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ECG cloud monitoring and analysis information system

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ECG cloud monitoring and analysis information system

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Abstract. The article shows the possibility of implementing a technical solution for a dynamic cloud-based ECG monitoring system. It can conduct continuous remote monitoring of the dynamics of the human circulatory system state, aiming at quick detecting diseases of the circulatory system and its adjacent diseases. The system can perform 24/7 measurement of the health state of the circulatory system using a mobile cardiograph that sends received ECG data to the server where analysis and processing are performed. It can be used as patients who do not have the opportunity to visit a specialist in person, as well as in hospitals. The system is recommended for use in sports facilities for monitoring the health of athletes and life-threatening events.

1. Introduction

Recently, the leading positions in the structure of mortality in many countries have been held by diseases of the circulatory system. The class of these diseases includes the ischemic disease in its various nosological forms (myocardial infarction, angina pectoris, cardiac rhythm and conduction disturbances, sudden cardiac death, chronic heart failure), hypertension, pulmonary artery thrombus embolism and other diseases. According to estimates of the World Health Organization, the number of circulatory system diseases was 17.9 million, or 31% of all deaths in the world. The vast majority - 85% of these deaths occurred as a result of heart attack and stroke [1]. In Russia, statistics are also not optimistic: for example, according to the Rosstat of the Russian Federation in January 2019, the share of circulatory system diseases among all causes of death was 49.3%, which exceeded the same figure for the previous year [2]. Similar results have been obtained from the analysis of morbidity and mortality in Russia for the previous years [3, 4, 5, 6].

Thus, almost every second resident of Russia dies from diseases of the heart and blood vessels.

However, there is a way out of this tragic situation: according to the World Health Organization, 80% of premature heart attacks and strokes can be prevented if the victims were provided with medical assistance in time or the predisposition to such diseases was detected in advance. Indeed, early diagnosis of diseases and their individualized targeted prevention can significantly improve the situation with morbidity and mortality. For this, it is necessary to pass medical tests more often and consult with doctors. However, this is not always possible, since not in all regions of our country there is an accessible and free set of all high-class specialists and modern expensive equipment, very close to all citizens, including those that live in distance villages. Unfortunately, even regular observation of medical specialists does not always solve the problem of preserving health and life. There are cases, when during training in cardiovascular diseases you had athletes [7]. It can be assumed that in pursuing the goal of breaking a new record, an athlete may exceed the permissible level of load for a short time, thereby causing fleeting fatal pathological changes in the cardiovascular system. Since such violations can occur suddenly and quickly lead to death, they are almost impossible to identify even with daily check-ups by a doctor.

These facts reveal the need of creation of new methods and technologies to identify life-threatening conditions in a group of people with a high risk of death from circulatory system diseases. Such method is the continuous monitoring of vital parameters of the cardiovascular system. However, monitoring itself alone will not solve the problem. It should be complemented by cloud-based data transmission technology, their automated processing in real time and issuing operational recommendations to the patient on timely prevention of the onset of a life-threatening condition. Such continuously operating feedback system will help solve the problem of reducing mortality from socially significant cardiovascular diseases.

2. Scientific novelty

The idea of creating a portable device for monitoring of the cardiovascular system is not new to medical technology. Now on the Russian medical equipment market, the following devices have a telemetric transmission channel and are close in technical characteristics to the formulated tasks: Cardiotechnology 07-03 (Russia, Inkart), Cardiometer-MT (Russia, Schwabe) and Cardian-PM (Belarus). However, the first mentioned device has only 3 channels instead of the standard 12, and the remaining devices are not wearable.

The CardoiMem CM-3000 electrocardiograph (United States, GE) meets the requirements most closely met. However, it does not incorporate modern electrocardiogram processing capabilities.

To eliminate these shortcomings, it is proposed to use the system, having the following features:

Efficiency and accuracy of reading ECG, not inferior to the characteristics of stationary devices.

Additional analysis of volume parameters of external respiration and saturation of blood.

24/7 ECG monitoring.

Storage and access to cardiographic data in the "Cloud".

Inclusion of wavelet analysis in the original modification into the ECG processing program.

These features determine the scientific and technical novelty of the system, consisting in a combination of continuous remote monitoring of the circulatory and respiratory system parameters, continuous automated analysis of the obtained indicators with the inclusion of the wavelet transform and feedback to the patient in case of the occurrence of life-threatening conditions or their precursors.

3. Implementation methods

3.1. Architecture

The results of the studies performed by the authors earlier [4] showed the possibility of using web applications to monitor various processes. The obtained results also determined the choice of technical implementation methods for solving the monitoring problem [4].

The architectural structure of the proposed system is based on microservice software architecture, focused on the interaction of as small as possible, weakly connected and easily changeable modules. The system includes the following components, services, presented in Figure 1:

Cardiograph - wearable cardiograph module, producing ECG signal removal.

DesktopApp - desktop application that performs the analysis of cardiographs data, which was used for monitoring under conditions with limited access to the Internet, and sends the calculated cloud data after processing. It uses Electron.js technology which allows to share code of calculations and views used in the web application.

CardioEnvironment - computing environment in which all system algorithms run. Physically it is a sustem of several microservices.

WebApp - server-side web application that provides an RESTful API and processes http requests and controls the movement of data in the system. As an executable environment, the use of Node.js runtime is assumed due to its ease of use and scaling.

NoSQL database - MongoDB, which stores all the necessary information for monitoring.

Stream Service - service responsible for the continuous receipt of a signal from a wearable cardiograph over the UDP protocol, its primary processing and writing to files.

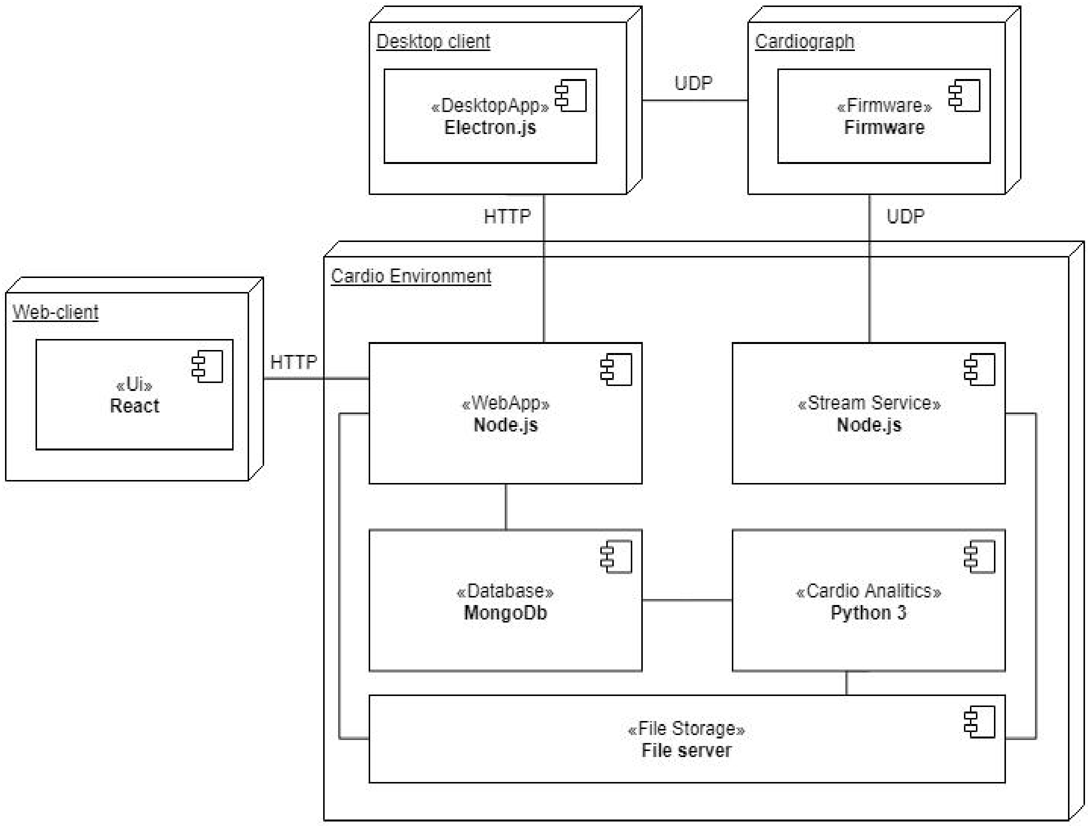

Figure 1. Deployment diagram

Cardio Analitics is a service that provides all methods of intellectual analysis of the received ECG, identification of key indicators (pulse, heart rate) and reconstruction of the three-dimensional vector EMF of the heart

File Storage - the storage of recorded cardiogram files.

Web-client is a client application using React, through which users interact with the system.

3.2. Database structure

For storing data NoSQL database MongoDB is used. MongoDB implements a new approach to building databases, where there are no tables, schemas, SQL queries, foreign keys, and many other things that are inherent in object-relational databases. The model (Fig. 2) of used collections corresponds to the main entities.

Based on this diagram, it is possible to describe the main business logic of the system. The main entities in the system are "Doctor" and "Patient". Doctors can view the list of patients in the system, view the patient's medical history, refer patients to other doctors, prescribe patients for examination. Patients can conduct tests using wearable cardiographs and view records of their illnesses. The main

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function of the system is to process and present data on the performed examinations, including indicators reviled during the examination, pathology, three-dimensional vector EMF of the heart, allowing the doctor to more accurately make diagnoses or at the right time to determine the pathology and hospitalize the patient.

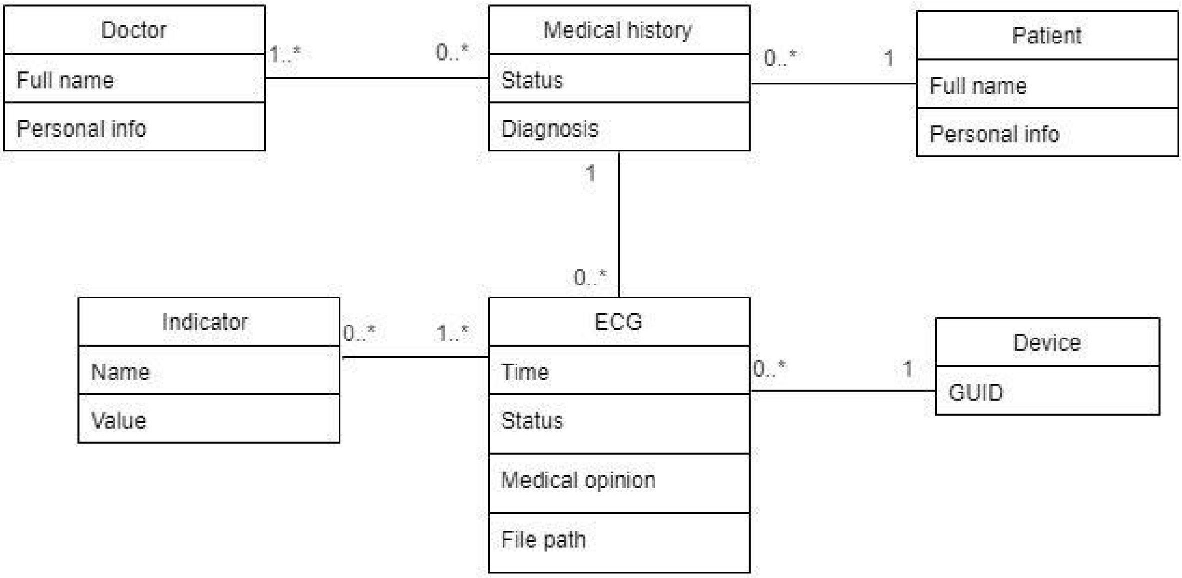

Figure 2. Main data entities

3.3. Mathematical signal transforms

One of the integral methods is direct reconstruction of the vector diagram. Fig. 3 shows the vector diagram of the harmonic process.

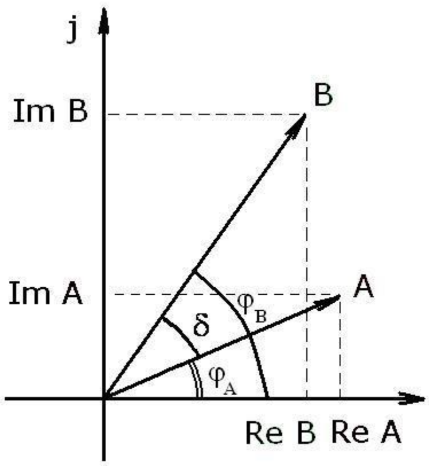

Figure 3. Vector diagram

The angle between angles $_A$ and $_B$ can be found from the expression:

$$arctg\frac{\mathrm{Re}\,A\ \ \mathrm{Im}\,B\quad \mathrm{Re}\,B\ \ \mathrm{Im}\,A}{\mathrm{Re}\,A\ \ \mathrm{Re}\,B\quad \mathrm{Im}\,A\ \ \mathrm{Im}\,B} \qquad (1)$$

The amplitude of the vectors is from the Pythagorean theorem:

$$|A| \sqrt{\mathrm{Re}\,A^{2} \quad \mathrm{Im}\,A^{2}} \text{ and } |B| \sqrt{\mathrm{Re}\,B^{2} \quad \mathrm{Im}\,B^{2}} \; . \tag{2}$$

Vectors $\vec{A}$ and $\vec{B}$ in fig. 3 can describe the various processes occurring in the measuring apparatus.

The first case. Vectors $\vec{A}$ and $\vec{B}$ describe the flow of processes in different data processing channels, for example, the phase shift between current and voltage.

The second case. Vectors describe the change in the position of the same vector for the time interval t, then the angle between angles $_A$ and $_B$ is the change in the phase of the signal during the specified interval. The frequency is the time derivative of the phase shift:

$$f \quad \frac{}{2} \quad \frac{1}{2}\frac{d}{dt} \quad \frac{1}{2}\frac{}{t} \; . \tag{3}$$

Thus, after restoring the vector diagram, it is possible to determine the most important parameters of the signals, amplitude, phase shift and frequency, without resorting to the use of different thresholds, as is customary in analogue technology.

To implement the integral method of recovery of the vector diagram presented in fig. 3, it is necessary to filter the two data streams by orthogonal filters [5], then it is necessary to calculate the numerator and denominator of formula (2), and then calculate the amplitude and phase of the signal.

4. Results

At the first stage of developing a system for testing methods of interaction with a wearable cardiograph, the following practical results are obtained: a desktop application is created that can interact with a wearable cardiograph and has the following functionality: reading and visualising ECG in real time and viewing the recorded cardiogram (fig. 7), applying the integral method of vector diagram recovery in digital data processing systems [6] (fig.8 - 9)

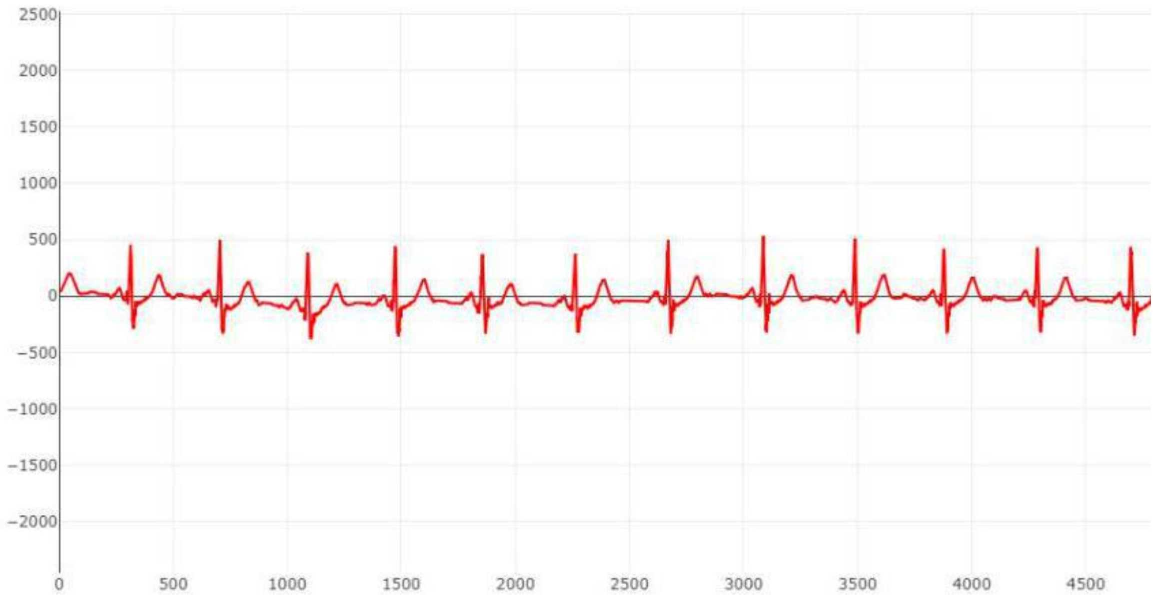

Figure 4. Recorded cardiogram

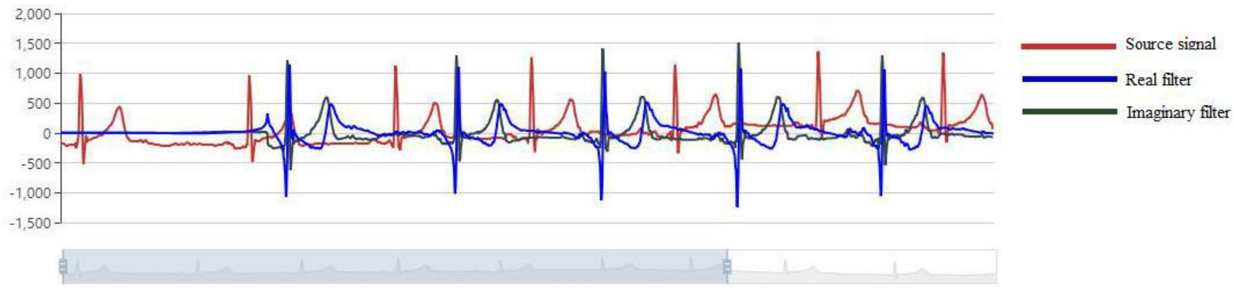

Figure 5. Filtered cardio signal

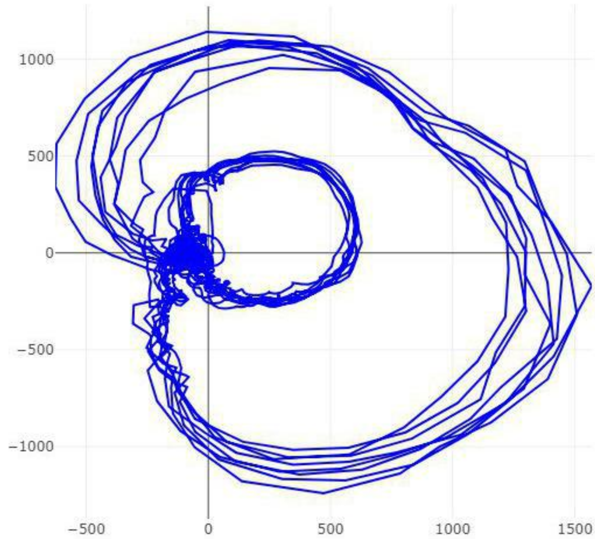

Figure 6. Cardiogram fragment translated by the integral method of restoring a vector diagram

5. Conclusion

In this paper, aspects of creating an information system for remote monitoring and analysis of ECG are considered. It is proved that the development of this kind is relevant in view of the high attention to the problem of diseases of the cardiovascular system, and features of the system that distinguish it from direct competitors are also revealed. An information system project has been developed, implementation methods and software have been chosen, showing the feasibility of the system.

The information system for remote monitoring and analysis of ECG is considered for use in the diagnosis of cardiovascular diseases, continuous monitoring of the state of the cardiovascular system. It can be used as patients who do not have the opportunity to visit a specialist in person, as well as in hospitals. The system is recommended for use in sports facilities for monitoring the health of athletes and life-threatening events.

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Abstrak : Artikel tersebut menunjukkan kemungkinan penerapan solusi teknis untuk dinamika sistem pemantauan EKG berbasis cloud. Itu dapat melakukan pemantauan jarak jauh terus menerus dari dinamika keadaan sistem peredaran darah manusia, yang bertujuan untuk mendeteksi penyakit secara cepat pada sistem peredaran darah dan penyakit yang berdekatan. Sistem dapat melakukan pengukuran 24/7 dari keadaan kesehatan sistem peredaran darah menggunakan kardiograf seluler yang mengirimkan data EKG yang diterima ke server lalu dilakukan analisis dan pemrosesan. Ini dapat digunakan untuk pasien yang tidak memiliki kesempatan untuk mengunjungi spesialis secara langsung, serta di rumah sakit. Sistemnya adalah direkomendasikan untuk digunakan di fasilitas olahraga untuk memantau kesehatan atlet dan peristiwa yang mengancam nyawa.

Latar Belakang : Baru-baru ini, posisi terdepan dalam struktur kematian di banyak negara dipegang oleh penyakit dari sistem peredaran darah. Kelas penyakit ini termasuk penyakit iskemik dalam berbagai bentuk nosologis (infark miokard, angina pektoris, irama jantung dan gangguan konduksi, kematian jantung mendadak, gagal jantung kronis), hipertensi, emboli trombus arteri pulmonalis dan penyakit lainnya. Menurut perkiraan Organisasi Kesehatan Dunia, jumlah penyakit sistem peredaran darah adalah 17,9 juta, atau 31% dari semua kematian di dunia. Sebagian besar - 85% dari kematian ini terjadi akibat serangan jantung dan stroke. Di Rusia, statistik juga tidak optimis: contohnya , menurut Rosstat Federasi Rusia pada Januari 2019, penyebaran penyakit sistem peredaran darah di antara semua penyebab kematian adalah 49,3%, yang melebihi angka yang sama untuk tahun sebelumnya. Hasil serupa telah diperoleh dari analisis morbiditas dan mortalitas di Rusia untuk tahun-tahun sebelumnya.

Kesimpulan : Dalam makalah ini, aspek pembuatan sistem informasi untuk pemantauan jarak jauh dan analisis EKG akan dipertimbangkan. Perkembangan semacam ini terbukti relevan mengingat tingginya perhatian terhadap masalah penyakit pada sistem kardiovaskular, dan fitur sistem yang membedakannya dari pesaing juga terungkap. Sebuah proyek sistem informasi telah dikembangkan, metode implementasi dan perangkat lunak telah dipilih, menunjukkan kelayakan sistem tersebut. Sistem informasi untuk pemantauan jarak jauh dan analisis EKG dipertimbangkan untuk digunakan dalam diagnosis penyakit kardiovaskular, pemantauan terus menerus terhadap keadaan sistem kardiovaskular. Itu dapat digunakan ketika pasien yang tidak memiliki kesempatan untuk mengunjungi spesialis secara langsung, ataupun ke rumah sakit. Sistem ini direkomendasikan untuk digunakan di fasilitas olahraga untuk memantau kesehatan atlet dan kejadian yang mengancam nyawa.