Fuzzy Expert System for Coronary Heart Disease Diagnosis

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Abstract

Expert systems are typically developed to solve unclear application fields or problems. Expert systems based on fuzzy logic has two advantages over traditional expert systems: high approximation ability and high accuracy. Therefore fuzzy expert systems are widely used in the fields which have very high complexity and uncertainty. In this paper, a fuzzy expert system for Coronary Heart Disease diagnosis will be developed. There exists no strict boundary between what is Healthy and what is Diseased, thus distinguish is uncertain and vague. Therefore this proposed system will be very useful to diagnosis for Coronary Heart Disease. The proposed system will use 12 input fields and one output field. If the user absence of disease, the result shows Healthy. If the user presence of disease, the result shows the situations of Coronary Heart Disease. And this system will give advices and drug treatment for the user's disease.

1. Introduction

Nowadays, the use of computer technology in the fields of medicine has highly increased. These fields have very high complexity and uncertainty. So the use of intelligent systems such as fuzzy logic, artificial neural network and genetic algorithm has been developed. Some expert systems use fuzzy logic. In standard, non-fuzzy, logic there are only two "truth values", true and false. According to standard logic, there are no such in-between values – no "degrees of truth" – and any statement is either completely true or completely false.

Fuzzy logic is particularly useful when it is necessary to deal with vague expressions. Often the rules elicit from human experts contain vague expressions, therefore it is useful if an expert system's inference engine employs fuzzy logic. Many of commercial applications use fuzzy logic such as in Braking systems, Copier quality control, Rice cooker temperature control, Other Control systems and Expert systems, etc [2]. In domain of heart disease, there are uncertain risk factors. Therefore, heart diseases diagnosis may be hard for experts. In this paper, we will propose an expert system to diagnose Coronary Heart Disease based on Fuzzy Logic.

This paper is organized as follows. Section 2 presents the related works of fuzzy expert system. Background theory of fuzzy logic is discussed in section 3. The overview of the proposed system is presented in section 4 and section 5 shows the design of the proposed system. Finally, the conclusion of the system is presented in section 6.

2. Related Works

P. Lalit Mohan and A. Ganju developed a rule base for prediction of direct action avalanches of Chowkibal- Tangdhar road axis in Indian Himalaya using fuzzy logic. The condition attributes of the rule- based system are six snow-related parameters. Different fuzzy sets are defined for each parameter on the basis of their distribution with four danger labels of avalanche activity. They tried to predict avalanches with various danger labels using fuzzy logic [5].

Mu-Chun Su presented a fuzzy rule-based approach to spatio-temporal hand gesture recognition. He employed a powerful method based on hyper rectangular composite neural networks for selecting templates. Templates for each hand shape are represented in the form of crisp IF-THEN rules.Each crisp IF-THEN rule is then fuzzified by employing a special membership function in order to represent the degree to which a pattern is similar to the corresponding antecedent part. When an unknown gesture is to be classified, each sample of the unknown gesture is tested by each fuzzy rule. The accumulated similarity associated with all samples of the input is computed for each hand gesture in the vocabulary, and the unknown gesture is classified as the gesture yielding the highest accumulative similarity. Based on the method, they implemented a small-sized dynamic hand gesture recognition system [3].

3. Background Theory

The background theory of the fuzzy logic expert system is discussed in this section.

3.1 Fuzzy Logic

Fuzzy Logic (FL) allows intermediate values to be defined between evaluations like true/false, yes/no, high/low, etc. As in Boolean logic, a true statement is expressed by the value "1" and a false statement by the value "0". However, unlike in probability theory, the value must not be interpreted as a confidence level but rather as a Membership Function (MF). Therefore, every statement is "True" to a certain degree and "False" to another. An interesting property of these MFs is that, because they vary between zero and one [4].

3.2 Fuzzy Set

A fuzzy set allows its elements to have a degree of membership. In a fuzzy set, an element can be in three states: not a member of the set, a full member of the set, or a partial member of the set. The core of a fuzzy set is its membership function. Membership value is represented as a continuous range of values in the interval {0, 1} with {0} indicating no set membership, {1} indicating complete set of membership, and values in the range {0<x<1} indicating a partial degree of membership. [2].

A fuzzy set has three principal components:

1. A degree of membership measure along the vertical (Y-axis).
2. The possible domain values for the set along the horizontal (X-axis).
3. The set membership function (a continuous curve that connects a domain value to its degree of membership in the set).

3.3 Membership Function

The fuzzy membership function is a set of function values corresponding to input variables. The function that ties a number to each element x of the universe is called the membership function μ(x). An item's grade of membership is normally a real number between 0 and 1, often denoted by the Greek letter μ. The membership functions can be represented by graphs such as straight lines and triangular shape, etc. [6].

3.4 Term Set

The collection of fuzzy sets that defines the semantics of a variable is called the variable's term set. Each variable used in a fuzzy rule must have a term set. The individual fuzzy set in a term set is the linguistic variable associated with the variable. A linguistic variable takes words or sentences as values.

3.5 Fuzzy Expert System

A fuzzy expert system is an expert system that uses Fuzzy logic instead of Boolean logic. It is a collection of membership functions and rules that are used to reason about data [2]. The rules in a fuzzy expert system are usually of a form similar to the following:

if x is low and y is high then z is medium,

where,

x and y = input variables.
z = output variable.
low = a membership function (fuzzy subset) defined on x.
high = a membership function defined on y.
medium = a membership function defined on z.

Basic architecture of fuzzy expert system is shown in Figure 1 [1]. The process of fuzzy expert system is as follows:

1. Inputs are transformed into memberships of fuzzy sets by fuzzifying functions (fuzzification).
2. This information is given to the inference engine (inferencing).
3. Membership values are transformed into required number output variables by a defuzzification step (defuzzification).

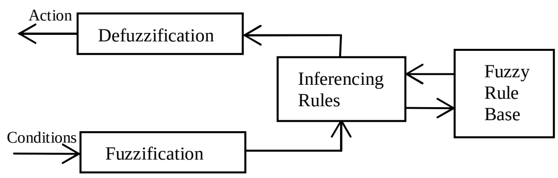

Figure 1. Basic Architecture of Fuzzy Expert System

3.6 Fuzzification

The process of finding the membership value of a scalar (a number) in a fuzzy set is called fuzzification. Fuzzification converts the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base. The membership function defined for each fuzzy set is applied on the input parameter to determine the degree of truth for each rule premise [4].

3.7 Fuzzy Inference Engine

The inference engine collects and executes rules. In fuzzy inference engine, the truth-value for the premise of each rule is computed and applied to the conclusion part of each rule. This results in one fuzzy subset being assigned to each output variable for each rule. The inference engine converts fuzzy inputs to the fuzzy output value by using IF-THEN type fuzzy rules. Fuzzification and defuzzification need to access the corresponding membership functions. And inferencing rules need to find the fired rules. All membership functions and rules are stored in knowledge base. The inference engine is the only one who accesses the knowledge base. Therefore, the work of inference engine contains three parts: (1) fuzzification (2) inferencing rules and (3) defuzzification.

3.8 Defuzzification

Defuzzification is used to convert the fuzzy sets output values to a crisp value. There are various methods for defuzzification. In this system, we will use the Centroid method (centre of gravity method) [2, 4]. The equation for the Centroid method is as follows:

$$u = \frac{\sum_{j=1}^{l} \mu(x_{mj}) \cdot x_{mj}}{\sum_{j=1}^{l} \mu(x_{mj})}$$

where,

u = defuzzified value.

$\mu_{(xmj)}$ = membership value of each output fuzzy set: "Healthy", "Level(1)", "Level(2)", "Level(3)" and "Level(4)".

x_{mj} = centroid value of each output fuzzy set.

4 System Overview

The system is proposed as a fuzzy expert system for Coronary Heart Disease diagnosis as shown in figure 2. By using the knowledge from heart-specialists, we defined term sets such as Cholesterol, Heart Rate, Blood Pressure and so on. And we determined fuzzy sets for each term set such as Low, Medium, High and Very High. Then we determined membership functions for each fuzzy set. We get patient records from UCI (University of California, Irvine) machine learning repository data sets. And we considered many IF-THEN rules.

For example:

"**IF** Age = young and Gender = female and Chest Pain Type = atypical angina and Blood Pressure = medium and Cholesterol = high and Blood Sugar = >120 and ECG=ST-T abnormal and Heart Rate = medium and Angina = no and Old Peak = Risk and Slope = up sloping and Thallium Scan = normal **THEN** Result = Presence Level (1)".

"**IF** Age = very old and Gender = male and Chest Pain Type=asymptomatic and Blood Pressure= high and Cholesterol =very high and Blood Sugar = >120 and ECG = L-V hypertrophy and Heart Rate = high and Angina = yes and Old Peak= terrible and Slope = flat and Thallium Scan = reversible defect **THEN** Result = Presence Level (4)".

These IF-THEN rules, membership functions and fuzzy sets are stored in fuzzy knowledge base.

Firstly, the input fields are fuzzified and fuzzy values are placed onto the corresponding membership functions. Then the fuzzy inference engine inferences the rules from fuzzy knowledge base by using the respective membership values. Then the system executes with min-max fuzzy inference method using fuzzy IF-THEN rules. Finally, the result is defuzzified to get the crisp value. The result can be one of five outputs:

- Healthy,
- Presence Level (1),
- Presence Level (2),
- Presence Level (3) or
- Presence Level (4).

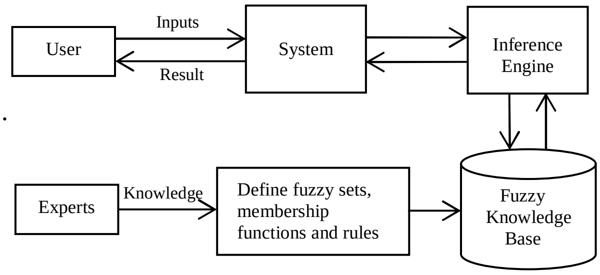

Figure 2. Overview of the Proposed System

5 System Design

In this system, 12 input fields are used as shown in table 1. Among these, only six attributes are defined as fuzzy term sets: Age, Blood Pressure, Cholesterol, Resting ECG, Heart Rate and Old Peak. Therefore if we want to know the result of a patient, we have to make fuzzification only for them. Other attributes values are taken from the original input values.

An example of calculation result for a patient is shown in following. The attributes values of a patient are in table 2.

The process flow diagram is shown in figure 3.

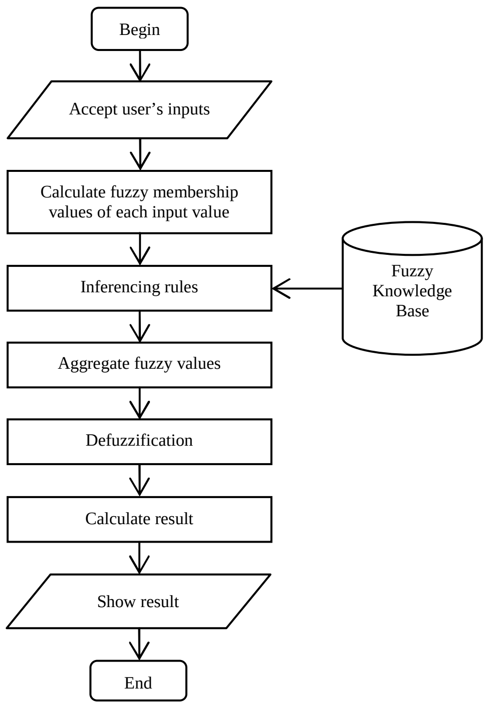

Figure 3. Process Flow Diagram

Table 1.Attributes of the System

Attributes	Values	Fuzzy Sets
Age	Numerical (0 to 120)	Young, Mild, Old, Very Old
Gender	Male and Female	-
Chest Pain Type	1. Typical Angina 2.Atypical Angina 3.Non-Angina Pain 4. Asymptomatic	-
Blood Pressure	Numerical (50 to 200)	Low, Medium, High, Very High
Cholesterol	Numerical (100 to 400)	Low, Medium, High, Very High
Blood Sugar	Numerical (105 to 150)	High
Resting ECG	0.Normal, 1.ST_T abnormal 2.LV Hypertrophy	-
Heart Rate	Numerical (30 to 250)	Low, Medium, High
Exercise Induced Angina	Yes and No	-
Old Peak	Numerical (0 to 6.5)	Low, Risk, Terrible
Slope	1. Upsloping 2.Flat 3.Downsloping	-
Thallium Scan	3. Normal 6.Fixed Defect 7. Reversible Defect	-

An example of calculation result for a patient is shown in following. The attributes values of a patient are in table 2.

Table 2. Attributes Values of a Patient

Age	**Gender**	**Chest Pain Type**	**Blood Pressure**
23	Female	2	145
Cholesterol	**Blood Sugar**	**Resting ECG**	**Heart Rate**
230	130	1	145
Exercise Induced Angina	**Old Peak**	**Slope**	**Thallium Scan**
No	3.5	1	3

As the first step, the fuzzy values of each attribute are calculated using membership functions (fuzzification). Respective fuzzy sets of each of the six attributes are shown in table 3.

Table 3. Fuzzy Sets and Values for Each Attributes of a Patient

Attribute	Fuzzy Sets	Fuzzy values
Age	Young	1.0
Blood Pressure	Medium, High	0.737,0.25
Cholesterol	Medium, High	0.370, 0.233
Blood Sugar	High	1.0
Heart Rate	Medium, High	0.417,0.056
Old Peak	Risk, Terrible	0.411,0.655

We have defined ranges and membership functions for all fuzzy term set. Among them, the ranges and membership functions for "Heart Rate" is shown in table 4.

Table 4. Ranges for Heart Rate

Input Field	Range	Fuzzy Sets
Heart rate	<100 70-165 >140	Low Medium High

$$\mu_{Low(x)} = \begin{cases} 1 & , x<80 \\ 1 - \dfrac{x-80}{100-80} & , 80 \le x < 100 \\ 0 & , x \ge 100 \end{cases}$$

$$\mu_{Medium(x)} = \begin{cases} 0 & , x<70 \\ \dfrac{x-70}{117-70} & , 70 \le x < 117 \\ 1 & , x=117 \\ 1- \dfrac{x-117}{165-117} & , 117 < x \le 165 \\ 0 & , x>165 \end{cases}$$

$$\mu_{High(x)} = \begin{cases} 0 & , x<140 \\ \dfrac{x-140}{230-140} & , 140 \le x < 230 \\ 1 & , x \ge 230 \end{cases}$$

As the second step, we have to find the fired rules using input values and fuzzy values.

As the third step, we have to aggregate the fuzzy values according to the fired rules by using Mamdani min-max inference method.

As the fourth step, we have to defuzzify the values to make the decision by using "Centroid" method.

As the final step, the result must be calculated by using the ouput ranges. In this example, the defuzzified value falls 1.44 in Presence Level (1).

Therefore final output result is "The patient suffers Coronary Heart Disease Presence Level (1)." And this system can describe the knowledge, drug treatment and advice for his suffered disease level.

The user inputs and system output are shown in figure 4.The final result graph is also shown in figure 5.The knowledge, drug treatment and advices for his disease level are shown in figure 6.

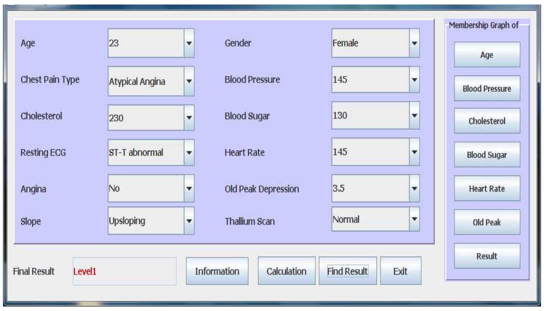

Figure 4. User Inputs and System Output

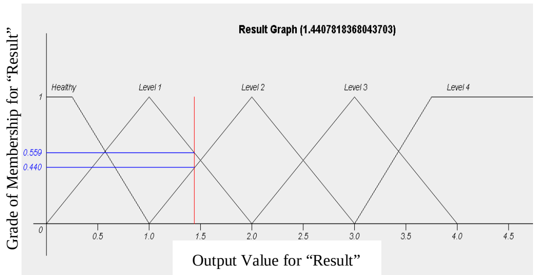

Figure 5. The Result Graph of the System

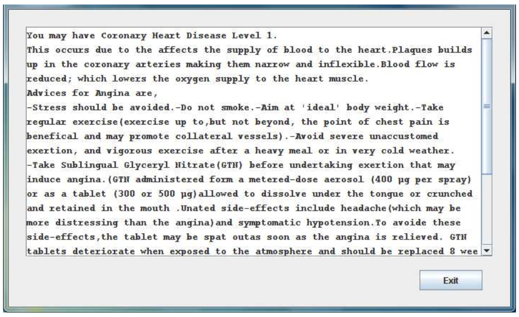

Figure 6. The Knowledge and Advices for His Disease Level

6. Conclusion

In this paper, we proposed a fuzzy expert system for Coronary Heart Disease diagnosis. We use 12 attributes to diagnosis the Coronary Heart Disease. Therefore, we will use 13 variables: 12 input variables and one output variable. Rules are derived using the knowledge of well experience heart-specialists. This system will give the fast and accurate result to the users as an actual expert. And the users can know experts' advices and drug treatment for their disease. Therefore, the users can timely cure according to their disease level.

7. References

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