POLYVARIANT METHODS OF ANALYSIS, MODELLING AND VISUALIZATION OF CARDIOGRAPHIC INFORMATION

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Pathologies and diseases of the cardiovascular system are the most serious present-day problems in medicine. The object of this paper is to substantiate the working out of polivariant methods of analysis, modeling and visualization of cardiographic information for diagnosing the myocardial infarction.

Now in Russia there are no manufacturers of diagnosis system or heart condition evaluation, providing polyvariant analysis, simulation and visualization of heart-vascular system.

Conception of Computer Diagnostic System (CDS) "Cardiovid" is presented on fig.1.

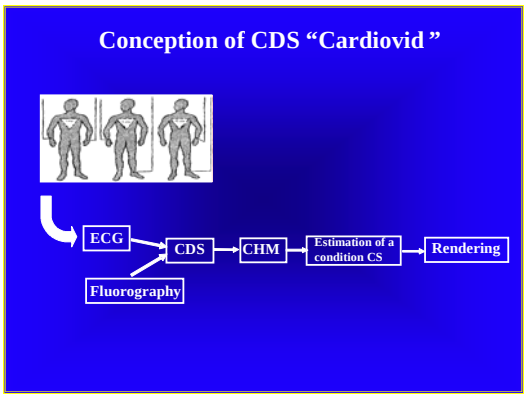

fig.1

Features of CDS:

- Conducting a database of patients;
- Electrocardiography and fluorography viewing;
- Polyvariant methods of analysis, modeling and visualization of cardiographic information.

The proposed project decisions are fully based on the original diagnosis of heart and vascular system method. PSU made an application for invention rights № 2004107011/14 (007326), 09/03/2004 according to the results of which the positive conclusion was made. Besides, according to the expertise results 7 more positive decisions for awarding patents were made. Penza State University (PSU) has the right for the patents.

The standard configuration IBM PC type computer and digital electrocardiograph are necessary for "Cardiovid" CDS operation. Fluorography photos of a patient in the digital form are supplied separately.

CDS users must have a primary training for p.c. operating and skill of working in Windows system. "Cardiovid" CDS can be used both independently and in the information network as an element of the medical complex.

The diagram of work CDS "Cardiovid" is presented on fig.2.

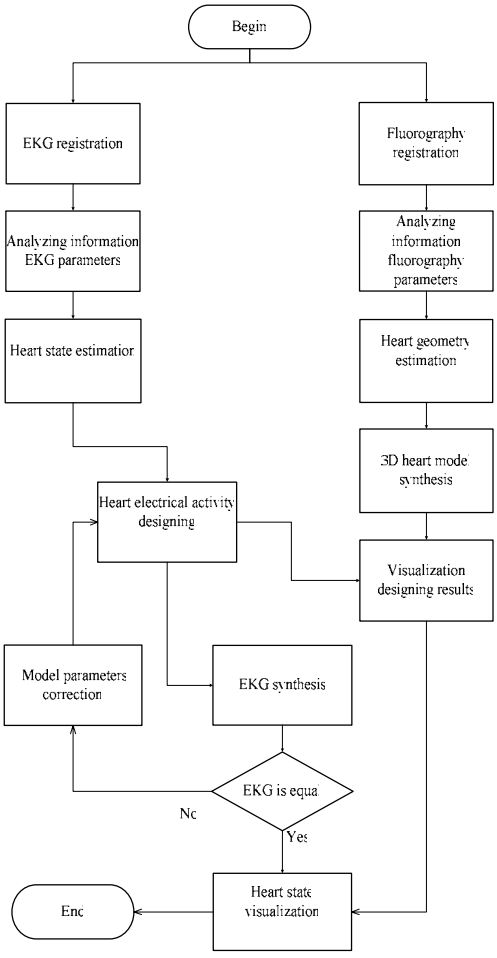

fig.2

Electrocardiography and fluorography are used to obtain the initial diagnostic information. In the author's opinion, the distinctive feature of the polivariant methods of diagnosing the state of the cardiovascular system is the principal opportunity to get new diagnostic information. The realization of this

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potentiality is carried out by means of modeling the state of the cardiovascular system based on the results of the analysis of the cardiographic information.

Classical methods of analysis, neuro-network algorithms, wavelet-transformation, and methods of non-linear dynamic systems, which allow raising the quality of the ECG analysis are used to analyze the electrocardiographic information.

The usage of the latest achievements of information technologies to analyze the electrocardiographic information is a vital necessity. It is known that the ECG signal possesses signs of chaotic oscillations difficult to express by a formula and therefore its analysis in diagnosing the state of the cardiovascular system by means of traditionally used algorithms is difficult. On other hand, if we take into account dozens of thousands of ECG made annually in our country and the fact that a highly qualified specialist needs half an hour to interpret on ECG, then the urgency of creating, on the basis of information technologies, a set of instruments capable of analyzing the electrocardiographic information, will be evident. To accomplish this task, the following important questions should be solved:

- selection of ECG parameters which should be controlled;
- selection of the mathematical model reflecting the most important characteristics of the state of the cardiovascular system and the way the stable an unstable parts of the controlled ECG parameters are connected;
- selection of the method to measure the controlled ECG parameters;
- selections of the kind of mathematical transformations permitting an effective enough extraction of data from the initial measuring information;
- selection of a method of mathematical treatment of obtained data;
- statistical evaluation of mistakes of the first and second order;
- visual presentation of the results of analyses.

Each of the enumerated questions is a complex problem by itself. Nevertheless, to scientists` opinion, the main link in the chain of analysis of the ECG signal is the mathematical method of treatment of the obtained data.

Scientific research of individual microcharacteristics of ECG has proved that to diagnose the state of the cardiovascular system is needed a mechanism capable to model the potentialities of the human brain. The neuron network is such mechanism (NN).

In order to brink to a proper correlation the ECG signal with a concrete disease, the NN must realize its function of discerning and classification of patterns. To do this, the network is “taught” to recognize the most important indications of patterns. In the process of “teaching”, single out the indications distinguishing the patterns from each other, which make up the basis for deciding to what corresponding class to attribute the pattern. The peculiarity of functioning of the NN is the preliminary wavelet-transformation of the ECG signal, that is to the inlets of the NN are sent not the readings of the ECG signal but the coefficients of the wavelet-transformation, that provides the decrease of the dimension of the incoming vector of the NN approximately to an order. It should also be marked that the wavelet-transformation of the ECG signal is a subject of independent scientific research, which is supposed to give important results when diagnosing the state of the cardiovascular system. The wavelet-transformation permits to apportion the analyzed signal into compact, well-localized, according to time in frequency bases, having at the same time polynomal complexity. It has good time results and bad frequency ones in the field of high frequency and good results in frequency and bad in time in the field of low frequency. This approach gives good results especially when the components of the high-frequency signal have not a long duration and low-frequency components are rather long. The ECG signal, as most of the biological signals, has just a structure.

The instruction of the created NN happens according to the algorithm of a competitive instruction. The laws of the competitive instruction have such a quality which stimulates a competitive process between some or all f the treated elements of the NN. The elements which turn out to be the winners of the competition get the right to change their weights. At the same time, the loosers do not change their weight (or change it according to another rule). The competitive instruction is known as ”Kokhonen`s instruction”. Kokhonen`s instruction differs by its principle of self-organization (in contrast to the principle of instruction under the guidance of a teacher).

During the test-stage ECG signals of different diseases of myocardial infarction were tested by the NN. According to the test-results the created NN has demonstrating its ability to discern an ECG signal and refer if to a particular kind of disease.

To analyze the fluorographic information are used: classical methods of contour analysis, gradient methods of singling out the contour, neuro-network algorithms to detect forms, which help to define the anatomic peculiarities of the patient’s heart structure serving as initial parameters of the patient’s heart model when visualizing.

To model the conducting subsystem is used Khodzhkin-Xuksly’s model, to model the front of stimulation of the action of the heart-muscle is used Aliyev-Panfilov’s model, and Titomir’s multidipole model is used for modeling the electric activity of the heart. According to the results of the conducting subsystem, spreading the front of stimulation of the heart-muscle’s action and the electric activity of the heart is determined the value (значение) of the potential in the point of the standard tapping on the patient’s torso, that is, the main electrocardiographic problem is being solved: according to the transmembrane potential on the surface of the heart is

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the ECG in 12 tappings. Then the patient's ECG is compared with the ECG received by modeling and the divergence of parameters is determined. The analysis of the divergence allows to determine the changes, which should be added to the model. Thus, we correct the parameters of the model in order to obtain identical ECGs. Having obtained, by modeling the ECG, the patient's identical ECG model, the state of the patient's heart is being visualized. With the help of special computer made algorithms the results of the analysis and modeling are studied, interpreted visualized. From the multitude of the ways of synthesizing the three-dimensional model has been selected the method of constructing the heart by means of dots on the surface of the heart and their joining up with the help of polygonal nettings. In the process of visualization to reflect the "geometry" of the patient's heart, a non-linear deformation of the initial model takes place. The superposition of the texture provides a visual and real idea of the cardio-vascular system's state. The real image of model of the patient's heart is presented on fig.3.

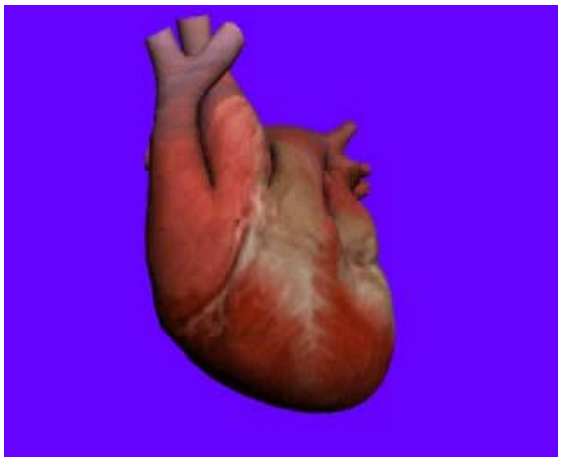

fig.3

The suggested polivariant methods of analysis, modeling and visualization allow by means of the real three-dimensional reflection of the patient's heart, to localize more precisely the spatial electric activity. The results of the cardiographic information obtained by this method of analysis need a clinical confirmation. In the author's opinion, the computer diagnostic system, worked out on the bases on the suggested method of analysis, permits to raise the preciseness, informativeness and obviousness of the diagnosis, eliminate bad mistakes, and provide a correct therapeutic treatment.

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