
5.	Chest pain	1.0	0.75	0.50	0.25	0.00
6.	Difficulty breathing	1.0	0.75	0.50	0.25	0.00
7.	Irregular heartbeat	1.0	0.75	0.50	0.25	0.00
8.	Blood in the urine	1.0	0.75	0.50	0.25	0.00
9.	Pounding in your chest, neck, or ears.	1.0	0.75	0.50	0.25	0.00
10.	Dizziness	1.0	0.75	0.50	0.25	0.00
11.	Nervousness	1.0	0.75	0.50	0.25	0.00
12.	Sweating	1.0	0.75	0.50	0.25	0.00
13.	Trouble sleeping	1.0	0.75	0.50	0.25	0.00
14.	Facial flushing	1.0	0.75	0.50	0.25	0.00

D denotes ”disease 1, disease 2, disease 3,” and S denotes ”set of 14 symptoms, s1, s2,..., s14.” Our diagnostic technique will be demonstrated using three hypothetical instances. As a result, P = p_1, p_2, and p_3, and we’ve built a fuzzy relation rs on the set PS in which membership grades r_s(p, s) (where p_P, sS reflect the severity or frequency of symptoms identified in these three people) suggest:

Table 2: Expert knowledge-base obtained in a robust manner

SSr. No.	Symptom	Disease 1		Disease 2		Disease 3	
		i	j	i	j	i	j
1.	Severe headaches	**0.16**	0.07	**0.50**	0.37	**0.51**	0.41
2.	Nosebleed	**0.20**	0.10	**0.89**	0.80	**0.09**	0.05
3.	Fatigue or confusion	**0.86**	0.74	**0.08**	0.05	0.05	**0.07**
4.	Vision problems	**0.47**	0.36	**0.17**	0.11	**0.07**	0.03
5.	Chest pain	**0.39**	0.38	**0.16**	0.11	0.08	**0.09**
6.	Difficulty breathing	**0.02**	0.02	**0.49**	0.37	**0.80**	0.70
7.	Irregular heartbeat	**0.52**	0.45	**0.25**	0.19	**0.37**	0.27
8.	Blood in the urine	**0.16**	0.07	**0.50**	0.37	**0.51**	0.41
9.	Pounding in your chest, neck or ears.	**0.71**	0.64	**0.85**	0.75	**0.33**	0.22
10.	Dizziness	0.17	**0.19**	**0.52**	0.43	**0.03**	0. 00
11.	Nervousness	**0.79**	0.66	**0.60**	0.54	0.13	**0.79**
12.	Sweating	**0.19**	0.15	**0.39**	0.27	**0.04**	0.03
13.	Trouble sleeping	**0.34**	0.24	0.61	**0.64**	**0.10**	0.07
14.	Facial flushing	**0.15**	0.05	**0.55**	0.54	**0.04**	0.02

Note: i = Occurrence of a symptom & j =Confirmation of a disease

Table 3: The presence of a disease is confirmed by the symptoms

Sr. No.	SYMPTOMS	P_1	P_2	P_3
1.	Severe headaches	0.51	0.15	0.00
2.	Nosebleed	**1.00**	0.00	0.51
3.	Fatigue or confusion	0.15	**1.00**	**1.00**
4.	Vision problems	0.00	0.15	0.51
5.	Chest pain	**1.00**	0.51	0.00
6.	Difficulty breathing	0.00	**1.00**	0.26
7.	Irregular heartbeat	0.00	0.00	0.00
8.	Blood in the urine	0.00	0.15	0.51
9.	Pounding in your chest, neck, or ears.	0.51	0.26	**1.00**
10.	Dizziness	0.15	0.00	0.00
11.	Nervousness	**1.00**	0.00	0.51
12.	Sweating	0.26	0.00	0.00
13.	Trouble sleeping	0.51	0.00	**1.00**
14.	Facial flushing	**1.00**	0.51	0.15

$$R1 = Rs \circ Ri$$

$$R_1 = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{ccc} D_1 & D_2 & D_3 \end{array} \\ \begin{pmatrix} 0.51 & 0.50 & 0.16 \\ 0.10 & 0.08 & 0.02 \\ 0.08 & 0.37 & 0.05 \end{pmatrix} \end{array}$$

$$R2 = Rs \circ Rj$$

$$R_2 = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{ccc} D_1 & D_2 & D_3 \end{array} \\ \begin{pmatrix} 0.57 & 0.52 & 0.58 \\ 0.55 & 0.56 & 0.53 \\ 0.52 & 0.59 & 0.53 \end{pmatrix} \end{array}$$

$$R_3 = R_j \circ (1-R_i)$$

$$R_3 = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{ccc} D_1 & D_2 & D_3 \end{array} \\ \begin{pmatrix} 0.65 & 0.66 & 0.76 \\ 0.76 & 0.66 & 0.65 \\ 0.65 & 0.76 & 0.65 \end{pmatrix} \end{array}$$

Table 4: The existence of illness is confirmed by the symptoms 'd'

SSr. No.	**Symptom**	**r_i**			**r_j**		
		Disease 1	**Disease 2**	**Disease 3**	**Disease 1**	**Disease 2**	**Disease 3**
1.	Severe headaches	0.16	0.50	0.51	0.07	0.37	0.41
2.	Nosebleed	0.20	0.89	0.09	0.10	0.80	0.05
3.	Fatigue or confusion	0.86	0.08	0.07	0.74	0.05	0.05
4.	Vision problems	0.47	0.17	0.07	0.36	0.11	0.03
5.	Chest pain	0.39	0.16	0.09	0.38	0.11	0.08
6.	Difficulty breathing	0.02	0.49	0.80	0.02	0.37	0.70
7.	Irregular heartbeat	0.52	0.25	0.37	0.45	0.19	0.27
8.	Blood in the urine	0.16	0.50	0.51	0.07	0.37	0.41
9.	Pounding in your chest, neck, or ears.	0.71	0.85	0.33	0.64	0.75	0.22
10.	Dizziness	0.19	0.52	0.03	0.17	0.43	0. 00
11.	Nervousness	0.79	0.60	0.79	0.66	0.54	0.13
12.	Sweating	0.19	0.39	0.04	0.15	0.27	0.03
13.	Trouble sleeping	0.34	0.64	0.10	0.24	0.61	0.07
14.	Facial flushing	0.15	0.55	0.04	0.05	0.54	0.02

Using the relations R_s, R_i, and R_j, we developed four alternative indicator relations, namely R_1, R_2, R_3, and R_4.

We may get a number of diagnostic conclusions from these four indicator associations. For example, if (p, d) = 1, we can validate patient p's diagnosis of disease d. Despite the fact that none of our four patients had this condition, it appears to suggest that disease d_1 is strongly confirmed for patient p1, sickness d_2 is highly confirmed for patient p_3, and disease d^3 has a 90% probability of occurring for patient p_2.

Using the standards described above, we may conclude that patient p1 has high blood pressure, patient p3 has hypertension, and patient p2 has anaemia and mild hypertension. We utilised our programme to diagnose 50 cases using this method, and we compared our findings to physician diagnoses. In 43 of 50 instances of diabetes, anaemia, and hypertension, our diagnosis and the doctors' diagnosis were identical. The degree of accuracy of the model may be calculated as follows: ***Finding of Accuracy*** = [(The number of accurate data)/ (The number of total data)]*100

= (86/90)*100 = 95.55%

As a consequence, the Chi-square test, often known as the "goodness of fit test," was used to check that our mathematical model was statistically sound. Before utilising the Chi-square test, we assumed that the medical professionals' diagnoses were completely correct.

H_0: The medical professionals' and our diagnoses are identical.
H_1: Our diagnosis differs from that of the physicians.
Aceptance level (α) = 0.05 & DF= 2 at Critical value= 5.991

Table 5: Contingency Table for Chi- square test

	Observed	**Expected**
Stress	50	50
Anxiety	47	50
Hypertension	46	50

The Chi-square test calculation formula is as follows: $\chi^2 = \Sigma\ [(O - E)^2 / E]$ where O is observed frequency, E is expected frequency.

1. where E is the expected frequency and O is the actual frequency
2. Using the contingency table, we calculated the chi-square (**??**) as follows: (χ^2) as ,

χ^2 = ((50-50)²/50) + ((47-50)²/50) + (46-50)²/50)
= 0.50.

Because 0.50 is greater than 5.991, or the ”2” critical value, the null hypothesis H0 is accepted. We got to the conclusion that the physicians’ and our diagnosis are similar.

4 Conclusions

Fuzzy logic can be used to improve the precision and verification of medical diagnosis. The diagnosis offered by the ”max-min” composition of fuzzy relations built using the ”mean” of the physicians’ data matches to the physicians’ diagnosis. According to the chi-square test, which measures dependability, the proposed mathematical model gets a reliability score of 95.55%. This study’s innovative technique tries to quantify the core principle behind the diagnostic procedure. This technique distinguishes itself by thoroughly investigating the connections between the indicators, particularly the ”non-symptom indication-non-occurrence indication-conformability indication.”

This method of preserving specialised information allows patients and general practitioners to access it. While it does not replace a doctor’s diagnosis, it does help to reinforce it. The diagnostic implications of this mathematical model might be considered as a second opinion to the doctor’s diagnosis. This mathematical approach is mostly employed to improve diagnostic accuracy.

The main flaw of the proposed mathematical model is that it will be off-target if a patient supplies incorrect inputs, resulting in incorrect diagnostic findings. As more doctor data is collected, software and an Android app will be created in the future. The development of new algorithms to improve accuracy is one of the future goals.

In recent trends they are given for 95 percent of accurate results. But our proposed concept given more than 95 percent accuracy compared to other existing model. Also our proposed method performed all direction (360o). In future work we are trying to write the coding with the help of Python and analyze the data for the betterment of the concept.

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