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Removal of Low Frequency Noise from ECG signal using Genetic Algorithm

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***Abstract* - The Electrocardiogram is commonly used technique for non-invasive analysis of the electrical activity of the heart in real-time. Electrocardiographic signals can be degraded by different types of noises like power-line interference, electrode contact, motion artifacts, muscle contraction, baseline drift, instrumental noise and electrosurgical noise. Baseline noise is low frequency signal caused by the loose connection of electrode and skin. Genetic algorithm is applied to remove this type of noise to get better diagnosis of the signal and observe the results in term of mean square error of the error signal for baseline wander noise. In this paper, the comparison of the results obtained from genetic algorithm and the results obtained from the digital FIR filters are done. To validate this method, the recording of signals from MIT-BIH is used. The examining of the purposed algorithm was conducted in MATLAB environment.**

***Index Terms* - ECG, Baseline Wander, Genetic Algorithm, Digital Filters, Mean square error.**

I. INTRODUCTION

The electrocardiogram (ECG) is a recording of the electrical signals that manage the cardiac function. By examining these recorded signals, physicians can observe the rhythmic function of the cardiac system. To record an electrocardiogram (ECG) signal from a patient, a number of electrodes are kept on the chest of the patient. The number of electrodes can vary between two and fourteen depends on which parts of the heart are examined. The ECG estimates the variation in the electrical potential across the electrodes. The recorded potential values are transformed into a waveform after the process of signal filtering and amplification. The frequency of the signal is between 0 - 250 Hz [1].

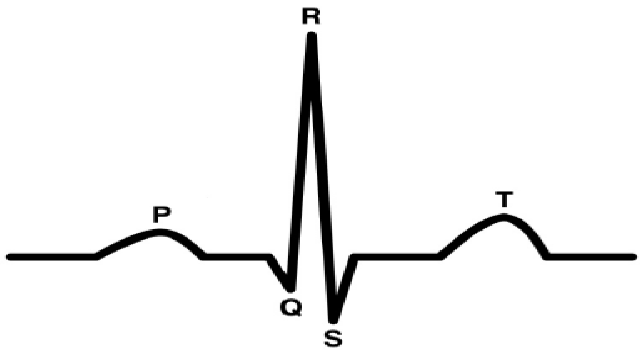

Fig. 1: Basic ECG Signal

A basic wave form of the ECG is of one cardiac cycle as shown in figure 1. It contains a P-wave, QRS-complex and a T-wave [2].The P wave is produced due to the contraction of the artia (depolarization) caused by the propagation of the SA action potential through the artia.The QRS complex represents the period of ventricular contraction or depolarization. The T wave generates from the re-polarization of the ventricles. The duration of the T segment is large as compared to the QRS segment [3].

The ECG signal is degraded due to various noises like power line interference, electrode contract noise, motion artifacts etc. These noises present in the ECG signal leads to wrong diagnosis. These noises change the amplitude or the time duration of the segment and make it difficult task to recognize the true condition of the patient. Therefore, the primary concern is to pre-process the ECG signal before the diagnosis is applied.

Baseline wander is low frequency noise caused in the chest lead ECG signals by breathing, with movements of the chest or when an arm or leg is moved during the ECG data measuring. The loose contact of the electrodes and perspiration of the patient under the electrodes may affect the electrode impedance which produces low frequency artifacts. This type of noise is unwanted and needs to be eliminated before further signal processing, for proper analysis and display of the ECG signal [4] [5].

The noise reduction is an essential factor in the ECG since the signal must be perfectly represented for the further analysis. The type of the filter for the de-noising is depends on the various factors like extraction of type of the waves, time required for the pre-processing, complexity involved, and reconstruction of the signal. Therefore, it is necessary to remove the baseline wandering noise in ECG issue to get better results.

Several methods to avoid the problem of baseline wander noise have been used in the ECG signal. Rinky Lakhwani,Shahanaz Ayub, J.P. Saini presented the design and comparison of digital filters for the removal of baseline wandering from ECG signal and demonstrate that the Kaiser window gives best results[6]. Baby Paul, P. Mythili [7] proposed a technique using GA tuned sign-data least mean square algorithm for ECG noise removal and demonstrate that this technique has reduced the mean-squared error between the primary input, which is a corrupted ECG, and a reference input which may be either noise. The results have explained that the applicable information in the ECG has not been converted by the application of the algorithm. Seema rani, Amanpreet Kaur, J S Ubhi[8] presented the comparisons of digital FIR &IIR filter complexity and their performances to remove baseline noises from the ECG signal and demonstrate that IIR filters can gives better results.

The aim of this paper is to design Genetic algorithm (GA) for the removal of baseline wandering from ECG signal. The comparison is done with digital FIR filters using windows. The electrocardiogram signals are taken from MITBIH database to validate the genetic algorithm [9].

The sections of this paper is organised as follows. The methodology to remove noise is illustrated in Section II. The purposed algorithm is described in Section III. Section IV represents the results. Finally, the conclusions are provided in Section V.

II. METHODOLOGY

A.Digital FIR filter

A digital filter utilizes a digital processor to execute numerical calculations on the sampled values of the signal for filtering. These filters are discrete time systems and are featured by their impulse responses. An impulse response can either have a finite or an infinite time period. A digital filter is featured by its transfer function and its difference equation. The mathematical analysis of the transfer function can explain the response of filter to any input [10] [11]. The transfer function of digital filter can be expressed in the Z-domain and if it is in causal form then is given below:

$$H(z) = \frac{B(Z)}{A(Z)} = \frac{b_0 + b_1 \ldots + b_N z^{-N}}{1 + a_1 z^{-1} \ldots + a_M z^{-M}} \quad \text{....... (1.1)}$$

where the order of the filter is the greater of N or M.

FIR filters are linear discrete time systems in which the obtained output sequence is related to the given input and the impulse response of the filter by the convolution sum:

$$y(n) = \sum_{m=0}^{N} x(m).h(n-m) \quad \text{...... (1.2)}$$

The summation on the right hand side is the convolution between the input sequence i.e. x(n), and the impulse response of the filter i.e. h(n). The frequency response of an N'th order FIR filter is given below:

$$H(w) = \sum_{n=0}^{N-1} h(n).e^{-j.w.n} \quad \text{....... (1.3)}$$

FIR filters can be designed using the windowing method. Windows are performed in order to take finite number of samples in time domain for realizable filter design. We have used only Kaiser window to design the FIR filters used to remove the baseline wander noise from the ECG signal. These window is demonstrated given below:

Kaiser window*:* In a Kaiser window, the side lobe level can be managed with respect to the main lobe peak by varying a parameter β [12]. The width of main lobe can be varied by changing the length of the filter. The Kaiser window function is given below:

$$w(n) = \frac{I_0\left(\beta\sqrt{1-\left(\frac{2n}{M}-1\right)^2}\right)}{I_0 \beta} \quad \text{.........(1.4)}$$

where I_0 is zeroth order modified bessel function of the first kind. The variable parameter α calculates the tradeoff between main lobe width and side lobe levels of the spectral leakage pattern. The main lobe width is given by $2\sqrt{1+\alpha^2}$ in between the nulls, mostly the value of α is 3.

B. ECG Database

The ECG signals are taken from MITBIH Arrhythmia Database to validate the purposed method. The MIT-BIH Arrhythmia Database carries 48 half-hour excerpts of two-channel ambulatory ECG recordings. The recordings were converted into digital version at 360 samples per second per channel with 11-bit resolution over a 10 mV range. Five signals are taken from the recordings to validate the method.

III. PURPOSED ALGORITHM

Genetic algorithms are the general purpose search algorithms that are based on the mechanics of natural selection and genetics. The basic principle is that the fittest member of a population has the highest probability for survival. First of all, the different possible solutions to a given problem are produced. They are tested for their performance, to check how good a solution is in terms of a cost function. A fraction of the good solutions is selected, and the others are removed. Then the selected solutions undergo the processes of reproduction, crossover, and mutation to generate a new generation of possible solutions, which is expected to achieve better than the previous generation. The production and evaluation of new generations is iterated until convergence. This algorithm explores for a solution from a broad spectrum of possible solutions, rather than where the results would generally be expected [13]. The main characteristic of GAs is providing a valid approach to problems that are requiring effective search techniques, especially in large, complex, and unknown search spaces.

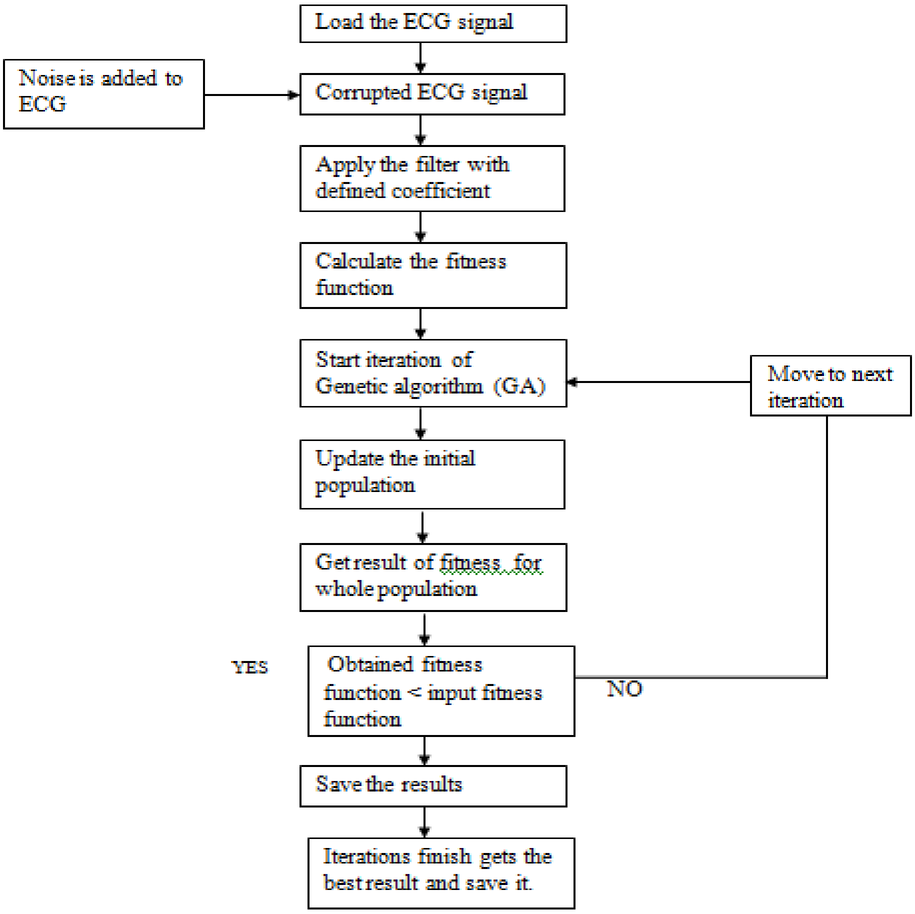

Fig.1. Flow chart for genetic algorithm

Initially load the Electrocardiogram signal, on which the filter is to be applied to reduce the noise. After loading the signal, next step is to add noise to the ECG signal. Now apply the filter with defined coefficient on the signal that is generated after adding the noise. After the filter is applied on the signal, next step is to calculate the fitness value which is dependent on the mean square error of the signal. For reduction of the noise start iteration of Genetic algorithm (GA), as it is the optimization algorithm. After Genetic algorithm is applied, update the initial population of the signal. Next is to calculate the result of mean square error of the whole population as noise is reduced on the basis of the mean square error of the signal. If the new calculated error is greater than the input error, save the results. If the calculated error is less than the input error, then move to the next iteration and update population. After finishing the iteration, get the best result among all the possible cases and then save the best result.

IV. RESULTS

The electrocardiogram signal is taken from the MITBIH database to validate genetic algorithm. In order to get a comparison with results obtained from FIR filters using Kaiser window and purposed algorithm, five records from this database are taken. The original sample of electrocardiogram signal and the signal obtained after applying genetic algorithm is shown in fig. 2.

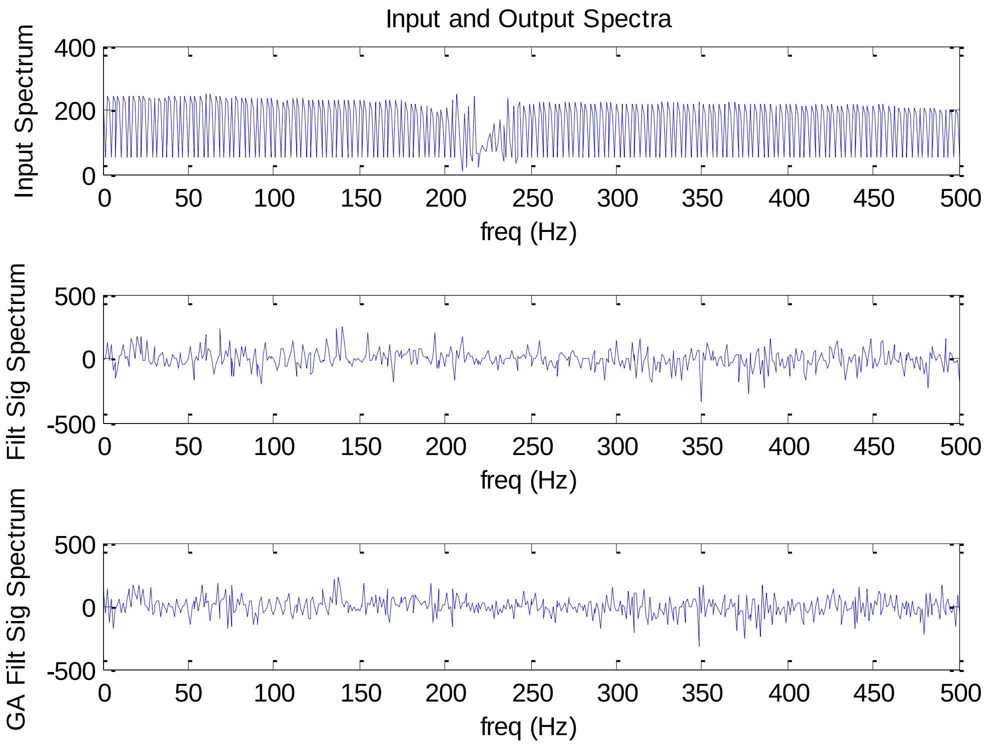

Fig.2. The filtered ECG signal using genetic algorithm of sample 100.

The comparison of the results was done on basis of mean square error obtained with filtration and the genetic algorithm for the ECG signal after removal of baseline wander noise. The results are presented in tabular form:

Table 1. Comparison of Genetic Algorithm and FIR filter on basis of Mean Square Error.

Samples	FIR Filter using Kaiser Window	Genetic Algorithm
100	0.028769	0.00468
101	0.029854	0.0057
102	0.026386	0.00485
103	0.027874	0.00416
104	0.024879	0.00306

V.CONCLUSION

Electrocardiography (ECG) is an essential tool used in locating irregularities which influences the normal functioning of the heart. The various noises change the amplitude or the time duration of the segment and make it difficult task to recognize the true condition of the patient. Therefore, the primary concern is to pre-process the ECG signal before the diagnosis is applied. This paper represents the genetic algorithm to remove the baseline wander noise from electrocardiogram signal. The comparison is done with FIR filter designed with Kaiser Window on the basis of mean square error. The genetic Algorithm gives better results as compared to FIR filter.

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