QUASI-FREQUENCY ANALYSIS OF ELECTROGASTROGRAMS

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Electrogastrography is a method for myoelectrical activity recording of the gastric muscle wall, using both internally and cutaneosly located electrodes [1]. The method could be very useful for assessment of gastric motility abnormalities, but it is still not routinely applied because of either the invasive internal technique or the difficulties in obtaining good quality recordings. The examination with noninvasive surface electrode positioned on the abdominal skin is not painful and usually is preferable despite the global information acquired due to the distance to the stomach and the large electrode area.

The electrogastrogram (EGG) is a sequence of sinusoid-like waves with amplitudes of about 100 through 500 μV and frequencies in the range of 0,03-0,25 Hz. The EGG measurement and analysis are preceded by suppression of unwanted accompanying events such as cardiac and respiratory artefacts and electrically induced noise [2].

Different methods of spectral analysis for EGG signals are used [3]. The power spectral analysis is the most commonly applied. In order to present the signal changes with time, the running spectral analysis is implemented over a window of samples shifted consecutively forward. The classical Fourier transform or its fast version FFT are used. However thus the participation of the low-frequency components in the spectrum is enhanced for lack of objective criterion for choosing the analyzed epoch length. Decisive advantage is offered by the quasi-frequency analysis (QFA) [4], allowing a wave selection using amplitude ($\mathbf{A_T}$) and time-interval ($\mathbf{T_T}$) thresholds. A version of such a selection and further analysis is elaborated, adapted to the specific EGG characteristics.

The first step of the wave recognition and subsequent discrimination consists of location of the extrema and measurement of their amplitudes $\mathbf{a_k}$ and time-intervals with respect to the beginning of the epoch $\mathbf{t_k}$. Here the mathematical extremum definition can not be directly applied without confusion, because very often among the analog-to-digital converted data many highest and respectively lowest values are consecutively encountered. Therefore the first value of the sequence is elected as maximum or minimum, the next samples being neglected. Thus a correct alternation of maxima and minima is established.

In general each wave $\mathbf{W_k}$ is associated with the time-interval $\mathbf{T_{k,k+n}=t_{k+1}-t_k}$ and the difference between the amplitudes $\mathbf{A_{k,k+n}=a_{k+1}-a_k}$ of the extrema $\mathbf{E_k}$ and $\mathbf{E_{k+n}}$. In particular, at the beginning of the local waves search, **k** and **n** are equal to 1.

In fact each selected pair of $\mathbf{A_k}$ and $\mathbf{T_k}$ represents a half-wave. Dividing the number of half-waves by two, we can obtain the full-wave periods.

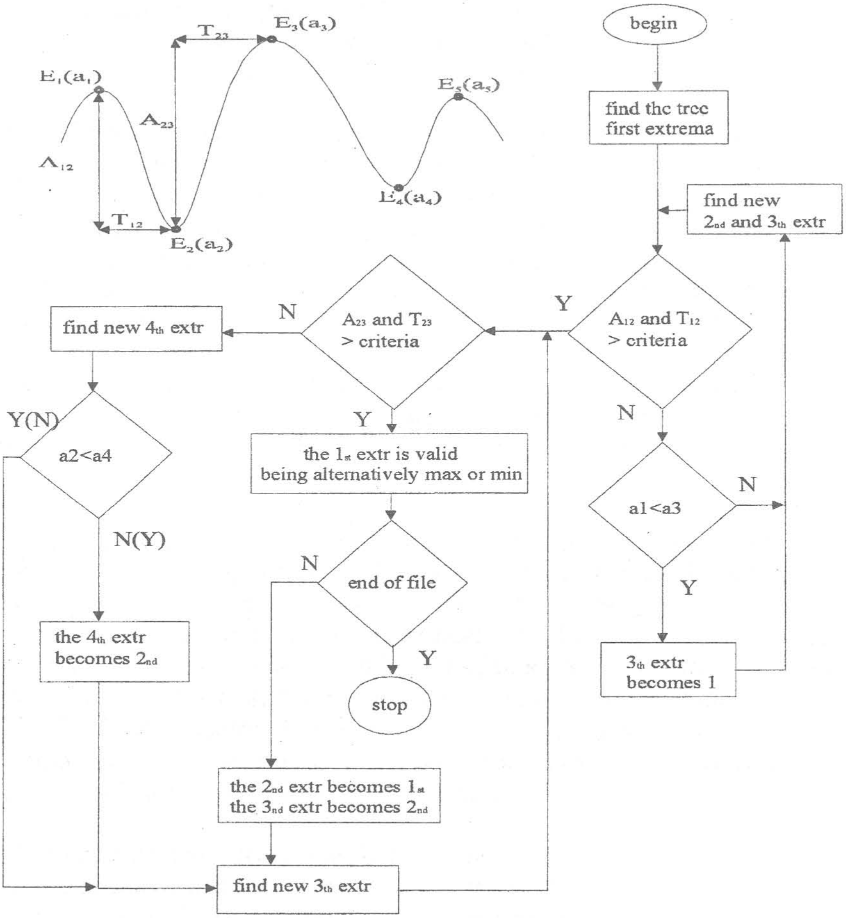

Fig. 1

Using the QFA, only the intrinsic signal frequency components may be admitted to contribute to the spectrum evaluation. Any kind of remaining noise and artefacts outside the signal frequency band can be deleted by appropriately determined thresholds, canceling low-amplitude high-frequency waves. Thus the QFA recognition procedure is equivalent to low-pass filtering.

The algorithm describing the elaborated version of QFA is shown in Fig. 1.

The head of the program (the right part of the diagram) deals with the detection of the first extremum in the analyzed epoch, whose pair of parameters $\mathbf{A_{k,k+n}}$ and $\mathbf{T_{k,k+n}}$

exceed the thresholds A_T and T_T. This extremum should be chosen to be either maximum or minimum, thus warranting a successful first half-wave recognition, independently of any bizarre sequence of extremum parameters in the epoch. For the sake of brevity, the search of a first maximum will be exposed only. Let us examine the three first extrema E_1, E_2 and E_3 in the epoch, assuming that the parameters of E_1 do not exceed the thresholds A_T and T_T. There are two possible reasons for that, tested by the unequality **$a1<a3$**: 1) the 1-st maximum E_1 is too low ($a_1<a_3$, see Fig. 2), therefore by skipping E_1 and the minimum E_2, the next two extrema have to be included in consideration, i.e. E_3, E_4 and E_5 will be now considered as E_1, E_2 and E_3; 2) the 1-st minimum E_2 is too high ($a_1 \geq a_3$, see Fig. 3), then E_4 with E_5 take place of E_2 and E_3, thereby setting up the sequence E_1, E_4 and E_5 to be tested as three first consecutive extrema **E1**, E_2 and E_3.

After the first maximum (following our consideration) has been selected, the program goes through the cycle (the left part of the diagram) till the end of the epoch is reached. The notations **Y** and **N** outside the parentheses of one of the conditional branches concern the cases of minimum, while the notations inside the parentheses must be used for maximum. At the beginning, the parameters A_{23} and T_{23} of E_2 are compared with the thresholds. If the parameters are higher, then E_2 is elected as the alternate extremum with respect to the previous one (in our case it will be a minimum). Further the 1-st extremum is dropped, the next two are shifted forward taking 1-st and 2-nd position and the next extremum is nominated as 3-rd. Now let us assume that the parameters A_{23} and T_{23} of E_2 are lower than the thresholds. A 4-th extremum is added to the sequence. It is declared as 2-nd if $a_2 \geq a_4$, the following 5-th extremum being accepted to be 3-rd, before the next A_{23} and T_{23} test (Fig. 4). In case of $a_2<a_4$, the 5-th extremum becomes 3-rd (Fig. 5). Finally a minimum that meets the requirements must be elected and running futther the cycle, maxima and minima are detected and marked in succession.

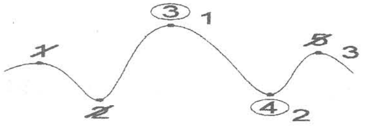

Fig. 2

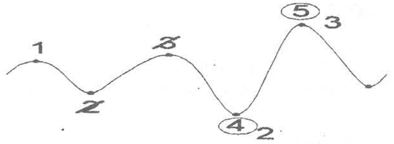

Fig. 3

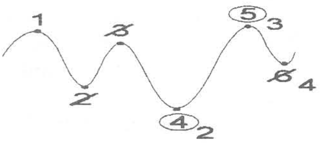

Fig. 4

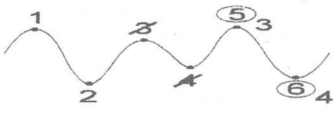

Fig. 5

In the next figure an example with quasi-frequency EGG analysis is shown. The detected wave extrema are marked by dashes.

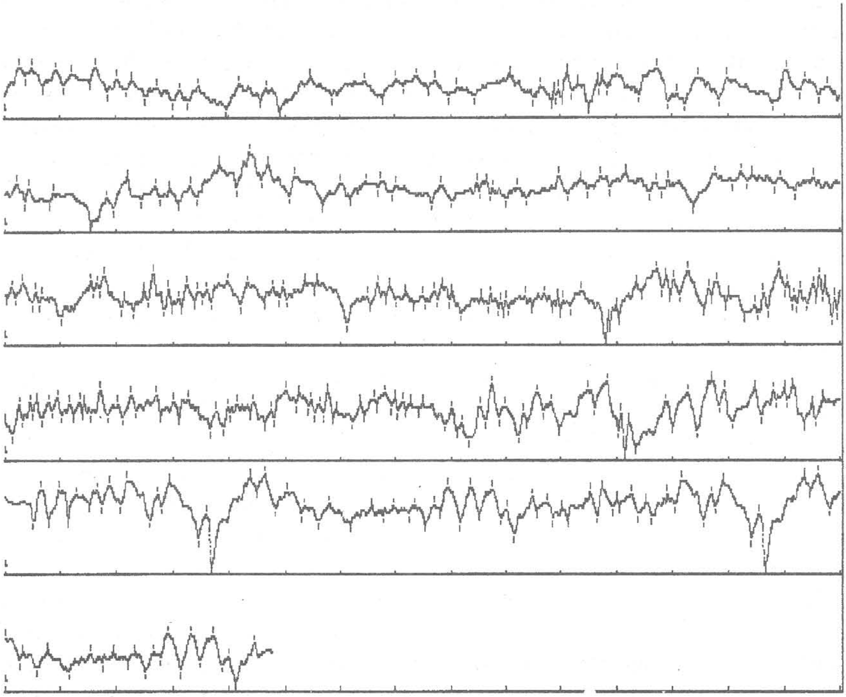

Fig. 6

Using the parameters of the relevant half-waves, spectra and histograms can be obtained more accurately than by Fourier transform, especially in their low-frequency components.

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