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MEDICAL DIAGNOSIS OF UNIDENTIFIED FEVER USING FUZZY RELATIONAL MATRICES

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ABSTRACT

This paper gives a brief survey on "MEDICAL DIAGNOSIS OF UNIDENTIFIED FEVER USING FUZZY RELATIONAL MATRICES". In this paper the concept of fuzzy medical diagnosis, method of application of fuzzy relational matrices and the graphical representation of the patients to be affected by the diseases are discussed. Conclusion and some suggestions are also discussed.

Keywords: *fuzzy medical diagnosis, method of application of fuzzy relational matrices, and the graphical representation of the patients to be affected by the diseases.*

2010 Mathematics Subject Classification: *54A40-03E72.*

1. INTRODUCTION

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth values between "completely true" and "completely false". It was introduced by Zadeh [10] in 1965 as a means to model the uncertainty of natural language.

By a fuzzy matrix, we mean a matrix over a fuzzy algebra. A Boolean matrix is a special case of fuzzy matrix with entries from the set {0, 1}. In practice, fuzzy matrices have proposed to represent fuzzy relations in a system based on fuzzy set theory. A fuzzy matrix can be interpreted as a binary fuzzy relation. In a recent work, Phan and Chen [7] described the application of fuzzy logic to a healthcare diagnostic system. The relational fuzzy matrix was studied in [6].

Unidentified fever is a dangerous disease that is caused due to unhygienic conditions. It is febrile illness that affects infants, young children and adults with symptoms like high fever, cold, joint pain, treatment, moreover there is no vaccine to prevent the people from the disease. Symptoms of this infection are rapid and violent to patients in a short time. The diagnosis of unidentified fever in early phase of illness helps in designing effective public health management and biological surveillance strategies. In this paper, we find out the certainty whether a patient having some specified symptoms suffers from any one of a set of suspected diseases. This paper work is based on a surveys carried out in Panchanthangiaeri in salem.

2. PRELIMINARIES

Definition 2.1[3]: A fuzzy set A in X is a mapping with domain X and values in [0, 1].

Definition 2.2[3]: A fuzzy relation is a fuzzy set defined on the Cartesian product of crisp sets $X_1, X_2, \ldots, X_n$. The membership grade indicates the strength of the relation present between the elements of the tuple.

Definition 2.3[3]: A relation among the crisp sets $X_1, X_2, \ldots, X_n$ is a subset of the cartesian product $\prod_{i \in N_n} X_i$. It is denoted by $R(X_1, X2, \ldots, X_n)$. Thus $R(X_1, X_2, \ldots X_n) \subseteq X1 \times X2 \times \ldots \times X_n$. A relation and its characteristic function is denoted by

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$$R(x_1, x_2, .. x_n) = \begin{cases} 1 & iff\ (x_1, x_2, .. x_n) \in R \\ 0 & otherwise \end{cases}$$

Relations between two sets are called binary.
Relations between three sets are called ternary.
Relations between four sets are called quaternary.
Relations between n sets are called n-dimensional.

Definition 2.4[3]: Given a fuzzy relation R(X, Y) its domain is a fuzzy set on X, dom R, whose membership function is defined by dom $R(x) = \max_{y \in Y} R(x, y)$ for each $x \in X$.

Definition 2.5[3]: The range of R(X, Y) is a fuzzy relation on Y, ran R, whose membership function is defined by ran

$$R(Y) = \max_{x \in X} R(x,y) \text{ for each } y \in Y.$$

Definition 2.6[3]: The height of a fuzzy relation R(X, Y) is a number, h(R) defined by

$$h(R) = \max_{y \in Y} \max_{x \in X} R(x, y).$$

Definition 2.7[3]: Consider two binary fuzzy relations P(X, Y) and Q(X, Y) with a common set Y. The standard composition of these relations, which is denoted by P(X, Y)∘ Q(Y, Z) produces a binary relation R(X, Z) on X×Z defined by

$$R(x, z) = [P \circ Q] (x, z) = \max_{y \in Y} \min [P(x, y), Q(y, z)] \text{ for all } x \in X \text{ and } z \in Z.$$

Definition 2.8[3]: A crisp binary relation R(X, X) that is reflexive, symmetric and transitive is called an equivalence relation (or) similarity relation.

Definition 2.9[3]: A crisp relation R(X, X) is reflexive if and only if (x, x) ∈ R for each x ∈ X, that is, if every element of X is related to itself.A fuzzy relation R(X, X) is reflexive if and only if R(x, x) = 1 for all x ∈ X.

Definition 2.10[3]: A crisp relation R(X, X) is symmetric if and only if for every (x, y) ∈ R, it is also the case that (y, x) ∈ R where x, y ∈ X. Thus whenever an x is related to an element y through a symmetric relation, y is also related to x.A fuzzy relation is symmetric if and only if R(x, y) = R(y, x) for all x, y ∈ X.

Definition 2.11[3]: A crisp relation R(X, X) is transitive if and only if (x, z) ∈ R whenever both (x, y) ∈ R and (y, z) ∈ R for at least one y ∈ X. In other words, the relation of x to y and of y to z implies the relation of x to z in a transitive relation.

A fuzzy relation R(X, X) is transitive if $R(x, z) > \max_{y \in Y} \min[R(x, y), R(y, z)]$ is satisfied for each pair $(x, z) \in X^2$.

Definition 2.12[3]: Given a relation R(X, X) its transitive closure $R_T(x, x)$ can be determined by a simple algorithm that consists of the following three steps.

1. R' = R U (R∘R)
2. If R' ≠ R, make R = R' and goto step 1.

When max-min composition and the max operator for set union are used, we call R_T the transitive max-min closure.

Definition 2.13[3]: A binary relation R(X, X) that is reflexive and symmetric is usually called a compatibility relation (or) tolerance relation when R(X, X) is a reflexive and symmetric fuzzy relation, it is sometimes called a proximity relation.

Definition 2.14[3]: A fuzzy relation μ on X is said to be reflexive if μ(x, x) = 1 for all x ∈ X.

Definition 2.15[3]: A fuzzy relation μ on X is said to be symmetric if μ(x, y) = μ(y, x) for all x, y ∈ X.

Definition 2.16[3]: If μ_1 and μ_2 are two relations on X, then their max- product composition denoted by $\mu_1 \circ \mu_2$ is defined as

$$\mu_1 \circ \mu_2 (x, y) = \max_{z} \{\mu_1(x, z), \mu_2(z, y)\}$$

Definition 2.17[3]: If $\mu_1 = \mu_2 = \mu$ say and $\mu \circ \mu \leq \mu$ then the fuzzy relation μ is called transitive.

Definition 2.18[3]: A fuzzy binary relation μ in X is called similarity relation if μ is reflexive, symmetric and transitive.

Definition 2.19[6]: Let $\mathcal{F}_{mn}$ denote the set of all m × n matrices over $\mathcal{F}$. If m = n, in short, we write $\mathcal{F}_n$. Elements of $\mathcal{F}_{mn}$ are called as membership value matrices, binary fuzzy relation matrices (or) in short, fuzzy matrices. Boolean matrices over the Boolean algebra {0, 1} are special types of fuzzy matrices.

Definition 2.20[6]: Let $A = (a_{ij}) \in \mathcal{F}_{mn}$. Then the element $a_{ij}$is called the (i, j)th entry of A. Let $A_{i*}(A_{*j})$ denote the i^{th} row (j^{th}column) of A.

Definition 2.21[6]: Then n×m zero matrix O is the matrix all of whose entries are zero. Then n×n identity matrix I is the matrix (δ_{ij}) such that $\delta_{ij}= 1$ if i = j and $\delta_{ij} = 0$ if $i \neq j$.
Then n×m universal matrix J is the matrix all of whose entries are 1.

Definition 2.22[6]: Let $A = (a_{ij}) \in \mathcal{F}_{mn}$ and $B = (b_{ij}) \in \mathcal{F}_{mn}$. Then the matrix
$A + B = (\sup\{ a_{ij}, b_{ij} \}) \in \mathcal{F}_{mn}$ is called the sum of A and B.

Definition 2.23[6]: Let $A = (a_{ij}) \in \mathcal{F}_{mn}$ and $c \in \mathcal{F}$ then the fuzzy multiplication, that is, scalar multiplication with scalars restricted to $\mathcal{F}$ is defined as$cA = (\inf\{c,a_{ij}\}) \in \mathcal{F}_{mn}$

Definition 2.24[6]: For $A = (a_{ij}) \in \mathcal{F}_{mp}$and $B = (b_{ij}) \in \mathcal{F}_{pn}$, the max-min product
$AB = (\mathrm{Sup}\{\inf\{a_{ik},b_{kj}\}\}) \in \mathcal{F}_{mn}$. The product AB is defined if and only if the number of columns of A is the same as the number of rows of B; A and B are said to be conformable for the multiplication.

3. MAIN RESULT

In this section we discuss about the fuzzy Medical Diagnosis method, the method of application of Fuzzy relational matrices and the Fuzzy relational matrix to the problem.

3.1.1. Fuzzy Medical Diagnosis: Medical artificial intelligence is primarily concerned with the construction of AI programs that perform diagnosis and make therapy recommendations. Unlike medical applications based on another programming method such as purely statistical and probabilistic methods, medical AI programs are based on symbolic models of disease entities and their relationship to patient factors and clinical manifestations. Medical expert systems contain medical knowledge, usually about very specifically defined task, and are able to reason with data from individual patients to come up with reasoned conclusions. Here we used collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data. Leung, Lau and Kwong [5] describe a general structure of a fuzzy system to be used as a core part of a fuzzy application. The structure can be summarized in the following four steps, carried out in order:

(1) Fuzzification: the membership functions defined on the input variables are applied to their actual values to determine the degree of truth for each rule premise.

(2) Inference: the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. This result in one fuzzy subset to be assigned to each output variable for each rule.

(3) Composition: all of the fuzzy subsets assigned to each output variable are combined together to form a single fuzzy subset for each output variable.

(4) Defuzzification: is an optional step which is used when it is useful to convert the fuzzy output set to a crisp number.

Many defuzzification methods are available [3], such as MAXMIN, MIN MAX, MAX PRODUCT, MAX AVERAGE., however the MAXMIN method is used to calculate the product of fuzzy matrices which gives the results that match with doctor's diagnosis.

The developed fuzzy system prototype would query the user for the relevant patient symptoms. The strength of each single symptom is specified by a fuzzy value such as low, moderate, and high for those symptoms that cannot be measured quantitatively. Other measurable symptoms such as the temperature, were input directly as numeric values that would be properly fuzzified. The prototype proceeds through the above-mentioned inference process and provides a percent value for the certainty of presence for each one of the considered diseases.

3.2.2 The method of application of Fuzzy relational matrices. The field of medicine is one of the most interesting area of applications for fuzzy set theory. In the discrimination analysis, the symptoms are ranked according to the grade of discrimination of each disease by a particular symptom and are represented in the form of a gradation chart.

The experience of the expert physician regarding the set of considered diseases D is captured and two matrices are created which contain values from [0, 1]. These matrices are fuzzy matrices. The size of matrices depends on number of symptoms and number of diseases. Also when doctor examines the patient then each symptom is considered and depending on the intensity of the symptom in that patient the gradation of symptom observed in that patient is entered.

For this user has to prepare "Reference chart". Reference chart can be developed with the help of expert doctors. So we create matrices R_o and R_c which denote occurrence level and confirmation level of the symptoms corresponding to selected diseases and reference chart which consists of information about gradation of symptoms occurring in the patients, using expert knowledge base that is used here. Using this knowledge base four matrices which are named as

1) Occurrence indication matrix
2) Confirmation indication matrix
3) Non-occurrence indication matrix
4) No symptom indication matrix are formed. These matrices are calculated by use of concept of fuzzy relational matrices. These four matrices are used to perform diagnosis.

3.2.3. Case Study

The unidentified fever can lead to any disease such as swine flu, Dengue, malaria, viral, etc. Here we have considered three diseases namely swine flu, Dengue and malaria which are very threatening diseases in not only rural area but in cities also. There are 17 symptoms that are found in these three diseases and some of these are common in both. Medical practitioners were consulted and knowledge base was generated about occurrence and confirmation level. It is as follows.

Code	symptoms	Dengue		Swine flu		Malaria	
		Occ	Con	Occ	Con	Occ	Con
1	Fever	0.94	0.31	0.93	0.17	0.95	0.23
2	Head ache	0.87	0.18	0.76	0.12	0.78	0.16
3	Fatigue	0.69	0.22	0.83	0.18	0.72	0.20
4	Vomiting	0.3	0.15	0.23	0.13	0.28	0.12
5	Nausea	0.37	0.22	0.1	0.0	0.30	0.11
6	Pain behind the eyes	0.5	0.22	0.1	0.0	0.2	0.03
7	Severe joint pain	0.77	0.54	0.18	0.05	0.15	0.10
8	Skin rash	0.52	0.34	0.04	0.01	0.02	0.01
9	Mild bleeding	0.35	0.38	0.01	0.0	0.01	0.0
10	Cough	0.23	0.03	0.75	0.12	0.25	0.11
11	Sore throat	0.06	0.0	0.78	0.17	0.28	0.01
12	Runny nose	0.06	0.0	0.46	0.16	0.05	0.0
13	Body aches	0.43	0.04	0.68	0.27	0.54	0.25
14	Chills	0.24	0.08	0.45	0.11	0.47	0.2
15	Loss of appetite	0.26	0.05	0.72	0.27	0.35	0.13
16	Aching muscles	0.45	0.1	0.58	0.16	0.64	0.15
17	Diarrhoea	0.02	0.0	0.25	0.32	0.35	0.23

Here **Occ** refers to Occurrence of the disease and **Con** refers to the confirmation of the disease.

To specify the symptoms of a patient, the fuzzy values are selected from the set.

{Very low, Low, Moderate, High, Extreme}

The gradation chart is also created, which will help us to enter grades of each symptom when patient is checked.

Gradation chart

Level of symptom	**Range of values**
Extreme	1 – 0.8
High	0.8 – 0.6
Moderate	0.6 – 0.4
Low	0.4 – 0.2
Very low	0.2 – 0.0

Let P1, P2, P3, P4, P5 be the five patients from Panchanthangiaeri in Salem. Using gradation chart and considering their responses to questions asked about each symptom and measurements of temperature etc., gradation of each symptom is entered in matrix. It is 3×17 matrix as it is about 5 patients and the number of symptoms is 17. This matrix is denoted by R_s.**MATRIX FOR RELATION R_s**

$$\begin{array}{c} P1 \\ P2 \\ P3 \\ P4 \\ P5 \end{array}\begin{pmatrix} 0.2 & 0.5 & 0.4 & 0.2 & 0.5 & 1 & 0.5 & 0.6 & 0.2 & 0.2 & 0.2 & 0.5 & 0.0 & 0.2 & 0.1 & 0.0 & 0.1 \\ 0.4 & 0.3 & 0.2 & 0.0 & 0.3 & 0.2 & 0.4 & 0.2 & 0.3 & 0.2 & 0.1 & 0.7 & 0.5 & 0.1 & 0.2 & 0.7 & 0.2 \\ 0.2 & 0.0 & 0.2 & 0.2 & 0.5 & 0.0 & 0.2 & 0.0 & 0.0 & 0.2 & 0.0 & 0.0 & 0.2 & 0.0 & 0.2 & 0.0 & 0.0 \\ 0.3 & 0.1 & 0.3 & 0.5 & 0.0 & 0.2 & 0.3 & 0.1 & 0.3 & 0.1 & 0.2 & 0.3 & 0.4 & 1 & 0.0 & 0.2 & 0.1 \\ 0.2 & 0.1 & 0.2 & 0.3 & 0.1 & 0.0 & 0.2 & 0.2 & 0.0 & 0.2 & 0.0 & 0.0 & 0.22 & 0.0 & 0.1 & 0.0 & 0.2 \end{pmatrix}$$

The occurrence matrix R_o and confirmation matrix R_s are as follows

$$R_o = \begin{pmatrix} 0.94 & 0.93 & 0.95 \\ 0.87 & 0.76 & 0.78 \\ 0.69 & 0.83 & 0.72 \\ 0.3 & 0.23 & 0.28 \\ 0.37 & 0.1 & 0.30 \\ 0.5 & 0.1 & 0.2 \\ 0.77 & 0.18 & 0.15 \\ 0.52 & 0.04 & 0.02 \\ 0.35 & 0.01 & 0.01 \\ 0.23 & 0.75 & 0.25 \\ 0.06 & 0.78 & 0.28 \\ 0.06 & 0.46 & 0.05 \\ 0.43 & 0.68 & 0.54 \\ 0.24 & 0.45 & 0.47 \\ 0.26 & 0.72 & 0.35 \\ 0.45 & 0.58 & 0.64 \\ 0.02 & 0.25 & 0.35 \end{pmatrix} \qquad R_c = \begin{pmatrix} 0.31 & 0.17 & 0.23 \\ 0.18 & 0.12 & 0.16 \\ 0.22 & 0.18 & 0.20 \\ 0.15 & 0.13 & 0.12 \\ 0.22 & 0.0 & 0.11 \\ 0.22 & 0.0 & 0.03 \\ 0.54 & 0.05 & 0.1 \\ 0.34 & 0.01 & 0.01 \\ 0.38 & 0.0 & 0.0 \\ 0.03 & 0.12 & 0.11 \\ 0.0 & 0.17 & 0.01 \\ 0.0 & 0.16 & 0.0 \\ 0.04 & 0.27 & 0.25 \\ 0.08 & 0.11 & 0.2 \\ 0.05 & 0.27 & 0.13 \\ 0.1 & 0.16 & 0.15 \\ 0.0 & 0.32 & 0.23 \end{pmatrix}$$

Thus we have calculated 4 product matrices viz $R1 = R_s \circ R_o$,
$R2 = R_s \circ R_c$, $R3 = R_s \circ (1- R_o)$, $R4 = (1- R_s) \circ R_o$.

Matrix $R1 = R_s \circ R_o$ Matrix $R2 = R_s \circ R_c$

$$\begin{array}{cc} & \begin{matrix} Dengue & Swineflu & Malaria \end{matrix} \\ \begin{matrix} P1 \\ P2 \\ P3 \\ P4 \\ P5 \end{matrix} & \begin{pmatrix} 0.52 & 0.5 & 0.5 \\ 0.43 & 0.46 & 0.64 \\ 0.37 & 0.2 & 0.3 \\ 0.3 & 0.45 & 0.54 \\ 0.3 & 0.23 & 0.28 \end{pmatrix} \end{array} \qquad \begin{array}{cc} & \begin{matrix} Dengue & Swineflu & Malaria \end{matrix} \\ \begin{matrix} P1 \\ P2 \\ P3 \\ P4 \\ P5 \end{matrix} & \begin{pmatrix} 0.5 & 0.18 & 0.2 \\ 0.4 & 0.27 & 0.25 \\ 0.22 & 0.2 & 0.2 \\ 0.3 & 0.27 & 0.25 \\ 0.2 & 0.22 & 0.22 \end{pmatrix} \end{array}$$

Matrix R3 = $R_s \circ (1- R_o)$ Matrix R4 = $(1- R_s) \circ R_o$

$$\begin{array}{cc} & \begin{matrix} Dengue & Swineflu & Malaria \end{matrix} \\ \begin{matrix} P1 \\ P2 \\ P3 \\ P4 \\ P5 \end{matrix} & \begin{pmatrix} 0.5 & 0.5 & 0.8 \\ 0.7 & 0.54 & 0.7 \\ 0.5 & 0.5 & 0.5 \\ 0.76 & 0.55 & 0.53 \\ 0.3 & 0.3 & 0.3 \end{pmatrix} \end{array} \qquad \begin{array}{cc} & \begin{matrix} Dengue & Swineflu & Malaria \end{matrix} \\ \begin{matrix} P1 \\ P2 \\ P3 \\ P4 \\ P5 \end{matrix} & \begin{pmatrix} 0.8 & 0.8 & 0.8 \\ 0.7 & 0.8 & 0.72 \\ 0.87 & 0.78 & 0.8 \\ 0.87 & 0.78 & 0.78 \\ 0.87 & 0.8 & 0.8 \end{pmatrix} \end{array}$$

These four matrices are used to predict the diagnosis.

Rules for Diagnosis
If R3 (p, d)=1 OR R4 (p, d)=1;
{Disease 'd' is not present in patient 'p'}

Else if R2(p, d)=1
{Disease 'd' is confirmed in patient 'p'}

Else if max [R1(p, d),R2(p,d)] < 0.05
{Then disease 'd' is not present in patient 'p'}

Else if 0.05 ≤ max [R1(p, d),R2(p,d)] < 0.3
{Then disease 'd' is present at very low level in patient 'p'}

Else if 0.3 ≤ max [R1(p, d),R2(p,d)] < 0.5
{Then disease 'd' is at low level in patient 'p'}

Else if 0.5 ≤ max [R1(p, d),R2(p,d)] < 0.7
{Then disease 'd' is at moderate level in patient 'p'}

Else if 0.7 ≤ max [R1(p, d),R2(p,d)] < 0.9
{Then disease 'd' is at high level in patient 'p'}

Else if max [R1(p, d),R2(p,d)] ≥ 0.9
{Then disease 'd' is at extreme level in patient 'p'}

CONCLUSION OF CASE STUDY

In matrices R3 & R4, there is no value equal to 1 under Dengue, Swine flu and Malaria. From this we conclude that there is no patient having Dengue, Swine flu and Malaria at extreme level. Hence we have to compare the matrices R1 & R2. After comparing R1 and R2 we come to the following conclusion.

Consider the patient P1.
In matrices R1 and R2

- Under Dengue, 0.52 is maximum. So the patient P1 has Dengue at moderate level.
- Under Swine flu, 0.5 is maximum. So the patient P1 has Swine flu at moderate level.
- Under Malaria, 0.5 is maximum. So the patient P1 has Malaria at moderate level.

Consider the patient P2.
In matrices R1 and R2

- Under Dengue, 0.43 is maximum. So the patient P2 has Dengue at low level.
- Under Swine flu, 0.46 is maximum. So the patient P2 has Swine flu at low level.
- Under Malaria, 0.64 is maximum. So the patient P2 has Malaria at moderate level.

Consider the patient P3.
In matrices R1 and R2

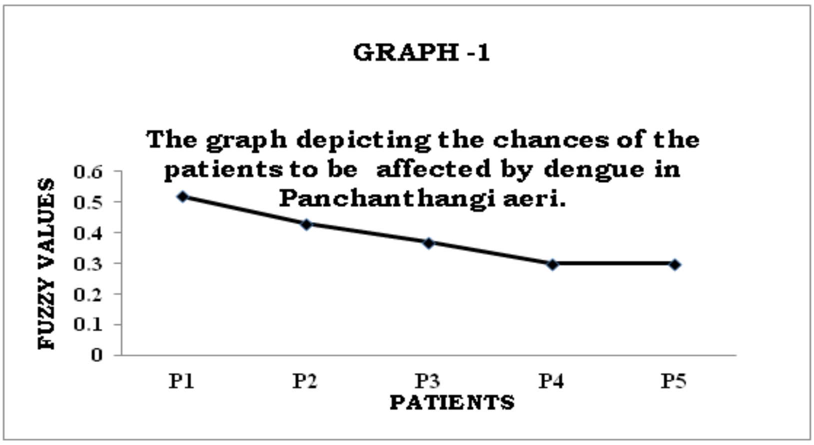
- Under Dengue, 0.37 is maximum. So the patient P3 has Dengue at low level.
- Under Swine flu, 0.2 is maximum. So the patient P3 has Swine flu at very low level.
- Under Malaria, 0.3 is maximum. So the patient P3 has Malaria at low level.

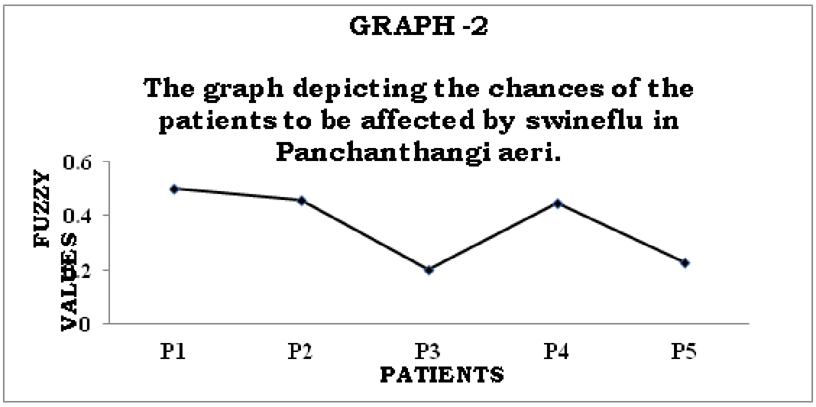
Consider the patient P4.
In matrices R1 and R2

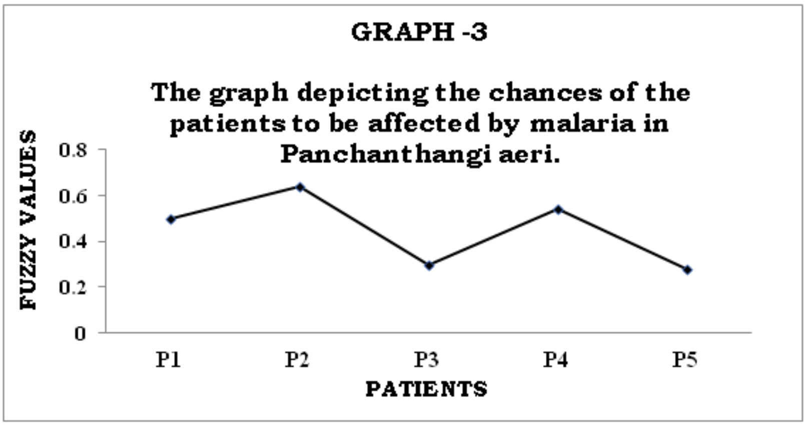
- Under Dengue, 0.3 is maximum. So the patient P4 has Dengue at low level.
- Under Swine flu, 0.45 is maximum. So the patient P4 has swine flu at low level.
- Under Malaria, 0.54 is maximum. So the patient P4 has Malaria at moderate level.

Consider the patient P5.
In matrices R1 and R2

- Under Dengue, 0.3 is maximum. So the patient P5 has Dengue at low level.
- Under Swine flu, 0.23 is maximum. So the patient P5 has Swine flu at very low level.
- Under Malaria, 0.28 is maximum. So the patient P5 has Malaria at very low level.







3.2.4 Conclusion and Suggestions:

1. It is observed from the graph,
    - The patient P1 has more chances to be affected by Dengue.
    - The patient P1 has more chances to be affected by Swine flu.
    - The patient P2 has more chances to be affected by Malaria.
2. Fuzzy logic is a simple and effective technique that can be advantageously used for diagnosis of a wide range of diseases.
3. Simple fuzzy matrix techniques can be used to provide sound diagnosis decisions.

The government of Tamil Nadu had taken steps to control Dengue, Swine flu, Malaria and few of them are:

- Spraying mosquito killing sprays in every area.
- Laying new roads to avoid the stagnation of water.
- Making advertisement by showing how to prevent these diseases.
- Implementation of food safety measures.
- Testing the quality of water periodically.
- Using Ultra Low Volume (ULV) applications to kill adult mosquitoes.
- Launched mobile app for Dengue awareness on October 27, 2016.
- Conducting awareness programs regarding the precautions that should be taken by the people.
- District level rapid response teams were formed to protect the people from diseases.
- National programme for control these diseases are implemented by the government.

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