Nonlinear electrocardiographic leads system transformations

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Abstract - **This article discusses the problem of electrocardiographic leads transformation. We solve the problem using the method of maximum likelihood for the linear and nonlinear model of transformation. Comparison of derived algorithms quality is present.**

Keywords - **ECG leads transformation, maximum likelihood, nonlinear model of transformation, electrocardiographic leads reconstruction.**

I. INTRODUCTION

Electrocardiographic (ECG) leads transformation problem has many potential clinical applications. This problem is transformation of signals recorded in some locations on the surface of the patient's body to the signals corresponding to other points.

Firstly, this is transformation of leads systems, with a small number of recording electrodes in the other, more familiar for the medical interpretation multi-channel ECG [1].

Secondly, this is reconstruction of the missing or distorted by artifacts leads from available with higher quality leads [1].

All proposed in the literature methods for the leads transformation [1, 2, 3] based on the model of a fixed dipole (vectorcardiographic model of the electrical activity of the heart), and on the concept of lead vector. This model assumes a linear relationship between the various leads of one ECG record. Ability to convert leads is conditioned by the fact that the signals in all leads of one ECG have a common source - heart.

II. Evaluation of the leads transformation coefficients using maximum likelihood

We use discrete time $k = 0,1,2,\ldots,M$. For ease of computation we consider relationship only one of us synthesized leads S_k to the original system leads $\vec{U}_k$. Then actually registered signal R_k in the current lead and obtained by the linear transformation S_k connected as follows:

$$R_k = S_k + \eta_k = \vec{C}^T \cdot \vec{U}_k + \eta_k , \qquad (3.1)$$

where $\vec{C}$ - vector of transformation coefficient; η_k - a random variable, which determines the transformation error.

Thus, the problem of leads transformation is simplified to the problem of determining the transformation coefficients. For determining these coefficients we propose to use approach, based on the maximum likelihood method.

But model of the electrical activity of the heart in the form of a fixed dipole, which is usually used to transform electrocardiographic leads, is quite simplistic. It suggests that the resultant dipole moment does not change its position in space, but during the cardiac cycle is contracting different parts of the heart muscle. In addition, while contraction the form of heart muscle is changing, and changing the volume configuration of the high conducting blood supply. This leads to the fact that the leads transformation coefficients within the cardiac cycle can fluctuate significantly. To account for these changes, we introduce into the transformation model dynamic transformation coefficients $\vec{G}$, witch depend on the phase of the cardiac cycle $\theta_k \in (-\pi;\pi)$. Nonlinear transformation the original (recorded) system leads $\vec{U}_k$ to one of the unknown leads S_k in this case will look like:

$$S_k = \vec{G}(\theta_k)^T \cdot \vec{U}_k , \qquad (3.2)$$

To determine these dynamic coefficients using maximum likelihood method we expand the functions $G_n(\theta_k)$ in a series in a system of orthogonal Chebyshev functions $\varphi_i(\theta_k)$, and will use only the first p terms:

$$G_n(\theta_k) = \sum_{i=0}^{p} H_{ni} \cdot \varphi_i(\theta_k) , \qquad (3.3)$$

Then using maximum likelihood method we got an algorithm for calculating coefficients H .

Using dynamic coefficients we must to determine the phase of the cardiac cycle θ_k . This is done by determining the position of R-peaks in the ECG.

III. CONCLUSIONS

Studies have shown that the obtained algorithm for determining the transformation coefficients of ECG signals from one system leads to the other can synthesize a 12-channel ECG from the signals recorded in systems with a reduced number of electrodes, for example - EASI. There is a fairly good agreement between the actual recorded ECG leads-12 and synthesized by the system EASI. Despite some morphological differences between these records, doctors evaluate the diagnostic performance of real and synthetic ECG, as the same or similar. When using the transformation coefficients individually for each patient, we can achieve significant improvement in the quality of the transformation, using the proposed nonlinear algorithm.

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