Development of a User Monitoring Device in Extreme Conditions

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***Abstract*— Nowadays, the need to monitor the health status of people is becoming more and more acute. However, there are some non-standard situations when monitoring devices cannot adequately register the signal. An example of such cases are extreme conditions, due to the influence of various factors affecting the person and the monitoring devices. In such cases, the probability of violation of the examination process and loss of data increases, resulting in low reliability of the data obtained. Proceeding from this, the actual task is to develop a wearable system of human monitoring in extreme conditions, necessary for the timely control of human health.**

Keywords— PPG, monitoring, Vital signs, extreme conditions

I. INTRODUCTION

Human health monitoring is one of the main tasks of medicine, as registration of various biological signals allows to make an assessment of human health and to observe the adaptation reactions to various external influences or internal processes. But medical monitoring is applicable not only in everyday life and medical practice, also in various emergency circumstances. These systems can allow a better study of the body's response to such situations, as well as timely provision of necessary assistance in critical cases when a person is in a dangerous situation (for example, in extreme weather conditions, as well as in various stressful or dangerous scenarios). Therefore, in extreme conditions, it is especially important to have a reliable and sufficiently informative monitoring system to obtain up-to-date information on the body's reaction to stressful situations.

II. VITAL SIGNS

The initial stage of development of the device is a choice of registered parameters of the person. In case of a portable device for human monitoring it is necessary to choose the minimum set of the most informative parameters of vital activity of an organism. Despite all their advantages portable systems have a number of disadvantages, for example such systems have hardware limitations, in comparison with stationary devices. That is why vital signs, which are a set of 4-6 signs indicating the state of the most important systems of the human organism, will be used to control the user's condition. In classical literature, such indicators are considered: blood pressure, heart rate (HR), temperature, respiratory rate (RR), which show the functioning of vital body processes. If these vital signs deteriorate, the user should be treated as quickly as possible.

III. SELECTED REGISTRATION METHODS

Since the majority of signals interact in various ways with the human cardiovascular system, it was decided to use the circulatory system as the main source of information for further processing and filtering in order to minimize hardware modules. Similar solutions were previously used in developments [1] using the photoplethysmography (PPG), and the accelerometer as the main modules for recording the signal on the state of the body. To increase the reliability of the obtained indicators, a neural network was developed to reduce motion interference. A complex [2] based on combined data acquisition by means of electrocardiography (ECG) was also developed. Among the closest developments in terms of the specificity of the task is the system [3], based on the acquisition of ECG and electroencephalography (EEG) signals, as well as the recorder of respiratory movements. Nevertheless, the most part of developments is directed on daily use, and it is necessary to make additional researches for verification of use of the given technical solutions in extreme conditions. The project [3] assumes the possibility of use in emergency situations. For example, as a monitoring system for the military, but this system is quite bulky and involves the use of multiple devices, which increases the likelihood of breakage or incorrect data due to the complexity of the installation.

Researchers have also conducted studies to determine blood pressure [4] and RR [5,6], which have been used to develop methods for recording the human condition.

AAt a choice of methods of registration the estimation of possible external factors influencing the person and on the developed device which can be characterized by changes of temperature, environment of stay of the person and the reason of a stress reaction was carried out. For example, the human got into water, the temperature of which is lower than 20 ℃. When the body temperature decreases, there is an outflow of blood from the body extremities, which worsens the quality of the recorded signal and requires monitoring the temperature of the person as such processes are indicative of a dangerous situation for the person.

Existing analogs do not have the ability to monitor human body temperature, as they are not provided for the use of such cases. Therefore, when developing this device, the following modules were chosen:

- PPG module (MAX30101 sensor), by means of which pulse wave registration is performed, which is used to determine HR, RR , saturation and arterial pressure;.

- Accelerometer (sensor ADXL345) is necessary to control motion activity, and, taking into account the results [1], helps to improve the reliability of the signal obtained from the PPG sensor;

- The temperature module (AS6221 Sensor) is required to register changes in human skin temperature for subsequent PPG signal processing, as well as transmitting information about the current state of the person.

IV. Approaches to minimize distortion

When designing any ergatic biotechnical system, it is necessary to take into account possible distortions caused by various external factors, as well as peculiarities of system operation. For example, factors affecting the effectiveness of body condition monitoring should be considered:

- Motion distortions caused by movement of the device due to muscle contraction in the area where the system is attached [1] or movement of the user with the device loosely fixed.

- Influence of temperature on the peripheral blood flow [7], due to which the pulse wave parameters change.

- Additional factors affecting the PPG signal registration [8].

Minimization of the influence of these factors is due to the design and software solutions presented in the section of the proposed solution.

V. The proposed solution

After selecting methods of signal registration it is necessary to develop a structural diagram reflecting all main functional parts of the product (elements, devices and functional groups) and main interconnections between them. Fig. 1 shows the structural diagram of the developed complex of registration of parameters of human health in extreme conditions, as a part of biotechnical system, including the user and the object under study - a section of the patient's circulatory system.

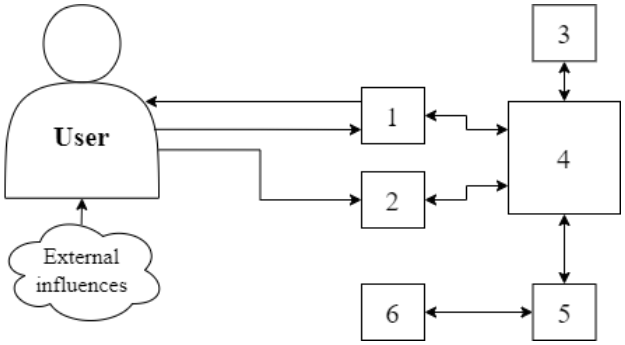

Fig.1. Block diagram of the device for registering the parameters of human condition in extreme conditions. 1) PPG module; 2) Temperature module; 3)Accelerometer; 4) Microcontroller; 5) Bluetooth module; 6) Electronic calculating machine (ECM)

The principle of operation consists in signal reception by means of diodes emitting visible (green and red color light) and infrared spectrum and registration of reflected emission by means of photodiodes with further processing inside the module. In parallel with recording of a photoplethysmogram, motion activity is recorded using an accelerometer, which is used to obtain information on changes of the person's position in space. The temperature of the body surface is also recorded using a temperature sensor. After that the data from three sensors are transmitted to the microcontroller for their pre-processing and transferring by means of the Bluetooth module to the ECM, where the main calculations will be carried out. To stop the module at the end of the data packet transfer the device expects to check the receipt of a stop signal from the computer.

After data transfer from the device to the ECM, heart rate variability (HRV), saturation, respiratory rate is calculated. The algorithm for determining these indices is performed by calculating the first and second derivatives, determined from the filtered PPG signal.

The transfer of calculations to an ECM is foreseen in view of increasing the autonomy of the device activity and subsequent development of a neural network for indirect determination of systolic and diastolic pressure values using existing data on pressure changes and trained on datasets containing simultaneously recorded PPG signals with arterial pressure, according to the method proposed in the study [9].

This device should be fixed in the forearm area of the user with elastic bands to minimize motion interference. Also, the designed corpus of the complex will be hermetically sealed to avoid breakage of the system when in contact with water and dust.

VI. Conclusion

In the course of this work the concept of portable complex for human condition monitoring in extreme conditions was developed, due to which HR, HRV, BP, saturation, temperature is supposed to be registered. Structural scheme and algorithm of the device operation were proposed, considering possible risks of signals distortion.

Further, a neural network will be developed for indirect identification of systolic and diastolic blood pressure using existing datasets containing simultaneously recorded PPG signals with arterial pressure, according to the method proposed in the study [9].

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