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R.F Exposed Electrocardiogram Waves Using Different Transforms: A Review

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Abstract

The effect of radio frequencies on the human health is an interesting area of study these days due to the large scale use of the radio frequencies. Electrocardiogram is one of the most important and mostly used biological signals. E.C.G is used to record the electrical activity of the heart. In this paper various methods for analyzing E.C.G waves is discussed. E.C.G signal is highly non linear and non stationary. Hilbert Huang transform is a new tool for analyzing non- stationary and nonlinear data. This paper proposed the use of HHT to analyze R.F exposed ECG waves.

Keywords: E.C.G, Fourier Transform, Hilbert Huang Transform, Wavelet Transform

1. Introduction

The collected data is meaningless unless it is not properly analyzed e.g. in census door to door data is collected and then it is analyzed to draw some conclusion based on the data collected. There are few problems in data analysis such as quantity of data, nature of data, etc, data should not be too short that it will give inaccurate results or should not be too long that it will take too much time in the analysis. Second is the non-stationary nature of the real data. Third is non-linearity in the real data. In the signal processing, the data is basically the parameters of signal mainly statistical in nature. Signal analysis in signal processing is done to extract information from the signal to know the mechanism of various physical phenomena's. There are various signal processing tools available to analyze the signals which are listed in subsequent sections.

Electrocardiogram (ECG) signal is one of the most important and most used biological signals which have a significant role in diagnosis of heart diseases. ECG or EKG came from a Greek word Kardia, meaning heart. ECG is the recording of electrical activity of the heart. It picks up electrical impulses generated by the polarization and depolarization of cardiac tissues and translates it into a waveform. The waveform is used to measure the rate and regularity of heart beat. Most ECG is performed for diagnostic or research purpose on human hearts. ECG signal is non linear, non-stationary weak signal that has strong randomness and many random noises. The main interferences include baseline drift, electromyographical interference and frequency interference, power line interference and electrical contact noise, etc. ECG has 3 distinct waveforms the P wave, which represents the arterial depolarization (the atria contract), the QRS complex, which represents the ventricular polarization (the ventricles contract while the atria begin to relax), the T wave which denotes ventricular re- polarization (the ventricles relax) [1].

2. Signal Processing Tools

Some of the commonly used tools for signal processing are:

2.1 Fourier Transform

Fourier Transform is traditional tool in signal processing which gives representation in frequency domain. The Fourier transform based spectral analysis has been widely used to characterize the average energy frequency distribution of the various kinds of signals. Spectrum and Fourier Transform became synonymous of each other. Fourier analysis performs well when the system is linear [2]. There are two restrictions while using Fourier analysis. (i) The system must be linear and (ii) the data must be stationary. Unfortunately, most signals don't satisfy the above restrictive conditions [2]. In spite of these limitations, classical Fourier spectral analysis is still widely used to process biomedical data, for lack of alternatives. The uncritical use of Fourier spectral analysis and the careless adoption of the stationary and linear assumptions may give misleading results.

2.2 Fast Fourier Transform

Fast Fourier Transform is another tool for analyzing the data which transforms the data to amplitude vs. frequency description [3]. FFT treats amplitude vs. time information globally. FFT also assumes stationary and linearity of data and relies on globally defined orthogonal basis states. FFT provides an effective algorithm for converting data from the time domain into frequency domain [3].

2.3 Wigner-Ville Distribution

Winger-Ville Distribution is a method to process non-stationary signals [2]. However, the quality of signal analysis suffers degradation due to the cross-term interference. The time resolution and frequency resolution are also restricted in the Wigner-Ville Distribution [2].

2.4 Wavelet Transform

A Wavelet is the small oscillatory waveform that look likes a wave and it has the ability to allow simultaneously time and frequency analysis [4]. It gives information about the time frequency localization of the input signal. Wavelet analysis was developed to overcome the constraints of the Fourier and Wigner-Ville distribution. Wavelet Transform also has some limitations. Wavelet Transform is not adaptive in nature, once the Wavelet mother function is given, one will have to use it to analyze all the data. In addition to it wavelet transform also underlies the uncertainty principle. The wavelet approach is essentially an adjustable window Fourier spectral analysis. So, in reality Wavelet transform is based on Fourier Transform and it also suffers many shortcomings of the Fourier spectral analysis. If the Wavelet analysis is used in analysis of non-stationary signals then the signal in the window is approximated as stationary signal [4]. The issue of non-linearity remains problematic.

3. Hilbert Huang Transform

The limitations of the Fourier transform based methods of data analysis are that the system must be linear and data must be stationary. In 1998 a Chinese-American scientist Norden E Huang proposed a novel signal processing algorithm for analyzing nonlinear and non-stationary data. He named the method as Hilbert Huang Transform (HHT).It has proven to be powerful tool for analyzing non-stationary and nonlinear signals and has been successively applied to various fields of science, such as bio-medical, engineering, machine monitoring failure diagnosis, non-destructive testing, oceanography, geography, medicine, image processing and seismology [2]. The key part of the method developed by the Haung and others is the empirical mode decomposition with which any complicated data set can be decomposed into a finite and often small number of intrinsic mode functions that admit well behaved Hilbert transform. This decomposition method is adaptive and highly efficient [5]. Properties of Hilbert spectrum are: Linearity, real number property, local property and adaptive multi-resolution property.

3.1 Empirical mode decomposition

Empirical Mode Decomposition (EMD) is the key part of the Hilbert Huang Transform (HHT). The EMD decomposes the original complicated signal into several Intermediate Frequency (IMF) Components and every Intermediate Frequency (IMF) Components meet the following two conditions: (a) In the entire signal length, an IMF with the number of extreme points and zero crossing must equal or differ at most by one. (b) At any moment, the mean value of the envelope defined by the maximum points and the envelope defined by the minimum points is zero [6].

The result of the EMD produces n IMF's $C_i(t)$ and a residue signal $r_n(t)$, so the original sequence can be expressed as

$$x(t) = \sum C_i(t) + r_n(t) \qquad (1)$$

Every IMF sequence is steady, so, it can use Hilbert Transform or other stationary methods for further analysis and processing. [6]. This decomposition method is highly adaptive and highly efficient. Since decomposition is based on the local characteristics time scale of the data, it is applicable to non stationary processes.

3.2 Hilbert Transform

The Hilbert Transform is introduced by the German scientist David Hilbert in 20th century. It is a mathematical tool widely used in signal theory to describe the complex envelope of a full- scale modulated by a signal. Given a real time function x (t), its Hilbert transform is defined in [1]:

$$x(t)' = H[x(t)] = x(t) * \frac{1}{\pi t} = \frac{1}{\pi}\int \frac{x(\tau)}{t-\tau} d\tau \qquad (2)$$

The Hilbert transform is a transformation which is limited to the time domain in contrast to the Fourier transform. Furthermore $x(t)'$ is a linear function of x(t). It is obtained from x (t) applying convolution with a linear system whose the impulse response is $(1/\pi t)$ so,

$$x(t)' = x(t) * 1/\pi t \qquad (3)$$

x(t) and x(t) are related to each other in such a way that they together create a strong analytic signal. The analytic signal is expressed as:

$$x_a(t) = x(t) + iH[x(t)] \qquad (4)$$

The module of the analytical signal provides the Hilbert envelope of x (t) which is defined in [1], [7]:

$$B(t) = \sqrt{x(t)^2 + H[x(t)]^2} \qquad (5)$$

3.3 Instantaneous Frequency

Instantaneous Frequency is defined as the time derivative of phase of the analytical signal. The analytical signal is given in [8]:

$$B(t) = \sqrt{x(t)^2 + H[x(t)]^2} \qquad (6)$$

The phase function is:

$$\theta(t) = \arctan \frac{\mathrm{H[x(t)]}}{\mathrm{x(t)}} \qquad (7)$$

Instantaneous Frequency of the IMF component is given in [8].

$$f(t) = \frac{1}{2\pi} \frac{d\theta(t)}{d(t)} \qquad (8)$$

The intermediate frequency of each IMF has real physical meaning. The amplitude and IF can express signal amplitude, instantaneous frequency and time distribution completely, the amplitude-frequency-time distribution is called Hilbert Amplitude Spectrum [6].

4. Analyzing E.C.G Signal Using H.H.T

HHT is used in analysis of heart rate variability in cardiac health. A modified technique based on HHT is used to improve the spectrum estimates of Heart rate variability (HRV). HHT is applied to extract the features of preprocessed time series and to characterize the dynamic behavior of parasympathetic and sympathetic nervous system of heart. The frequency behaviors of the Hilbert Spectrum and Hilbert marginal spectrum (HMS) are studied to estimate the spectral traits of HRV signals. Two kinds of experiment data are used to compare the above method with the conventional power spectral density (PSD) method. HSM is superior to PSD estimation. Compared to the Fourier spectrum this method is more sensitive and effective to identify the low-frequency and high-frequency bands of HRV [9].

HHT is used to de noise the ECG signals. Energy analysis is conducted on the IMF's to find out the boundary between the noise-dominated IMF's and ECG signal dominated IMF's. This method is simpler than wavelet de noising method [6], [8].

HHT is used to detect the R-peak in the ECG signal [1]. HHT and wavelet transform are used to detect the R peak. Initially Wavelet transform is used to de noise the ECG signal, after that Empirical Mode Decomposition is done. Then R peaks are identified by adding the first three IMF's. The result shows that the above algorithm can detect the position of R peak as sensitive as wavelet method. The exact rate of detection is 99.8% on the bad ECG signal [10]. Combination of Hilbert and wavelet transform has a significant effect in the detection of R wave in ECG signal due to the impressive characters of Hilbert and wavelet transforms [11].

5. H.H.T versus Traditional Spectrum Methods

The FFT transforms the data to the amplitude vs. frequency description. The HHT is not constraint by the assumption of stationary and linearity which is required for FFT and generates both amplitude and frequency information as a function of time. HHT is computationally complex than FFT. HHT not only provides instantaneously frequency and amplitude description but it is much more meaningful physically as compared to FFT [3].

In comparison with the DWT, HHT avoids the need of selecting mother wavelet. Its bases are adaptively produced depending on the signal itself, which brings not only high decomposition efficiently, but also sharp time and frequency localization. Because of its superiority, HHT has been utilized and investigated widely to analyze data in the wide variety of applications by researchers and experts. It is first local and adaptive method in time frequency analysis [9].

This method is established on instantaneous frequency. IMF gives meaningful IF. The process of extracting IMF's terminates when the residue contains no significant information. The non-stationary signals whose frequency contents changes with time are encountered in many research areas. The important feature of non-stationary signal is that they have varying spectrum. The frequency at a particular point is described by the concept of IF. IF is used to know when frequency component exists and its change with time. IF characterizes the important parameters of the signal [2].

Compared with Wavelet analysis, Hilbert spectrum has adaptive frequency multi-resolution characteristics [12]. Compared with the traditional spectrum method such as Fourier decomposition and wavelet decomposition, EMD has no specified bases [9].

6. Conclusion

HHT is a powerful tool for analyzing non-linear and non-stationary data. Computation of HHT is complex but it gives much more meaningful physical results. Algorithm of HHT is simple. It can be applied to various fields such as bio-medical, engineering, image processing, geography, oceanography, etc. All real world applications are non-stationary and non-linear. ECG signals are typically non stationary signals so, HHT method in ECG signal processing has broad application prospectus. RF exposed ECG signals are much more nonlinear and non-stationary. Mobile phones are now extensively used by us. The effect of radio frequencies on the heart is a topic of research. Hence use of HHT shall be an accurate approach for analysis of RF exposed signal. The non-linearity and non-stationary nature of these signals puts HHT as a powerful tool to process signals with those properties, avoiding artifacts related to the use of linear and stationary assumptions.

References

[1] Rebeh Mabrouki, Balkine Khaddoumi and Mounir Sayadi, "R Peak Detection in Electrocardiogram Signal Based on a Combination between Empirical Mode Decomposition and Hilbert Transform" ,IEEE first International conference on Advanced Technologies for signal and image processing, pp.183-187,march 2014.

[2] Zhao Zhidong, Wang Yang, " A New Method for Processing End Effect In Empirical Mode Decomposition", IEEE International conference on communications, circuits and systems, pp. 841-845, 2007

[3] Denis Donnelly, "The Fast Fourier and Hilbert-Huang Transforms: A Comparison", Multiconference on computational Engineering in systems applications" pp.84-88,October 2006.

[4] P Karthikeyan, M Murugappan, S Yaacob, "ECG Signal Based Mental Stress Assessment Using Wavelet Transform", IEEE International conference on control system, computing and engineering, pp. 258-262, 2011

[5] N. E. Huang, Z. Shen, S. R. Long, "The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Non stationary Time Series Analysis", Proc .R. Soc. London., vol. A 454, pp. 903–995, 1998

[6] Changnian Zhang, Xia Li, Mengmeng Zhang, "A novel ECG signal denoising method based on Hilbert- Huang Transform", IEEE International conference on computer and communication technologies in agriculture engineering, pp.284-287, 2010.

[7] Hilbert-Huang Transform, lecture 12-13, http://cseweb.ucsd.edu.

[8] Lixin Song, Qian Wang, Lili Guan, and Yujing Wang, "Denoising of Electrocardiogram Signal Based on Hilbert-Huang Transform", IEEE 7th International forum on strategic technologies, pp. 1-5, 2012

[9] Helong Li. Sam Kwong, Lihua Yang, and Dongping Xiao, "Hilbert-Huang Transform for Analysis of Heart Rate Variability in Cardiac Health" ,IEEE/ACM Transactions on Computational Biology and Bioinformatics, vol.8, no. 6, pp. 1557-1567,November 2011.

[10] Xiao-li Yang, Jing-tian Tang, "Hilbert-Huang Transform and Wavelet Transform for ECG Detection", IEEE 4th fourth International conference on wireless communications, Networking and mobile computing, pp.1-4, 2008.

[11] Amin Farahabadi, Eiman Farahabadi, Hossein Rabbani, Mohammad Parsa Mahjoub, "Detection of QRS complex in Electrocardiogram Signal Based on a Combination of Hilbert Transform, Wavelet Transform and Adaptive Thresholding" ,IEEE Proceedings of International conference on Biomedical and Health Informatics, pp. 170-173, january2012.

[12] Ren Zhong, Zhang Haiyong, "Research on Properties of Hilbert Spectrum", IEEE eighth international conference on Electronic measurement and instrumentations, pp.322-325, 2007.