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Medical Diagnosis using Fuzzy Logic

Rahul Shetty[1], Ravi Yadav[2], Jai Hinduja[3], Prof. Roopkala Ravindran[4], Prof. Asha Bharambe[5]
[1, 2, 3]Student, IT Dept VESIT, Chembur, Mumbai - 400074
[4, 5]IT Dept, VESIT, Chembur, Mumbai - 400074

Abstract: This paper presents a generalized and effective methodology for prediction of any disease which has measurable symptoms using fuzzy logic. Medical data has ample of imprecision and ambiguity due to which its difficult to predict the consequences of symptoms at the personal level. We have made an attempt to apply this methodology for diagnosis of heart disease. The dataset was taken from UCI repository. In this approach, all the symptoms that cause a particular disease are fuzzified. For each fuzzy value of a particular symptom, we assign an effect value that denotes the possibility of the occurrence of the disease when the symptom has that fuzzy value. This data is filled in a tabular format which forms the knowledge base for the disease. A knowledge base is built by domain experts who have in-depth knowledge of the subject. When user symptoms are fed to the inference engine, the output is in fuzzy values. A defuzzification module transforms fuzzy output to crisp output. This output denotes the certainty of the presence of disease. A web app prototype is developed for this system with an aim for reaching to general masses.
Keywords: fuzzy logic, heart disease prediction, tabular knowledge base, defuzzification module.

I. INTRODUCTION

Cardiovascular disease is the number 1 cause of death globally. More people die annually from cardiovascular diseases than from any other cause. An estimated 17.7 million people died from cardiovascular diseases in 2015, representing 31% of all global deaths. Of these deaths, an estimated 7.4 million were due to coronary heart disease and 6.7 million were due to stroke.

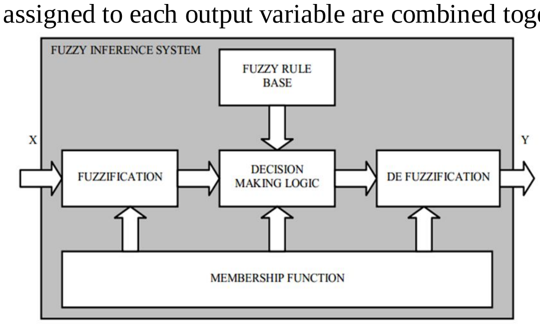
Due to this, prediction of cardiovascular diseases at early stages is vital. Fuzzy logic systems are proficient in dealing with uncertain data.The main advantage of Fuzzy Logic is that it does not need lots of data to train (can work with no data at all, as long as we know the domain we are modelling and its reaction/behaviour rules). The second main advantage is the interpretability and simplicity, as it is used to “compute with words” as Zadeh puts it, or allows modelling near natural language rules.

A. Fuzzy Inference Systems

In this paper we develop a fuzzy expert system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data.

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.



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

In this approach, we have used Centroid defuzzification method. In the CENTROID method, the crisp value of the output variable is computed by finding the variable value of the center of gravity of the membership function for the fuzzy value.

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II. METHODOLOGY

The developed fuzzy expert system prototype would query the user for the relevant patient symptoms. The strength of each single symptom is specified by a fuzzy value. Measurable symptoms such as the age or cholesterol are divided into range values first and user would select the range in which his age or cholesterol lies. The prototype proceeds through the above mentioned inference process and provides a percent value for the certainty of presence for a disease whose knowledge base in available.If a particular disease is detected, the user will be able to find the nearest specialists of that disease in vicinity through google maps.

A. Fuzzification

We have taken 10 symptoms into consideration from c level and dataset. For each symptom, a weighting factor is assigned which allows the physician to specify that some symptoms can have more or less significance than others when diagnosing a disease, and he should set proper relative values to the weights. Each symptom is further divided into fuzzy sets. Symptom values are of two types, namely categorical and numeric. Categorical value can be directly taken as fuzzy value of the symptom, whereas numeric value are first divided into range and later each range is considered as a fuzzy value. Range is specified by physicians keeping in mind that symptom values having similar effect should be in same range set.

B. Fuzzy Knowledge Representation

The experience of the expert physician regarding the heart disease is captured in a fuzzy table. We consider three fuzzy sets Yes, May Be, and No as shown in fig.1 to represent the certainty of disease presence.

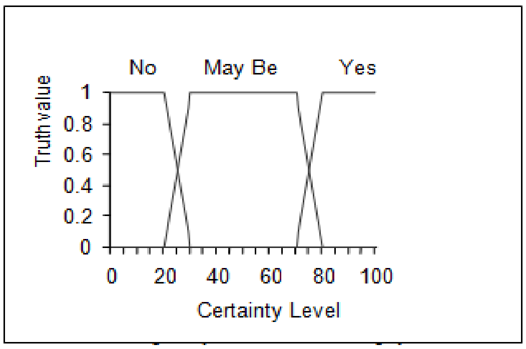

Fig.1 Fuzzy sets for the certainty of disease presence.

It is the responsibility of the expert physician to suggest suitable values for each and every entry in the disease profile table based on his experience. Table 2 shows the profile table for heart disease based on an expert physician consultation. Similar profile tables are also obtained for any other disease.

Table 2 : Profile Table for Coronary Heart Disease

No	Symptom	Wt	Fuzzy Value	Effect
1	Age(in years)	0.2	<35	No
			35 - 45	May Be
			>45	Yes
2	Sex	0.1	M	Yes
			F	Yes

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3	Cholesterol (serum cholesterol in mg/dl)	0.5	<197	No
			197-217	May Be
			>217	Yes
4	Fasting Blood Sugar	0.2	<=126	No
			>126	Yes
5	Rest ECG	0.8	Normal	No
			ST-T wave normality	May Be
			Left ventricular hypertrophy	Yes
6	Maximum HRA	0.7	0	No
			1	Yes
7	Exercise Induced Angina	0.5	0	No
			1	Yes
8	No. of major vessels colored by fluoroscopy	0.9	0	No
			1,2,3	Yes
9	Chest Pain	0.6	1,2,3,4	Yes
10	Thal Scan	0.8	Normal	No
			Fixed Defect	Yes
			Reversible Effect	May Be

User will enter his/her symptoms in terms of fuzzy value.The effect of the fuzzy value is obtained from the profile table in terms of Yes, May Be, and No.

C. Defuzzification

1) Assume that a given disease d has 10 symptoms, all of which has the same weight in the diagnosis. That is:

$k = 10$,

$w_j = 1$ for all j = 1, … , 10.

1) Assume that the result was 7 Yes, 2 May Be, and 1 No.
2) The overall diagnostic decision will be of the considered disease d_i in percent

Consequently, the crisp decision value for the disease will be computed as shown below. It should be noted that if the results were Yes for all relevant symptoms of disease, the decision would be 100%.

$$q_i = (c_i / c_y) \times 100\%$$

For the present example, the values of c_i and c_y are 0.69 and 0.87, respectively. This tells that the certainty of presence of the considered disease is 79% as shown in Fig.2.

The centroid of a given function f(x) is computed as follows using the discrete values for the range from $x= x_1$ to $x= x_n$, with increments of Δx.

$$C = (\sum x * \Delta x * f(x)) / (\sum \Delta x * f(x))$$

In this computation, $x_1 = 1$, $x_n = 100$, and $\Delta x = 1$.

$c_i = 0.69$ $c_y = 0.87$ $q_i = 79\ \%$

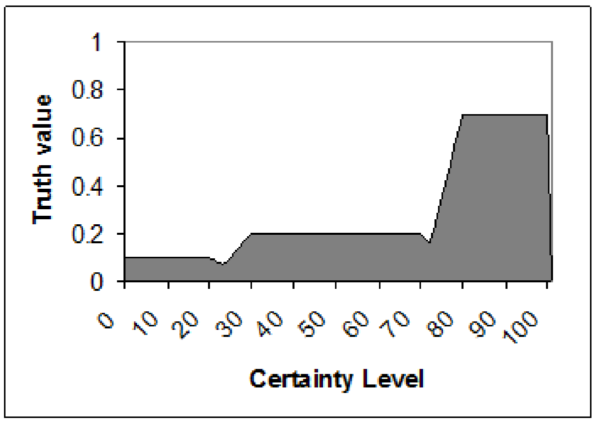

Fig.2 Fuzzy set representing the overall diagnosis decision for the example case.

The percentage value(q_i) is confusing to a naive user to figure out whether the patient has heart disease or not.After training on two third of dataset, the threshold percentage which gave the best accuracy was 51.3%.We will be using this threshold percentage to further classify whether the patient has heart disease or not.

For a particular patient symptom set, if q_i comes out to be less than or equal to 63% then patient is disease free (< 50% diameter narrowing), whereas if q_i is greater than 63% the the patient is suffering from heart disease(> 50% diameter narrowing).

III. TEST CASE

Symptoms that are considered for heart disease prediction are [Age, Sex, Cholesterol, Fasting Blood Sugar, Rest ECG, Maximum HRA, Exercise Induced Angina, No. of major vessels colored by fluoroscopy, Chest Pain, Thal Scan].

Suppose that a user has entered the following values as per his present condition ['>45', 'M', '>217', '<=126', 'Left ventricular hypertrophy', '1', '1', '2', '3', 'Reversible Effect'].

wts of symptoms having effect value Yes = 4.3
wts of symptoms having effect value No = 0.2
wts of symptoms having effect value May Be = 0.8
Overall Diagnostic Decision,

σ = (4.3 Yes + 0.8 May Be + 0.2 No) / 5.3
c_i = 0.75
c_y = 0.87
q_i = 86.77

As q_i > 63, therefore there is high probability that person is suffering from heart disease.

IV. RESULTS

Following are the result statistics obtained from this methodology :

N=299	Predicted NO	Predicted YES	
Actual NO	TN = 136	FP = 24	160
Actual YES	FN = 52	TP = 87	139
	188	111	299

Accuracy : 74.58%
True Positive Rate(Sensitivity) : 62.59%
False Positive Rate : 15.00%
Specificity : 85.00%
Precision : 78.38%
Error Rate : 25.42%
Prevalence: 46.49%

V. CONCLUSION

Fuzzy logic is a simple and effective technique that can be advantageously used for medical diagnosis of a wide range of diseases. We present in this study a methodology to capture the experience of expert physicians and store it in fuzzy tables to represent disease profiles. Simple fuzzy inference techniques can be used to provide sound diagnosis decisions. A case study is provided to illustrate the quality of obtained results for a typical input case. Complete agreement with the diagnosis of human expert physicians has been obtained in many experiments with different input symptoms in each case study.

The developed system may be enhanced to reduce the effort of initial physical checking and manual feeding of the input symptoms. It is highly appreciated to develop on online front end in which sensors and measuring instruments are used to collect as much as possible of the required patient data and feed it automatically to the fuzzy expert system.

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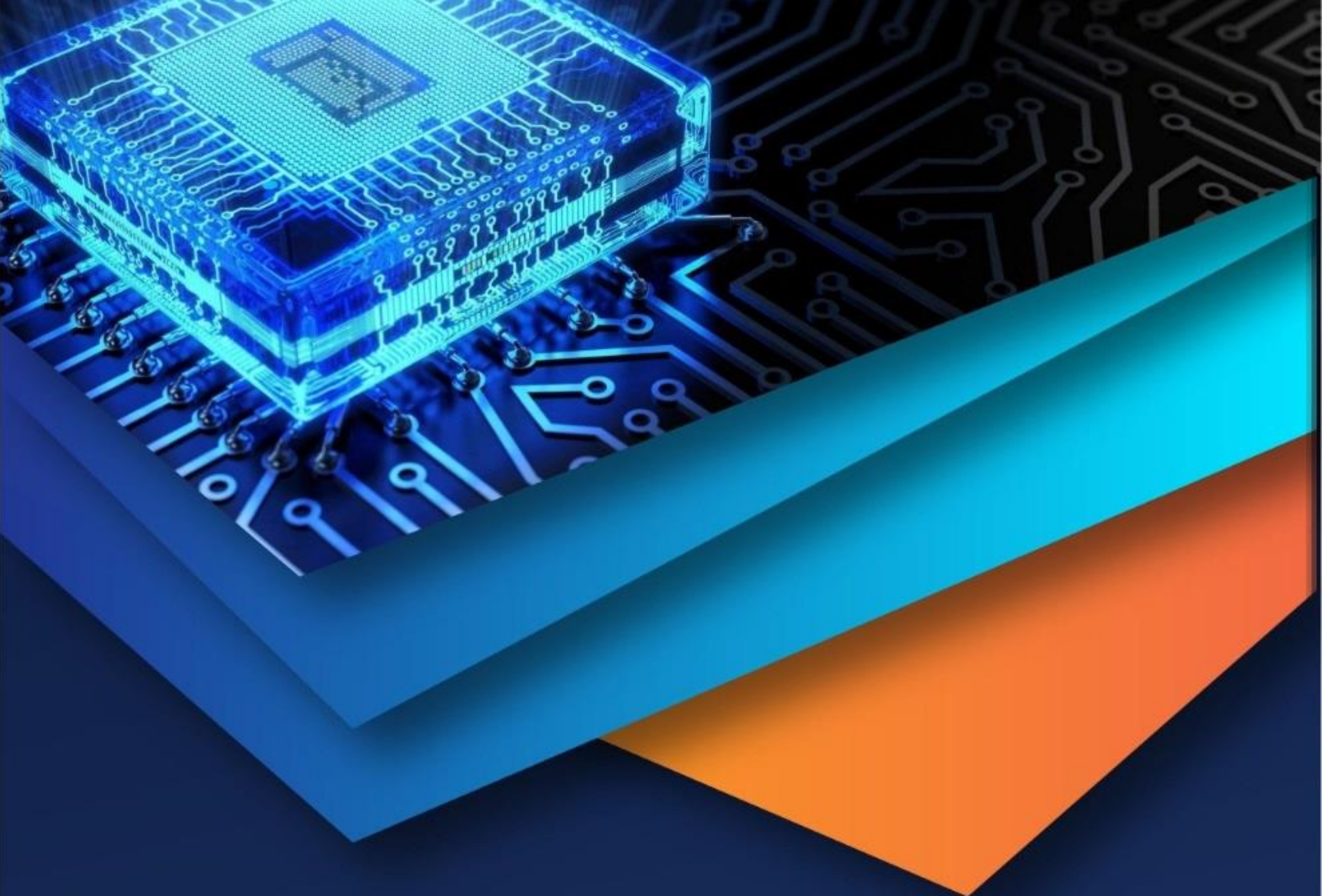

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