Multidimensional Adaptive Noise Cancellation of Stress ECG Signal

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ABSTRACT

In ubiquitous computing environment the biological signal ECG (Electrocardiogram signal) is usually recorded with noise components. Adaptive interference (or noise) canceller do adaptive filtering of the noise reference input to maximally match and subtract out noise or interference from the primary (signal plus noise) input thereby adaptively eliminate unwanted interference from the ECG signal. Measured Stress ECG (or exercise ECG signal) signal have three major noisy component like baseline wander noise, motion artifact noise and EMG (Electro-mayo-cardiogram) noise. These noises are not only distorted signal but also root of incorrect diagnosis while ECG data are analyzed. Motion artifact and EMG noises behave like wide band spectrum signals, and they considerably do overlapping with the ECG spectrum. Here the multidimensional adaptive method used for filtering which is more effective to improve signal to noise ratio.

Keyword

Electrocardiogram (ECG), Multidimensional adaptive filtering, EMG noise, motion artifacts, ubiquitous computing environment.

Ⅰ. Introduction

For the ECG measurement, the sensor situated on USN (Ubiquitous sensor network) node are used. The measured ECG contains major noises like low frequency baseline wander noise (<0.03 Hz) due to respiration and ECG electrodes movement from their places, high frequency EMG noise or muscle noise (1-5000Hz) due to human muscles movement and motion artifact noise due to displacement of measuring device and also due to human body movement. Other noises are also present in ECG signal such as electrode contact noise, electrosurgical noise, radio frequency noise etc. These noises required to be removed for proper diagnosis.

Various methods have been proposed for processing and filtering of Electrocardiogram signal. In this paper we are mainly concerned about multidimensional adaptive filtering.

ECG signal varies from 0.1 Hz to 250 Hz and the noise signals also have wide frequency band, there by noise signals overlaps the ECG signal. In conventional filtering techniques, such as finite impulse response (FIR) low pass filtering, of low utility in high -quality reconstruction of the signal. Low pass filtering causes distortion and blurring of rising edges of ECG signal.

Adaptive filtering method is the good solution of removing the noises from ECG signal. Commonly, this method is based on least mean square (LMS) and recursive least square (RMS) algorithms. This group of algorithms has good performance in removing narrow band frequency and base line wander noise but in case of wide band of noise, reference signal is the challenging portion of adaptive filtering to achieve good performance. In [1] reference input an impulse signal that is coincident with the beginning of each P-QRS-T complex. In [2] accelerometer signal used as a source of noise reference.

Ⅱ. Stress ECG

ECG examination may be performed not only for patient's laying and sitting condition, but

also under stress conditions as some deceases may be detected when patient isn't in the rest. For stress ECG, should be measured when patient is actively moving. We know that ECG signal is very weak among various artefacts. Motion artefacts are ones which is hard to filter out using regular methods. Various researches show that motion artefacts may be extracted by using accelerometers. Accelerometer reads motion pattern and simultaneously analyse and filter it out from ECG using adaptive filtering algorithms including Least Mean Squares (LMS), Recursive Least Squares (RLS) [2]. Motion artifact, artifacts caused by patient movement, is superimposed on exercise ECG, also known as stress ECG.

III. Multidimensional Adaptive Filtering

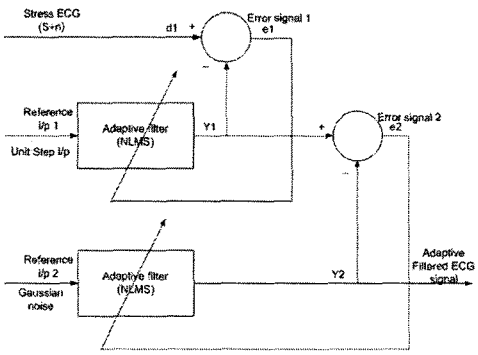


Fig. 1. Multidimensional adaptive filtering for ECG noise cancellation.

Figure (1) shows the Multidimensional adaptive filtering for ECG noise cancellation [3]. Primary input is raw ECG signal. First input reference signal is unit step signal for baseline wander noise and second input signal is random gaussian noise for denoising the ECG signal.

The adaptive filter is usually implement as a finite impulse response (FIR) with finite number of weights, due to its computational stability. The filter weight are adjusted using Normalized Least Mean Square (NLMS) algorithm [4]. Its form, implementation is simple and also provide high performance during adaptation process. The NLMS algorithm has step-size parameter, that need to be selected properly to control stability and convergence speed of algorithm. In noisy ECG, S is the useful ECG and n the noise signal.

$$e1=d1-y1=S+n-y1 \quad (1)$$

Squaring the output:

$$e1^2= (S+n)^2-2y1(S+n)+y1^2$$
$$= (S-y1)^2+n^2+2n(S-y) \quad (2)$$

Taking the mathematics expectation of both sides:

$$E(e1^2)=E[(S-y1)^2]+E[n^2]+2E[n(S-y)] \quad (3)$$

Since n is uncorrected with S and y1 the equation (3) becomes:

$$E(e1^2)=E[(S-y1)^2]+E[n^2] \quad (4)$$

if we minimize error:

$$\min E(e1^2)= \min[E[(S-y1)^2]+E[n^2]] \quad (5)$$

Equation (5) shows that when the average power of the error e1 is minimized, the output y1 is then the best least means square estimation of ECG(S).

For e2:

$$e2=y1-y2 \quad (6)$$

squaring both sides:

$$e2^2=(y1-y2)^2 \quad (7)$$

Taking mathematical expectation of both sides:

$$E[e2^2]=E[(y1-y2)^2] \quad (8)$$

minimizing the error:

$$\min E[e2^2]=\min E[(y1-y2)^2]=0 \quad (9)$$

then the output is the best least mean square estimation of the ECG (S)

IV. Results and Discussion

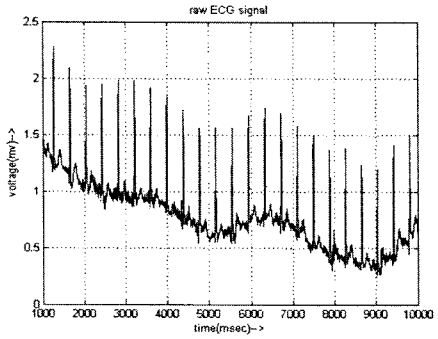
Figures shows MATLAB's results using its built-in NLMS functions. In figure 2(a) shows the Stress ECG signal when person running on tread mill. This signal have basically baseline

wander noise, EMG noise and motion artifacts.

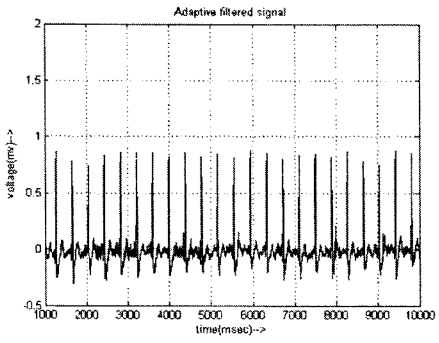
On this raw ECG the adaptive filtering is applied for removing baseline wander noise with unit step input as reference signal so resultant baseline filtered ECG signal shows in figure 2(b). which still have EMG noise and motion artifacts.

Next step of filtering is suppression of EMG noise with adaptive filtering by having random gaussian noise as reference signal which doesn't have any correlation with ECG signal but strongly correlated with EMG noise, resultant ECG signal shows in figure 2(c). By comparing figure 2(b) and 2(c), it's analyzed that noise level of signal 2(c) is comparatively reduce and more clear.

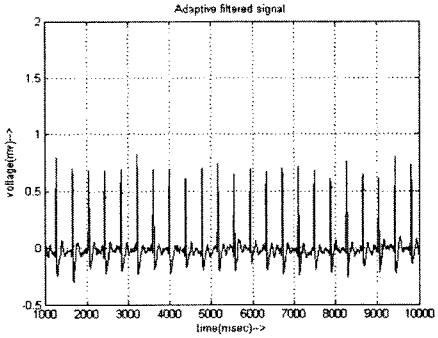
After multidimensional adaptive filtering the resultant filtered signal is figure 2(c), then ECG signal is smooth out with smoothing command in MATLAB which remove the very low frequency from ECG signal resultant wave is shown in figure 2(d). which is more clear than figure 2(a) and noise level is also low.



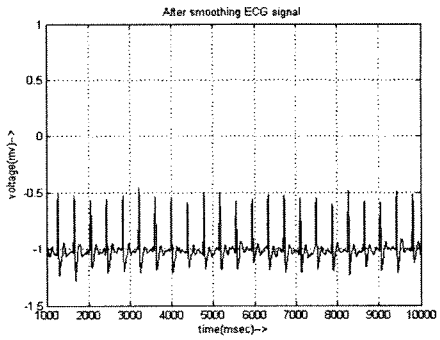
(a)



(b)



(c)



(d)

Fig. 2. (a) Shows Raw stress ECG signal (b) Baseline filtered ECG signal (c) resultant output from Multidimensional Adaptive filter (d) smoothing ECG signal after adaptive filtering

An FIR (finite impulse response) filter order is 5 and adaptive step size parameter (μ) are 0.01 used for base line wander noise reduction and filter order 7 are used for further adaptive filtering.

The values of filter order and adaptation steps size parameters are the values which represent a compromise between a good convergence and a good stability of the filter. After adaptive filtering smoothing function is used for removing very low frequencies from ECG signal, which smooth out ECG signal at some level and give more clear ECG signal.

V. Conclusion

In this paper the multidimensional adaptive filtering technique used for denoising the ECG

signal. By comparing figures we can analysed noise level is reduced at some level after filtering and before filtering.

Although after filtering resultant ECG signal have motion artifact at some level those are very difficult to remove due to reference signal. Because motion artifacts are changes gradually with time according to not only human movement but also human posture, activity and device movement also, so if accelerometer attach with the ECG sensor even than accelerometer can only detect human movement neither his posture nor device movement. So its hard to find the correlation between acceleration signal and noise present in ECG signal due to motion artifact. Future work is on going to motion artifact cancellation with efficient method.

REFERENCES

[1] N.V. Thakor and Y. Zhu, "Aplications of adaptive filtering to ECG analysis: noise cancellation and arrhythmia detection",IEEE Trans. Biomedical Engineering, Vol.38, NO.8,pp. 785-794,August 1991.

[2] Mary Anne D. Raya,Student member, IEEE and Luis G. Sison, Phd,member, IEEE instrumentation"Adaptive Noise Cancelling of Motion Artifact in Stress ECG signals Uing Accelerometer"EMBS/BMES conference,2002

[3] Yasmina Bensadoun,Emile Novakov, member IEEE, and Kosai RAOOF, member IEEE. "Multidimensional Adaptive Method For cancelling EMG Signal From The ECG signal" 1995 IEEE-EMBC and CMBEC Theme 1: cardiovasculae system.

[4] Alexander D. poularikas Zaved M. Ramadan "Adaptive filtering primer with matlab"