

Electrocardiograph Signals Diagnosis Using Adaptive Neuro-Fuzzy Inference System

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Abstract

Electrocardiograph (ECG) is a bioelectrical signal that is obtained by non-invasive method to register the electrical activities of the heart. This paper provides an attempt to develop computerized system for ECG signal filtering and classification. The proposed system encompass: pre-processing of the signal, extraction of pattern features through Independent Component Analysis (ICA), power spectrum, and RR interval calculation. These processes provide an input feature vector to the Adaptive Neuro Fuzzy Inference System (ANFIS) that acts as a signal classifier. All of the classification process steps are implemented in MATLAB environment. This paper also provides a Graphical User Interface (GUI) that makes classification process easier. Three cases of ECG waveforms that are selected from MIT-BIH database are considered for the system test; they are Normal (N), Ventricle Fibrillation (VF), and Ventricular tachycardia (VTachy). An accuracy of 96.66% has been achieved by the proposed system.

Key words-ANFIS, ECG, ICA, Power spectrum, RR interval, GUI, MIT-BIH

I. INTRODUCTION

In hospitals and health community, there are considerable commercial interests in the automation of the Electrocardiogram Signals (ECG) diagnosis process. The (ECG) is an important tool in determining the state of a patients health. In fact, it is often one of the first things a medical doctor may check in trying to know the physical condition of a patient. Physicians undergo extensive training in interpreting ECG signals in terms of heart functions, for diagnosing heart illnesses. Such interpretations can be particularly difficult in detecting early signs of heart illness, when ECG abnormalities may not be readily apparent, even up to the actual onset of heart attack. Therefore, its analysis represents an efficient way to detect and treat different kinds of cardiac diseases [1]. The ECG waveform, shown in figure Fig. 1 is composed of P-wave, QRS complex PR-interval, PR-segment, ST-segment, and T-wave. These segments, without details, represent the atrial and ventricular depolarization, and repolarization, activates [2]. The QRS complex is a very useful in the diagnosis of Arrhythmias diseases. Its analysis is considered as an efficient way to identify and treat different kinds of cardiac diseases [1], [3]. In general, irregularity in the QRS complex indicates that the patient has arrhythmia. Adaptive Neuro-Fuzzy Inference System (ANFIS) has been considered as one of the excellent function approximation techniques, where it implements a first order TS fuzzy inference system [4]. It is considered as a fuzzy system that can be trained using training algorithms similar to neural network training algorithms, When supplied with a suitable feature, ANFIS embody a powerful pattern classifier suitable for ECG diagnosis. This paper utilizes ANFIS to build an efficient and easy to use ECG diagnosis system. The development of this system and its GUI is done in Matlab environment

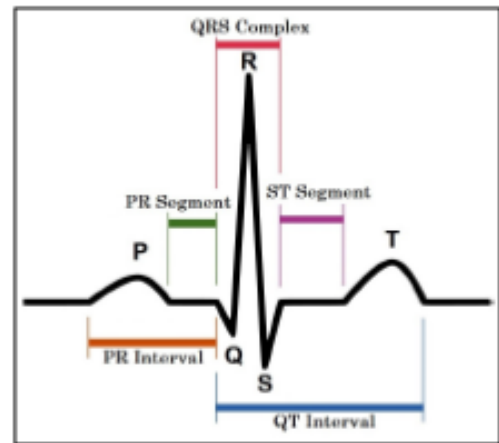


Fig. 1. Image of one complete ECG waveform

II. METHODOLOGY AND IMPLEMENTATION

Diagnosis process of ECG signal encompasses; signal acquirement, noise elimination, features extraction, and signal classification using ANFIS as shown in Fig. 2.

A. ECG signal acquisition

For the purpose of paper, no experimental data acquisition has been done. Instead, the ECG signals used here are obtained from the MIT-BIH arrhythmia database. The samples in this online data base were sampled at a sampling frequency of, 128, 250, 360 and 1000 H_z .

B. ECG Signal pre-processing

To remove the signal bias, a normalization process is carried out to adjust the base line of each signal to zero [5].

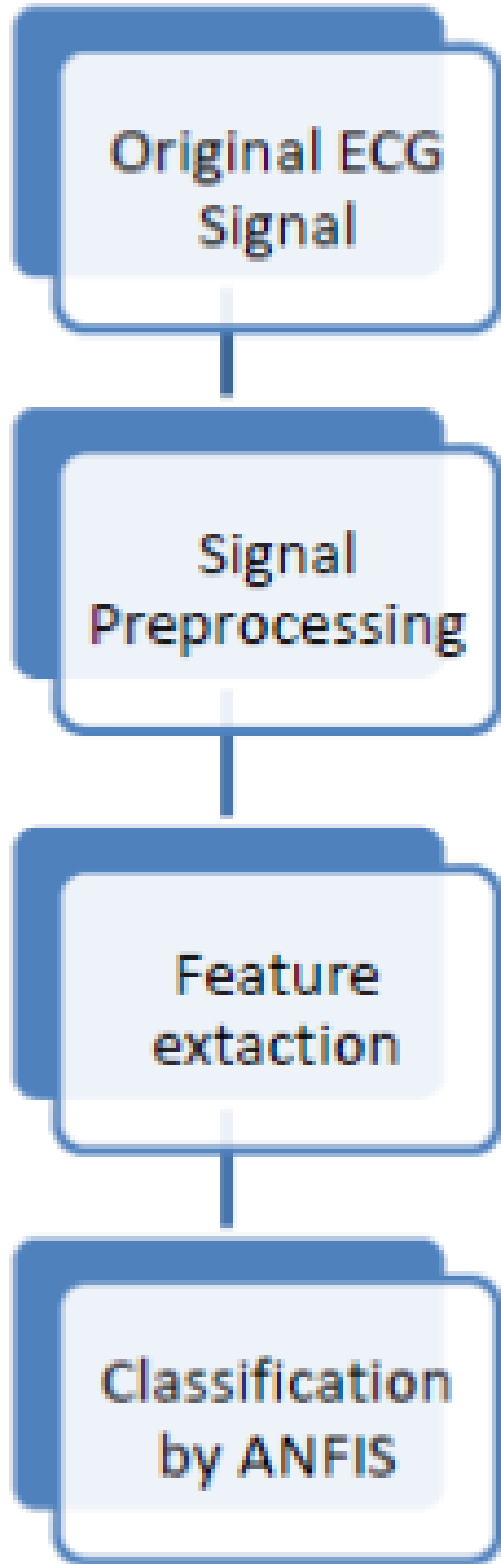


Fig. 2. ECG classification process

C. ECG Feature extraction

To minimize the ANFIS input vector, and to make the network size smaller in order to ease the training phase, feature vectors are extracted from the ECG signals. The feature

vector minimizes the n training data size while preserving the information necessary for the recognition. Several feature extraction methods are tested in this research.

1) *Independent Component Analysis* : A well-known technique in signal processing is the independent component analysis (ICA). It is a computational method for splitting a complex signal into additive subcomponents. ICA is carried out assuming that at most one subcomponent is a non-Gaussian signal, and that the components are statistically independent. Several algorithms are available for performing ICA. A fast fixed-point algorithm was used in this research to estimate the independent components of the ECG waveform.

2) *Spectral Density* : The subcomponents of the ECG signals are then passed through a Power Spectral analysis phase. This process provides information about the power distribution of the signal over the frequency based on a finite set of data. It gives estimation of both magnitude and phase information that are useful in cardiac signal classification [6].

3) *RR interval detection* : The distance between two subsequent QRS complexes is known as RR interval. It represents another important feature for many ECG arrhythmias recognition. The time difference between the R points of the present and previous beat represents the R-R interval. Several algorithms for the detection of the R-wave are available. In this research Pan-Tompkins algorithm is adopted.

D. Classification by ANFIS

The goal of classification problem is to identify the characteristics that indicate the group to which each case belongs. This paper presents an ANFIS-based heart disease classification tool to assist physicians in the classification of heart diseases. ANFIS is a hybrid approach that combines fuzzy inference systems and neural networks (NN). By combining these two intelligent approaches, we can achieve effective reasoning in both quality and quantity. In this work, ECG signals are classified into three types based on their characteristics. The ANFIS network has a total of 128 fuzzy rules and one output. MATLAB was used to perform ANFIS. In order to evaluate the performance of the classifier, the following performance measures were used: Accuracy, hitrate (sensitivity), rue-negatives-ratio (tnratio), and precision. They are defined as [7]:

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$sensitivity = \frac{TP}{TP + FN} \quad (2)$$

$$Tnratio = \frac{TN}{TN + FP} \quad (3)$$

$$PrecisionN = \frac{TP}{TP + FP} \quad (4)$$

TP, TN, FP, FN are respectively true positive, true negative, false positive, and false negative.

III. RESULTS AND DISCUSSION

This section presents the application of the abovementioned methodology for a set of ECG signal and discusses the obtained results.

A. ECG signal preprocessing

The graphical signal generation commands in Matlab make it easy to view the results of preprocessing methods applied to ECG signals. An ASCII format of the ECG records is imported to Matlab from MIT/BIH database for experiments purpose. Each sample of the ECG data is normalized and its bias is removed. An example of an ECG after this step is shown in Fig. 3. After that the sample is passed through a digital filter. Figure Fig. 4 presents an example of a filtered ECG signal.

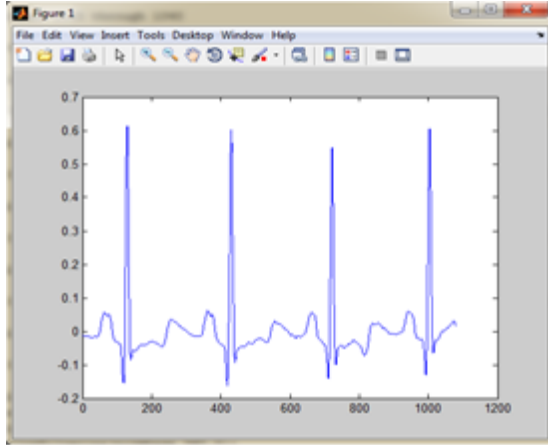


Fig. 3. Normalized ECG signal

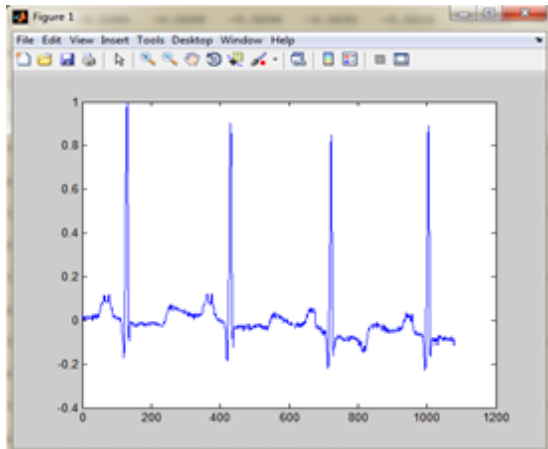


Fig. 4. ECG Signal filtered with 1D and zero phase digital filter

B. ECG feature extraction

A feature vector containing the following features was employed as the input for the ANFIS classifier. It has three features. These are:

- The R-R interval which is considered as a Morphological feature, and
- Two Statistic features ; which are the ICA, and Power spectrum as shown in Fig. 5.

C. Classification ECG with ANFIS classifier

The obtained performance measures of ANFIS classifier are as follows:

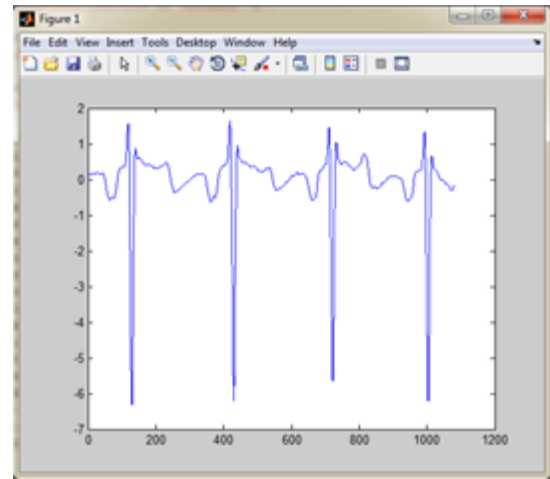


Fig. 5. ICA of ECG signal

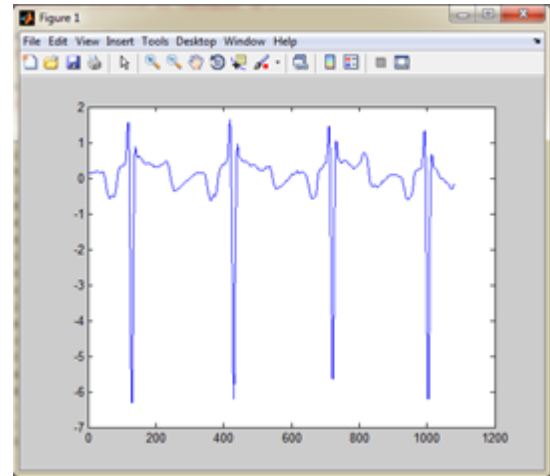


Fig. 6. Power spectrum of ECG signal

$$\begin{aligned} \text{accuracy} &= \frac{58}{60} * 100\% = 96.66\% \\ \text{sensitivity VT} &= \frac{19}{19+1} * 100\% = 95\% \\ \text{sensitivity V} &= \frac{20}{20} * 100\% = 100\% \\ \text{Pr ecision N} &= \frac{19}{19} * 100\% = 100\% \\ \text{Pr ecision VT} &= \frac{19}{19} * 100\% = 100\% \\ \text{Pr ecision VF} &= \frac{20}{20} * 100\% = 100\% \end{aligned}$$

D. Graphical user interface (GUI)

A graphical user interface has been built using Matlab. It enables the user to read the patient data, run the classification process, and prints the heart rate and the diagnosis result easily. Fig. 7 shows the proposed GUI.

IV. CONCLUSION

As a contribution to the active reach area of disease diagnosis automation, this paper presents an ANFIS based classification system for ECG signal. Tools from the Matlab DSP toolbox are used to extract the ECG signal features. This research provides a complete description of the procedure required in a system that categorizes the ECG signals into

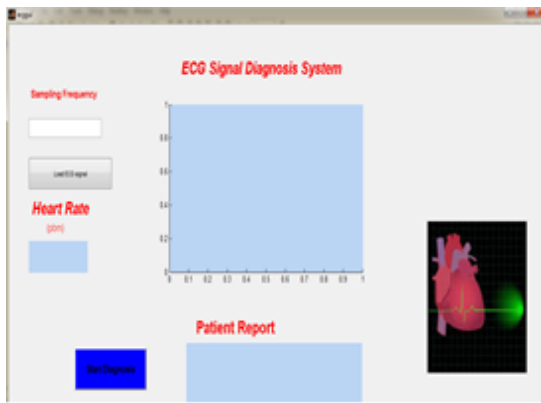


Fig. 7. GUI of ECG diagnosis systems



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three cardiac conditions. A GUI that ease the utilization of the propose classification system was built using Matlab. The proposed system was tested using 20 normal signals, 20 signal with ventricular tachycardia, and 20 ventricular fibrillation signals. The test results showed that the proposed system has an accuracy of 96.66%.

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