ECG Signal Analysis Using SVM Classifier And Noise Reduction Usng IIR And Adaptive Filter

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Abstract- *Electrocardiography (ECG) is the graphical recording used to determine the electrical activity of the heart and recognized biological signal is used for clinical diagnosis. The ECG signal is very sensitive in nature, and the presence of small noise in an original ECG signal alters various characteristics. Filtering of ECG signal is very important because noisy ECG signal can mask some important features of the Electrocardiogram (ECG). Hence it is desirable to reduce this noise for proper analysis of the ECG signal. This project presents the study of noise reduction by using band pass Infinite Impulse Response (IIR) filter and Adaptive filter. The filtering technique is used to filter out the noise embedded in the input ECG signal. Discrete Wavelet Transform (DWT) was utilized as a feature extraction methodology to extract the reduced feature set from the input ECG signal and classified in support vector machine (SVM). The support vector machine classifies the feature extracted signal according to the abnormalities. This is synthesized using Xilinx system generator (XSG) and coded in verilog. It is observed that, FPGA is more efficient than DSP as it requires less power. Also better results have been observed and attached in this paper.*

I. INTRODUCTION

The electrocardiogram (ECG) depicts the electrical activity of the heart. ECG processing is a topic of great interest because of two reasons: (1) ECG is collected by non invasive means, which allows easy and wide availability and (2) the ECG contains very much information, which is highly valuable for diagnosing. The electrocardiogram is a surface measurement of the electrical potential generated by electrical activity in cardiac tissue.

A subject's ECG information can be recorded using a portable Holter monitor which is worn by the subject. A Holter monitor typically employs a few electrodes and stores a recording of the subject's heart rhythm as they go about their daily activities over a 24 to 48 Hour period. The Holter monitor is then returned to a cardiologist who examines the recordings and determines a diagnosis. Examining these recordings is a time-consuming and hence any automated processing of the ECG that assists the cardiologist in determining a diagnosis

In recent years, cardiovascular disease, including heart disease and stroke, remains the leading cause of death around the world. Yet most heart attacks and strokes could be prevented if some method of pre-monitoring and pre-diagnosing can be provided. In particular, early detection of abnormalities in the function of the heart can be valuable for clinicians.

Many researches depend on digital signal processing (DSP) techniques as a methodology to design automated ECG signal analysis systems. Most DSP systems use typical main stages for analyzing ECG signals; those main stages include denoising stages, feature extraction stages, and classification stages. The noise from the ECG system is a major source of noise during the recording and monitoring of ECG signal. Different noises have different frequencies. The various types of noises in ECG signal are as follows.

Baseline wander Noise:

Baseline wandering noise is a low frequency component present in ECG signal. This noise is due to the offset voltages in the electrodes, respiration, and body movements. Baseline wander noise has frequency greater than 1Hz.

Power Line Interference:

Power line interference of 50/60 Hz is the source of interference and it corrupts the recordings of Electrocardiogram (ECG) which are extremely important for the diagnosis of patients. The power line interference is mainly caused by:

- Electromagnetic interference by power line
- Electromagnetic field (EMF) by the nearby machines. The signal component holds harmonics with different amplitude and frequency. The harmonics frequency is

the integral multiple of fundamental frequency such as 50Hz.

- Stray effect of the alternating current fields due to loops in the cables
- Improper grounding of patient or the ECG machine
- The electrical equipments such as air conditioner, elevators and X-ray machines draw heavy power line current. This induces furthermore 50 Hz signals to the input circuits of ECG machine.

Patient-Electrode Motion Artifacts:

It is the movement of the electrode away from the contact area on the skin this leads to variation in the impedance between the electrode and skin causing potential variations in the ECG.

Contact Noise:

This noise is caused by the loss of contact between the electrode and the skin, which effectively disconnects the measurement system and generates large artifacts since the ECG signal is usually capacitively coupled to the system, The characteristics of this noise signal include the amplitude of the initial transition, the amplitude of the 60Hz component and the constant time of the decay.

Electrosurgical Noise:

Electrosurgical noise is generated by other medical equipment present in the patient care environment at frequencies between 100 KHz and 1 MHz. The noise remains approximately for 1 to 10 seconds.

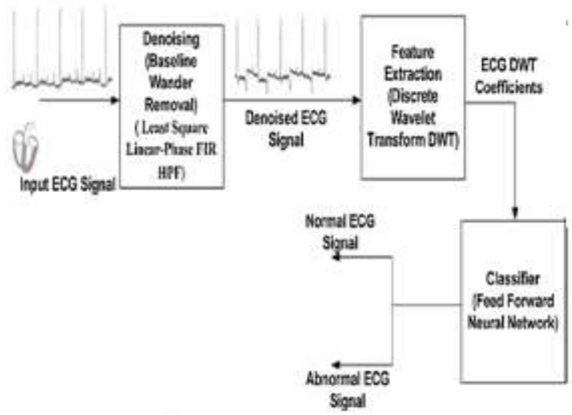
Channel noise:

Poor channel conditions can introduce noise when ECG signal is transmitted. It is like white Gaussian noise which contains all frequency components.

This paper discusses the problem of analyzing the electrocardiography (ECG) signals using least-square linear-phase FIR filter. A new system for analyzing ECG signal is presented. The proposed system uses least-square IIR filter methodology to overcome the limitations of the previous methodologies.

II. RELATED WORK

The ECG signal analysis system consists of three main blocks, denoising block, feature extraction block and classifier block. Different blocks are described in the following subsections. The LLFE design depends on classifying the input ECG signal into normal or abnormal ECG signal after passing through the three circuit main blocks, the result of this diagnosis can be sent further to a health caring professionals or remote health caring centers to provide the required assistance. LLFE employs the basic blocks for a typical pattern recognition system.



The input ECG signals design are extracted from the standard MIT-BIH Arrhythmia Database normal/abnormal Electrocardiography (ECG) signal beats based on MIT-BIH database that are considered are classified, such beats are considered to be processed using the discrete wavelet transform block. Each signal is referenced from the MIT-BIH database by selecting the target database (MIT-BIH Arrhythmia Database (MITDB)) that contains the selected records. The records are digitized at 360 samples per second per channel with 11-bit resolution over a 10 mV range. Those records are fed to the denoising block to start the processing of the acquired ECG signals.

The ECG signals suffer from two main types of noise: (1) Low frequency noise represented in baseline wander noise, (2) High frequency noise such as power-line interference noise and muscle contraction. In LLFE, high frequency noise is removed by discarding the first detail component resulting from wavelet transform decomposition in the feature extraction block. The low frequency noise is represented by baseline wandering noise. In wandering baseline, the iso-electric line changes position.

Primary possible causes for baseline wandering noise are the cables moving during reading, patient movement, dirty lead wires/electrodes, loose electrodes, in addition to other minor sources. Baseline wandering noise is removed in LLFE design using least square linear-phase FIR high-pass filtering. The high-pass filter type used in LLFE is least-square linear-phase FIR high-pass filter with cut-off frequency of 0.5 Hz to remove the low frequency baseline wandering noise embedded in the input ECG signal. The denoising block is modeled and implemented in MATLAB Simulink using Xilinx System Generator blocks. The least-square linear phase FIR filter structure is modeled and implemented using Xilinx System Generator FIR Compiler block.

LLFE feature extraction block uses discrete wavelet transform (DWT) methodology. The input signal is filtered by the low-pass (LP) and the high-pass (HP) filters. The outputs from the low pass filter are called the approximation coefficients while the outputs from the high-pass filter are called the detail coefficients.

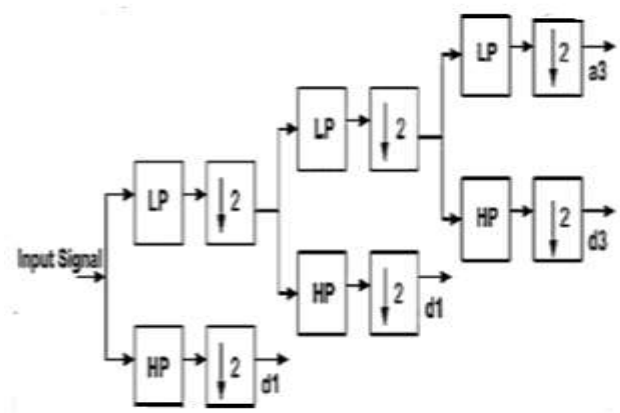
The output of each filter is then down sampled by a factor of 2. The low pass output is further filtered and this process goes on until enough steps of decomposition are reached. In LLFE the input signal is passed through three levels of filtering results in four signals (d1, d2, d3 and a3).

The feature extraction is done by wavelet transform decomposition. In this step, the continuous ECG signals are transformed into individual ECG beats. The width of individual beats is approximated to 300 sample data, and the extracted beat is centered around the R peak. For each R-peak, the continuous signal for each beat start at R − 150 position is cut-off until R+ 149 position therefore a beat with 300 sample data in width is achieved. In this decomposition, daubechies order 3 is used as a mother wavelet

The input signal with 300 samples will be down sampled by a factor of 2 in each stage, reaching only 38 samples in the 3rd stage (d3, a3). The detail d1 is usually noise signal and has to be eliminated.

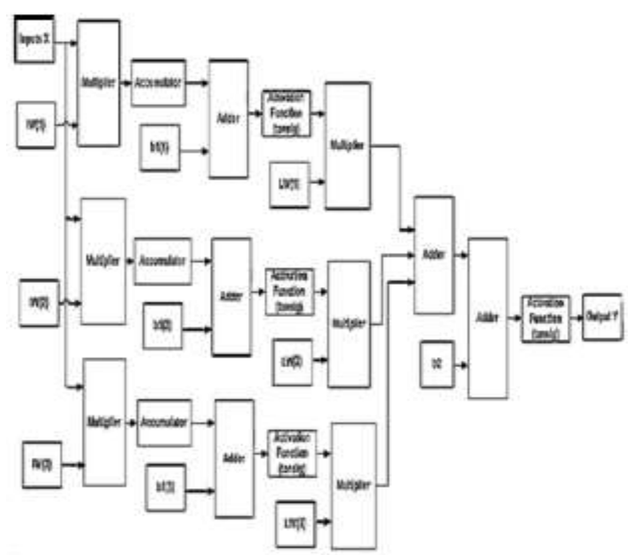
On the other hand, d2 and d3 represent the high frequency coefficients of the signal. Since a3, represented by 38 samples, represents the approximation of the signal, and contains the main features of the signal, thus a3 is considered as the reduced feature vector that is used in the subsequent stage for the classifier.

The filter bank is implemented using Xilinx System Generator FIR complier blocks to implement both low pass and high pass filters.



Neural Networks has an extensive application to biomedical systems. They are helpful in the research on parts of the human body and recognising diseases from various scans (e.g. Electrocardiograms, CT scans, ultrasonic scans, etc.). Neural Networks are used experimentally to model the human cardiovascular system. Diagnosis can be achieved by building a model of the cardiovascular system of an individual and comparing it with the real time physiological measurements taken from the patient. If this routine is carried out regularly, potential harmful medical conditions can be detected at an early stage and thus make the process of combating the disease much easier.

The classifier used for classifying the ECG signal is neural network classifier.. It based on feed forward back-propagation neural network; the neural network output indicates whether the sample provided in the input of the design represents a normal ECG beat or abnormal ECG beat.



The basic blocks of the neural network are: multiplier blocks, adder blocks and the activation function blocks. The neural network in the proposed LLFE design has one hidden layer with 3 hidden neurons and 1 output layer. The neural network is implemented using MATLAB simulink in terms of Xilinx System Generator (XSG) blocks.

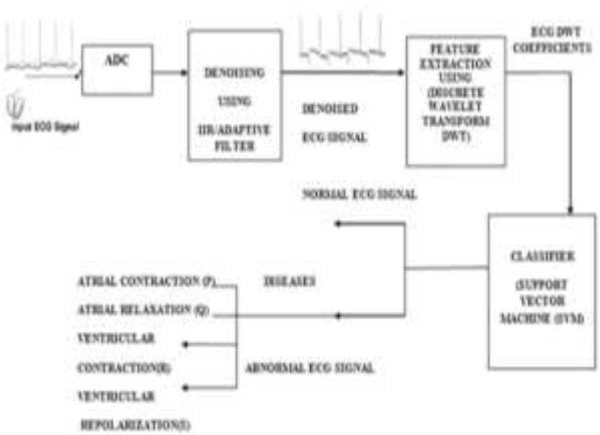
The input to the neural network the approximated signal (a3) (Inputs X) output from the feature extraction block, along with the weight vectors IW and LW, along with the bias values b1 and b2, while the output of the neural network classifier is the diagnosed ECG signal (Output Y) which represents the diagnosed ECG signal. The neural network classifier is created using new MATLAB function to create a feed-forward back propagation network.

III. METHODS

The ECG signal analysis system is used for analyzing electrocardiography (ECG) signals. This methodology employs band pass Infinite Impulse Response (IIR) filtering and adaptive filtering technique to filter out the noises embedded in ECG signal.

Discrete Wavelet Transform (DWT) was utilized as a feature extraction methodology to extract the reduced feature set from the input ECG signal and classified in support vector machine (SVM).

The support vector machine classifies the feature extracted signal according to the abnormalities. This system is also synthesized using Xilinx system generator (XSG) and coded in verilog. The system is further implemented in Field Programming Gate Array (FPGA) board using Xilinx.



The input ECG signals are extracted from the standard MIT-BIH Arrhythmia Database. The records are digitized at 360 samples per second per channel with 11-bit resolution over a 10 mV range.

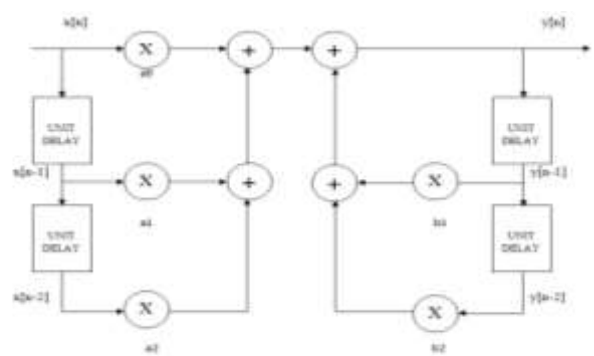
A raw ECG signal is often contaminated by disturbances such as baseline wander noise and power line interference. IIR filter uses a digital processor to perform numerical calculations on sampled values of the signal. The advantages of digital filters are

1. IIR filter produce sharp / steep response almost close to ideal.
2. Digital filters can provide linear phase response.
3. As digital filter implementations use the programmable processor, the frequency response can be changed automatically.
4. Digital filters can reduce the cost of production.

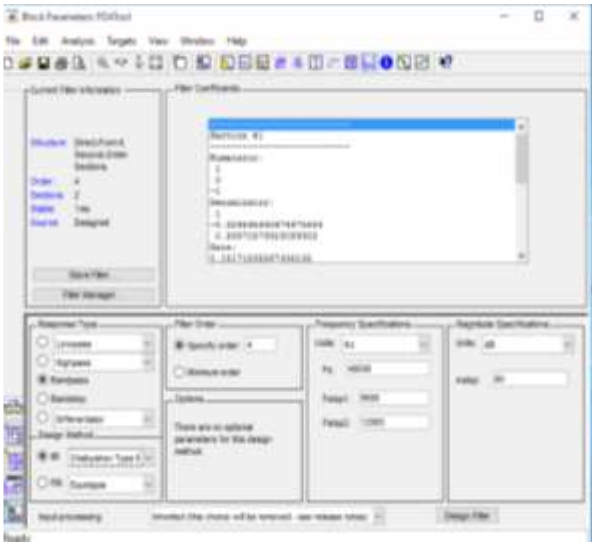
Based on the length of the impulse response, the digital filters are classified into two types

1. Infinite Impulse Response (IIR)
2. Finite Impulse Response (FIR)

Impulse Infinite Response filter consists of a feed forward path as well as a feedback path.



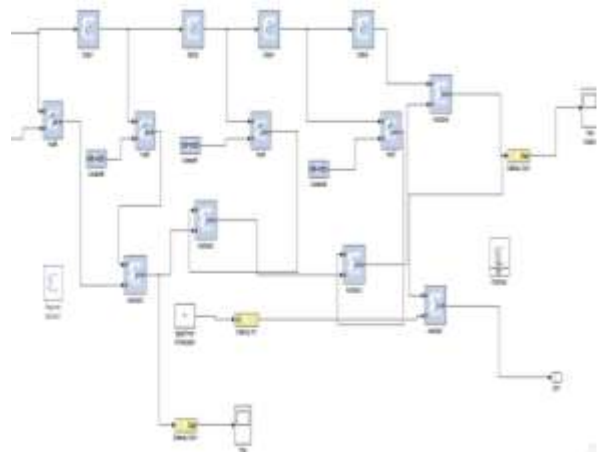
The IIR band pass filter is used to remove the baseline wander noise embedded in the Electrocardiography (ECG) signal which occurs due to the respiration and muscular movements. The baseline wander noise has the frequency of about 1Hz. The IIR filtering is implemented using Filter Design Tool (FDA) in simulink.

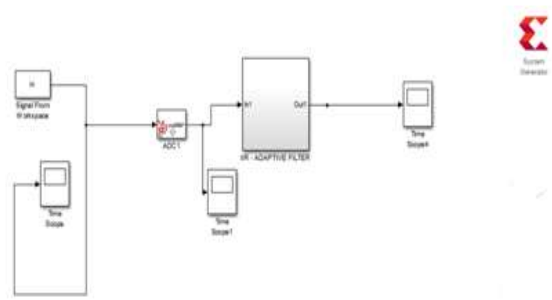


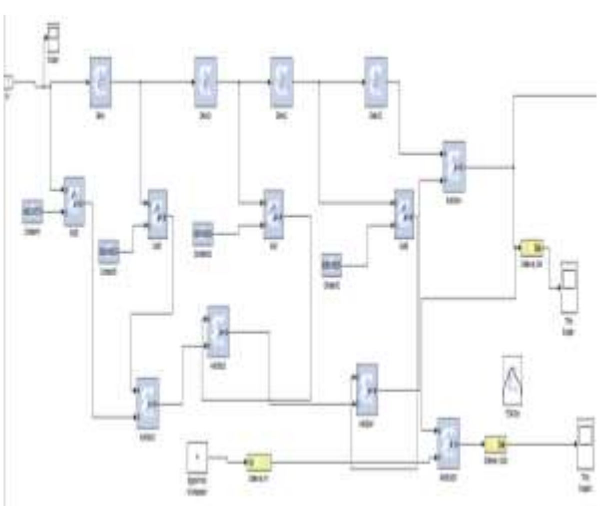
The specifications for designing IIR filter is

1. Design Method: Infinite Impulse Response
2. Type of filter: Chebyshev Type II
3. Response type: Band Pass filter
4. Order: 4

The design block of IIR and Adaptive filter consists of feedback a feed forward network.

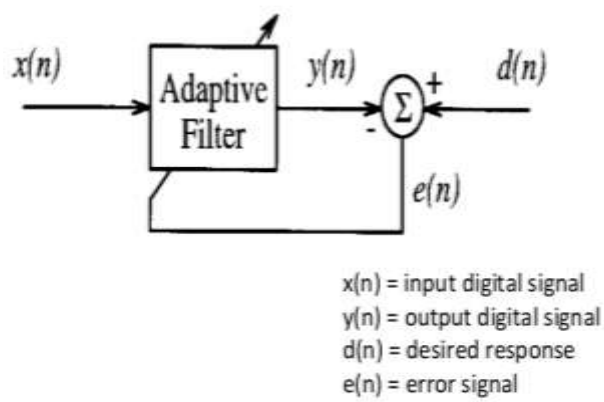






After setting the design specifications, the Design Filter button at the bottom designs the filter according to specification. The magnitude response of the filter is displayed in the Filter Analysis area after the coefficients are computed. Thus the IIR filter is designed and the denoised ECG signal is displayed in the respective time scope.

An adaptive filter is a system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. Because of the complexity of the optimization algorithms, almost all adaptive filters are digital filters. The adaptive filter is used to remove the power line interference in an ECG signal. The power line interference causes 50/60 Hz of signal to corrupt the recordings of Electrocardiogram (ECG).

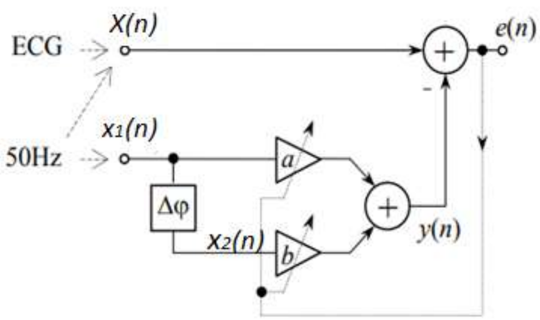


The need for adaptive filter is,

- Adaptive filter removes the power line interference in an ECG signal.
- Adaptive filter reduces noises to its fullest.
- It has better accuracy and fast detection of abnormalities.

A input sample x(n) from the digital input is fed to the device, called an adaptive filter which produces an output signal y(n) based on the input output relationship which is nothing but the physical architecture of the filter. Adaptive filters contains some adjustable parameters and these values decide how y(n) is computed. An error signal e(n) is generated by taking the difference between the desired signal d(n) and the actual obtained output signal.

$$e(n) = d(n) - y(n)$$



By using the error signal, we will produce adapts or alters that are used to update the parameters of the filter from n time to (n+1) time. As the time index is increased from n, it is hoping that the output of the filter is better matched with the desired signal by the adaption process. Therefore the error between the two signals is decreased over the time.

From the reference signal X1(n), the power line interference of certain frequency is combined and this can be removed by means of adaptive filtering technique.
The powerline interference noise interrupted signal X1(n) is phase shifted and then the phase shifted signal X2(n) is then combined with the signal interference and finally the denoised output is been obtained.

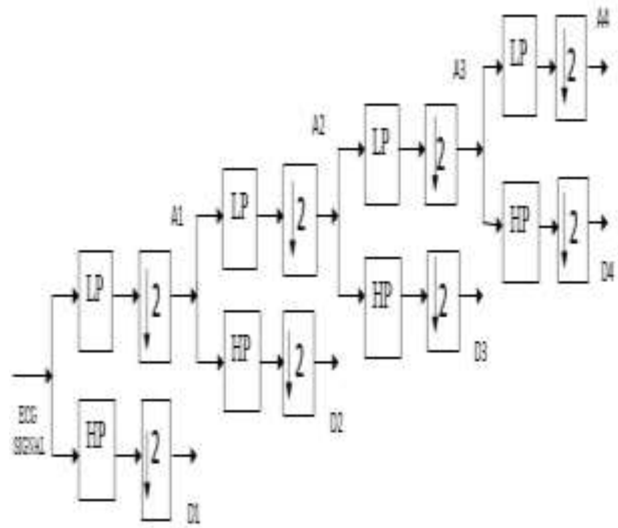
$$y(n) = A \cdot \cos(\theta_0 n + \varphi) = a \cdot x_1(n) + b \cdot x_2(n)$$

Thus the baseline wander noise and the power line interference noise in an ECG signal is removed using the IIR filtering and the Adaptive filtering technique respectively.
Discrete wavelet transform is used to extract characteristics from a signal on various scales proceeding by successive high pass and low pass filtering. The wavelet coefficients are the successive continuation of the approximation and detailed coefficients.

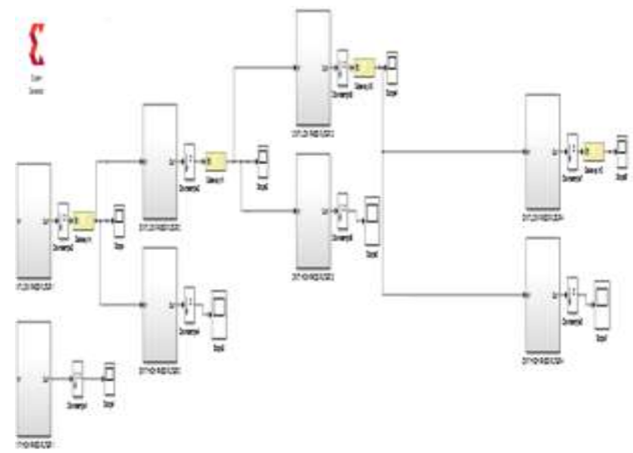
The basic feature extraction procedure consists of

1. Decomposing the signal using DWT into N levels using filtering and decimation to obtain the approximation and detailed coefficients
2. Extracting the features from the DWT coefficients

The ECG signals are decomposed into time-frequency representations using Discrete Wavelet Transform (DWT). The DWT technique has been widely used in signal processing tasks in recent years. The major advantage of the DWT is that it provides good time resolution. Good resolution at high frequency and good frequency resolution at low frequency. Because of its great time and frequency localization ability, the DWT can reveal the local characteristics of the input signal.



The denoised signal is feature extracted using DWT. The DWT consists of two filters. They are low pass filter and high pass filter. These filters are designed using Filter Design Analysis Tool (FDA Tool). The output of each filter is then down sampled by a factor of 2. The low pass output is further filtered and this process goes on until enough steps of decomposition are reached. In this method the input signal is passed through four levels of filtering results in five signals (d1, d2, d3, d4 and a4).



The result obtained from the DWT is given as the input to the support vector machine (SVM) classifier. The SVM classifier performs the further diagnosis in the obtained feature extracted signal.

Support Vector Machine (SVM) is a new paradigm of learning system. The technique of SVM is a powerful, widely used technique for solving supervised classification problems due to its generalization ability. In essence, SVM classifiers maximize the margin between training data and the decision boundary (optimal separating hyper lane), which can be formulated as a quadratic optimization problem in a feature space. The subset of patterns those are closest to the decision boundary are called as support vectors

SVMs based classification methods representation a major development in pattern recognition research. Two innovations of SVMs are responsible for the success of these methods, namely, the ability to find a hyper lane that divides samples into two classes with the widest margin between them, and the extension of this concept to a higher dimensional setting using kernel function to represent a similarity measure on that setting. Both innovations can be formulated in a quadratic programming framework whose optimum solution is obtained in a computation time of a polynomial order.

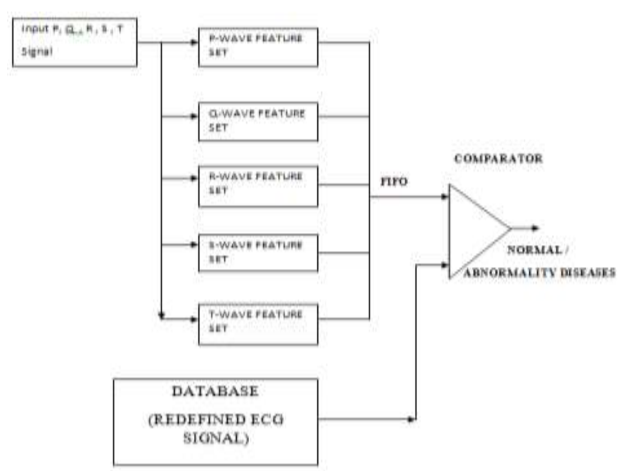
This makes SVMs a practical and effective solution for many pattern recognition and classification problems in bioinformatics. The successful use of SVMs is applied to gene expression data, classification of lung data, cancer diagnosis. The SVM is also applied for ECG signal analysis and arrhythmia classification. SVM is applied in the present work is to classify the feature extracted ECG signal into the normality and the abnormalities in the ECG signal.

SVM classifier is a binary classifier. Thus SVM works in the state of bit values while the ECG signal after denoising, it is feature extracted using DWT algorithm where DWT will extract four signals which is the sub bands of the original denoised ECG signal. The feature extracted ECG signal is classified by the abnormalities in each sub bands.
When the electrical impulse is conducted from the SA (Sino atrial) node towards the AV (Atrio Ventricular) node and spreads from right to left atrium, the depolarization (contraction) of the atria occurs. This results the P wave to atria depolarization. Ventricular repolarisation results the preceding of ST segment and the T wave.

The PR interval begins with the onset of the P wave and ends in the onset of the Q wave. It represents the duration of the conduction through the atria to the ventricles. The QRS complex consists of waves, sequentially known as Q, R and S. The rapid depolarization of both the ventricles have large muscle mass than that of atria, hence its amplitude is much larger than that of P wave.

The ST segment represents the time between the ventricular depolarization and the repolarisation. The ST segment begins at the end of the QRS complex and ends at the beginning of the T wave. Normally, the ST segment measures 0.12 second or less. The precise end of depolarization (S) is difficult to determine as some of the ventricular cells are beginning to repolarise.

The QT interval begins at the onset of the Q wave and ends at the endpoint of the T wave, representing the duration of the ventricular depolarization/ repolarisation cycle. The normal QT interval measures about 0.38 second, and varies in males and females and with age. As a general rule, the QT interval should be about 40 percent of the measured R-R interval.



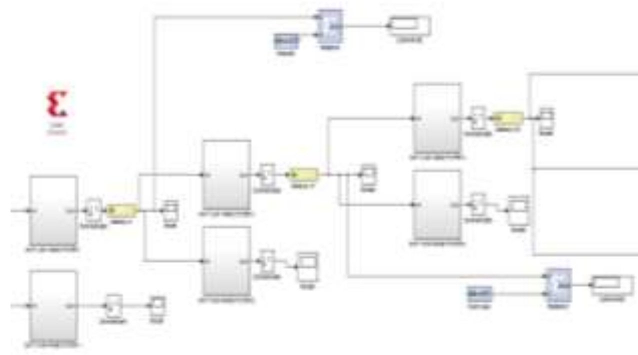
Diagnosing a beat of the heart is based on investigating the shape, the duration, and the relationship between these waves. However, interpretation of these waves or the heart state is not an easy task. In fact, the ECG signal is non-stationary, and thus, symptoms of a disease, if any, may not occur regularly. Therefore, Physicians used to record and monitor the heart for a long time before they are able to classify the rhythm into a well-known type. In addition, the size of the generated data can be huge which requires a lot of time and effort, which necessitates the need for an automatic classification system. The SVM block consists of a relational block that compares the feature extracted signal with the signal in the standard database. The output of the SVM class is represented in the binary form since SVM classifier is a binary classifier. After these feature extracted ECG signals, it is given to a classifier block, in this classifier block, each signal is given to a relational operator to compare the abnormalities of P,Q,R,S and T signals.

The first sub-band is considered to be detection of P abnormality, and from the observed first Dwt signal, we consider threshold as a main parameter to detect p abnormality. Threshold is nothing but the highest peak value, such as p is mostly obtained in threshold region, we consider this parameter to detect the abnormality and the range of this threshold seems to be 1.75 – 4.75 for a normal person. The range more than the observed is considered a abnormal and found to be abnormality.

Similarly from the second dwt signal, we consider mean to be the main parameter, since Q signal is the linking signal between the P and R signal, thus mean of these values is considered to find abnormality in Q. 1.07-4.45 this is the normal person mean range, if it is higher than this, there is an abnormality.

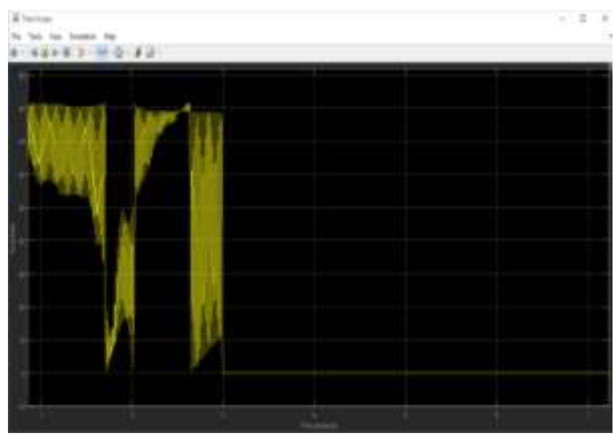
Also from the third dwt signal, we consider kernel values to be the parameter to detect abnormality in R, thus kernel means the lowest range of the waves. Thus the range for the third stage DWT is 0.35 – 2.35 is for normal signal, if it goes beyond is considered as abnormality.

And last from the fourth observed DWT signal, we obtain the variance value, thus variance is nothing but the range of two waves, namely S and T waves, thus its value must be 1, if it is 0 , no range of next cycle of PQRST, thus is the abnormality factor method of S. Thus the relation operator compares the values with the reference database and the output is displayed in binary form.

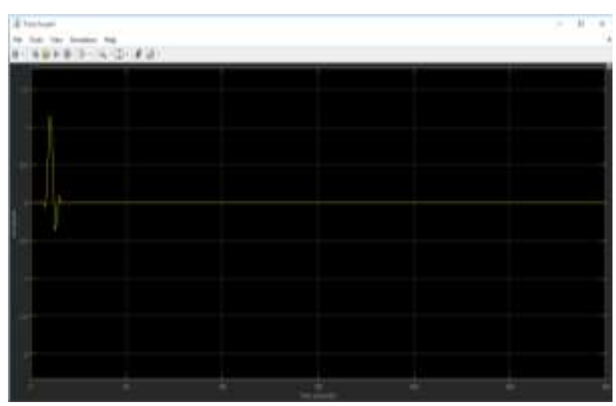


IV. RESULT AND DISCUSSION

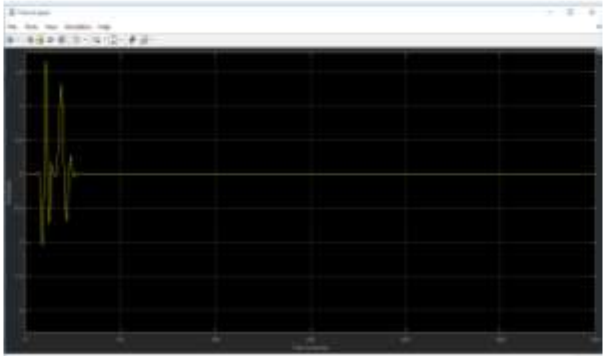
The Electrocardiography (ECG) signal is a bio medical signal which gives the electrical activity of the heart. The ECG signal is obtained from a database called MIT-BIH database.

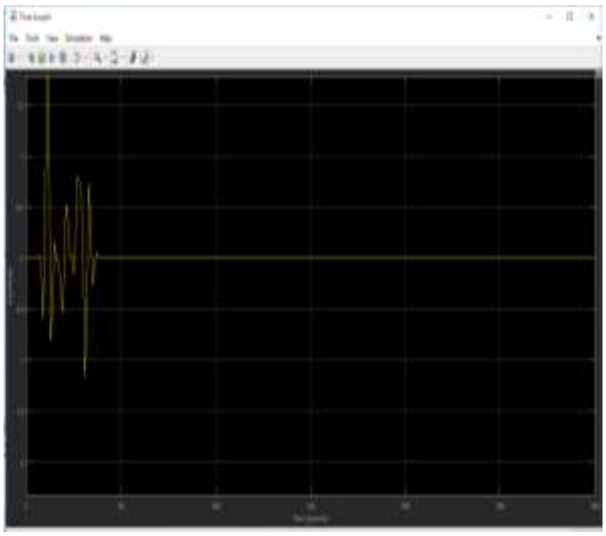


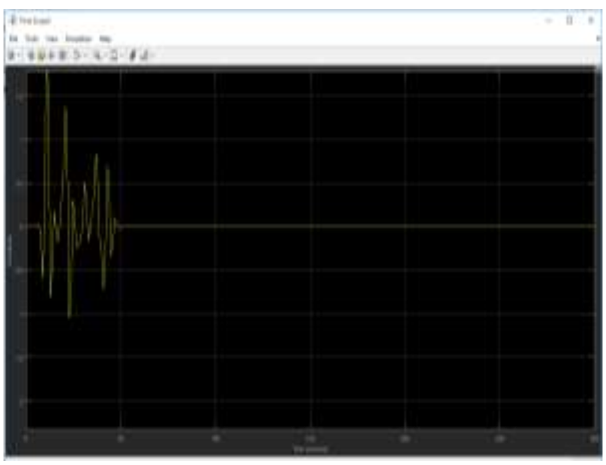
The input ECG signal obtained from the database is given to the noise reduction stage. The signal is denoised by using IIR and Adaptive filter. The band pass filter is used in order to remove the noise embedded in the input ECG signal.

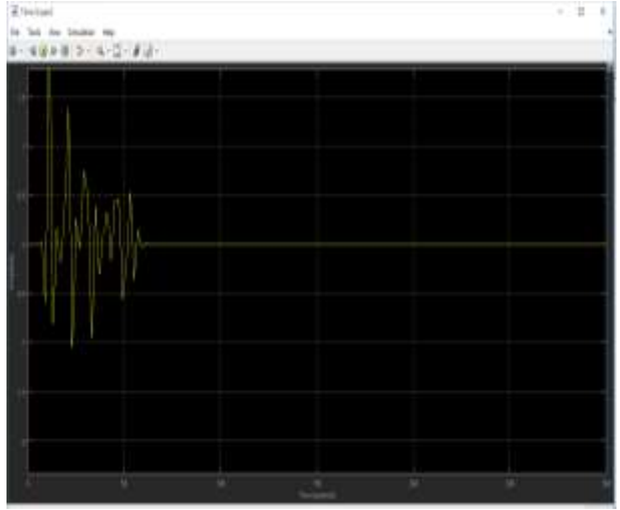


The denoised signal is given for the process of feature extraction. The feature extraction is done using Discrete Wavelet transform (DWT). The DWT is the process of reducing the redundancy by retaining only the useful part of the signal. The four stages of DWT is as follows.

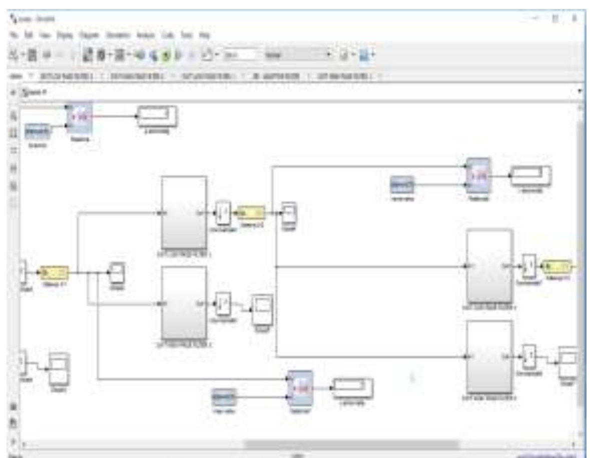


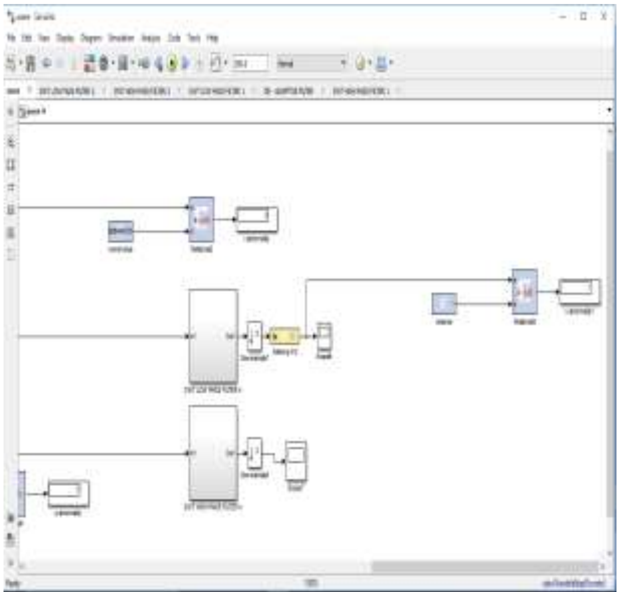






The feature extracted signal is given as the input to the classification block. The support vector classification block classifies the feature extracted signal according to the abnormalities in the signal. The output of the SVM classifier is represented in the binary form. The binary digit in SVM output 1 represents the presence of abnormalities and the binary digit 0 represents normal the ECG signal. For the given input signal, it is known that the abnormality is detected at the S wave.





Thus the abnormality in the ECG signal is detected using SVM classifier.

The project is further implemented using FPGA. The noise reduction and the classification is carried both the FIR and IIR filter with SVM classification.

The results from the Xilinx system tool is obtained as shown in figure 5.9 and 5.10. The X represents the input ECG SIGNAL and the sub bands of the DWT are represented by D1, D2, D3, and D4. The noise reduction performed by FIR filter is represented by FIROUT. If OUT is 0, then the signal is said to be normal.

The X represents the input ECG SIGNAL and the sub bands of the DWT are represented by D1, D2, D3, and D4. The noise reduction performed by IIR filter is represented by IIROUT. If OUT is 0, then the signal is said to be normal.

V. CONCLUSION

In this project, the ECG signal is being analysed and it is denoised by means of IIR and Adaptive filter. Here the IIR filter has removed the baseline wander noise and adaptive filter removes the power line interference noise of 50 Hz in an effective way. The denoised signals are processed by Discrete Wavelet Transform (DWT) as it does not require any reference model and accuracy is much better, as this algorithm is simple with computational overhead and good detection sensitivity. The support vector machine provides useful information of ECG signal classification and cardiac diagnosis.

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