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INTELLECTUAL INFORMATION TECHNOLOGIES ON SMARTPHONE

THE REPORT DISCUSSES THE ORIGINAL IT FOR SIGNAL ANALYSIS AND INTERPRETATION IMPLEMENTED ON A SMARTPHONE UNDER THE ANDROID OPERATING SYSTEM. A DISTINCTIVE FEATURE OF THE TECHNOLOGIES IS THE PROCESSING OF SIGNALS $z(t)$ *ON THE PHASE PLANE* $z(t), z'(t)$, *WHERE* $z'(t)$ *IS CHANGE RATE OF THE SIGNAL* $z(t)$.

The rapid development of smartphone technology has led to the emergence of many applications, including medical applications [1,2]. And this is no accident because the approach of medical information technologies (MIS) directly to the patient is one of the main tasks of modern digital medicine and a smartphone is more convenient for use by the patient than desktop or laptop computers.

It is known that heart rate (HR) is one of the most important indicators of the vital activity of the human body. The diagnostic value of assessing heart rhythm was known in ancient Greek medicine, and pulse diagnosis is one of the main elements of Tibetan medicine. Therefore, smartphones have long been used to solve both fairly simple tasks (determining the average heart rate over a certain period of time) and to evaluate the regulatory systems of the body based on a mathematical analysis of heart rate variability (HRV).

The International Research and Training Center for Information Technologies and Systems of NAS and MES of Ukraine (IRTC IT&S) conducts basic and applied research in the field of a new class of information technologies - intellectual IT with elements of human thinking. Unlike traditional IT intellectual IT operate with generalized concepts (images) that provide more complete information about the environment, and the analysis of such images generates a holistic picture of the phenomena being studied.

The report discusses examples of the successful implementation of intelligent information technology on the smartphone, which are focused on solving urgent applied problems.

It is known that cardiovascular diseases are still leading in the structure of morbidity in industrially developed countries. However, the chronic forms of such diseases often occur asymptomatically, and the patients consider themselves healthy, first encountering a cardiologist already in the intensive care unit for an acute coronary syndrome. Therefore, scientists are constantly looking for new approaches to the detection of the risk of cardiac disease in the early stages.

Within this area an innovative cardiac electrocardiogram (ECG) processing method called FASEGRAPHY is a clear example of using of intelligent IT in digital medicine. The distinguishing feature of FASEGRAPHY is the analysis and interpretation of the electrocardiogram on the phase plane $z(t), z'(t)$, where $z'(t)$ is change rate of the ECG $z(t)$ [3].

Based on the FASEGRAPHY the domestic microprocessor software and technical complex FASEGRAPH® was created, which received Certificate of State Registration No. 14006/2014 of medical products with unlimited validity, Methodological Recommendations of the Ministry of Health of Ukraine No. 163.16/13.17, is issued serially and is used in clinical trials establishments and diagnostic centers, technogenic enterprises, sports organizations and ordinary citizens at home.

FASEGRAPH® software is adapted to a modern smartphone (Fig 1).

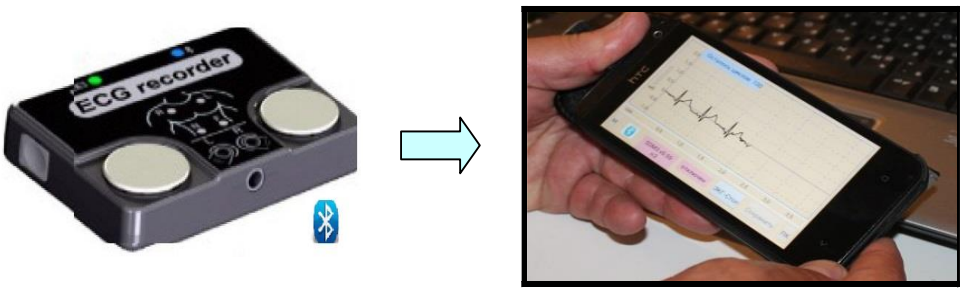

Fig. 1. FASEGRAPH® complex: on left – sensor of ECG, on right - smartphone

FASEGRAPH® was initially oriented to screening examinations for the detection of cardiovascular pathologies in the early stages. However, it turned out that the scope of the application of the

FASEGRAPHY is much wider. The intellectual capabilities of the method allowed to obtain new scientific and practical results not only in prophylactic, but also in clinical medicine.

New diagnostic features of ECG in the phase space, which had not previously been used in traditional ECG diagnostics, proved effective in pediatric cardiology and sports medicine.

FASEGRAPH® has also proved to be useful in carrying out scientific research in various fields, including studying the effect on man of external fields in the process of solar activity, the harmful effect of smoking on the human body, assessment of the effectiveness of drug and surgical treatment of cardiac patients and also in others application.

The intellectual capabilities of FASEGRAPHY are continuously being developed due to the inclusion of additional software modules in the technology that realize the analysis of subtle changes in the ECG signal, which are underestimated by cardiologists when analyzing ECG in the time domain.

So, for example, the technology includes a module for evaluating the randomness of ECG signal parameters, in which traditional and modified entropy estimates are implemented. The diagnostic value of these improvements has been demonstrated on the task of detecting the effect of electrical alternation of the heart, which has recently been considered by cardiologists as a predictor of sudden cardiac death.

A new method for assessing the tolerance of an organism to physical activity is implemented in FASEGRAPHY. This method based on a qualitative assessment of regulatory patterns and cognitive computer graphics. The main advantage of the method is the speed and convenience of testing in the field.

For the first time, FASEGRAPHY on a compact device demonstrated the practical feasibility and effectiveness of the basic principle of personalized diagnostics – to treat a patient, not a disease. To this end, FASEGRAPH® ensures the accumulation of individual data of a particular patient and automatically calculates its "personalized norm", which makes it possible to make diagnostic decisions not only by comparing current indicators with the population norm but also to comparing current indicators from personal norms.

It is such integral information that interests the patient when using the FASEGRAPH® complex independently in home conditions to correct lifestyle, rational distribution of labor and rest, assess the need for additional intake of prescribed medications or urgent medical attention.

FASEGRAPHY is based on fundamental research of signal processing of complex shapes and implements high technology for extracting diagnostic information from real signals distorted by internal and external disturbances. At the same time, the user of the FASEGRAPH® complex does not need to know the mathematical subtleties of the algorithms used: the interaction with the complex is accessible not only to the doctor, but also to the average medical worker and even to a person who does not have a special medical education, who are provided with a convenient form the final results of computer processing in the form of detailed text and graphic information, as well as duplicated by corresponding voice messages.

FASEGRAPH® is targeted not only at health care professionals but also at users without special medical training who wish to monitor their health. Its constant use at home allows you to reasonably distribute the regime of loads and rest, to determine the need for additional administration of prescribed medicines, to evaluate possible dangerous deviations in the heart from the personal norm and to independently accumulate data over a large period of time for further consultation with a doctor.

FASEGRAPHY is useful not only in medical diagnostic systems, but also opens the way to the development of new methods of biometric identification of an individual by ECG [3].

Currently the International Center has begun promising studies aimed at creating a new generation of smartphone intellectual application, in particular, for analyzing and interpreting a pulse wave – a photoplethysmograph on a smartphone that does not require an additional external signal source (the pulse wave will be obtained using the camera built into the smartphone) .

Figure 2 shows the main screen forms of the developed software modules, which provide:

- automatic analysis of the sequence of functions $\Psi_{кт1}(x,y)$, $\Psi_{кт2}(x,y)$, $\Psi_{кт3}(x,y)$, …, characterizing the brightness of the pixels from user's finger phalanx images on the plane at fixed points in time $t = 1,2,...,N$ according to which a special computational procedure is used to form a sequence of discrete values of the pulse wave $q_1, q_2, ..., q_N$ (Fig. 1, a) ;
- allocation of local maxima of $q_1, q_2, ..., q_N$ under the background of possible interference;
- adaptive filtering providing increased accuracy in determining cardio intervals by selected extreme values of the pulse wave;
- definition and graphic display of standard statistical and spectral characteristics of HRV (Fig. 2, b);
- display of the results of the analysis of the integral characteristics of HRV and notification of their deviations from the norm;

- selection of unreliable cardio intervals based on a original algorithm;
- building a standard pulse wave by averaging selected cardio cycles;
- assessment of the first and second derivatives of the reference pulse wave using special computational procedures;
- determination of the characteristic points of the reference pulse wave and its derivatives, by which a vector $s = (s_1, s_2, ..., s_M)$ of diagnostic features is formed;
- accumulation of experimental data in the training sample of observations for constructing the rules of the diagnostic solution (Fig. 2, c).

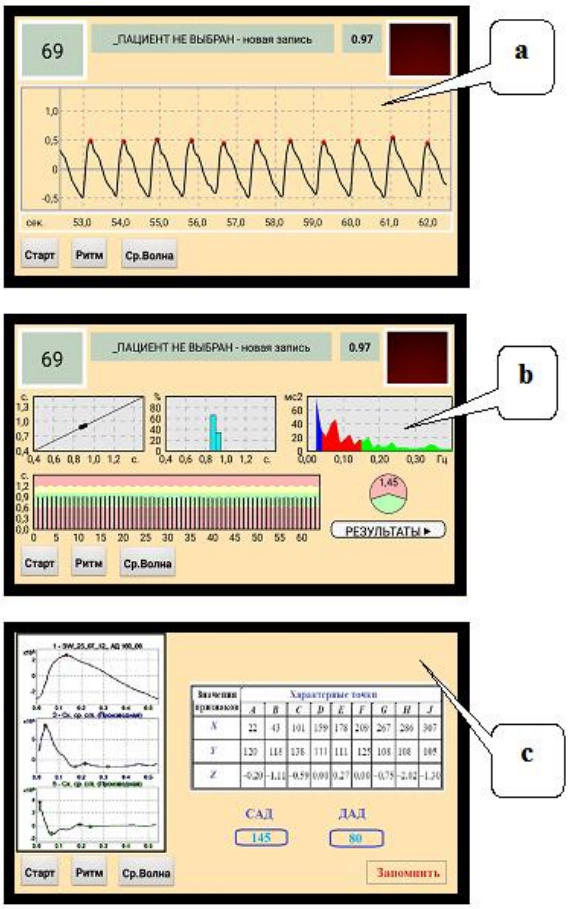

Fig 2. Photoplethysmograph on a smartphone
a: pulse wave graph; b: interpretation of HRV analysis results;
c: raining sample generation module interface

The experiments confirmed the reproducibility of the values of diagnostic signs of reference pulse waves, built for specific users with fixed indicators of the functional states of their body. This result opens the possibility of building a competitive MIS, which is implemented on a smartphone without additional external signal sources.

Conclusions: The implementation of intelligent IT on modern smartphones allows you to solve high-tech tasks and provide the user with integrated results in a convenient form.

1. Boland P. The emerging role of cell phone technology in ambulatory care. – Journal of Ambulatory Care Managemen. – 2007. – Vol. 30. – No. 2. – P. 126-133.
2. Saquib N., Papon M.T.I., Ahmad I., Rachman A. Measurement of Heart Rate Using Photoplethysmography. – Proceeding of 2015 International Conference on Networking Systems and Security. – Dhaka, 2015. – P. 158-163.
3. Fainzilberg L.S. Fundamentals of fasegraphy. – Kiev: Oswita of Ukraine, 2017. – 264 p.