ECG Baseline Wander Elimination using Wavelet Packets

Behzad Mozaffary Mohammad A. Tinati

Abstract— **Baseline wander elimination is considered as a classical problem. We present a wavelet based search algorithm using the energy of the signal in different scales to isolate baseline wander from ECG signal. The algorithm calculates the wavelet packet coefficients. In each scale the energy of the signal is calculated. Comparison is made and the branch of the wavelet binary tree corresponding to higher energy wavelet spaces is chosen. This algorithm is tested using the data record from MIT/BIH and excellent results are obtained.**

***Keywords*—**ECG, Baseline wander, wavelet Packets.

I. Introduction

In recent years computer aided ECG signal analysis has gained momentum and tremendous amount of work has been carried out. One area of interest has been removing artifacts from data records, baseline wanders is considered as an artifact which produces atrifactual data when measuring the ECG parameters, especially the ST segment measures are strongly affected by this wandering. In most of the ECG recordings the respiration, electrode impedance change due to perspiration and increased body movements are the main causes of the baseline wandering [1]. Therefore, elimination of the baseline can very much change the clinical information of the ECG signal.

Baseline removal has been addressed in many different ways in literature. Baseline estimation using cubic spline is proposed in [2]. This is a third order approximation where the baseline is estimated by polynomial approximations and then subtracted from the original ECG signal. In [3] baseline is constructed by linearly interpolating between pre-known isoelectric levels estimated from PR intervals. This is a nonlinear approach and becomes less accurate in low heart rates, where the cubic spline approximation achieved better results. Linear filtering is another method applied to baseline wander problem. Using this approach a digital narrow-band linear-phase filter with cut-off frequency of 0.8 Hz has been suggested in [4]. Another filtering technique using digital and hybrid linear-phase with cut-off frequency of 0.64 Hz is used in [5]. There are numerous problems associated with filtering: first, when the FIR structure is used, the number of coefficients is too high and therefore long impulse response; second, there is an overlap on the spectrums of the baseline and ECG, removing baseline spectrum will cause distortion on the ECG components. Third, the cut-off frequencies are not in keeping with the AHA recommendations for ECG which state the lower frequency limit must be 0.05 Hz and removing any frequencies above it will cause distortion in the ST segment as well as QRS complex [7]. Time-varying filtering was proposed in [1]. Filter banks with different cut-off frequencies which depends on heart rate and baseline level was implemented.

Manuscript received November 30, 2004. This work was supported by the University of Tabriz, Iran.

M. A. Tinati is with University of Tabriz, Faculty of Electrical Engineering, Communication Department, Tabriz, Iran. E-mail: tinati@tabrizu.ac.ir.

B. Mozaffary is with Electrical Engineering Department, Islamic Azad University of Tabriz, Tabriz, 51579-1655, Iran. E-mail: mozaffary@tabrizu.ac.ir.

II. Background Material

Wavelets are transform methods that has received great deal of attention over the past several years. The wavelet transform is a time-scale representation method that decomposes signals into basis functions of time and scale, which makes it useful in applications such as signal denoising, wave detection, data compression, feature extraction, etc. There are many techniques based on wavelet theory, such as wavelet packets, wavelet approximation and decomposition, discrete and continuous wavelet transform, etc.

Wavelets are generated according to the following equation from a mother wavelet.

$$\psi_{j,k}(t) = 2^{j/2}\psi(2^j - k) \qquad (1)$$

The wavelet system is a set of building blocks to construct or represent a signal or function. It is a two dimensional expansion set. A linear expansion would be:

$$f(t) = \sum_{k=-\infty}^{+\infty} c_k \varphi(t-k) + \sum_{k=-\infty}^{+\infty}\sum_{j=0}^{+\infty} d_{j,k}\psi(2^j t - k) \qquad (2)$$

Most of the results of wavelet theory are developed using filter banks. In applications one never has to deal directly with the scaling functions or wavelets, only the coefficients of the filters in the filter banks are needed[8]. A full wavelet packet decomposition binary tree for tree scale wavelet packet transform is shown in figure (1).

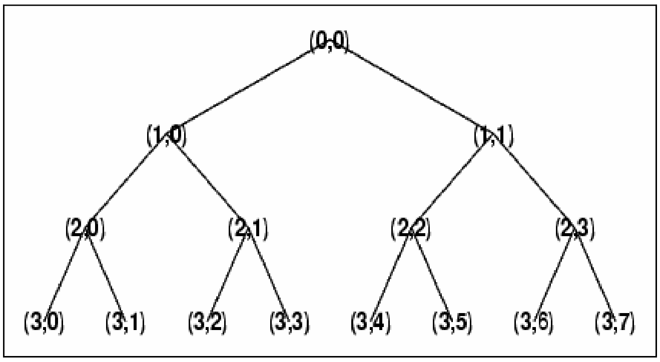

Figure (1)

The Energy in a signal is given in terms of the WT coefficients by Parsaval's relation as:

$$\int |f(t)|^2 \, dt = \sum_{l=-\infty}^{\infty} |c_l|^2 + \sum_{j=0}^{\infty} \sum_{k=-\infty}^{\infty} |d_{jk}|^2 \qquad (3)$$

III. METHOD

We propose a new algorithm for the removal of the baseline wander in ECG signal based on the assumption that the baseline and ECG signal constitute a mixture of two independent signals, mixed in a linear fashion. The wavelet transform of this signal is computed. In each scale using the wavelet coefficients, the energy of the signal for both the coarse and detail levels is calculated. These energies represent the energy of the decomposed signal in assumed scale.

$$E_{j,l} = \sum_{m=-\infty}^{\infty} |c_m|^2 \quad , \quad E_{j,h} = \sum_{k=-\infty}^{\infty} |d_{j,k}|^2 \qquad (4)$$

In above equations $E_{j,l}$ is the energy of the signal in the coarse level of scale j (low pass filtering branch), and $E_{j,h}$ is the energy of the signal in the detail level of scale j (high pass filtering branch).

The next step is to compare $E_{j,l}$ and $E_{j,h}$ then choose the branch of binary tree that has the higher energy. The higher energy branches will be followed until a point is reached where energy difference exceeds a preset threshold level. In this point the binary tree is complete, and the baseline wander signal is identified. Using the wavelet coefficients obtained, the inverse wavelet transform is calculated. In wavelet domain the baseline wander is subtracted from original data record and a baseline wander free ECG signal is identified. In figure (2) the block diagram of the algorithm is shown.

III RESUTS

Baseline wander removing using the above concept was tested on ECG data records. The test database was extracted from the MIT-BIH databases, and "103" record was used. We tested the algorithm to remove the baseline wander of the record itself as shown in figure (3), and also we added different low frequency waveforms such as ramp and sine wave to ECG record and the algorithm was applied. These are shown in figures (4) and (5). As figures show, this algorithm removes baseline wander excellently.

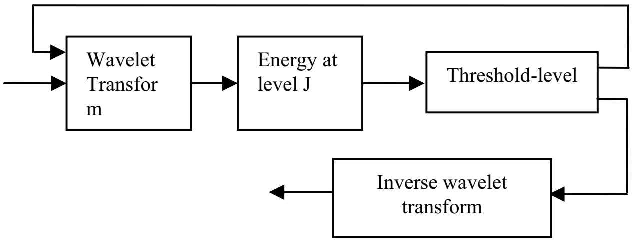

Figure (2)

IV. CONCLUSION

The proposed wavelet based algorithm remove the baseline wander from ECG signal and preserve the clinical information of ECG record. It removes the components that are not correlated to ECG and have such characteristics that are somehow added to it. Since the spectrum of the baseline is below the spectrum of the ECG signal, therefore its energy concentration in corresponding time-scale plane does not change much as the scale is changed in the binary tree, but the energy of the ECG signal decreases as the scale is changed. Therefore, in the binary tree search we reach a point that the energy of the ECG signal almost vanishes (no details in that scale) but we still have considerable energy for baseline wander.

REFERENCES

[1] L. Sornmo, "Time varying digital filtering of ECG baseline wander", Med. & Biol. Engg. & Computing, September 1993, pp 503-508.

[2] C. R. Meyer, H. N. Kelser, "Electrocardiogram baseline noise estimation and removal using cubic splines and state-space computation techniques", Computers and Biomedical Research, vol. 10, pp. 459-470, 1977.

[3] P. W. MacFarlane, J. Peden, J. Lennox, M. P. Watts, T. D. Lawrie, "The Glasgow system", Proc. Of Trends in Computer-Processed Electrocardiograms, North-Holland, pp. 143-150, 1977.

[4] J. A. Van Aleste, T. S. Schilder, "Removal of baseline wander and power-line interference from the ECG by an efficient FIR filter with a reduced number of taps", IEEE Trans. Biomed. Eng., vol BME-32, no. 12, pp. 1052-1060, 1985.

[5] I. I. Christov, I. A. Dotsinsky, I. K. Daskalov, "High pass filtering of ECG signals using QRS elimination", Med. & Biol. Eng. & Computing, pp. 253-256, March 1992.
[6] L. Sornmo, "Time-varying filtering for removal of baseline wander in exercise ECG", in Computers in Cardiology, IEEE Computer Society press, pp. 145-148, 1991.
[7] American Heart Associations on Electrocardiography, "Recommendations for standardization of lead and specifications for instruments in ECG/VCG", Circulation, 52, pp. 11-25, 1975.
[8] C. S. Burrus, R. A. Gopinath, H. Guo, "Introduction to Wavelets and Wavelet Transforms, a primer" Prentice Hall New jersey, 1998.

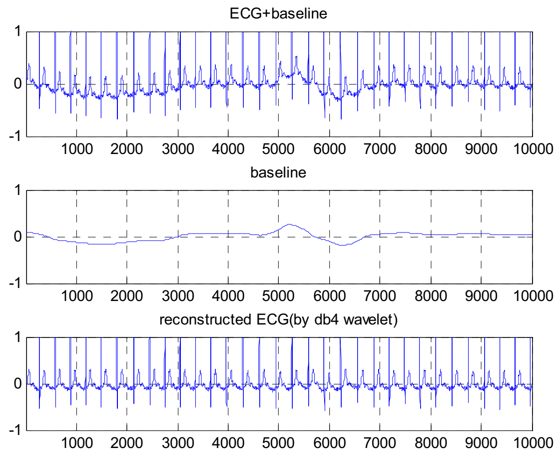

Figure (3)

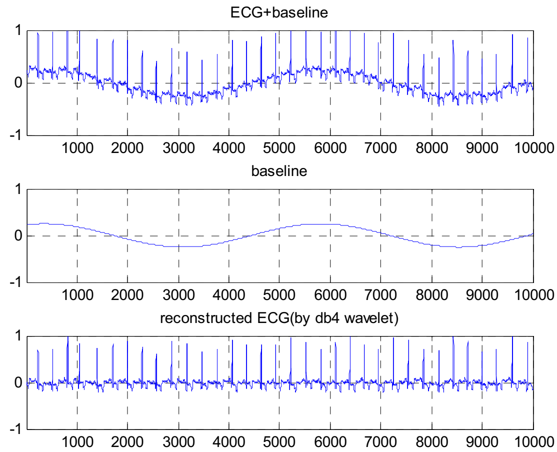

Figure (4)

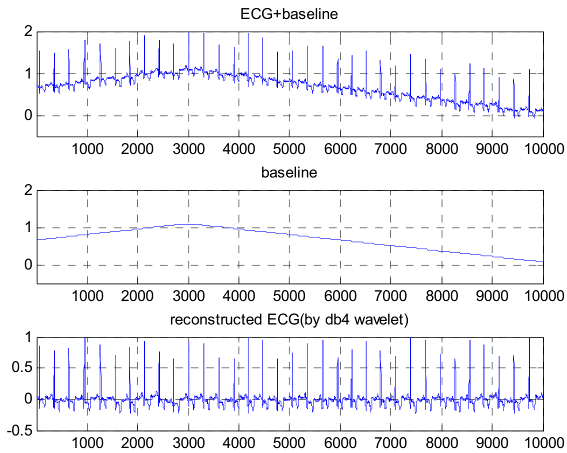

Figure (5)