NEW INTEGRATED METHODS OF ELEMENTS OF ELECTROCARDIOSIGNAL MORPHOLOGY PARAMETERS ESTIMATION

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New noise proof integrated approach to estimation of clinically important of elements of electrocardiosignal morphology parameters is offered. It based on the analysis of spectral structure of elements in some orthogonal basis.

It is developed new methods of electrocardiosignal segmentation in time-domain interval at real-time mode. They allow to reveal a fiducial point and borders of researched elements in each heart-beat.

The developed methods allow to estimate of elements of electrocardiosignal morphology parameters authentically even within the limits of one heart-beat. That raises diagnostic and prognostic importance of the results of ECS processing.

Introduction

In the field of diagnostics and treatment of cardiac diseases urgent is the task of development of a firmware for automatic control of elements of electrocardiosignal (ECS) morphology parameters, allowing to make express train diagnostics. The creation of new methods and algorithms of an estimation of ECS parameters will allow not only to confirm or to deny operatively the diagnosis, but also to reveal infringements of intimate activity at early stages then proceeding practically imperceptibly.

Mast of used on today in automatic systems methods of direct measurement of amplitude-temporary parameters of ECS elements and complexes do not provide of acceptable accuracy of measurements. It is connected that real ECS acting an additive handicapes, on amplitude comparable with a useful signal. The presence of handicapes is not traced and can result in failures in work of diagnostic algorithms and, so, to statement of the erroneous diagnosis by automatic system. The offered approach to the decision of a task of increase stability to the influence of the noise handicapes of estimated parameters is use as diagnostic criteria of integrated parameters, such as spectral coefficientes of a signal in some basis.

Materials and Methods

The analitical part of work is constructed on the basis of the spectral analysis, theory of approximation of functions, theory of detection of signals and mathematical statistics. The experimental researches were carried out with the use of annotated ECS databases, intended for testing automatic algorithms of ECS processing (European ST-T Database, QT-T Database). The results of researches are received in the program environments Mathcad, Matlab and Delphi.

Results

The ECS feature in comparison with other biomedical signals is definiteness of the form of its elements that allows, with use of modeling representation, to predict character of its spectral structure in the chosen basis.

From the medical point of view of the most important clinical parameters at research such ECS elements, as a P- and P-waves and especially ST-segment are a degree and sign of displacement from iso-line and form, which in a general view can be described as a superposition of slopping and nonlinear components. Therefore at a choice of basis of spectral representation it is necessary to be guided by presence of clear interrelation between the specified amplitude-temporary attributes and spectral structure of a signal. There was stated that to the best advantage supplied requirements satisfy the bases of Legendre polynomials and Walsh functions.

Calculation of spectral coefficientes An for Legendre polynomials is produced on formula

$$A_n = \int_{-1}^{1} U_{ST}(x) L_n(x) dx = 2 \int_{0}^{1} U_{ST}(\theta) L_n(2\theta - 1) d\theta$$

there $L_n(x)$ Legendre polynomial order n, orthogonal on interval [-1,1] with single function $h(x)=1$;

for Walsh functions

$$A_n = \int_{0}^{\theta} U_{ST}(\theta)\, pal_n(\theta) d\theta$$

there $pal_n(\theta)$ the Walsh function number n ranked on Paly.

Was declared that zero, the first and the second spectral amplitudes in Legendre basis and 0, 1 and 3 - in Walsh basis ranked on Paly characterize, accordingly, degree and sign of offset, direction of slopping and presence of proturberance or concavities [1, 2]. Values of given spectral amplitudes possible to consider as morphology parameters - offsets (PO), slopping (PS) and proturberances/concavities (PP/C).

Existence of constant coefficients of intercoupling between spectral amplitudes values and morphology parameters allows not only qualitative, but also quantitative to value it. The factors of issue each of morphology parameters on corresponding to spectral amplitudes are presented in Table 1.

Table 1: Factors of issue

	PO / K_0	PS / K_1	PP/C / K_2
Legendre	A_0/ 1	A_1/ 0,33(3)	A_2/ 0,2
Walsh	A_0/ 1	A_1/ -0,5	A_2/ 0,375

The sets of the decisive rules allowing to make a classification of types of elements of electrocardiosignal morphology according to the requirements, accepted in medical practice, to normal and describing deviations from norm on the base of three spectral coefficients making in Legendre or Walsh bases, displaying clinical main of elements of electrocardiosignal morphology parameters, have been developed, and the algorithms of classification on the base of the sets as well.

The methods of ST segment, P- and T-waves parameters revealing in its spectral composition in bases of Legendre polynomials and Walsh functions are designed [1,3,4]. Thus each of spectral coefficients is an integrated estimation of the appropriate attribute, that allows authentically to measure parameters of a signal even in high noise conditions. In the comparison with standard methods, they provide a 6-8 times larger stability to the influence of the noise handicapes on ECS, that raises sensitivity to the low-level changes of the morphology of a signal and the short-term deviations as well.

These methods also allow to provide a storage of the information about electrocardiosignal morphology with the minimal set of informatical parameters. Thus there is an opportunity of restoration of a signal cleared of handicapes. The number of spectral factors, used at it, will be determined by required accuracy of restoration of details of the form, and for practical tasks is equal to three.

As a method of restoration of the form of an initial signal it is possible to offer of polynomial approximation procedure, which in case of use of basis of Legendre polynomials does not require intermediate computing procedures. At use of representation of a signal in basis of discrete Walsh functions the procedure of transformation of bases was developed.

The real procedure of ECS analysis must to include such stages, as allocation of a fiducial point in heart-beat, eliminating the iso-line drift, allocation of time-domain interval, belonging to each elements, estimation of morfology parameters and categorization of type of morfology.

As a result of analysis is stated that most stable form has the electrocardiosignal area between T and P waves (TP segment). This segment corresponds to electrical diastole of heart and at absence of additive noise and artifact is on iso-line. It is offerred use the procedure of allocation of a fiducial point on TP segment [5].

The allocation of a fiducial point previous to all basic ECS elements, allows on the basis of knowledge of electrocardiosignal morphology to identify all its elements correctly. Also in this case fiducial points, selected on electrocardiosignal, simultaneously are discrete samples of the iso-line drift signal. They are represent square-wave pulses modulated on amplitude,

Following with frequency of heart rate. The filtration method for separation of signal of iso-line drift is possible to use. Chosen signal of driftage is subtracted from source signal.

The methods and algorithms for selection of ECS element boundaries based on apmlitude and time-domain features are investigated. The methods are founded on summation of energy of first derived energy in driven time-domain windows, whose duration determined by settlement duration of ECS elements. Use of additional control functions, adaptive thresholds of comparison and algorithms determining the order of following of elements, allows to reveal boundaries of a ST-segment [6], P- and T-waves in real-time mode. The high accuracy of offered methods was proved by tests on a number of real ECS from the specialized test databases.

The most further processing of signal is concluded in calculation offered integral morphology parameters and estimation of morphology type in accordance with brought decisive rules. There were designed firmwares, realizing offered methods.

Conclusion

The methods of revealing of an ECS elements morfology parameters in its spectral structure in basis Legendre polinomial and Walsh functions has been developed and investigated. In the comparison with standard dot methods, they provide a 6-8 times larger stability to the influence of the noise handicapes on ECS, that raises sensitivity to the low-level changes of the morfology of a signal and the short-term deviations as well. These methods also allow to provide a storage of the information about waves and segments with the minimal set of informatical parameters.

The sets of the decisive rules allowing to make a classification of ECS element types have been developed, and the algorithms of classification on the base of the sets as well.

The methods of allocation of a ECS element boundaries are developed. This methods ensures steady work in a real time mode in the conditions of amplitude-temporary parameters variability of ECS waves and complexes.

The hardware and software realizing the set of the offered methods has been developed.

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