International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013 2027
ISSN 2229-5518

Eradication of Artifacts within ECG Signal by means of IIR Filter

Govind Sharan Yadav, Anjali Kumari Gupta, Varsha Pathak*

Abstract— The Electrocardiogram (ECG) belongs to a family of multicomponent non-stationary signals. These non-stationary components are observed even when the ECG signal of a perfectly healthy person is taken. One of the main problems with ECG is the extraction of required cardiac components by rejecting the background noise caused by power line interference, external electromagnetic fields, random body movements and respiration. Different types of digital filters are used to separate the signal of interest from entire frequency range of the signal. This paper deals with the denoising and filtering of the raw ECG signal and the data set is taken from MIT-BIH arrhythmia database.

Index Terms— *PSD, Electrocardiogram, IIR, MIT-BIH Arrhythmia Database.*

1 Introduction

The Electrocardiogram (ECG) interprets the electrical activity of the heart over a specified period of time. It is a multi component and non-stationary signal [1]. ECG signal is a prognostic tool used for the measurement and recording of electrical activity of heart and it also helps in measuring the rhythm and invariability of heart beat. The potential difference between two points on human body is represented by ECG . The normal ECG signal is poised of a P-wave, a QRS complex and a T-wave[2]. The waveform shown in fig.1 initiates with a peak which is usually referred as P-wave[3]. It exemplifies the atrial depolarization that is the requisite time for an electrical impulse generated from the sinoatrial node to proliferate throughout the atrial musculature and its duration is about 0.06-0.11 seconds. P-R interval as shown in fig 1, starts from the

beginning of the P-wave and ends to the beginning of the QRS complex. It reflects the time that the impulse elapse to travel the entire distance from sinoatrial node to the ventricular muscle fibres[4]. Its normal duration is about 0.12-0.20 seconds[5]. The QRS complex represents ventricular depolarization and is composed of three waves - the Q-wave, the R-wave and the S-wave[6]. Q wave is present at the beginning of QRS complex. It is the first negative deflection. The first positive deflection observed is depicted by R-wave, irrespective of the fact that it is transcended by a Q-wave or not S wave is the next negative aberration which is superseded by the R-wave[7].

Normal duration of the QRS complex is 0.05 to 0.10 seconds. Q-T interval reflects the requisite time for ventricular depolarization and repolarisation[8]. It extends from the initiation of QRS complex to the termination of the T-wave. In the S-T segment the T-wave exemplify the time indispensible for the ventricular repolarisation [9]. Sometimes, a U-wave can also be observed which follows the T-wave. It represents the repolarisation of the His-purkinje fibres.

2.3 Figures

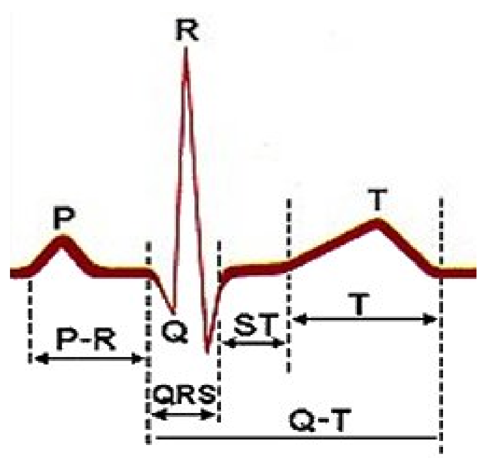

Fig.1 ECG waveform

ECG signal processing is a huge challenge since many factors like AC power supply interference, RF interference from surgical equipment and implanted devices like pace makers and physiological monitoring system can also impact accuracy [10]. The

- *Govind sharan yadav is currently working as an assistant professor in department of electronics and communication SRMSWCET bareilly, utter predesh technical university Lunknow , india , PH-9897710553. E-mail: er.govindyadav@gmail.com.*
- *Anjali Kr. Gupta and varsha pathak are currently pursuing B.Tech in electronics and communication SRMSWCET bareilly, utter predesh technical Universitylucknow , india , E-mail: anjaligupta1091@gmail.com,,varsha1792@gmail.com*

ISSN 2229-5518

main source of noises in the ECG signal are baseline wander which is low frequency noise, powerline interference occurring at 50 Hz or 60 Hz noise from power lines, muscle noise and other interference that is the radio frequency noise from other equipment[12].

2. DATASET

The dataset used in this study is acquired from physio-Bank named "MIT-BIH Arrhythmia Database" which is available on-line. The source of the ECGs included in the Database is a set of over 4000 long-term Holter recordings[11]. These recordings were obtained by the Beth Israel Hospital Arrhythmia Laboratory between 1975 and 1979. Approximately 60% of these recordings were obtained from inpatients. The database contains 10 records (numbered from 100 to 110) that were chosen from the same set. It comprises of a variety of rare but clinically important phenomena that would not be well-depicted by a small random sample of Holter recordings[13]. The first group acts as a representative sample of the variety of waveforms and shows that an arrhythmia detector might be confronted in routine clinical use. The second groups were chosen to include complex ventricular, junctional, and supraventricular arrhythmias and conduction aberrancies. By placing the electrodes on the chest, we can obtain a modified limb lead II (MLII) that is the upper signal in most of the records. The lower signal is usually a modified lead V1. Nine Del Mar Avionics model 445 two-channel recorders were used for original analog recordings [14].

In order to limit analog-to-digital converter (ADC) saturation firstly the analog outputs of the playback unit were filtered and then anti-aliasing is done by using a pass band from 0.1 to 100 Hz relative to real time[15]. The band pass-filtered signals were digitized at 360 Hz per signal relative to real time using hardware constructed at the MIT Biomedical Engineering Center and at the BIH Biomedical Engineering Laboratory[16]. The sampling frequency was chosen in such a way that it facilitates the implementations of 60 Hz (mains frequency) digital notch filters in arrhythmia detectors[17].

3. IIR FILTERING TECHNIQUE

Sometimes, the ECG is recorded during ambulatory or strenuous conditions therefore the signal is corrupted by different types of noise, frequently evolving from various other physiological process of the body[18]. Hence one of the important objectives of ECG signal processing is noise reduction. We have to apply appropriate signal processing so that the waveform of interest can be revealed from the heavily noise masked ECG signal[19]. Various noises affecting the measured ECG signal are baseline wandering, electrode contact noise, muscle noise, electrosurgical noise and power line interference. Baseline noise distorts the low frequency segment of ECG signal [20]. The low frequency segment is S-T segment. This segment is very important and has the information pertaining to heart attack. Efficient removal of baseline noise may provide us certain information that are hidden from the doctors until now, which may help to save the life of a person. Different signal from MIT-BIH database were also analyzed. For denoising and filtering of ECG signal we have employed the digital IIR filter[21]. Filters have functions of the signal separation and signal restoration. The signal separation is done when signal is affected by the interference, noise or by other noise factors. For instance, if we imagine a device that measures the electrical activity of a baby's heart while still in the womb, the raw signal is supposed to be corrupted by the breathing and heart beat of the mother. Therefore to individually analyze these signals we make use of filter for separating them. In case of signal distortion by some means signal restoration is used. In audio recording made with poor equipment may be filtered to better represent the sound as it actually occurred [22].

The impulse response function of an IIR system is non-zero over an infinite length of time. They may be implemented as either analog or digital filter. The butter worth filter has the best taylor series approximation for the ideal low pass filter response at analog frequencies Ω= (-∞) and Ω= ∞. For any order N, the magnitude squared response has 2N-1 zero derivative at these locations [23]. Response is monotonically decreasing from Ω= 0 to Ω= ∞.

$$H(j\Omega) = \sqrt{\frac{1}{2}} \; at \; \Omega = 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Here, we have made use of Lowpass Butterworth filter whose magnitude squared response is given as[24]:

$$G^2(\Omega) = |H(j\Omega)|^2 = \frac{G_0^{\,2}}{\left[1 + \left(\frac{\Omega}{\Omega_c}\right)^{2N}\right]} \ldots\ldots\ldots\ldots 2$$

where,

n = order of the filter

Ω_c = cut off frequency

G_0 = DC gain

ISSN 2229-5518

4. RESULT AND DISCUSSION

We have considered the case of 100m ECG signal for our analysis. Raw ECG was taken as shown in fig. 2(a).

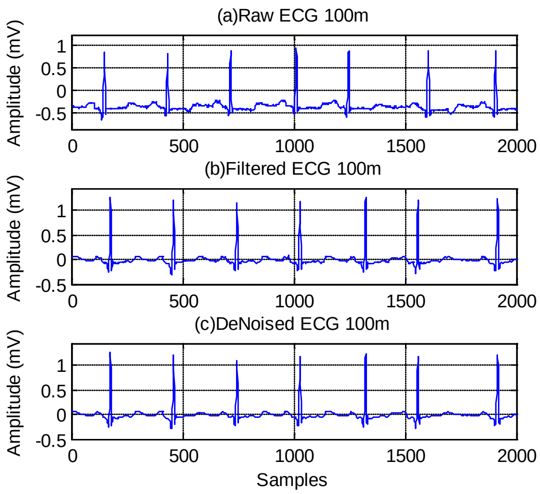

Fig.2 Amplitude and Time Represrentation of ECG

a) Raw ECG signal
b) Filtered ECG signal
c) De-noised ECG signal

Now we know that this ECG signal contains different types of noise. Here, we are dealing with two principal noises that mainly occur in the ECG signal. These noises are the power line interference and baseline wandering.

Baseline wander is actually the effect where the base axis of any signal viewed on the screen appears to wander or move up and down rather than to be straight. It causes the entire signal to shift from its base. It is caused due to improper electrodes (rusted or broken) and due to the respiration of the patient while recording the ECG signal.

The fig.2(a) clearly shows that the base line of the signal is shifted from the 0-axis to -0.5 on the amplitude scale. This depicts the baseline wandering effect present in the ECG signal.

The fig.2(b) is the filtered version of the raw ECG signal. The filtering is done with the help of IIR filter since it has many advantages over the other type of filters. In the figure we can clearly observe that the baseline which was at -0.5 on the amplitude axis in the raw ECG has now been shifted to 0-axis. This eliminates the baseline wandering effect as clearly depicted in the Welch power spectral density of the denoised signal.

Now the fig.2(c) shows the denoised form of the raw ECG signal. We can clearly observe in the denoised ECG signal that the unwanted components that were present in the raw ECG signal are now removed. Hence we have obtained the filtered and denoised form of the ECG that can be further used to analyse the condition of any person.

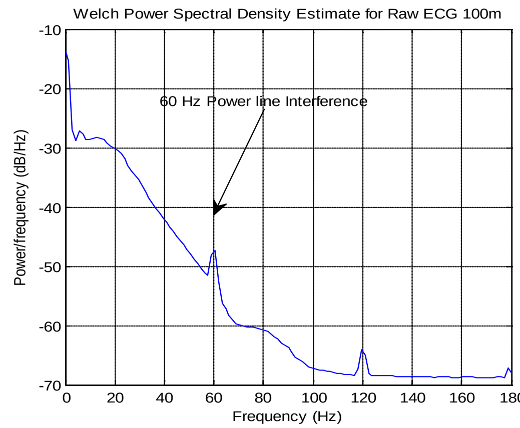

Fig3. PSD of Raw ECG signal

The raw ECG also has noise and power line interference. Power line interference is significant in electrocardiography and even a proper recording environment is not sufficient to avoid this interference. The amplitude of power line interference should be less than 0.5% of peak to peak QRS amplitude of high quality analysis of ECG. This corresponds to a signal to interference ratio (SIR) of about 30dB.The power ratio between the ECG signal and power line interference is known as SIR.

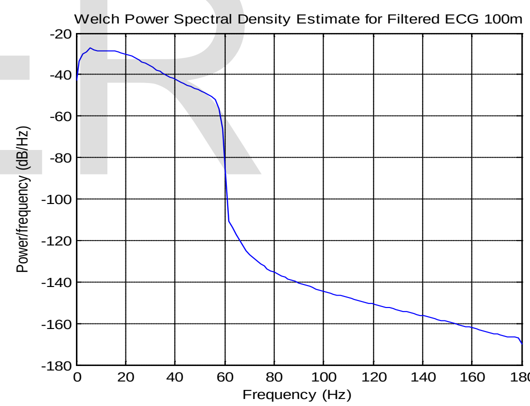

Fig.4 PSD of filtered ECG

Normally, the SIRs between 0 to 40 dB are encountered with contact electrodes and after filtering the SIR of the ECG signal has been improved.

Welch method is used for estimating the power of the signal at different frequencies for spectral density estimation. The time domain view of the ECG signal reveals the presence of noise which is confirmed by the power spectral density estimate having power line interference at 60 Hz as shown in fig. 3.

Fig.4 shows the Welch power spectral density of the filtered ECG signal. We can easily observe from the figure that there is no peak occurring at 60 Hz which was present earlier in the raw ECG signal due to power line interference.

In the raw ECG signal the power was decreasing steeply at lower frequencies due to the presence of baseline wandering effect while, in the filtered signal the power is decreasing gradually. Hence, the power line interference and baseline wandering both are removed in the filtered signal.

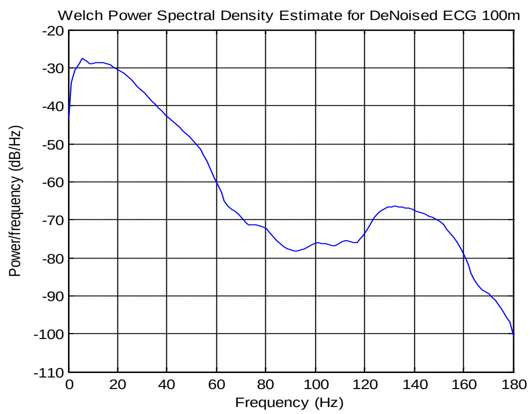

Fig 5.PSD of Denoised ECG

After denoising the filtered signal, all the unwanted components from the ECG signal have been removed. This improves the Signal to Noise Ratio (SNR) of the filtered ECG signal and it can be seen in fig.5 which is the Welch power spectral density of denoised ECG signal.

5. CONCLUSION

This paper deals with the filtering and denoising of the ECG signal. Firstly, we have taken the raw ECG signal and observed that it contains baseline wandering and power line interference. To remove these noises, we have filtered and denoised the ECG signal using IIR filter. This removes the noises as well as improves the signal to interference and signal to noise ratio of the ECG signal. The removal of noise will be useful in analyzing the exact condition of any person.

REFERENCE

[1] Gramatikov B. and Thakor, N. 1993. Wavelet analysis of coronary artery occlusion related changes in ECG. In: Proc. 15th Ann. Int. Conf. IEEE Eng. Med. Biol. Soc. Dan Diego. p. 731.

[2] Ivo Provazn´ık and Ji˘r´ı Kozumpl´ık. 1997. Wavelet transform in electrocardiography data compression International Journal of Medical Informatics. 45(1-2):111-128, June.

[3] M.P. Wachowiak, G.S. Rash, P.M. Quesada, and A.H Desoky. 2000. Waveletbased noise removal for biomechanical signals: a comparative study. IEEE Trans. Biomed. Eng. 47(3):360-368, March.

[4] Cuiwei Li, Chongxun Zheng, and Changfeng Tai. 1995. Detection of ECG characteristic points using wavelet transforms. IEEE Trans. Biomed. Eng. 42(1): 21-28, January.

[5] Mahamoodabadi S.Z., Ahmedian A., Abolhasani M.D. 2005. ECG feature extraction using daubechies wavelet, Proceedings of the fifth IASTED International Conference VISUALIZATION, IMAGING and IMAGE PROCESSING, September 7-9, Benidorm, Spain.

[6] David Cuesta-Frau, Daniel Novak, Vladimir Eck, Juan C. Pérez-Cortés. 2002. Electrocardiogram Baseline Removal Using Wavelet Approximations, Computer-Based Medical Systems, (CBMS 2002), Proceedings of the 15th IEEE Symposium.

[7] N. Nikolaev, Z. Nikolov, A. Gotchev, K. Egiazarian. 2000. Wavelet Domain Wiener Filtering For Ecg Denoising Using Improved Signal Estimate, IEEE.

[8] Oktem R., Yaroslavsky L., Egiazarian K. 1998. Signal and Image De-noising in Transform Domain and Wavelet Shrinkage: A Comparative Study. Proceedings of EUSIPCO-98. pp. 2269-2272, Island of Rhodes, Greece. Sept.

[9] Ghael S., Sayeed A., and Baraniuk R. 1997. Improved Wavelet Denoising via Empirical Wiener Filtering. Proceedings of SPIE. 3169: 289-299, San Diego. July.

[10] P. V. Madeiro, Paulo C. Cortez, Francisco I Oliveira, S. Robson Siqueira "A new approach to QRS segmentation based on waveletbases and adaptive threshold technique". Medical Engineering &Physics 29, 2007, pp 26–37.

[11] http://www.physionet.org/cgi-bin/atm/ATM "MIT-BIH Arrhythmia Database"

[12] O. Faust, R. Acharya, S. M. Krishnan, L. C. Min, "Analysis of cardiacsignal using spatial filling index and time-frequency domain" BioMedical Engineering OnLine, 2004.

[13] N. Jafarnia-Dabanlooa, D. C. McLernona, H. Zhangb, A. Ayatollahic, V. Johari-Majd "A modified Zeeman model for producing HRV signals and its application to ECG signal generation", Journal of Theoretical Biology 244, 2007, pp 180–189.

[14] V. Pichot, J. M. Gaspoz, S. Molliex, A. Antoniadis, T. Busso, F. Roche F. Costes, L. Quintin, J. R. Lacor, J. Barthelemy, "Wavelet transform to quantify heart rate variability and to assess its instantaneous changes" J. Appl. Physiol. 86, pp 1081–1091, 1999.

[15] N. Y. Belova, S. V. Mihaylov, G. Piryova, "Wavelet transform: A better approach for the evaluation of instantaneous changes in heart rate variability", Autonomic Neuroscience: Basic and Clinical 131, pp 107-122, 2007.

[16] D. E. Vigo, S. M. Guinjoan, M. Scaramal, L. N; Siri, D. P. Cardinali "Wavelet transform shows age-related changes of heart rate variability within independent frequency components", Autonomic Neuroscience Basic and Clinical 123, 2005, pp 94 – 100.

[17] E. Toledo, O. Gurevitz, H. Hod, M. Eldar, S; Akselro, " Wavelet analysis of instantaneous heart rate: a study of autonomic control during thrombolysis". Am J Physiol Regulatory Integrative Comp Physiol 284, 2003, pp 1079-1091.

[18] H. Burri, P. Chevalier, M. Arzi, P. Rubel, G. Kirkorian, P. Touboul "Wavelet transform for analysis of heart rate variability preceding ventricular arrhythmias in patients with ischemic heart disease" International Journal of Cardiology 109, 2003, pp 101 – 107.

[19] G. Kheder, R. Taleb, A. Kachouri, M. BenMassoued, M. Samet "Feature extraction by wavelet transforms to analyze the heart rate variability during two meditation technique", Chapter Book, Springer-Verlag2008.

[20] N. Jafarnia-Dabanlooa, D. C. McLernona, H. Zhangb, A. Ayatollahic, V. Johari-Majd "A modified Zeeman model for producing HRV signals and its application to ECG signal generation", Journal of Theoretical Biology 244, 2007, pp 180–189.

[21] V. Pichot, J. M. Gaspoz, S. Molliex, A. Antoniadis, T. Busso, F. Roche F. Costes, L. Quintin, J. R. Lacor, J. Barthelemy, "Wavelet transform to quantify heart rate variability and to assess its instantaneous changes" J. Appl. Physiol. 86, pp 1081–1091, 1999.

[22] N. Y. Belova, S. V. Mihaylov, G. Piryova, "Wavelet transform: A better approach for the evaluation of instantaneous changes in heart rate variability", Autonomic Neuroscience: Basic and Clinical 131, pp 107-122, 2007.

[23] D. E. Vigo, S. M. Guinjoan, M. Scaramal, L. N; Siri, D. P. Cardinali "Wavelet transform shows age-related changes of heart rate.

[24] variability within independent frequency components", Autonomic Neuroscience Basic and Clinical 123, 2005, pp 94 – 100.

[25] E. Toledo, O. Gurevitz, H. Hod, M. Eldar, S; Akselro, "Wavelet analysis of instantaneous heart rate: a study of autonomic control during thrombolysis". Am J Physiol Regulatory Integrative Comp Physiol 284, 2003, pp 1079-1091.