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ECG's SIGNAL PREPROCESSING BY WAVELET

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ABSTRACT—

Wavelet theory allows us to work in sub-bands and in frequency domain without losing the temporal information present in the useful signal (in our case this signal is a biomedical signal " ECG") and therefore is can eliminate the noise present in the original signal and to rebuild the subsequent signal, and we will get a clear signal. This operation is called preprocessing.

We have applied the continuous wavelet transform (CWT), that eliminates noise, but when we wanted to do the opposite way ie inverse transform to reconstruct the original signal de-noised we could not. The reconstruction of the signal itself being another function further that the de-noising forced us to apply another wavelet transforms category reconstruction- -in order to realize this, which is the discrete wavelet transform (DWT).

After running the 'DWT' Matlab we had got convincing results.

***Keywords*— ECG, wavelet, DWT, inverse DWT, reconstructed signal.**

I. INTRODUCTION

Data pre-processing is an important step in the data mining process. It describes any type of processing procedures that are performed on raw data to prepare it for another processing procedure and ultimately, analysis. Pre-processing laniaries the relationships among the variables in our Dataset and removes extraneous sources of variation that are of no interest to the analysis [1]. We have many methods for preprocessing and among these appear the wavelet transform. the origin of the theory of wavelet Transform goes back to 1975, or a certain physician Jean Morlet working at Elf Aquitaine company at this time -created small mathematical functions with small waves hence the name wavelet.

Wavelet theory has affected all areas of technology despite its appearance of pure mathematics -in beginning-. But it is in the field of signal processing it found its full expansion. One of these fields is the biomedical engineering. For our case we have applied this technique (wavelets) for analyzing ECG. Our search is focused on the physiological signal's "ECG" reconstruction by the wavelet technique -after applying a de-noising operation-.

II. THEORETICAL BACKGROUND

II.1. Wavelet Transform:

Mathematically, a wavelet series is a representation of a square-integrable function . A wavelet is a function based on the wavelet decomposition, decomposition similar to the Short-time Fourier transform, used in the signal processing. It corresponds to the intuitive idea of a function corresponding to a small oscillation, hence its name. But compared to the Fourier transform, it can implement a different basis, not necessarily sinusoidal [2].

The wavelet transform is accomplished using the translated and scaled versions of a mother wavelet y (x) defined by [3]:

$$\psi_{a,b}(t) = |a|^{-1/2}\psi\left(\frac{t-b}{a}\right) \qquad (1)$$

Where (a) and (b) are scaling (dilation) and translation parameters, respectively. So (a) and (b) expresses the duality between time and frequency domain resolution which is another advantage comparatively to Fourier transform.

We have several mother wavelets such as Haar [4] and Daubechies (see figure below).

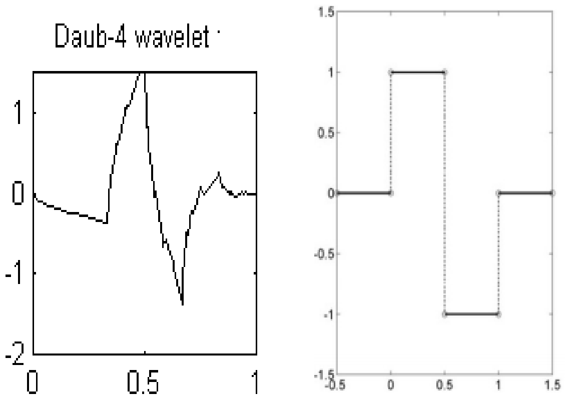


Fig.1. Diagram of the wavelets mother function: (a) Daubechies, (b) Haar.

Analyze a square summable function wavelet is to calculate all of its scalar products with the wavelet family. Numbers obtained are called wavelet coefficients, and combining the transaction to a function its wavelet coefficients is called wavelet transform [2].
This defines the continuous wavelet transform of a function f \ in $f \in L^2(\mathbb{R})$ by:

$$g(s,\tau) = \int_{-\infty}^{\infty} f(t)\psi_{s,\tau}(t)^*\,dt \quad (2)$$

Where $\psi_{s,\tau}$ is a wavelet from the family of wavelets, * denotes the complex conjugate, τ is the translation factor and s is the expansion factor.
Discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. The sampling gives:

$$\psi_{m,n}[t] = s_0^{-m/2}\psi(s_0^{-m}t - n\tau_0) \quad (3)$$

Where s_0 and τ_0 are constants.
We then wrote the discrete wavelet transform:

$$g[t] = \sum_{m\in\mathbb{Z}}\sum_{n\in\mathbb{Z}}\langle x,\, \psi_{m,n}\rangle \cdot \psi_{m,n}[t] \quad (4)$$

The inverse discrete wavelet transform function reconstructs data from the given coefficients by performing single levels.

II.2. Electrocardiography (ECG):

Electrocardiography (ECG) is a physiological signal which interprets the electrical activity of the heart over a period of time.
It can be represented by a succession of waves (QRS complex, P and T waves) 'see figure 2'.

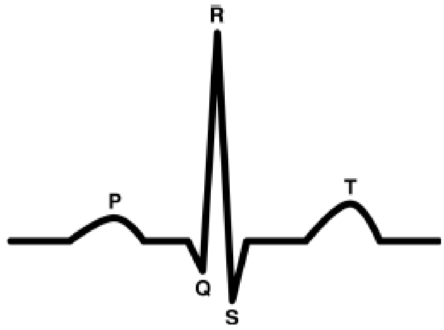


Fig. 2.Characterization of a standard ECG.

Any irregularity of the signal represents a cardiac pathology such as arrhythmia and it's very important to detect this abnormality at time [5].
The P curve indicates the contractions of the auricles and the QRS wave associated the ventricles (systolic state or blood is expelled to arterial system). T wave indicates the moment when the ventricles are relaxed (diastolic state). Various parasitic elements affect the ECG signal and can make it unusable, such as noise (see figure 3). So we have to do a data processing before exploit the ECG, that's what we call preprocessing [6].

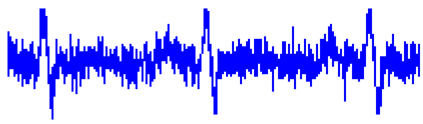


Fig. 3. A strong noisy ECG.

III. Results and Discussion

After executing the discrete wavelet transform 'DWT' on a noised signal (Fig.4) -under Matlab- we got these results:

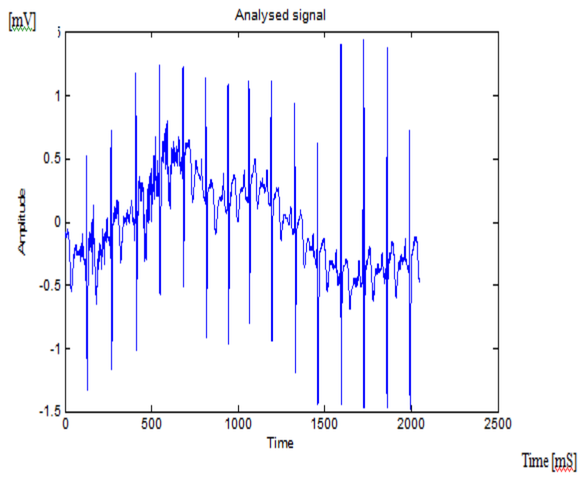


Fig. 4. Original –noised- signal.

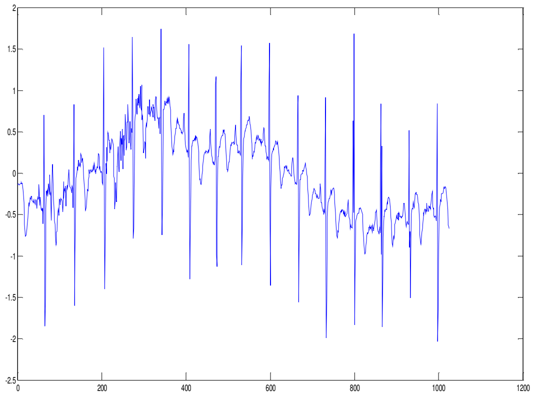


Fig. 5. Signal de-noised by wavelet "DWT".

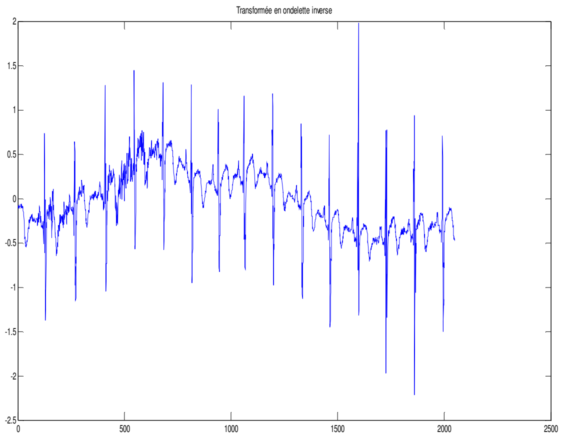
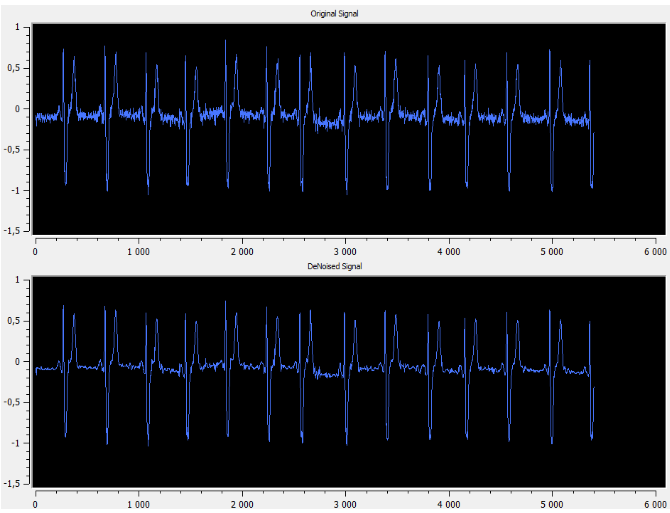


Fig.6. Signal reconstructed by the inverse Wavelet transform of DWT.

We see particularly from the figures'4, 5&6' as the noise of the analysed signal –approximately between '0' and '750' milliseconds- was reduced after the implementation of the DWT, plus we had a good signal (faithful throughout the time band) and we get our original signal (more or less entirely) during reconstitution.



Another example –just to compare with an application - to see the reconstitution of the ECG by DWT but this time associated with soft thresholding (method) and Daubechies wavelet (type 5, decomposition level 4 is an average noise suppression level), we see the following signals :

IV. Conclusion

While smart sensors and even integrated sensors -biomedical or not- do the function of preprocessing (mainly the de-noising) we need to apply processing software's in addition for doing other features such as reconstruction, segmentation, and others.
That is why the data processing is an essential function in medical engineering.

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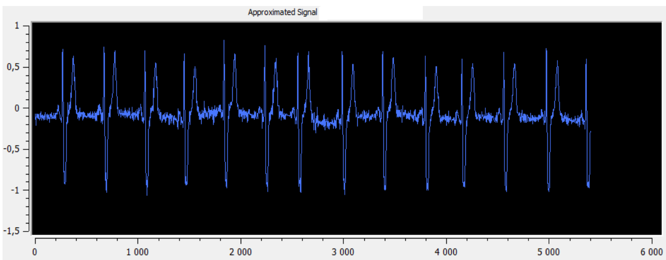

Fig.7. Application of DWT and inverse DWT on an ECG signal.

We can ascertain that we have the same results for the two methods of discrete wavelet transform.