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Heart condition imaging with the help of hardware and software complex based on the cardiographic equipment on nanosensors

The World Health Organization (WHO) published a report on non-communicable diseases that affect humanity. This report was based on the statistics resulting from the studies conducted by the health services from 193 countries. According to WHO, cardiovascular diseases (CVD) are the reason for 48 % of deaths, various types of cancer – 21 %, chronic respiratory diseases kill 12 % of people and diabetes – 3 %. In 2008, 36 of 58 million of deaths were caused by these diseases. Statistics shows that cardiovascular diseases affect young people more often. Heart diseases are diagnosed in 10 % of population over the last 35 years. More than 5 million people were killed by CVD at the fairly young age. Among them, 22 % were men and 35 % were women in economically backward countries, and 8 % of men and 10 % of women in economically developed countries. In 2008, 1 million 232 thousand 182 people died of cardiovascular diseases (CVD) in Russia [1–3].

Electrocardiography is a set of methods and techniques for recording and studying of electric fields generated by the heart during its work. Electrocardiography is an inexpensive but valuable diagnostics method in cardiology. The direct result of electrocardiography is an electrocardiogram (ECG). ECG is a graphic representation of difference of potentials, resulting from the heart work and projected on the body surface. Appearing at a certain moment of the heart work vectors of action potentials are averaged and recorded on the ECG. The first cardiographic studies were carried out in the late 19th century by the Scottish scientist Alexander Muirhead [4, 5].

In order to simulate the process of excitation propagation, one of the excitable medium models [6], a two-component FitzHugh – Nagumo model is suggested. This model includes a fast variable u, which corresponds to membrane potential in the full model, and a slow variable v.

$$\frac{\partial u}{\partial t} = C\varepsilon^{-1} \cdot \left(u - \frac{u^3}{3} - v \right) + \Delta u,$$

$$\frac{\partial v}{\partial t} = \varepsilon \cdot \left(u + \beta - \gamma v \right),$$

where C, ε, β, γ, are model parameters, and ε parameter is assumed to be small: $\varepsilon << 1$. Communication between cells of the heart muscle is described by the diffusion terms in the equations, and the dynamics of a single cell – by the reactionary nonlinear terms of equations. After a series of experiments, the model parameters of the system were determined for better reflection of the cardiac muscle properties: $C = 1.0$, $\varepsilon = 0{,}1$, $\beta = 0.004$, $\lambda = 0.03$.

The proposed method of assessment of the patient's condition is based on the combined use of the methods of analysis, modeling and imaging of cardiographic information that allows combining the solutions of direct and inverse problems of electrocardiography within one examination. The main advantage of such a combination is the ability to use the modeling results for the analysis of patient's condition. A hardware and software complex is suggested to be developed, within the concept of assessing the condition of the cardiovascular system (CVS), on the basis of the laboratory No. 63 of the Institute of Non-Destructive Testing, in order to implement the modeling of heart excitation propagation. HSC operating procedure is shown in fig. 2.

The analysis of the algorithm shows that it includes the following stages:

- analysis of cardiographic information;
- modeling of CVS condition;
- imaging of CVS condition.

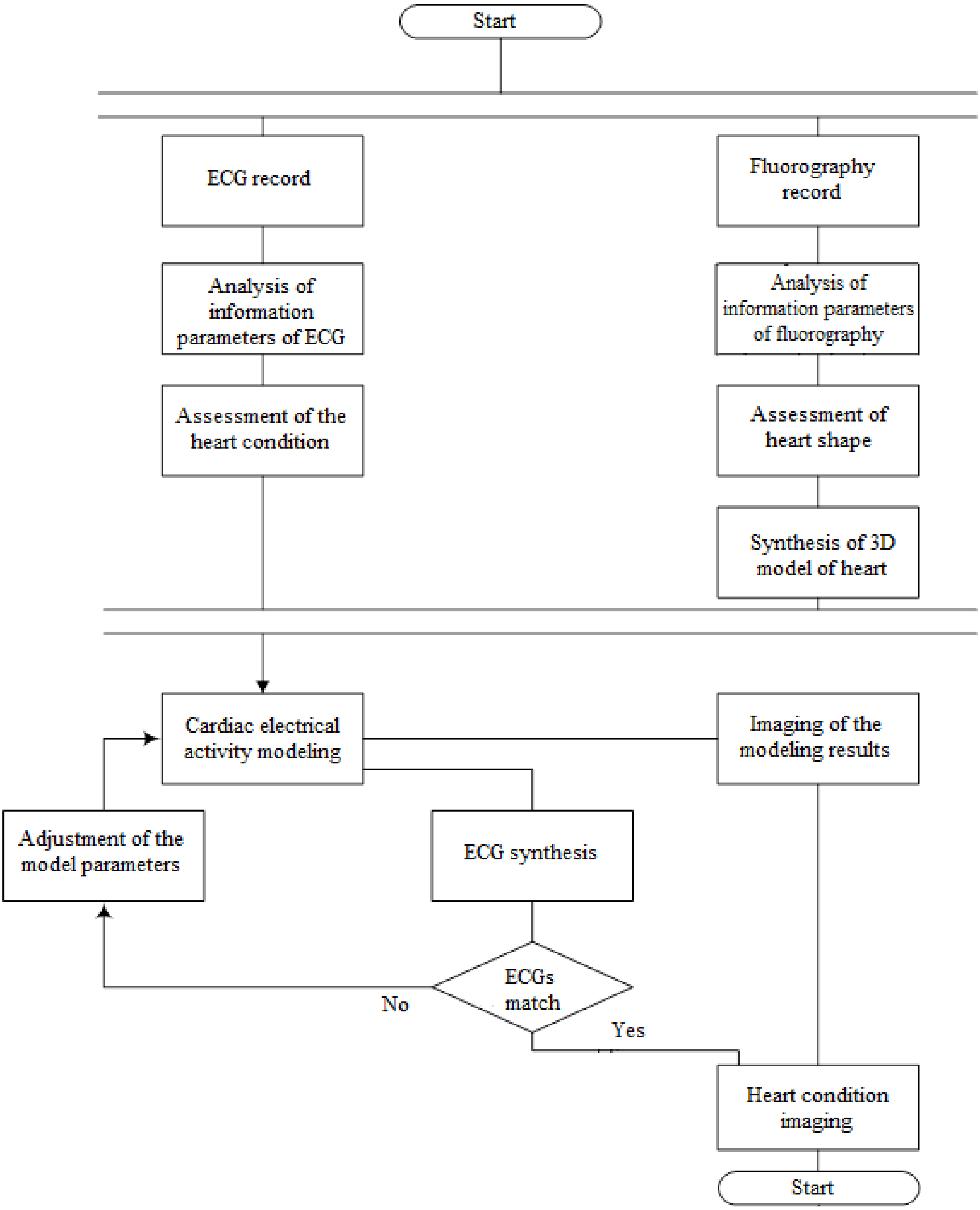

Fig. 1. Algorithm for simulation of heart condition imaging

Graphical imaging of the excitation propagation over the surface of the patient's heart is made on the basis of the modeling results.

Use of the cardiac electrical activity model ensures the determination of the "electrical portrait" of the patient's heart during the cardiac cycle, which enables to identify the diagnostic features in the analysis of indirect parameters determined by simulating the electrical processes in the heart and the output data from the electrocardiograph on nanosensors.

Definitely, the successful implementation of a new methodological approach to the diagnostics of the patient's CVS requires in-depth basic and applied studies of a wide class of mathematical methods for the analysis and processing of cardiographic data, modeling and imaging of CVS condition, as well as clinical evidence.

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