Motion Artifact Cancellation in Plethysmography Signal

Swetal K.Phepale, Pranav K.Patil, Jyothi S.Warrier, Aparna S.Lakhe

Abstract— Photoplethysmogram(PPG) is a non-invasive technique that measures relative blood volume changes in the blood vessels close to the skin.Photoplethysmogram(PPG) signal provides useful cardiovascular information .The PPG signal acquired using NI-DAQ card from heart rate monitorning system are usually corrupted with Motion Artifact(MA) due to voluntary or involuntary movement of patient. Here we proposed different method for motion artifact suppression of PPG signal such as Adaptive Line Enhancement (ALE) and Wavelet transform.The mean, standard deviation and SNR are calculated for motion artifact corrupted PPG signal as well as motion artifact suppressed PPG signal using Adaptive Line Enhancement (ALE)and Wavelet transform.

Index Terms— Photoplethysmogram, blood volume, NI-DAQ card, cardiovascular, motion artifact (MA), Adaptive line enhancement (ALE),Wavelet transform

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1 Introduction

Photoplethysmogram (PPG) is an optically obtained plethysmogram, a volumetric measurement of an organ.[6] Light travelling through a capillary bed whose absorption and reflection properties change in response to changes in volume of the vessels. The PPG signal consists of two components referred to as AC and DC component. The AC component is caused by the pulsatile changes in arterial blood volume and is synchronous with the heart beat because of which it can be used as a source for the heart rate information.[5] The DC component is caused by the tissues and average blood volume that superimposes with the AC component. The DC component should be removed from the whole signal to get desired information of heart rate from the AC component. Photoplethysmogram (PPG) can be used in clinical assessment such as heart rate estimation, blood pressure measurement and extraction of atrial flow waveform. Here photoplethysmogram signal is obtained from sensor .Reflectance type of PPG sensor has been used to diagnose the parameters. A heart rate monitoring instrument makes use of photoplethysmogram (PPG) signals acquired with the help of suitable sensors attached to the finger of the volunteer. However, photoplethysmogram signal are usually corrupted by motion artifact (MA) due to voluntary or involuntary movements of the volunteer while acquiring the data. Particularly, the motion artifacts cannot be easily managed because of the frequency overlapping between PPG signal and the motion artifact signal.[7] Typically the frequency band caused by motion artifact is 0.1Hz and above. The normal frequency range of PPG signal is 0.5 to5 Hz and hence the overlapping makes the use of classical signal processing techniques impractical in order to separate it. Here we have used different method for motion artifact suppression of PPG signal such as Adaptive line enhancement and Wavelet transform. According to Widrow, ALE is an adaptive self-tuning filter capable of separating the periodic and stochastic components in a signal and it's based on adaptive filter algorithm. Wavelet Transform method is also used for motion artifact suppression.

- Swetal.K.Phepale is currently pursuing masters degree program in biomedical engineering inMGMCET,Mumbai University, India.
- Pranav.K.Patil is currently pursuing masters degree program in biomedical engineering inMGMCET, Mumbai University, India.
- Jyothi.S.Warrier is working as assistant professor in biomedical engineering inMGMCET,Mumbai University, India.
- Aparna.S.Lakhe is working as assistant professor in biomedical engineering in MGMCET,Mumbai University, India.

2 Material and methods

PPG signal which was acquired from heart rate monitoring system through laptop using NI-DAQ (USB-6009) card and data acquisition at a sampling rate of 500 Hz.display in Lab VIEW software. The data was processed in matlab software to suppress the motion artifact using various methods and various graphs were plotted.

2.1 Motion Artifact Suppression using Adaptive Line Enhancement

In adaptive filtering a sample from input signal $x(n)$ and desired signal $d(n)$ is fed to the filter.It computes corresponding output $y(n)$, depending on the adjustable parameter weight.The weight vector is defined as

$$w(n)=[w_0(n)w_1(n)......w_{L-1}(n)]^T$$

Where $w_i(n)$ are L parameter of filter at time n$(0 \le i \le L-1)$.The output $y(n)$ is computed as

$$y(n)=\sum_{i=0}^{L-1} w_i(n)x(n-i)$$

The output $y(n)$ is compared to desired signal $d(n)$ by substracting the two samples at time n, the difference, called error signal $e(n)$,can be given as

$$e(n) = d(n) + y(n)$$

This error signal is fed back to the filter to adapt the weight from time n to time $(n+1)$,with the increment of time index n,filter output converges to the desired signal by reducing the error.[8]It is always not possible to obtain the reference or desired signal as in this particular case.In such circumstances it is derived from the input by introducing a delay and the technique is called adaptive line enhacement.[4]In ALE,as shown in Fig.1.The input signal serves as desired signal $d(n)$ and $x(n)$ is derived from the desired signal as

$$x(n) = d(n-\Delta)$$

Where Δ is the integer value of delay.

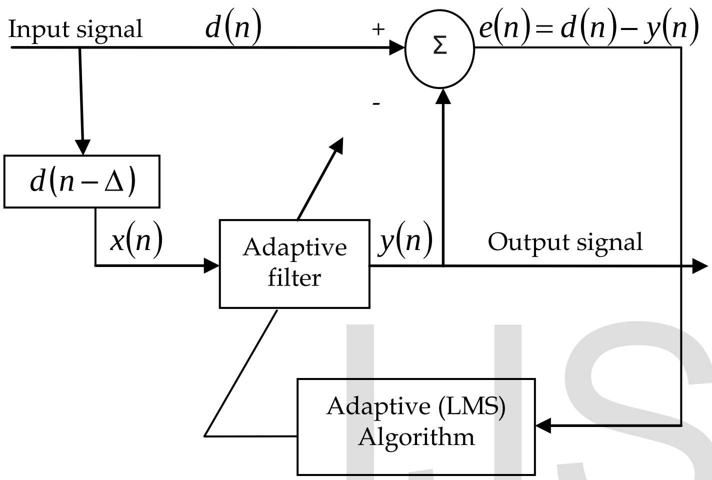


Fig1: Block diagram of adaptive line enhancer.

The delay is set such that broad band components in $d(n-\Delta)$ become uncorrelated from those in $d(n)$.The delay should be greater than the decorrelation time of the broad band signal (BB) and less than the decorrelation time of the narrow band signal (NB).[9]

$$Td(BB) < \text{delay} < Td(NB)$$

The Least mean square algorithm is used to update weights for the adaptive filtering.weights are updated as

$$w(n+1) = w(n) + \mu e(n) x(n)$$

Where μ is the step size.

2.2 Motion Artifact Suppression using Wavelet Transform

In wavelet decomposition the signal is decomposed into shifted and scaled versions of the original wavelet.The low frequencies correspond to high scales and a dilated wavlet function. At high scales, the global information is obtained called as approximations. At low scales the fine information is obtained called as detail levels.The acquired PPG signal which is analysed sequentially. It consists of three successive procedures: decomposition, level based thresholding and signal reconstruction.[2,3] The wavelet selection is very important factor in any type signal processing. Here we are going to process the PPG signal. Depending on the shape of signal we will select the wavelet. The Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function (called the father wavelet). [1]The various types of daubechies wavelets are shown in Fig.2. Out of which db4 is having same shape as our PPG signal. Therefore we are using the db4 wavelet for artifact suppression.Firstly; the wavelet transform is derived to a chosen level10 .Secondly, detail coefficients from level 1 to10 are threshold using db4 wavelet. Lastly, the original signal is synthesized using the altered detail coefficients from level 1 to 10 and approximation coefficients of level 1to10.[11]Detailed levels and approximate levels are shown in Fig. 3 & Fig. 4 respectivly. 8th approximate level was taken as reconstructed signal.

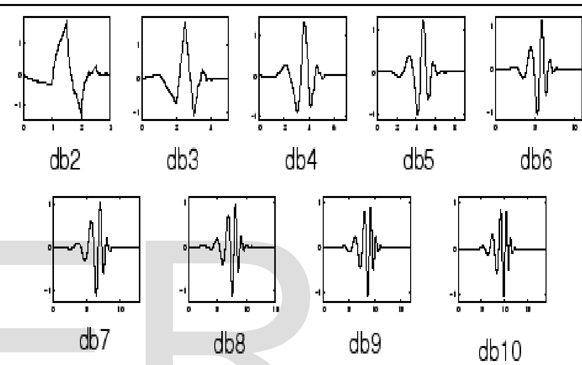
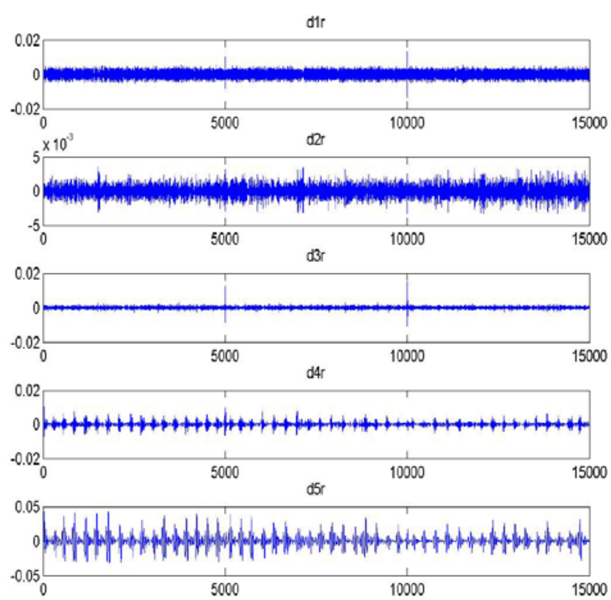


Fig. 2. Different types of daubechies Wavelet

Figure 2: Different types of daubechies wavelet



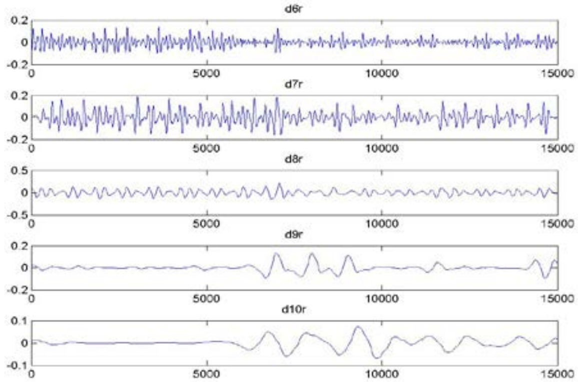


Fig.3.Detailed level (d1r to d10r) using db4 wavelet decomposition

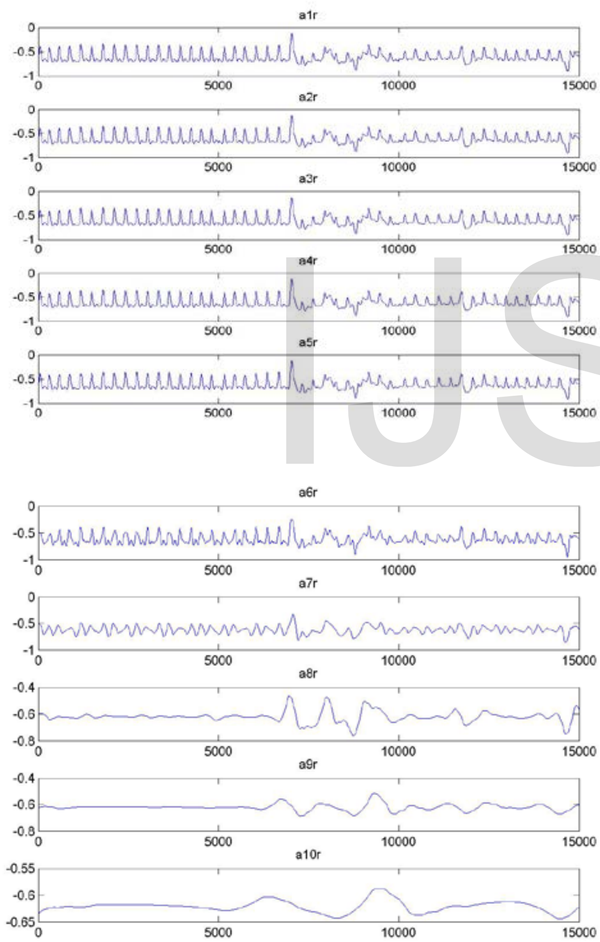


Fig.4.Approximate level (a1r to a10r) using db4 wavelet decomposition

3 RESULT AND DISCUSSION

Experiments were carried out on 5 volunteers within the age group of 21–30.Motion artifacts were intentionally created, and the PPG signal were recorded with movement of finger. Each recording was done for a span of 2 min, for all the subjects tested for all the movements. A typical PPG signal corrupted with the motion of the finger is shown in Fig. 5.

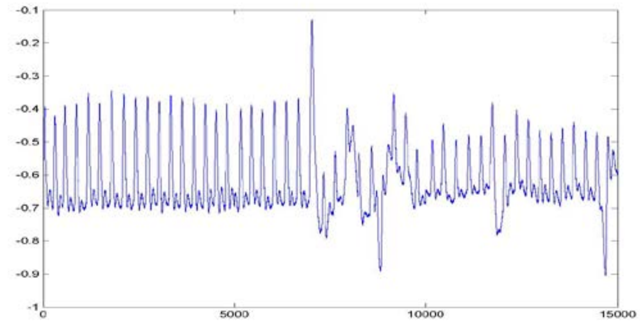


Fig.5.Motion artifact corrupted PPG signal

3.1 Motion artifact suppression using Adaptive Line Enhacement

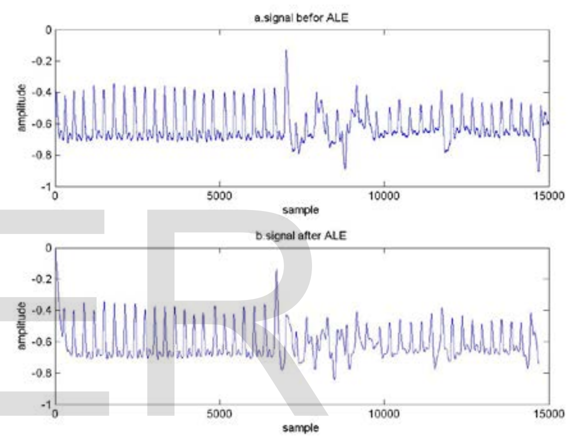


Fig. 6.PPG signal (a).signal befor ALE. (b).signal after ALE

Fig.6 (a) shows the waveform of motion artifact corrupted PPG signal and Fig.6 (b) signal after ALE filter.In Fig.6 (b) the high frequency noise and very small portion motion artifact suppress

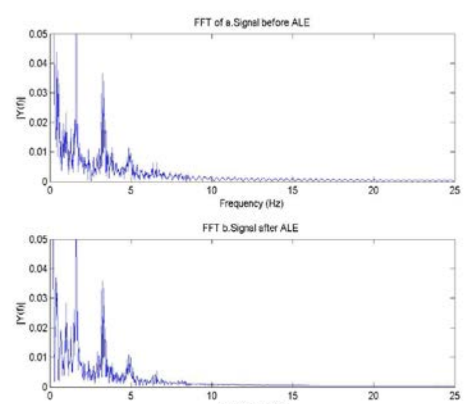


Fig. 7. FFT of PPG (a).signal befor ALE.(b)signal after ALE.

From approach in Fig.7 (a) shows FFTof PPG signal befor ALE and Fig.7 (b) shows FFT of PPG signal after ALE.observed frequency of peak and calculated delay.

3.2 Motion artifact suppression using Wavelet Transform

Fig.8 (b) Reconstructed PPG signal using approximate 8th level is substracting from original PPG signal.Fig.8 (b) shows the motion artifact suppression is better than Fig.6 (b).

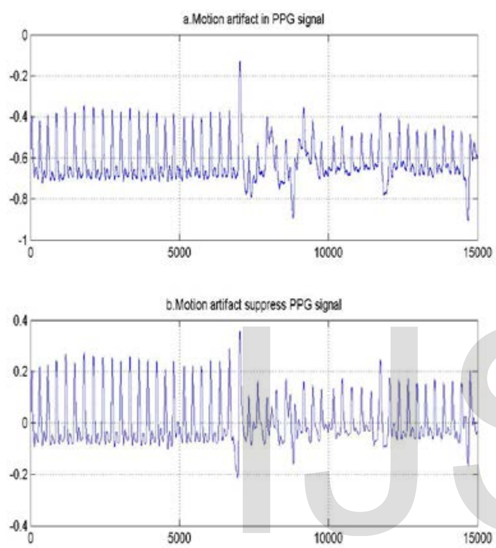


Fig. 8. (a)Motion artifact corrupted PPG signal.(b)Motion artifact suppress PPG signal.

The statistical analysis is carried for five subject.We have suppressed motion artifact from motion artifact corrupted PPG signal and calculated the Mean, Standard deviation and SNR of motion artifact corrupted PPG signal as well as artifact suppression methods.as shown in table 1,table2,table3.

TABLE 1
MEAN,STANDARD DEVIATION AND SNR OF MOTION ARTIFACT CORRUPTED PPG SIGNAL

Subject	Mean	Standard Deviation	SNR(dB)
1	0.7801	0.0863	19.12
2	0.7806	0.0868	19.07
3	0.7826	0.0795	19.86
4	0.7807	0.0743	20.43
5	0.7805	0.1028	17.60

TABLE 2
MEAN,STANDARD DEVIATION,SNR OF MOTION ARTIFACT SUPPRESS PPG SIGNAL USING ADAPTIVE LINE ENHANCEMENT

Subject	Mean	Standard Deviation	SNR(dB)
1	0.7854	0.0877	19
2	0.7942	0.0851	19.4
3	0.791	0.0852	19.3
4	0.79	0.108	17.2
5	0.7892	0.0743	20.52

TABLE 3
MEAN,STANDARD DEVIATION AND SNR OF MOTION ARTIFACT SUPPRESS PPG SIGNAL USING WAVELET TRANSFORM

Subject	Mean	Standard Deviation	SNR(dB)
1	1.4	0.079	24.9
2	1.39	0.075	25.3
3	1.4	0.065	26.5
4	1.3	0.094	23.38
5	1.4	0.071	25.8

4 CONCLUSION

The Mean, standard deviation and SNR of PPG signal contaminated with motion artifact and after suppression of the artifact using adaptive line enhancement and wavelet transform were calculated.The wavelet transform is found to be better technique for suppression of motion artifact as compared to adaptive line enhancement.

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