



ECG Signal Analysis Using Data Clustering and Artificial Neural Networks

Nalla.Srinivas¹, A.Vinay Babu², M.D.Rajak³,
¹Research Scholar, Department Computer Science
Acharya Nagarjuna University, Guntur, India
²Director of JNTU, Hyderabad, India
³Acharya Nagarjuna University, Guntur, India

Abstract: In this paper analysis of 'Electrocardiogram (ECG) PQRSTU-waveforms and prediction of particular disease infection or state of a patient' is done using Fuzzy logic and Artificial Neural Network (FANN), Precise Electrocardiogram (ECG) classification to diagnose patient's condition is essential. For classification of such Difficult-to-Diagnose-Signals, i.e. ECG signal, classification is performed using various pulses, like v1, v2, v3, v4, v5, v6 etc corresponding hidden layer in ANN i.e., P-Wave, PR-Interval, QRS-Interval, ST-Interval, T-Wave etc analysis of each Input pulse used to train the neural network. Output of the neural network gives weight factors of each signal to create a data set. Data sets are organized with clusters. These cluster data sets Are analysis by Adaptive Resonance theory.

Keywords: Electrocardiogram, Adaptive Resonance Theory, Neural Network, Premature Ventricular contraction, sinus tachycardia, sinus brady cardia, Hypertext Preprocessor.

I. INTRODUCTION

Heart disease has become the most common disease that affects human beings worldwide. Each year millions of people die from heart attacks and an equal number undergo coronary artery bypass surgery or balloon angioplasty for advanced heart disease. Early detection and timely treatment can prevent such events. This would improve the quality of life and slow the progression of heart failure [1]. The first step in the diagnosis is to record the ECG of the patient. An ECG record is a non-invasive diagnostic tool used for the assessment of a patient's heart condition [2]. The features of the ECG, when recognized by simple observations, and combined with heart rate, can lead to a fairly accurate and fast diagnosis.

ANN has a significant advantage to solve problems that either do not have an algorithmic solution or solution that is too complex. These networks have been applied effectively with in medical domain for clinical diagnosis, image and signal analysis and interpretation of these signals. The conventional (Heart Attack perdition system) has been identified as one of the ANN structures that can accurately perform classification tasks. Neural Network is one of the most used methods of ECG beat classification, Multi-Layer Perception (MLP) based on the Neural Networks has been chosen to be able to classify the ECG signals. they are trained with Supervision, using Back- Propagation which minimize the squared error between the actual outputs of the network and the desired outputs. Neural network structure consists of four layers (an input layer, two hidden layers, and output layer) using Feed-Forward, Back-propagation, the input is mapped onto each node like P, QRS, ST, T Intervals in the hidden layer weight factors of Sinus tachycardia, Sinus Bradycardia, Atrial tachycardia and atrial flutter, Atrial fibrillation, Atrioventricular block and output layer is a linear combination of hidden layer outputs multiplied by their weights.

II. REVIEW OF PREVIOUS WORK

Numerous works in literature related with heart disease diagnosis using fuzzy and artificial intelligence techniques were demonstrated in [1],[2]. In their work three classes of ECG signals selected viz, the normal sinus rhythm, malignant ventricular ectopic and atrial fibrillation were selected and the shape of the PQRST waveforms was demonstrated. Different classes of ECG signals were also reported in [3].

Nikon E.mastorakis have developed [4] an Expert system for ECG Analysis that works by hierarchically organizing the knowledge in a context free Environment. They have used Turbo C for analysis and Turbo prolog for diagnosis. Hamiltonp[5] has developed a software for ECG beat detection and classification and made

available as an open source system for use by researchers. silipo R and marchesis[6] used neural networks for automatic ECG analysis for the classification of different cardiac abnormalities. The premature ventricular contraction (PVC) and the premature atrial contraction (PAC) are cardiac arrhythmias as shown in figure 1, 2, which are widely encountered in the cardiologic field they can be detected using electrocardiogram signal parameter. Implemented Neuro-fuzzy approach to identify these abnormal beats. Classifier was also reported in [8], [9].

The electrocardiogram ECG is a physiological signal that represents the mechanical heart contraction and relaxation as shown healthy persons ECG signals in figure 3 from [10]. If p is upward and QRS is upward and T is Downward RR0 is Normal RR1 is Normal then type is Normal ECG Signal.

- P wave: is the contraction of the atria.
- QRS complex: equivalent to a contraction the ventricles.
- T wave: is the relaxation of ventricles.

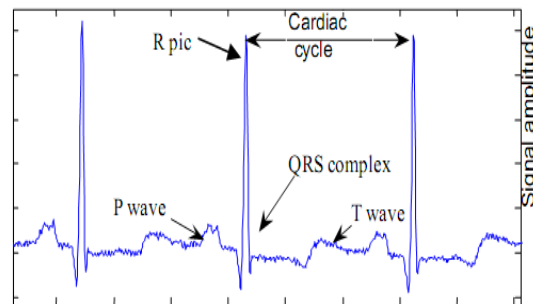


Fig.1: ECG of a health person

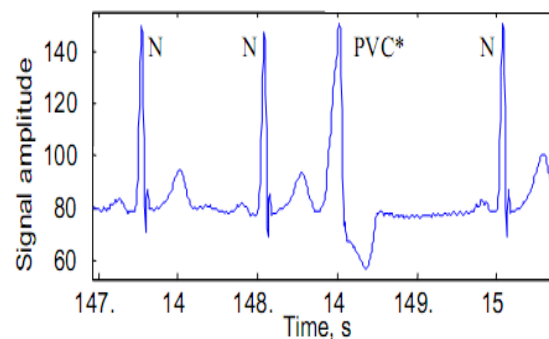


Fig 2: The premature ventricular contraction (PVC)

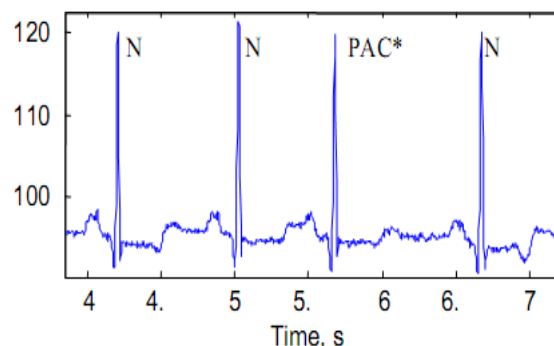


Fig.3: The premature atrial contraction (PAC)

III. HEART AND SIGNALS

The heart is divided two right and left part. Each part has two chambers called atrium and ventricle. The heart has four valves as shown in figure 4, 5, 6 from [10]. It produced by an electrocardiograph, which records the electrical activity of the heart over time.

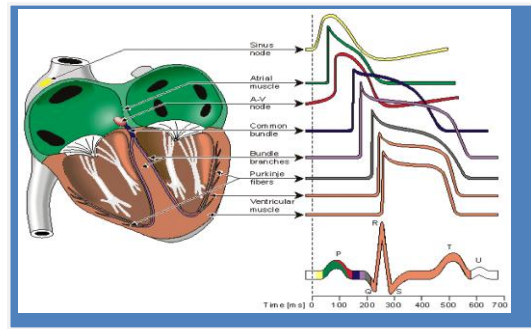


Fig. 4: Structure of heart and various signals

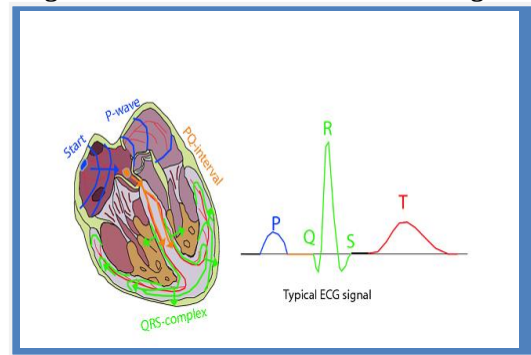


Fig. 5: The activation cycle of the heart

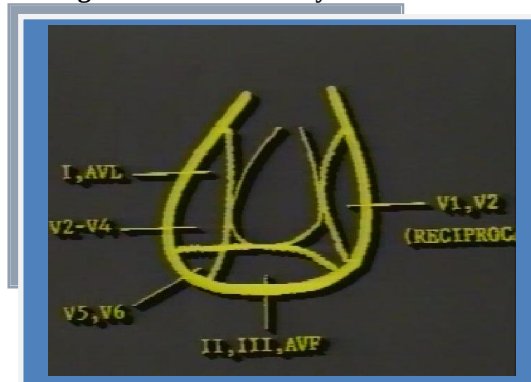


Fig. 6: v1, v2, v3, v4, v5, v6 pulses in heart

A. Reading the Interpreting the ECG

The ECG signals must be interpreted and examined systematically. A convenient method is as follows:

- Determine the cardiac rate and rhythm.
- Assess the P-R interval and the width of the QRS complex.
- Examine the P wave the QRS complex
- Examine the S-T segment and T wave.

B. ECG Signal

ECG signal is generated by rhythmic contractions of the heart measured by electrodes .This signal can be effectively used for heart disease diagnosis. The analysis problem can be divided into two parts, the feature extraction and classification. The feature extraction procedure is necessary to detect abnormality of the signal, while the classification procedure is used to distinguish disease type.

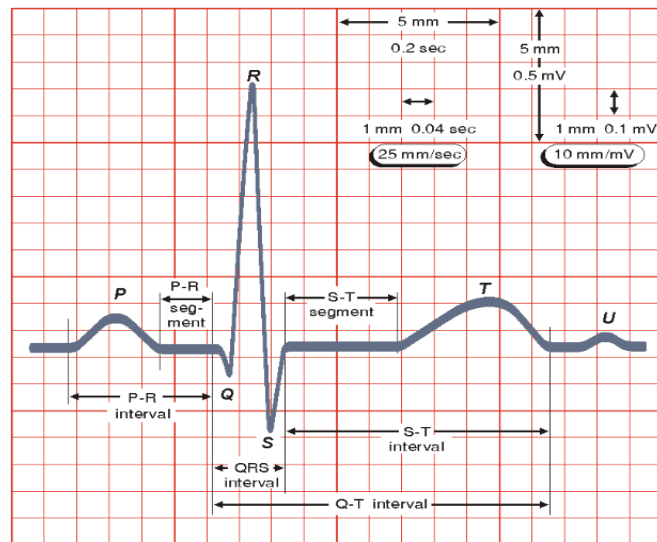


Fig. 7: Normal PQRST waveform and its intervals.

There are four major ECG intervals RR, QRS, QT, ST, T segments. The heart rate (beats per minute) can be readily computed from the inter beat (R-R) interval by dividing the number of large (0.20s) time units between consecutive R waves into 300 or the number of small (0.04s) time units between consecutive R waves into 1500. The PR interval measures the time (normally 120 to 200 ms) between atrial and ventricular depolarization.

It includes the physiologic delay imposed by stimulation of cells in the AV junction area. The QRS interval (normally 100ms or less) reflects the duration of ventricular depolarization. The QT interval includes both ventricular depolarization and repolarization times and A rate related QT interval, QTc can be calculated as $QT/R-R$ and normally is ≤ 0.44 s.

The QRS complex is subdivided into specific deflections or waves if the initial QRS deflection in a given lead is negative it is termed as Q wave [6]. The first positive deflection is termed an R wave, A negative deflection after an R wave is an S wave subsequent positive or negative wave are labeled R and s respectively. Lowercase letter (qrs) are used for waves of relatively small amplitude. An entirely negative QRS complex is termed a QS wave. The ECG signal is made up of a group of repetitive PQRST signals. The normal class of PQRSTU is shown in figure 7.

IV. SAMPLE ECG SIGNALS

The cardiac impulse arises normally from the sinus node in sinus tachycardia and the ecg is Normal Form. The pulse rate is increases above 100 beats/min (adults). Sinus tachycardia may result from emotion, exercise, fever, hyperthyroidism and anemia as shown in figure 8-11 reference from [10].

A. Sinus bradycardia

The heart rate is less than 60 beats/min. Sinus bradycardia occurs in trained athletes and in patients with increased intracranial pressure, myxoedema and jaundice are presented in figure 8.

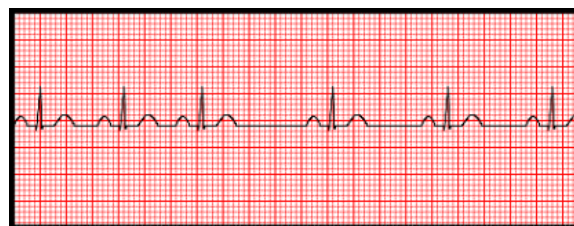


Fig. 8: ECG Sinus arrhythmia signal

B. Atrial Tachycardia And Atrial Flutter

Atrial tachycardia and atrial flutter are due to the presence of an ectopic focus in the atrium which beats regularly at a rapid rate. The p waves are abnormal in shape, but the QRS complexes are usually normal as presented in figure 9.

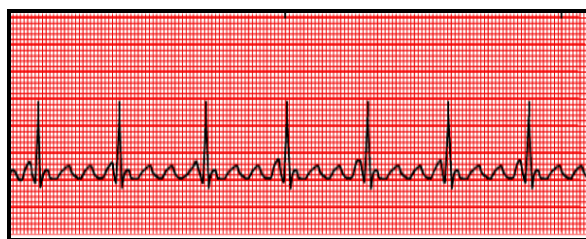


Fig. 9: ECG Atrial Flutter signal

C. Atrial Fibrillation

There is no co-ordinate atrial activity (either electrical or mechanical in atrial fibrillation. The ECG (figure10) illustrates f (fibrillation) waves representing the atrial activity instead of P waves especially in lead V1, The QRS complexes are normal but occur irregularly.



Fig. 10: ECG Atrial Fibrillation signal.

D. Atrioventricular Block (Heart Block)

In first degree atrioventricular block The P-R interval exceeds 0.2 second and all atrial impulses reach the ventricles .When some impulses fail to reach the ventricles but others do reach it, then there is second-degree atrioventricular block. In third degree atrioventricular block (complete) the atria and ventricles beat independently, i.e, they are dissociated the ventricular rate is usually slow, 20-40 beats for min, and often erratic and may fail completely ventricular stands stills as presented in figure 11.

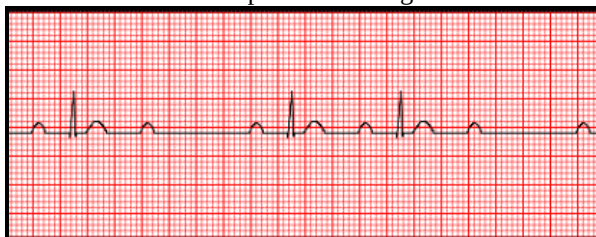


Fig. 11 ECG Atrioventricular Block (Heart Block) Signal

V. METHODOLOGY

Five classes of ECG signals have been selected for the classification tasks. The normal sinus tachycardia, sinus bradycardia, Atrial tachycardia and a trial flutter, Atrial fibrillation, Atrioventricular Block (heart block). From the web site of physionet the database provides 22 sinus rhythm type,23 atrial fibrillation type,20 Atrioventricular Block. The signals from the five classes are sampled at the rate of 128 samples for second. All signal input to neural network .These feature representations involve one set of PQRST-wave from a series of PQRST-waves in a period of one second. To extract accurate information from each set of ECG data, five sets of PQRST-wave from different locations in one ECG signal input to neural networks. For every ECG data, five sets of PQRST-wave were extracted using wavelet decomposition technique. This technique would detect the location of maximum P-wave and P-R interval, QRS, S-T segment and T wave. Detection by mat lab provides valuable information found in the interval and amplitude of ECG signals. Input to train the neural network. Output of the neural network gives weight factors of each signal. Each weight factor can represents 0's and 1's.

VI. NETWORK ARCHITECTURE AND TRAINING METHOD

An FANN classifier is presented as a diagnostic tool to aid physicians in the classification of heart diseases. For the classification of the cardiac beats A Multi-Layer Feed-forward Neural Network (MLFN) used to analyze the PQRST is referenced to as NN in this paper. NN was constructed using the neural network software packages in Matlab. Figure 12 illustrates the architecture of NN. which included an input layer a hidden layer and an output layer neurons in the input layer act only as buffers for distributing the input signals .Input signals are P-Wave, PR-Interval, QRS-Interval, ST-Interval, T-Wave in the hidden layer sums up its input signals x_i after weighting them with the strengths of the respective connection w_{ij} form the input layer and computes its

output as an activation function f of the sum. Where f is hyperbolic tangent function. As illustrate in figure 12. The back propagation (BP) algorithm was chosen as the training algorithm for Neural Network.

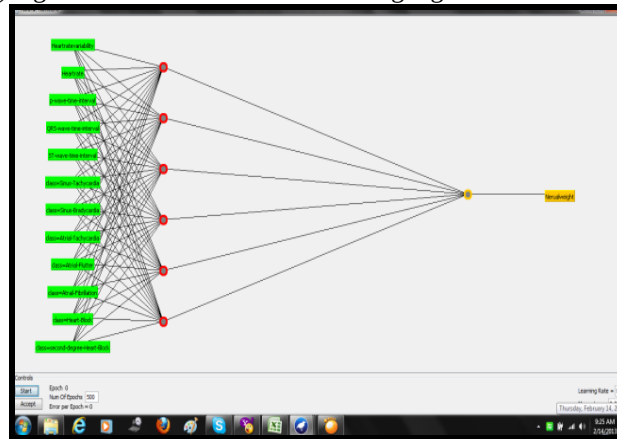


Fig. 12 Neural Network architecture

VII. Adaptive Resonance Theory Algorithm for ECG Signal Analysis

The detail procedure of the implemented algorithm is given below.

Step 1. Initialize top down and bottom up connection weights

Top-down connection weights: $t_{ij}(0) = 1$

Bottom-up connection weights:

$$B_{ij}(0) = 1 / (1+N)$$

For all input nodes $i = 0, 1, \dots, (N-1)$ and

Output nodes $j = 0, 1, \dots, (M-1)$

Select a value for vigilance threshold between zero and One $0 \leq \rho \leq 1$

Step 2. Apply new input vector X , consisting of zero / one Elements x_i , then it is treated as the member of the first group.

Step 3. Compute matching score, The output μ_j , of every output node j equals :

$$\mu_j = \sum b_{ij}(t)x_i$$

Step 4. Select best matching exemplar i.e. node with

Maximum output

$$\mu_{\theta} = \max_j \{\mu_j\}$$

Outputs of other neurons are suppressed (lateral inhibition); in case of tie choose the neuron with lower j .

Step 5. Vigilance test (i.e. test of similarity with best Matching exemplar)

$\|TX\| = \sum t_{i\theta} x_i$ number of perfectly matching '1's between input vector and best matching exemplar

$\|X\| = \sum x_i$ number of '1's in input vector represent the new class

If similarity $\frac{\|TX\|}{\|X\|} > \rho$

go to step 7; else go to step 6.

Step 6. Disable best matching exemplar temporarily Output of the best matching node selected in step 4 is Temporarily set to zero; other outputs have a inhibition then go to step 3 . In step 3, a new neuron in the output layer gets selected to selected to represent the new class.

Step 7. Update best matching exemplar temporarily

$$B_{i\theta}(t+1) = \frac{t_{i\theta}(t)x_i}{0.5 + t_{i\theta}(t)x_i}$$

Step 8: Repeat Go to step 2, after enabling any nodes disabled in step 6.

VIII. WORKING OF DEVELOPED CLUSTERING SYSTEM IMPLEMENTING USING ECG SIGNALS

The developed system as shown in figure 13 is based on ART Algorithm to cluster the data Based on the algorithm, a complete package has been developed .This software has been tested successfully with a number of

examples. One example is shown in figure 14 and 15 having nine parts with different features. The developed package clusters are divided according to the similarities of features.

0	0	1	0	0	1	1	0	0
1	0	0	0	1	0	0	1	0
0	1	0	1	0	0	0	0	1
0	0	0	0	1	0	0	1	0
0	0	1	0	0	1	1	0	0
0	1	0	1	0	0	1	0	1
0	1	0	1	0	0	0	0	0
1	0	0	0	1	0	0	1	0
0	0	0	0	0	0	1	0	0

Fig. 13 Output of the neural network gives weight factors of each signal representation of 0's and 1's.

Fig. 14. Developed Clustering package

Enter the input file name in which input is defined in the Following order given below.

No. of Bottom layer neurons (equal to number of Features) = 9

Max. Expected number of Groups (equal to total parts) = 9

No. of top layer neurons (equal to total number of parts) = 9

Vigilance parameter = .7

A. FINAL RESULTS

1 Part: 0 0 1 0 0 1 1 0 0 Cluster: 1

2 Part: 1 0 0 0 1 0 0 1 0 Cluster: 2

3 Part: 0 1 0 1 0 0 0 0 1 Cluster: 3

4 Part: 0 0 0 0 1 0 0 1 0 Cluster: 2

5 Part: 0 0 1 0 0 1 1 0 0 Cluster: 1

6 Part: 0 1 0 1 0 0 1 0 1 Cluster: 3

7 Part: 0 1 0 1 0 0 0 0 0 Cluster: 3

8 Part: 1 0 0 0 1 0 0 1 0 Cluster: 4

9 Part: 0 0 0 0 0 0 1 0 0 Cluster: 1

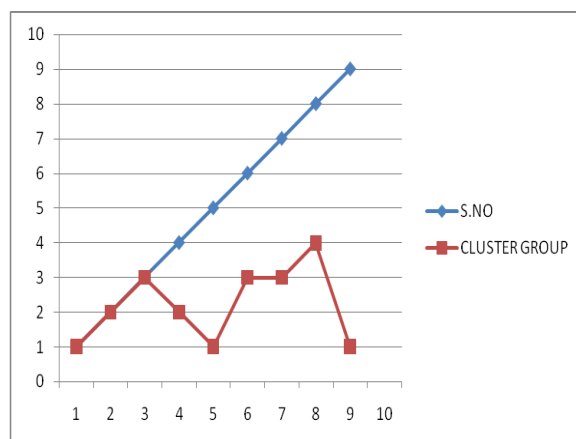


Fig. 15 Comparison of cluster group and its weight factors

When the first input vector (part 1) is presented, it is coded as belonging to cluster 1 (i.e. part family 1) and the first neuron of the recognition layer (i.e. top layer) is made to identify this class. Similarly the parts 2 and 3 as cluster 2 and 3 respectively. Next part 4 is classified as cluster 2 (i.e. part family 2) based on the level of similarity with part 2. Part 5 is coded as cluster 1, while parts 6 and 7 get coded as cluster 3 vectors. when part 8 is presented, it is not found to be similar to part 2, because of the earlier contraction of this exemplar due to part 4, hence part 8 gets coded under a new cluster 4. Thus after all the parts are processed, there four clusters or part families. In a similar we get alternative solutions for the same problem by talking different value of vigilance parameter. These clusters indicate that finding type of ECG signals.

IX. CONCLUSION

Based on the results it can be concluded that Yi can accurately classify ECG Signals into Sinus brady cardia, Atrial tachy cardia, Atrial fibrillation, Atrioventricular Block. The Wavelet decomposition technique Used in feature extraction process performed satisfactorily to effectively project P, Q, R, S and T Waves From original ECG signal. The result indicate a high level of efficient the proposed thod outperforms the other methods with an impressive accuracy of 98% our system has many advantages including efficieny and simplicity, We believe that it is a very suitable to arrhythmic detection in clinical practice

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Nalla.Srinivas received M.Tech degree in Computer Science engineering, M.Phil (Computer Science) from Alagappa university, Tamilnadu, india. He is pursuing Ph.D in Computer Science and Engineering from Nagarjuna University Guntur. He is a member IEEE. He worked as Assistant Professor in Sirte University Sirte Libya. He has 12 years experience in teaching in various Educational Institutes. His field of interest in Artificial Neural Networks and fuzzy Logic. He took an initiative in Artificial neural network, intelligent fuzzy computing.



Dr. Vinay Babu, received B.E. (OU), M.E. (OU), M.Tech. (JNTU), Ph.D. (JNTU). He is the current Director of the Admissions and also Professor of CSE at JNTU. He performs both his roles with ease. He is indeed a widely read and active person in the academic front. His articles and publications are published all over the world. An expert in his field and also societal contribution in organizing NSS related activities. He is a complete individual and a believer in holistic education. A man of essence, he holds great interest in the major areas of Electronics and Engineering.

M.D.Razack is a Assistant Professor in computer Science Department, Acharya Nagarjuna University, guntur. His field of Interest is Data mining, Artificial Neural Network.