Design Methodology of a Controller to Predict the Uncertain Cardiac Arrest using Fuzzy Logic Approach

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Abstract

The main objective of design methodology of a controller for forecasting cardiac arrest using fuzzy logic approach is to provide the prediction of period of life time for the patients affected by sudden death due to cardiac arrest. In this paper, the controllable risk factors "blood pressure, cholesterol, diabetic, obesity" are taken as inputs for the fuzzy logic controller and "the period of life time" is the output. The input triangular membership functions are Low, Normal, High, VeryHigh.The output triangular membership functions are Very Short, Short, Medium, Long, Very Long. As the rate of mortality increases due to the uncertain, unexpected and sudden arrest of cardio vascular system, a Fuzzy Logic Controller is designed to perform optimal control on high risk controllable risk factors. Fuzzy Logic is used to incorporate the available knowledge into intelligent control system, based on the clinical observations, medical diagnosis, and the expert's knowledge. The controller is validated with the captured data as a tracking system with accuracy and robustness. Also, a basic design of a logic circuit is developed to devise a device for test and implementation as a further enhancement.

Keywords : Cardiac arrest, Controllable risk factors, Fuzzy Logic Controller, Membership Functions, Fuzzifier, Defuzzifier, Digital Logic Circuit.

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1. Introduction

Blood supply, blood flow, the heart beat rate of cardiac has to be maintained always at normal level, for the cardio vascular system to operate effectively and efficiently. The rate of mortality increases due to the uncertain, unexpected and sudden arrest of cardio vascular system, a Fuzzy Logic Controller is designed, to perform optimal control on high risk controllable risk factors. The goal of the study is to validate the Fuzzy Logic Controller with respect to the domain expert's knowledge[3].

- The prime objective is to control the growth rate of mortality due to high risk disease like heart attack. This objective is attained by controlling the main four risk factors which suddenly stops the heart.
- Uncertainty is captured and implemented as a rule based knowledge system which is implemented using Matlab.Rule base is constructed for all ranges specified for all the four risk factors. It is a generalized rule-based system so that rules can be formed for any patient with any one, two, three or all the four risk factors.
- The controller can be validated with the captured data to reduce the errors, and to normalize the results.
- The nature of blood flow is predicted to avoid inadequate supply and abnormal flow of blood which in turn control the heart beat and pulse rate to normal level. The blood flow is normalized by controlling the risk factors parallely using the basic logic circuit of the given design of the device.

- The importance of the controller designed is to capture the uncertainty happens by acquiring expert's knowledge, ambiguity by the patient's description of the disease, occurrence of errors during diagnosis.
- The controller can be validated with the captured data to reduce the errors, and to normalize the results. According to the sample data collected the errors are normalized.

2. Fuzzy Logic And Cardiac Arrest

Every trustworthy expert knows that his/her medical knowledge and resulting diagnosis are pervaded by uncertainty with imprecise formulations. This imprecision is not a consequence of inability, but an intrinsic part of expert knowledge acquired through laborious experience. Stripping of uncertainty entails the degree of fallacies due to misplaced precision. On the other hand fuzzy was conceived with the formulization of vague knowledge in mind together with the appropriate rules of inference; it provides a powerful framework for the combination of evidence and deduction of consequences based on knowledge specified in syl-logistic form. Ultimately fuzzification and defuzzification of fuzzy logic controller allows the treatment of uncertainty that lies in controllable risk factors at the intersection of qualitative and quantitative methods. Therefore, to overcome the stripping time of uncertainty and slipping tone of heart beat, a controller is designed to control the risk factors, to prevent and preserve the life of heart to minimize the rate of mortality with maximum efficiency. Simultaneously, a suggestion is given to protect sudden cardiac arrest form non-controllable risk factors and reduction of contributing factors by diagnostically meaningful observations[7].

3. Design And Validation Of The Proposed Fuzzy Logic Controller

Fuzzy logic can be described as (i) an effective conceptual framework for dealing with the problem of knowledge representation in an environment of uncertainty and imprecision. (ii) A logic with underlying models of reasoning which are appropriate rather than exact. (iii) Computing words rather than numbers. By applying the powerful technique fuzzy logic, where the evaluation of knowledge domain is uncertain, vague and ambiguous. A controller is designed and experimented with a set of available knowledge source and sample data set related to "coronary heart disease" to regularize the blood flow, to make the circulatory system to circulate the blood without any abstraction and distractions. Therefore, in this paper, a design methodology of a controller is provided to control the controllable risk factors to regularize the blood flow to forecast the sudden cardiac arrest, which in turn reduces the rate of mortality.

3.1 Fuzzy Representation Of Input And Output Parameters As Membership Function

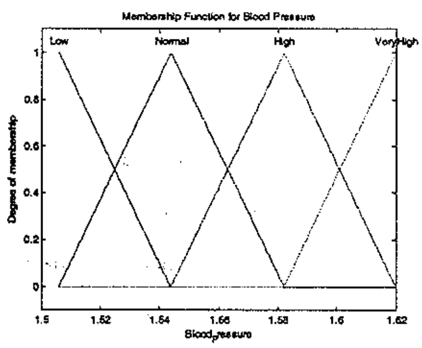

Fig 3.1 Membership function for blood pressure

Like blood pressure the membership functions are constructed for other risk factors also

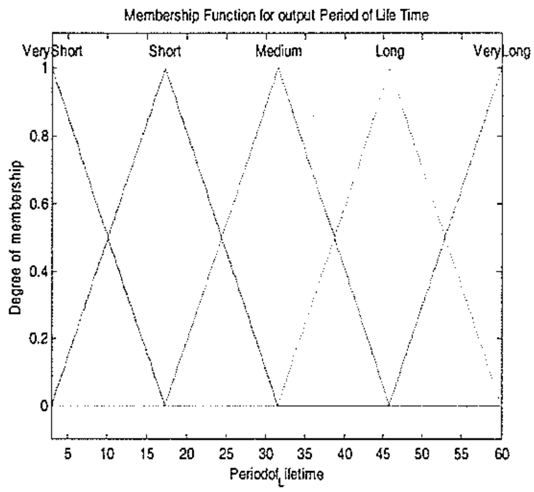

Fig 3.2 Membership function for the output period of life time

3.2 Rule Base

The heart of Fuzzy Logic Controller is the Rule Base. The Rule Base consists of a set of Fuzzy Propositions and is derived from the knowledge Base of the Medical Expertise. A fuzzy proposition or a statement establishes a relationship between different input fuzzy sets and output fuzzy sets.

Table-1: SAMPLE RULES FRAMED FOR THE PROPSED FUZZY LOGIC CONTROLLER

	IF				THEN
Rule No	Blood Pressure	Cholesterol	Diabetic	Obesity	Period of life time
1	Low	Low	Low	Low	Very Long
2	Low	Low	Low	Normal	Very Long
3	Low	Low	Low	High	Very Long
4	Low	Low	Low	Very High	Long
5	Low	Normal	Low	Low	Very Long
6	Low	Normal	Low	Normal	Very Long
7	Low	Normal	Low	High	Very Long
8	Low	Normal	Low	Very High	Long
9	Low	High	Low	Low	Long
10	Low	High	Low	Normal	Long
11	Low	High	Low	High	Long
12	Low	High	Low	Very High	Medium
13	Low	Very High	Low	Low	Medium
14	Low	Very High	Low	Normal	Medium
15	Low	Very High	Low	High	Short
16	Low	Very High	Low	Very High	Short

3.3 Inference Engine

It may be noted that the controllable risk factors varies from individual to individual and also depending upon the human body nature, the rule base is time variant,adaptive,robust in structure. When the number of fuzzy sets describing input variables increases, the number of propositions also increases. Hence writing all propositions is a tedious job, a matrix like representation is followed and is known as Fuzzy Associative Memory (FAM).

LOB / BP,CL	LL	LN	LH	LVH
LL	VL	VL	VL	L
LN	VL	VL	VL	L
LH	L	L	L	M
LVH	M	M	S	S

3.4 Decision Making Logic Component Performs the Following Functions

- Simulates the human decision making procedure based on fuzzy concepts
- Infers fuzzy control actions employing fuzzy complications and linguistic rules

In this phase, the decision rules are constructed for input parameter and control output values to find the active cells so that what control actions should be taken as a result of firing several rules and finally the aggregation of minimum control outputs are taken into consideration to maximize the grade of output to resolve the uncertain linguistic input to produce crisp output. There are four inference methods are available for Fuzzy Logic Controller. Here, the "**MAMDANI INFERENCE METHOD**" is considered. According to this method, with the sample set of data values, the aggregation of control output is [12]

$\mu_{agg(p)=max}\{ \min(2/5,\mu_L(p)), \min(1/2,\mu_{VL}(p)), \min(2/5,\mu_M(p)), \min(1/2,\mu_S(p)) \}$

(iv) Defuzzification Interface

A defuzzification is a process to get a non-fuzzy control action that best represents possibility distribution of an inferred fuzzy control action. Unfortunately, there is no systematic procedure for choosing, a good defuzzification strategy, thus, by considering the properties of application case any one of five methods available can be selected for defuzzification methods. In this study, the "**MEAN OF MAXIMUM**" defuzzification method is applied to find the intersection point of $\mu = 2/5$ with the triangular fuzzy number μ_L (p) and μ_M (p). Substituting $\mu = 2/5$ into

$\mu = p\text{-}6/6,\ 6\mu = p\text{-}6,\ 6\mu + 6 = p,\ 6*2/5 + 6 = 8.4$

$\mu = 36 - p/20,\ 20\mu = 36 - p,\ 20\mu - 36 = -p,\ 20*2/5 - 36 = -24,$ p=24.

Correspondingly the values are ¶1 = 8.4, ¶2= 24.the period of life time in terms of crisp output is

$Zm^* = 8.4+24/2 = 32.4/2 = 16.1 = 16.$

the medium life time membership function. Hence, according to the value applied

$\mu = 2/5$ the period of lifetime to be considered as "**MEDIUM**" (i.e.) the patient can survive for about 12 to 36 months. Therefore, the designed fuzzy logic controller can be used (i) to control the controllable risk factors to regularize the blood flow (ii) how a patient can control the contributing factors of inactivity, (iii) to find the life time of postponement of attack, to protect the patient from high risk of cardiac arrest, (iv) to minimize the sudden death at maximum duration of 3 months to 5 years to reduce the rate of mortality.[4][12].

4. Results

In order to validate the fuzzy logic approach used in construction of Fuzzy Inference System, the extensive simulation is carried out on the simulated model. The system responses with

(a) variations defined in the membership functions as a rule viewer, surface viewer, cluster formation and preservation.

(b) data training, checking, testing with sample data is done to capture the error.

(c) modulation of risk factors reading, which varies, from patient to patient with the level of risk of heart attack, which helps to control the sudden attack.

4.1 Micro View of Simulated Rule Base for Cardiac Arrest

The rule-base constructed are simulated using Matlab to identify the output parameter period of life time

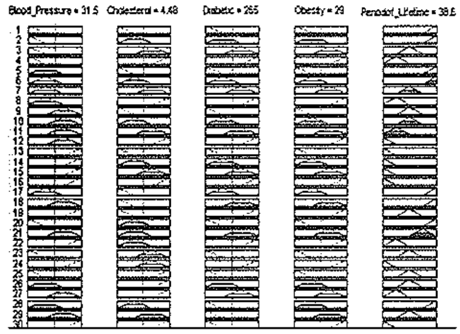

Fig 4.1 Simulated View of the Rule-Base of Cardiac Arrest

4.2 Surface View of Mapping with Input Parameters Vs Output Parameters

Surface View, presents a three-dimensional view curve that represents the mapping with input parameters Vs the output parameter period of life time.. Surface view of the fuzzy logic controller is shown as per the rules framed.

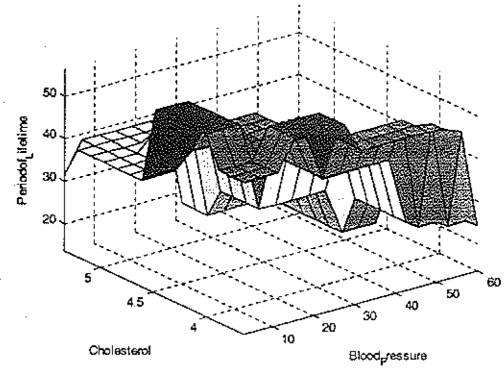

Fig 3.4 Surface View of Blood Pressure vs Cholesterol generated in cardiac arrest fuzzy inference system

4.3 Grouping of Patients Data According to the Risk Factors as Clusters

Cluster analysis is a way to examine similarities and dissimilarities of observations or objects. Data often fall naturally into groups, or clusters, of observations, where the characteristics of objects in the same cluster are similar and the characteristics of objects in different clusters are dissimilar. In this proposed fuzzy logic controller, cluster analysis is used for the purpose of segregating the patients with high risk and low risk. Grouping of clusters are used to identify the patients who need the emergency care. Using the Adaptive Neuro-Fuzzy Inference System (ANFIS) Editor, membership functions are shaped by training them with input/output data rather than specifying them manually. The back propagation algorithm alone or in combination with a least square systems to learn from the data.

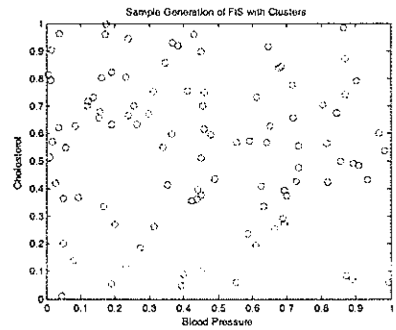

Fig 4.1 Generation of Clusters for the Fuzzy Inference System of Cardiac Arrest

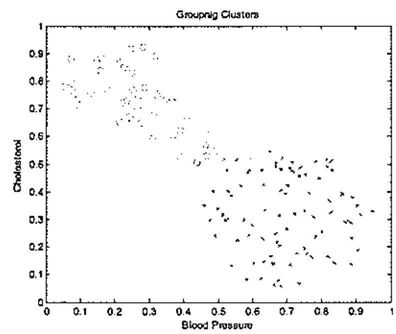

Fig 4.2 Grouping of Clusters for the Cardiac Arrest Fuzzy Inference System

4.4 Generation of FIS for Cluster Shape Preservation Using Adaptive Neuro-Fuzzy Inference System (ANFIS).

The shape preservation is applied to organize the same size and shape clusters, to maintain the characteristics and properties of data in such a way to identify and differentiate the patient's level of risk for emergency treatment.

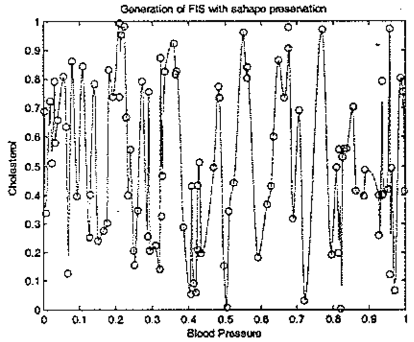

Fig 4.3 Shape Preservation of Cardiac Arrest Fuzzy Inference System

5. Design of the Fundamental Logic Circuit

The circuit is designed as follows. There are two levels in the circuit. The output obtained from the first level is given as an input to the second level, the final output (i.e.) the period of life time to postpone the death is obtained in the third level

Table 4 Truth Table for Logic Circuit

INPUT				OUTPUT	PERIOD OF LIFE TIME
Y0	Y1	Y2	Y3	Z	P
0	0	0	0	0	0----Very Long
1	0	0	0	0	1 ---- M,VS,S
0	1	0	0	1	1 ---- M,VS,S
0	0	1	0	1	1 ---- M,VS,S
0	0	0	1	1	1 ---- M,VS,S
1	1	0	0	1	1 ---- M,VS,S
0	1	1	0	1	1 ---- M,VS,S
1	0	0	1	1	1 ---- M,VS,S
1	0	1	0	1	1 ---- M,VS,S
0	0	1	1	1	1 ---- M,VS,S
0	1	0	1	1	1 ---- M,VS,S
1	1	1	0	1	1 ---- M,VS,S
1	1	0	1	1	1 ---- M,VS,S
1	0	1	1	1	1 ---- M,VS,S
0	1	1	1	1	1---- M,VS,S
1	1	1	1	1	1---- Very Short

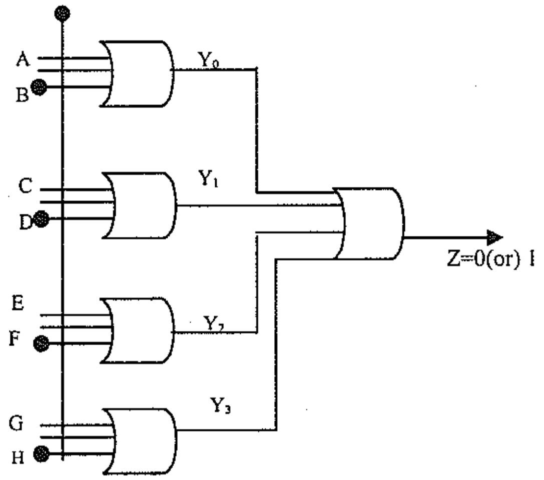

Fig. 4.5 Design of Logic Circuit to Implement the Rule-Base

Once the rules are framed, it is evaluated to overcome the conflicts, rule strength identification and finally, the rules are conjugated to perform the control action to minimize the grade of output to resolve the uncertain input to certain output. Likewise the rules can be framed and evaluated for contributing factors which can be controlled depending on individual responsibility with medical diagnosis and experts advise, ultimately the rate of mortality may be minimized to the maximum level.

6. Conclusion

Uncertainty that arise commonly in human thought process," Much of the decision making in real world takes place in an environment in which the goals, the constraints and the consequences of possible actions are not known precisely" uncertainty arises in the form of vagueness and conflicts which are not represented within the probabilistic framework. This paper describes the motivation and merits for the use of fuzzy logic in Medical Diagnosis. It focuses how a FUZZY LOGIC CONTROLLER can be designed and forecasted to overcome the uncertain and inexact nature of coronary heart disease which can be controlled by a set of linguistic control strategy based on experts knowledge into an automatic control strategy as a rapid rule –based application , to monitor, predict & forecast the nature of blood regularization and to avoid (i) the inadequate blood supply (ii) abnormal flow of blood based on controllable and the contributing factors which successfully reduce the rate of mortality. The proposed Fuzzy Logic Controller can be tested for some quantitative measure by devising a MEMS device and can be used for constructing an optimal Universe of Discourse to normalize and reduce the medical errors from broad to narrow sense.

7. Further Scope of The Work

In the absence of medical diagnosis evidences, it is difficult for the experts to opine about the grade of disease with affirmation. There is a need to undertake diagnostic studies medically to construct more realistic fuzzy numbers for characterizing the imprecision and thereby fuzzily describing the patient's disease nature. Hence, prediction of the postponement period of lifetime of a patient affected by cardiac disease can be detected by devising a MEMS device which can be used for monitoring the status of the controllable risk factors in a normal condition with changing lifestyle, food habits of human beings as the further extension of this work. Also, with the help the device the medical errors can be reduced from broad sense to narrow sense[13].

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