iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5139

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Extraction of Respiratory Activity from Photoplethysmographic Signals

P. Rajesh[1], G. Jalalu[2]
[1, 2] Department of Electronics &Instrumentation Engineering, V .R. Siddhartha Engineering College, AP, INDIA.

Abstract: The clinical significance of certain cardiac arrhythmias can be understood only with reference to respiration. In normal healthy conditions, the respiratory rate is 10-20 breaths/minute. But, certain problems of illness, accidents or some other causes affect the regular sinus rhythm. A non-invasive, non-occlusive and non-intrusive respiration monitoring is desirable in a number of situations such as ambulatory monitoring, stress tests and sleep disorder investigations. Such methods are based on deriving the respiratory activity from signals such as the electrocardiogram (ECG), the photoplethysmogram (PPG). There have been several efforts for such a purpose particularly in the case of ECG-Derived Respiration (EDR). This paper presents an efficient filtering technique with a pre-processing block for extraction of respiratory signal from PPG signal. A PPG is obtained by illuminating a part of the body of interest and acquiring either the reflected or transmitted light. As the PPG signals are most frequently corrupted by the motion artifacts, the pre-processing block essentially includes a motion artifact reduction algorithm. We applied an efficient algorithm based on singular value decomposition (SVD) to extract artifact-free PPG signals. The power spectral density (PSD) of the artifact-free PPG signal, thus obtained, clearly indicates the respiration induced component in addition to the heart rate. An adaptive FIR filter, designed in frequency sampling method with suitable specifications drawn automatically from the PSD, efficiently separated heart and respiratory related signals. The respiratory rate is estimated by an automatic peak-detection algorithm applied on the extracted respiratory signal. The results indicate the efficacy of the proposed method.
Keywords: Photoplethysmogram (PPG), Electrocardiogram (ECG) Respiratory signal, Power Spectral Density (PSD)

I. INTRODUCTION

Photoplethysmography is a non-invasive electro-optic method developed by Hertzman, which provides information on the blood volume flowing at a particular test site on the body close to the skin. A photoplethysmogram (PPG) is obtained by illuminating a part of the body of interest with either red or infrared light and acquiring either the reflected or transmitted light [1]-[2]. PPG waveform contains two components; one, attributable to the pulsatile component in the vessels, i.e. the arterial pulse, which is caused by the heartbeat, and gives a rapidly alternating signal (AC component). The second one is due to the blood volume and its change in the skin which gives a steady signal that changes very slowly (DC component). PPG signal consists of not only the heart-beat information but also a respiratory signal. Heart rate (or pulse rate) and respiratory rate are two important vital signs, they are of great importance when critically ill adults and newborn infants are monitored. Clinical monitoring of heart rate is generally performed by counting QRS complexes of the electrocardiogram (ECG) per time unit. As the AC component of PPG signal is synchronous with the heart beat and thus can be identified as a source of heart rate information. In addition to heart-synchronous variations, the PPG signal contains respiratory-induced intensity variations (RIIV) [2]-[4]. As it is well recognized that there are breath related characteristics in the ECG, much work has been done on ECG derived respiratory activity [5]-[9], however significant work is to be done on deriving respiratory activity from PPG signals. Analog filters with required cut-off frequencies can be used to separate the heart signals and respiratory signals from the PPG signals. However, this technique is difficult to use during stress tests, because of the continuous variation of respiratory rate. Whereas a digital filter designed in frequency domain can give better result in extracting the respiratory information from the PPG signals. Continuous digital filtering of PPG signal can be used to extract the respiratory effort during the stress tests by continuously adopting to the frequency variations in the respiratory activity. We have developed such a digital filter with continuously adoptable cut-off frequencies to separate the respiratory information from the PPG signals.

II. SIGNAL ACQUISITION AND PROCESSING

To verify the practicality of the proposed technique for extraction of respiratory information from a PPG signal, the necessary hardware for sensing and software for acquiring and processing the PPG signals have been developed. A clip-on-type sensor with two light-emitting diodes (LEDs) (an IR and a red) on one side and a photodiode on the other side of a soft plastic clip was

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

developed. The plastic clip is shaped such that the clip snugly fits on the finger of a person. The drives to the LEDs were time sliced, and the output from the photodiode is suitably demultiplexed to separate the red and IR PPG signals. The analog red and IR PPG signals are then acquired with a 16-bit resolution data acquisition card NI DAQPad-6015 manufactured by National Instruments. Fig. 1 shows the experimental setup. The data were acquired at a sampling rate of 200 Hz and processing of the acquired samples was accomplished under the Lab VIEW environment.

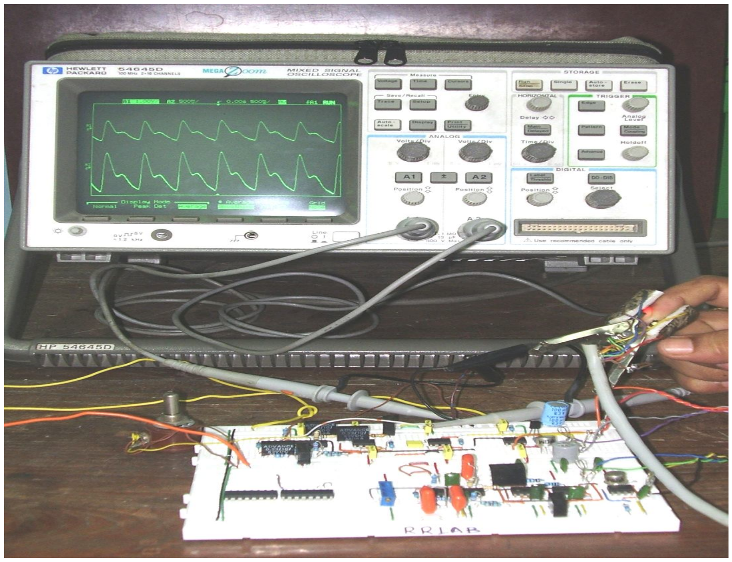

Fig. 1 Developed analog front-end for PPG

Experiments were carried out on ten volunteers within the age group of 22–35 after obtaining "informed consent." A typical PPG signal recorded from one of the subjects, for duration of 130 seconds, along with the spectrum of the recorded signal is shown in Fig. 2. The spectrum clearly shows frequency components belonging to the respiratory effort along with motion artefacts. After acquiring the PPG signal from the subject the same is being pre processed by an SVD block to reduce the motion artifacts. This is only to suppress that no motion artifact should be falling in the frequency range of respiration.

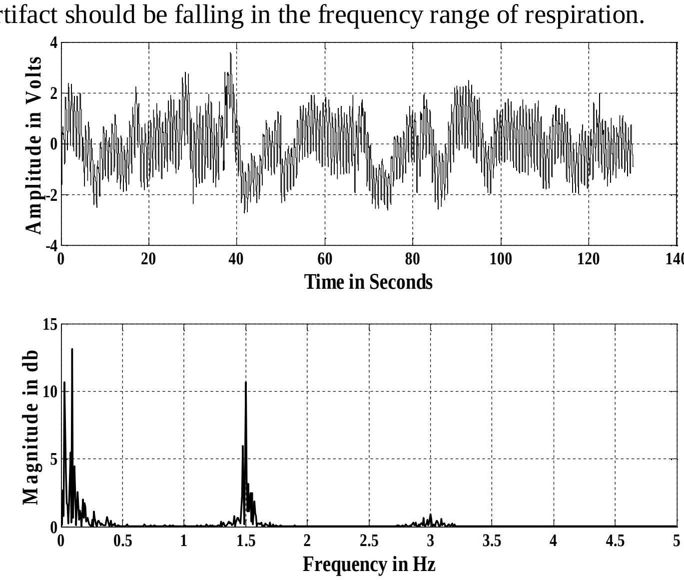

Fig. 2   Artifact corrupted PPG signal recorded from a volunteer in top trace and its spectrum in bottom trace

III. SVD FOR MOTION ARTIFACT REDUCTION

Even slightest movement of the patient would disturb the contact between the sensor and the patient's body, corrupting the PPG obtained during such periods with motion artifacts, resulting erroneous estimation of respiratory effort. Hence, processing of PPG signals with a view to remove or reduce motion artifacts, if any, present in PPG signal is of particular concern in the context of

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

extraction of respiratory activity from PPG signals. Using different techniques like filtering, wavelets and ICA analysis [10]-[14] have been addressed earlier but are not statistically independent of motion artifacts. Whereas using singular value decomposition (SVD) method would preserve the respiratory information and only remove the motion artifacts [15]. SVD is performed in MATLAB environment. A typical waveform of motion artifact corrupted signal is shown in Fig 3, which also shows a motion artifact free signal which is being obtained after applying SVD on the raw data of PPG signal.

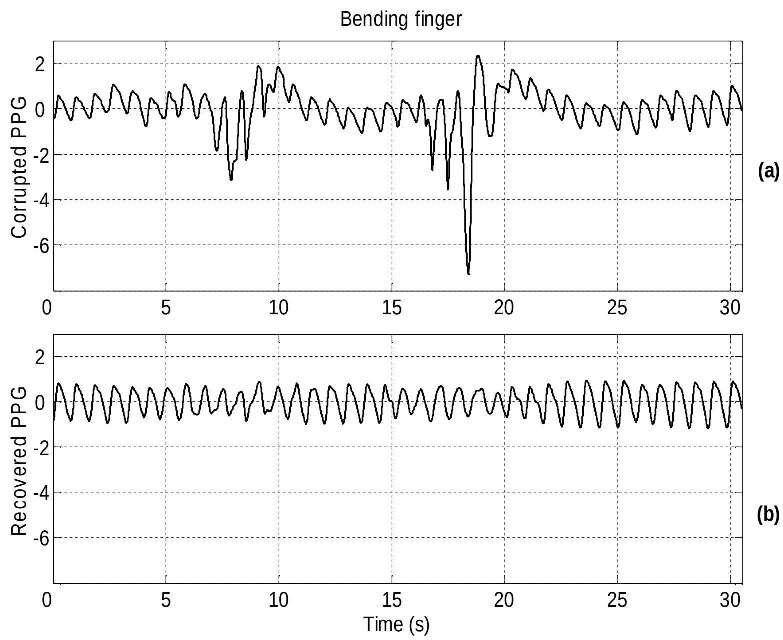

Fig. 3 Artifact corrupted PPG in top trace and reconstructed PPG using SVD based algorithm in bottom trace

IV. ADAPTIVE FIR FILTER FOR EXTRACTION OF RESPIRATORY SIGNAL

Digital filters are basically algorithms which can be implemented for processing the digital data and mainly divided into two categories: infinite impulse response (IIR) and finite impulse response (FIR) filters. Input and output signals to these filters are related by the convolution sum. The basic relation for calculating the current output for IIR filter can be given as

$$y(n) = \left\{\sum_{k=0}^{N} a_k x(n-k)\right\} - \left\{\sum_{k=1}^{M} b_k y(n-k)\right\} \quad (1)$$

And the of an FIR can be given as

$$y(n) = \sum_{k=0}^{N-1} a_k x(n-k) \quad (2)$$

where a_k and b_k are the coefficients of the filters, and N & M are the number of values of a_k and b_k, respectively. FIR filters requires larger N for sharp cut-off filters than IIR filter. Therefore for given amplitude response specification, more processing time and storage are required by FIR implementation. But in some cases FIR filters are more advantageous, because FIR filters can be constructed to have a strictly linear phase response, so that no phase distortion is introduced into the signal by the filter. FIR filters can be realized nonrecursively, by a direct evaluation equation (2), are always stable. And also the affects of using a limited number of bits to implement filters such as round-off noise and coefficient quantization errors are much less severe in FIR filters than in IIR filters. Finally a DSP processor or computer can calculate and extract rapidly the respiratory effort information, from the PPG signal for real-time monitoring of respirator information

The FIR filter can be designed in two different ways. One is the windowing method and the second is frequency sampling method. The second method provides us another means for designing linear phase FIR filters, in this paper particularly we use frequency sampling method, because its major advantage lies in the efficient frequency sampling structure, which is obtained when most of frequency samples are zero. Typical values of such an FIR band pass filters designed with the required specifications are shown in Table I, to extract the respiratory information from the PPG signal.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

TABLE I. FILTER SPECIFICATIONS

Filter type	pass band (Hz)	Transition width (Hz)	Pass band ripple (dB)	Stop band attenuation (dB)
BPF	0.15- 0.33	0.33 – 0.4	5	140

For the specified, desired frequency response $H_d(w)$ at a set of equally spaced frequencies namely

$$\omega_k = \frac{2\pi}{M}(k+\alpha), \quad k = 0,1,.....,{(M-1)}/{2}, \quad M \ odd \qquad (3)$$

$$k = 0,1,.....,\frac{M}{2}-1, \quad M \ even$$

$$\alpha = 0 \ or \ \frac{1}{2}$$; where M is the order of filter

and solve for unit sample response h (n) of the FIR filter from these equally spaced frequency specifications.
If the desired response of the FIR filter is $H_d(w)$ given as

$$H(\omega) = \sum_{n=0}^{M-1} h(n) e^{-j\omega n} \qquad (4)$$

Then

$$H(k+\alpha) = H\left(\frac{2\pi}{M}(k+\alpha)\right) \qquad (5)$$

$$H(k+\alpha) = \sum_{n=0}^{M-1} h(n) e^{-j2\pi(k+\alpha)n/M}, \quad n = 0,1,....,M-1 \qquad (6)$$

Since, h(n) is real that the frequency samples satisfy the symmetry condition.

$$H(k+\alpha) = H^*(M-k-\alpha) \qquad (7)$$

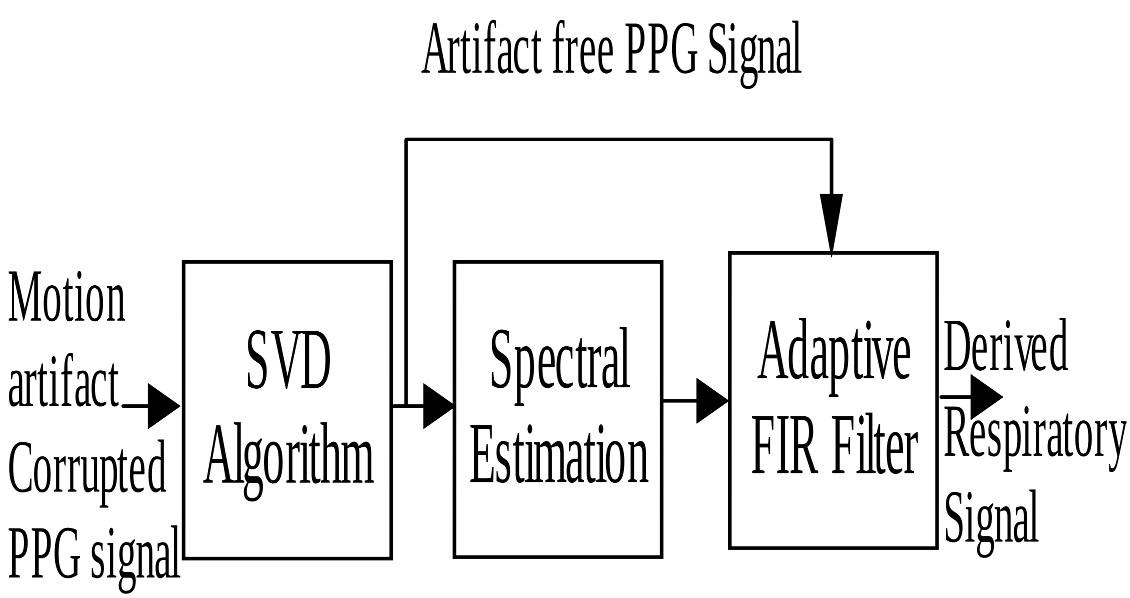

Fig. 4 Block diagram of filter.

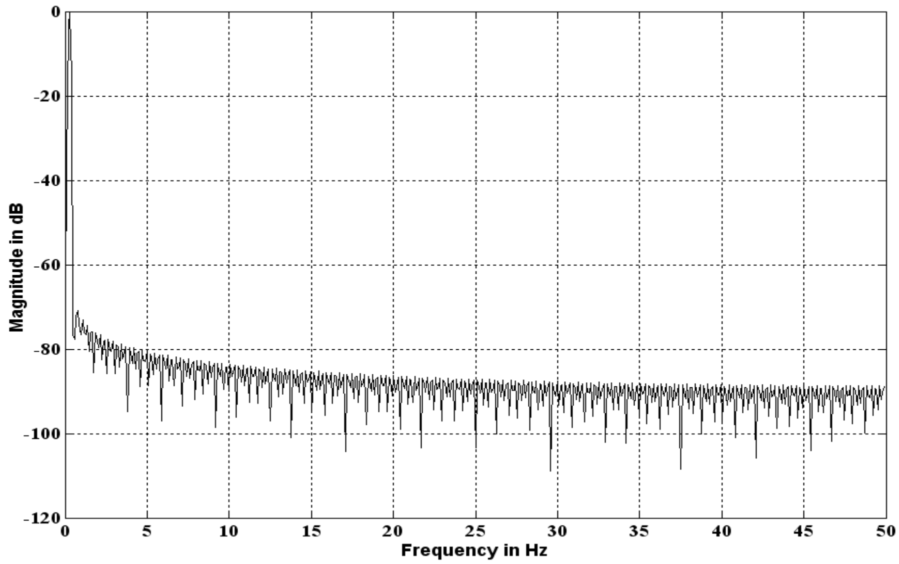

Fig. 5 Filter Response

V. RESULTS AND DISCUSSION

The filter is adaptive in the sense that the filter specifications automatically change according to the characteristics of the PPG signal encountered by the filter. The extracted respiratory signal and its spectrum are shown in Fig. 4. An automatic peak-detection algorithm applied to the extracted respiratory signal estimated the respiratory rate of the subject to be 13.4 breaths per minute. Original breath rate of the subject during PPG recording was 13 breaths per minute, which is in good agreement with the estimated breath rate. Presently, the effort is in the direction of simultaneous recording of ECG and PPG signals from a subject so that the PPG derived respiratory activity is comparable with EDR.

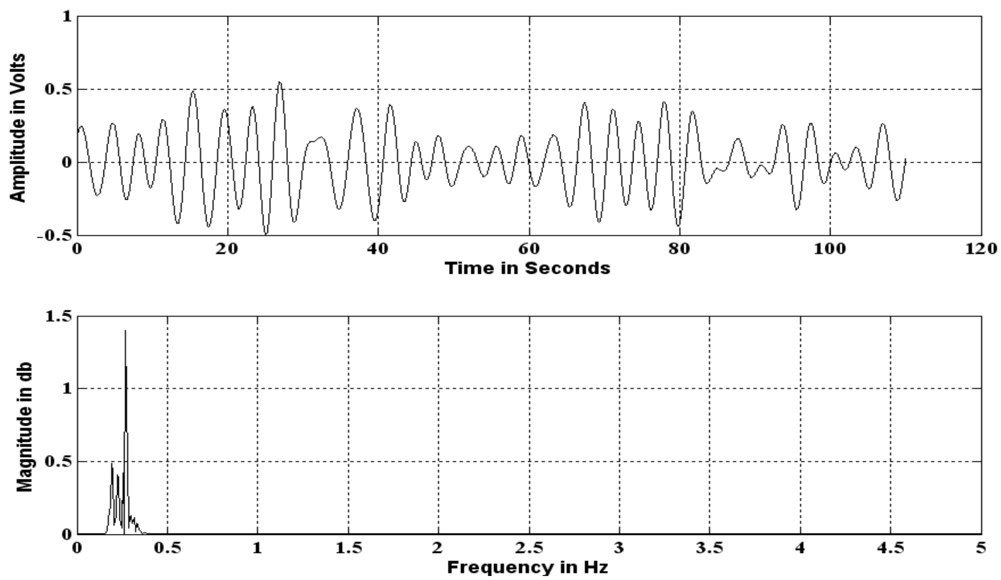

Fig. 6 Extracted respiratory signal in top trace and its spectrum in bottom trace

VI. CONCLUSION

PPG signals have important clinical applications. Among such, the relationship between respiration and PPG signal has attracted attention of researchers. An efficient method based on adaptive band pass filtering technique to extract the respiratory information is being addressed in this paper. The results revel that the extracted respiratory signal is with in the acceptable limits and can be used as an effective tool for monitoring the patient's respiratory information along with the vital recording of PPG and ECG signals. Presently, the effort is in the direction of simultaneous recording of ECG, PPG and trans-thoracic impedance-plethysmographic signals from subjects so that the PPG derived respiratory activity can be compared with EDR, for which the authors are working on simultaneous ECG-PPG recording experimental set-up.

REFERENCES

[1] AB Hertzman, " The blood supply of various skin areas as estimated y photoelectric plethysmograph," Am. J. Physl.,vol.124. pp. 328-340, 193
[2] Y. Mendelson and B. D. Ochs, "Noninvasive pulse oximetry utilizing skin reflective photoplethysmography," IEEE Trans. Biomed. Eng., vol. 35, no. 10, pp. 798-805, 1988
[3] A. Johansson, L. Nilsson, S. Kalman, and P. Å. Öberg, "Respiratory monitoring using photpplethysmography," Proc. 20 th Ann. Conf. IEEE EMBS vol. 20, No.6, 1998
[4] Yue-Der Lin, Wei-Ting Liu, Ching-Che Tsai, and Wen-Hsiu Chen " Coherence Analysis between Respiration and PPG Signal by Bivariate AR Model," World Acady. of Scie. Engg. and Tech. 53, 2009
[5] L. Nilsson, A. Johansson and S. Kalman, "Monitoring of respiratory rate in postoperative care using a new photoplethysmographic technique", J. Clin. Monit., 2000, vol.16, pp.309-315
[6] Moody GB, Mark RG, Zoccola A, Manterso S, " Derivation of respiratory signals from Multi-lead ECGs" Computers in Cardiology, 1986, IEEE Computer Society Press vol. 12, pp. 113-116.
[7] A Travaglini, C Lamberti, J DeBie, and M Ferri, "Respiratory Signal Derived from Eight-lead ECG," in Computers in Cardiology Proceedings, vol. 25, pp. 65-68, 1998.
[8] P Varady, T Micsik, S Benedek, and Z Benyo. A Novel Method for the Detection of Apnea and Hypopnea Events in Respiration Signals. IEEE Transactions on Biomedical Engineering, vol. 49, no.9, pp. 936-942, 2002.
[9] S.Ding, X. Zhu, W. Chen and D. Wei, "Derivation of respiratory signal from single-channel ECGs based on Source Statistics," International Journal of Bioelectromagnetism, vol. 6, 2004.
[10] J. Lee, W. Jung, I. Kang, Y. Kim and G. Lee, "Design of filter to reject motion artifact of pulse oximetry," Computer Standards and Interfaces, vol. 26, no. 3, pp. 241-249, 2004.
[11] Y. S. Yan, C. C. Poon and Y. T. Zhang, "Reduction of motion artifact in pulse oximetry by smoothed pseudo wigner-ville distribution," J Neuroengineering Rehabil., 2005, 2:3, available from http://www.jneuroengrehab.com/content/2/1/3
[12] C. M. Lee and Y. T. Zhang, "Reduction of motion artifacts from photoplethysmographic recordings using a wavelet denoising approach," in Proc. IEEE EMBS Asian-Pacific Conf. on Biomed.Engg., pp. 194- 195, 20-22 Oct. 2003.
[13] B. S. Kim and S. K. Yoo, "Motion artifact reduction in photoplethysmography using independent component analysis," IEEE Trans. Biomed. Engg., vol. 53, no. 3, pp. 566- 568, 2006.
[14] J. Yao and S. Warren, "A short study to assess the potential of independent component analysis for motion artifact separation in wearable pulse oximeter signals," in Proc. 27th Annual Conf. IEEE Engg. Medicine and Biology, pp. 3585-3588, 1-4 Sept. 2005
[15] K. A. Reddy and V. J. Kumar, "Motion artifact reduction in photoplethysmographic signals using singular value decomposition," in Proc. 24th Int. Conf. IEEE, IMTC-2007, Warsaw, Poland, pp. 1-4, 1–3 May, 2007.