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Performance Analysis of Cascaded Denoising Block for ECG Signal Analysis using Different Filters

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ABSTRACT:Electrocardiography(ECGs)are necessary medic al specialty signals that are reflective of an electrical activity of theheart. Within the recent years there has been an intensive analysis withthe intent of developing economical and effective ways of process & analysis of graphical record ECG signals.This paper presents the review of various papers based on the analysis of ECG. Later this paper illustrates various noise removal techniques.In this paper, different low pass IIR filter, high pass FIR filter, notch filter and adaptive filter has been designed by using various approximation methods, windowing techniques and algorithms. Comparisons of two physical parameters i.e. signal to noise ratio (SNR) and power spectral density (PSD) has been done on the basis of before and after filtering. These filters have been designed using MATLAB R2016a. Results with the best filters were cascaded to attain denoised ECG signal better performance. The cascaded filter design gives the high SNR of 2.1081dB and low PSD i.e. -71.7429.

Keywords: ECG, Electrical Activity, FIR, IIR, Adaptive filters

I. INTRODUCTION:

Electrocardiography (ECG or EKG) is a method of recording anelectrical activity of the center over an amount of the time victimization electrodes placed on the skin [1, 2]. These electrodes observe the little electrical changes on the skin that arise from the center muscle's electrophysiological pattern of depolarizing and repolarizing throughout every heartbeat. In the normal heart, the electrical activity associated with each cardiac cycle originated in a specialized group of cells in the high right atrium known as the Sino atrial Node (SA Node). SA Nodal cells spontaneously depolarize at a rate that is dependent on the relative balance of sympathetic and parasympathetic tone. At rest, vagal (parasympathetic) tone predominates and the SA node spontaneously depolarizes, on average, 60-100 times per minute. From SA node the wave ofdepolarization propagates in an orderly timed fashion to the remaining atrial tissue, to the Atrioventricular Node (AV Node), the His-Purkinje system and then to the left and right ventricular myocardium (Figure 1) [3]. The AV node conducts relatively slowly, thereby allowing the atrium to fully contract before the start of ventricular contraction. The His-Purkinje system (also named a specialized physical phenomenon system) consists of the left and right bundle branches and the diffuse fine network of bodily cavity Purkinje fibers. Relatively rapid conduction in the His-Purkinje system allows for synchronized contraction of the ventricles.

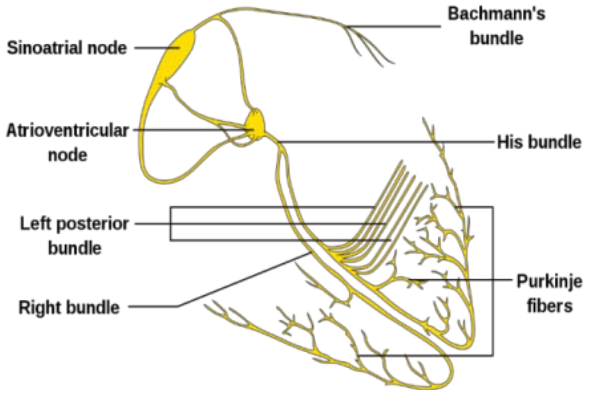

Fig. 1. His-Purkinje system [3]

ECG signal consists of different waves, segments. Its signal consists of noise. This paper works on denoising of signal. Various noises were removed by different digital filter techniques.Section 2 explains the literature review, Section III gives the methodology and section IV explains the results and discussions for the various noises which is followed by the conclusion and future work.

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II. LITERATURE REVIEW

Various papers were reviewed which are explained as follows:

1. Osowski*et al* 2001 [4]:This paper shows the use of the fuzzy neural system for ECG beat characterization. The new arrangement calculation of the ECG beats by applying fuzzy method and neural system and the highlights wasdrawn from the higher request measurements. The consequences of trials have affirmed great effectiveness of the proposed approach.
2. Lera*et al* 2002 [5] :In spite of the fact that the Levenberg–Marquardt (LM) calculation has been widely connected as a neural-arrange preparing technique. In this paper, the conduct of a proposed variety of calculation is contemplated. The conduct of the strategy for a few neighborhood sizes has been contemplated, contrasted and both backpropagation and LM strategies, demonstrated that great outcomes can be normal for neighborhoods of direct size, when the quantity of versatile weights are huge, it was conceivable to accomplish better execution with the NBLM calculation than with alternate techniques considered
3. Sadaphule *et al* 2007 [6] : This Paper tried to build up a calculation to identify and group three sorts of ECG flag beats which include typical right bundle beats (R), beats (N),and left bundle beats (L)using aArtificial neural network (ANN). Different types of classification algorithm had been implemented using Unsupervised Soft Competitive Learning (USCL) neural network Fourier Transform Neural Network (FTNN) and Discrete Wavelet Transform (DWT). Accuracy level has been found to be greatest for the DWT approach.
4. Rajini *et al*2010 [7] : This paper give varioustechniques which was used to detectthe abnormalities in ECG signal. Thereare different methodsfor ECG signal analysis.Earlier ECG signal analysis was done in time domain method but it is not sufficient for an analysis of different type of characteristics of ECG signal. To overcome with this problem another methods were discussed a) Fast Fourier transform (FFT) (converting time domain into a frequency domain to obtain all coefficients of frequency). b) Short Time fourier transform (STFT) (it helps in providing both time and frequency information. But its time frequency precision is not optimal)c)DWT.
5. Rani *et al*2011 [8] : This paper shows the examinations of Digital Finite Impulse Response (FIR)& Infinite Impulse Response (IIR) filter. IIR filter have a stage twisting that is caused by nonlinear reaction. On the off chance we increment the request of channel then vast motions can get delivered.
6. Islam *et al*2012 [9]: This paper manages the examination and investigation of ECG signal process by implies MATLABand LabVIEW. They are so valuable and helpful that even one can screen his/her heart condition basically using the energy of MATLAB as well as LabVIEW without having an ECG machine and furthermore self conclusion was conceivable.
7. Dubey *et al*2013 [10]:Signal pre-preparing, QRS identification, highlight extraction and neural system for flag order are those procedures which utilized as a part of analysis of ECG. Among various structures, it was discovered that a three layer organize structure with 25 inputs, 5 neurons in the yield layer and 5 neurons in its shrouded layers had the best execution with most elevated acknowledgment rate .Several retraining trials showed that accomplishing ideal execution, amid information handling, requires the non-linear neural system model to comprise of 2 concealed layers of 20 neurons each. A more mind boggling model leads to an emotional increment of reaction time.
8. Sao*et al*2013 [11] : The concept of pattern recognition refers to characterization of information designs and recognized them into predefined set of classes. The ECG signal produced waveform gives all data about movement of the heart. The ANN classifier was nourished by three parameters which are entropy, Poincare plot geometry and biggest Lyapunovexponent (LLE) got from the heart rate signals.
9. Sharma *et al*2014 [12] : This paper presents expulsion of noise from the ECG motion by utilizing digital channels planned with FIR and IIR procedure .By looking at the power otherworldly thickness and normal power, prior and then afterward filtration utilizing diverse window methods. It reasons that the decision of the cut-off frequency is vital, a lower than required cut-off frequency does not channel the real ECG signal segment, however a portion of the noise effectively, yet the ECG signal is twisted all the while. Slice off frequency differs comparing to heart rate and standard noise spectra. In this manner, consistent cut-off frequency isn't generally fitting for baseline noise concealment; it ought to be chosen after a watchful examination of the signal range.
10. Egila*et al*2016 [13] : This paper present how the baseline wander (low frequency interference) and electromyography noise (high frequency noise) In ECG signal was removed.The results were evaluated on the basis of PSD, SNR, Mean square error (MSE).
11. Gachake*et al* 2014 [14] : One of the fundamental issues in biomedical signals like ECG is the partition of the signal from noises caused by control line impedance, muscle antiquities, benchmark meandering and terminal ancient rarities. Distinctive sorts of digital filters are utilized to isolate signal segments from undesirable frequency ranges. Along these lines noise evacuation utilizing FIR advanced filter is better choice in examination with IIR digital filter. Thus it was cleared from the results that FIR Equiripple Notch Filter is the best option as compared to Kaiser Window and IIR filter to remove the power line interference from the ECG signal due to sufficient noise reduction with minimum order.
12. Jadhav*et al* 2017 [15] : In this paper we have contemplated FIR filter in view of different windows and IIR filters for commotion expulsion of ECG signal. This paper indicates

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FPGA usage for noise concealment of ECG signals. Consequently this paper demonstrated the strategy used to evacuate ECG commotion is more proficient than the conventional middle filter technique.

13. Gupta *et al* 2014 [16]: This paper gives electronic execution of ECG circuit by utilizing instrumentation amplifier (IA) as bio-potential amplifier in such a way which lessens commotion, basic voltage, DC balance esteem and RF obstruction from the current circuit. Commotion and normal voltage can be expelled from ECG utilizing driven right leg circuit or by utilizing isolator circuit. This paper likewise discloses the few methods to lessen noise and to build CMRR by utilizing driven right leg circuit.
14. Dhiman *et al* 2014 [17] : The aim of this paper is hardware optimization of the electronic circuit of ECG by using a bio-potential amplifier in such a manner that it reduces noise, RF interference, DC offset value, and common voltage from the existing circuit. This work indicates the performance of ECG circuit in terms of electronics using an IA. It further explains several procedures carried out to reduce the circuitry to increase CMRR and noise with the help of right leg drive circuit. DC offset can be diminished with the help of high pass filter and RF interference can also be reduced by filters.

III. MATERIAL AND METHODS

For the analysis of ECG signal a flow graph was made which consists of mainly three blocks [18, 19, 20] which are shown in Figure 2.

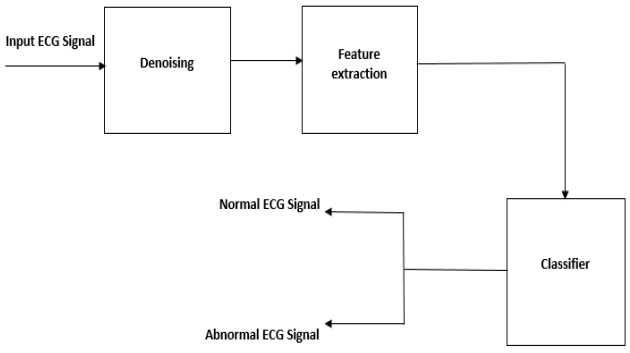

Fig. 2. Flow graph showing ECG analysis

A. DENOISING BLOCK:

In an ECG signal there are various types of noises like low frequency noise, power line interference noise, burst noise, and electromyography noise.

1) Low frequency noise (baseline wander noise):

These are those noise which is caused due to the patient movement and movement of cable, leads wire and loose electrodes. The range of frequency in which baseline wander is dominant is typically less than 1.0 Hz.

2) High frequency noise (power line interference and muscle contraction):

These noise are being removed using FIR high pass filter. Amplitude of EMG is random in nature and is modeled by Gaussian distribution function. Mean of noise assume to be zero, while variance may vary.

3) Medium frequency range (Power line interference noise):

This noise is due to electromagnetic interference of frequency (50 Hz or 60 Hz). Capacitive and inductive coupling are the mechanisms that contribute to Power line interference.

4) Burst noise:

classified as a white Gaussian noise (WGN), Some of examples are - electrode popup noise, electrode motion artifact, electro surgical noise, instrumentation noise etc. The frequency ranges for these noises are not well defined.

There are mainly different types of filters: Digital filters (FIR and IIR), notch filter and adaptive filter.Graphical record signal generally varies from five cycle -120 cycles. Among these, the foremost action is the calculation of cut off frequency (f_c) of the filter and its characteristics function.The f_c needs to be selected in such a way that the clinical data within the graphical record signals remains ingenuous whereas removing the baseline wander the maximum amount as attainable. Hence, it's essential to seek out all-time low frequency element of the graphical record spectrum.

B. FEATURE EXTRACTION BLOCK:

There are different methods to analyze the ECG signal which are wavelet transform, genetic algorithm, fuzzy logic method, artificial neural network, signal analysis etc. [18]

1) FAST FOURIER TRANSFORM :

A FFT rule computes the separate Fourier transform of a sequence, or its inverse (IFFT). Analysis converts a proof from its original domain (time) to an illustration within the frequency domain and contrariwise. Earlier technique used for analysis of EKG is in time domain however this methodology is not comfy for study of all characteristics of ECG signal. FT is a technique that converts time domain to frequency domainto calculate frequency coefficients. But it filed to give the exact location of frequency components ion time.

2) SHORT TIME FOURIER TRANSFORM (STFT) :

It is related to a Fourier transform which is used to determine the sinusoidal frequency and phasor value of a signal as it varies with a time. To overcome the problem of a FFT windowed-Fourier transform, i.e. STFT was introduced which is now known as *Gabor transform*. STFT has bothfrequency and time info. STFT can be written as

$$STFT = X(a,w) = \underbrace{\int x(t)\, w(t-\tau)\, dt}_{Fourier\,Transform} \quad (1)$$

where$w(t)$ is a window, having duration T, centred at time t. To overcome the drawback of STFT, WT can be used.

3) WAVELET TRANFORM (WT) :

WT decomposes the signal into reciprocally orthogonal set of wavelets that the main distinction from the continuous wavelet transform (CWT), or its implementation for the separate statistic generally referred to as discrete-time continuous wavelet transform (DT-CWT). Wavelet transform contains a multi resolution that offer time and frequency info of signal by variable window size. Wavelet families include Biorthogonal, Haar, Coiflet, Symlet, Daubechies Wavelets, etc [21, 22, 23, 24]. WT can be analyzed for non-stationary signals such as ECG which have frequent level variations and uneven features.

C. CLASSIFICATION BLOCK:

Classification is the process of grouping the testing samples into the corresponding classes. Classification is characterized into two types viz. supervised classification and the unsupervised classification. Classification is supervised if the classes are already defined for the training sets otherwise it is unsupervised classification. In the classification module, performance of four different classifiers namely k-NN, probabilistic neural network (PNN), SVM and smooth support vector machine (SSVM) [25, 26, 27] was evaluated to obtain the class of the unknown testing instances. MIN-MAX normalization procedure is used to normalize the extracted features in the range [0,1] in order to avoid any bias by unbalanced features. There are various classification techniques which classify the data into two classes or three classes according to its use [28, 29, 30].

IV. RESULTS AND DISCUSSIONS

An ECG signal consists of five waves namely P, Q, R, S, T. ECG signals are sensitive signals. These signals get contaminated due to noise resulted it unsuitable for various Biomedical Applications. These noises were removed by filtering of signal from ECG recordings. There are different types of filters which are useful to remove different noises. There are various types of filters those are :Mean filter, Median filter, Center weighted median, Adaptive median filter, Savitzky–Golay filter, Moving average filter, Weiner filter, Lee filter, Anisotropic diffusion filter and Homomorphic filter. Except these filters we have digital filters, adaptive filters and notch filter which are mainly used to remove the different noises occurred in an ECG signals.Fig 3 shows the flow graph of filtered ECG signals by cascading. Input is noisy ECG signal. Later it is passed to high pass filter which is used to remove baseline wander noise which can be done by using FIR filters. There are different FIR filters which include Rectangular, Hann, Blackman, Hamming, and Kaiser. FIR filters with varied windows evaluated the PSD, SNR and MSE of ECG signal.

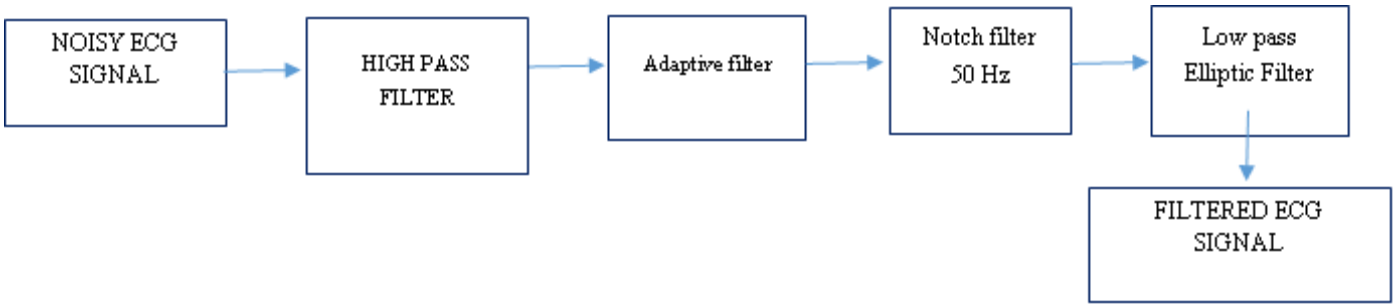

Fig. 3. Flow graph of filtered ECG signal by Cascading

Using these windows, we have a tendency to design the high pass filter of cut-off frequency 0.5 cycles per second for removing baseline wandering.We have a tendency to optimize the filter in many ways. The fundamental plan is to style the filter coefficients till a specific error is reduced. The goal of the improvement method is to search out the best filter coefficients that closely approximate the required frequency response. Once we do the frequency sampling technique there's no constraint on the response between the sample points, and poor results is also obtained.

To remove the electromyographynoise, low pass filter was designedusing IIR filters(butetrworth, elliptic, chebyshev) were designed to remove these noises. Table 1show the SNR and MSE values of different filters. ECG input signal MIT-BIH Arrhythmia v5 is taken from Physio Bank ATM database of 100 records. This input ECG signal has length of 1454 samples. ECG signal has frequency range between 0.5 Hz -100 Hz and sampling frequency taken for data signal is 360 Hz. SNR should be high while MSE should be minimum so based on this Elliptic filter comes out the best.

TABLE I. SNR AND MSE VALUES OF DIFFERENT IIR FILTERS

Filter Name	Filter Order	SNR	MSE
Chebyshev I	3	-7.655	0.0095
Chebyshev II	5	-7.029	0.0514
Butterworth	5	-8.122	0.0163
Elliptic	3	-7.655	0.0093

Later Notch filter was designed with f_c= 49.5Hz- 50.5 Hz. In the end an Adaptive filter was designed to remove the burst noise. The frequency of burst noise is not defined. We have cascaded all the best filters whose flow graph is shown in Fig 3

TABLE II. SNR AND PSD USING CASCADING FILTER

SNR Before Filtering	SNR after filtering	PSD Before filtering	PSD after filtering
-5.5313	2.1081	-54.883	-71.7429

Performance metrics has been obtained in terms of SNR and PSD by filtering the noisy ECG signal by different digital filters. These parameters i.e. SNR and PSD before filtering and after filtering has been observed and shown in tabular form (Table 2). Time domain output waveform of ECG signal filtered by Cascading Filter is shown in Figure 4) and corresponding Frequency spectrum of an ECG filtered signal is shown in Figure 5.

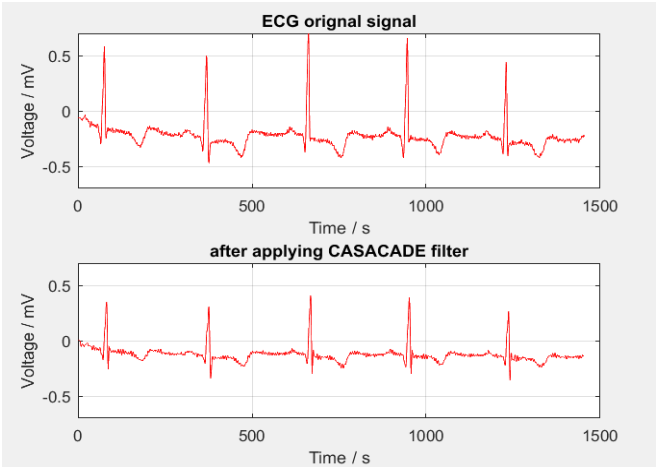

Fig. 4. Time domain analysis of ECG signal by Cascading

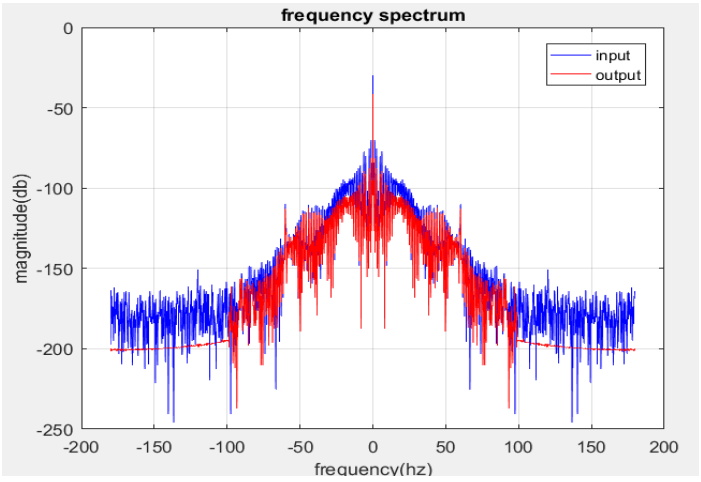

Fig. 5. Frequency spectrum of an ECG signal by Cascading

V. CONCLUSION

This paper outlines the various approximation methods, windowing techniques and different algorithms for designing of IIR and FIR digital filters to remove the noise from ECG signal. The performance metrics of these filters in terms of Signal to noise ratio and Power Spectral density has been obtained. On comparing these parameters Elliptic IIR filter and Blackman window of FIR filter showed better results. By combining these high performances FIR and IIR filters along with notch and adaptive filter in series, we have designed a cascaded filter design to remove different noises from ECG signal. Results with cascaded filter design get the high SNR i.e. 2.1081 db and low PSD (-71.7429).

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