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HYBRID ADAPTIVE FILTERING OF ECG WITH TRANSMISSION OVER GSM/PSTN VOICE CHANNEL

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Abstract: Cardiac disease is one of the loading causes of death worldwide. One of the effective ways to diagnose heart disease is ECG. Electrocardiogram(ECG) is the measure of heart's electrical activity and analysis of ECG signal is of very high importance in detection of cardiac abnormalities. Hybrid adaptive filtering is a combination of a band-pass butter worth filter and an adaptive spectral filter. Apart from filtering the raw ECG signal, the proposed system processed the filtered ECG signal to extract P,Q,R,S,T peaks from the ECG signal. Also, the system computes heartbeat based on R-Peak e repetition.

The comprehensive system that has been proposed allows to export the proposed ECG signal with P,Q,R,S,T markings in an image that can be sent via E-mail or other detail mediums over internet to health care professionals. Also, the system allows modulation of exported ECG image into a voice signal that can be transmitted over GSM / PSTN channel, so that processed ECG signal can be transmitted over mobile/landline phone(s) where internet is not available.

Keywords: ECG, Adaptive Filtering, Spectral Filtering, P,Q,R,S,T Detection, GSM / PSTN Channel.

1. INTRODUCTION

Filters: A program that accepts a certain type of data as input transforms it in some manner and then outputs the transformed data. Filters are analog circuits which perform signal processing functions specifically to remove unwanted frequency components from the signal to enhance wanted ones or both. Filters can be of two types: Analog or Digital.

WHY ADAPTIVE FILTER

A filter that self-adjusts its transfer function according to an algorithm driven by an error signal is called an adaptive filter [1]. Due to the complexity of the optimization algorithms, such filters are sometimes called as digital filters. In order to minimize the error, it adapts to the change in signal characteristics. Therefore, it has wide applications such as in adaptive noise cancellation, frequency tracking, system identification and channel equalization.

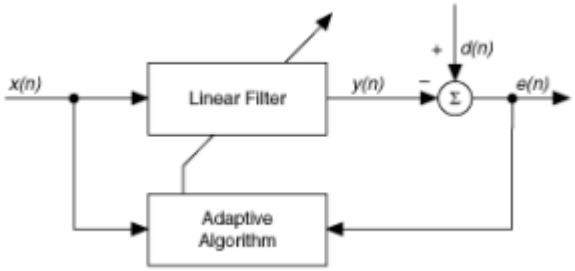


Figure 1 : Basic structure of adaptive filter

In Fig. 1, x(n) represents the input signal. A digital filter is applied on the input signal x(n) which produce output signal y(n). Adaptive algorithm adjusts the filter coefficient of vector w(n), to get the smallest error signal e(n). Eq (1) represents the vector x(n). Noise corrupts this input signal. Therefore, it represents the sum of desired signal d(n) and noise v(n), as given in Eq (2). The input signal vector x(n) is given by x(n)=[x(n),x(n-1),x(n-2),……..x(n-N-1)]T ..(1) x(n)=d(n)+v(n) ..(2) The adaptive filter has a structure of Finite Impulse Response (FIR). For FIR structure, the impulse response is equal to the filter coefficients. For a filter of order N , the coefficients are defined as W(n)=[wn(0),wn(1),……..wn(N-1)]T ..(3) The output of the adaptive filter is y(n) is given by y(n)=W(n)Tx(n) ..(4) The error signal is the difference between the desired signal and the estimated signal. e(n)=d(n)-y(n) ..(5) Also the variable filter updates the filter coefficients at every instant of time W(n+1)=W(n)+ΔW(n) ..(6) Where ΔW(n) is a correction factor for the filter coefficients. This correction factor is generated by adaptive algorithm based on the input and error signals [2].

WHY GSM/PSTN TECHNIQUE IS USED

A major shortcoming of using internet-based SMS is the probability of unavailability of internet connection at remote patient site. Hence, we must need to seek another cost-effective alternative for fast transmission-reception of compressed ECG signal. Second Generation (2G) Global System for Mobile Communication (GSM) SMS is found as the most suitable one which may replace internet based free SMS.

2. LITERATURE SURVEY

This paper deals with the ECG noise removal and its analysis in MATLAB environment. This work includes ECG analysis which consists of three main basic steps. The first step is receiving recorded ECG signal. The received raw ECG is corrupted with various kinds of noise such as powerline interference, baseline drift, patient electrode motion so the second step includes elimination of these noises from the signal. The third step includes development of algorithm for finding various peaks and detection of intervals between those peaks in MATLAB environment [3].

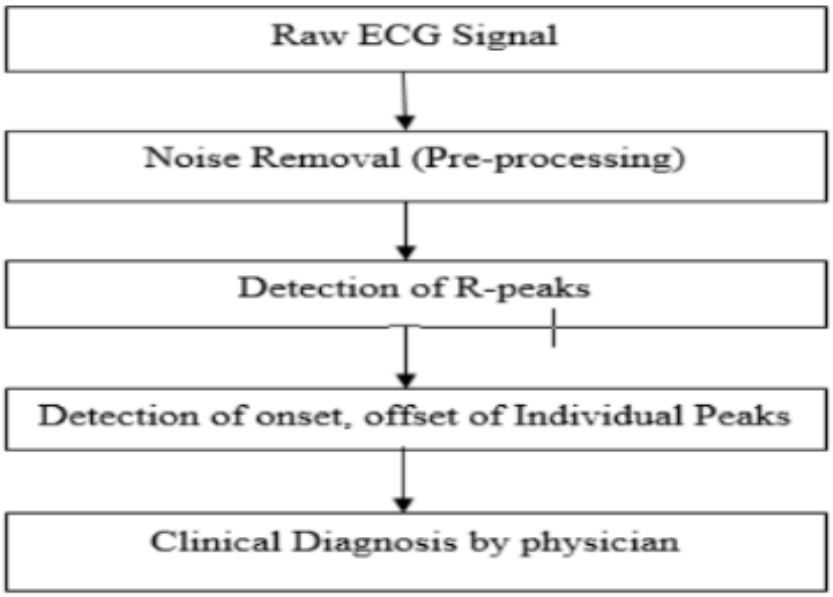


Figure 2 : General steps for ECG analysis

In this project, five common and important denoising methods are presented and applied on real ECG signals contaminated with different levels of noise. These algorithms are discrete wavelet transform (universal and local thresholding), adaptive filters (LMS and RLS) and Savitzky-Golay filtering. Their denoising performances are implemented, compared and analyzed in a MATLAB environment.

In this paper, these methods are presented and applied for ECG denoising with a comparison between their performances. The algorithms are discrete wavelet transform (universal and local thresholds), adaptive LMS filtering, adaptive RLS filtering, and Savitzky-Golay filtering. The performance measure is based on the difference between the original ECG (without noise) and the denoised version after contamination with noise. Actual recorded ECG signals are available online, such as [12-14]. In this project, these signals are used after adding different levels of noise and then compared to the original and the denoised versions for the prescribed methods [4].

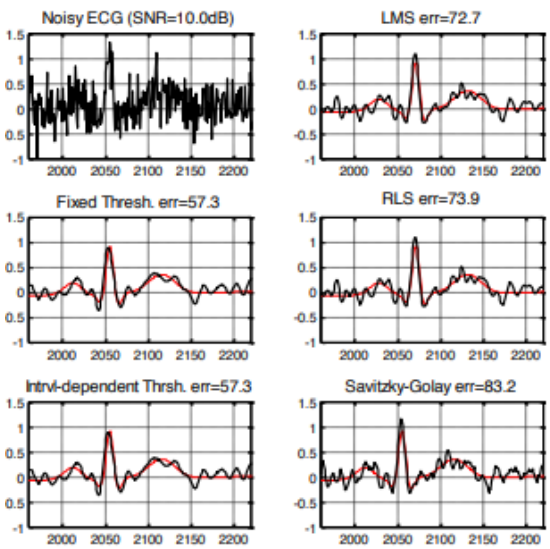


Figure3: A time segment showing one noisy ECG Pattern at SNR=10DB

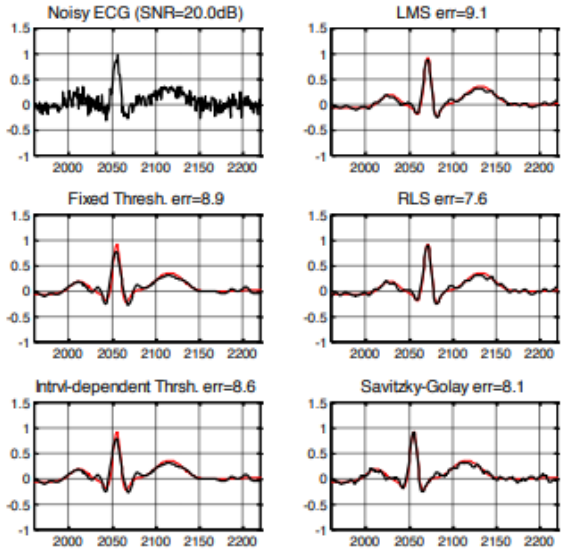


Figure 4: Time segment showing in fig1.3 at SNR=20DB

ECG signals are weak and easily susceptible to noise and interference. In this paper I have presented an implementation of Least Mean Squares (LMS). Least mean squares (LMS) algorithms are a type of adaptive filter which is used to mimic a desired filter by finding the filter coefficients that related to the least mean squares of the error signal. It is a gradient descent method which is only adapted based on the error at current time [5].

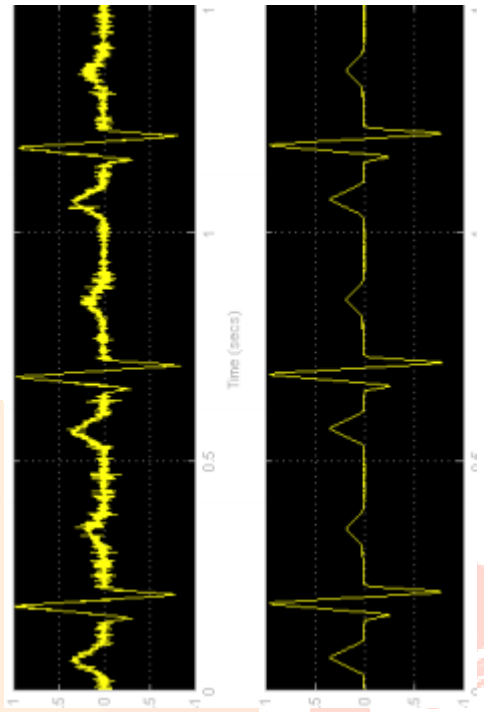


Figure 5: Removing external noise

TABLE I: Illustrates the SNR ratio evaluation of the ECG signal after being filtered through LMS.

SNR before filtering	SNR after filtering	SNR improvement
-8.6948	2.3801	11.0749

In this paper we have presented an implementation of Least Mean Squares (LMS) and Normalized Least Mean Squares (NLMS) algorithm on MATLAB platform with the intention to compare their performances in noise reduction application. The ECG samples are recorded from MIT-BIH database and additive white Gaussian noise (AWGN) is added to the raw ECG signal. We simulate the adaptive filter in MATLAB with a noisy ECG signal and analyze the performance of algorithms in terms of SNR improvement and average power [6].

TABLE II: SNR evaluation

Adaptive algorithm	SNR		
	SNR before filtering	SNR after filtering	SNR improvement
LMS	-8.6948	2.3801	11.0749
NLMS	-8.6948	10.4057	19.1005

In this paper, we have implemented an adaptive noise canceller (ANC) for ECG signals with the help of Modified Particle Swarm Optimization (MPSO). Implementing MPSO on ANC provides better performance than any other optimization technique used to enhance the ECG signal [7].

This paper presents the adaptive filters algorithms for removing noise from the Electrocardiogram to receive noise less pure embryo signals. Adaptive filtering has been used to reduce the noise from the desired ECG signals by using LMS algorithm. Other algorithms like NLMS and RLS can also be used but LMS gives least MMSE amongst them so it can be used where accuracy is required [8].

In this paper, we will discuss how we can remove different type of noises like 50Hz Power-Line Interference, Base-line Wandering and Muscle Contraction noise from an ECG signal using an adaptive filter. Real time data has been collected from MITBIH arrhythmia database. At the end, results show the better performance of adaptive NLMS filter for removing different noises over adaptive LMS filter [9].

In this paper, a descendent structure consists of adaptive filters is used to eliminate the three different types of noises (i.e., motion artefact noise, baseline wander noise and muscle noise). The two different adaptive filtering algorithms have been implemented; least mean square (LMS) and recursive least square (RLS) algorithm [10].

We propose RLS Method (Recursive Least Square) to remove noise from ECG Signal Based on three modulation technique BPSK(Binary Phase Shift Keying),QPSK(Quadrature Phase Shift Keying),8-QAM(Quadrature Amplitude Modulation), Since RLS system simulation shows best result on noise reduction with BPSK modulation technique in terms of the signal to noise ratio(SNR) and bit error rate(BER) on MATLAB [11].

The paper focuses on the performance evaluation of adaptive noise cancellation algorithms in the context of electrocardiogram (ECG) signals. Four different algorithms i.e. Adaptive Filtering with Averaging (AFA), Least Mean Square (LMS), Normalized Least Mean Square (NLMS) and Recursive Least Square (RLS) are chosen for evaluation purposes [12].

3. ECG Acquisition, Filtering, Processing & Transmission Block

First, we input raw ECG signal then display raw ECG signal and apply 3rd order butter worth filter then apply adaptive spectral filtering. Segregate noise & display filtered signal & noise. Computed and display SNR of raw & filtered signal. Then we compute P,Q,R,S,T thresholds, transmission point & segment and also compute & display heartbeat using R-R peak differentiation. After that display processed ECG signal with PQRST manner, then save ECG snapshot as JPEG image. Then convert JPEG snapshot to audio signal and save audio signal as wav file.

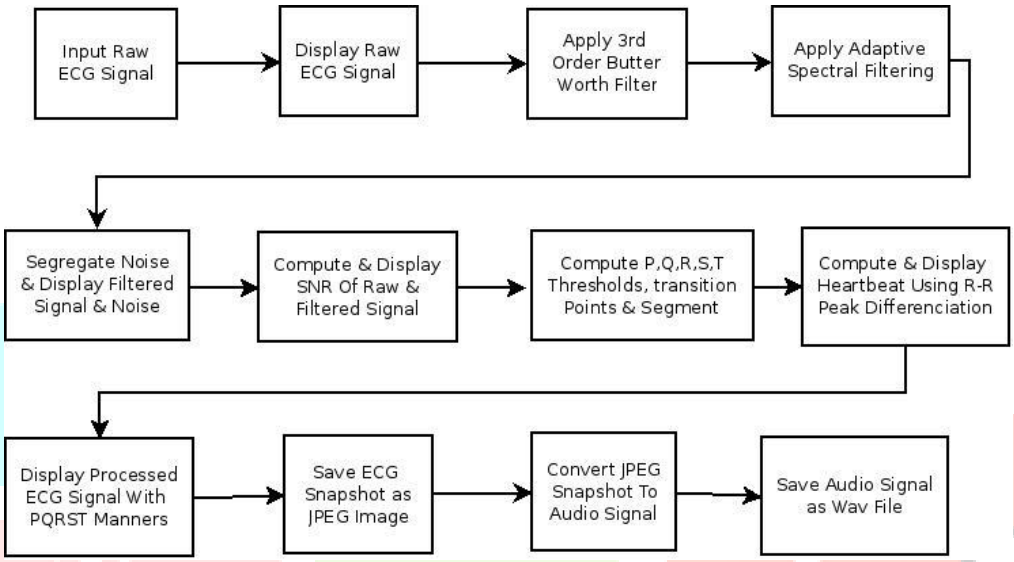


Figure 6: Transmission Block

Reception Block

First, we input audio signal from wav file then convert audio signal to image. After that save image on display as JPEG image then read & display image

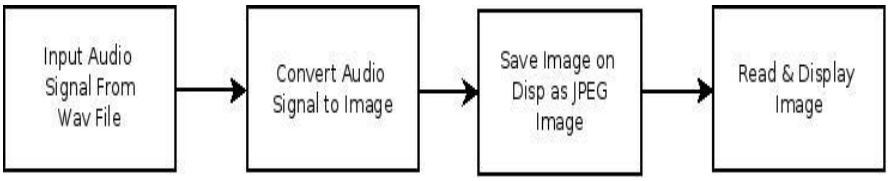
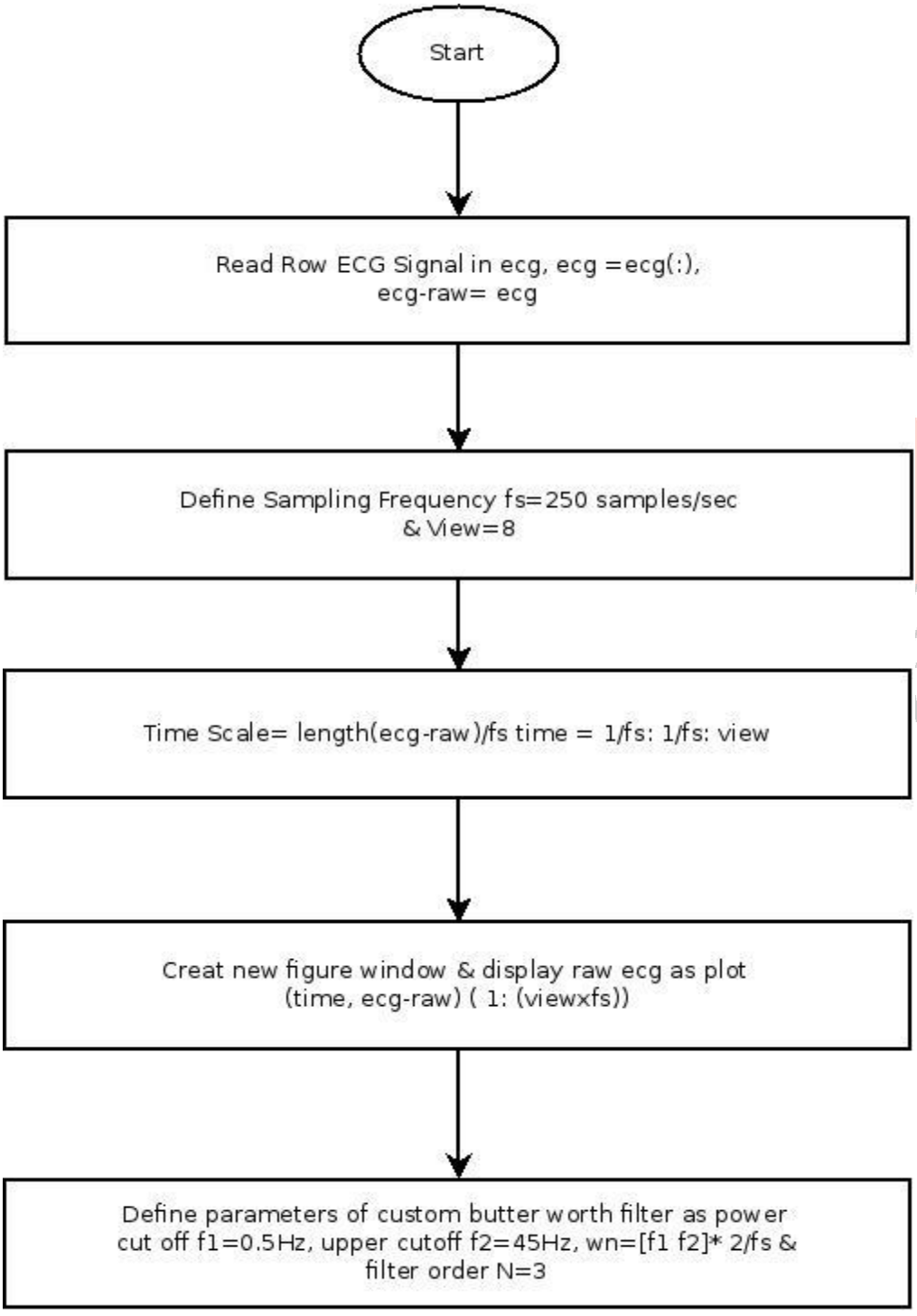


Figure 7: Reception Block

ECG Filtering Flow chart

First, we read row ECG signal and define sampling frequency, update time scale. Create new figure window & display raw ECG as plot. Define parameter of custom butter worth filter as power cut off, upper cut off and wavelength. Create Nth butter worth filter, apply 3rd order butter worth filter as ECG. Apply adaptive spectral subtraction filter on butter worth filtered as ECG. Create new figure window and display filtered ECG and noise as plot.



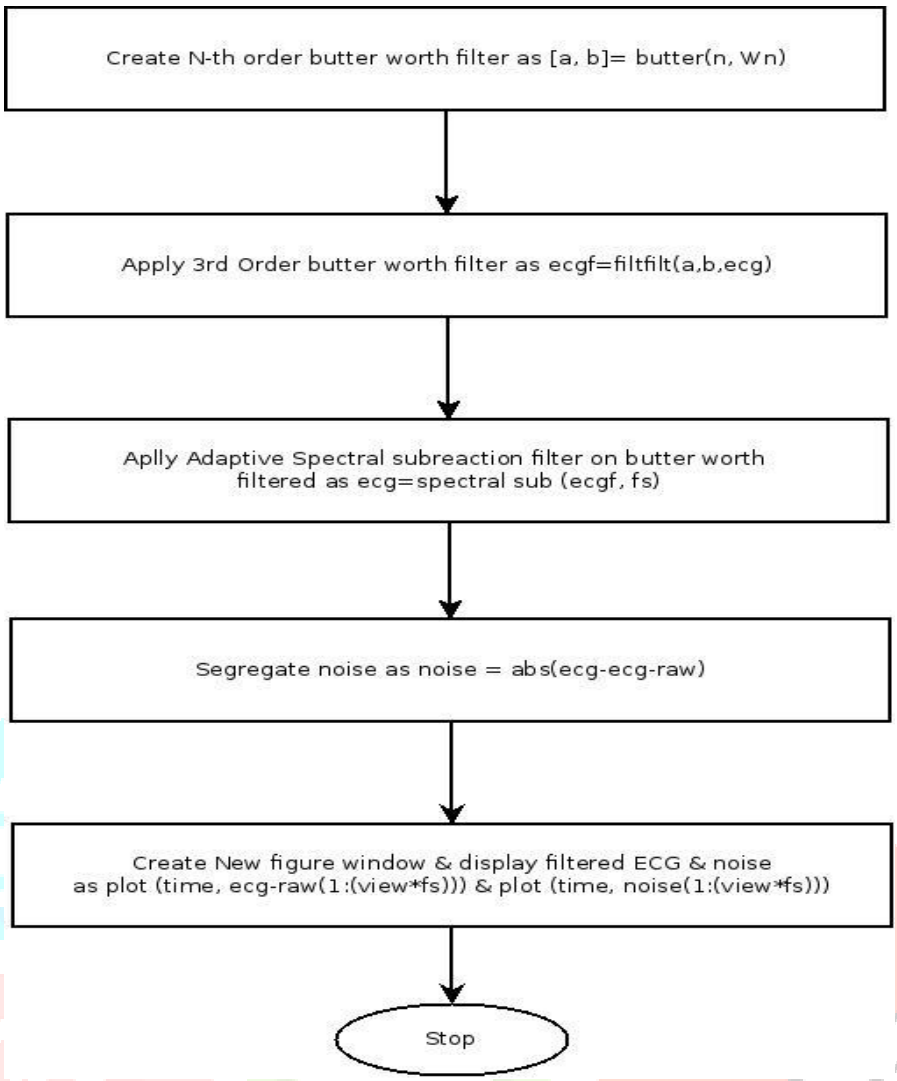


Figure 8: ECG Filtering

4. RESULTS

ECG Signal Used for Experimental Analysis

We have taken sample of ECG signal, with respective length 16350, 16350, 216000,

216000, 216000 and respective frequency 250HZ, 250HZ, 250HZ, 250HZ, 250HZ.

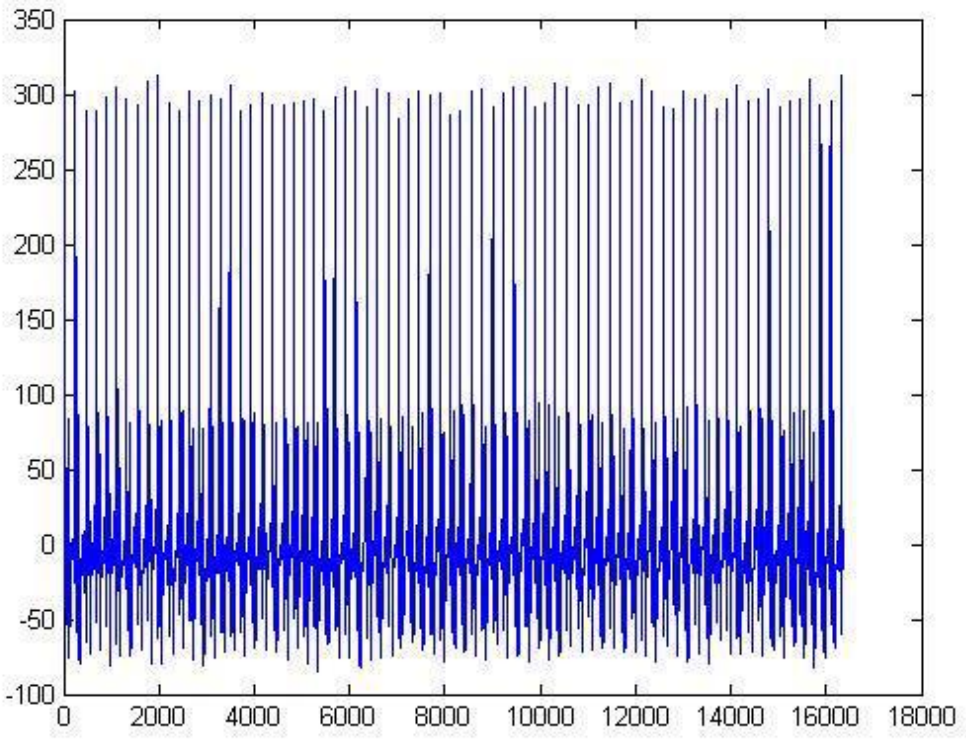


Figure 9: ECG signal

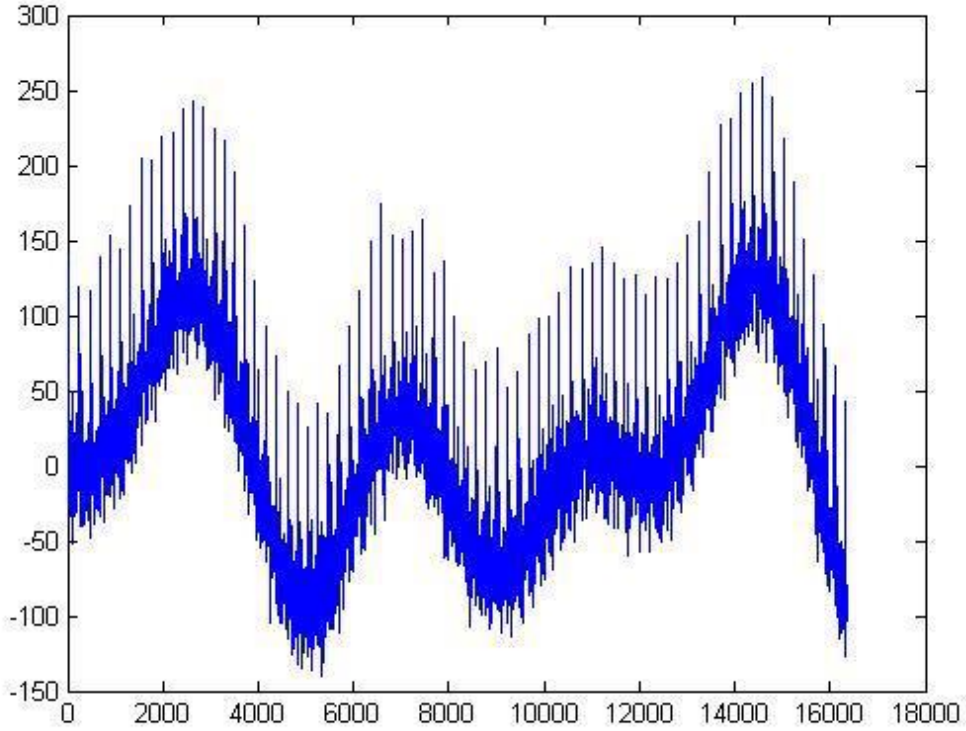


Figure 10: ECG Signal

Experimental Results

User Define Butter Worth Filter & Adaptive Spectral Filtering Results

This is user define butter worth filter & adaptive spectral filtering process. In this process Raw ECG, Filter ECG, Noise filtered signal appear.

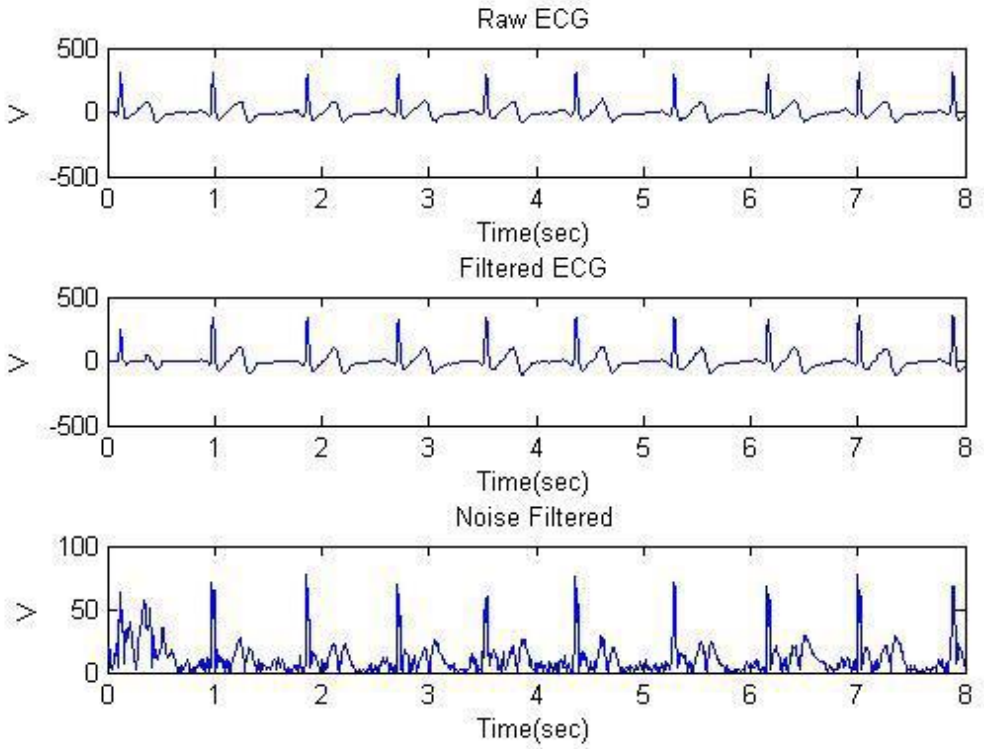


Figure 11: Raw ECG, Filtered ECG and Noise Filtered1

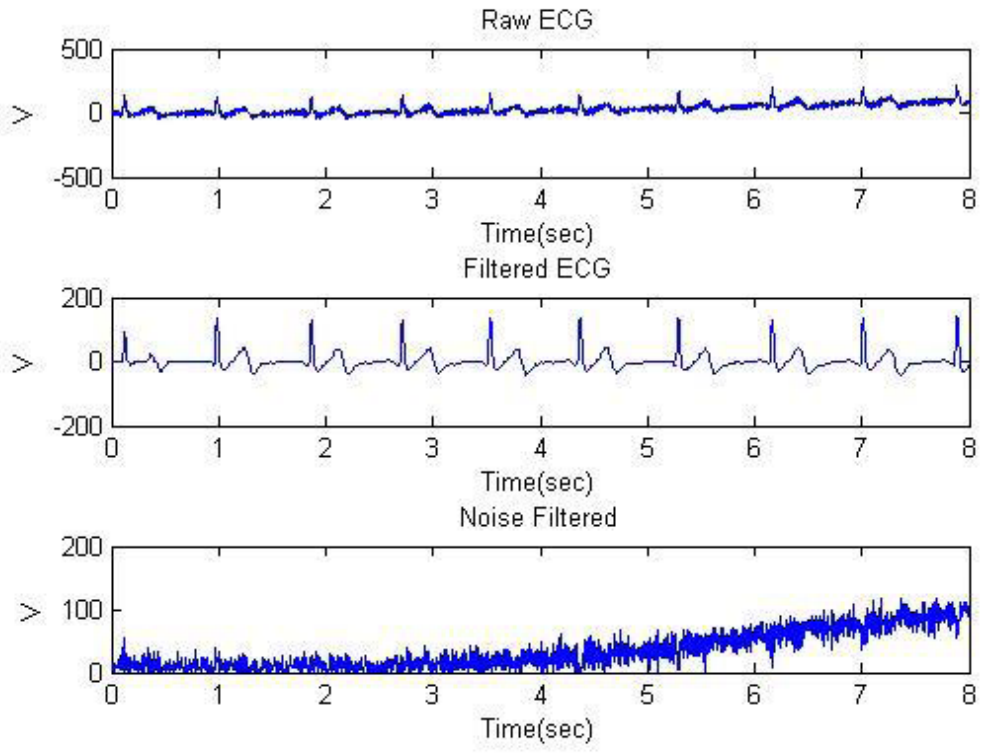


Figure 12: Raw ECG, Filtered ECG and Noise Filtered2

TABLE III: SNR IMPROVEMENT

SNR IMPROVEMENT

S. No.	ECG Signal Name	Raw ECG SNR	Filtered ECG SNR	SNR Improvement
1.	EKG1	10.2114	12.2835	2.0721
2.	EKG2	0.4708	7.3780	6.9072

5. Conclusion

In this paper the hybrid adaptive filter is designed for noise removal in ECG with transmission over GSM/PSTN voice channel. In this paper, multistage filtering setup for ECG filtering is also done. The two-stage filter comprises of a band pass better worth filter followed by a custom adaptive filter. The adaptive filter is based on spectral subtraction techniques, so moving noise in the frequency domain. Also, noise is extracted from the filtering process to compute Signal to Noise Ratio (SNR) of raw & filtered ECG signal.

Also, the proposed technique can process the filtered ECG signal to extract P,Q,R,S,T segments of the ECG signal along with the heartbeat computation. Due to unavailability of internet connection GSM/PSTN voice channel is used through which ECG is transmitted.

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