IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 08, Issue 8 (August. 2018), ||V (VI) || PP 70-77

A Fuzzy Logic Decision Support System for The Diagnosis of Heart Disease

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Abstract: In real world situation, making decision is very difficult in any field. In medical field, clinical support system have been constructed by the aid of Artificial Intelligence. These systems are widely used in hospitals and clinics. By using technique the treatment on medical diagnosis, treatment of illness and patient pursuit have been taken as per affected illness. The objective of this paper is to detect the heart diseases in the person by using Fuzzy Expert Systems. The system consists of six inputs and two output fields. From these systems, we investigate the patients to whom the treatment can be taken from severe attack to mild attack which the data indicates from priority vectors. The results are obtained by using Analytic Hierarchy Processes with priority vectors.

Keywords: Clinical decision support system, Fuzzy logic, Cardiovascular system, Priority vectors, Analytic Hierarchy Processes.

Date of Submission: 26-08-2018 Date of acceptance: 07-09-2018

I. INTRODUCTION

In real world computing environment, if the information is not complete, precise and certain, it makes very difficult to derive an actual decision. Medical diagnosis is basically a pattern classification phenomena based on some input provided by a patient, an expert gives a conclusion on the basis of its knowledge which is normally stored in a binary form and finally the result is calculated that whether the patient suffering or not. The domain of medical decision making is one driven by problems of vagueness and uncertainty. The doctor makes decisions on treatment based not simply on matching precise symptoms or measurements to diagnosis.

II. CLINICAL DECISION SUPPORT SYSTEMS (CDSSS)

Clinical Decision Support Systems are very useful for patient as well as for medical experts in making the decisions. A Clinical Decision Support System (CDSS) is a health information technology system that is designed to provide physicians and other health professionals with clinical decision support. A working definition has been proposed by Dr. Robert Hayward of the centre for Health Evidence " Clinical Decision Support Systems link health observations with health knowledge to influence health choices by clinicians for improved health care"

III. TYPES OF CLINICAL DECISION SUPPORT SYSTEMS

Clinical decision support systems are broadly classified into two main groups.

- Knowledge based CDSS
- Non-knowledge based CDSS

A. Knowledge Based CDSSs

The knowledge based clinical decision support system contains rules mostly in the form of IF-Then statements. The data is usually associated with these rules. For example if the pain intensity is up to a certain level then generate warning etc., The knowledge based CDSSs generally consists of three main parts: Knowledge base, Inference rules and a mechanism to communicate. Knowledge base contains the rules, inference engine combines rules with the patient data and the communication mechanism is used to show the result to the users as well as to provide input to the system

.

1) Fuzzy Logic Rule Based:

Fuzzy Logic is a knowledge based approach that facilitates to resolve vagueness in decision support system. It has achieved several important techniques and mechanisms to diagnose the disease and pain in patient. The Fuzzy Logic Rule classifier is very effective in high degree of positive predictive value and diagnostic accuracy.

2) The Bayesian network:

The Bayesian network is the knowledge based graphical representation that shows a set of variables and their probabilistic relationships between diseases and symptoms. They are based on conditional probabilities, the probability of an event given the occurrence of another event, such as interpretation of diagnostic tests. In the context of CDSS , the Bayesian network can be used to compute the probabilities of the presence of the possible diseases given their symptoms.

3) Rule- Based Systems & Evidence Based Systems:

They tend to capture the knowledge of domain experts into expressions that can be evaluated as rules. When a large number of rules have been compiled into a rule base, the working knowledge will be evaluated against rule base by combining rules until a conclusion is obtained. It is helpful for storing a large amount of data and information. However it is difficult for an expert to transfer their knowledge into distinct rules. It has the potential to improve quality and safety as well as reducing the cost.

B. Non Knowledge Based CDSS:

CDSS without a knowledge base are called as non knowledge based CDSS. These systems instead used a form of artificial intelligence called as machine learning. Non- knowledge based CDSSs are then further divided into two main categories.

1) Artificial Neural Network :(ANN)

To derive relationship between the symptoms and diagnosis, neural networks use the nodes called neuron and weighted connections that transmit signals between the neurons in a forward or looped fashion. Neural network have been widely applied to non- linear statistical modeling problem and for modeling large and complex databases of medical information. The ANN maintains correct classification rates and allows a large reduction in complexity of the systems. This fulfills the need, not to write rules for input. However, the system fails to explain the reason for using the data in a particular way. So its reliability and accountability can be a reason.

2) Genetic Algorithms:

A Genetic Algorithm is a non-knowledge based method on Darwin's evolutionary theories that dealt with the survival of the fittest. Selection algorithm evaluates components of solutions to a problem. Solution that comes on top are recombined and the process runs again until a proper solution is observed. The genetic system goes through an iterative procedure to produce the best solution of a problem.

IV. FUZZY LOGIC

The idea of the Fuzzy Logic was first introduced by Professor Lotfi Ahmad Zadeh, at University of Berkeley, California in his seminal paper “Fuzzy Sets”. Fuzzy Logic is a form of multi-valued logic derived from Fuzzy set theory to deal with approximate reasoning. It provides the means to represent and process the linguistic information and subjective attributes of the real world.

V. APPLICATIONS OF FUZZY LOGIC IN MEDICAL FIELD

A. Tuberculosis

A fuzzy rule based system is designed to serve as a decision support for tuberculosis diagnosis. This system is designed to detect class of tuberculosis and these fuzzy rules are updated using rule mining techniques. Based on this method that generates classes of tuberculosis suits the needs of pulmonary physicians and reduce the time consumed in generating diagnosis. A decision support system for diagnosing TB has been developed. Fuzzy logic for medical diagnosis provides an efficient way to assist in experienced physicians to arrive at the final diagnosis of TB more quickly and efficiently [6].

B. Cancer

The four heterogeneous childhood cancers, neuroblastoma, non-Hodgkin lymphoma, rhabdomyosarcoma, and Ewing sarcoma present a similar histology of small round blue cell tumor (SRBCT) and thus often lead to misdiagnosis. Identification of biomarkers for distinguishing these cancers is a well studied problem. Multi layer networks with online gene selection ability and relational fuzzy clustering to identify a small set of biomarkers for accurate classification of the training and blind test cases of a well studied dataset [9]. Multi-Objective Evolutionary Algorithms based Interpretable Fuzzy (MOEAIF) methods for analyzing high dimensional bio-medical data sets, such as microarray gene expression data and proteomics mass spectroscopy data. This is used in evaluating the lung cancer. Fuzzy rules that can be used to process the relevant data from breast cancer cases in order to give a breast cancer risk prognosis which can be qualitatively compared to that of an expert. A fuzzy logic technique for the prediction of the risk of breast cancer based on a set of judiciously chosen fuzzy rules utilizing patient age and automatically extracted tumor features.

C. Image and Signal Processing

Fetal electrocardiogram (FECG) signal contains potentially precise information that could assist clinicians in making more appropriate and timely decisions during labor. This paper provides concise information about FECG and reveals the different methodologies to analyze the signal for efficient FHR monitoring. An optimized fuzzy logic method for Magnetic Resonance Imaging (MRI) brain images segmentation is presented. This method effectively segmented MRI brain images with spatial information, and the segmented MRI normal brain image and MRI brain images with tumor can be analyzed for diagnosis purpose.

D. Asthma

Asthma is a chronic inflammatory lung disease. An automated system has been developed using a self-organizing fuzzy rule-based system .A fuzzy system for diagnosis and treatment of integrated western and eastern Medicine is developed and the performance of the diagnostic system for Lung diseases diagnosis using fuzzy logic [5].

E. Diabetes

The MDLAP system is a promising tool for individualized glucose control in patients with type-1 diabetes. It is designed to minimize high glucose peaks while preventing hypoglycemia. A fuzzy logic controller has been proposed to maintain the normoglycaemic for diabetic patient of type-1[8]. A telemedical monitoring platform, which should include artificial intelligence for giving decision support to patients and physicians, will represent the core of a more complex global agent for diabetes care, which will provide control algorithms and risk analysis among other essential functions. Fuzzy measures and similar nonlinear model scan be used in pain relief control they can be used to determine the parameters of the model which describes the dependence of the pain relief on the applied stimulation. Thus fuzzy measures lead to the determination for a given pain distribution of the optimal pain relief stimulation. Clinical stroke, its diagnosis and treatment is unique to the individual patient, and is best captured by a scientific approach which not only can represent but also measure the changing causal role of known and unknown patient context in determining his/her condition.

F. Malaria

A fuzzy expert system for the management of malaria (FESMM) was presented for providing decision support platform to malaria researchers, physicians to assist malaria researchers, physicians and other health practitioners in malaria endemic regions [7].

G. HIV

A fuzzy mathematical model of HIV infection consisting of a linear fuzzy differential equations (FDEs) system describing the ambiguous immune cells level and the viral load which are due to the intrinsic fuzziness of the immune system's strength in HIV-infected patients [11].

H. Arthritis

Arthritis is a chronic disease and about three fourth of the patients are suffering from osteoarthritis and rheumatoid arthritis which are undiagnosed and the delay of detection may cause the severity of the disease at higher risk. Thus, earlier detection of arthritis and treatment of its type of arthritis and related locomotry abnormalities is of vital importance. A system for the diagnosis of arthritis using fuzzy logic controller (FLC) is designed which is, a successful application of Zadeh's fuzzy set theory. It is a potential tool for dealing with uncertainty and imprecision.

I. Anesthesia

Fuzzy Logic based Smart Anesthesia Monitoring System to enhance the developed diagnostic alarm system for detecting critical events during anesthesia and to accurately diagnose a hypovolaemia event in anaesthetized patients. Fuzzy Expert System for Fluid Management in General Anesthesia developed a fuzzy expert system for fluid management in general anesthesia.

J. Menigioma

An algorithm integrating fuzzy-c-mean (FCM) and region growing techniques for automated tumor image segmentation from patients with menigioma which is used to correctly locate tumors in the images and to detect those situated in the midline position of the brain. Meningitis is characterized by an inflammation of the meninges, or the membranes surrounding the brain and spinal cord. Fuzzy cognitive maps are used to assist in the modeling of meningitis, as a support tool for physicians in the accurate diagnosis and treatment of the condition [13].

K. Heart Diseases

Heart disease, sometime defined as coronary artery disease (CAD), is a well known term that can be referred to any condition that affects the heart. Most of the people with heart diseases have symptoms such as chest pain, blockage and fatigue, as many as 50% have no symptoms until a heart attack occurs. Fuzzy expert system for heart disease diagnosis designed with follow membership functions, input variables, output variables and rule base. This system simulates the manner of expert-doctor [1].

VI. DETECTION OF HEART DISEASES USING FUZZY LOGIC

The objective of this paper is to detect the heart diseases in the person by using Fuzzy Expert System. The system consists of 6 input fields and two output fields.

Input fields : Chest pain type, Cholesterol, Maximum heart rate, Blood pressure, Blood sugar, and Old peak.
Output fields : Detects the presence of heart disease in the patient and Precautions accordingly. It is integer valued from 0 (no presence) to 1 [distinguish presence (values 0.1 to 1.0)].

VII. HEART DISEASES (CARDIOVASCULAR DISEASES)

Heart disease is one of the main reasons behind adult death. In order to decrease the mortality rate of cardiovascular disease, it is necessary for the disease to be diagnosed at an early stage. So having so many factors to analyze to diagnose the heart disease of a patient makes the physician's job difficult. So, experts require an accurate tool that considering these risk factors and show certain result in uncertain term. Motivated by the need of such an important tool, in this study, we designed an expert system to diagnose the heart disease. The designed expert system based on Fuzzy Logic. The designed system aims to achieve the following:

- Detection of heart diseases and risks using fuzzy logic
- The system also defines the precautions according to the risk of the patient.
- System has 6 inputs and 2 outputs
- Each input and output have fuzzy variables
- Each fuzzy variable is associated with membership function
- The rules strength is calculated based on the membership function of the fuzzy variable.

VIII. DATA SET

The purpose of this data set is to diagnose the presence or absence of heart disease given the results of various medical tests carried out on a patient. This system uses 6 attributes for input and 2 attribute for result. Input fields (attributes) are chest pain type, blood pressure, cholesterol, resting blood sugar, resting maximum heart rate, old peak (ST depression induced by exercise relative to rest), . The output field refers to the presence of heart disease in the patient and the precautions according to the risk. It is integer value from 0 (no presence) to 1; increasing value shows increasing heart disease risk. In this study, we use low density lipoprotein (LDL) cholesterol, about the blood, we use systolic blood pressure. In this data set there are five different types of membership functions namely, very low, low, medium, high and very high are used in the fields of chest pain type, cholesterol, maximum heart rate, blood pressure, blood sugar, and old peak.

IX. RULE BASE

Rule base is the main part in fuzzy inference system and quality of results in a fuzzy system depends on the fuzzy rules. This system includes 22 rules. In the other hand, results with 22 rules tend to the expert's idea and laboratory results. The rules are shown in below.

Table no 1: Fuzzy Logic Decision Table

Rule	Chest Pain					Cholestrol					Max. Heart Rate					Blood Pressure					Blood Sugar					Old Peak					Result	Pre Cautions
	Very low	Low	Medium	High	Very high	Very low	Low	Medium	High	Very high	Very low	Low	Medium	High	Very high	Very low	Low	Medium	High	Very high	Very low	Low	Medium	High	Very high	Very low	Low	Medium	High	Very high		
1	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	–	Y	–	–	–	Y	–	–	–	–	Healthy	Exercise
2	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	–	Y	–	–	–	–	Y	–	–	–	Healthy	Exercise
3	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	–		Y		–	–	–	Y		–	Low risk	Exercise
4	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	–	–	–	Y	–	–	–	Y		–	–	–	Y	–	–	Low risk	Low salt Diet
5	Y	–	–	–	–	Y	–	–	–	–			–	Y	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	Moderate risk	Low salt Diet
6	Y	–	–	–	–	–	–		Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	Risk	Low salt Diet
7	–	–		Y	–	–	–		Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	Risk	Low salt Diet
8	–	–	Y	–	–	–	–	Y		–	–	–	Y		–	–	–	Y		–	–	–	Y	–	–	–	–	Y	–	–	Moderate risk	Use olive Oil
9	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	–	–	–	Y	High risk	Any other
10	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	–	–	Y	–	Risk	Any other
11	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	–	–	Y	–	High risk	Any other
12	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–		Y	–	–	Y	–	–	–	–	–	Y	–	Risk	Any other
13	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Risk	Any other
14	–	–	–	–	Y	–	–	–	–	Y	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Moderate risk	Any other
15	–	–	–	–	Y	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Low risk	Any other
16	–	–	–	Y	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Low risk	Balanced Diet
17	–	Y	–	–	–	–	–	–	–	Y	–	–			Y	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Low risk	Balanced Diet
18	–	–	Y	–	–	–	–	–	Y	–	–	–		Y	–	–	–	–	–	Y	–	–	–	–	Y	–	–	–	Y	–	Risk	Balanced Diet
19	–	–	Y	–	–	–		–	Y	–	–	–		Y	–	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	High risk	Use olive Oil
20	–	Y	–	–	–	–	–	Y	–	–	–	–	Y		–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Moderate risk	Use olive Oil
21	–	Y	–	–	–	Y	–	–	–	–	Y	–	–	–	–	–	–	Y	–	–	–	–	Y	–	–	–	–	Y	–	–	Low risk	Use olive Oil
22	Y	–	–	–	–	–	Y	–	–	–	–	–	–	Y	–	–	–		Y	–	–	–	–	Y	–	–	–	–	Y	–	Risk	Use olive Oil

Remark: Y – Yes

X. OUTPUT VARIABLES

Result

The "goal" field refers to the presence of heart disease in the patient. It is integer value from 0 (no presence) to 1. By increasing of this value, heart disease risk increases in patient. In this system, we have considered a different output variable, which divides to 5 fuzzy sets Healthy, Low Risk, Moderate Risk, Risk, and High Risk. Table shows these fuzzy sets with their ranges. The range is from 0-1.

A. Precautions

The output variable is precautions; this system gives the precautions according to the risk and result of the patient. The range of precaution is set from 0-1.

XI. DEFUZZIFICATION

Membership functions are used to retranslate the fuzzy output into a crisp value. This method is known as Defuzzification. The fuzzy inference evaluates the control rules stored in the fuzzy rule base. Defuzzification is a process to convert the fuzzy output values of a fuzzy inference to real crisp values. First a typical value is computed for each term in the linguistic variable and finally a best compromise is determined by balancing out the results using different methods like center of sum, center of area, center of area mean of maximum, Analytic Hierarchy Processes with priority vectors, etc., But for this application we use Analytic Hierarchy Processes with priority vectors method to process defuzzification of the output variable extension time. This method is mostly used because this method has better performance in terms of continuity, computer complexity and counting.

XII. Real Time Evaluation

We can check the diseases and risks in the patient according to the values of the attributes. If the values of the attributes or inputs are high then the patient has high risk and if the values or inputs are low than the patient has low heart risk. And similarly if the values are normal then the patient and results shows that the patient is normal. Here we are showing some examples that show the high risk, low risk etc., in the person. We have tested the designed system with following values for each field and graphical result. In the following table we can see the different values of different input variables and their results accordingly. If the values of the inputs lies in their low ranges then the risk is also low that is the result is of minimum value. Similarly for the high values of the input which explained in the following table.

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Table no 2 : Normal Range In System Testing

Patient	**Chestpain** 0-1	**Cholesterol** 120-180	**Maximum Heart rate** 70-80	**Blood Pressure** 120-80	**Blood Sugar** 80-120	**Old Peak** 0-1
1	0	100	70	60	50	0
2	0.1	155	78	74	83	0.1
3	0.16	158.5	83.2	78.9	123	0.2
4	0.5	250	110	130	150	0.5
5	0.1	281	121	150	161	0.7
6	0.89	353.5	136.8	190.9	231	0.866
7	1	400	150	185.3	235	0.92

Table *no: 3* Mean Value In System Testing

Patient	Chestpain 0.5	Cholesterol 150	Maximum Heart rate 75	Blood Pressure 100	Blood Sugar 100	Old Peak 0.5
1	0	100	70	60	50	0
2	0.1	155	78	74	83	0.1
3	0.16	158.5	83.2	78.9	123	0.2
4	0.5	250	110	130	150	0.5
5	0.1	281	121	150	161	0.7
6	0.89	353.5	136.8	190.9	231	0.866
7	1	400	150	185.3	235	0.92
Total	2.75	1698	749	869.1	1033	3.286

Table *no: 4* Fuzzy Conversion Values

Patient	Chestpain 0.0012	Cholesterol 0.3521	Maximum Heart rate 0.1761	Blood Pressure 0.2347	Blood Sugar 0.2347	Old Peak 0.0012
1	0	0.0589	0.0935	0.0690	0.0484	0
2	0.0364	0.0913	0.1041	0.0852	0.0804	0.0304
3	0.0582	0.0934	0.1111	0.0908	0.1191	0.0607
4	0.1818	0.1472	0.1469	0.1496	0.1452	0.1522
5	0.0364	0.1655	0.1616	0.1726	0.1559	0.2130
6	0.3236	0.2082	0.1826	0.2197	0.2236	0.2635
7	0.3636	0.2356	0.2002	0.2132	0.2275	0.2799
Total	1	1.0009	1	1.0001	1.0001	0.9997

Table *no: 5* Analytic Hierarchy Processes Decision Table

Patient	Chestpain 0.0012	Cholesterol 0.3521	Maximum Heart rate 0.1761	Blood Pressure 0.2347	Blood Sugar 0.2347	Old Peak 0.0012	Total 0.9999	RESULT
1	0	0.0207	0.0165	0.0162	0.0114	0	0.0648	0.0648
2	0.0004	0.0321	0.0183	0.0199	0.0189	0.0001	0.0897	0.0896
3	0.0001	0.0329	0.0196	0.0213	0.0279	0.0001	0.1019	0.1018
4	0.0002	0.0518	0.0259	0.0351	0.0341	0.0002	0.1473	0.1472
5	0.0001	0.0583	0.0285	0.0405	0.0366	0.0003	0.1643	0.1642
6	0.0004	0.0733	0.0322	0.0516	0.0525	0.0003	0.2103	0.2102
7	0.0004	0.0829	0.0353	0.0500	0.0534	0.0003	0.2223	0.2222
Total							1.0006	1

XIII. CONCLUSION

From the above result, we obtained the following conclusion : The 7th patient has high priority vector. So this person has attacked by heart diseases more severely. So first care should be taken over the person. In succession, each person should be taken care according to their priority vectors and first member has very low priority vector. So efficient care need not be taken over that person. Using the above Analytic Hierarchy Processes with priority vectors, we could be achieved for the disease with other diseases like cancer, fever etc., This Fuzzy model can be formulated with other models also.

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IOSR Journal of Engineering (IOSRJEN) is UGC approved Journal with Sl. No. 3240, Journal no. 48995.

Dr.S.Subbulakshmi1" A Fuzzy Logic Decision Support System For The Diagnosis of Heart Disease ." IOSR Journal of Engineering (IOSRJEN), vol. 08, no. 8, 2018, pp. 70-77.