Elements of Signal ECG Evaluations with Wavelet Transform

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Abstract: - A method for predicting clinically relevant levels of ECG signal will be described. The method makes use of the wavelet transform. Wavelet transform of the signal ECG has been shown to be a nonstationary analysis technique describing the time evolution of frequency spectra throughout the QRS complex. In Wavelet transform, which is applied to the RR time serie (the cardiac period), are three zones of frequency. Behind these zones are the physiological mechanisms. This study estimates quantitatively the spectral power of these three zones and the level of the interactions among these zones.
Keywords:- ECG, RR series, wavelet transform

1. Introduction

Developments in medical instrumentation only started to take off recently, when technological revolution in microelectronics started to provide ways for examining the complexities of living organism [1].

Biological signal by his nature generally presents a nestationar character, what can make the study by spectral methods Fourier to be applicable whit to many restrictions. For series of intervals RR, cardiac periods extracts by ECG signal, wavelet transform offer a reduction of restrictions stationary by stationarity in that way spectral analyzable zones of RR records (cardiotahograms) can be enlarged three times.

Wavelets are mathematical function that cut up data into different frequency components, and then study each component with a resolution matched to its scale. They have advantages over traditional Fourier methods. Discontinuities and function with sharp spikes usually take substantially fewer basic functions than sine-cosine based functions to achieve a comparable approximation. The computational complexity is much less using wavelets than Fast Fourier Transform [3],[4],[5].

2. Spectral variations of rr series

In wavelet transform which is applied to the RR time serie (the cardiac period), are three frequencies bands [6],[7]. Behind these bands are the physiological mechanisms. This study estimates quantitatively the spectral power of these three frequencies bands and the level of the interactions among these.

Spectral variations of RR series contains three bands of frequency:

a) a lowest band (LF), generally centred by value 0.1Hz (in one interval by 0.04-0.15 Hz), with a power variation was associated with the simpatic activity on clinical and pharmaceutical experimental fondation;
b) a high frequency band (HF) synchronized by respiration rhythm (in one interval by 0.15 and 0.4 Hz); that is an expression of medium respiratory sounds mediated by vagal activity;
c) a very lowest band (VLB) until 0.04 Hz, with a function of mechanical delay control of temperature like a umoral and thermo-regulated factors.
Interactions of frequency bands are: HF-LF to 0.15 Hz and LF-VLF to 0.04 Hz.
Analyzing the causes of interactions apparitions we can stop to few observations:
- a slower respiration who stimulate the oscillations of simpatic nature and makes LF-VLF interactions;
- a faster respiration who stimulate the oscillations of simpatic nature and makes HF-LF interactions;
- generally physical and psychical efforts who make the needs of protection of body;
- also that kind of passages can be a smaller part of a record and provides by the momentary states.

3. Wavelet Transform and ECG

The Wavelet Transform, signal processing technique for applications such as non-stationary signal analysis, can be embedded in a variety of distinct and useful algorithms [Daubechies, Vetterli-Kovacevic] [2]. The signal is decomposed by means of a special analysis function, called the basic wavelet, which is translated in time or space (for selecting the part of the signal to be analyzed) and then dilated or contracted by using a scale parameter (in order to focus on a given range of oscillations).
The Wavelet Transform comprises the coefficients of the expansion of the original signal $x(t)$ with respect to a basis $\Psi_{\omega,n}(t)$, each element of which is a dilated and translated version of a function Ψ called the mother wavelet, according to:

$$\Psi_{\omega,n}(t) = \frac{1}{\sqrt{2^{\omega}}} \cdot \Psi\left(\frac{t - 2^{\omega} n}{2^{\omega}}\right) \qquad \omega, n \in Z \qquad (1)$$

where Z is the set of integers. Depending on the choice of the mother wavelet appropriately, the basis can be orthogonal or biorthogonal. The Wavelet Transform coefficients, given by the inner product of x(t) and the basis functions:

$$W(\omega, n) = \langle x(t), \Psi_{\omega,n}(t) \rangle \qquad (2)$$

comprise the time-frequency representation of the original signal.
The Wavelet Transform has good localization in both frequency and time domains, having fine frequency resolution and coarse time resolution at lower frequency, and coarse frequency resolution and fine time resolution at higher frequency. Since this matches the characteristic of most signals, it makes the Wavelet Transform suitable for time-frequency analysis.

4. Decomposition algorithm

The algorithm for wavelet decompositions has been implemented in MATLAB and it his three mean steps:
a) wavelet decomposition with an octave-by-octave algorithm;
b) interpolation in time (to have a dense time axis);
c) frequency-interpolation (to have a dense time axis).
The results are presennted like images in wich the intensity at each pixel represents the magnitude of Wavelet Transform in that moment of time and for that scale (in time - scale plane) – Figure 1.
The study evaluates the interactions HF-LF (to 0.15Hz) and LF-VLF (to 0.04Hz) and the level of spectral power showed in the three raw bands of cardiotahogram.

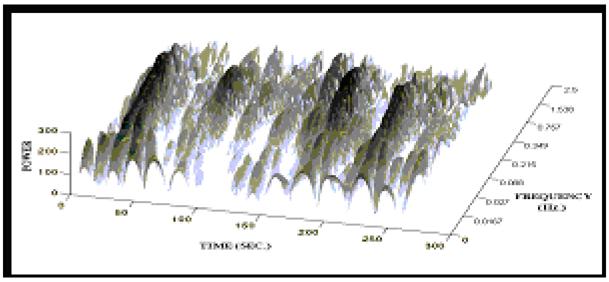

Fig. 1. Wavelet matrix - series of time RR – 3D representation.

Until now the analysis about those portions of signal was made only by visual qualitative evaluation; contribution of that study is the transition between qualitative to semi-quantitative.
For that it was necessary a complex program to process the wavelet matrix (Figure 1) in a "island of power" - slides parts by Wavelet matrix limited by the other about spectral power criterion, in that way additional "islands of power" are with 10-30% smaller than those inside his area Figure 2.

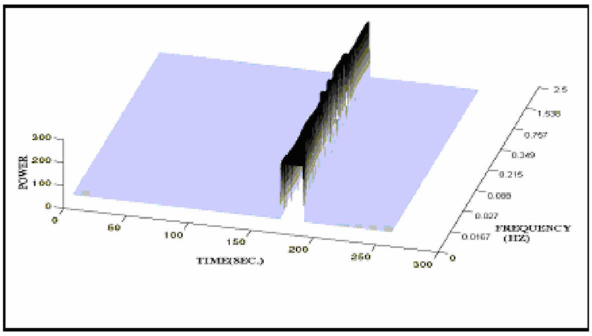

Fig. 2. Selection of “islands of power”

Power decimalization is realized with the help of two subprograms. Once detected, "island of power" is retained and excluded by the original Wavelet matrix. Thus by program cycling is obtained a number approximately 200 "islands of power". Each "island of power" is analyzed function of position, which is occupied in frequency and his interactions with neighbor "islands of power". It will result a certain level of interaction between different band of interest Figure 3. In final, if interaction grade between the bands is reasonable, it may be acceptable the time series RR to be submit Fourier canalization on studied segment.

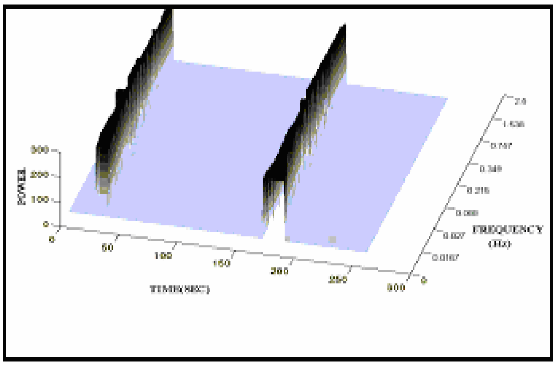

Fig. 3. Interactions between “island of power”.

How it can be seen in Figure 4, for chosed spectral epoch we have an interaction level to higher at LF-VLF; levels of interactions are highly enough thus analyzed signal will not be validate for Fourier analysis in that example. Acceptable interaction level will be 1 500 000 (units of spectral power), for future validation of Fourier analysis.

5. Conclusions

The paper presents a method, based on Wavelet Transform, applied to the RR time serie (the cardiac period).

Wavelet Transform describes the signal simultaneous by time and frequency and it is realizable in the case of that study that produced 3D images (time-frequency-spectral power) whit the help of programming medium Matlab.

The evaluations of interactions between frequency bands of ECG signal with Wavelet Transform is a competitive digital technique.

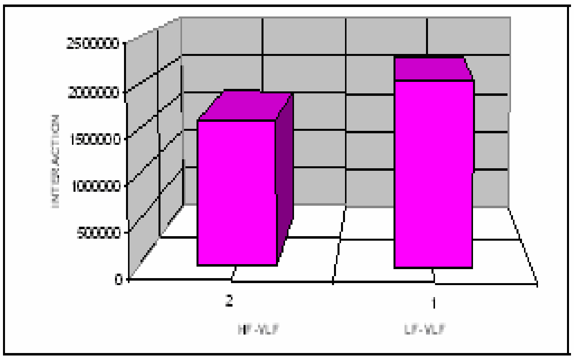

Fig. 4. Interaction between frequency bands.

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