Processing of Photoplethysmography (PPG) Signal Using Virtual Instrumentation

Arvind Raut[1], M.S.Panse[2]

[1]*Student M. Tech Electronics,* [2]*Professor*

Department of Electrical Engineering, VJTI, Mumbai, Maharashtra, India

Abstract **– Photoplethysmography (PPG) sensor is an optical sensor and is used to measure the blood volumetric changes occurring in the various parts of the body. They can be well utilized to extract information related to cardiovascular system. In this study the PPG signal is acquired at rate of 125Hz through Arduino and processed to determine the characteristic point such as peaks. In PPG signals analysis, the accuracy is affected by Motion Artifacts and noise. To remove these noises Wavelet transform is used and the performance is evaluated based on comparative results of cross correlation.**

Index Terms **— Photoplethysmography, cardiovascular system, Wavelet transform, Arduino, Motion artefact.**

I. INTRODUCTION

The Instruments used for measuring blood volume changes are called Plethysmographs and the technique is called Plethysmography. It is a non-invasive and widely adapted in a variety of wearable systems due to its ease of implementation. There is much information contained within PPG waveform, which may be interpreted with appropriate signal analysis [1] PPG signal comprise two components, first is pulsatile (AC) component and second non pulsatile (DC) component. Due to change in pulsatile blood volume it results in AC component. The DC component resulted due to background absorption which is the component without a pulsatile signal.

There are two PPG operational configurations one is transmission mode where the tissue sample e.g. Fingertip is placed between the source and photo detector, and in reflection mode where the LED and photo detector are placed side-by-side to tissue sample [2] The photoplethysmographic sensors are that to be attached to afinger, can be integrated into the ear-phones[3],can be implemented in a forehead band or used as a wristsensor[4].The noise may introduced at analog front end due to probe tissue movement i.e. by subject's movements, ambient light interference but it can be reduced using Velcro wrap around cuff. Also the power line noise gets added in signal, to remove these noises especially the motion artifact various approaches were proposed. Among them Fast Fourier transform (FFT) analysis signals have been shown to reduce the impact of motion artifact. However, FFT analysis has shown to perform poorly for quasi-periodic data sets [5].Different approach based on Adaptive Filters, for motion artifact reduction in PPG signals. But, in order to use adaptive filter technique, a reference signal is needed and it requires an additional hardware setup [6]-[8].

II. METHODOLOGY

In the area of biomedical technology, signal analysis and processing have importance, in this system LabVIEW (Laboratory Virtual Instrument Engineering Workbench) a product of National Instruments, is software that contains data acquisition, instrument control and data processing is used. Since it is graphical programming language the data flow can be visualized, different debugging tools provided to debug the code. Also it can be easily interfaced with various devices [12]. This section explains PPG signal acquisition, signal conditioning and peak detection of the proposed work.

A. *PPG Signal Acquisition*

Signal acquisition contains two hardware parts sensor and microcontroller where PPG sensor acquires data from subject fingertip and then give it to Arduino with analog pins, to convert signal into digital form through ADC. Arduino IDE environment which is written in java is programmed to acquire data and transmit it to LabVIEW

1) *PPG sensor*: It consists of a LED that transmits light Signal, through the fingertip of the subject a part of which is reflected by the blood cells by sensing the change in blood volume in a finger artery. The reflected signal is detected by a photo diode sensor. The change in blood volume results in a train of pulses at the output of the photo diode.

2) *Arduino:* Arduino is a microcontroller board having 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack and a reset button. In this system we simply connect it to a computer where LabVIEW platform is installed with a USB cable or it can be powered with an adapter or battery to get started.

B. *Signal Conditioning*

In this section PPG signal is processed to remove unwanted noise, firstly to remove power line noise signal is passed through a 50Hz notch filter. Then it is band passed.Further to remove the noise signal is given to wavelet denoise block i.e. undecimated wavelet transform (UWT) which is provided by LabVIEW software. Various wavelets can be used for decomposition and reconstruction of the signal. Unlike Discrete Wavelet Transform (DWT) as it down samples the approximation coefficients and detail coefficients at each decomposition level [9]. The undecimated wavelet transform (UWT) does not incorporate the down sampling operations [12]. This result in approximation of coefficients and detail coefficients at each level are the same length as the original signal.

C. Detection of PPG Peaks

After signal conditioning to detect the peaks an algorithm is developed, where samples are collected for 8 sec duration then for the current set of values maximum value is calculated to set threshold value. Samples are continuously added with removal of previous values. So this way threshold value is adapted to detect the Peaks, Valleys as well as detection of Secondary Peaks. The locations of peak detected can be used for calculation of P-P intervals [10].

III. RESULTS

The following results are shown in 8 Second window formats which are processed and displayed simultaneously The PPG signal is collected at sampling rate of 125Hz is shown in fig1. It shows noise content, to remove noise the wavelet denoising is used shown in following fig2, fig3

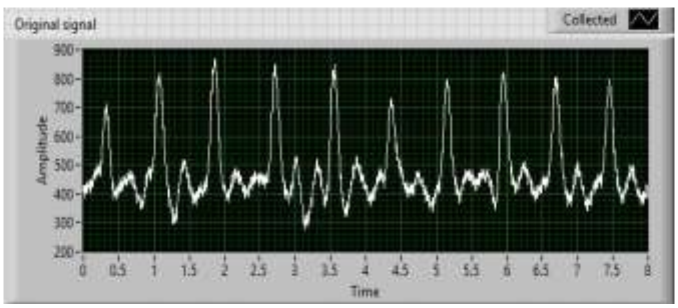

Fig1.Signal with Noise

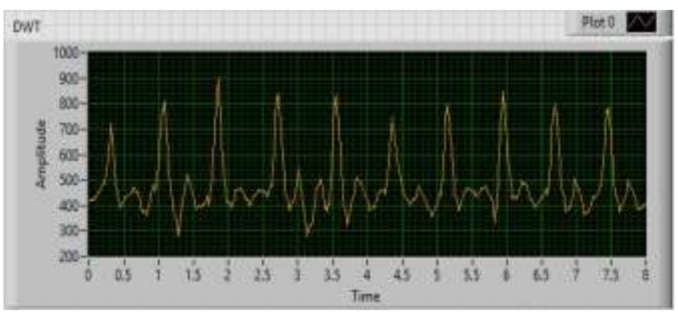

Fig 2.DWT output denoised waveform

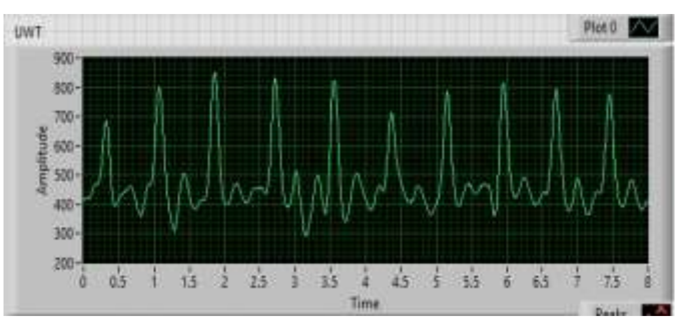

Fig 3.UWT output denoised waveform

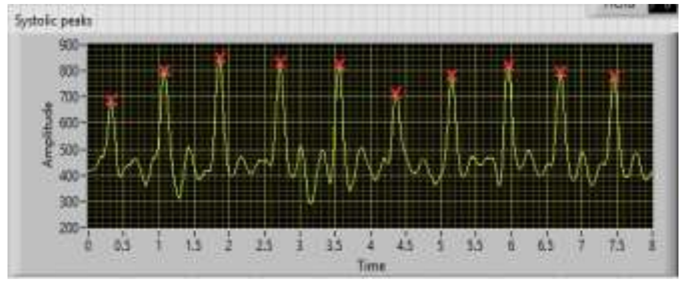

Fig 4. Signal with detected systolic peaks

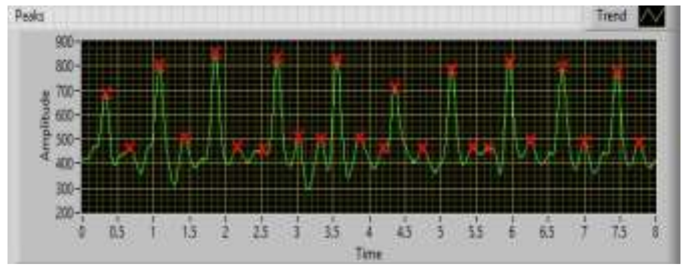

Fig 5. Signal with detected systolic and diastolic peaks

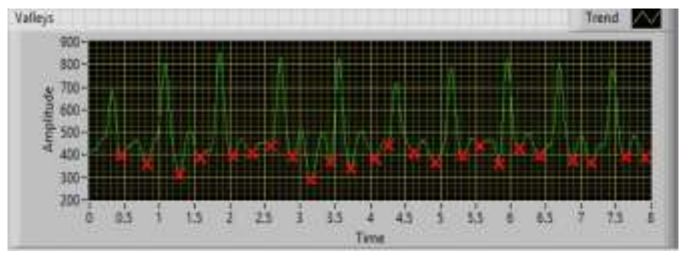

Fig 6. Signal with detected valley points

TABLE I

EXPERMENTAL RESULTS

Wavelet	Cross Correlation
DWT	0.99785
UWT	0.99824

For wavelet denoising using Daubechies 8 (db8) mother wavelet results are shown. Fig 4, 5 and 6 shows the detection of peaks and valleys of the PPG signal. Table I shows cross correlation of the signals.

IV. CONCLUSIONS

The PPG signal is acquired using Arduino board and represented on front panel window. Algorithm developed adapts the different signal voltage levels and set threshold value accordingly. Different characteristic points systolic peak, diastolic peaks along with valleys are detected. Peaks detected they can be used for calculation of intervals. The comparison between DWT and UWT is shown, with use of UWT better denoising and smoothing is obtained and related statistical analysis results shown.

REFERENCES

[1]. Shelley, H. Kirk, "Photoplethysmography: beyond the calculation of arterial oxygen saturation and heart rate", Anesthesia& Analgesia, vol. 105, no. 6, pp. 31-36, 2007.

[2]. J. Allen, "Photoplethysmography and its application in clinical physiological measurement," Physiol. Meas., vol. 28, no. 3, p. R1, 2007

[3]. L. Wang, B. Lo, and G.-Z. Yang, "Multichannel reflective PPG earpiecesensor with passive motion cancellation," *IEEE Trans. Biomed.Circuits Syst.*, vol. 1, no. 4, pp. 235–241, Dec. 2007.

[4]. T. Tamura, Y. Maeda, M. Sekine, and M. Yoshida, "Wearable photoplethysmographic sensors – Past and present," *Electronics*, vol. 3, no.2, pp. 282–302, 2014.

[5]. Joydeep Bhattacharya ParthaPratimKanjilal and V.Muralidhar, "Analysis and Characterization of Photo-PlethysmographicSignal",IEEE Transaction on BioMedical Engineering, vol 48,No.1, pp 5-23, January 2001

[6]. M. Raghu Ram, K. VenuMadhav, "A Novel Approach for Motion Artifact Reduction in PPG Signals Based on AS-LMS Adaptive Filter" IEEE Transactions on Instrumentation and Measurement, vol. 61, no. 5, May 2012

[7]. Huijie Pan, DogancanTemel, GhassanAlRegib,"HeartBEAT: Heart beat estimation through adaptive tracking"IEEE-EMBS International Conference onBiomedical and Health Informatics (BHI), 2016, pp 587-590

[8]. Chih-Chin Wu, I-Wei Chen, and Wai-Chi Fang," An Implementation of Motion Artifacts Elimination for PPG SignalProcessing Based on Recursive Least Squares Adaptive Filter",IEEE Biomedical Circuits and Systems Conference (BioCAS),2017, pp 1-4

[9]. B. N. Singh et al., "Optimal selection of wavelet basis function applied to ECG signal denoising," Digital Signal Process., vol. 16, no. 3, pp. 275–287, 2006.

[10]. Ding Xing-Yun, Chang Qing, Song Chao,"Study on the Extract Method of Time Domain Characteristic Parameters of Pulse Wave"IEEE International Conference onSignal and Image Processing (ICSIP),2016,pp 432-436

[11]. https://www.arduino.cc

[12]. https://www.ni.com