Pre-processing of PPG Signal with Performance based Methods

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ABSTRACT

Analyzing PPG signals carefully can give us information related to diabetes and arthritis patient, because in their case there is a difference in the pulse shape changes as a function of disease which can be well observed visually. Photoplethysmography is a non-invasive technique that measures relative blood volume changes in the blood vessels close to the skin. We present the results of analysis of photoplethysmography (PPG) signals having motion artefacts which are as like Gaussian noise in nature with baseline drift. This paper discusses a methodology to analysis the performance of moving average algorithm (MAA) for baseline drift removal and noise cancellation with the help of wavelet transformation by 'db4' wavelet. The results obtained are efficient and accurate. The decomposition levels during filtering process also analyzed.

Key words: PPG Signal, Gaussian noise, baseline drift, noise cancellation, MAA, db4 wavelet

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INTRODUCTION

Photoplethysmography (PPG) is an optical measurement technique that can be used to detect blood volume changes in the microvascular bed of a tissue [1]. The basic form of PPG technology requires only a few opto-electronic components: a light source to illuminate the tissue (e.g. skin), and a photodetector to measure the small variations in light intensity associated with changes in perfusion in the catchment volume. PPG is most often employed non-invasively and operates in the red region or in the near infrared region. The most recognized waveform feature is the peripheral pulse, and it is synchronized to each heartbeat. Despite its simplicity the origins of the different components of the PPG signal are still not fully understood. It is generally accepted, however, that they can provide valuable information about the cardiovascular system [2]. There has been a resurgence of interest in the technique in recent years, driven by the demand for low cost, simple and portable technology for the primary care and community based clinical settings, the wide availability of low cost and small semiconductor components, and the advancement of computer-based pulse wave analysis techniques [3]. The PPG technology has been used in a wide range of commercially available medical devices for measuring oxygen saturation, blood pressure and cardiac output, assessing autonomic function and also detecting peripheral vascular diseases.

The PPG waveform was first described in the 1930s. Although considered an interesting ancillary monitor, the "pulse waveform" never underwent intensive investigation. Its importance in clinical medicine was greatly increased with the introduction of the pulse oximeter into routine clinical care in the 1980s. Its waveform is now commonly displayed in the clinical setting. Active Research efforts are beginning to demonstrate a utility beyond oxygen saturation and heart rate determination. Future trends are being heavily influenced by modern digital signal processing, which is allowing a re-examination of this ubiquitous waveform. Key to unlocking the potential of this waveform is an unfettered access to the raw signal, combined with standardization of its presentation, and methods of analysis. Human skin plays an important role in various physiological processes including thermoregulation, neural reception, and mechanical and biochemical protection. The heart-generated blood-pressure waves propagate along the skin arteries, locally increasing and decreasing the tissue blood volume with the periodicity of heartbeats. The dynamic blood volume changes basically depend on the features of the heart function, size and elasticity of the blood vessels, and specific neural processes. Therefore *direct monitoring of skin blood pulsations may provide useful diagnostic information, especially if realized non-invasively*.

The PPG waveform comprises of a pulsatile ('AC') physiological waveform attributed to cardiac synchronous changes in the blood volume with each heart beat, and is superimposed on a slowly varying ('DC') baseline with various lower frequency components attributed to respiration, sympathetic nervous system activity and thermoregulation. These characteristics are also site dependent. [15] The AC and DC components of the PPG signal can be extracted with suitable filtering and amplification and subsequently used for pulse wave analysis. Reflection PPG method uses the back scattered Optical signals for analysis of skin blood volume pulsation [2]. In the transmission method, an optical signal change according to its absorption at the pulsation as oxygenated allows red wavelength more and deoxygenated blood allows infrared wavelength. It employs the principle that oxygenated blood is bright red. Whereas reduced or deoxygenated blood is dark red so combination of red and near infrared LED's and photo sensors can be used to monitor the colour of blood [2]. In case of the contact and noncontact PPG, in which both are has nearly same potential only difference in the amplitude of the received signal and clarity. In the noncontact PPG signals are not so cleared as compared to contact type PPG. The second issue concerns the dynamic range of the detected signal. The detected pulsatile (AC) signal is very small compared to the non-pulsatile (DC) signal as shown in figure1. The third issue is ambient light artifact. The detector will receive increased ambient light due to the probe separation from the tissue bed. Introducing close packaging of finger bed with detector could reduce this effect. [6][11]

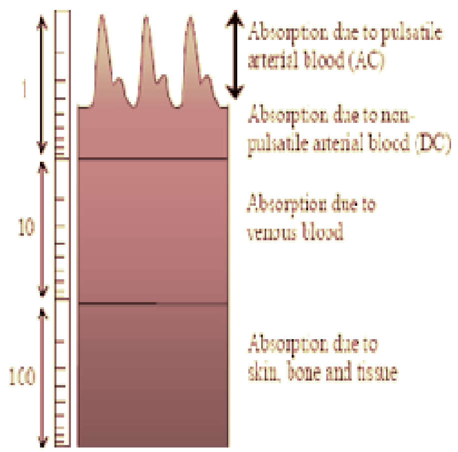

Fig.1. Breakdown of the component of the detected PPG signal

METHODOLOGY & RESULTS ANALYSIS

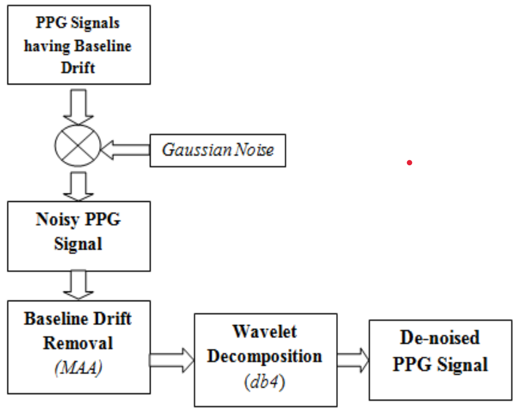

Fig.2. Block diagram of main stages of this work

The block diagram (Fig.2) shows the process of our current work where the collected PPG signal is analyzed sequentially. At first stage we added Gaussian noise in the input PPG signal which is having baseline drift, then the Moving Average Algorithm is applied for baseline Drift removal and after that we have performed the filtering operation by using wavelet transformation (DWT) approach wavelet (db4) with level-8 decomposition was used to study the filtering process.

a. PPG Database

The database is prepared by downloading PPG signals from PhysioBank ATM and recording PPG signals from Heart/Pulse Rate Measurement Trainer (ST2357) at Medical Instrumentation Lab of SMIT.

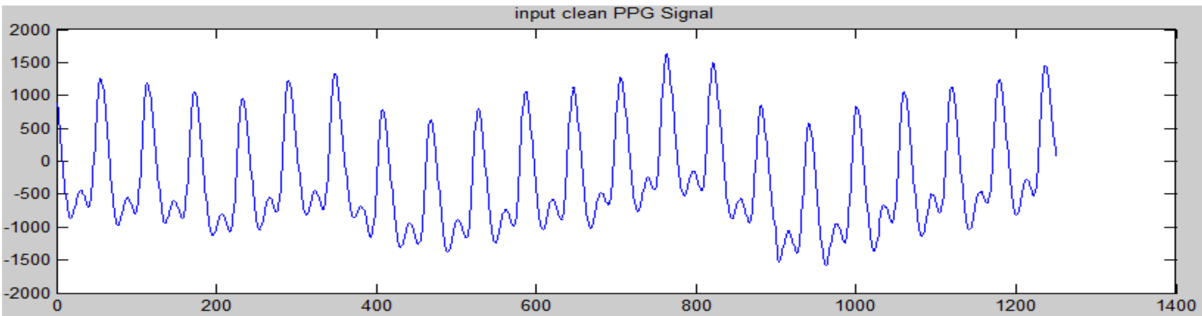

Fig.3. Input Clean PPG signal having Baseline Drift

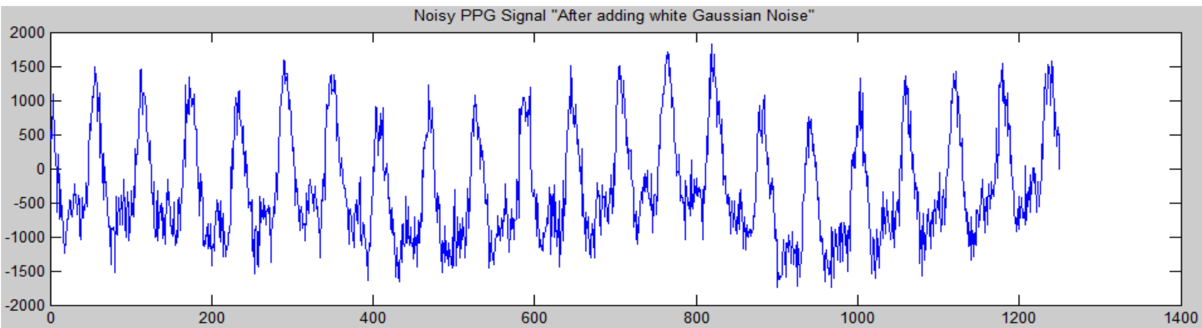

Fig.4. the noisy PPG signal (having Baseline Drift) after adding white Gaussian Noise

b. BASELINE DRIFT REMOVAL

b.1. Moving Average Filter Theory

It can be used as a low-pass filter to attenuate the noise inherent in many types of waveforms, or as a high-pass filter to eliminate a drifting baseline from a higher frequency signal. The procedure used by the algorithm to determine the amount of filtering involves the use of a smoothing factor. This smoothing factor, controlled by you through the software, can be increased or decreased to specify the number of actual waveform data points or samples that the moving average will span. Any periodic waveform can be thought of as a long string or collection of data points. The algorithm accomplishes a moving average by taking two or more of these data points from the acquired waveform, adding them, dividing their sum by the total number of data points added, replacing the first data point of the waveform with the average just computed, and repeating the steps with the second, third, and so on data points until the end of the data is reached. The result is a second or generated waveform consisting of the averaged data and having the same number of points as the original waveform. [17]
This equation can be further generalized. The moving average of a waveform can be calculated by:

$a(n) = 1/\mathrm{s}\sum_{n}^{s+(s-1)} \mathrm{y(n)}$-------------------------- (1)

Where: a = averaged value n = data point position s = smoothing factor y = actual data point value.

b.2. Applying the Moving Average Algorithm

A salient feature of the moving average algorithm is that it can be applied many times to the same waveform if necessary to get the desired filtering result. Waveform filtering is a very subjective exercise. What may be a properly filtered waveform to one user may be unacceptably noisy to another. Only you can judge whether the number of averaged points selected was too high, too low, or just right. The flexibility of the algorithm allows you to adjust the smoothing factor and make another pass through the algorithm when satisfactory results are not achieved with the initial attempt.

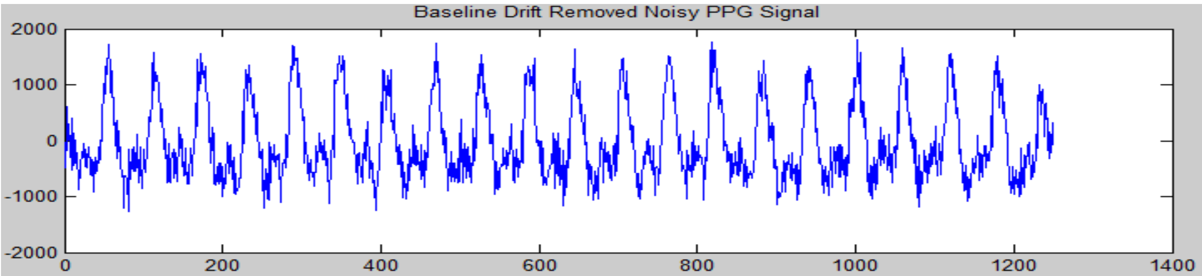

Fig.5. Baseline Drift Removed Noisy PPG Signal (after performing MAA)

c. NOISE CANCELLATION

Discrete wavelet transform (DWT) is obtained simply by passing a discrete signal through a filter bank. Wavelet theory can be understood and developed only by using such digital filters. This is the meeting point between wavelets and sub band coding and the origin of two different nomenclatures for the same concepts. In fact, wavelet transform and sub band coding are so closely connected that both terms are often used interchangeably. Filter banks are structures that allow a signal to be decomposed into sub signals through digital filters, typically at a lower sampling rate. Wavedec performs a multilevel one-dimensional wavelet analysis using either a specific wavelet ('wname') or a specific wavelet decomposition filters. wavedec supports only Type 1 (orthogonal) or Type 2 (biorthogonal) wavelets. For noise removal wavedec performed 8 levels decomposition by considering the higher components and simultaneously it performs the reconstruction of the signal. [13][8]

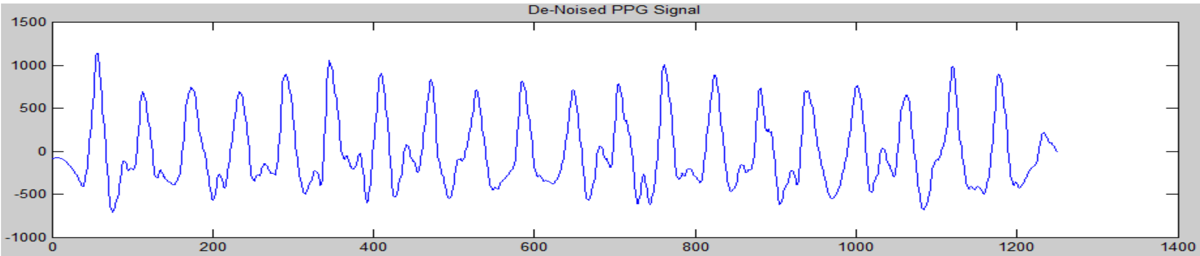

Fig.6. Noise free PPG Signal without Baseline Drift

d. Wavelet Transforms in Signal Decomposition

A transform can be thought of as a remapping of a signal that provides more information than the original. The Fourier transform fits this definition quite well because the frequency information it provides often leads to new insights about the original signal. Fourier analysis provides a good description of the frequencies in a waveform, but not their timing. However, the inability of the Fourier transform to describe both time and frequency characteristics of the waveform led to a number of different approaches. None of these approaches was able to completely solve the time–frequency problem. Timing information is often of primary interest in many biomedical signals. A wide range of approaches have been developed to try to extract both time and frequency information from a waveform. Basically they can be divided into two groups: time–frequency methods and time–scale methods. The wavelet transform can be used as yet another way to describe the properties of a waveform that changes over time, but in this case the waveform is divided not into sections of time, but segments of scale [9]. In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency *and* location information. For our analysis we have taken wavelet 'db4'. [16]

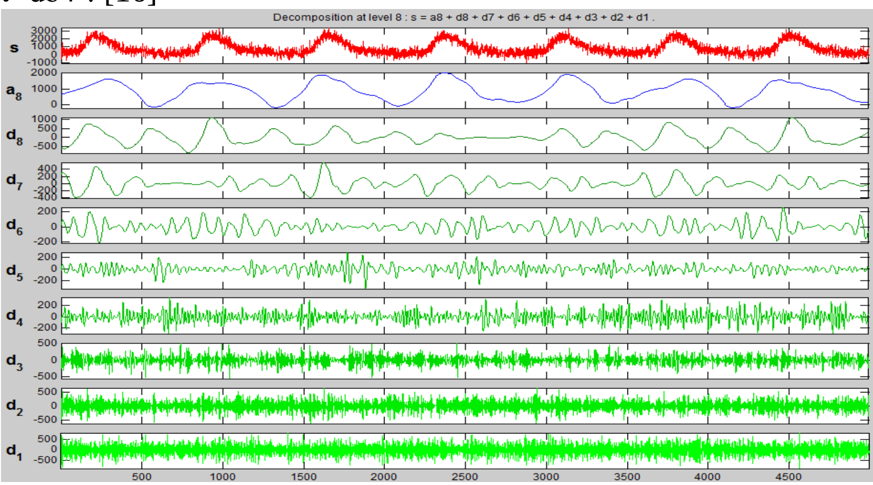

Fig.7. 8-level decomposition of noisy PPG signal with wavelet 'db4'

CONCLUSION

Analysis of Biomedical signals in efficient manner can lead to finding out critical diseases and for the patient treatment it will be helpful. Now a day's Analysis of bio-signals in the clinical point of view is gaining wide range of application. *Direct monitoring of skin blood pulsations may provide useful diagnostic information, especially if realized non-invasively. In the present method of PPG analysis, the aim of this study was to analyze the waveform after baseline drift removal with MAA method and analyzed the filtering process which is done by wavelet 'db4' at level-8. The obtained waveform after each process is very accurate and particular based on the standard values.* Our future research involves in studying heart beat pulse wave propagation in real time from PPG Signal and to evaluate the vascular blood flow resistance which is an important physiological parameter for vascular diagnostics.

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