

Electrocardiograph (ECG) Signal Analysis by Neural Networks



Engineering

KEYWORDS : Arrhythmia, Artificial Neural Network, Electrocardiogram, Premature Ventricular contraction.

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ABSTRACT

The present study is Electrocardiogram (ECG), - waveforms and prediction of particular disease infection or state of a patient is done using Genetic Algorithm and Artificial Neural Network, precise Electrocardiogram classification to diagnose patient's condition is essential. Cardiac Arrhythmias shows a condition of abnormal electrical activity in the heart which is a threat to humans. This presents a method to analyze electrocardiogram (ECG) signal, extract the features, for the classification of heart beats according to different arrhythmias. In the first step an attempt was made to generate Electrocardiogram waveforms by developing a suitable MATLAB simulator. For classification of such difficult to diagnose signals. The peaks in the ECG signal and then Neural Networks are applied to identify the diseases. Genetic Algorithm is used to train the network.

INTRODUCTION

The development of bio-signal analysis systems has become a major investigative field, due to technological progress in signal processing systems, and the large number of alternative solutions to a specific problem. Electrocardiography is amongst the most studied type of bio-signals, since several decades of Electrocardiographic (ECG) signal research has made this basic discipline a tool for the diagnosis of cardiac disorders. Because of its simplicity, low cost and a non-invasive nature it, is still widely used despite the appearance of newer techniques. This paper covers the problem of long-term recording analysis corresponding to ECG signals of Holter records. The motivation for studying this issue focuses on the development of methods for cardiac arrhythmia analysis to identify particular events that occur at specific periods in time. These events are associated with cardiac disorders that may become potentially harmful to the patient. The developed methods are aimed at further development of specialized equipment that provide clinical monitoring for both the patient and the specialist, and that support the diagnosis in real time, improving mortality rates for heart problems especially for people in rural areas, to improve their access to this type of procedure that is currently not widely accessible. The wave of depolarization produces a flow of electric current and it can be detected by keeping the electrodes on the surface of the body. Once the depolarization is complete, the cardiac cells are able to restore their normal polarity by a process called re-polarization. This is also sensed by the electrodes Cromwell et. al [1]. Srinivas et.al [3] Identification of Cardiac Arrhythmia with respect to ECG Signal by Neural Networks and Genetic Programming.

The context analysis of such signals involves two major aspects that are studied in this work. The first one corresponds to the large amount of data stored in the records, reaching up to 100.000 heartbeats for its evaluation, which becomes a hard task for the specialist who evaluates the information and decides what heartbeats are important for a determined analysis. There are cases where only a few beats of the recording become essential in the diagnosis of some pathology or prevention of deadly diseases. Therefore, a detailed analysis of the entire record is needed. The second aspect corresponds to the intrinsic characteristics of the signal, such as heart rate variability, morphological variety, among others, that could be the result of driving problems in the cardiac system or may be a patient's physical characteristics. The electrical nature of ECG signals and its transmission toward acquisition devices increases the noise sensitivity, which can completely alter the diagnostic information contained in the signal, changing the training processes in the identification of cardiac pathologies. Heart disease diagnosis using fuzzy and artificial intelligence techniques were demonstrated in Hafizah Husain and

Lai Len, Ahuja et. al [4, 8]. 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 Cohen [6]. Chikh, and Beereksi Regig [5] Application of Artificial neural networks to identify the premature Ventricular contraction (PVC) beats.

Consequently, both aspects have been strongly considered in the automatic ECG processing and analysis procedures to detect, classify, and cluster heartbeats. Thus, several methods have been reported in the scientific literature to carry out those classification-related tasks, using either supervised or unsupervised approaches. Saritha et.al [7] ECG Signal Analysis Using Wavelet Transforms. However, due to a large variability in ECG heartbeat morphology, the former methods tuned in a specific ECG dataset may have decreased performances in other datasets. In addition, these techniques require a considerable amount of known and labelled heartbeats which is not feasible when having long-term ECG monitoring. Regarding unsupervised methods, even their performance usually does not over-perform supervised training, yet former methods can be applied to a broader set of ECG recordings as they can dynamically adapt to new signal features. Moreover, additional factors must be taken into account, such as highly unbalanced classes, uncertainty of the number of classes, signal variability, artifacts, etc. Unsupervised analysis is preferred for Holter monitoring.

HEART AND SIGNALS

Heart is divided into right and left parts. Each part has two chambers called atrium and ventricle. The heart has four valves as shown in figures (1) - (2). It is produced by an electrocardiograph (ECG), which records the electrical activity of the heart over time.

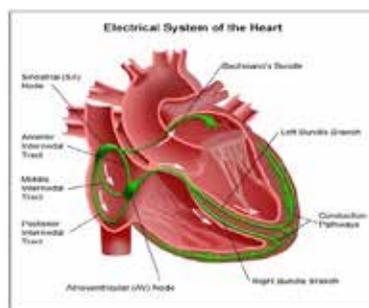


Figure (1): Structure of heart and various electrical signals

(i) Reading / Interpreting the Electrocardiograph (ECG)

The electrocardiograph (ECG) signals must be interpreted and examined systematically. A convenient method is:

- 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

(ii) Electrocardiograph (ECG) Signal

The ECG records the electrical activity of the heart, where each heart beat is displayed as a series of electrical waves characterized by peaks and valleys. Any ECG gives two kinds of information. One, the duration of the electrical wave crossing the heart which in turn decides whether the electrical activity is normal or slow or irregular and the second is the amount of electrical activity passing through the heart muscle which enables to find whether the parts of the heart are too large or overworked. Normally, the frequency range of an ECG signal is of 0.05–100 Hz and its dynamic range – of 1–10 mV. The ECG signal is characterized by five peaks and valleys labelled by the letters P, Q, R, S, T. In some cases we also use another peak called U. The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the QRS complex, as well as T- and P waves. The P-wave represents the activation of the upper chambers of the heart, the atria, while the QRS complex and T-wave represent the excitation of the ventricles or the lower chamber of the heart. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate, the ST segment *etc.* can be performed [2].

In the normal sinus rhythm (normal state of the heart) the P-R interval is in the range of 0.12 to 0.2 seconds. The QRS interval is from 0.04 to 0.12 seconds. The Q-T interval is less than 0.42 seconds and the normal rate of the heart is from 60 to 100 beats per minute. So, from the recorded shape of the ECG, we can say whether the heart activity is normal or abnormal. The electrocardiogram is a graphic recording or display of the time variant voltages produced by the myocardium during the cardiac cycle. The P-, QRS- and T-waves reflect the rhythmic electrical depolarization and repolarisation of the myocardium associated with the contractions of the atria and ventricles. This ECG is used clinically in diagnosing various abnormalities and conditions associated with the heart. This ECG is used clinically in diagnosing various abnormalities and conditions associated with the heart. The normal class of PQRSTU is shown in figure (4).

Amplitude

P-wave	: 0.25 mV
R-wave	: 1.60 mV
Q-wave	: 25% R wave
T-wave	: 0.1 to 0.5 mV

Duration

P-R interval	: 0.12 to 0.20 s
Q-T interval	: 0.35 to 0.44 s
S-T interval	: 0.05 to 0.15 s
P-wave interval	: 0.11 s
QRS interval	: 0.09 s

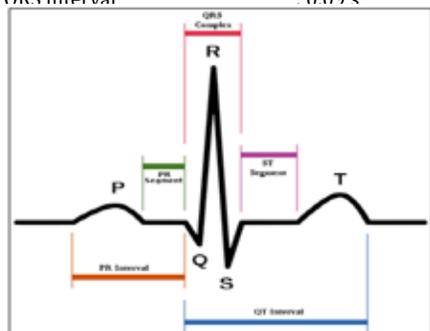


Figure (2): Normal PQRSTU waveform and its intervals

SAMPLE ECG SIGNALS

The cardiac impulse arises normally from the sinus node in sinus tachycardia and the electrocardiograph (ECG) is Normal Form. The pulse rate increases above 100 beats/min (in adults). Sinus tachycardia may result from emotion, exercise, fever, hyperthyroidism and anemia.

(i) Sinus bradycardia:

Each action potential in the heart originates near the top of the right atrium at a point called the pacemaker or sinoatrial (SA) node. 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 (5).

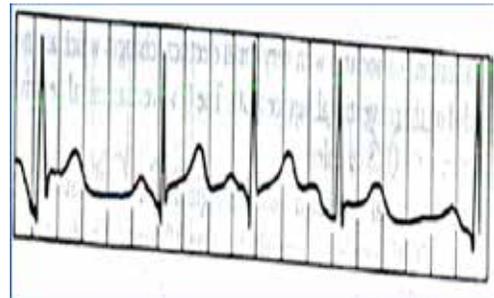


Figure (5): Electrocardiograph (ECG) Sinus arrhythmia signal

(ii) 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 (6).

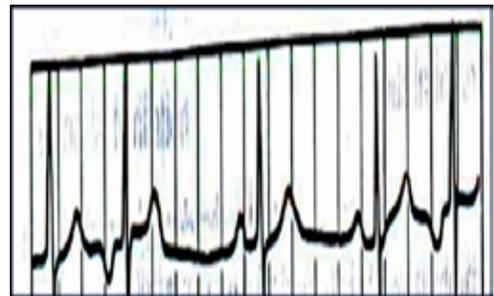


Figure (6): Electrocardiograph (ECG) Atrial extra systoles signal

(iii) Atrial Fibrillation:

The horizontal segment of this waveform preceding the P-wave is designated as the baseline or the isopotential line. The P-wave represents depolarization of the atrial musculature. The QRS complex is the combined result of the repolarization of the atria and depolarization of the ventricles, which occur almost simultaneously. There is no co-ordinate atrial activity (either electrical or mechanical in atrial fibrillation). The ECG illustrates figure (7) f (fibrillation) waves representing the atrial activity instead of P waves especially in lead V1, The QRS complexes are normal but occur irregularly.

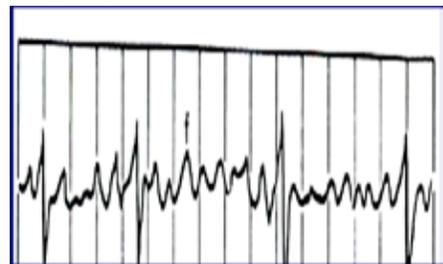


Figure (7): Electrocardiograph (ECG) Atrial Tachycardia signal

Atrioventricular Block (Heart Block):

The normal value of heart beat lies in the range of 60 to 100 beats/minute. A slower rate than this is called bradycardia

(Slow heart) and a higher rate are called tachycardia (Fast heart). If the cycles are not evenly spaced, an arrhythmia may be indicated. If the P-R interval is greater than 0.2 seconds, it may suggest blockage of the AV node. This is presented detailed in figure (8).

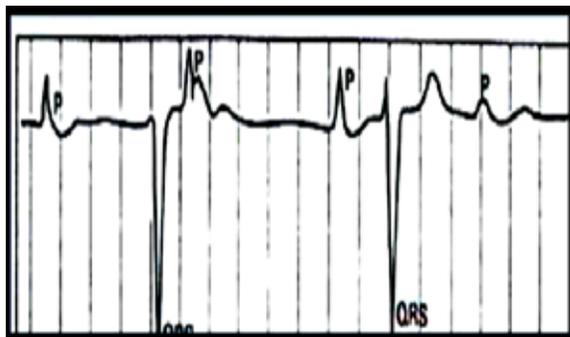


Figure (8): Electrocardiograph (ECG) Atrial flutter (2:1 block) Signal

PROPOSED WORK

This work is focused on the study of the first type of pathologies described above. In particular, the experiments are developed over the entire QRS complexes that are associated with ventricular electrical activity. They contain clinic important information, for example its morphology presents significant changes in abnormal ventricular heartbeats. QRS complex is also present in most of the heartbeats and its signal to noise ratio is the highest among all waves present in the signal. The main problem of ECG analysis is the wide variability into signal morphology, not only among patients but also due to patient movements, changes in the electrical conduction and characteristics of the body among others. Because of this, it is not possible to form a training set that takes into account all cases of interest. In addition, the ECG signal is contaminated by several noise sources, both external sources (interference of the power line, movement of the electrodes) and biological sources (muscle movement that causes high-frequency interference and the breathing that causes displacement of the baseline). Then, this kind of analysis requires special care to choose appropriate techniques for signal conditioning (pre-processing), since the quality of input signal for the further classifier has a direct impact on the performance of it. MATLAB provides system-identification methods compose a mathematical model, or series of models, from measurements of inputs and outputs of dynamic systems. Detection by MATLAB provides valuable information found in the interval and amplitude of Electrocardiograph (ECG) signals. Input to train the neural network. Output of the neural network gives weight factors of each signal. Each weight factors input to a software program is written in visual basic result to be displays risk factors.

CARDIAC ARRHYTHMIAS

The pathologies observed using the ECG are divided into three categories:

- Heart rhythm disturbances or arrhythmias.
- Dysfunctions of blood perfusion in the myocardium or cardiac ischemia.
- Chronic disorders of the mechanical structure of the heart, such as left ventricular hypertrophy.

CLASSIFICATION

- Normal Beat (NB)
- Left Bundle Branch Block Beat (LBBB)
- Right Bundle Branch Block Beat (RBBB)
- Premature Ventricular Contraction (PVC)
- Fusion of Ventricular and Normal Beat (FUSION)
- Atrial Premature Contraction (APC)
- Pace Beat (PACE)

Table (1): Effective features that are selected to distinguish each arrhythmia

Features	NB	LBBB	RBBB	PVC	FUSION	APC	PACE
----------	----	------	------	-----	--------	-----	------

Mean	Yes		Yes		Yes		Yes
RMSSD			Yes				Yes
SDNN		Yes					
SDSD		Yes		Yes	Yes	Yes	Yes
pNN50			Yes	Yes		Yes	
pNN10	Yes						
pNN5					Yes		Yes

NETWORK ARCHITECTURE AND TRAINING METHOD

An Artificial Neural Network classifier is presented as a diagnostic tool to aid physicians in the classification of heart diseases [5]. For the classification of the cardiac beats a Multi-Layer Feed-forward Neural Network (MLFN) is used to analyze the PQRST, referenced as Neural Network in this paper. Neural Network was constructed using the Neural Network software packages in MATLAB. Figure (9) illustrates the architecture of Neural Network. This includes 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_i form the input layer and computes its output as an activation function f of the sum. Where f is hyperbolic tangent function. The back propagation (BP) algorithm was chosen as the training algorithm for Neural Network.

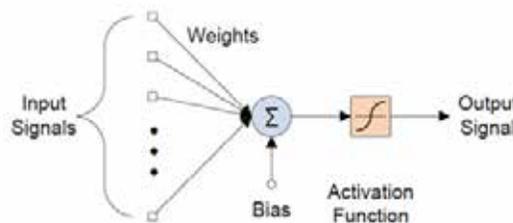


Figure (9): Neural Network architecture

Sparsely Connected Y_{NN} when

$$Y_{NN} = f(w_{i1}x_1 + w_{i2}x_2 + w_{i3}x_3 + w_{im}x_m)$$

$$Y_{NN} = f(\sum w_{ij}x_j)$$

when x_i = input and w_{ij} = weight

Advantages

- Do not require a priori knowledge about the data, which is often the opposite to traditional statistical model-based methods.
- Have robustness and fault-tolerant capability.
- Can perform nonlinear modeling.
- Typically structured as parallel-processing structures.

SIMULATON RESULTS

The complete set of rules initially input to the system has been checked with MATLAB finding different intervals like P-Wave, PR-Interval, QRS-Interval, ST-Interval, T-Wave etc analysis of each Input pulse is Input to train the Neural Network. Output of the neural network gives weight factors of each signal to create a data set. Corresponding output-datasets indicates related disease and predict the causes .The validation result obtained from a software program is written in MATLAB are presented in figure (10).



Figure (10): Detecting ECG waveforms in simulation (P-Wave, PR-Interval, QRS-Interval, ST-Interval, T-Wave, p-wave)

THE PROPOSED GENETIC ALGORITHM

The block diagram of the proposed algorithm is demonstrated in figure (11). As seen, it consists of four steps: pre-processing on ECG signals to divide ECG signals to eight consecutive RR intervals and extract HRV signal, feature extraction from ECG and HRV signal, creating seven optimal trees to detect each arrhythmia by a genetic programming algorithm and finally arrhythmia classification. The following sections describe each block of this algorithm in more details. Genetic Algorithm is from the biological system where biological cell has set of chromosomes.

(i) Population

Each chromosome consists of genes and each gene encodes a trait. Set of chromosomes is called Genome and particular set of genes in genome is called genotype. Genetic algorithm starts with generating set of chromosomes called population.

(ii) Fitness Function

Fitness values will be assigned to each chromosome. Better fitness will be the bigger chances of selection. Fitness function for each chromosome is evaluated according to the respective fitness value.

Purpose

- Parent selection
- Measure for convergence
- For Steady state: Selection of individuals to die
- Should reflect the value of the chromosome in some "real" way
- Next to coding the most critical part of a GA

(iii) Selection

According to fitness value, Chromosomes will be selected for further process of recombination.

Purpose:

- To focus the search in promising regions of the space
- Trade-off between exploration and exploitation of the search space

(iv) Crossover

Enables the evolutionary process to move toward promising regions of the search space Matches good parents' sub-solutions to construct better offspring.

- Few types of crossover:
 - One-point
 - Multiple points

(v) Mutation

Purpose: to simulate the effect of errors that happens with low probability during duplication

Results:

- Movement in the search space
- Restoration of lost information to the population

(vi) Elitism

In order to prevent losing the better chromosomes, Elitism process is used, in which the better chromosomes will be just copied into new population.

(vii) Termination

A pre-determined number of generations or time has elapsed

A satisfactory solution has been achieved

No improvement in solution quality has taken place for a pre-determined number of generations

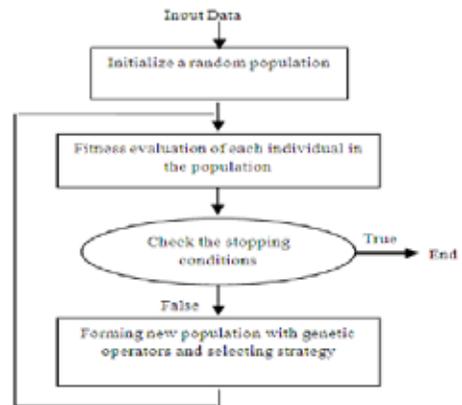


Figure (11): Flow chart of Genetic Programme Start

```

{
  initialize random population;
  evaluate each individual population;
  while Termination Criteria Not Satisfied
  {
    select parents for reproduction;
    perform recombination and mutation;
    evaluate population;
  }
}
End
  
```

Result: GAs explore the search space by short, low-order schemata which, subsequently, are used for information exchange during crossover

CONCLUSION

One of the crucial steps in the ECG analysis is to accurately detect the different waves forming the entire cardiac cycle. Most of the studies based around wavelet transformation identify 99.8% of ECG. Especially the worth investigating in P- and T-wave recognition. Some authors use wavelet technique for identification of the ECG changes resulting from acute coronary artery occlusion and are able to identify specific detailed time frequency components of ECG signal, which are sensitive to transient ischemia and eventual restoration of electrophysiological function of the myocardial tissue. The practical benefit of the wavelet based ECG approach is that T-wave abnormalities can be assessed without the need for T-wave end point identification. The wavelet transformation is a new promising technique in non-invasive electro cardiology providing improved methods for late potential detection. We can observe that the peaks of QRS complexes flatten and P- and T-waves containing lower frequencies become more visible. At the same time we can also find that details at lower scales constitutes the higher frequencies of the signal. It can be concluded that can accurately classify ECG signals into Sinus Brady cardia, Atrial tachy cardia, Atrial fibrillation, Atrio-ventricular Block. The Wavelet decomposition technique used in feature extraction process has performed effectively to project P, Q, R, S and T waves from original ECG signal. The ECG signal obtained is verified by Genetic Algorithm.

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