

Automated Detection Of Cardiac Arrhythmias From Ecg Signals

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Abstract

Cardiovascular disease (CVD) represents disturbances found in cardiac cycle affecting the heart and the blood vessels of coronary arteries. Most commonly CVDs result in irregular heartbeat called cardiac arrhythmia. It is used to represent the malfunctioning of the heart. Its severity can cause sudden cardiac death like a heart attack or heart stroke. For real time monitoring, Contact and Non-Contact ECG systems have been developed for bring the possibility to detect heart conditions at early stage. These ECG methods use a smaller number of electrodes as compared to conventional 12-lead ECG systems and are developed for user convenience in daily life. In the contact method, ECG electrodes are directly placed on the skin and are wearable. But, in Non-Contact ECG methods, there can be air, cloth, or explicit gaps between electrodes and skin. Presently, research is focusing on wearable monitoring platforms that emerge smart enabling technologies to detect heart conditions at an early stage and are used in long-term applications. Some of these methods are Sensor Patches, Smart Garments, Gloves, Belts, etc. Some of the systems have been installed into Mobile Phones and Watches. However, these approaches have various limitations in self-health care situations which alter ECG characterises features over time according to the following factors.

Keywords: Cardiovascular disease, malfunctioning, World Health Organization, prediction

INTRODUCTION

The statistical data of the European Health Network reported that 3.9 million deaths in Europe happen due to CVDs every year. Cable News Network (2019) declared more than 840,000 CVD mortality rates in America. In 2020, the World Health Organization reported that 17.9 million people die due to CVDs worldwide. It is projected that such casualties may grow further to 23.3 million by 2030 [1]. It is estimated that 60% of citizens who suffered from a stroke die due to their dependency on others for help in their everyday living and almost 67% of cardiac deaths occur outside of hospitals because people misinterpret early symptoms and delay to visit the specialized units [2]. Thus, CVDs have become the primary cause of death in India as well as across the world. As reported by the National Institute of Health, ECG has the potential to save many lives worldwide. For prevention and early treatment of CVDs, the conjunction of conventional signal processing methods with Computer-Aided Design (CAD) based diagnostic systems is developed. It removes diagnostic errors and presents a detailed review of stages-based process models to clarify ECG signals [9]. It is a journey starting from traditional ECG systems to supervised advanced machine learning methods to make ECG analysis systems fully automated. Numerous computational techniques have been used to recognize and analyse these ECG wave patterns. It provides effective ECG monitoring systems and motivates public health along with the economy. Computerized analysis of the ECG signals helps the cardiologist to diagnose heart disease much more accurately as compared to the interpretation performed by unaided hand and naked eye [3]. Thus, machine learning techniques with traditional assistance have been developed to retrieve relevant information from ECG signals and enhance the

reliability of the diagnostic process. However, enormous diversity in computational schemes of ECG monitoring system becomes difficult before medical practitioners to classify and analyse the recorded ECG signal [13].

REVIEW OF LITERATURE

Since ECG exhibits random time variant behaviour therefore two consecutive ECG signals may consist of rate-dependent temporal and frequency dependent features. These features are characterized by lucid spectral and temporal information simultaneously. As multi-resolution approach of the wavelet can be used to de-noise the signal without distortion, a wavelet is an optimal choice for this purpose. The chapter discusses methodology to remove noise from ECG signal using the Discrete Wavelet Transform (DWT) with related mathematical relations and formulae [4]. Hard thresholding and soft thresholding are conventional methods used in ECG signal denoising in conjunction with DWT, as discussed in section. However, they have encountered various challenges, like large threshold value reduced large signal data, it results poor reconstructed signal. However, small value of threshold produces large data size; it affects computational time and signal fidelity. Thus, signal smoothing and filtering both are achieved by proper selection of thresholding method and set of rules. Therefore, there is a need to optimize thresholding technique which should be applied on ECG signal to make the signal noiseless. The proposed method comprises features of both hard and soft thresholding methods. It truncates noisy wavelet coefficients using hard thresholding and remaining wavelet coefficients are modified using soft thresholding [5].

It has been concluded from that the denoised ECG signals after applying soft thresholding with fixed threshold rule offers smoother signal edges as compared to other thresholding rules. It depends on the inherent property of the thresholding method and thresholding rules to shrinkage those wavelet coefficients which make roughening of signal edges. But reconstructed signal has shifted baseline from zero mean therefore, it needs baseline correction in ECG signal processing[6]. Features characterize distinctive measurements of a signal pattern and provide useful information about the signal by analysing a segment of the portion. Broadly, ECG features are divided into four categories, as discussed in section [10]. This chapter discusses the methodology to measure heart rate based on temporal features using windowing method, adaptive level thresholding method and proposed method, and the results of all three methods are compared [11].

MATERIALS AND METHODS

As discussed in section ANN is one of the supervised learning methods which is used to mimic the behaviour of human brain. The ANN based classifiers are designed to create millions of artificial neurons using connecting weights to take information. As the ANN based algorithms can generalize for some unknown signal, that's why it is one of the most popular choices among researchers. The section discussed some of the main parameters to designed ANN based classifier, including, layered architecture, layer size, weights, neurons, activation function and performance indices.

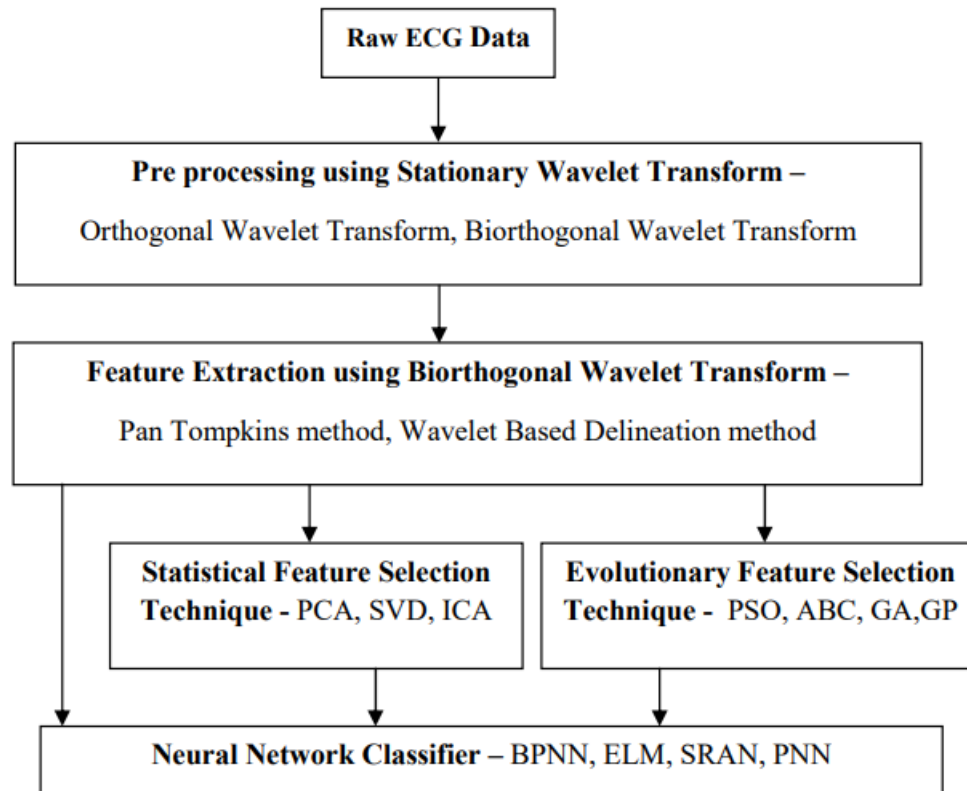


Figure 1: proposed diagram

The most straight forward and topological arrangements of neurons is found in Multi-Layer Perceptron Neural Network which is used to create and train data in a defined network. It consists of minimum of three layers of nodes, (I) Input layer that represents input features set, (II) Hidden layer, is responsible for processing, and (III) Output layer, equivalent to classes to be classified. Each Input layer has assigned some value, called weights, used to generate the outputs. These outputs are compared with desired outputs by adjusting weights, called target output. This type of neural network architecture is called feed forward network. The network is adjusted according to, (i) its error called training phase; (ii) & (iii) its independent and generalized measurement for network performance called testing and validation phases, respectively [7].

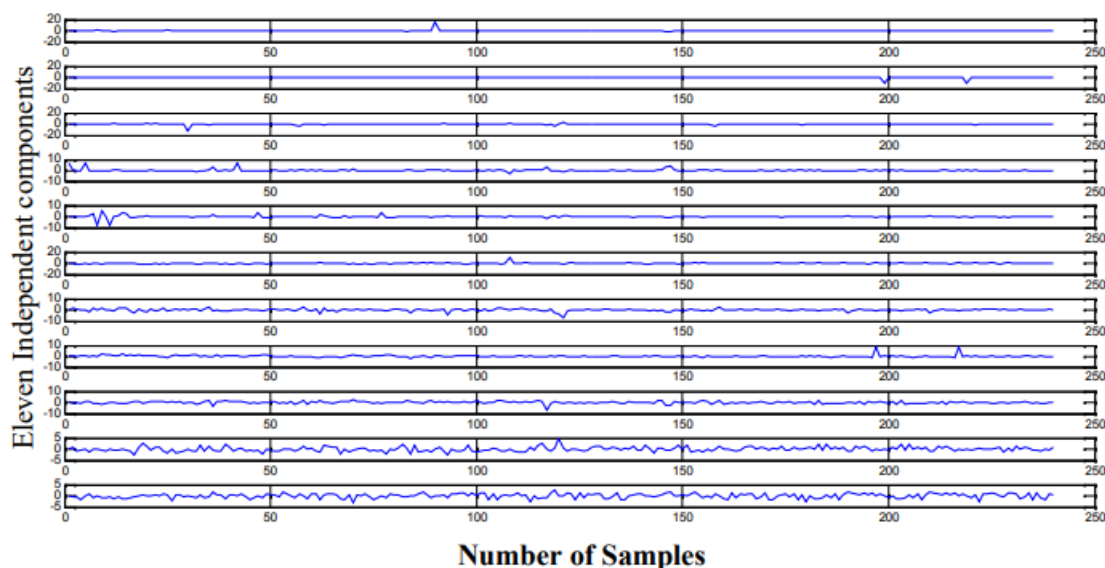


Figure 1: Independent Components of ECG signal

To find appropriate transformation in between various layers, a completely trial-and-error process is followed. However, in-built feature of NN not only predict correlations in cascaded layer structure but also automates transformation to feed as input to train the NN. It used genetic optimizer to assess datasets and identify suitable learning rule from trail-error process, at last transformed values to produce most influential values. The optimal weights of the network are measured using back propagation method and the most popular training. The proposed Neural Network based classifier is trained with a scale conjugate gradient back propagation algorithm classifies the extracted ECG features from six types of ECG signals in normal and abnormal categories with reference to the target output. The extracted feature vector applied at the input of the classifier which automatically framed them in testing and training datasets. The annotation files which are downloaded from MIT BIH arrhythmia database containing actual information about the type of class of each imported ECG beats. This annotation file is used to prepare the target file, using piece of MATLAB code in workspace.

RESULT AND DISCUSSION

For hardware implementation of proposed automatic ECG detection and classification system, a high-level programming tool 'Xilinx System Generator from Xilinx Design suite is used which is configured in Simulink MATLAB. This paper deals with FPGA based models to design various functional blocks and dataflow defined in the proposed system. Once the executable and synthesized Simulink Block sets are created, it automatically invokes Xilinx core generator to generate optimized netlists to get a bitstream file for downstream programming of FPGA devices [8]. Xilinx is the most extended manufacturer of FPGA worldwide and provides system modelling and optimized hardware resources followed by Hardware Description language (HDL) for code generation [12].

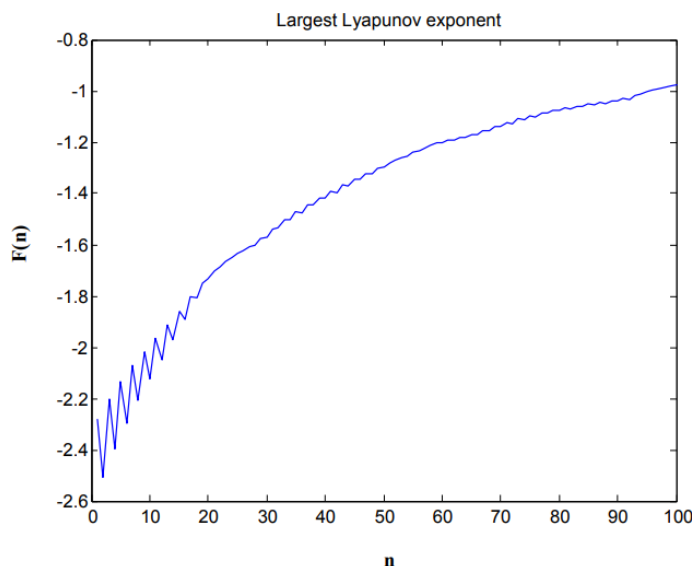


Figure 2: ECG signal magnitude plot using Hanning window

Thus, the MATLAB workspace is used for simulation while the hardware blocks are designed using XSG [14]. The final implementation stage is completed in Xilinx Design suite where VHDL codes obtained from the designed XSG blocks are synthesized to obtain information of utilized hardware resources.

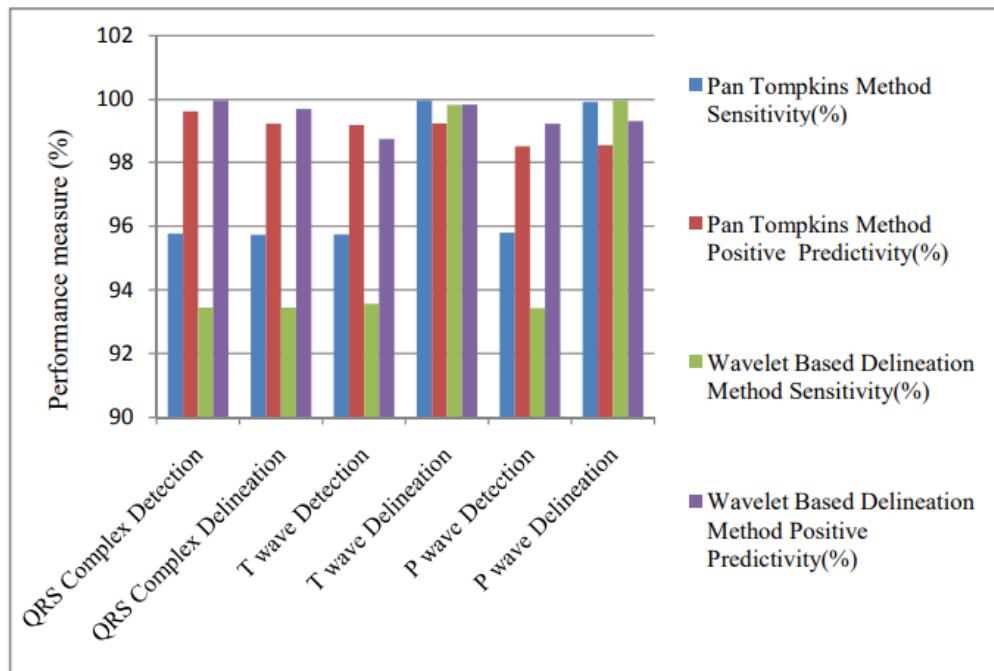


Figure 3: Performance comparison of Feature Extraction Techniques

In order to obtain wavelet detail and approximation coefficients at one level of wavelet decomposition using Daubechies wavelet of order is realizable on XSG using the DSP tool box is shown.

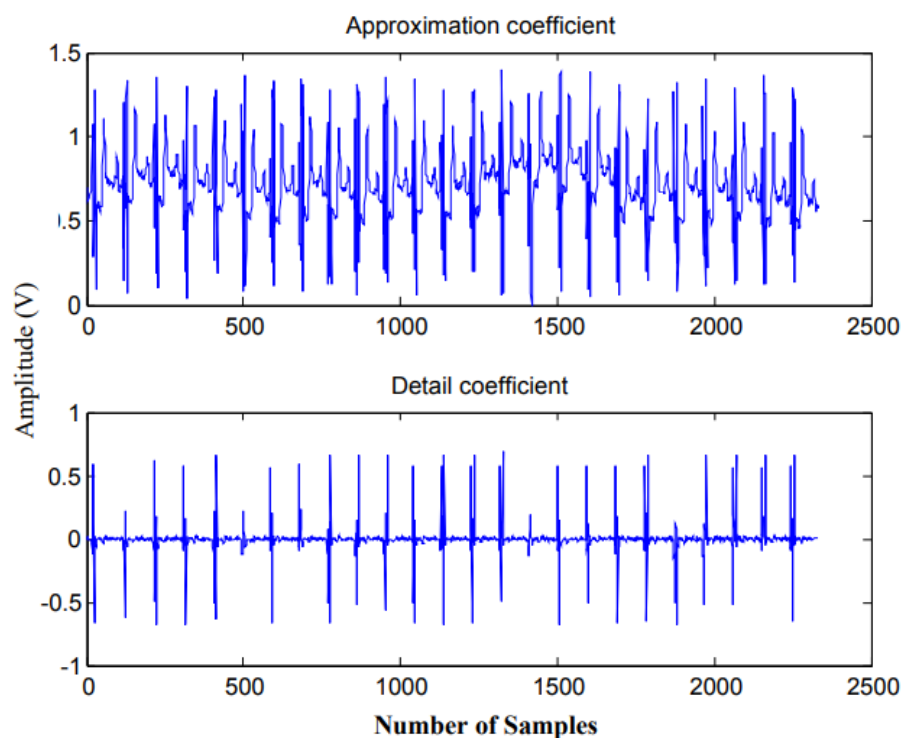


Figure 4: Approximate and Detailed coefficients of Decomposed ECG signal

The corresponding DWT detail and approximation coefficients are obtained in a form of array vector which are saved in workspace. Daubechies wavelet function of the order of is used to implement FIR response of DWT LPF and HPF filters [15].

CONCLUSION

Successful treatment of cardiac disease is possible only if there could be early detection of abnormal functionality of the heart. The same can be achieved via image processing approaches for ECG analysis. However, the performance of the image processing techniques for early detection of cardiac arrhythmia can be improved with the development of an effective wavelet transform based preprocessing stage on ECG. The presence of noise leads to inaccurate identification of characteristic points of ECG (and it merely depends on wavelet performance parameters as discussed under). Recalling the problem statement, the present research has been directed towards the development of a computer-aided analysis system that can effectively aid in detection of abnormal heart rate in ECG. Based on this paradigm, the research objectives were formulated for ECG signal processing and the evolutionary development during the various phases of this research work has been summarized in the succeeding paragraphs. The primary results obtained in this thesis belongs to the choice of wavelet-based features in the proposed method. Detection of life-threatening ECG arrhythmia is performed by analysing ECG waves with and without abnormalities along with other morphological patterns. In the pre-processing stage, the results show variations in terms of MSE and percentage of retained energy to remove low and high frequency noises using various wavelet basis functions.

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