Electrocardiographical Signals Parameters Measuring

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Abstract-This paper present a virtual instrument using for analysing a electrocardiographical signals. An interesting analisys can be made having on the base the graphical representation of samples series depending on this derivative, using a wavelette transform or fractal analysis.

I. Introduction

Qualitative and quantitative studying the passive and active electrical properties of biological systems, the phenomenological theory of electromagnetism is used, into a general wording, concerning the electrical field inside a conductive volume, generated by a certain applied current density and conventionally admitting the existence of a linear, infinite, homogenous and isotropic medium, characterized by the electroconductibility, permeability and permittivity.

The biological potential sources are situated in electrolytic medium, with complex character, whose time nonlinearity and variableness are generated by functional characteristic features of biological structures. Concurrently, the interpretation of potential difference existent between two points of the biological conductive medium requires studying the properties of whole system, in which the biological sources are in interdependence. Given the ideal formulation of electromagnetism laws, which are applied however in biological phenomena, are evident difficulties in mathematical simulation of real electrical features of the living body, which is a no homogeneous conductive volume, delimited in no uniform space, with electrical anisotropy, composed of a multitude of independent sources, which interfere spatial and temporal in variable way.

On the base of living matter, there are molecules, with biological structures and noteworthinesses, submitted to some permanent changes by chemical reactions, and to some perturbations produced by electromagnetic radiations, taking place continuous reshufflings of biological structure organization. In case of the variation of the environmental conditions, inside a biological system, occure opposite processes, that diminishes and annihilates the action of the perturbator factor. In the living cellule occur numerous energetical transformations that have correspondent in electrmargnetical energy.

Specific to living organism is the fact that its electrical and magnetic properties depend on the kind of the atomic and molecular linkages, which determine directing effects of dipoles, induction effect of polarizable molecules and dispersion effects of a quantum nature. Inside the living systems there, certain features, proper to semiconductors, were emphasized, linked to their chemical structure. It was proving the dependence of conductibility of some biological structure by the action of temperature and electromagnetic radiations from visible spectrum, effects similar to thermoconductive and photoconductive substances.

We can affirm that the interactions of organism with the environment, also its internal functions, are connected with electromagnetic phenomena. Thus, we can say that, in the study of electromagnetic phenomena, the biological, physical and technical sciences could bring an important contribution in the others' progress, for achieving some improved technical devices. The understanding of biological phenomena requires the ability of some theoretical interpretations, as well as the achievement of some investigation methods on wich the technique can hold or can produce its.

II. The generation and transmission of electrical signal inside living bodies

The biological electrical medium has some special features, proper to living bodies. It is a nonuniform, nonhomogeneus and nonisotropic medium, with numerous structural and functional differentiations, complex correlated.

The living body is, at the same time, a source of electrical voltages, generated through energy mechanisms that result by cellular metabolism, and an electrolytic conductor in which the electrical

charges remove through ionic transfer.
The electrical features of biological mediums are being determinate by water and electrolytes repartition as against the active membranes. The membrane's aim in adjusting of the hidroelectrical distribution confirms the idea that the biological activity takes place at separation limit between two distinct mediums, through an active separation membrane.
The cellular membrane has a capability generated by the existence of some dielectric substances contained into the membrane structure and by the electrical charges' polarization aside and another side of its. The limited membrane's permeability in comparison with certain ions in rest state and the increasing of the permeability during the depolarization make that this electrolytic capacitor being an imperfect capacitor with important electrical losses.
The time constant of membrane is defined as product between the resistance and the capacity of membrane and represent graphically by a charge and discharge curve at a ΔV voltage.

$$\tau_m = r_m \cdot C_m \qquad (1)$$

The electrical capacity of cellular membrane has value as μF/cm^2 order (from 0,5 to 1,5 μF/cm^2), at muscular cellules having the highest capacities (till 5 – 8 μF/cm^2).
The probing of the impedance in alternative current led to establishing of the real values of electrical capacity of cellular membrane. The following relation defines the transmembrane impedance:

$$Z_m = \left(C_m + jB_m\right)^{-1} \qquad (2)$$

where: C_m –membrane conductance, B_m –membrane electric susceptibility $B_m = \omega \cdot C_m$, ω being the pulsation of alternative current.
The inverse value of impedance Z_m is represented by the membrane's admittance $Y_m = 1/Z_m$. The exploring on alternative current show a negative electrical reaction in cellular structures:

$$X_c = -\frac{1}{\omega \cdot C_m} \qquad (3)$$

At the cutaneous level, the polarization phenomenon, intense in continuous current and attenuated in alternative current, has three main aspects:
1. *ionic polarization*, consisting of limited displacement under the action of electrical current of the ions which determine introducing the temporary electrical moments.
2. *dipolar polarization*, aspect represented by the orientation of the electrical axes of the polar molelecules, parallel with the electrical field direction;
3. *interface polarization*, between structures, which are due to the nonhomogeneous of biological conductors.

At the electrical current crossing through the skin, a contraelectromotive voltage is produced, during the time, those increasing the real rezistanec value. At the low and medium frequency, alternative electrical current crossing through the body we can observe not only a rezistnace, but also a capacitive reactance, both determined in the main by the skin, what determines the using of the impedance notion.

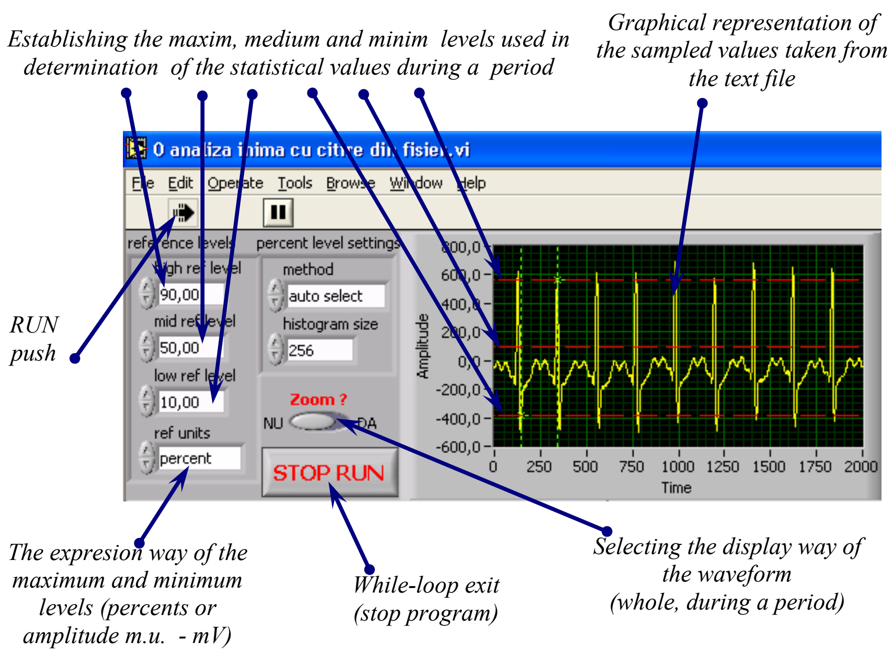

Figure 1.

III. Software application meant for mathematical analisys of heart signals

The achieved application allows the processing of an electrocardiogram signal saved as sample type into a text file. These can be obtained from medical equipments as electrocardiographs interfaced with the computer. The execution launch of the application requests to user, through a frame, to indicate the text file, which contains data that will be processed. After the samples recording on the memory, the program runs into a while-loop. The outgoing from the loop can be commanded through a switch placed on the frontal panel.
The frontal panel of the instrument will be presented as groups of elements specific to a certain type of waveform data processing.
In figure 1 is shown the zone of frontal panel in which the user can view the waveform taken from file, complete or during a period, reacting on the *Zoom* switch. Also here it can selected the maximum and minimum levels depending on which will be compute the specific values of the processed periodic signal as well as the number of the histogram representation levels. There is the possibility to indicate the threshold values or the reference value as percents or in measurement units for amplitude (mV). Also in this zone is situated the *STOP* button which allows the outgoing from the while-loop and so the program stopping.

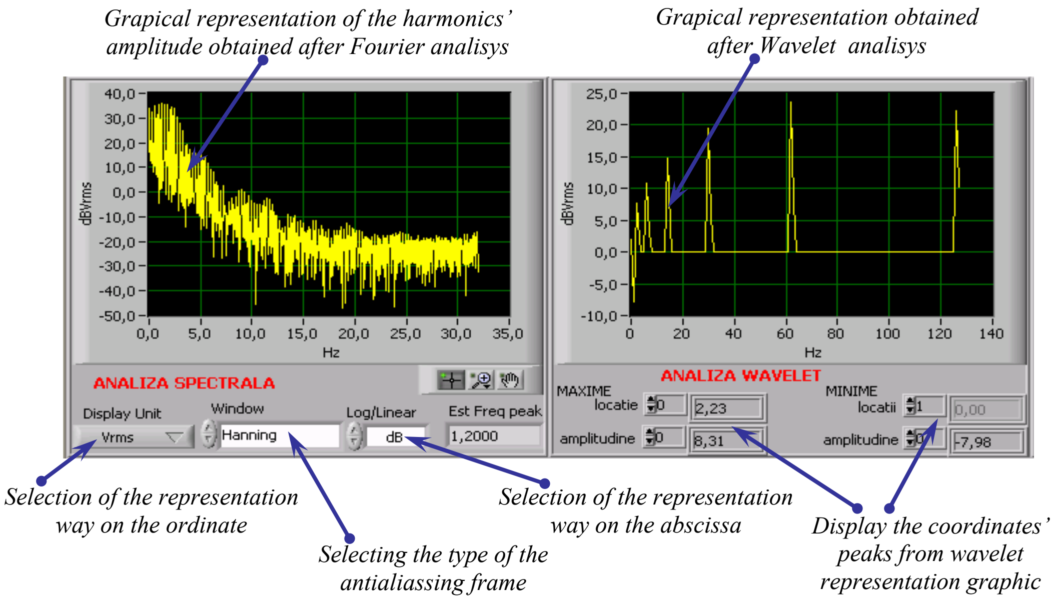

Figure 2.

On this first zone can be viewed the graphics obtained after the evaluation of Fourier and Wavelet transforming for the heart signal. The firs graphic represents the harmonics' amplitude obtained through Fourier analysis. The user has the possibility to choose the representation way on ordinate (the representation unit) and on the abscissa (the representation way). It is valuated the frequency also, with a satisfactory accuracy. Also in the lower part of this frame, the user can choose the used antialiasing frame.
In case of Wavelet representation, on the lower part of the graphic can be viewed the coordinates of the maximums and minimums choosing their order.
Figure 3 presents the zone on the frontal panel of the virtual instrument in which there is represented the variation of increasing speed of the signal amplitude depending on the samples' amplitude. We can observe the obtaining of a closed curve for each period of cardiogram, curve similar with a cardioide. This representation differs from an EKG signal to another, existing the possibility that this form to be an indicator of some person's general emotional condition, of a

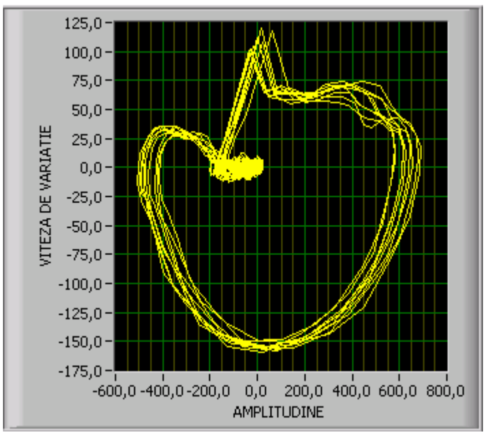

Figure 3. The cardioideimagine obtained representing the signal variation speed depending on the amplitude

disfunction at the sanguine system level (pathological case) or even a way to indentify a person.
On the right zone of the frontal panel, we can obtain some datum about analyzed waveform. Figure 4 show these program's function ways. A first zone offers details referring to the increasing and decreasing time of signal for any period of analyzed signal simultaneously with a graphical representation (on *Zoom* function) where we can identify the zones of which features are determinate. In the second zone are indicated the length of time for positive and negative impulses for the chosen period for analysis. The next zone evaluates the average and the r.m.s. (root-mean-square) value of the signal during a period as well as the representation of the histogram of the analyzed series' values. The last zone computes the amplitude, minimum and maximum values as well as some statistic values (variance, mean-square-error, variance/average ratio) for the whole signal.
The lower zone of application evaluates the fractal dimension of cardiographic signal, the correction coefficient and Hurst coefficient, simultaneous with the graphical displaying of the values iterative

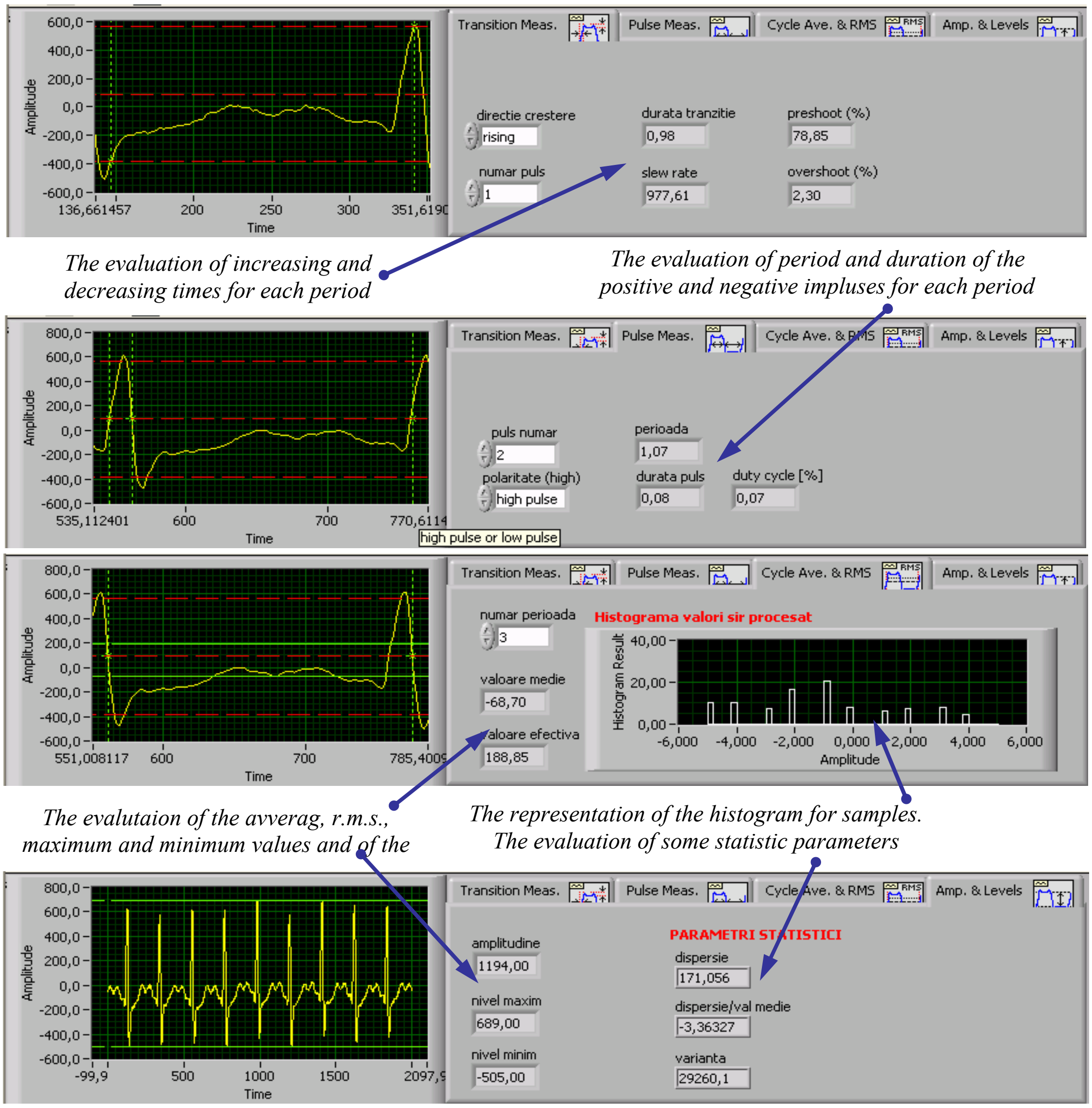

Figure 4. The evaluation of some sizes specific to periodical signals as well as of some statistic parameters (succesive imagines of the same zone)

obtained on the process of determination of the fractal dimension and of the interpolation function. Herewith there are indetified the extremal points of graphic in the seight to determine the evolution period of the signal between these values. In order to be used successfully in case of different signals without to give rise to errors through nondetecting of an extreme, the user has the possibility to modify the maximum and minimum limits actinoning some cursors placed on the graphic. The values of the extremal points' coordinates as well as the value of the second derivate on those points are displayied choosing its order. These points are represented superposed over the signal for analised.

IV. Experimental data and conclusions

The experimental data were taken from patients with age between 16 and 19 years, which are not suspected of circulatory system's complaints. The number of pateinets was reduced (3 patients) because at this stage it was aimed the feature of some knowledges about data acquisition and processing techniques. The used signals are drawn from patients without pathological symptoms.
The pletismographic signals were drawn during 2 days, first time in quiet and repaus conditions and second time on a diverse musical background. First day the environmental temperature was about 20°C and the data aquistion's length time was 5 minutes. Second day the environmental temperature was about 25 - 26°C and the data aquistion's length time was 12 minutes. In the following examples were processed only short parts from aquisioned series.

Tabel V.1. The results of analisys of some electrocardiographic signals

	EKG1	**EKG2**	**EKG3**
Detected amplitude	77,48	128,8	102,7
Maximum value	743	582	689
Minimum value	-555	-669	-505
Averrage	-19,512	-42,539	-56
Max value - Min value	1298	1251	1194
Dispersion	156,093	170,735	171,05
Variance	24365	29150,5	29266
Dispersion/Variance	-7,999	-4,0135	-3,363
Number of samples	1024	1024	1024
Correction coefficient	0,97	0,98	0,96
Hurst coefficient H_m	0,27	0,4	0,33
Fractal dimension	1,732	1,599	1,673

After data analisys, it can observe that for signals aquired from equipments and from different patients, although the maximum and minimum values vary, due to the device calibration process and of the positioning of reference electrode, the amplitude diference is constant.
For the first signal the variance differ due to the the computed average so due to the centereing of electrocardiographic signal in comparison with reference voltage. The dispersion/variance ratio indicates problems regarding the data aquisiton. So, for the first signal, a ratio by far smaller is observed, in concordance with the signal waveform, which has evident variations from a period to another period.
Thew correction coefficient is similar but probably the Hurst coefficient is not a relevant parameter in the analisys of this kind of signals or there exist a cause not determinated until now, which influence it.
It seems that the fractal dimension is influenced in a large measure by the electrical noise, which superposes over the electrocardiographic signal, the main source of this noise being the skin-electrode interface.
The pletismograph analisys together with an ECG (electrocardiographic) mark allow study of the possible serious pathological cases or only the particularities of the cutaneous system or of the peripheric sanguine system.

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