Segregation of Cardiac Arrhythmias in Electrocardiography employing Fuzzy- Genetic classifier

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***Abstract* - One of the important reason for the increase in mortality rate is Cardiac Arrhythmias. These arrhythmias disrupt the normal cardiac functioning and leads to irregular cardiac cyclicity. . It may be too fast (above 100 beats per minute) – Tachycardia or may be too slow (below 60 beats per minute) – Bradycardia. The abnormality of arrhythmias can be assessed medically using Electrocardiography (ECG). The ECG basically represents the P – QRS – T cardiac cyclicity. If any hinderance affects this cyclicity the results might become severe in some cases. For this, timely detection and diagnosis of cardiac arrhythmias is of essence. Such a detection is carried out in this paper. For this, initially the mathematical model that describes the ECG signal is presented and the P, Q, R, S and T features of a normal person is compared with the person who is suffering from one of the arrhythmias. To improve the accuracy of detection, the fuzzy classifier is developed using MATLAB. The ECG signals are the standardised MIT – BIH database. The fuzzification is carried out so that the proper manipulation of imprecise data can be carried out. But, to further improve the accuracy, Genetic Algorithm is applied that is known for finding the optimal solution for a given problem by following various iterations. On comparing, the results obtained from both fuzzy and genetic classifier, it is seen that the Genetic Algorithm gives the best results and improves the accuracy of classification and detection of Cardiac Arrhythmias.**

***Index Terms* - Electrocardiography, Arrhythmias, Fuzzy logic, Genetic Algorithm.**

I. INTRODUCTION

Cardiac Arrhythmia is the major cause of concern these days as it is associated with irregular heartbeat i.e. it might be too fast or too low. As, we know that heart plays a vital role for proper functioning of our body so adequate care must be taken before it becomes too late. The heart is a pumping organ which pumps about 5 litre of blood in human body every minute throughout the body. So, for its proper diagnosis and analysis Electrocardiography (ECG) is used. Electrocardiography is meant to record the electrical activity of heart over a period of time by placing electrodes over the patient's body [8]. There are various reasons for performing ECG some of them are listed as follows:-

- To know the information about the suspected heart attack
- To detect the disturbances in heart rhythm and conduction
- Decreased oxygen supplement to the heart
- To access the electrolyte concentrations
- Sudden collapse or fainting
- Assessing the pulmonary embolism
- To monitor the effect of medication on patient's heart
- Monitoring the abnormal thickening of heart muscle
- Irregular spreading of electrical impulses across the heart.

Therefore, the exact condition of heart is usually reflected by the nature of ECG waveform and heart rate. If proper analysis of ECG is carried out, then ECG could yield valuable information regarding various arrhythmias and disorders related to the heart [8]. Although, ECG is a non-stationary signal, the irregularities in ECG waveform are non-periodic in nature and for clinical observations it might take several hours and is quite a tedious work.

II. STRUCTURE OF HEART

The human heart is a muscular organ that weighs about 250-350 grams and is approximately equal to the size of the fist. The heart is situated behind the breastbone in the chest. The heart wall is composed of three layers i.e. the inner endocardium,

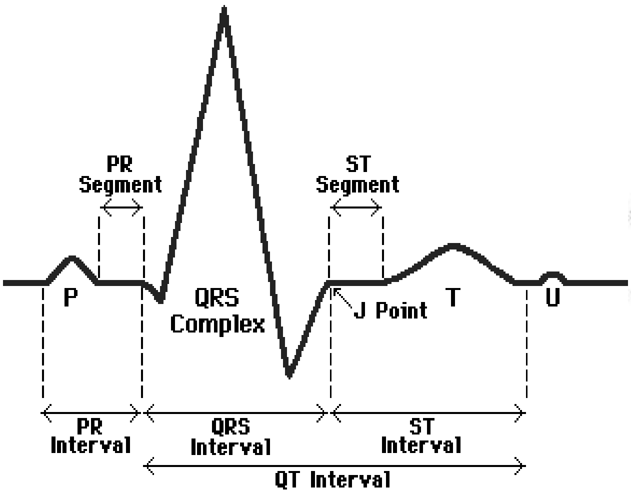

Figure 1 The Structure of Heart

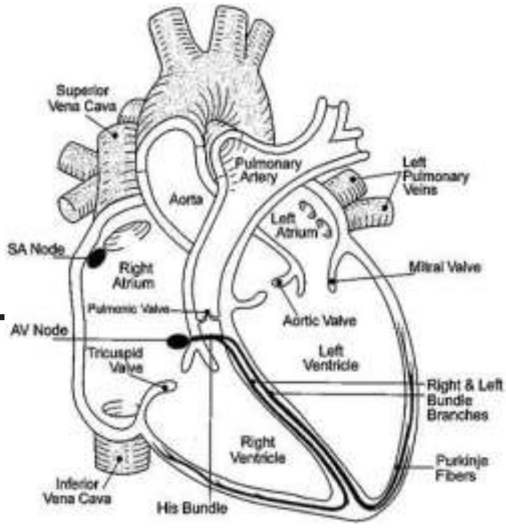

Figure 2 Basic ECG signal

middle myocardium and outer epicardium[9].

The heart is divided into four chambers i.e. two upper atria and the two lower ventricles. The atria act as the receiving chambers and the ventricles act as the discharging chambers. The atria are attached to the ventricles by fibrous, non-conductive tissue that keeps the ventricles electrically isolated from the atria. The Tricuspid valve is responsible for separating the right atrium from the right ventricle. The Mitral (also known as the Bicuspid) valve separates the left atrium from the left ventricle.

III. ELECTROCARDIOGRAPHY (ECG)

The electrocardiography (ECG) refers to the process of recording the electrical signals that arise on the patient's body. By examining these electrical signals, physicians can observe the rhythmic function of the cardiac system.

To record an electrocardiogram (ECG) signal of the patient, a number of electrodes are kept on the chest of the patient. The number of electrodes can vary between two and fourteen depending on the part of the heart to be examined. The ECG estimates the variation in the electrical potential using the electrodes [8]. The recorded potential values are then transformed into a waveform after which the process of signal filtering and amplification is carried out.

During each heartbeat, the normal heart will have an orderly progression of depolarization that starts from the pacemaker cells in the sinoatrial node(SA) and spreads out through the atrium, then passes through the atrioventricular(AV) node down into the bundle of His and then into the Purkinje fibers spreading down and finally to the left throughout the ventricles[9]. This orderly organised pattern of depolarization gives rise to the basic characteristic ECG tracing. To the trained clinician, the ECG can convey a large amount of information i.e. about the structure of the heart and the function of its electrical conduction system. ECG can also be used to measure the rate and rhythm of heart, the size and position of the heart chambers, the presence of any variation in the heart's muscle cells or conduction system, the effects of cardiac drugs used, and the function of implanted pacemakers.

IV. CARDIAC ARRHYTHMIAS

There are chances that heart may get affected by the Arrhythmias which severely affects the cardiac functioning[9]. Cardiac Arrhythmia refers to the irregular functioning of heartbeat. It may be too fast (above 100 beats per minute) – Tachycardia or may be too slow (below 60 beats per minute) – Bradycardia. Arrhythmias can be classified according to the site of origin of problem. The Arrhythmias originating at Atria are classified as Atrial Fibrillation, Atrial Flutter, Wandering Atrial Pacemaker and Sinus Bradycardia. Junctional Arrhythmias are Premature Junctional Tachycardia, Junctional rhythm and Junctional Tachycardia. Ventricular Arrhythmias are classified as Ventricular Fibrillation, Premature Ventricular Contraction and Polymorphic Ventricular Tachycardia. Heart block such as First Degree heart Attack, Second Degree Heart Attack and Third Degree Heart Attack[9].

V. MATHEMATICAL MODEL OF ECG SIGNAL

The first ECG model was developed by Zeeman in 1972. Over the years , many theories have been put forward for the design of these three non-linear equations. These equations can also be derived using the Runge – Kutta (RK) method. The dynamical model generates a trajectory in 3D state space environment with coordinates (x, y, z). The typically generated trajectory is drawn as follows:-

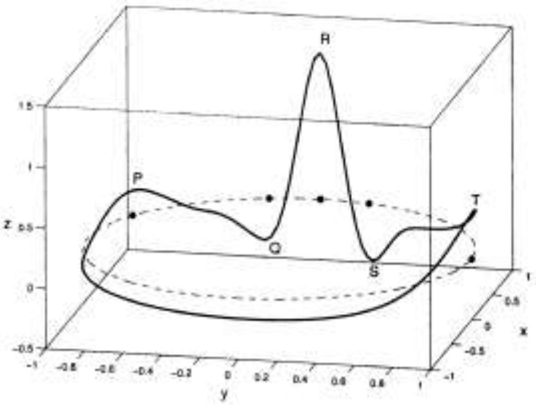

Figure 3 Typical trajectory generated by the dynamical mathematical model [6] in the 3-D space given by (x ,y, z). The dashed line reflects the limit cycle of unit radius while small circle shows the position of the P, Q, R, S and T events.

The three equations are as follows:

$$\dot{x} = \alpha x - wy$$

$$\dot{y} = \alpha y - wx$$

$$\dot{z} = -\sum_{i\in(P,Q,R,S,T)} ai\Delta\theta i \exp\left(-\frac{\Delta\theta i^2}{2ki^2}\right) - (z - zo)$$

where,

$\alpha = 1 - \sqrt{x^2 + y^2}$,

$\Delta\theta i = (\theta - \theta i) \bmod 2\pi$

$\theta = a \tan 2\ (y, x)$

ω = is the angular velocity of the trajectory as it moves around the limit cycle.
These equations of motions are found using the 4th order Runge- Kutta method with time step size, Δt = 1/ fs, where fs is sampling frequency.
Since, the mathematical model is a classical method of prediction of Cardiac Arrhythmia and involves the morphological features that is quite a tedious and complicated work. So, to improve its accuracy the fuzzy logic is developed .

VI. FUZZIFICATION

Fuzzy logic was developed by Zadeh in 1965 to provide the set of tools for manipulating the set of imprecise data. Since its introduction, fuzzy logic has been applied in many areas, some of the specific areas are: signal processing, signal analysis, decision analysis, pattern recognition, control and diagnostics [12]. Fuzzy logic is basically about the four basic concepts i.e.-

1) Fuzzy sets: - the sets with smooth boundaries.
2) Linguistic Variables: - The variables whose values are both qualitatively and quantitatively described by a fuzzy set.
3) Possibility distributions: - The constraints on the value of a linguistic variable that is being imposed by assigning it a fuzzy set.
4) Fuzzy if – then rule: - It is used as the knowledge representation scheme for describing a functional mapping or a logical formula that usually generalise an implication in two – valued logic [13].

The fuzzy rule used here is functional in nature given as:

IF x1 is A1 AND x2 is A2 AND… xn is An THEN y = a0 + $\sum_{i=1}^{n} ai * xi$

Basically, there are three fundamental operations in Fuzzy system i.e. union, intersection and complement. The union of two sets A and B is denoted as A∪B, defined as the collection of those objects that belong to either A or B. The intersection of A and B is denoted as A∩B, defined as the collection of those objects that belong to both A and B. The complement of a set A is denoted as Ā, defined as the collection of objects not belonging to A.
Defuzzification is defined as the process of converting a fuzzy system to a non-fuzzy form. Consequently, one must defuzzify the fuzzy control action (output) that can be inferred from the fuzzy control algorithm, i.e.

z0 = defuzzifier (C)

where, z0 is the non – fuzzy control output and defuzzifier is the defuzzification operator.

VII. GENETIC ALGORITHM

Genetic algorithms are the general purpose search algorithms that are based on the mechanics of natural selection and genetics. The basic principle is that the fittest member of a population has the highest probability for survival. A genetic algorithm likes imitates the evolution of populations. Then the selected solutions undergo the processes of reproduction, crossover, and mutation to generate a new generation of possible solutions, which is expected to achieve better than the previous generation. The production and evaluation of new generations is iterated until convergence. Genetic algorithm is a method which is very easy to understand and does not demand the knowledge of mathematics practically.

VIII. ANALYSIS OF CARDIAC ARRHYTHMIAS USING FUZZY LOGIC

The figure 4 shows the flow diagram of how the fuzzy logic is defined in this paper. This fuzzy classifier is applied on the ECG signals so as to have the precise and smooth prediction of Cardiac Arrhythmias. The membership functions are generated after estimating the 100 ECG signals whose heart conditions are known. The figure 5 represents the graphical view of ECG parameter a_1 , a_2 , a_3 , a_4, a_5 where the minimum and maximum values are represented along with the Cardiac Arrhythmia. The minimum and maximum value of b_1, b_2, b_3, b_4 and b_5 that is the ECG parameter is shown graphically in the figure 6. The minimum and maximum value of θ_1 ,θ_2 , θ_4 and θ_5 that is the ECG parameter is shown graphically in the figure 7.

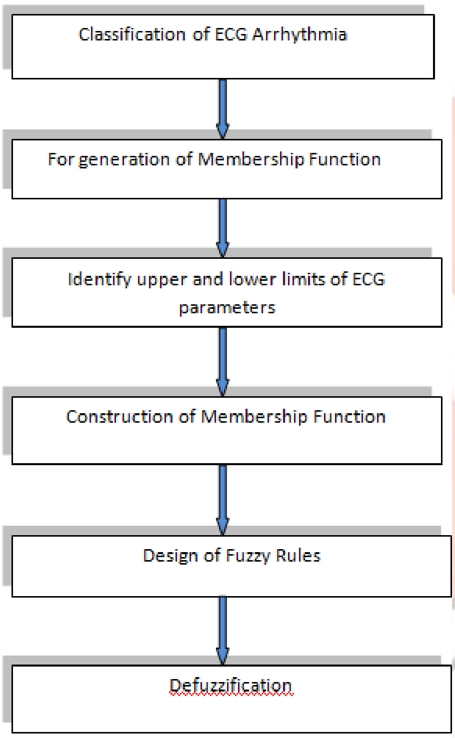

Figure 4 Flow diagram for designing Fuzzy Logic

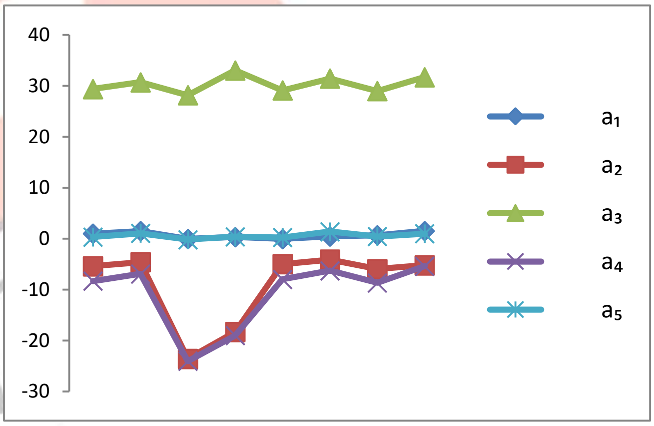

Figure 5 The ECG parameter a_i

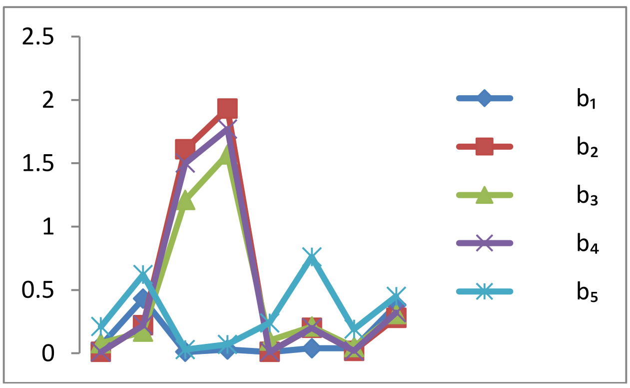

Figure 6 The ECG parameter b_i

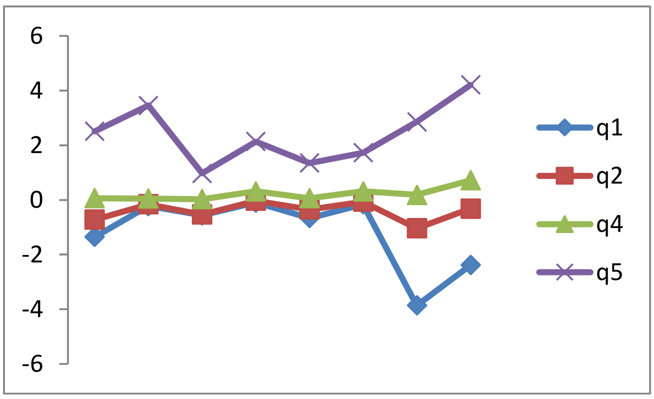

Figure 7 The ECG parameter θ_i

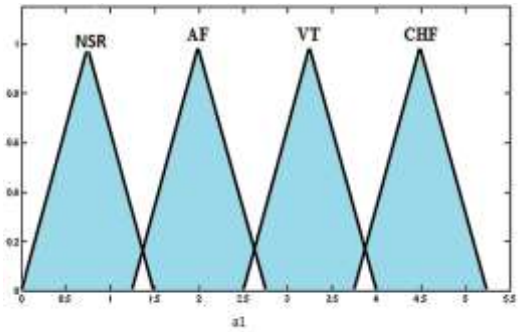

Figure 8 The membership function of output

Table1 Classification of ECG signal on applying Genetic classifier.

ECG Groups with 25 Members	Number of ECG signals placed in each group using the **Genetic classifier**			
	NSR	**CHF**	**VTC**	**AF**
NSR	24	0	1	0
CHF	0	25	0	0
VTC	0	0	24	1
AF	0	1	0	24

Table2 Classification of ECG signal on applying Fuzzy classifier.

ECG Groups with 25 Members	Number of ECG signals placed in each group using the **Fuzzy classifier**			
	NSR	**CHF**	**VTC**	**AF**
NSR	20	2	2	1
CHF	1	22	0	2
VTC	1	1	22	1
AF	1	0	1	23

Therefore, proper construction of fuzzy sets must be done so that defuzzification can be done in a proper manner as shown in figure 8. Also, the generation of membership function in such a way that inappropriate selection of arrhythmia must be prevented.

IX. ANALYSIS OF CARDIAC ARRHYTHMIAS USING THE GENETIC ALGORITHM

Genetic algorithm is known for finding the best optimal solution out of a number of solutions. In this paper, the mutation rate is considered to be 0.06 and crossover rate is taken to be 0.6 for the population size of 100.
The Table1 shows the results on applying the Genetic Classifier on 100 ECG signals each belonging to different set of arrhythmia[23].
The Table 2 shows the classification of ECG signal Using Fuzzy Classifier. Therefore, out of 100 ECG signals only 87 signals could be segregated accurately showing that accuracy obtained on applying fuzzy classifier is 87%.Using Genetic classifer, out of 100 ECG signals 97 signals can be segregated accurately showing that accuracy obtained on applying genetic classifier is 97%. Clearly, showing that the better results are obtained using Genetic classifier and makes the Cardiac Arrhythmia prediction more possible and precise.

X. CONCLUSION

In medical clinics, the Cardiac Arrhythmias are detected by the continuous monitoring of ECG signals over several hours that is quite a tedious and time consuming task. Therefore, efforts are needed to be made so that automatic detection and classification can be carried out. In the process of automatic detection, the accuracy is a key factor for cardiac arrhythmia detection and classification. So, the method which provides the maximum accuracy must be adopted. For this purpose, Genetic Algorithm is adopted in our proposed work so that better analysis of various arrhythmias can be carried out. The Genetic Algorithm is applied on 100 ECG signals so as to optimise the performance of the fuzzy classifier. The genetic algorithm is applied on certain number of population so as to yield the best optimal solution. The comparison is made between the fuzzy and genetic classifier in such a way to segregate between the different types of cardiac arrhythmias. The results show that the Genetic Algorithm give the minimum error function and the accuracy of such detection is improved. For proper validation, the record of ECG signal is obtained from the MIT – BIH database. The purposed algorithm is conducted in the MATLAB environment.
Therefore, the present work is done for cardiac arrhythmias like Normal Sinus Rhythm (NSR), Congestive Heart Failure (CHF), Atrial Fibrillation (AF) and Ventricular Tachycardia (VTC). Further, the other arrhythmias must be considered with other improved algorithms

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