TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 2863 - 2870

Hybrid Algorithm for Denoising of Vibrocardiographic Signals Using Savitzky Golay Filter and Hilbert-Huang Transform

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Article Info
Volume 82
Page Number: 2863 - 2870
Publication Issue:
January-February 2020

Article History
***Article Received**: 14 March 2019*
***Revised**: 27 May 2019*
***Accepted**: 16 October 2019*
***Publication**: 18 January 2020*

Abstract:
Vibrocardiography is an important diagnostic tool used to fetch out the cardiac vibration at the chest surface simply by attaching the electrodes. But these vibration signals can contaminated by artifacts and to get exact outcomes for better and restorative diagnosis of heart problems, denoising of VCG signal is used. In Vibrocardiographic (VCG) signals, several filter methodologies are accessible for expulsion of noise artifacts. In this work the adaptive Savitzky Golay filter and Hilbert-Huang Transformation (HHT) is used for denoising of noise interference from VCG signals. In this paper better search results are obtained by adaptive hybrid optimization Algorithms. Intrinsic Mode Functions (IMFs) are decomposed in a limited number using the Empirical Mode Decomposition (EMD) to Vibrocardiographic signals. To examine the VCG signal dominated IMFs and noise dominated IMFs boundary, energy investigation is led on the IMFs.The next contribution is to implement the denoising of VCG signal using Hybrid Bat Optimization (HBO) algorithm. The proposed technique centers around the remarkable noise decrease execution for VCG signals, and the noise removed signal is reasonable for clinical finding. The proposed techniques were tried utilizing the MIT-BIH dataset.

Keywords:*Vibrocardiographic,Optimiaztion Algorithms, Savitzky Golay filter, Empirical Mode Decomposition, Hilbert-Huang Transform, Hybrid Bat Algorithm.*

I. INTRODUCTION

A Vibrocardiography signal is created from human heart exercises. VCG is monitored by fixing electrodes on the chest for a time period of 10s. A significant issue experienced with non-stationary signal is noise removal. Scientists have proposed different proficient techniques for signal noise reduction. Digital filter techniques are used for the removal of baseline wander and noise from VCG signal.Digital filter and signal processing are compelling methodology for compressing VCG signal. Digital filter is anything but difficult to actualize and it has utilized scientific condition for structuring or expelling noise from signal. In biomedical signal recording, Power Line Interference is a substantial source of supply noise. For the elimination of interference in the VCG signal, wiener filter is used. It is used for removal artifacts from VCG signal.

Hilbert-Huang Transform (HHT) strategy is entirely appropriate for non-stationary and nonlinear sign handling. HHT method uses empirical mode decomposition (EMD) for decompose the signal into intrinsic functions. At present, it as of now accomplishes extraordinary effective application in biomedical and mechanical building territories.

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Experimental mode deterioration is directed to get IMFs. In the deterioration procedure, the littlest scale IMF is isolated from the start, at that point pursued by expanding scale IMF. To get the IMFs that are dominated by clamor precisely, vitality examination are directed on the IMF parts. From that point forward, Donoho delicate limit technique is applied to the most boisterous IMF parts for handling. The exploratory outcomes confirms that the proposed technique in this paper is a completely self-versatile noise cancellation strategy, contrasted and the wavelet denoising strategy, there is no doubt on the choice of fundamental capacities and this strategy can accomplish generally excellent noise reduction impact.

Denoising is the first step in quite a while. Different applications incorporate therapeutic signal/image investigation (VCG, CT...etc), radio space science image examination, data mining etc. In many sorts of noise, VCG measurements can be corrupted. Some of the primary interests are

1. Power line interference
2. EMG noise
3. Baseline wander noise
4. Colored noise
5. Instrumentation noise

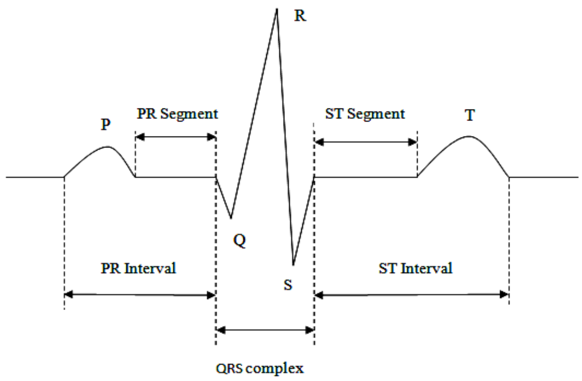

Figure 1 A Sampled VCG Waveform

VCG signal shows in figure 1 comprise with P, QRS complex and T waves. During the preprocessing phase of a Vibrocardiography (VCG) signal, the actual VCG signal is separated by certain methods for sifting systems for dispensing with commotion aggravations. From the separated signal, highlights are to be extricated for a point by point investigation of the VCG which aides in legitimate determination of the patient. All the separated highlights are can't be helpful or a portion of the highlights won't give appropriate data for legitimate grouping of the signal. Henceforth it is a lot of attractive to distinguish or choose the best highlights from the general extricated highlights which lessen intricacy and computational examination. Figure 2 shows the basic block diagram of VCG signal Processing and Figure 3 shows the Flow Chart of the proposed methodology.

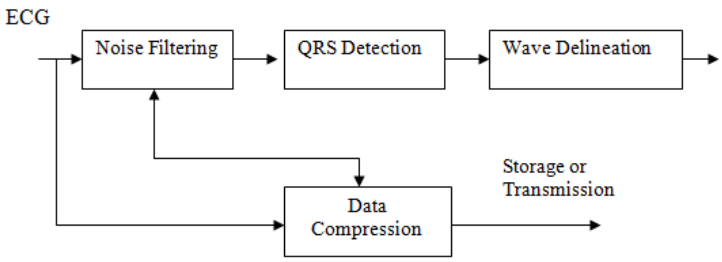

Figure 2 Basic block diagram of VCG signal processing

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In this paper, Hilbert-Huang change is proposed for VCG signal denoising. Donoho delicate edge denoising technique is utilized for denoising the most uproarious IMFs. For separating kalman channel is utilized.

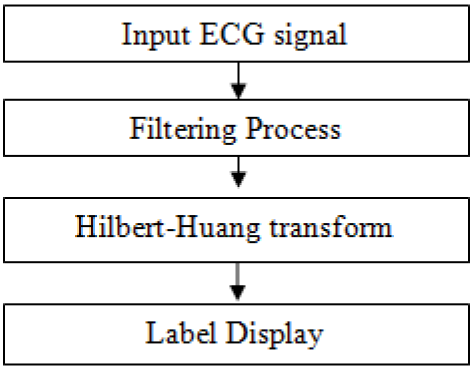

Figure 3 Flow Chart of the proposed methodology

This work is sorted out as pursues. Area 2 depicts the Savitzky Golay filter. Area 3 exhibits the signal decomposition. Area 4 depicts the Hilbert-Huang change Area 5 depicts the denoising approach based on HHT. Area 6 depicts the hybrid bat algorithm. The proposed investigations and conclusions are discussed in Section 7 and Section 8.

II. SAVITZKY GOLAY FILTER

As a digital filter, S-G could be employed to a collection of digital data points for the intention of smoothing the data, that is, to augment the SNR without distorting the signal (Nidhi & Mehra 2013). This is attained in the convolution process, by fitting consecutive subsets of nearby low-degree polynomial data points utilizing the Linear Least Square (LLS) methodology. At the point when these information focuses are uniformly separated, an investigated answer for the LLS conditions is accomplished in the format of a single set of 'convolution coefficients' which could be employed to every data subset, to acquire smoothed signal estimates or derivatives at the mid-point of every sub-set. This method centered on the mathematical strategies was propounded by Abraham Savitzky & Marcel Golay (1964) who also published the convolution coefficient table for disparate subset sizes and polynomials (Aravind *et al.* 2017). Certain errors in this table were corrected. The methodology is extended for treating the 2-D and 3-D data.

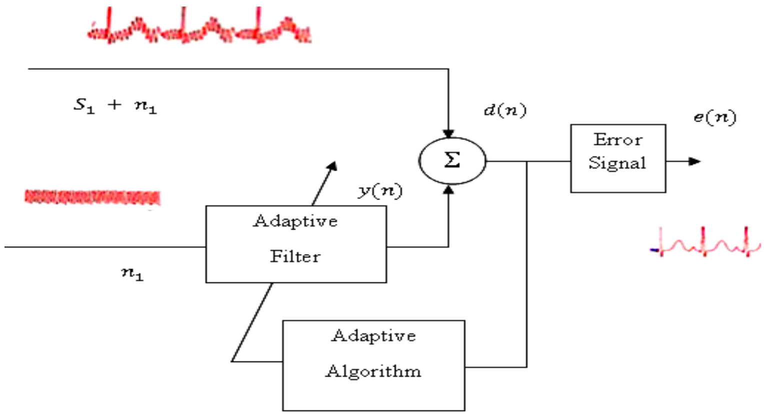

Figure 4 Adaptive filter denoising

This filter remains as a computerized channel that is executed to a gathering of advanced information focuses to smooth the information, to be specific, to build the SNR without mutilating the signal. Now, when the information inspiration stories in life are equitably separated, a consistent answer for the LLS conditions is found as a solitary group of "convolution coefficients". Figure 4 shows the block diagram of Adaptive filter denoising

$$x(n-m)=\sum_{k=0}^{B}\alpha_k(n)\psi_k(m) \quad (1)$$

$$x(n-m)=\sum_{k=0}^{B}\beta_k(n)\psi_k(m) \quad (2)$$

$$y(n)=x(n)+\varepsilon \quad (3)$$

$$Correlation=\frac{\sum_{i=1}^{n}(X_i-\bar{X})(X_i-\bar{X})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2(X_i-\bar{X})^2}} \quad (4)$$

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III. Signal Decomposition

Mode decomposition is the viable strategy and has been used by the name of EMD (Empirical Mode Decomposition). Be that as it may, these are not used for speech augmentation (Uday and Pal 2016). Like EMD, VMD helps in decomposition of a signal resulting different IMFs (Intrinsic Mode Functions) which are basically contingent on the levels taken into consideration. Further, out of these mode-decomposition algorithms, VMD found better than the other two and hence it is applied for speech augmentation.

$$f(t) = \sum_{k=1}^{K} s_k(t) \quad (5)$$

$$s_k(t) = A_k(t)\cos(\phi_k(t)) \quad (6)$$

IV. HILBERT-HUANG TRANSFORM

The EMD produces the results as n IMFs c_j and a residue signal $r_n(t)$, so the original sequence can be defined by,

$$x(t)=\sum_{j=1}^{n} c_j(t) + r_n(t) \quad (7)$$

Each IMF succession is unfaltering, so it very well may be completed Hilbert change or other stationary strategies for further investigation and preparing.

The IMFs can be performed Hilbert change individually:

$$y_i(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{c_i(\tau)}{t-\tau}\, d\tau \quad (8)$$

$$x(t) = Re\big(z(t)\big) = Re\ \sum_{j=1}^{n} a_j(t)e^{i\theta(t)} = Re\ \sum_{j=1}^{n} a_j(t)e^{i\int w_j(t)dt} \quad (9)$$

V. THE DENOISING APPROACH BASED ON HHT

On the off chance that wavelet denoising approach is utilized on the IMFs after EMD, it is viable for the commotion overwhelmed IMF parts. At the point when the sign parts are prevailing, this technique will cause helpful sign is sifted. This work, proposed a noise decrease technique that utilizations multi-scale channels dependent on IMF energy examination. It is mainly separated into two stages:

A. Energy analysis

The accompanying advances are actualized for every IMF part: Hilbert transform are executed on the IMF segments as condition (10). In condition (11), explanatory sign Z(t) is conjugate sets comprises of X (t) and Y (t). So a(t) is the amplitude function of the signal as condition (12).

$$Y(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{X(\tau)}{t-\tau} d\tau \quad (10)$$

$$Z(t) = X(t) + iY(t) = a(t)e^{i\theta(t)} \quad (11)$$

$$a(t) = [X^2(t) + Y^2(t)]^{½} \quad (12)$$

$$E = \sum_{t=1}^{T} a^2(t) \quad (13)$$

B. Soft-threshold denoising processing

The denoising processing on the IMFs that are overwhelmed by noise is performed, the corresponding threshold is

$$thr_i = \sigma_i\sqrt{2\log(N)}$$

N is the length of each IMF component.

σ_i^2 is the variance of the noisy component contained in each IMF.

$$(\sigma_i^2 = MAD_i / 0.6745)$$

MAD_i is the absolute median deviation of the i-layer

$$MAD_i = median\ (abs\ (IMF_i - median\ (IMF_i)))$$

VI. HYBRID BAT ALGORITHM

The Bat Algorithm is based on the bats' echolocation activities. All bats utilize the echolocation methodology to ascertain the prey position or other background difficulties. In general, bats fly at a position, p_i, with the velocity v_i varying wavelength λ, loudness A_i and the fixed frequency $f_{\min}$. The bats adjust the frequency or wavelength of the created pulses and also adjust the rates of pulse emission $r \in [0,1]$ automatically. This is reliant on the food proximity.

The frequency, velocities, and position of the bats could be updated grounded on the equations are

$$f_i = f_{\min} + (f_{\max} - f_{\min})\beta \qquad (14)$$

$$v_i^t = v_i^{t-1} + (p_i^t - p_*) f_i \qquad (15)$$

$$p_i^t = p_i^{t-1} + v_i^t \qquad (16)$$

It was chiefly utilized to optimize one parameter (radii) in ANFIS classification algorithm. This radii value is a centroid point of a cluster in ANFIS classification. While training time, Initial fuzzy was generated using feature values, target values, and radii. In this, the radii value was generated randomly between the ranges -25 to 25. Here the radii value was generated randomly. So we didn't get an accurate result. So we optimize the radii value utilizing HBO. HBO is the integration of BA and Genetic Operators. HBO is chiefly utilized to optimize the radii value in ANFIS classification. In this the populations, radii value was initiated with default values ν and γ. Next, find the best solutions and check with various conditions. Finally, rank the best solutions. At last, execute cross over and mutation with best solutions. After, optimized radii value is attained. That was embraced with ANFIS algorithm to boost the classification accuracy.

VII. RESULTS

The noise debased VCG signal separated by utilizing Weiner filter, Hilbert huang transform and better results obtained by optimization algorithms. A few standard benchmarks were acquired from MIT-BIH to test and assess the effectiveness of the proposed VCG denoising strategy. This database has around 48 half hour VCG recordings. The proposed VCG denoising technique was tested on the MITBIH database for 48 VCG signals. Each VCG record has the accompanying determinations: inspecting rate is 360 Hz, signal length is 650,000 examples, bit rate is 3960 bps and resolution is 11 bits over a 10 mV extend. The MIT-BIH database has been openly accessible in PhysioNet. For looking at and assessing the exhibition of various noise decrease methods, the MIT-BIH database is utilized. Following EMD on the noisy sign, energy investigation is executed for IMFs to discover the high-recurrence IMFs that the noise concentrated on. At that point the high-recurrence IMFs are carried out the soft-threshold denoising.

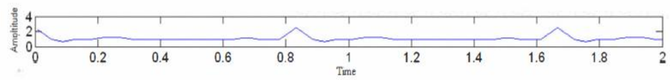

Figure 5 Original VCG signal

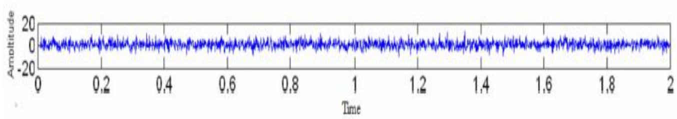

Figure 6 Noisy VCG signal

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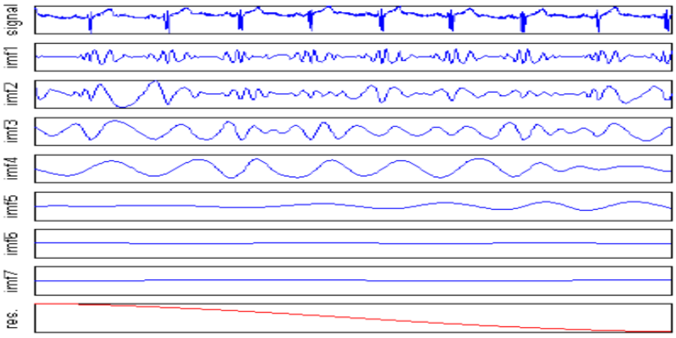

Figure 7 Eight intrinsic mode functions are acquired by Emprical mode decomposition

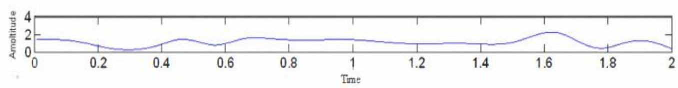

Figure 8 Denoised VCG signal

Wavelet denoising technique utilizes randomly chosen wavelet basis and fixed edge strategy, and embraces system wavelet for soft-threshold denoising and five layers disintegration to get the denoising result. It shows that utilizing wavelet strategies must pick the best wavelet premise good with the signal and decide the appropriate decay layers so as to improve denoising impact. Be that as it may, utilizing the EMD denoising technique is moderately straightforward.

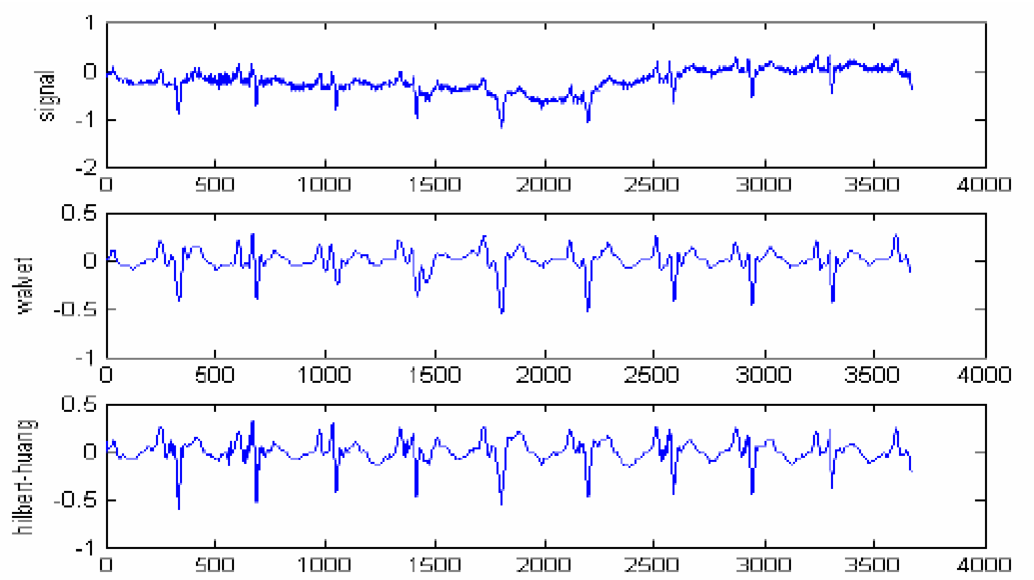

Figure 9 Comparison of de-noising effects between HHT and wavelet methods

Since VCG signal are normally non-stationary sign, HHT technique in VCG signal preparing has wide application possibilities. In this example, the standard VCG information is chosen to direct trials. To recreate the electromyography impedance, the Gaussian repetitive sound added to the VCG signal and the SNR of the noise is - 10dB. The first VCG signal and noisy signal are individually appeared in Figure 5 and Figure 6. At first, we will lead EMD on the noisy signal. Besides, we will break down the energy of every part. At that point, soft-threshold denoising strategy is directed on the most noisy IMFs. Finally, the signal-noise proportion is determined after the EMD denoising, the outcome is 8.7280dB. Since the SNR of noisy VCG signal is - 10dB, the SNR is improved by 18.7380dB.

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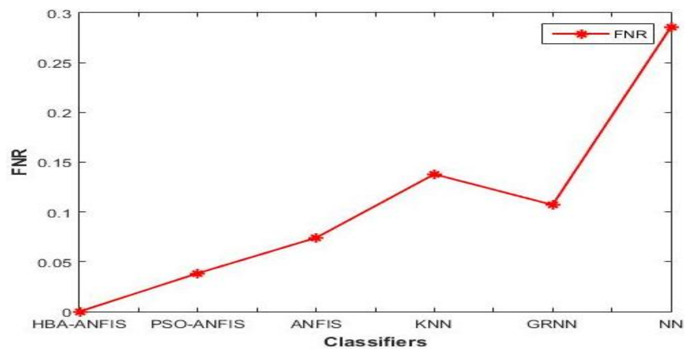

Figure 10Performance of HBO in terms of FNR

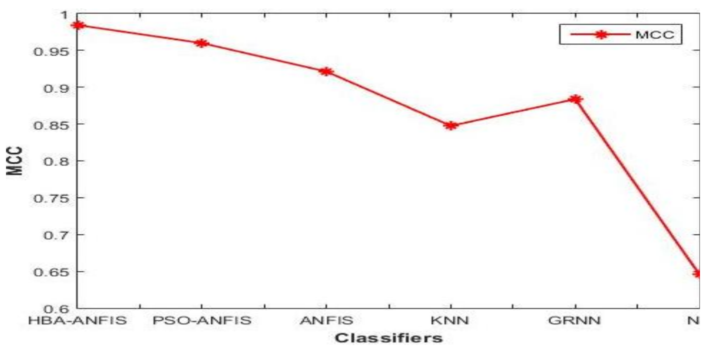

Figure 11 Performance of HBO in terms of MCC

In this paper the better search results are obtained using the hybrid Bat algorithm. To improve the performance of the original BPNN algorithm, it concentrated on the selection number of hidden layer neurons, learning rate and momentum constant by using the optimization algorithms. The hybrid Bat algorithm uses less processing time to get higher accuracy than the PSO algorithm and BPNN algorithm The hybrid ABC algorithm evolved the best solution and the residual error obtained was 0.007. Figures 10 & 11 demonstrate the proposed HBO-ANFIS's divergence from the prevailing systems. When comparing each of those methods, Neural Network has the most elevated False Negative Rate (FNR) value and the least Mathew's Correlation Coefficient (MCC) value. Though the proposed HBO-ANFIS has the least FNR value and the highest MCC value, it evinces the prominence of the HBO-ANFIS classifier.

VIII. CONCLUSION

In this paper, a Weiner filter and Hilbert huang transform strategies have been produced for denoising of VCG signal. Weiner filter is used for removal artifacts from VCG signal. This work introduces an energy and optimization techniques for reducing the noise. The EMD is multi-scale filtering which can adequately remove noise. The proposed HBO strategy exhibited better performance in terms of noise minimization in VCG signals. Donoho soft-threshold denoising method is used for denoising of most noisy IMFs. This method is less complex than the wavelet denoising technique which can be verified by the experimental results. From the results obtained in this paper, it can be concluded that the performance of Savitzky Golay filter is improved by optimizing filter parameters using hybrid Bat algorithm for denoising of VCG signal.

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