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An Efficient Method for Noise Removal in PPG Signals Using Wavelet De-Noising

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ABSTRACT

Wavelet de-noising represents a common pre-processing step for several biomedical applications exposing low SNR. These applications require real time processing along with minimization of power and area, only custom VLSI implementations can be adopted for this fulfilment. In this paper, Photo plethysmography (PPG) signal is used as a biomedical signal as an example. PPG is a non-invasive method in which relative blood volume changes in the blood close to skin is measured. The "pulse waveform" never underwent intensive investigation. Active investigation efforts are opening to reveal its effectiveness beyond oxygen saturation and determination of heart rate. With the introduction of pulse oximeter, this is one of the important waveforms that are normally displayed in the clinical settings nowadays. But, the acquired PPG signal using PPG sensors are usually corrupted with different kinds of interference like Motion Artifacts, Power Line Noise, etc. We consider Power Line Noise for the performance evaluation of VLSI Wavelet based denoising of PPG signal. Different kinds of Wavelets such as db4, Coif1, Haar for denoising.

Keywords: Motion artifact; Wavelet transform; De-noising, Wavelet, Heart rate, Power line interference, wavelet de-noising

I. INTRODUCTION

Digital Signal Processing (DSP) has been increasing in popularly known due to the declining cost of general purpose computers and Application Specific hardware. Since telephony and data communications applications have been moving to digital, the need for digital filtering methods continues to grow. Along with the advancement in Very Large Scale Integration (VLSI) technology and the DSP has become increasingly popular over the years, the fast in realization of FIR digital filters with less power consumption has become much more demanding. Since the complexity of implementation in fir filters are growing with the filter order and the precision of computation, real-time realization of these filters with accuracy is a challenging task. Pulse wave analysis helps to study diabetes & arthritis & it is unique for each individual so it would also give unique identification as biometric identification [4]. Pulse wave analysis also helps to study large artery damage & an abnormality in the cardiovascular disease, which is one of the common causes of high mortality rate. PPG analysis emphasizes the importance of early evaluation of the diseases [5].

II. RELATED WORKS

Photoplethysmography-Based Heart Rate Monitoring in Physical Activities via Joint Sparse Spectrum Reconstruction.

This deals with the Wearable Health Monitoring. Then VLSI Wavelet Based De-noising of PPG Signal performs using Wavelet transform. In this Real-time implementation of discrete wavelet transform on FPGA deals with Wavelet transform, hardware implementation. In 2013, A comprehensive survey of wearable and wireless ECG monitoring systems for older adults is processed by using Signal Recovery, Compressed Sensing. The disadvantages of existing system are follows as High power consumption due to not using of specific filters to processing of medical signals. Complexity is very more when it is implanted in hardware medical applications. Designing and implementation of circuits are difficult. Replacement of device is difficult since components are costly. Then transportation of equipment's are not possible. Only few diseases are examined.

III. PROPOSED METHOD

PPG is a non-invasive method in which relative blood volume changes in the blood close to skin is measured. The "pulse waveform" never underwent intensive investigation. Active investigation efforts are opening to reveal its effectiveness beyond oxygen saturation and determination of heart rate. With the introduction of pulse oximeter, this is one of the important waveforms that are normally displayed in the clinical settings nowadays. But, the acquired PPG signal using PPG sensors are usually corrupted with different kinds of interference like Motion Artefacts, Power Line Noise, etc. We consider Power Line Noise for the performance evaluation of VLSI Wavelet based denoising of PPG signal.

The wavelet transform is similar to the Fourier transform (or much more to the windowed Fourier transform) with a completely different merit function. The main difference is this: Fourier transform decomposes the signal into sines and cosines, i.e. the functions localized in Fourier space; in contrary the wavelet transform uses functions that are localized in both the real and Fourier space. Generally, the wavelet transform can be expressed by the following equation:

$$F(a,b) = \int_{-\infty}^{\infty} f(x)\, \psi^{*}_{(a,b)}(x)\, \mathrm{d}x$$

where the * is the complex conjugate symbol and function ψ is some function. This function can be chosen arbitrarily provided that it obeys certain rules.

Discrete wavelet transform can be used for easy and fast denoising of a noisy signal. If we take only a limited number of highest coefficients of the discrete wavelet transform spectrum, and we perform an inverse transform (with the same wavelet basis) we can obtain more or less denoised signal. There are several ways how to choose the coefficients that will be kept. Within Gwyddion, the universal thresholding, scale adaptive thresholding [2] and scale and space adaptive thresholding [3] is implemented. For threshold determination within these methods we first determine the noise variance guess given by

$$\hat{\sigma} = \frac{\text{Median}\,|Y_{ij}|}{0.6745}$$

where Y_{ij} corresponds to all the coefficients of the highest scale subband of the decomposition (where most of the noise is assumed to be present). Alternatively, the noise variance can be obtained in an independent way, for example from the AFM signal variance while not scanning. For the highest frequency subband (universal thresholding) or for each subband (for scale adaptive thresholding) or for each pixel neighbourhood within subband (for scale and space adaptive thresholding) the variance is computed as

$$\hat{\sigma}_Y^2 = \frac{1}{n^2} \sum_{i,j=1}^{n} Y_{ij}^2$$

Threshold value is finally computed as

$$T(\hat{\sigma}_X) = \hat{\sigma}^2 / \hat{\sigma}_X$$

where

$$\hat{\sigma}_X = \sqrt{\max(\hat{\sigma}_Y^2 - \hat{\sigma}^2, 0)}$$

When threshold for given scale is known, we can remove all the coefficients smaller than threshold value (hard thresholding) or we can lower the absolute value of these coefficients by threshold value (soft thresholding).

Mean filter, or **average filter** is windowed filter of linear class, that smoothes signal. The filter works as low-pass one. The basic idea behind filter is for any element of the signal take an average across its neighborhood. To understand how that is made in practice, let us start with window idea.

DWT denoising can be accessed with Data Process → Integral Transforms → DWT Denoise.

DWT be successfully used in filtering of the signal, here called as "denoising". It consists of four successive steps: signal decomposition, threshold estimation, thresholding, and signal reconstruction. The architecture for real time denoising of a signal is as shown in Fig.

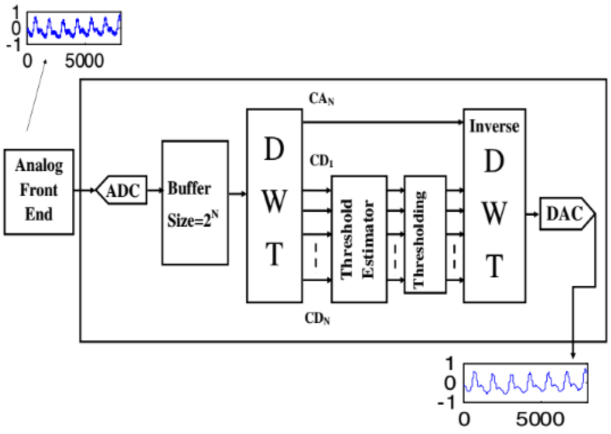

Figure 1 : Real time block diagram of PPG signal de-noising

The dilation function of the discrete wavelet transform can be represented as a tree of low and high pass filters, with each step transforming the low pass filter as shown in Figure 5. The original signal is successively decomposed into components of lower resolution, while the high frequency components are not analysed any further. The maximum number of dilations that can be performed is dependent on the input size of the data to be analysed, with 2N data samples enabling the breakdown of the signal into N discrete levels using the discrete wavelet transform.

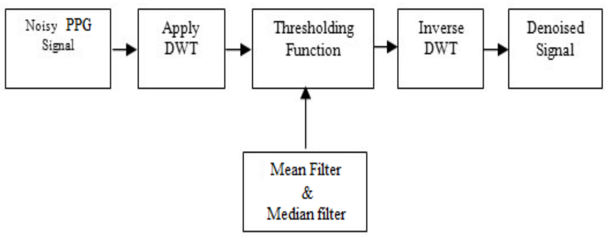

Figure 2 : block diagram of proposed method

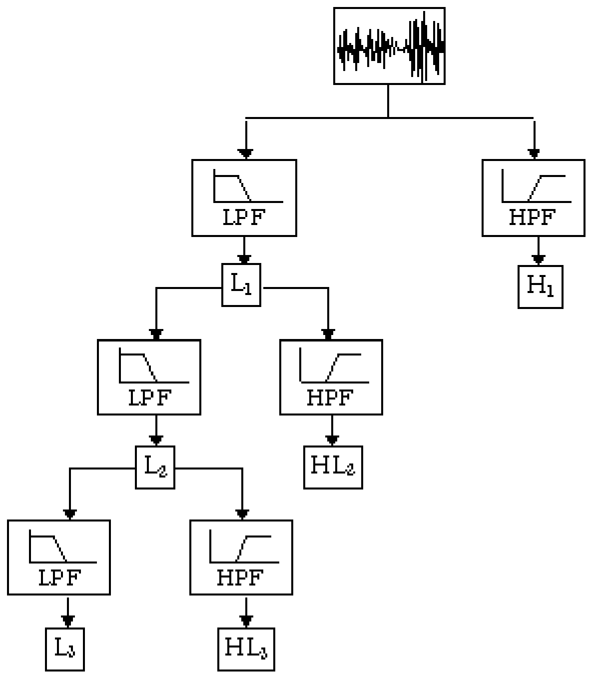

Figure 3 : filter bank representations of the dwt dilations

For the proposed wavelet based denoising system a three level decompostion-reconstruction tree is realized. However, the intensity of the noise was estimated with the second level wavelet coefficient as this matches to the frequency band of a narrow-band Power Line noise signal. It consists of a pair of Lowpass *Ld* and a High-Pass *Hd* filters for the decomposition at each level. For each *jth* decomposition level following *i*, the *Ld* and *Hd* filters a downsampling operator ↓ 2 is used that represents the decrease of a sampling rate by 2. For each *jth* decomposition level *CAj* and *CDj* represents the approximate and detailed coefficients respectively. For the reconstruction of the signal first the threshold is estimated using second level wavelet coefficient followed by applying suitable thresholding technique to all the levels of wavelet coefficients then upsampling denoted by upsampling operator ↑ 2 and finally filtering by filters *Lr* and *Hr*. All the filters are characterized by the values of their coefficient and these values are typically be floating point, with different vector lengths and can differ from the simplest ones like Haar, to a slightly complex Daubechies upto those like Quadartic Spline.

There is a rapid growth in the field of Biosignal processing with increase in the understanding of a complex biological process in a broad diversity of areas. Different WT functions are a powerful time frequency approach. In this project, this has been applied to PPG signal preprocessing. The signal reconstruction is however, more exact in db4 wavelet transform whereas others are less effective for the signal under consideration.

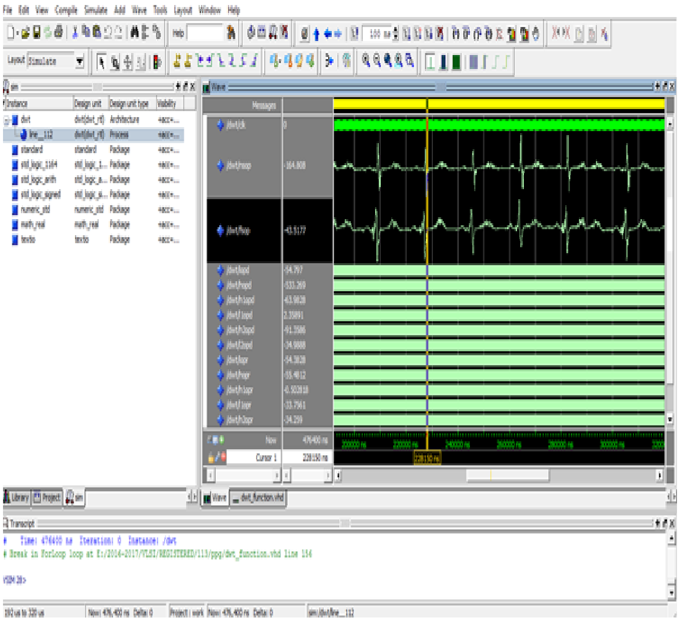

Figure 4 : output waveform

IV. CONCLUSION

A real-time VLSIWavelet Transform based denoising technique is proposed in this paper to remove the power-line from PPG signal. From output waveform it is clear that the original signal and mean filter based denoised signal are more correlated and shows better results compared to other wavelets used in denoising the PPG signal. Hence it can be used for analyzing PPG signal. Careful analysis of the PPG signals can give us information associated to patient suffering from diabetes and arthritis 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. We also investigated heart rate and respiratory rate using PPG signal.

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