*THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE*

# Estimation of Heart Rate from Photoplethysmographic Signal Using SVR Method

**Remya Raj**
PG Scholar, Department of Electronics and Instrumentation, Karunya university, India
**Smily Jaya Jothi**
Assistant Professor, Department of Electronics and Instrumentation, Karunya University, India

***Abstract:***
*Photoplethysmography is a non-invasive technique that measures relative blood volume changes in the blood vessels near to the skin. The early evaluation of the cardiac diseases and respiratory diseases can be done easily through PPG analysis. It has been used to measure indirectly heart rate, blood oxygen saturation (SPO2) and many other biological parameters. The proposed methodology is to detect heart rate from the noisy PPG signal using the singular value decomposition (SVD) method.*
*General Terms: Herat rate, Singular Value Ratio (SVR), Orthonormal matrix, Bio kit Physiograph.*

***Key words:*** *Photoplethysmography, Singular Value Decomposition (SVD)*

**1. Introduction**

Photoplethysmography is a physiological signal measured to represent the flow of blood in the arteries below the surface of the skin. It can obtained by illuminating a part of the body extremities such as index finger or ear lobe with either infrared or red light and acquiring either the reflected or transmitted light [1] Heart pumps blood through the different arteries of the body in a rhythmic fashion known as cardiac cycle. This rhythmic flow of blood can be seen in decreasing degrees of clarity in arterial blood flow up until the level of capillaries. The rhythmic flow is barely apparent after the blood crosses over into the venous return. Thus it can be said that given a vascular bed the majority of the pulsatile blood flow is due to the arterial blood. Thus PPG wave represents the flow of blood in the arteries of the area being investigated. PPG contains abundance of information in its shape, height and timing. The second peak present in each of its period at an instance called "Dichrotic Notch" represents the closure of the aortic valve after the end of diastole, thus causing a momentary increase in blood volume of the arteries [6]. The time period between each of the successive periods of the PPG waveform represents the repetition of the cardiac cycle and thus can be used to calculate the heart rate manually.

The PPG signal has five different frequency components in the interval 0.007–1.5 Hz as it is composite in nature [2]. Sources of these frequency components may be relating to respiration, blood pressure control, thermoregulation, autonomous nervous system (ANS) and heart synchronous pulse waveform. only two components dominate the signal out of the five components, one is due to the pulsatile component corresponding to the blood flow in the vessels, i.e. the arterial pulse, caused by the heartbeat, and gives an alternating signal (AC component) and the other is, large quasi-DC component that relates to the tissues, bones and to the average blood volume which gives a steady signal. The DC component varies very slowly due to respiration. The fundamental frequency of pulsatile AC component is usually around 1 Hz, and varies according to the heart rate of subject under test. In this paper a new method is introduced to calculate the heart rate from the PPG. The underlying hypothesis of this methodology is to find the Singular Value Ratio (SVR) of the PPG signal using Singular Value Decomposition (SVD) method.

**2. Databases**

The data's needed for the analysis is taken from the bio kit physiograph using PPG sensor and PPG amplifier. Data's were taken for 1 minute duration with a sampling frequency of 100 HZ.

**3. Methodology**

*3.1. Singular Value Decomposition (SVD)*

Singular value decomposition (SVD) is an important tool of linear algebra. Singular value decomposition (SVD) can be looked at from three mutually compatible points of view. It is also a method for transforming correlated variables into a set of uncorrelated ones that better expose the various relationships among the original data items. SVD is a method for identifying and ordering the

dimensions along which data points exhibit the most variation. Most important point that emphasizes SVD is that once we have identified where the most variation is, it is possible to find the best approximation of the original data points using fewer dimensions. So for data reduction, SVD can be used as a better method.

SVD is based on a theorem from linear algebra which says that a rectangular matrix A can be broken down into the product of three matrices - an orthogonal matrix U, a diagonal matrix S, and the transpose of an orthogonal matrix V .

$A_{mn=} U_{mn} \ S_{mn} V_{nn}^{T}$

where $U^TU = I$, $V^TV = I$; the columns of U are orthonormal eigenvectors of $AA^T$ , the columns of V are orthonormal eigenvectors of $A^TA$, and S is a diagonal matrix containing the square roots of Eigen values from U or V in descending order. The fact that singular values of a given data matrix contains information about the noise level in the data, energy and rank of the matrix is exploited for signal processing (data compression, noise removal and pattern extraction). We now exploit this feature to remove motion artifacts from corrupted PPGs.

Generally PPG signal is in synchronous with the ECG signal, so it can provide heart rate information. The value of the heart rate is not constant, but the PPG signal is a periodic signal with continuous change in period as heart rate changes. The matrix formation of the PPG signal is done with the frequency of the PPG signal and the expected range of heart rate for each cycle of data. The SVD of these matrices will reduce the complexity of the data and there by remove the motion artifacts.

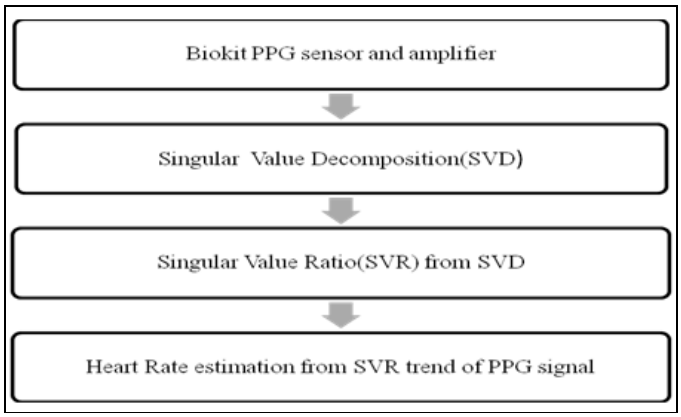


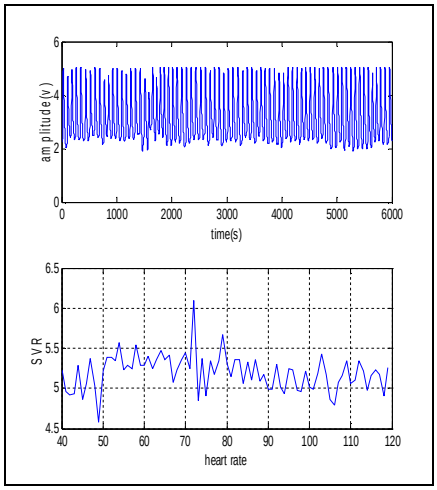

*Figure 1 : Flowchart Of The Proposed Methodology*

*3.2. Identifying Heart Rate using SVR*

SVD is applied to aligned data matrix, the ratio of first two singular values, called singular value ratio (SVR) is computed in each case of length of signal to be considered as a period for expected range of heart rates. The ratios are then plotted against the period to obtain graph called SVR spectrum of the signal. From SVR spectrum, the particular value of period for which the SVR is maximum, is considered as the heart rate. The methodology is clearly explained as flowchart in figure 1.

**4. Experimental Result**

The signals from biokit physiograph, having continuous recordings of PPG without any breaks for about 1 minute duration each, and the heart rate of the person which has taken manually were identified for use in assessing the performance of the algorithm estimation of heart rate to validate the algorithm. The estimated heart rate from PPG signal using SVR is shown in figure 2 and figure 3.



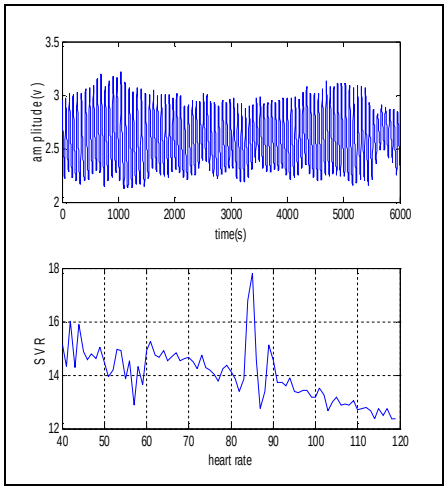




*Figure 2: Original PPG signal and the SVR trend of signal for first subject*

*Figure 3: Original PPG signal and the SVR trend of signal for second subject*

The figure 2 shows a heart rate of 72 beats per minute and figure 3 shows a heart rate of 85 beats per minute. Table 1 shows the comparison of the actual heart rate and the expected heart rate.

| Subject | Actual heart rate | Estimated heart rate |
|---|---|---|
| Subject 1 | 72 | 72 |
| Subject 2 | 83 | 85 |
| Subject 3 | 77 | 79 |
| Subject 4 | 69 | 70 |
| Subject 5 | 76 | 76 |
| Subject 6 | 78 | 78 |

*Table 1: Comparison of actual and estimated heart rate*

The estimated heart rate is compared with the actual heart rate for six subjects and a good correlation can be seen in the result.

**5. Conclusion**

Photoplethysmography is a promising technology due to its noninvasiveness, low cost, and simplicity, and. It has potential for early screening for various atherosclerotic pathologies .The heart rate is the most important parameter present in the PPG signal and its estimation can be easily done with the help of SVR method. The SVR method gives high correlation with that of actual output when compared to other techniques.

**6. Acknowledgments**

We extent our sincere thanks to our department and the authors for their support and guidance.

**7. References**

1. A. B. Hertzman, Jul. 1938 “The blood supply of various skin areas as estimated by photoelectric plethysmograph,” Am. J. Physl., vol. 124, pp. 328-340
2. A Ubel, D Gordon,S.Akselrod, ,F, 1981”Power Spectrum Analysis of Heart Rate Fluctuations Quantitative probe to beat to beat Cardiovascular Control,”Science,10:220-222
3. Asada HH, Hutchinson RC, Shaltis P, Sokwoo R, 2003 “Mobile monitoring with wearable photoplethysmographic biosensors,” IEEE Engineering in Medicine and Biology Magazine.; 22(3):28-40.
4. Bail ´on R ,Gil1 E, Laguna P, Mainardi L, Orini1 M, , Vergara J, 2010 ,. “Photoplethysmography pulse rate variability as a surrogate measurement of heart rate variability during non-stationary conditions. Physiological Measurement,”; 31(9):127-1290.
5. Bok Y. Lee , Lee E. Ostrander, June 1990,”Weijia Cui “In Vivo Reflectance of Blood and Tissue as a Function of Light Wavelength, “I EEE Transaction on Biomedical. Egg. Vol - 37, No. 6, pp.1-1
6. Deon Won Kim, Sung Woo Kim, 2007 “Detection of Diabetic Neuropathy Using Blood Volume Ratio of Finger and Toe by PPG,” Engineering in Medicine and biology Society, 2007.EMBS.29TH Annual international Conference of the IEEE. pp. 2211-2214.
7. Evans M, Geddes L, 1988” An assessment of blood vessel vasoactivity using photoplethysmography “Med Instrumentation; 22(1): 29-32.
8. Grabovskis A, Grube J, Rubins U, 2008, Kukulis I”Photoplethysmography Analysis of Artery Properties in Patients with Cardiovascular Diseases,” Springer Berlin Heidelberg.
9. H. Mike, K. Nakajima, T. Ohta, T. Tamura, 1996, , “Monitoring of heart and respiratory rates by photoplethysmography using a digital filtering technique”, Med. Eng. Phy., vol. 18, no. 5, pp. 365-372.
10. J.A.Blom, J.JSchreuder, J.R.C Jansen, S.A.A.PHoeksel, 1997,”Detection of dichrotic notch in arterial pressure signal,”J.clin.monit.comput vol 13,pp 309-316 09/01.
11. Janis Spigulis, 2005 “Optical Non-Invasive Monitoring of Skin Blood Pulsations‖”” Applied Optics Vol. 44, No.10.April.pp.1850-1857.
12. Kuo-Tai, Shing-Hong Liu, Tsu-Hsun Fu Tang, 2008”Heart Rate Extraction from PPG waveform Using Wavelet Multiresolution Analysis, “Journal of medical and biological engineering.
13. Lambert D, Lees T, 1993”Patterns of venous reflux in limbs with skin changes associated with chronic venous insufficiency,” British Journal of Surgery.; 80(6):725-8.
14. Liang YP, Pickwell-MacPherson E, Wang L, Zhang YT, 2009”Noninvasive cardiac output estimation using a novel photoplethysmogram index,”. Annual International Conference of the IEEE Engineering in Medicine and Biology Society.
15. M.H.Sherebin, R.Z. Sherebin, March 1999 “Frequency Analysis of Peripheral Pulse Wave Detected in the Finger with Photoplethysmography,”IEEE Transaction on Biomedical Engineering, Vol.37No.3.
16. Mohamed Elgendi, 2012, “On the Analysis of Fingertip Photoplethysmogram Signals,” Current Cardiology Reviews, 8, 14-25
17. Poon CCY, Teng XF, Wong YM, Zhang C, Zhang YT., 2004 “Changes in the photoplethysmogram waveform after exercise. Computer Architectures for Machine Perception,” 2003 IEEE International Workshop.
18. Shelley K., 2007“ Photoplethysmography: Beyond the Calculation of Arterial Oxygen Saturation and Heart Rate,” Anesth Analg.