

Heart beat peak detection using signal filtering in ECG data

J.Rexy^{1*}, P.Velmani² and T.C.Rajakumar³

Research Scholar (RegNo: 11980), Department of Computer Science, Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, Tamilnadu, India¹

Assistant Professor, Department of Computer Science, MDT Hindu College, Tirunelveli, Tamil Nadu, India²

Associate Professor, Department of Computer Science, St. Xavier's College, Palayamkottai, Tamil Nadu, India³

Received: 09-December-2018; Revised: 22-January-2019; Accepted: 25-January-2019

©2019 J.Rexy et al. This is an open access article distributed under the Creative Commons Attribution (CC BY) License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

Current trends in health industry reveal that the major cause for death ratio increase is due to heart disease. Malfunctioning of heart leads to heart disease and there are multiple forms of heart disease. Electrocardiogram (ECG) is painless and basic test which can detect basic heart related problems. Heart beat variations can be identified by detecting heart beat peaks. Heart beat peak detection plays a vital role for efficient analysis of ECG signals. This paper deals with detecting heart beat peaks in noisy ECG signals which will be helpful to extract required features, to detect heart disease in earlier stage. ECG Signals are taken as primary input to detect the heartbeat peaks for feature extraction purpose. As the noisy ECG signal is normal due to distortion of the original ECG signal because of the various levels of noises, filtering the noisy ECG signal is necessary to detect the heartbeat peaks. Existing digital IIR filters such as Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic are commonly used for denoising ECG signals to retrieve sharp ECG signal waves. This paper is an attempt to apply the existing methodologies to Massachusetts Institute of Technology-Beth Israel Hospital (MIT-BIH) noise, stress test database ECG signals and perform a quantitative study based on the performance metrics such as specificity, sensitivity, accuracy, mean square error and signal to noise ratio. Both Chebyshev Type II and Elliptic filters reflected poor performance over this dataset. Hence this paper proposes a novel hybrid methodology called ButterChev which is a combined version of Butterworth and Chebyshev Type I filters. The proposed methodology resulted with improved performance metrics and it paves the way for better noise removal and peak detection for the given noisy ECG signal. The implementation process has been carried out using Matlab software environment.

Keywords

ECG signal, Butterworth, Chebyshev Type I, Chebyshev Type II, Elliptic, ButterChev.

1.Introduction

The human heart is the muscular organ that pumps the blood through the circulatory system and paves way for a human to be alive. Human being loss their life if the heart malfunctions. Nowadays the death ratio of human being has been increased due to heart disease. Heart disease is the leading cause of many human deaths. The physical interpretation of the electrical behaviour throughout the cardiac cycle is recorded as electrocardiogram (ECG). ECG is used to measure the rate and rhythm of heartbeats which is the base to identify the heart beat disorders. ECG leads to monitor the heartbeat status and makes way for earlier detection of heart problems. ECG signal is a graphical representation or cardiac activity which helps to identify cardiac diseases [1].

ECG signal is composed of different waves, segments and few intervals. Waves in the basic ECG signal are labelled as P, Q, R, S and T. Patterns of P-QRS-T waves and time intervals between various peaks helps to extract useful information about heart disease. Parameters such as QRS complex, P and T waves, QRS-Q wave, R wave and S wave play a vital role to analyze the ECG Signal [2]. The electrode skin impedance may change due to human stress, movement, ECG machine cable dislocation, machine problem and misplacement of leads, this change leads to noisy signal which may be problematic for computer analysis and troublesome for interpretation for a cardiologist. Hence the ECG signal must be filtered before detecting the heart beat peak and for further processing. ECG signal noise is generated under different intensity levels, such as baseline wanders power line Interference and ECG noise.

*Author for correspondence

Baseline wander falls under low frequency range and power line interference in the medium frequency range and electromyography in high frequency range. Such noises are removed with the help of filters. Filters play a vital role in reducing the noise from the ECG input signal which leads to the extraction of the desired information from the signal [3].

ECG filtering is done using the following folds, they are high pass, low pass, band pass, band stop and all pass filter. Low pass filter allows only low frequency up to the cutoff frequency to pass through, high pass filter allows the higher frequency to pass through and band pass filter allows frequencies between lower and higher cutoff frequencies to pass through. Band stop filter attenuates the frequencies between low and high frequency and all pass filter passes all the frequencies of equal gain. Filters are categorized into analog and digital filters. Digital filters are again divided into finite impulse response (FIR) and infinite impulse response (IIR) Filters. IIR filter overcomes FIR filter as it works faster than IIR and requires less memory space than FIR filters. IIR filter is a recursive filter where the current output in its structure is related to the previous input and previous output and it is based on a single linear filter. IIR digital filters are recursive, feedback type systems that involve fewer design parameters, less memory requirements, and lower computational complexity than FIR digital filters [4]. Designing IIR filters requires fewer constraints and hence flexible for designing and implementation [5]. IIR filters require less parameters which leads to less complexity and it is more susceptible to noise and the time delay is less compared to FIR filters. The digital IIR filter is designed from the analog filter, preferably by bilinear transformation [6]. IIR filters are digital filters with unlimited impulse retort. Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic are popular IIR filters which are used to transform noisy ECG signals [7]. Each filter has their own unique characteristics and they are being used in different applications as needed. Performance metrics are employed to serve as an evaluator for best methodology selection and innovation of new methodology [8]. Performance metrics such as accuracy, signal to noise ratio (SNR), mean square error (MSE), specificity and sensitivity are calculated from measuring the performance of the existing and proposed methodology.

Accuracy metrics measure the ratio of correct predictions over the total number of instances evaluated.

$$\text{Accuracy} = \frac{(\text{True Positive} + \text{True Negative})}{(\text{True Positive} + \text{False Positive} + \text{True Negative} + \text{False Negative})} \quad (1)$$

Sensitivity measures the fraction of positive patterns that are correctly classified.

$$\text{Sensitivity} = \frac{(\text{True Positive})}{(\text{True Positive} + \text{False Negative})} \quad (2)$$

Specificity measures the fraction of negative patterns that are correctly classified.

$$\text{Specificity} = \frac{(\text{True Negative})}{(\text{True Positive} + \text{False Positive})} \quad (3)$$

Mean square error measures the difference between the predicted solutions and desired solutions.

$$\text{MSE} = \sum_{i=1}^N ((x(i) - d(i)))^2 \quad (4)$$

Here N is the total number of samples in given signal, x (i) is the original signal and d (i) is de-noised signal.

Signal to noise ratio is the ratio of signal power to the noise power.

$$\text{SNR} = 10 \log_{10} \frac{p_{\text{signal}}}{p_{\text{noise}}} \quad (5)$$

To improve the performance of the existing filtering methodologies this paper proposes an innovative hybrid filter called ButterChev for identifying the heart beat peaks efficiently.

2.Existing methodology

2.1Related works

Kim et al. [9] proposed a new method for implementing low order Chebyshev Type II, IIR Low pass filter to remove baseline wander in ECG signal in semi real time. Den trending fluctuation analysis is used to remove baseline draft in the ECG signal.

Cuomo et al. [10] proposed an IIR noise reducing algorithm by applying novel numerical scheme and it is based on analysis of the signal in the Fourier domain without the direct application of fast Fourier transforms.

Singh et al. [11] applied an IIR Butterworth filter to remove high power noise in the ECG. It is also stated that IIR Butterworth low pass filter offer better result of what IIR filter has to offer and the result shows that the power of filter signal is less as compared to power of noisy signal.

Li et al. [12] proposed an improved integer coefficient IIR filter and compared it with direct methods of integer coefficient. It has been proved that the low pass filter and high pass filter designed by IIR can not only eliminate power frequency interference but also baseline drift.

Gaikwad and Chavan [13] deals with removing noise in ECG signal with the help of the low pass Butterworth filter of cutoff frequency 100 Hz. The result reflects noise removal of about -18dB.

Amiri et al. [14] used discrete Fourier transform based, IIR, FIR, Kalman wavelet and higher order statistics filter to remove power line noise in ECG signal. SNR performance is calculated and stated that FIR and IIR filtering has higher SNR improvement.

Bhogeshwar et al. [15] explored various FIR and IIR filters such as Butterworth Chebyshev Type I, Chebyshev Type II and Elliptic Filtering to remove noise in ECG Signal. It is stated that IIR Elliptic Filter has improved SNR performance when applied to MIT-BIH ECG database ECG signals.

Dhar et al. [16] applied a Butterworth low pass filter to remove high frequency noises whose order have been selected on experimental basis. The filtered signal is then compressed by applying a strict lossless technique to reduce the ECG file size.

Das and Chakraborty [17] attempted to apply FIR and FIR filters to filter ECG signals. Among IIR Filters the result revealed that Chebyshev Type I and Elliptic Filter have the highest SNR values when the filter ranges of 2 to 4. When the filter order is between 12 and 14, the SNR value for Chebyshev Type II is high. It has been found that the SNR variations in the filter order leads to selecting the right filter for ECG filtering.

Muppalla et al. [18] evaluated Chebyshev Type I and Chebyshev Type I and the result obtained has represented that Chebyshev Type I filter outperformed better than Chebyshev Type II based on SNR, PSNR, MSE, and RMSE performance metrics.

Kumar et al. [19] utilized Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic filters reduce noise in ECG signal. Based on SNR and MSE Butterworth filter outperformed than other IIR filters.

Bhateja et al. [20] used an IIR Butterworth filter to remove power line interference and proposed an approach for decomposition of ECG signal in the sub-bands through morphology. It is also specified that Butterworth Filter was useful in suppression of power line interference.

Sandhu et al. [21] mathematically compared Butterworth, Chebyshev Type I, Chebyshev Type II and elliptic filters for speech signal and concluded that Butterworth filter is the best filter Bindu [22] used Butterworth, Chebychev Type I, Chebychev Type II, IIR Notch and elliptical filter filters in the proposed technique. Performance measures such as MSE, SNR, cross correlation and PSNR was performed and found that denoising worked well in the frequency domain rather than the time domain.

Alan et al. [23] proposed a technique of merging wavelet transform with genetic algorithm for better noise removal performance. Ten records from the MIT-BIH Arrhythmia Database have been used as the input ECG signals.

Saini et al. [24] attempted to remove the electromyography noise by designing low pass filter using IIR filters such as Butterworth, Elliptic and Chebyshev filter. FIR digital filters are also utilized. Elliptic IIR filter and Blackman window of FIR filter showed better results in SNR and Power spectral density performance parameters. Hence a cascaded filter of high-performance FIR and IIR was designed to remove different noises from ECG signals.

Latif et al. [25] proposed a cascaded version of adaptive dual threshold filter (ADTF) and discrete wavelet transform (DWT). An adaptive algorithm that permits to extract the fuzzy representation of the electrocardiogram ECG signal is proposed.

Shivani et al. [26] performed a survey related to ECG denoising and found that the wavelet technique can be used when the signal beat to beat variation is high. It is also represented that empirical mode decomposition method can be used to remove high frequency noise and adaptive filtering has been found to be best suited for removing power line interference noise.

Rishabhkumar and Parashar [27] implemented basic functions of IIR filters in the python language. The performance of Butterworth, and Chebyshev-I filters are compared. It is concluded that using an IIR filter is better than FIR filters and it has been stated that Chebyshev Type I has high performance.

2.2 Existing signal filtering methodologies

2.2.1 Butterworth filter

Butterworth filter has a property of the maximally flat response and no ripples in the pass band [28, 29].

Lowpass Butterworth filter magnitude response is presented by

$$|H(\omega)|^2 = \frac{1}{1 + \left(\frac{\omega}{\omega_c}\right)^{2N}} \quad (6)$$

Attenuation

$$A = -10 \log\left(1 + \left(\frac{\omega}{\omega_c}\right)^{2N}\right) \quad (7)$$

Where, ω_c is the cutoff frequency of 3 dB and N = Filter order

2.2.2 Chebyshev type I filter

Chebyshev Type I filter magnitude response is equiripple in the passband and monotonic in the stop band. The amplitude or the gain response is an angular frequency function of the nth order of the LPF (low pass filter) is equal to the total value of the transfer function $H_n(j\omega)$.

$$G_n(\omega) = |H_n(j\omega)| = 1 / \sqrt{1 + \epsilon^2 T_n^2(\omega/\omega_0)} \quad (8)$$

Where, ϵ is the ripple factor, ω_0 is the cutoff frequency and T_n is the polynomial of the nth order [30]

2.2.3 Chebyshev type II filter

Chebyshev Type II has no ripple in the passband, but does have equiripple in the stopband. Inverse Chebyshev filters are also called Type II Chebyshev filter [31, 32]. The gain is

$$G_n(\omega, \omega_0) = \frac{1}{\sqrt{1 + \frac{1}{\epsilon^2 T_n^2(\omega_0/\omega)}}} \quad (9)$$

2.2.4 Elliptic filter

Elliptic filter or Cauer filter exhibit equiripple behaviour in the pass band as well as in the stop band [33]. The magnitude squared frequency response of the normalized low-pass elliptic filter of order n is defined by

$$|H_n(j\omega)|^2 = \frac{1}{1 + \epsilon^2 R_n^2(\omega)} \quad (10)$$

Here $R_n(\omega)$ is a Chebyshev rational function of ω which is determined from specified ripple characteristics.

3. Proposed methodology

Existing filtering techniques such as Butterworth, Chebyshev I, Chebyshev II and Elliptic are applied to MIT-BIH Noise stress test Database ECG noisy signals. Based on this ECG data Butterworth and Chebyshev Type I performance metrics was better compared to Chebyshev Type II and Elliptic filters. To improve the performance for better denoising and peak detection of ECG signal, the lower and upper level boundary values of Butterworth and Chebyshev Type I are concatenated. Figure 1 represents the architectural diagram of the proposed methodology. Noisy ECG Signal is retrieved as input and the signal is filtered using Butterworth and Chebyshev Type I

filters. The upper and lower boundary of both the filters are calculated and concatenated to identify the heart beat peaks.

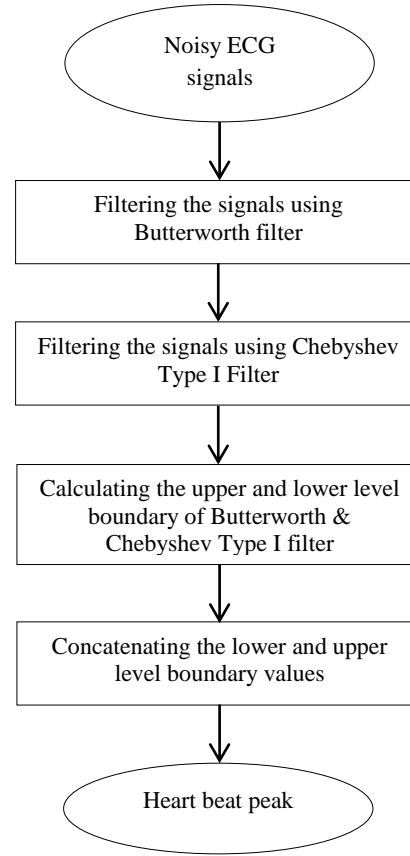


Figure 1 Proposed architectural diagram

3.1 Pseudo code for the proposed ButterChev Methodology

Input: ECG Signal:

Output: Heart beat peak detection

Step 1: Denoising the noisy ECG signal using Butterworth filter and assigning it in an array of values called x.

Step 2: Denoising noisy ECG signal using Chebyshev Type I and assigning it in an array of values called y.

Step 3: Calculate the upper level boundary of x1, y1 values in x and y.

Step 4: Calculate the lower level boundary of x2, y2 values in x and y.

Step 5: Concatenate the lower and upper level boundary values and assign it into an array of values called z.

Step 6: Find the peak values. [If z>0 assign 1 else assign 0]

Step 7: Identify the heart beat signal peak.

4.Result and discussion

Noisy raw ECG input signal has been given as input signal. The raw ECG input signals are retrieved from the MIT-BIH noise stress test database. This database includes 12 half-hour ECG recordings and 3 half-hour recordings of noise typical in ambulatory ECG recordings. In this database the noise recordings were made using physically active volunteers and standard ECG recorders. The ECG recordings were created using two clean recordings (118 and 119) from the MIT-BIH Arrhythmia database, to which calibrated amounts of noises were added. The signal level has been divided into initial level, middle level and end level for better analysis process. Sample signals and noise levels were also considered for analysis purpose. Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic denoising methodology are applied to de-noise the input signal. To analyse the signal level performance the signal is divided into initial level, middle level and end level. It is found that Chebyshev Type II and Elliptic filtering performance are poor with high MSE and low accuracy, sensitivity, SNR and accuracy. Hence Butterworth and Chebyshev Type I are considered and found it is better choice for filtering.

To improve the performance to a better level, both Butterworth and Chebyshev Type I are combined. The upper level boundary and lower level boundary are calculated and concatenated for better performance. Performance metrics such as SNR, MSE, specificity, sensitivity and accuracy are measured for both existing and proposed methodology. *Table 1, Table 2, Table 3 and Table 4* depict signal level performance metrics and it shows that the proposed method has high accuracy, specificity, sensitivity, and SNR performance. *Table 5* depicts that the MSE is less for the proposed methodology than the existing methodologies.

A sample of seven signals S1, S2, S3, S4, S5, S6 and S7 are taken and analysed. *Table 6, Table 7, Table 8, Table 9 and Table 10* depicts signal wise performance metrics for Butterworth (B), Chebyshev Type I (CI), Chebyshev Type II (CII) and Elliptic (E) filters and it shows that the proposed method has high accuracy, specificity, sensitivity, SNR performance and low MSE for all the sample signals.

Table 1 Accuracy based on signal level

Algorithms	Initial level	Mid-level	End level
ButterWorth	88.21	86.60	94.28
Chebyshev-I	84.99	75.18	92.30
Chebyshev-II	45.46	44.48	46.57
Elliptic	43.86	45.15	49.51
Proposed	89.67	87.62	95.28

Table 2 Specificity based on signal level

Algorithms	Initial level	Mid-level	End level
ButterWorth	80.54	91.42	91.71
Chebyshev-I	79.40	90.52	90.24
Chebyshev-II	70.34	92.58	71.32
Elliptic	56.03	77.50	54.61
Proposed	83.88	92.42	93.11

Table 3 Sensitivity based on signal level

Algorithms	Initial level	Mid-level	End level
ButterWorth	96.23	88.36	97.08
Chebyshev-I	92.78	70.66	95.54
Chebyshev-II	13.80	13.63	12.48
Elliptic	26.41	27.13	38.01
Proposed	99.00	89.92	99.00

Table 4 SNR based on signal level

Algorithms	Initial level	Mid-level	End level
ButterWorth	0.71	-0.04	0.32
Chebyshev-I	0.78	-0.05	0.42
Chebyshev-II	-2.90	-3.70	-3.10
Elliptic	-1.38	-0.26	-0.83

Algorithms	Initial level	Mid-level	End level
Proposed	1.01	0.08	0.52

Table 5 MSE based on signal level

Algorithms	Initial level	Mid-level	End level
ButterWorth	0.71	-0.04	0.32
Chebyshev-I	0.78	-0.05	0.42
Chebyshev-II	-2.90	-3.70	-3.10
Elliptic	-1.38	-0.26	-0.83
Proposed	1.01	0.08	0.52

Table 6 Signal wise accuracy

Signal	B	CI	CII	E	Proposed
S1	90.36	87.79	39.18	43.30	91.45
S2	89.85	78.94	38.03	42.05	90.80
S3	89.32	69.00	41.40	42.00	89.62
S4	86.92	85.85	58.25	48.06	88.19
S5	63.99	63.27	43.55	34.88	65.56
S6	70.30	64.40	53.17	50.74	71.75
S7	81.69	79.01	42.93	49.51	84.85

Table 7 Signal wise specificity

Signal	B	CI	CII	E	Proposed
S1	95.69	92.77	83.39	59.04	96.10
S2	94.69	92.36	88.79	66.87	95.01
S3	92.90	92.35	90.03	88.22	93.69
S4	80.17	80.39	76.21	50.05	83.30
S5	73.19	71.86	93.70	64.72	73.72
S6	44.42	47.47	79.84	43.56	53.49
S7	64.91	64.44	70.18	27.15	66.59

Table 8 Signal wise sensitivity

Signal	B	CI	CII	E	Proposed
S1	88.83	86.87	14.42	39.60	91.32
S2	88.63	71.08	8.18	31.97	90.89
S3	89.31	59.53	9.58	13.12	90.91
S4	97.85	96.82	26.09	46.51	100.00
S5	72.56	72.35	32.97	49.63	79.46
S6	86.77	81.08	26.89	61.58	100.00
S7	96.03	93.07	14.04	72.23	100.00

Table 9 Signal wise SNR

Sig	B	CI	CII	E	P
S1	-0.405	-0.379	-3.325	-0.429	-0.281
S2	-0.366	-0.383	-4.085	0.358	-0.262
S3	-0.231	0.017	-3.777	-2.578	-0.124
S4	1.173	1.340	-1.390	0.680	1.441
S5	0.723	0.837	-1.589	-2.369	0.880
S6	1.325	1.368	-3.327	0.128	1.990
S7	1.127	1.314	-3.351	1.376	1.321

Table 10 Signal wise MSE

Signal	B	CI	CII	E	Proposed
S1	0.096	0.122	0.608	0.567	0.086
S2	0.101	0.211	0.620	0.580	0.092
S3	0.107	0.310	0.586	0.580	0.104
S4	0.131	0.141	0.417	0.519	0.118

Signal	B	CI	CII	E	Proposed
S5	0.360	0.367	0.564	0.651	0.344
S6	0.297	0.356	0.468	0.493	0.282
S7	0.183	0.210	0.571	0.505	0.151

The performance in view of noise level i.e. signals type is also analysed. Noise level-6, noise level 00, noise level 06 and noise levels 12 are taken into account in evaluating the performance metrics for the existing and proposed filtering techniques. *Table 11*, *Table 12*, *Table 13*, *Table 14* and *Table 15* depict performance metrics of the existing and proposed methodology. Proposed methodology results in high accuracy, specificity, sensitivity and SNR and low MSE. *Table 16* represents the overall performance of the existing and proposed filtering methodology.

Sensitivity, specificity, accuracy and SNR for the proposed methodology are 93.22%, 80.28%, 83.17% and 0.71% reflects that the proposed methodology has improved peak detection. The MSE for the proposed methodology has been reduced to 0.168 which is less compared to the existing methodologies. Hence the proposed ButterChev filtering methodology well suited for filtering and efficient heart beat peak detection. *Figure 2* depicts the view of a given raw ECG signal and the corresponding filtered signal with peak detection.

Table 11 Accuracy based on noise level

Signal type	B	CI	CII	E	Proposed
Noise Level -6	92.41	89.25	38.66	41.83	93.75
Noise Level 00	90.05	78.74	45.94	44.79	90.58
Noise Level 06	84.56	83.88	57.96	52.44	86.34
Noise Level 12	91.77	84.76	39.44	45.64	92.76

Table 12 Specificity based on noise level

Signal type	B	CI	CII	E	Proposed
Noise Level -6	93.92	90.87	73.08	45.49	94.68
Noise Level 00	88.37	87.68	84.18	79.28	90.23
Noise Level 06	77.14	78.15	77.49	67.44	80.86
Noise Level 12	92.15	90.19	77.57	58.64	93.44

Table 13 Sensitivity based on noise level

Signal type	B	CI	CII	E	Proposed
Noise Level -6	92.24	89.65	13.51	45.41	95.66
Noise Level 00	93.30	77.55	11.62	15.41	95.46
Noise Level 06	97.75	95.91	17.69	21.80	100.00
Noise Level 12	92.28	82.20	10.39	39.44	95.44

Table 14 SNR based on noise level

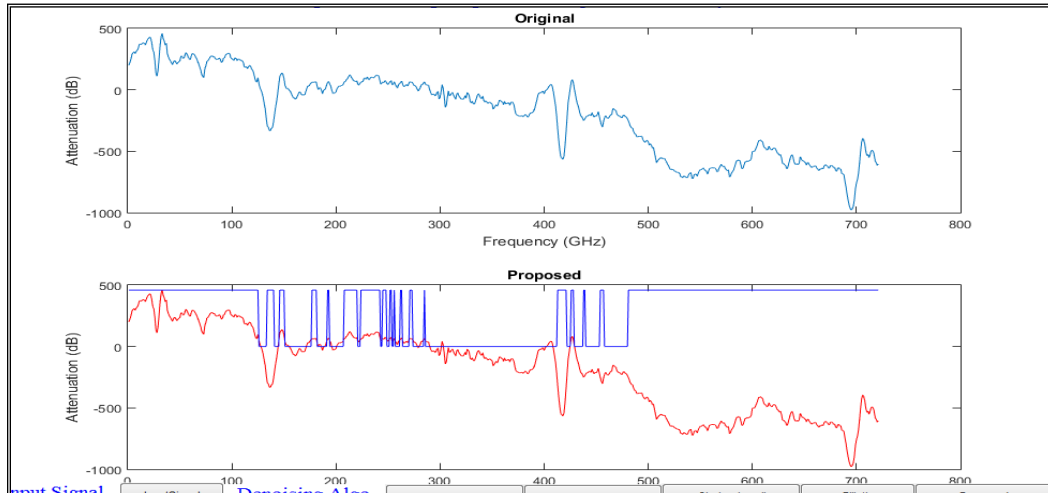
Signal type	B	CI	CII	E	Proposed
Noise Level -6	-0.15	-0.11	-3.18	-0.31	0.03
Noise Level 00	0.17	0.24	-3.78	-2.58	0.34
Noise Level 06	1.38	1.51	-1.90	-0.75	1.69
Noise Level 12	-0.08	-0.09	-4.09	0.36	0.09

Table 15 MSE based on noise level

Signal type	B	CI	CII	E	Proposed
Noise Level -6	0.08	0.11	0.61	0.58	0.06
Noise Level 00	0.10	0.21	0.54	0.55	0.09
Noise Level 06	0.15	0.16	0.42	0.48	0.14
Noise Level 12	0.08	0.15	0.61	0.54	0.07

Table 16 MSE based on noise level

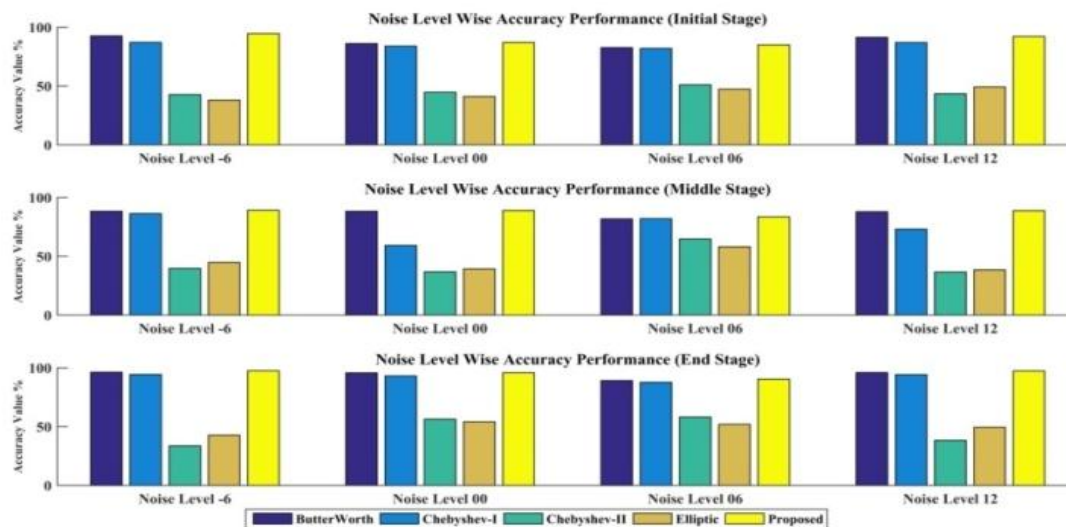
Algorithm	Sensitivity	Specificity	Accuracy	MSE	SNR
ButterWorth	88.57	77.99	81.77	0.182	0.48
Chebyshev-I	80.11	77.38	75.47	0.245	0.59
Chebyshev-II	18.88	83.16	45.21	0.548	-2.98
Elliptic	44.95	57.09	44.36	0.556	-0.40
Proposed	93.22	80.28	83.17	0.168	0.71

**Figure 2** Original and filtered signal with peak detection

5. Performance evaluation

Noise level, ECG records in the MIT-BIH noise, stress level database such as 118e-6, 118e00, 118e06, 118e12, 119e-6, 119e00, 119e06 and 119e12 are taken into account and performance metrics was calculated to analyze the performance in noise level. The signal range has also been divided into three ranges such as initial, middle and end for the better

performance measure. Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 depict the accuracy, specificity, sensitivity, SNR and MSE performance in Initial, middle and end range which shows that the proposed filtering methodology excels than existing Butterworth, Chebyshev I, Chebyshev II and Elliptic methodology.

**Figure 3** Noise level wise accuracy performance

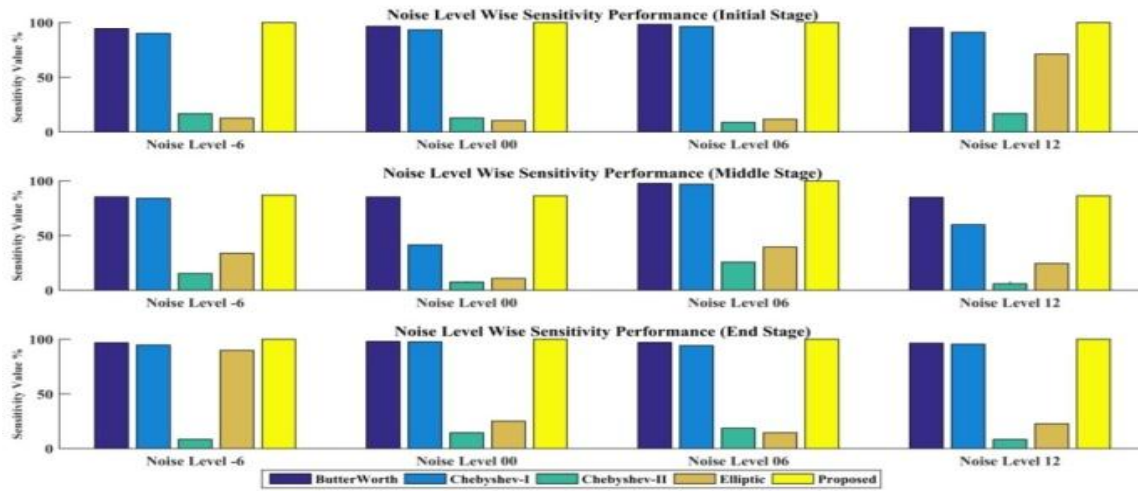


Figure 4 Noise level wise sensitivity performances

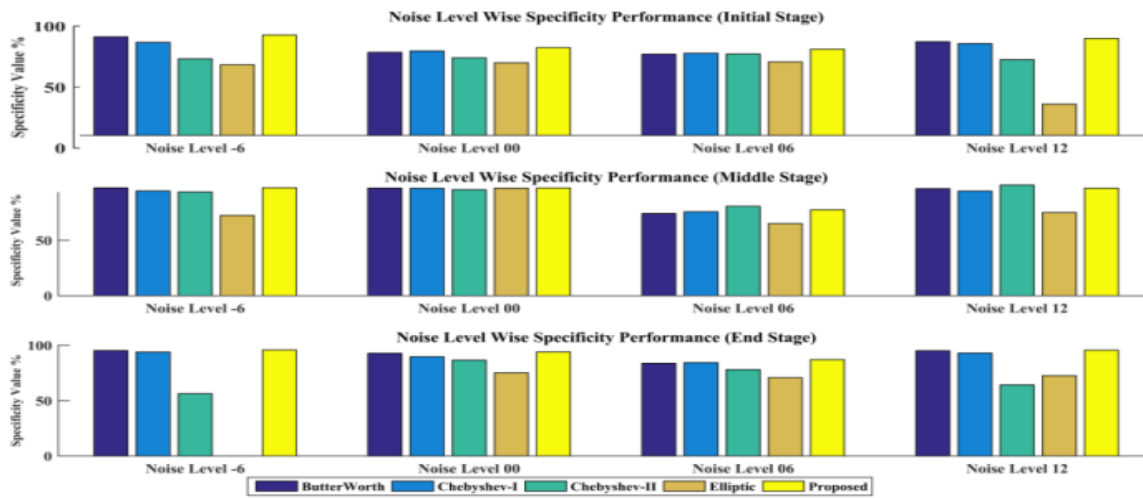


Figure 5 Noise level wise specificity performance

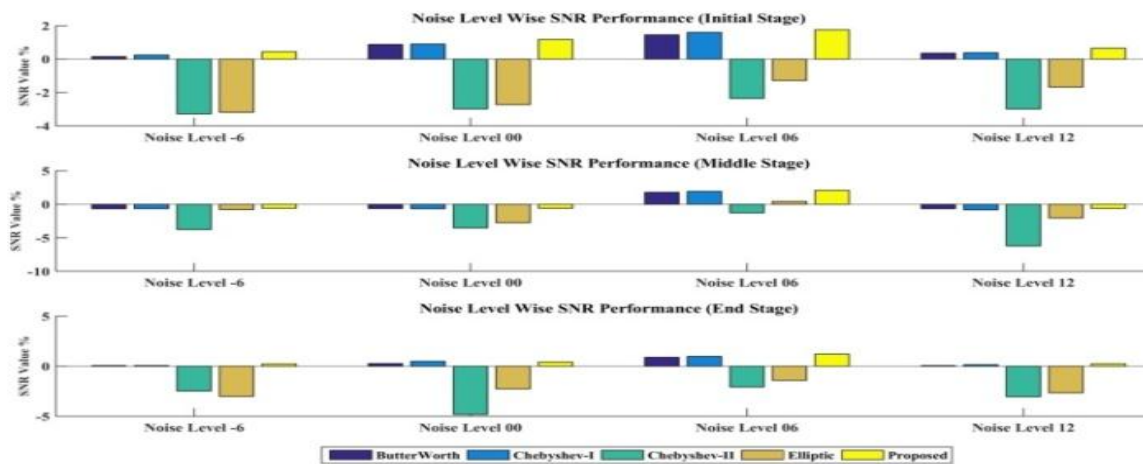


Figure 6 Noise level wise SNR performances

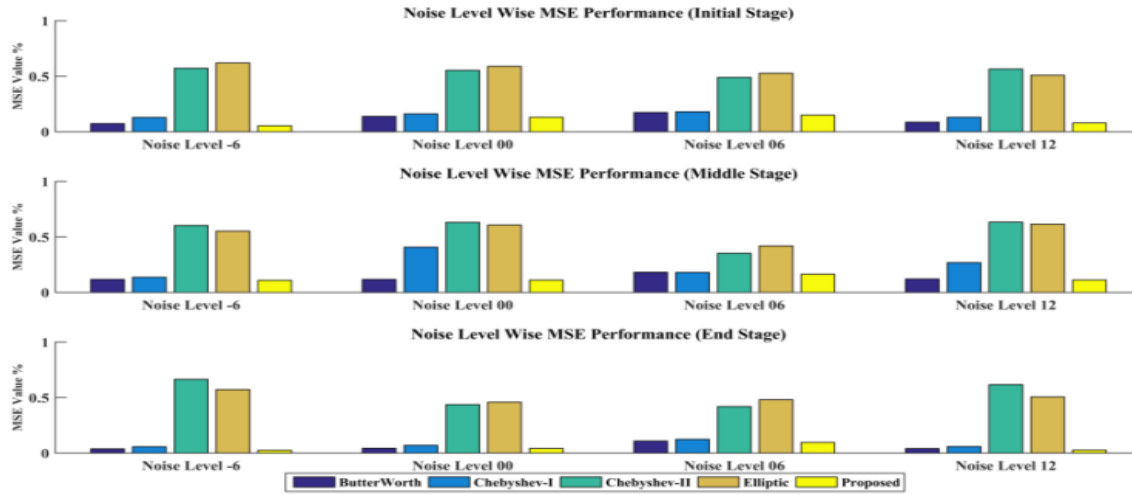


Figure 7 Noise level wise MSE performances

Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12 represent the signal wise accuracy, specificity, sensitivity, SNR and MSE performance metrics. The

proposed method shows the improved version of the existing methodologies.

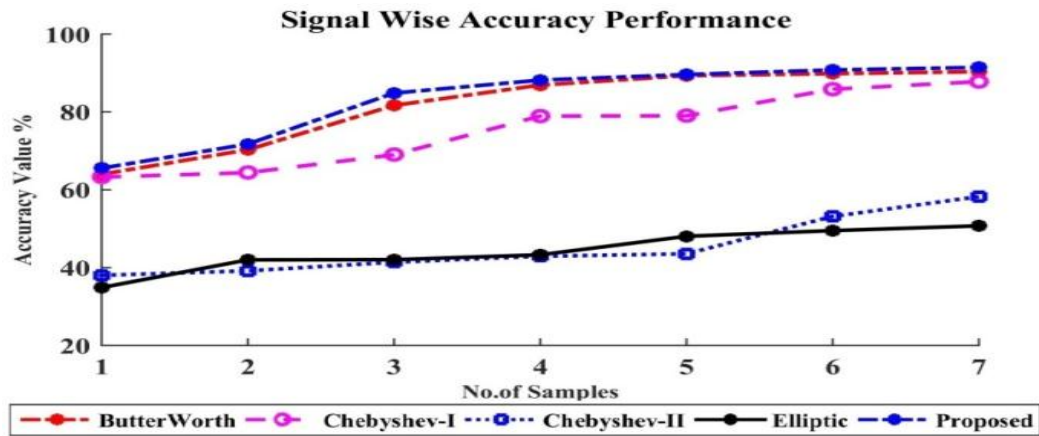


Figure 8 Signal wise accuracy performances

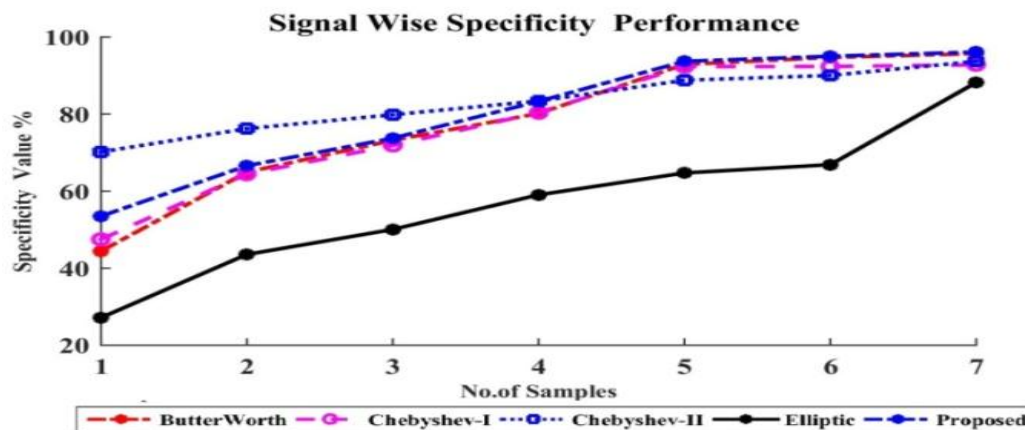


Figure 9 Signal wise Specificity performances

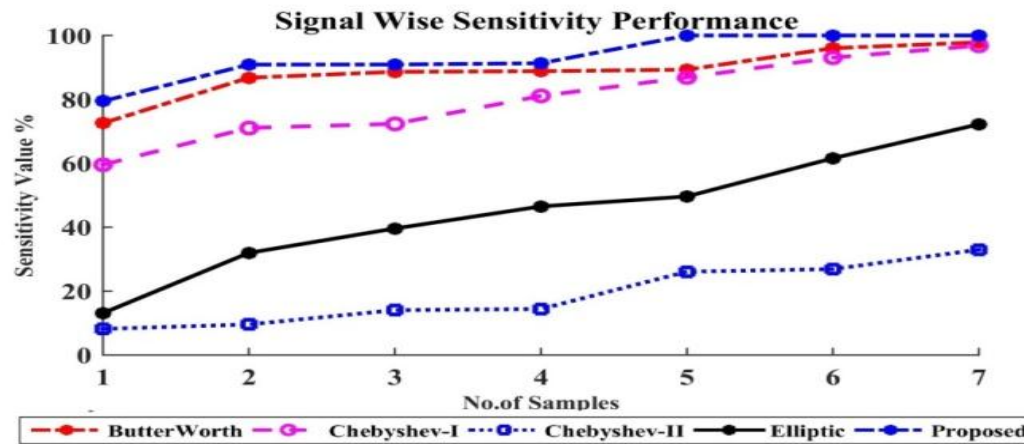


Figure 10 Signal wise Sensitivity performances

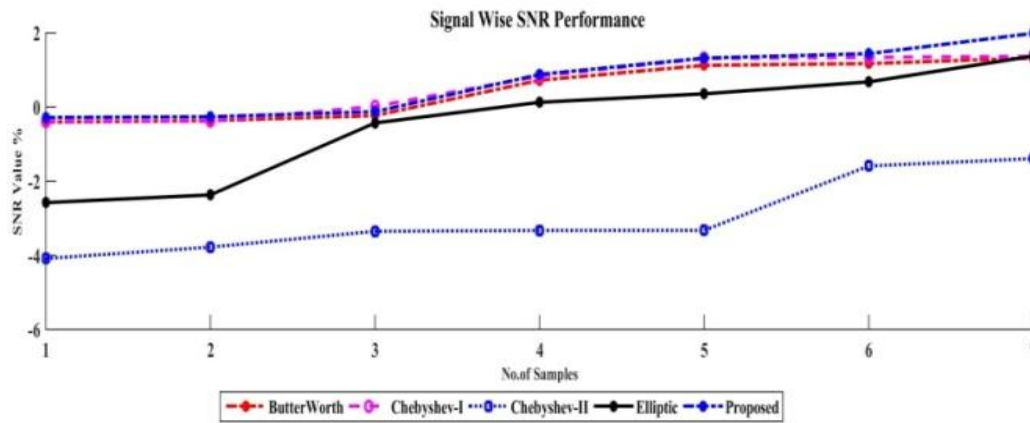


Figure 11 Signal wise SNR performances

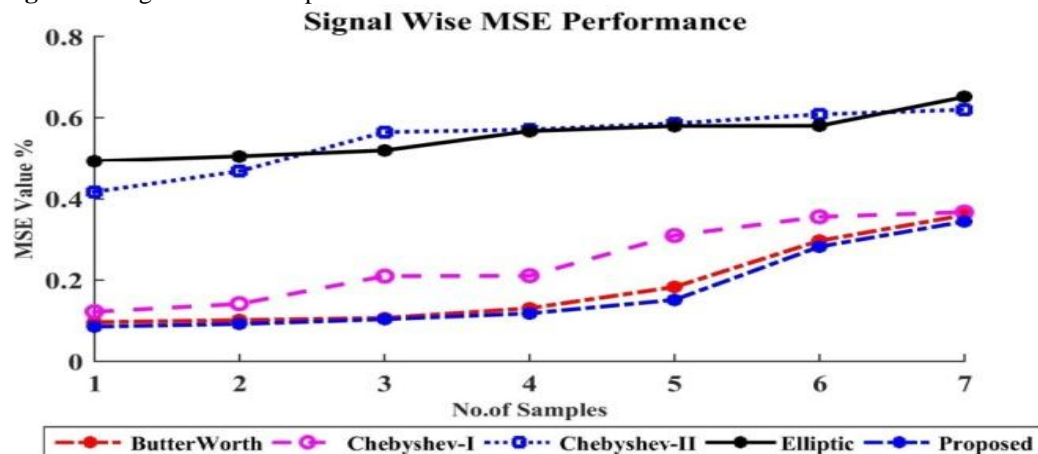


Figure 12 Signal wise MSE performances

6. Conclusion and future work

The paper presents the importance of ECG Signal to predict heart disease in the early stage. This paper focuses on detecting the peaks for feature extraction by filtering the raw input ECG Signal. It focuses on

IIR filters as it had been well suited for various applications and also faster than FIR filters. Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic filters are compared and found that Butterworth and Chebyshev Type I well suits this

ECG signal processing application. To improve the filtering performance for accurate peak detection Butterworth and Chebyshev Type I are combined with boundary levels and filtered. This combined filtering process leads to better peak detection than individual application. The sensitivity, specificity, accuracy and SNR obtained by the proposed method are 93.22%, 80.28%, 83.17% and 0.71%, which is better when compared to Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic individually. The MSE of the proposed methodology is 0.168 which is less when compared to Butterworth, Chebyshev Type I, Chebyshev Type II and Elliptic individually. Hence the proposed method leads to efficient peak detection of the given ECG Signal. Further, this peak detection can be extended to extract required features for heart disease detection.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

References

- [1] Chandrakar B, Yadav OP, Chandra VK. A survey of noise removal techniques for ECG signals. *International Journal of Advanced Research in Computer and Communication Engineering*. 2013; 2(3):1354-7.
- [2] Peterkova A, Stremy M. The raw ECG signal processing and the detection of QRS complex. *European modelling symposium 2015* (pp.80-5). IEEE.
- [3] Magsi H, Sodhro AH, Chachar FA, Abro SA. Analysis of signal noise reduction by using filters. In *international conference on computing, mathematics and engineering technologies 2018* (pp. 1-6). IEEE.
- [4] Singh T, Jain A, Chourasia B. Study and performance analysis of IIR filter for noise diminution in digital signal using MATLAB. *International Journal of Computer Science and Mobile Computing*. 2017; 6(4):111-7.
- [5] Acharya A, Lambe RM, Zodge S, Chaudhari J. Implementation of digital filters for ECG analysis. *International Journal of Computer Science and Information Technologies*. 2014; 5(1):181-3.
- [6] Pal R. Comparison of the design of FIR and IIR filters for a given specification and removal of phase distortion from IIR filters. In *international conference on advances in computing, communication and control 2017* (pp. 1-3). IEEE.
- [7] Prabhakar S, Sappal AS. Transition bandwidth analysis of infinite impulse response filters. *International Journal of Computer Science & Engineering Technology*. 2013; 4(8):1165-70.
- [8] Hossin M, Sulaiman MN. A review on evaluation metrics for data classification evaluations. *International Journal of Data Mining & Knowledge Management Process*. 2015; 5(2):1-11.
- [9] Kim JH, Lee KH, Lee JW, Kim KS. Semi-real-time removal of baseline fluctuations in electrocardiogram (ECG) signals by an infinite impulse response low-pass filter (IIR-LPF). *The Journal of Supercomputing*. 2018; 74(12):6785-93.
- [10] Cuomo S, De Pietro G, Farina R, Galletti A, Sannino G. A novel O (n) numerical scheme for ECG signal denoising. *Procedia Computer Science*. 2015; 51:775-84.
- [11] Singh N, Ayub S, Saini JP. Design of digital IIR filter for noise reduction in ECG signal. In *international conference and computational intelligence and communication networks 2013* (pp. 171-6). IEEE.
- [12] Li J, Deng G, Wei W, Wang H, Ming Z. Design of a real-time ECG filter for portable mobile medical systems. *IEEE Access*. 2017; 5:696-704.
- [13] Gaikwad KM, Chavan MS. Removal of high frequency noise from ECG signal using digital IIR butterworth filter. In *IEEE global conference on wireless computing & networking 2014* (pp. 121-4). IEEE.
- [14] Amiri M, Afzali M, Vahdat BV. Comparison of different electrocardiogram signal power line denoising methods based on SNR improvement. In *Iranian conference of biomedical engineering 2012* (pp. 159-62). IEEE.
- [15] Bhogeshwar SS, Soni MK, Bansal D. Design of simulink model to denoise ECG signal using various IIR & FIR filters. In *international conference on reliability optimization and information technology 2014* (pp. 477-83). IEEE.
- [16] Dhar S, Mukhopadhyay SK, Mitra S, Baig MM, Mitra M. Noise reduction and lossless ECG encoding. In *proceedings of the international conference on control, instrumentation, energy and communication 2014* (pp. 210-3). IEEE.
- [17] Das N, Chakraborty M. Performance analysis of FIR and IIR filters for ECG signal denoising based on SNR. In *international conference on research in computational intelligence and communication networks 2017* (pp. 90-7). IEEE.
- [18] Muppalla V, Suraj NS, Reddy VY, Suman D. Performance evaluation of different denoising techniques for physiological signals. In *India council international conference 2017* (pp. 1-6). IEEE.
- [19] Kumar KS, Yazdanpanah B, Kumar PR. Removal of noise from electrocardiogram using digital FIR and IIR filters with various methods. In *international conference on communications and signal processing 2015* (pp. 157-62). IEEE.
- [20] Bhateja V, Urooj S, Verma R, Mehrotra R. A novel approach for suppression of power line interference and impulse noise in ECG signals. In *IMPACT-2013* (pp. 103-7). IEEE.
- [21] Sandhu M, Kaur S, Kaur J. A study on design and implementation of butterworth, chebyshev and elliptic filter with matlab. *International Journal of Emerging*

- Technologies in Engineering Research. 2016; 4(6):111-4.
- [22] Bindu CH. Performance analysis of demising of ECG signals in time and frequency domain. In computational intelligence and big data analytics 2019 (pp. 81-95). Springer, Singapore.
- [23] Ahmad AS, Matti MS, ALhabib OA, Shaikhow S. Denoising of arrhythmia ECG signals. International Journal of Medical Research and Health Sciences. 2018; 7(3):83-93.
- [24] Saini A, Kumar N, Raj A, Jain S. Performance analysis of cascaded denoising block for ECG signal analysis using different filters. In international conference on "computing for sustainable global development. 2018 (pp. 2251-6).
- [25] Latif R, Jenkal W, Toumanari A, Hatim A. Electrocardiogram signal denoising using a hybrid technique. World Academy of Science, Engineering and Technology, International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering. 2017; 11(3):256-9.
- [26] Bhutada SN, Shinde AV, Thote CG. Efficient method for ECG denoising–survey. International Journal of Advanced Research in Electronics and Communication Engineering. 2017; 6(4):318-21.
- [27] Rishabhkumar MN, Parashar P. Design and implementation of butterworth, chebyshev-I filters for digital signal analysis. International Research Journal of Engineering and Technology (IRJET).2018; 5(3):2707-9.
- [28] Kumar A, Mamta. Comparison of different types of IIR filters. International Journal of Advanced Research in Electronics and Communication Engineering. 2016; 5(2):393-402.
- [29] Saini MS, Kaur K. Performance analysis of IIR filter design by using butterworth, chebyshev and cauer. International Journal of Advanced Engineering Research and Science. 2015; 2(3):29-36.
- [30] Yazdanpanah B, Raju KS. Design and comparison of digital IIR filters for reduction of artifacts from electrocardiogram waveform. International Journal of Engineering Research and General Science. 2014; 2(6):982-8.
- [31] Chavan MS, Agarwala RA, Uplane MD. Comparative study of chebyshev i and chebyshev II filter used for noise reduction in ECG signal. International Journal of Circuits, Systems and Signal Processing. 2008; 2(1):1-17.
- [32] Jagtap SK, Uplane MD. A real time approach: ECG noise reduction in chebyshev type II digital filter. International Journal of Computer Applications. 2012; 49(9):52-9.
- [33] Chavan MS, Agarwala RA, Uplane MD. Digital elliptic filter application for noise reduction in ECG signal. WSEAS international conference on electronics, control and signal processing, Miami, Florida, USA 2005(pp.58-63).



J.Rexy is pursuing Ph.D in Computer Science. She is currently working as an Assistant Professor in Department of Computer Science at St. Xavier's College, Tamilnadu, India. Her areas of interest are Data Mining and Signal Processing.

Email: rexyjeba@gmail.com



P.Velmani is currently working as Assistant Professor in Department of Computer Science, The M.D.T Hindu College, Tamilnad, India. Her areas of interest are Sensor Networking, Data Mining and Image Processing.

Email: vel_comp@yahoo.com



T.C.Rajakumar is currently working as an Associate Professor in Department of Computer Science in St.Xavier's college, Tamilnadu, India. His areas of interest are Image Processing and Data Mining.

Email: grajazion@gmail.com