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Comparative Study of Heart Rate Variability by Wavelets

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Abstract— **Changing our dietary habits and environmental poor quality have increased the risk of cardiovascular disease in Algeria and around the world [1]. It is found that the majority of these diseases are related to cardiac rhythm disorders. The waveform which is responsible of this rhythm is called R-wave (see Figure 1). In these pathologies it is desired the heart rate and therefore frequency of R-waves and their regularity.**

Our aim in this paper is to do a comparative study between two cardiac signals, one being full the other representing the QRS block using the resources offered by the data processing.

Keywords— **Synthetised signal, de noising, continuous wavelet, wavelet packet.**

I. Introduction

At present, public health is becoming increasingly important. And Among the ways used to improve the health has monitoring physiological parameters of the human being, especially the ECG because the latter reflects the activity of the heart.
The ECG has the following form:

Fig. 1. ECG's form.

Where Heart rate is given by the following law:

$$Heart\ Rate = (1/RR).60. \quad (1)$$

The main tool of diagnosis is the determination of the R-R interval with accuracy, but if the analyzed signal is noised this determination will be incorrect.
Many studies were done to get a de-noised ECG signal –and other signals-with different techniques [2] [3] [4]. All these techniques use the data processing tools; the wavelet technique is the most used of them.

II. THEORETICAL BACKGROUND

wavelet theory is relatively recent (late 80- early 90's), but the origin of this method goes back to 1975, or a certain Jean Morlet created small mathematical functions with as small waves hence the name wavelet. It took several years for the formalism of this theory be done by other scientists such as Stéphane Mallat, Ingrid Daubechie, Yves Meyer and others. A **wavelet** is a wave-like oscillation with an amplitude that begins at zero, increases, and then decreases back to zero. We have several mother wavelets (see figure 2).

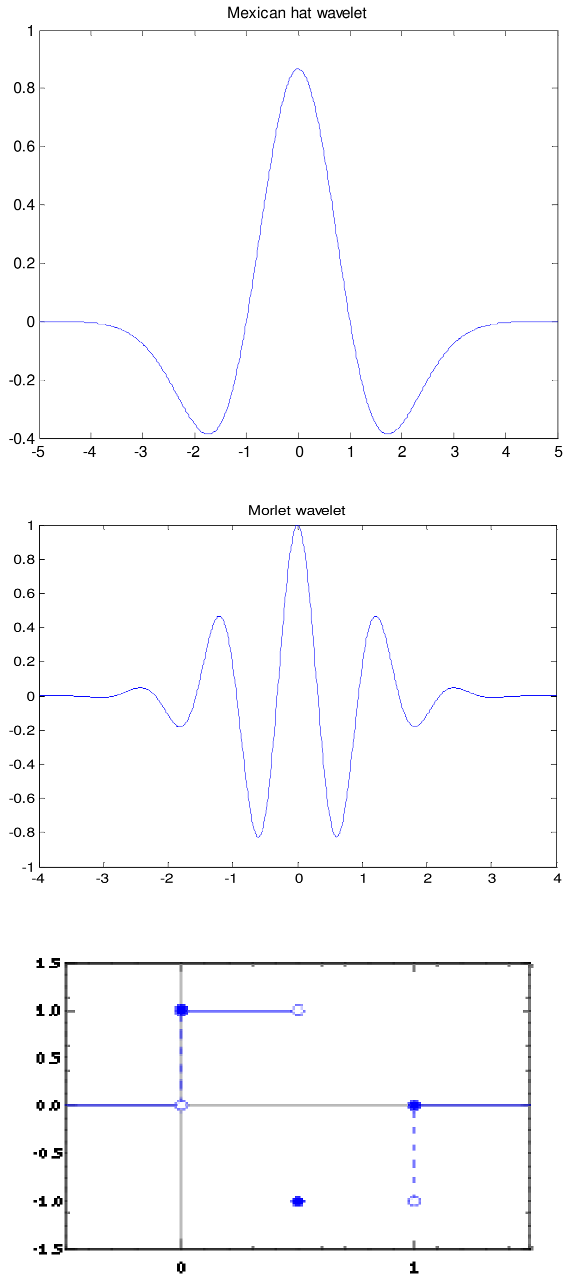


Fig. 2. Some mother wavelet functions.

Wavelet transforms are broadly divided into three classes: continuous and discrete.

Continuous wavelet transforms: In continuous wavelet transforms, a given signal of finite energy is projected on a continuous family of frequency bands (or similar subspaces of the L^p function space L^2(R)). For instance the signal may be represented on every frequency band of the form [f, 2f] for all positive frequencies $f > 0$.

The subspace of scale a or frequency band [1/a, 2/a] is generated by the functions (mother wavelet ψ(x)):

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right), \tag{2}$$

The wavelet transform of signal x(t) is defined as:

$$C(a,b) = |a|^{-1/2}\int_{-\infty}^{+\infty} x(t)\psi^*\left(\frac{t-b}{a}\right)dt \tag{3}$$

Where C(a,b) denote the wavelet coefficients of signal x(t).

(*) is a symbol of a complex conjugate function.

Wavelet packet transform (WPT)**:** However, the continuous wavelet transform (CWT) does not handle high frequencies. That's why we developed the wavelet packet transform (WPT) which can be implemented on the basis of wavelet filters and defined by the following equation:

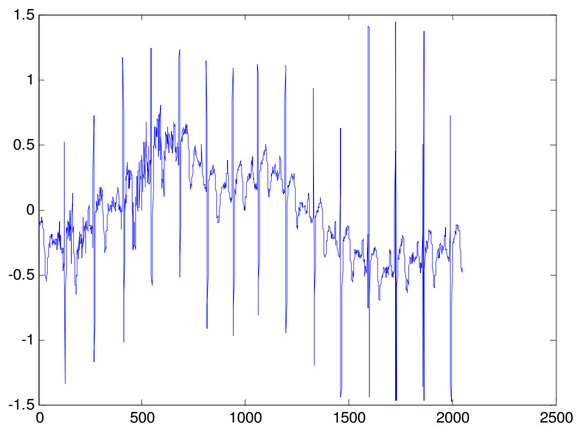
$$\begin{cases} b_{ij} = \sqrt{2}\sum_{n=0}^{k} H_n\, b_{i-1,\,j+n} \\ b_{ij} = \sqrt{2}\sum_{n=0}^{k} G_n\, b_{i-1,\,j+n} \end{cases} \tag{4}$$

Where b_{ij} *denotes* the jth decomposed frequency-band signal at level i (j= 1,2,. ..,J). where J is the number of the decomposed frequency-band signals and equals 2i ; i¼ 1,2,. . .,I, where I is the number of decomposition levels); *Hn* and *Gn* are the low pass filter and high-pass filter based on wavelets, respectively. The filter G is a high-pass filter with the same cutoff frequency as the filter H.

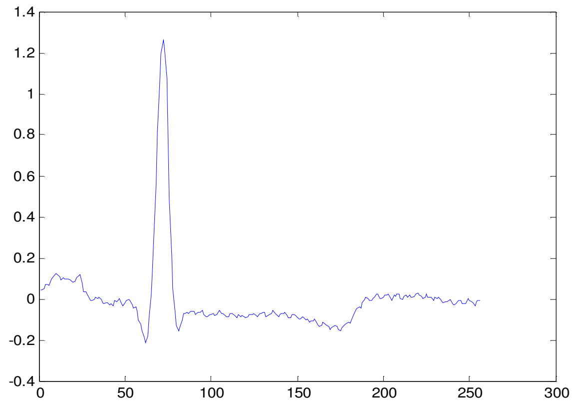
G and H are called conjugate mirror filters [2].

III. RESULTS AND DISCUSSION

We applied the different wavelet transforms on two real ECG signals selected in the basis of free physiologic data bank "Physio net". These raw data have the following shape:



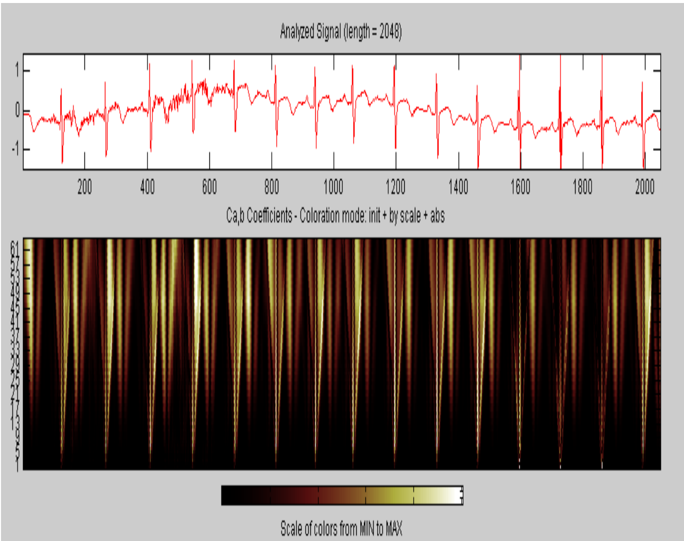
(a)

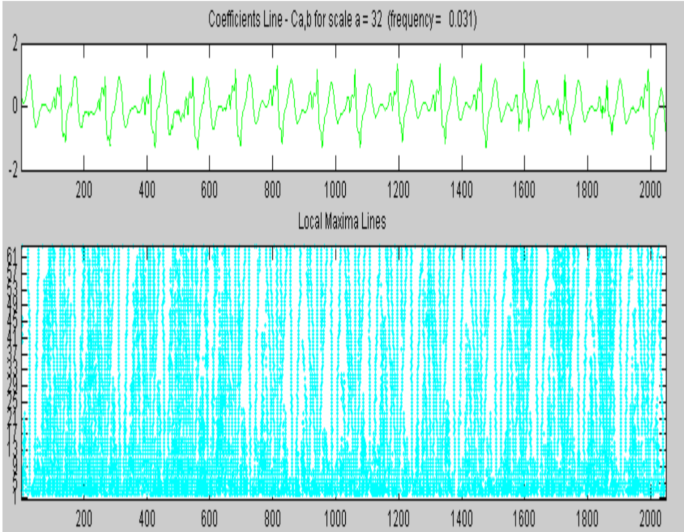


(b)

Fig. 3. ECG Of the two subjects – (a) Complete ECG, (b) QRS bloc of subject 2.

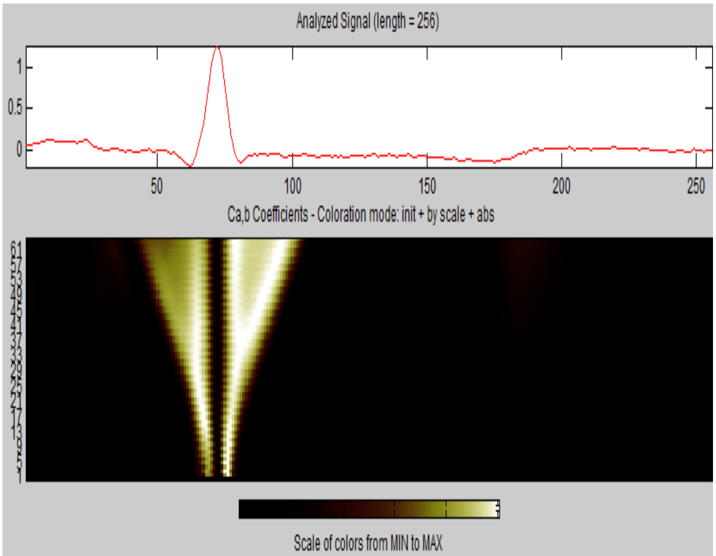
Firstly, we have applied the continuous wavelet transform (Haar level 1) on the data (a), by using the processing toolbox, we get these signals:





(a)

And for data (b):



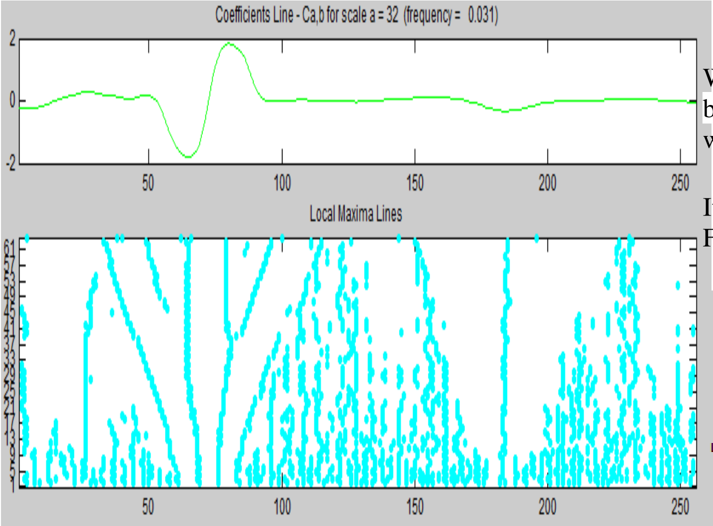
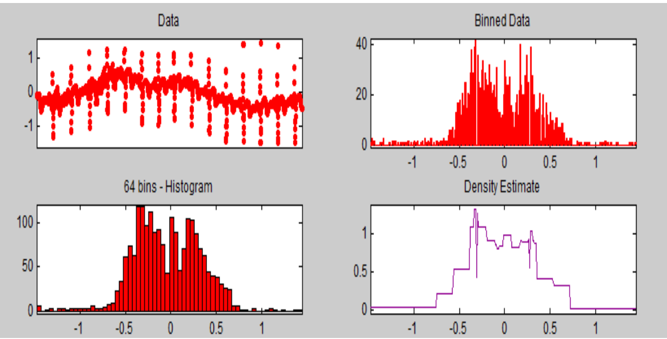


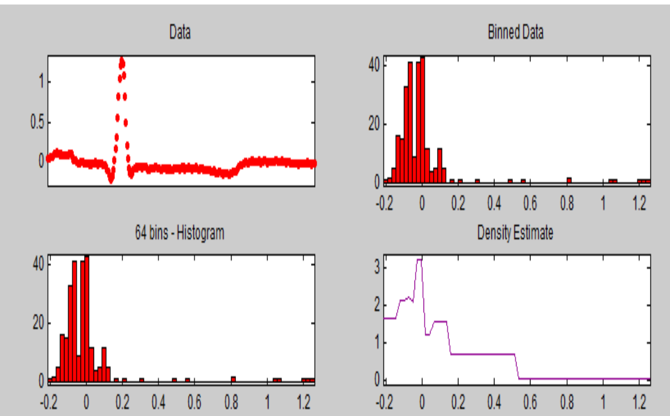
Fig. 4. Simulated analysis by continuous wavelet.

The first finding is concentration of wavelet coefficients on the peaks of R, which is understandable because the intensity of these peaks is important. The something is proofed by applying *wavelet packet transform (WPT).*

With this discrete wavelet transform density estimation with Haar (level 5), we get these results:



(a)

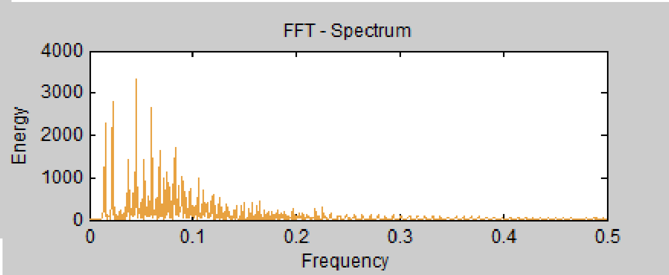


(b)

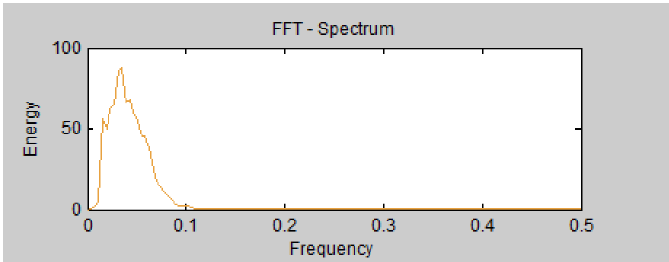
Fig. 5 Simulated analyses by density estimation.

We can see from the graph the irregular resulting density because of the concentration of the energy around zero. But we can perform it by applying different types of wavelet.

It's clearly demonstrated by another technique which is the FFT (see figure 6):



(a)



(b)

Fig. 6. FFT Spectrum of the two subjects.

We see also that the two signals are operating in low frequencies.

Finally in order to see the synthetised signal after de-noising, for the ECG of 2 subjects. The result was:

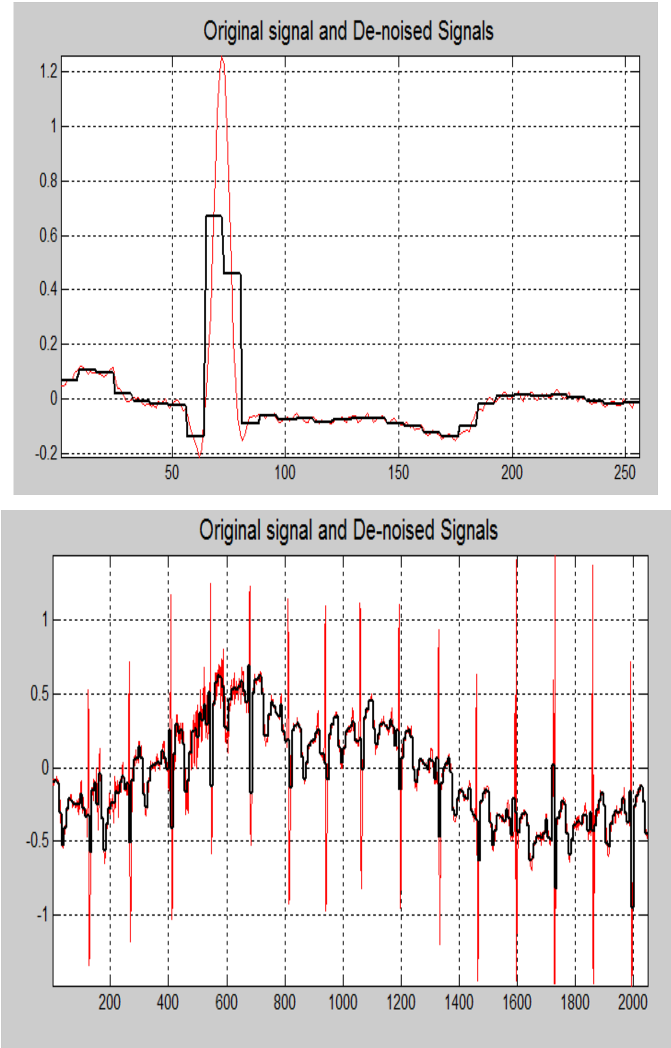


Fig. 7. Original and Synthetised signal (de-noised signal: black colour) after application of WPT.

IV. Conclusions

In the present work, a comparative processing approach of two types of ECG was done. The important for us was to know what's the particularity of an ECG constitutes by one pick (one QRS- subject n°2) compared to an compared to a conventional ECG (subject n°1). This work had decomposed and studied a physiological data (ECG) by using various wavelets tools. Another result of this research is improving knowledge of diagnostic tools.

We hope in the future to deepen this study by investigating other physiological aspects with more processing methods.

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