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DEVELOPMENT OF AN ALGORITHM FOR THE FUNCTIONING OF A SYSTEM FOR REMOTE MONITORING OF THE PSYCHO-PHYSIOLOGICAL STATE OF A PERSON

V.V. Bagriy, R.V. Voloshin, O.O. Zhulkovskyi, K.R. Voloshina

Dniprovsky State Technical University
2, Dniprobudivska str., Kamianske, 51918, Ukraine;
email: olalzh@ukr.net

The issue of maintaining human health is an important area of medicine. Today, there are many diagnostic, therapeutic and preventive measures and technologies aimed at improving the quality of health and increasing the life expectancy of the population. All existing diagnostic techniques are performed in direct contact with the patient and the doctor. At present, there is a rather low level of equipment with various medical and diagnostic devices, as well as a low professional level of medical staff. This has resulted in an increase in morbidity and mortality, and a real decline in life expectancy in Ukraine, which has been observed especially in recent years. Today, medicine is facing the issue of early diagnosis with a high probability of making an accurate diagnosis. This requires the development of methods and technical means of high sensitivity and specificity of equipment for determining biometric indicators and studying the measurement channels of biomedical parameters. The literature review has shown that in order to develop command control systems and speech-to-text conversion in a fused speech stream, it is necessary to use «mechanisms» for automatic recognition and understanding of the operator's speech. However, these «mechanisms» have some shortcomings, due to a large number of interferences. The main goal of the work is to develop a device for diagnostic processing and obtaining biomedical parameters for further analysis and electrophysiological studies, which will generally increase the reliability of diagnostics. The algorithm of operation of the system for remote monitoring of the psycho-physiological state of a person based on heart rate and electrocardiological signal is presented. One of the ways to improve the quality of human health prevention is to improve the quality of diagnostics of the functioning of human organs. It is possible to improve the quality of diagnostics by early detection of deviations from the norm of their functioning. It is known that the use of so-called «smart» clothing is gaining popularity. When testing and creating algorithms for processing experimentally obtained signals, it is necessary to thoroughly check them to assess the reliability of recognising informative fragments, the accuracy of measuring diagnostic features focused on these fragments, as well as a number of other indicators.

Keywords: system algorithm, heart rate, electrophysiological methods, electrocardiogram, microprocessor unit, microcontroller, remote monitoring.

Introduction. The problem of maintaining human health is an important aspect of medical science. Nowadays, there are many methods of diagnosis, treatment and prevention aimed at improving health and increasing the life expectancy of the population. All of these methods are usually performed during direct contact between the patient and medical staff. However, today we can observe an insufficient level of medical equipment in various healthcare facilities, as well as an insufficiently high professional level of medical staff. This leads to an increase in morbidity and mortality among the population, which leads to a real decrease in life expectancy in Ukraine, especially noticeable in recent years.

One of the main challenges in medicine is the need for timely diagnostics with high accuracy. This requires the development of highly sensitive and specific methods and technical means for determining biometric parameters and studying medical indicators.

Literature review. Today, so-called «smart» clothing (wearable technology), which can be used to monitor health indicators, is becoming increasingly popular. «Smart» clothing is clothing that can interact with the environment by sensing signals, processing information and triggering responses. In «smart» clothing, fabric electrodes are actively used to capture the electrocardiogram signal [1, 2]. However, the signal obtained using such electrodes has a significant drawback – a large number of artefacts (noise, various interferences) of various nature. When creating algorithms for processing experimentally obtained signals, they need to be thoroughly tested to assess the reliability of recognising informative fragments, the accuracy of measuring diagnostic features focused on these fragments, as well as a number of other indicators. In addition, in real life, the shape of informative fragments is distorted by various internal and external disturbances, which can only be reduced to additive obstacles in some cases. All this complicates digital signal processing, stimulating the creation of new processing algorithms. In this work, the research vector is aimed at improving the reliability of the diagnosis, using modern advances in microelectronics and nanotechnology [1].

The review and analysis of relevant literature and patent sources on the topic showed that the most valuable information for functional diagnostics is electrophysiological methods based on measuring the bioelectrical activity of various human organs and tissues, in particular the cardiovascular system. These methods are well-known and widely used in practice. However, they have fundamental disadvantages caused by their metrological characteristics.

Research Objective. The main goal of the work is to develop a device for diagnostic processing and obtaining biomedical parameters for further analysis and electrophysiological studies, which will generally increase the reliability of diagnostics. The algorithm of operation of the system for remote monitoring of the psycho-physiological state of a person based on heart rate and electrocardiological signal is presented. One of the ways to improve the quality of prevention of diseases is to improve the quality of diagnostics of organ functioning. Improving the quality of diagnostics is possible through the early detection of abnormalities in their functioning.

Main Body. The algorithm of operation of the device for remote monitoring of the psycho-physiological state of a person is shown in Fig. 1. The algorithm works as follows.

The patient puts on the suspension 2 with the belt part, which should fit the torso and provide «dry» galvanic contact with the nipple areas, one of which is the paracardial area of the anterior chest surface. After the suspension is installed, switch on the power supply (p. 2) by simultaneously pressing the buttons on the monitor unit body.

The next step is to check the functionality of the modules: ADC 12, accelerometer 18, Bluetooth contactless modem 17, RAM 15, clock 19, as well as the creation of a performance table (p. 3). Then the initialization is performed: ADC 12 (sampling rate Fd=500 Hz), accelerometer 18, Bluetooth contactless modem 17, RAM 15, clock 19 (p. 4).

Next, the portable monitor is switched to the monitoring mode (p. 5). At the same time, the ADC is polled (p. 6). Sampling and searching for RR intervals are accumulated in the memory of the microcontroller 13 (p. 7). If the RR interval is found (p. 8), the accelerometer 18 is polled: «Is there a patient movement?» (p. 9). If movement is detected, its duration is determined (p. 24), and if the movement lasts more than 2 seconds, the device is switched to the «sleep» mode (p. 25). During the «sleep» mode, the accelerometer 18 is periodically polled to detect the lack of motor activity in the patient.

If there is no movement for 10 seconds, the device enters the operating mode. When the patient is calm (accelerometer 18 does not show movement, i.e., there are no motion artefacts), the patient's condition is searched for cardiological pathologies (p. 10). To do this, the measured parameters are compared with the parameters obtained in p. 21 during training and the set thresholds:

– heart rate (HR) >140 – paroxysmal tachycardia;
– HR>240 – atrial flutter;
– absence of R-peak;
– arrhythmia (A variable arrhythmia ≥ A reference arrhythmia value + threshold);

– rhythm disturbance (HR number of measurements ≠ HR number of reference measurements, or if: N imperial measurements ≥ N imperial reference measurements with HR number of measurements = HR number of reference measurements);

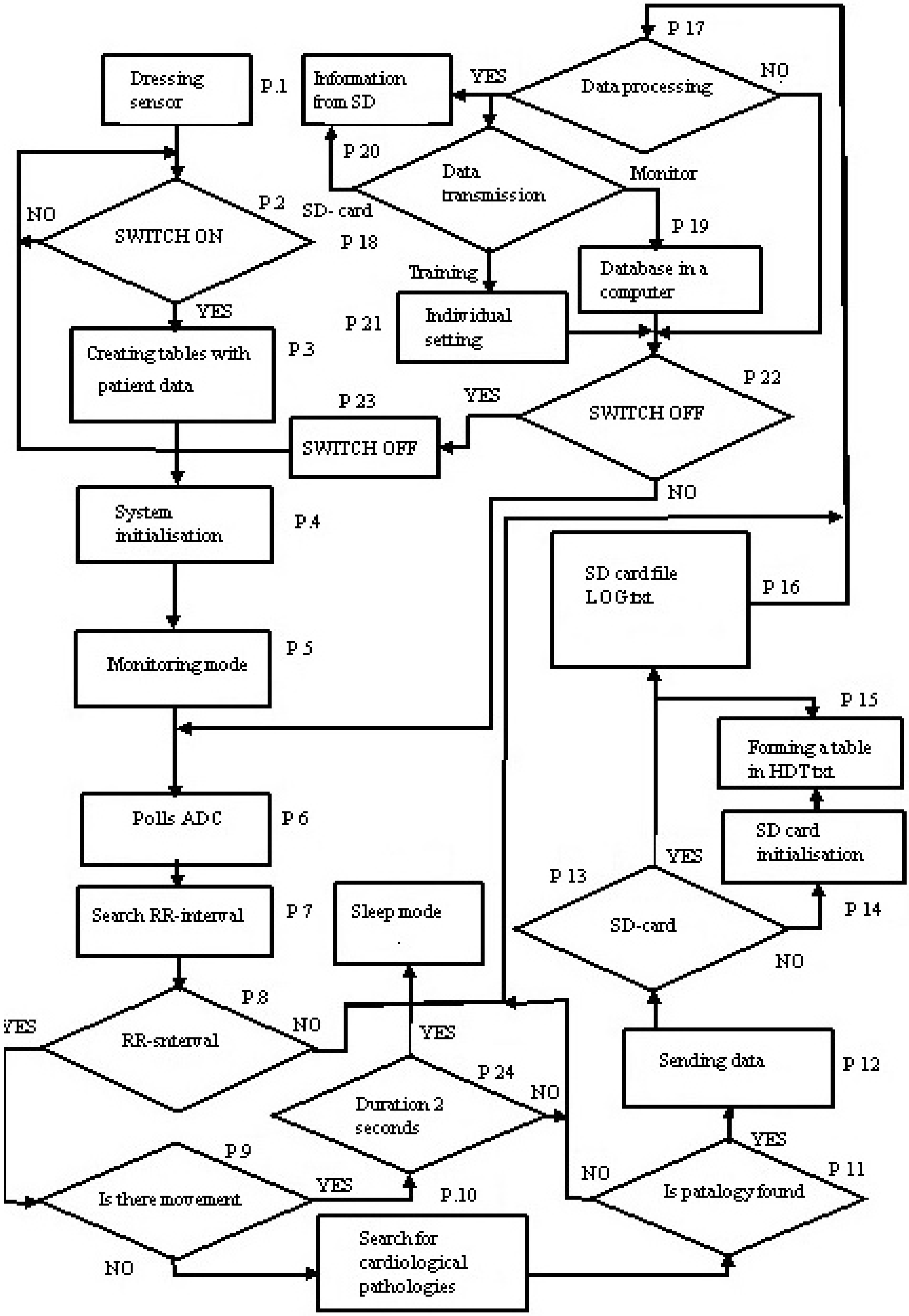

Fig. 1. Algorithm of the remote monitoring system of human psycho-physiological state

– check whether the sign of the P-peak has changed or the sign of the T-peak has changed.

If a pathology is found at the end of the analysis stage (p. 11), the modem 17 communicates with the GSM modem of the patient's phone – the microprocessor generates and sends an SMS message (p. 12).

This message may contain one of the following cardiological diagnoses:

– paroxysmal tachycardia;
– atrial flutter;
– absence of R-peak;
– arrhythmia
– heart rhythm disturbance;
– cardiac arrest;
–prognosis of dangerous ventricular arrhythmias;
– extrasystole;
–dangerous rise of the ST-segment;
– absence of R-peak or negative R-peak;
–absence of T-peak or negative T-peak.

Next, the SD memory card is initialised (p. 13, 14). The performance table (in the form of the HDT.txt file) is saved to it. Then, the LOG.txt file is created on the SD card and a 60-second «fragment» of the signal is saved in the ECG.txt file (p. 16). It is checked whether an external computer is connected via the USB port (p. 17), if so, the microprocessor reads a command from the computer via the USB port (p. 18). Depending on the command, either direct data transfer to the computer is performed (p. 19), or data is read from the SD memory card (p. 20), or the system is individually set up for the patient («training», p. 21).

Next, it checks whether the system needs to be switched off (by simultaneously pressing two buttons on the monitor unit case, p. 22). If «NO», the algorithm returns to p. 7. If «YES», the algorithm returns to p. 2. The algorithm can be run for many days according to this cycle of steps (p. 1-25). If necessary, the device can be switched off by pressing two buttons simultaneously on the monitor unit body (p. 22). Switching the monitor on and off is signalled by a tactile vibration alarm 21, which is mounted on the monitor body and is felt by the patient through the waist part of the bodice. The original design of the spherical electrode matrixes does not have an irritating action on the patient's body and allows for the acquisition of an electrocardiological signal (ECG), a signal with sufficient reliability for emergency diagnosis [4, 5].

The main advantage of the device is the ability to use ECG shapes in patients with pathology, which is ensured by the individual patient adjustment mode. In addition, the device allows to differentiate ECG signals obtained during patient movement from signals of cardiac emergencies due to the elimination of motion artefacts. In the presence of intense patient movements, the device's power supply is switched to sleep mode, which significantly extends the monitor's life [4, 5].

A mobile monitor for a cardiology patient, an electrocardiogram (ECG) block containing an analogue-to-digital converter (ADC), a removable memory card, connected to a microcontroller. The latter is distinguished by the fact that it additionally includes means for generating SMS messages through a GSM telephone modem, a three-axis accelerometer, a real-time clock, a USB port for communication with external devices, a common-mode interference suppression unit associated with a microcontroller and an operational device (RAM). At the same time, the ECG block contains two electrode arrays made with the possibility of fixing and «dry» contact with the areas of the front surface of the chest. Each matrix contains two groups of electrodes, one of which is connected to the in-phase interference suppression unit, and the other to the inputs of the operational amplifier, the output of which is connected to the ADC through a filter. At the same time, the microcontroller is designed to store individual ECG parameters of the patient in the RAM and compare them with the ECG parameters of the current monitoring, taking into account the ECG parameters, according to the established criteria. The ECG parameters are obtained in the absence of motion artifacts recorded by the 3-axis accelerometer, and if the ECG parameters of the current monitoring differ from the individual ECG parameters of the patient by more than the critical value, an SMS with a diagnosis is generated via the GSM modem of the phone.

As shown in Fig. 1, the algorithm can be seen that in the presence of motion artefacts registered by the 3-axis accelerometer, the microcontroller goes into sleep mode (p. 25) and the ECG unit is turned off (p. 22).

When changing memory cards, ECG parameters are entered into the table, or an SMS message with ECG parameters is transmitted (if a smartphone is used for data transmission) from the moment the parameters are formed in p. 19. Note that p. 8 distinguishes which ECG parameters determine the preferred duration of RR intervals, time and amplitude characteristics of the QRS complex and ST segment.

P. 1, is responsible for the installation of a bodice-type suspension on the patient, with the electrode matrices of the ECG block placed in the waist part of the bodice, connected by flexible wires to the device body, on the walls of which are mounted a three-coordinate accelerometer, a tactile vibration alarm and power buttons. The body itself is designed to fit into a pocket of a person's waistband.

With the development of telemedicine, an acute problem has arisen in the manufacture of tonometers that can be wirelessly connected to a PC or smartphone using a Bluetooth channel or other suitable modem. The stages of using such devices are as follows [6]:

– data transfer to a PC or smartphone;

– collection of statistics, the ability to analyse the collected data;

– derivation of trends.

The smartphone is used not only for data collection, but also for control with the ability to view pulse wave graphs.

Each block and its purpose is described in more detail below. Fig. 2 shows the functional electrical circuit of the complex for wireless remote monitoring of the human psycho-physiological state [1-5].

The developed device can be divided into several functional blocks:

– signal registration

– analogue processing;

– microprocessor block;

– power supply unit;

– visual presentation of results;

– data transmission block.

Conclusions. The work provides an analytical review of scientific and technical publications and patents on medical technology and biometric engineering in the field of monitoring the physiological state of the human body with a view to further developing technical means for assessing pathological changes in the human condition. The ways of building relevant devices using wireless networks are planned.

The algorithm of operation of the system for remote monitoring of the psycho-physiological state of a person using tissue electrodes is developed, and the functional diagram of the complex for wireless remote monitoring of the psycho-physiological state of a person is presented.

The results of this study can be used to create a system for monitoring a person's condition based on their ECG.

The results of the study point to new directions for improving the electrocardiograph's work.

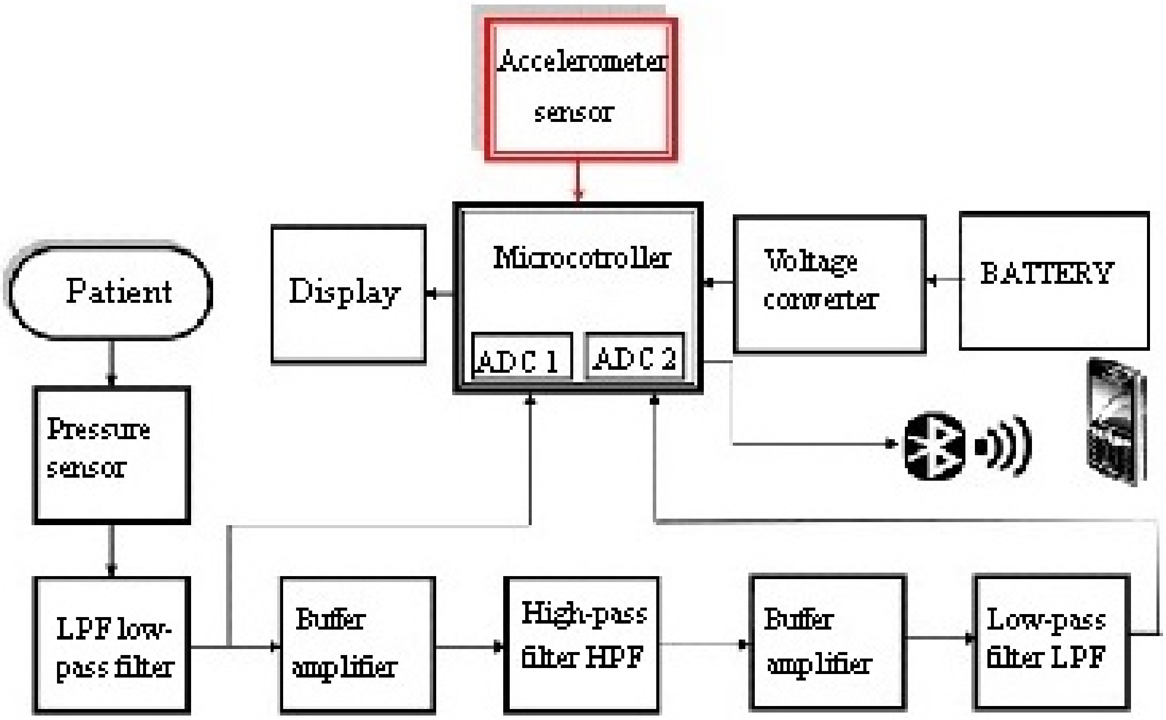

Fig. 2. Functional electrical circuit of the complex for wireless remote monitoring of human psycho-physiological state [6]

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РОЗРОБКА АЛГОРИТМУ ФУНКЦІОНУВАННЯ СИСТЕМИ ДИСТАНЦІЙНОГО МОНИТОРИНГУ ПСИХОФІЗІОЛОГІЧНОГО СТАНУ ЛЮДИНИ

В.В. Багрій, Р.В. Волошин, О.О. Жульковський, К.Р. Волошина

Дніпровський державний технічний університет
2, Дніпробудівська вул., Кам'янське, 51918, Україна
email: olalzh@ukr.net

Проблема збереження здоров'я людини є важливим напрямом медицини. Нині існує безліч діагностичних, лікувальних і профілактичних заходів та технологій, спрямованих на підвищення якості здоров'я, збільшення тривалості життя населення. Усі існуючі діагностичні методики виконуються при безпосередньому контакті хворого з лікарем. Наразі спостерігається достатньо низький рівень оснащеності різної лікувальної та діагностичною апаратурою, так само як і низький професійний рівень лікарського складу. Наслідком цього є зростання захворюваності і смертності населення, реальне зниження тривалості життя населення України, що відмічається особливо останніми роками. Зараз у медицині стоїть питання ранньої діагностики з високою ймовірністю поставлення точного діагнозу. Це вимагає розробки методів і технічних засобів високої чутливості і специфічності апаратури для визначення біометричних показників та дослідження вимірювальних каналів біомедичних параметрів. Літературний огляд показав що для розробки систем командного керування й перетворення «мова – текст» у потоці злитої мови, необхідно використовувати «механізми» автоматичного розпізнавання та розуміння мови оператора. Але ці «механізми» мають де які недоліки, це пов'язано з великою кількістю завад. Основною метою роботи є розробка пристрою діагностичної обробки, та отримання за його допомогою біомедичних параметрів для подальшого аналізу та електрофізіологічних досліджень, що в цілому підвищить достовірність діагностики. Представлено алгоритм роботи системи дистанційного моніторингу психофізіологічного стану людини за показаннями частоти серцевих скорочень та електрокардіологічного сигналу. Одним із способів підвищення якості профілактики здоров'я людини є поліпшення якості діагностики функціонування її органів. Підвищити якість діагностики можливо шляхом раннього виявлення відхилень від норми їх функціонування. Відомо, що нині набирає популярність використання так званого «розумного» одягу. При тестуванні і створенні алгоритмів обробки експериментально отриманих сигналів потрібна їх ретельна перевірка для оцінки достовірності розпізнавання інформативних фрагментів, точності виміру діагностичних ознак, зосереджених на цих фрагментах, а також ряду інших показників.

Ключові слова: алгоритм системи, частота серцевих скорочень, електрофізіологічні методи, електрокардіограма, мікропроцесорний блок, мікроконтролер, дистанційній моніторинг.