Survey on Filtering Techniques Applied to ECG Signal

Mala Sinnoor, Shanthi K J

Abstract*: This Analysis of ECG signals is crucial for early detection of cardiac ailments. With the sensors becoming more and more predominant and available in all wearable forms for measuring multiple physiological parameters, the importance of algorithms to detect the abnormalities are also gaining importance. The physiological signals are measured through noninvasive means unless very critical and hence are very weak in nature. Bio-amplifiers are applied during signal acquisition. The signals are weak and hence susceptible for the electrical disturbances in the environment. Selection of Filtering techniques is very important and is decided by many factors. This paper is a survey which presents digital filtering techniques the researchers have applied in the last decade. The study reveals the different types FIR/IIR filters the researchers have worked and also the performance metrics adapted by the researchers electronic document is a "live" template and already.

Keywords: FIR, IIR, De-noising, ECG, Noise, Power line interference

I. INTRODUCTION

World over heart related disease are the major causes of human deaths. Therefore, it is necessary to understand the functional and physiological status of heart, clinicians require efficient methods and tools for effective diagnosis of the heart disease. Electrocardiography (ECG) is a widely used tool to understand the condition of the heart. In recent years, computerized ECG analysis is considered as a primary and reliable technique for the diagnosis of cardiac related disease [1].

The ECG signal peak value is normally about 1 mV. The clinical ECG signal is usually filtered to a bandwidth of about 0.05 – 100Hz, with a recommended sampling rate of 500 Hz for diagnostic ECG is shown in Fig. 1. ECG for heart rate monitoring could use a reduced bandwidth 0.5 – 50 Hz. High resolution ECG requires a greater bandwidth of 0.05 – 500Hz.

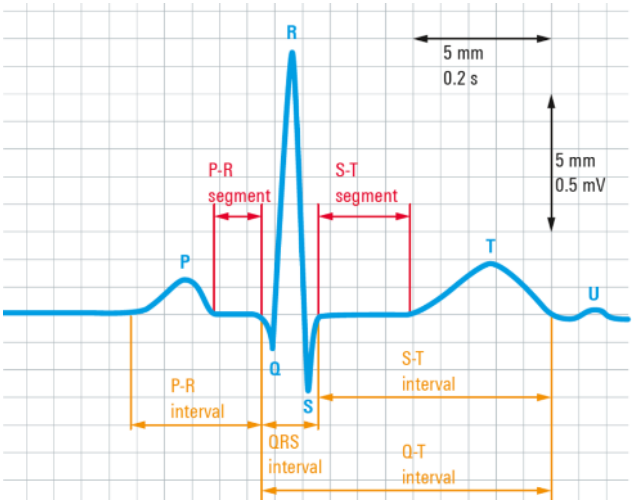

Fig. 1. ECG Wave

When R-R intervals of heart rate are collected over long periods of time (several Hours), expected signal could be of non-stationary. PSDs of R-R interval are analyzed for the following frequency bands: low-frequency (LF) band in the range 0.18-0.4Hz related to respiration and vagal activity; very-low- frequency (VLF) band in the range 0 – 0.03Hz related to humoral and thermoregulatory factors.

II. DIFFERENT TYPES OF NOISES IN ECG SIGNAL

A. Power Line Interference (PIL)

Power Line Interference is main source of noise and is introduced due to dirty electrodes or loose contacts, stray alternating current looped wires, electromagnetic interference from the power lines, improper grounding of ECG machine or the patient. The frequency component of power line interference is from 50 to 60 Hz whereas the frequency range of ECG signal is from 0.5 to 80 Hz and this will corrupt the ECG signal. The PLI can be introduced on account of badly grounded equipment, leakage of electrical power or due to of another instrument in the recording room of ECG signal [2] & [4].

B. Electrode Motion Noise

Good Electrode motion noise is due to the changes in electrode skin impedance which in turn affect the transient baseline. The changes in electrode skin impedance is caused by the sudden body movement of patients while recording the ECG signal. Frequency range of EMG signal is in the range of 5 to 450Hz which will overlaps with ECG frequency range 0.5 to 100Hz. EMG signal is non-stationary and is difficult to suppress or remove these signals [5] & [6].

Revised Manuscript Received on May 07, 2020.
***** Correspondence Author
Mala Sinnoor, Department of Electronics and Communication, Dr. Ambedkar Institute of Technology, Bengaluru, India**.** E-mail: mala.sinnoor@dr-ait.org
Shanthi K J, Department Medical Electronics, Dr. Ambedkar Institute of Technology, Bengaluru, India**.** E-mail: shanthi.kj@ieee.org

C. Baseline Wandering

While walking, running, pull-up or push-up or patient is not still or restless if ECG signal is acquired then different shapes of baseline wandering is added to ECG signal [7].

III. DENOISING TECHNIQUES

The different filtering techniques are employed for signal preprocessing and have been implemented in the ECG signal analysis system. Nature of ECG signal is quite sensitive, even if a small noise is mixed with an original ECG signal that will changes in the characteristics of signal. The corrupted signal that is due to noise must either be filtered or disposed [2].

In biomedical signal processing digital filters play a crucial role. A digital filter refers to a mathematical algorithm executed in hardware/software which works on a corrupted digital input signal to generate a desired digital output signal so as to achieve a filtering objective [1].

[1] In this paper the analysis of FIR and IIR filter is done to remove the Baseline noise from ECG signal and the analysis show that using of IIR filter is better than FIR filter as it removes Ringing effect which is small oscillation at the starting of the ECG signal. Also the analysis shows that IIR filter requires less computation-power and their implementation is easy.

[2] In this paper, the authors compare the different methods using Normalized Least Mean Square (NLMS) filter, Discrete Wavelet Transform (DWT), FIR and IIR filters were used. The different metrics used were Signal to Noise ratio (SNR), Mean Square Error (MSE), Mean Absolute Error (MAE), and peak signal to noise ratio (PSNR). Here the authors have made a comparison of IIR and FIR in terms of the order while removing the power line interference. The FIR of order 40 gives the desirable performance.

Filters are used for selectively classifying heart beat rhythm for detection of cardiac abnormalities. This can be done through supervised and unsupervised classification. Alternate ECG model based classification technique [3] using Kalman filter. The authors adapt Kalman filter for classification of heart beat using prior knowledge and also detection of noisy beats as unknown morphologies. As 3% of the beat in this case were discarded as unknown or X factor. The authors here carried out the classification of MIT-BIH arrhythmia data sets.

Different IIR filters performance is examined using ten datasets and found Chebyshev type I is the best for ECG denoising and its SNR average value is higher among the other filters [5].

The paper analyses several modes of high pass & low pass filters to arrive at a hybrid filter model [8]. An FIR filter of high order up to 400 is used and a Chebyshev low pass filter Mean Square Error (MSE) is used as the performance metric for comparing the different signals. The authors applied this for filtering EMG signal from the ECG.

[10] This paper observed and compared different digital filters and found that Chebyshev window give better signal-to-noise ratio and remove approximate 50Hz power line interference (PIL).

Various IIR and FIR filters are compared for different orders [11]. Power spectrums density (PSD), Mean Square Error (MSE) and signal to noise ratio (SNR) of various filtered are compared and found that Kaiser Window order 56 of FIR filter is better than other filters.

The SNR values of Equiripple FIR filter of 3rd order and Elliptic IIR filter of 1st order are compared and the result shows that Equiripple FIR will be the best filter [12].

SSRLS adaptive filter is proposed for tracking of accurate PIL and its harmonics [13]. The proposed filter is able to self-adjust its tuning frequency for highly precise filtration of 1st, 3rd, and 5th harmonics of PIL.

The Daubechies (DB) technique is used to reduce the noise in ECG signal and to improve the SNR upto value of 52.07374 dB [14].

Comparison between Kaiser Window filter and Bartlett window filter analysis has been done using SNR and PSD confirms the denoising of PLI [15].

[16] In this paper, IIR wavelet filters and FIR wavelet filters are compared and demonstrated that IIR filter is better for frequency selectivity with lesser arithmetic operations and is better filter than to denoising the ECG signal.

Comparative study of side-lobe roll-off ratio and ripple ratio of the FIR filter window and concludes that the proposed window is better than the adjustable window for removing high frequency noise which corrupt the ECG signal [17].

[18] This paper describes IIR filter will reduce number of multiplications and additions within the process of various filters. The paper shows the achievement of low power consumption in filters.

[19] This paper discuss various types of IIR filter and algorithm is presented to find appropriate filter. The result shows that algorithm is efficient in determining the apt filter for the parameters generated.

Comparison of SNR performance is done with different filter techniques and is observed that increase in filter order rises SNR and in some cases decreases with increasing filter order [20]. The study shows to choose the right filter for ECG denoising.

IV. CONCLUSION

A survey of different filtering techniques for removing of various types of noise in ECG signal is presented in this paper. We find that Baseline noise from ECG signal is removed by IIR filter. Comparison of FIR and IIR filter is done using DWT, NLMS methods for removing Power Line Interference and found FIR of order 40 gives the desirable performance. Different IIR filters and their algorithm are observed based on the observation appropriate filter can be adopted.

REFERENCES

1. Gandham Sreedevi, Bhuma Anuradha, “Using Of Fir And IIR Filters For Noise Removal From ECG Signal: A Performance Analysis”, International Journal of Electronics and Communication Engineering and Technology (IJECET) Volume 7, Issue 4, July-August 2016, pp. 91–99, Article ID: IJECET_07_04_011.
2. Shubhankar Saxena ; Rohan Jais ; Malaya Kumar Hota, “Removal of Powerline Interference from ECG Signal using FIR, IIR, DWT and NLMS Adaptive Filter” IEEE International Conference on Communication and Signal Processing, April 4-6, 2019, India.
3. Julien Oster∗, Joachim Behar, Omid Sayadi, Shamim Nemati, Alistair E. W. Johnson, “Semisupervised ECG Ventricular Beat Classification With Novelty Detection Based on Switching Kalman Filters”, IEEE TRANSACTIONS on Biomedical Engineering, vol. 62, no. 9, September 201.5

4. Sarang L. Joshi , Rambabu A.Vatti , Rupali V.Tornekar, "A Survey on ECG Signal Denoising Techniques", IEEE International Conference on Communication Systems and Network Technologies 2013.
5. Thion Ming Chieng, Yuan wen Hau, Zaid Omar, "The study and comparison between various digital filters for ECG De-noising", IEEE-EMBS Conference on Biomedical Engineering and Sciences (IECBES) 2018.
6. P. Raphisak, S.C. Schuckers, A.J. Curry, An algorithm for EMG noise detection in large ECG data, Comput", Cardiol, 31 (2004) 369– 372.
7. Md. Asadur Rahman ; Md. Mahmudul Haque Milu ; Anika Anjum ; Farzana Khanam ; Mohiuddin Ahmad , "Baseline wandering removal from ECG signal by wandering path finding algorithm", IEEE 3rd International Conference on Electrical Information and Communication Technology (EICT) 2017.
8. Mohammed Tali Almalchy, Vlad Ciobanu, Nirvana Popescu, 'Noise Removal from ECG Signal Based on Filtering Techniques", IEEE 22nd International Conference On Control Systems And Computer Science (CSCS), 2019.
9. Akanksha Mittal, Amit Rege, " Design of Digital FIR Filter Implemented with Window Techniques for Reduction of Power line Interference from ECG Signal", IEEE International Conference on Computer, Communication and Control (IC4-2015).
10. K.Sravan Kumar, Babak Yazdanpanah, P Rajesh Kumar, "Removal of Noise from Electrocardiogram Using Digital FIR and IIR Filters with Various Methods", the IEEE ICCSP 2015 conference.
11. Sande Seema Bhogeshwar, M.K.Soni, Dipali Bansal, "Design of Simulink Model to denoise ECG signal using various IIR & FIR filters", IEEE 2014 International Conference on Reliability, Optimization and Information Technology -ICROIT 2014, India, Feb 6-8 2014
12. Nauman Razzaq, Shafa-At Ali Sheikh, Muhammad Salman, And Tahir Zaidi , "An Intelligent Adaptive Filter for Elimination of Power Line Interference From High Resolution Electrocardiogram", IEEE Access (Volume: 4), Electronic ISSN: 2169-3536,page(s): 1676 – 1688, Date of Publication: 31 March 2016.
13. Tanuj Yadav , Rajesh Mehra ," Denoising and SNR Improvement of ECG Signals Using Wavelet Based Techniques", IEEE 2nd International Conference on Next Generation Computing Technologies (NGCT-2016)
14. Bharati Sharma, Jenkin Suji, "Analysis of Various Window Techniques used for denoising ECG signal", IEEE Symposium on Colossal Data Analysis and Networking (CDAN), 2016
15. Eminaga, Y., Coskun, A. and Kale, I., "IIR Wavelet Filter Banks for ECG Signal Denoising", 22nd IEEE International Conference on Signal Processing: Algorithms, Architectures, Arrangements, and Applications (SPA). Poznan, Poland, 19 - 21 Sep 2018.
16. Tapash Karmaker, Md. Shamim Anower, Muhammad Abdul Goffar Khan, Md. Ahasan Habib , "A New Adjustable Window Function to Design FIR Filter and Its Application in Noise Reduction From Contaminated ECG Signal" 2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC) 21 - 23 Dec 2017, Dhaka, Bangladesh
17. Yaprak Eminaga, Adem Coskun, Sterghios A. Moschos, and Izzet Kale1, "Low Complexity All-Pass Based Polyphase Decimation Filters for ECG Monitoring", 2015 11th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME).
18. Sujan Sarkar ; Shubham Sarkar ; Jishan MehediDept. "Comprehensive Study for Selection of proper IIR filter: Specifications Dependant Approach", 2018 3rd International Conference for Convergence in Technology (I2CT) The Gateway Hotel, XION Complex, Wakad Road, Pune, India. Apr 06-08, 2018.
19. Nilotpal Das, Monisha Chakraborty, "Performance Analysis of FIR and IIR Filters for ECG Signal Denoising based on SNR", Third International Conference On Research In Computational Intelligence And Communication Networks (ICRCICN), 2017.
20. Thandar Oo ; Pornchai Phukpattaranont ; Prapakorn Klabklay "Effects of SNR on removing ECG noise from EMG signal using DSWT" IEEE 15th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2018.

AUTHORS PROFILE

Author's Name: Mala Sinnoor,
Author's Profile: She is Assistant Professor in Electronics and Communication at Dr. Ambedkar Institute of Technology, Bengaluru, India. She is currently working in the field of ECG signal analysis.

Author's Name: Shanthi K J
Author's Profile: She is Professor and Head of Medical Electronics Department at Dr. Ambedkar Institute of Technology, Bengaluru, India. She has done her research in field of ECG signals and have 15 years of experience. Currently she is working on 'EEG signals analysis and classification'.