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ELABORATION OF A MONITORING SYSTEM OF THE HEALTH OF THE CARDIORESPIRATORY SYSTEM

165.01 - HUMAN AND ANIMAL PHYSIOLOGY

Summary of the doctoral thesis in biological sciences

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CONCEPTUAL GUIDELINES OF RESEARCH

The topicality and importance of the addressed issue. The relevance and significance of remote physiological parameters monitoring, as a matter of physiology, medicine and sanocreatology is determined by the demands of these sciences to highlight the peculiarities and physiological mechanisms of development and sanogenic manifestation of vital organs and systems in dynamic and predictable value of possible somato-vegetative health disorders. The development and creation of a telemonitoring system and remote use of physiological indices of the cardiovascular, respiratory and body temperature systems have made possible not only the continuous monitoring of the preventive functional state of these vital systems, but also the relative somato-vegetative health.

The description of the situation in the field of research. According to the scientific data of the founders of sanocreatology [24, 25, 26], one of the causes of the high morbidity of contemporary society is the lack of possibilities for operative and remote monitoring of physiological parameters that determine daily health and vital activity, which creates difficulties in performing expeditious and adequate recovery of functional disorders, as a result of what they get morbid.

The monitoring of the physiological condition of the body remotely is considered to be one of the most effective ways to solve the health problem, because only in this case there is the real and timely organization of medical care in favor of maintaining health [2]. It has been found that the future of telemonitoring and telemedicine services belongs, because it is indisputable that the development and implementation of telemonitoring equipment is a current research issue [3, 14, 15].

For the remote monitoring of physiological parameters, various telemonitoring systems are developed and used in medical practice, due to their high cost, large dimensions and low ergonomics, these telemonitoring systems cannot find the implementation required by dynamic physiology and sanocreatology. The development of a system of the functional state of the vital cardiovascular and respiratory systems, body temperature and the relative preventive state of somato-vegetative health, aims at the formation and maintenance of remote health in various ways of activity to stop dysanogenesis, and keeps of a reset, of a new approach to medicine demanded by practice.

Based on what was said above, **the aim of the research** is to substantiate the use of representative physiological indices of the vital cardiovascular and respiratory systems as indicator components of a device (prototype) for dynamic telemonitoring of preventive functional activities to the state of somato-visceral health of the body.

Having this as a goal to achieve, the following **objectives** have been determined:

1. Analysis of the practice of using technologies for remote monitoring of cardiovascular and respiratory system functions;
2. Estimation of physiological parameters (blood pressure, respiration rate, heart rate, blood oxygen saturation, body temperature), the use of which, in a telemonitoring system, would allow the preventive assessment of the functional activity of the cardiorespiratory system and the relative state of somato-vegetative health at a distance; The elaboration of a monitoring system of some representative indices of the functions of the cardiorespiratory system in order to remotely evaluate its functional activity and the relative state of somato-vegetative health;
3. Elaboration of a monitoring system of some representative indices of the functions of the cardiorespiratory system in order to remotely evaluate its functional activity and the relative state of somato-vegetative health;
4. Elaboration of a specialized interface for visualization and analysis of physiological information about the activity of the cardiorespiratory system;
5. Elaboration of the information transmission module with the help of communication networks, in case of need;
6. Testing the overall functional capabilities with continuous remote monitoring system.

The research hypothesis. The prevention of functional disorders of the cardiovascular and respiratory systems and the development of high morbidity of the corresponding diseases can be achieved by creating a system of telemonitoring and remote visualization of vital physiological parameters of the mentioned systems and relative somato-vegetative health in order to provide urgent precocious medical intervention.

Scientific novelty and originality: consist in argumentations of a concept regarding identification of some physiological systems and their functional parameters that would reflect their relative functional state and somato-vegetative health and could serve as indicators of telemonitoring and elaborations of an original prototype of remote monitoring.

The applicative value: is determined by the demands of the sciences: human and animal physiology, sanocreatology, medicine, bioengineering, to study changes of the functions of vital physiological systems in remote dynamics and in time to take preventive and recovery actions.

Approval of scientific results. The main results of the scientific research, presented in the thesis, have been communicated and approved at various specialized scientific forums in the country: International scientific-practical conference „Modern achievements of science and ways of innovative ascent of the economy of the region, country”. Comrat: „Progress”, May 8, 2017; Conference „ Superior education: traditions, values, perspectives” Exact and Natural Sciences and Didactics of Exact and Natural Sciences, Chisinau, 29-30 September 2020, Vol. 1.

The scientific research methodology. The methodology of scientific research was based on a concept in the field of physiology on the principle of identifying physiological systems with vital function and their representative indicators, which reflects both their functional state and the preventive state of somato-vegetative health, along with another concept in the field of bioengineering, to ensure the optimization of the collection, processing and remote transmission of information from biomedical signals from the architecture and structural components (electronic devices, sensors, transducers, embedded systems) of high performance and specialization. The prototype is based on the method of electrocardiography, thoracic transimpedance, pulseoximetry, thermometry, photoplethysmography. In order to establish the veracity and authenticity of the experimental data obtained, the standard statistical analysis program Excel-2019 has been applied. The open-source Arduino platform has been used for programming, which is an integrated development environment (IDE) based on the C / C ++ programming language.

Keywords: physiological parameters, blood pressure, frequency of respiration, heart rate, oxygen saturation in the blood, body temperature, somato-vegetative health, remote monitoring.

THESIS CONTENT

The **Introduction** reflects the theoretical and practical premises that emphasize the topicality and importance of the researched problem. Also, the purpose and objectives of the research are formulated, the theoretical and applied value of the thesis has been argued and how the results will be validated.

CHAPTER 1. THE CONTEMPORARY STATUS OF REMOTE SURVEILLANCE SERVICES STUDIES OF SOME PHYSIOLOGICAL SYSTEMS FUNCTIONS AND OF THE STATE OF SOMATO-VEGETATIVE HEALTH

The chapter includes an analysis of current data in the literature on the importance of telemedicine in ensuring the monitoring of functional status and somato-vegetative health. It analyzes the existing telemonitoring systems with various complexities, which are based on information and communication technologies, including Wi-Fi and Bluetooth, which facilitate the wireless transmission of information the Republic of Moldova according to the Government Decision no. 857 of 31.10.2013 on the National Strategy for the Development of the Information Society „Digital Moldova 2020”, approved the National Strategy for e-Health 2020, the use of technologies, information and communications for health, for example, patient treatment, continuous research, surveillance disease and health monitoring [6, 7].

The research report, which was presented by Berg Insight, shows that the annual cumulative growth rate of remote monitoring of patients by 2023 is expected to be 21.4%, reaching 46.4%, € 1 billion by the end of the forecast period [20]. The cost of the mobile healthcare segment, according to Yahoo Finance globally estimated, could reach over $ 82 billion by 2027, and interest in telemedicine will increase by more than 500% [8, 14, 15].

The use of telemedicine services has advantages during the COVID-19 pandemic, as it allows remote monitoring of patients, which means that the transmission of the new coronavirus from patient to physician or vice versa becomes impossible [9].

Cardiovascular diseases are the first in terms of chronic non-communicable disease mortality, with 17.5 million deaths annually, and respiratory diseases - 4 million deaths [10]. Some authors [11,16] confirm that the use of modern technologies that integrate technologies such as wireless sensor networks, for remote monitoring of vital parameters, can reduce the share of mortality caused by cardiovascular diseases by up to 70%, compared to monitoring in hospital [23].

Based on the principles of sanocreatology, regarding the significant role of the functions of somato-vegetative physiological systems in the formation and maintenance of health, the concept of early estimation of somato-vegetative health disorders has been developed, according to which the physiological parameters of vital physiological systems – cardiovascular and respiratory in association with body temperature, can serve as predictable indicators of somato-vegetative health [1].

2. THE IDENTIFICATION OF FUNCTIONAL INDICATORS OF REMOTE MONITORING, TECHNIQUES AND METHODS OF SAMPLING, PURCHASING AND ANALYSIS OF ELECTRICAL PHYSIOLOGICAL PARAMETERS

2.1. The concept of designing the telemonitoring prototype

According to the proposed purpose and objectives, but also the market trend, a concept has been developed regarding the design of a system that acquires biomedical signals from the patient and performs value calculation operations, and in case of a situation where the parameters are out of bounds. generates an alarm signal. Subsequently, the captured data is automatically transmitted over a predefined address over a wireless network.

The research was carried out within the laboratory of stress Physiology, adaptation and general sanocreatology of the Institute of Physiology and Sanocreatology, and within the Medical Service of the Ministry of Internal Affairs in the years 2016-2020.

The proposed prototype is based on the following methods of assessing vital activities:

1. The electrocardiography - the method of analyzing cardiac electrical activity in graphical form that records the evolution of voltage as a function of time. Using a mathematical algorithm, the heart rate expressed in beats per minute is extracted.
2. The thoracic transimpedance - the method of analyzing respiratory movements by time-dependent graphical dependence of the electrical impedance of thorax and extracting the respiratory rate for 1 minute.
3. Pulseoximetry - the optical method of determining the oxygen saturation of hemoglobin in the blood. The value is expressed as a percentage (%).
4. The thermometry - the method of determining with the help of sensors of body temperature. The value is expressed in degrees Celsius.
5. The pulse transit time - the method of analysis and determination of blood pressure by extracting the propagation time using photoplethysmography and electrocardiogram. The method approximates systolic and diastolic blood pressure expressed in mmHg.
6.

2.2. The sampling and analysis of cardiac electrical activity using the bioinstrumentation circuit

The electrocardiography module was used to develop the device, which is based on an ADS1292R chip produced by Texas Instruments Incorporated, which includes an integrated function for measuring biopotentials and thoracic transimpedance to detect respiratory movements. The analog signal is converted into a data packet every 8 milliseconds and transmitted to the central processing unit, the data is processed and displayed, while using the Pan-Tompkins algorithm, the heart rate is determined [19].

The algorithm developed for this prototype is to create a mass of collected data after which the digital filtering procedure for noise removal takes place. Following the application of adaptive threshold values, QRS complexes are detected [22].

To determine the heart rate, the time between consecutive R-R waves over a given period is estimated and the average of these time intervals is calculated. The value obtained is estimated according to the formula:

$$FCC = \frac{60}{R-R_n} \tag{2.1}$$

2.3. Method of sampling and analysis of respiratory movements using transimpedance

The method of analysis of the frequency of respiration used is the pneumogram which represents the graphical recording of respiratory movements by determining the electrical impedance. The graph obtained shows a faster ascending slope which represents the active process of inspiration and a slower descending slope showing the passive process of expiration.

The ADS1292R module was used to determine the thoracic impedance by means of an internal circuit that injects through the electrodes a modulated signal with a frequency of 32 kHz and a current value of 30 μA [11].

The circuit receives the signal, filters and deduces the impedance value, then the data is communicated to the central processing unit via the SPI interface. The central unit processes a mass of data for 30 seconds and then determines the number of breaths per minute that appear on the display.

2.4. Pulseoximetry - the optical method of determining the saturation of hemoglobin in the blood with oxygen

A module (MAX30100) based on integrated optical systems was implemented to monitor the value of blood saturation with oxygen (SpO2) by the pulse oximetry method. The MAX30100 module offers two wavelengths: red ($\lambda \approx 660$nm), infrared ($\lambda \approx 880$nm), with programmable pulse and power modulation [17]. The retrieved data is analyzed and processed using a special algorithm after which the oxygen saturation in the blood is calculated and displayed on the display.

2.5. The determination of the body temperature using the thermometry

The MAX30205 temperature sensor was implemented on the developed prototype with the help of which the skin temperature was measured. The module provides a measurement accuracy of ±0.1°C over the temperature range + 37 ÷ 39 ° C, and over the range + 35.8 ÷ 37 ° C the error does not exceed ± 0.2 ° C [18]. The temperature is measured every 4 seconds. The data, in digital form, is transmitted to the central unit that displays the result on the display.

2.6. The determination of the blood pressure

Method of estimating blood pressure by pulse propagation time (Pulse Transit Time) is based on the electrocardiography module, ADS1292R and the MAX30100 module which have the role of taking the electrocardiographic signal and the photoplethysmographic signal. The signals are taken in a buffer of processed and analyzed data, and as a result, the average pulse propagation time is calculated. The dependence between Pulse Transit Time (PTT) and blood pressure is dependent on the mechanical properties of the blood vessels. The relationship between the two is subject to the Moens-Korteweg equation which is related to PWV (Pulse Wave Velocity) as it follows:

$$PWV = \frac{L}{PTT} = \sqrt{\frac{gtE}{\rho d}} \tag{2.2}$$

Where d represents the diameter of the artery, E - Young's modulus, ρ - blood density, t - wall thickness, g - gravitational constant. Due to the small changes in PTT relative to blood pressure, the equation can be approximated as a linear dependence on the expression:

$$TA = -A\ (PTT) + B \tag{2.3}$$

where A and B are two constants that vary depending on the condition of the patient's circulatory system and is influenced by cardiac output, blood viscosity, peripheral resistance of blood vessels [12]. After calculating the linear regression, the blood pressure is determined [21].

2.7. Conclusions in Chapter 2

1.The architecture for selecting and combining the constituents of the prototype portable remote telemonitoring of physiological parameters (heart rate, respiration rate, blood oxygen saturation, blood pressure and body temperature) has been developed based on new techniques and methods, devices, integrated modules and systems, digital sensors, translators of specialized companies, with superior qualities, which ensure the veracity of the acquisition, execution of operations for calculating the values of parameters and their visualization.

2.The physiological parameters of the vital cardiovascular and respiratory systems, which reflect, although relatively and preventively, the functional state of these systems and the state of somato-vegetative health, have been identified as functional indicators of remote monitoring in order to obtain preventive information on functional status. of these systems and somato-vegetative health.

CHAPTER 3. DEVELOPMENT OF A SYSTEM FOR MONITORING THE FUNCTIONAL ACTIVITY OF CARDIOVASCULAR, RESPIRATORY SYSTEMS, BODY TEMPERATURES AND RELATIVE STATUS OF SOMATO-VEGETATIVE HEALTH

3.1. The structure of the constituent engineering components of the prototype

Due to the potential application in medicine, sports remote monitoring systems of vital signs is an increasingly important topic of practical interest in the last decade, and rapid progress in information technology will have a major impact on health services in the near future [3].

The developed system was based on the following components: the processing system (ESP32), the electrical activity of the cord and electrical transimpedance acquisition subsystem (ADS1292R), the temperature measurement system (MAX30205), the blood oxygen saturation acquisition subsystem, and photoplethysmography (MAX30100).

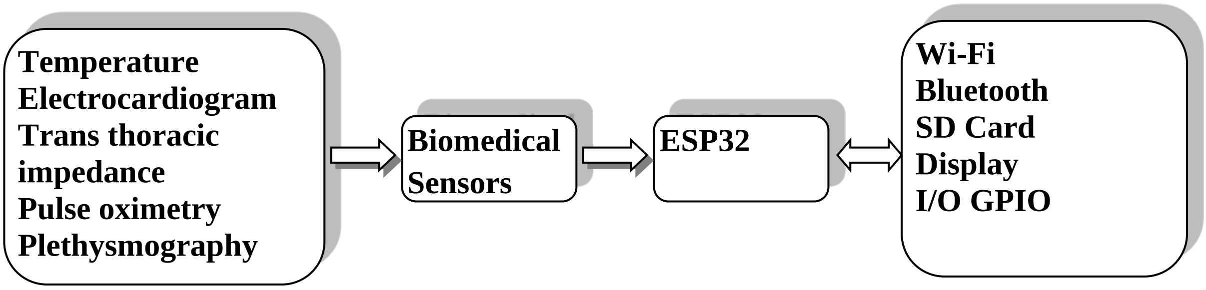

Fig. 3.1. The architecture of the cardiovascular and respiratory system monitoring system

The architecture of the cardiovascular and respiratory systems was composed of the following basic components: the acquisition system (MAX30205, MAX30100, ADS1292R), the data processing / transmission system (ESP32) (fig. 3.1.).

The acquisition of biomedical signals on a system with SoC architecture has been done (in English System-on-a-Chip) which is defined as a system with several electronic circuits, which are integrated on a single crystal. Based on technical needs, an ESP32 microcontroller has been used, an SoC system that integrates Wi-Fi 802.11 b/g/n/e/i technology and Bluetooth 4.2 BLE on a single crystal, created by Espressif Systems, ESP32 is a low-power, mobile-focused development module for mobile applications, portable devices and IoT applications.

The device contains 2 basic units: the unit for acquiring medical bio signals, which consists of the motherboard and all the modules for acquiring vital parameters, and the unit for processing/monitoring, which is represented by the embedded TTGO TM system. Acquired data represent blood oxygen saturation, body temperature, blood pressure, heart rate, and respiration rate. The advantage of this architecture is its low power consumption and volume, which is why it is widely recommended for use in portable devices. The device was designed as a bracelet that attaches to the forearm (fig. 3.2).

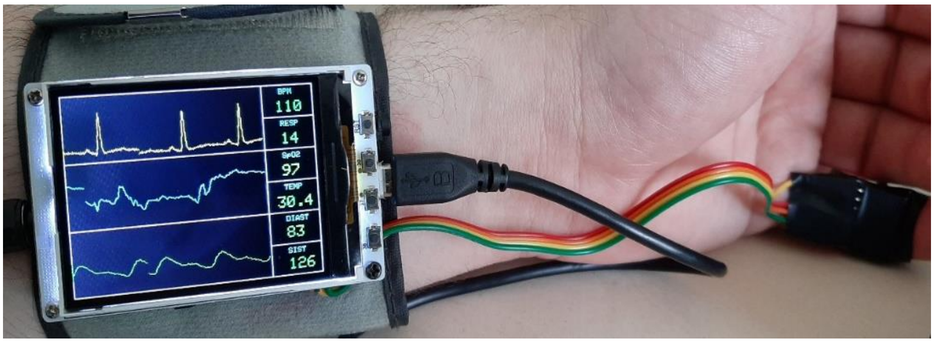

Fig. 3.2. Completed physical appearance of the original prototype

The small size, about 69 mm long by 44 mm wide and weighing about 50 grams make it the perfect choice for the portable system. The designed device ensures a good mobility and information of the patient in outpatient conditions, as well as in the hospital. The important thing is that the person who uses this device, which works continuously, will not interrupt his activity and will not be asked for attention (for example, drivers). The device needs to be placed directly on the skin and can be worn under clothing, thus ensuring good ergonomics.

3.2. The adaptation of the cardiac and respiratory activity acquisition subsystem

In recent decades, there has been an alarming increase in cardiovascular disease, one of the leading causes of death globally. The determined heart rate is a major indicator, which can restore the patient's condition. The sanogenic limits of this parameter are dependent on the age, sex, physical condition of the patient and are variable from subject to subject.

In order to establish the correctness of the values taken from the developed prototype, they were compared with the values indicated by medically certified devices (MAC2000 electrocardiograph produced by GE Healthcare). The data were taken from different categories of people, with different ages, sex, body weight and height, in the Hospital of the Medical Service of the Ministry of Internal Affairs.

According to the proposed objectives, the mean variation, deviation and error of the heart rate recorded by the prototype were evaluated, compared to the data indicated by the MAC2000 electrocardiograph.

Thus, following the analysis of the obtained data, an average variation of ± 2 beats per minute of the heart rate was established, with a standard deviation of 1.4 and a standard error of 0.2%. The average value of the accuracy is about 98.3%, which indicates that the prototype algorithm developed detects quite correctly the frequency of cardiac cycles.

Aiming to represent the variability of the heart rate of the data taken using the prototype, in relation to the general average, the Bland-Altman diagram was made in order to show the variability and distribution for the range of 40-100 beats / minute.

The two extremes represent the limit values, which are equal to the overall mean ± 1.96 × standard deviation. A value of 1.9 is given for a 95% degree of certainty in the case of a Gaussian distribution. This analysis of the data demonstrates that the accuracy of the Pan-Thompkins algorithm implemented on the developed device is consistent and close to the value displayed by the medical equipment (electrocardiograph) used in medicine (fig. 3.3).

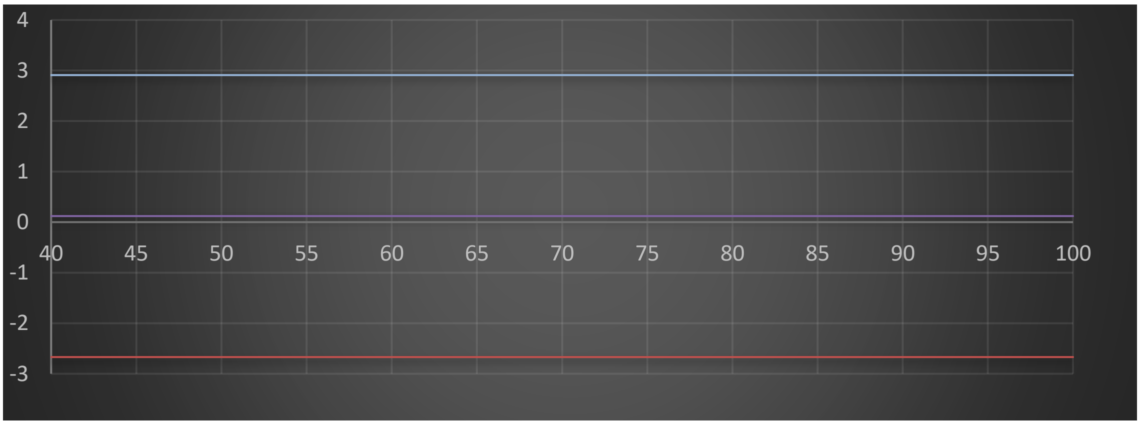

Fig. 3.3. Variability of heart rate

At the same time, the average value of the heart rate was calculated for 5 measurements, performed on 10 subjects, using the developed prototype, compared to the data taken using the MAC2000 electrocardiograph.

The following the analysis of the experimental data, it was established that the mean values of heart rate variability, taken with the help of the prototype, compared to the data taken with the MAC2000 electrocardiograph, has an average deviation of ± 0.4 beats per minute. This difference is within the error limits ± 3 beats per minute, standard values for the electrocardiograph (fig. 3.4.).

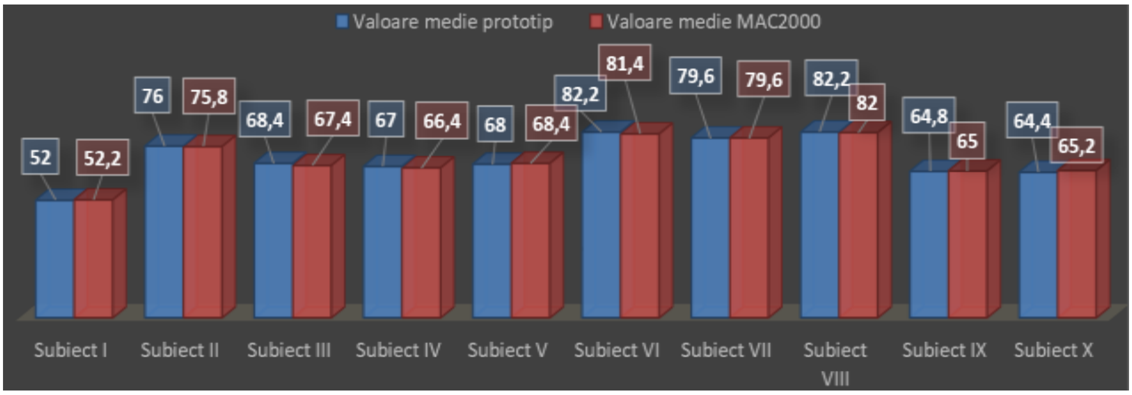

Fig. 3.4. Heart rate average values

Having as purpose to establish the sanogenic state of respiratory system, the values indicated on the display were compared with the preset range of 10-30 breaths per minute, this value is programmable. The number of breaths depends on many factors such as - sex, age, weight (degree of obesity), sleep phase (REM or non-REM), but also other factors.

Chest movements have been detected using chest transimpedance measurement technology. The ADS1292R integrated circuit was used to measure the impedance, which has a built-in chest movement detection circuit based on the variation of the tissue resistance.

The data is transmitted through the SPI interface to the microcontroller where it is analyzed. The recording of the movements of the thorax allows to obtain the pneumogram, with an ascending slope, which represents the inspiration and a descending slope representing the expiration (fig.3.5).

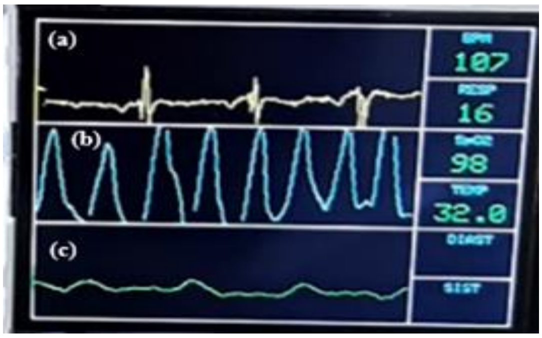

Fig. 3.5. Pneumography taken by measuring impedance

(a) – electrocardiography signal, (b) - pneumography, (c) - photoplethysmography

To validate the accuracy of the breathing frequency calculation algorithm, a comparison was made between the values obtained using the prototype and the values determined using the Spirobank spirometer.

Table 3.1. Comparison of results obtained using spirometry and transimpedance

Subject	Age (years)	Sex	Weight (kg)	Hight (cm)	FR Spirobank (resp/min)	FR prototype (resp/min)
I	66	M	78	174	14	15
II	53	M	90	173	15	14
III	58	M	100	178	15	15
IV	69	M	86	173	16	15
V	31	M	103	182	16	16
VI	61	M	92	175	14	15
Media					15,00	15,00

In this manner, the data obtained show that the respiration rate, determined by means of the developed prototype, has a standard deviation of 0.9, a variation of 0.8 and an error of 0.3%. The overall accuracy of respiration is 95.5%.

In conclusion, we can confirm with certainty that the determination of the number of breaths taken with the help of the developed prototype corresponds to the data taken with the help of the spirograph and can be proposed for monitoring the frequency of breathing at a distance. At the same time, the dynamics of the synchronous changes of the heart cycle frequency and of the respiration frequency were studied with the help of the elaborated prototype (tab. 3.2.).

Table 3.2. Synchronous changes in heart rate and respiration rate

Subject	Age (years)	Sex	Weight (kg)	Hight (cm)	Normal heart rate (BPM)	Heart rate with breath shortness	FR normal	FR with breath shortness
I	66	M	78	174	83	59	14	5
II	53	M	90	173	80	78	14	5
III	58	M	100	178	68	65	12	4
IV	69	M	86	173	70	66	14	5
V	30	M	103	182	75	65	14	4
VI	61	M	92	175	82	76	14	5
Media					76,3	68,2	13,7	4,7

The analysis of the recorded data highlights the fact that, with the decrease of the respiratory rate, there is a synchronous decrease and the decrease of the heart rate [4].

3.3. The integration of the MAX30100 pulse oximetry sensor

In the context of the COVID-19 pandemic, the monitoring the level of oxygen saturation in the blood over time is very important for groups of people at risk of infestation. Due to the fact that blood oxygen saturation measurement takes place non-invasively, this method is the perfect candidate for continuous monitoring applications. Of vital importance is the integration of the pulse oximeter to measure the level of oxygenation with the subsequent transmission of information via Wi-Fi or Bluetooth technology to a smartphone or computer.

The data were compared with medically certified devices in order to assess deviation, error and accuracy in order to determine the accuracy of the data collected. 10 volunteers were tested, using three pieces of equipment simultaneously. The methodology of the experiment consists in placing the patient in a sitting position, and the prototype was placed on the forearm. As a precaution, the subject should be at rest for 10 minutes before performing the test. The MAX30100 sensor was placed at the level of the phalanges in parallel with the sensor from the EDAN H100B and Contec CMS50D2 pulseoximeter, and the values of the blood oxygen saturation parameters were introduced in table 3.3.

Table 3.3. Comparative data on blood oxygen saturation taken from 3 types of devices

Subject	Age	Prototype Value	Contec Value CMS50D2	EDAN Value H100B	Deviation	Error (%)	Accuracy (%)
I	30	98	97	98	0,5	0,511	99,48805
II	31	96	96	98	-1	-1,034	98,96552
III	70	96	98	97	-1,5	-1,546	98,45361
IV	66	97	98	98	-1	-1,023	98,97611
V	65	98	98	97	0,5	0,511	99,48805
VI	66	97	97	97	0	0	100
VII	60	99	97	98	1,5	1,530	98,46939
VIII	55	97	97	97	0	0	100
IX	46	99	98	97	1,5	1,53	98,46939
X	68	97	98	98	-1	-1,023	98,97611

Aiming to determine the deviation, the standard error, the accuracy, the data taken from each individual were subjected to a statistical analysis using the EXCEL-2019 program. Research has shown that variability compared to medically certified industrial devices is ± 1%, the accuracy of blood oxygen saturation detection ranged from 98% to 100%, a deviation of ± 1%, and the standard margin of error is of 0.3%. Thus, it was established with certainty that the prototype determines exactly the oxygen saturation in the blood.

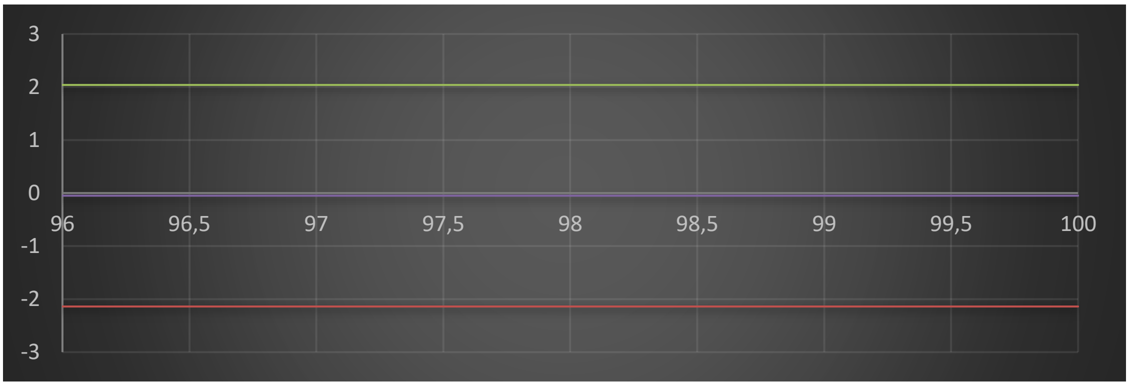

Fig. 3.6. Bland Altman diagram for blood oxygen saturation values

Having as purpose to illustrate the degree of certainty, the Bland-Altman diagram was created where the variability and distribution were displayed with a certainty of 95% for the range 95-100% (fig. 3.6.). The limits of the two extremities are equal to the mean ± standard deviation × 1.96 (the value indicates the area which occupies 95% below a normal distribution curve). The statistical analysis performed showed that the accuracy of the sensor on the developed prototype is quite true and close to the value displayed by the medically certified equipment.

The stability of the performance on the prototype is also quite stable, this is evidenced by the small standard deviation. It has been established that the linear dependence between the 3 devices is approximately equivalent. Thus, the correlation is true for the range 95-100% with a certainty of 95%. Therefore, using optical biosensors can determine the saturation of oxygen in the blood, which is a key parameter in assessing the patient's condition.

3.4. MAX30205 temperature sensor integration

The temperature of the human body can quickly restore the state of health of the individual. This can be measured with the help of special devices, which are divided into 3 categories – thermometers, non-contact probes, thermal cameras.

For the developed prototype, a specialized module developed by Protocentral LTD was used, which is based on a MAX30205 chip, specially designed for measuring human body temperature. For medical applications it is necessary to meet certain requirements related to the accuracy and precision of measurement, which are set out in the standard BS EN ISO 80601-2-56: 2017. In terms of accuracy, the temperature error must not exceed ± 0,1 ° C, which corresponds to the technical parameters of the MAX30205 chip.

The MAX30205 sensor requires a certain amount of time to establish the thermal balance, so the temperature determination period is longer. The data is in numeric form and is displayed on the display once every 5 seconds.

Table 3.4. Body temperature sampled using the prototype digital and infrared thermometer

Subject	Digital thermometer (in the armpit)	Infrared thermometer (at forearm)	Infrared thermometer (at forehead)	Prototype (at forearm)	Thermoscanner (at forehead)
1	2	3	4	5	6
I	36,5	35,2	35,4	35,8	35,3
II	37,0	36,4	36,8	36,1	36,2
III	36,7	35,4	36,3	35,5	36,3
IV	36,8	36,5	36,4	35,6	36,4
V	36,4	35,3	36,0	35,9	36,2
VI	36,4	35,3	35,6	35,6	35,4
VII	36,3	35,8	36,0	35,9	35,9
VIII	36,6	35,7	36,1	35,8	36,0
IX	36,9	35,8	36,5	35,4	36,5
X	36,5	35,7	36,3	35,3	36,4
Precision Class	±0,1ºC	±0,1ºC	±0,1ºC	±0,1ºC	±0,1ºC

To compare the accuracy and accuracy of measuring human body temperature, we compared the data taken by different types of thermometers with the MAX30205 temperature sensor implemented on the prototype. For comparison, a digital thermometer, an infrared thermometer and a thermal camera were used.The prototype in which the values of the human body temperature are taken was attached on the forearm for 15 minutes, later, they were inscribed in the table (table. 3.4.).

In comparison, using an electronic contact thermometer, the temperature was determined in the armpit and in the skin (forearm region), using an infrared thermometer and the thermal camera (forehead level) (photo. 3.8.)

Fig. 3.8. Taking the body temperature with the help of the prototype and the thermoscaner (a) - prototype temperature determination, (b) - Hikvision thermal chamber, (c) - display of the measurement result using the thermal chamber

As a result of the data obtained, an average difference of 0.4ºC ± 0.1ºC of temperatures measured with the prototype based on MAX30205 was established compared to the forearm infrared thermometer. This may be due to heat dissipation through the interconnect board. Due to the large surface area, in relation to the surface of the contact area of the temperature sensor, the thermodynamic system needs a longer time to reach the state of thermal equilibrium.

At the same time, it was established that the basal temperature differs from that measured at the forearm, on average lower by about 0.9ºC ± 0.1ºC. Given that in the forearm, the amount of heat carried by the blood is lower and depends on the patient's psychophysiological condition, position and thermal impedance, the forearm has a lower temperature than the armpit which, in turn, can be 0.4 ÷ 0.5ºC lower than basal temperature.

3.5. Determination of blood pressure using the method of pulse transit time

The number of deaths due to cardiovascular disease is currently a priority, and this number continues to rise either due to delayed medical care or the lack of means to continuously monitor the functioning of the cardiovascular system. High blood pressure is a major public health problem, being the most common cardiovascular disease.

In recent decades, continuous and noninvasive methods have been studied and implemented based on the inversely proportional dependence between pulse transit time and blood pressure. The transit time of the pulse can be defined as the time interval between the R segment of the electrocardiographic wave and the characteristic point that coincides with the peak of the anacrotic wave of the photoplethysmogram.

The value of the pulse transit time was determined by determining the time interval with the help of the prototype in which the controller counts the time between the peak of the R wave and the peak of the plethysmographic wave (the value expressed in milliseconds). The patient is placed in a seated position on the arm at the level of the heart, and the electrodes for collecting the electrocardiography signal are placed on the chest. The pulse oximetry sensor is placed at the level of the phalanges, which takes photoplethysmography.

In the same, the data were collected using an OMRON M2 Classic Intellisense automatic tonometer, which determines the systolic and diastolic blood pressure by the oscillometric method. The tonometer and the obligatory prototype were placed on different arms, in order to avoid the stagnation of the circulation, which is indispensable in the process of taking the photoplethysmography.

To analyze a greater variation in blood pressure, an exercise regimen (knee flexion) was implemented, maintaining a blood pressure range of 110-140 mmHg for systolic and 70-90 mmHg for diastolic. The aim was to ensure a greater variation of blood pressure and pulse transit time, respectively, so the mathematical correlation relationship can be more easily determined and will increase the accuracy of the system.

Subsequently, the correlation between blood pressure and pulse propagation time was performed using statistical techniques. For this, the calibration graph was created, which consists of the values of systolic and diastolic blood pressure on the abscissa axis and the value of the pulse propagation time expressed in milliseconds on the ordinate axis (fig. 3.9).

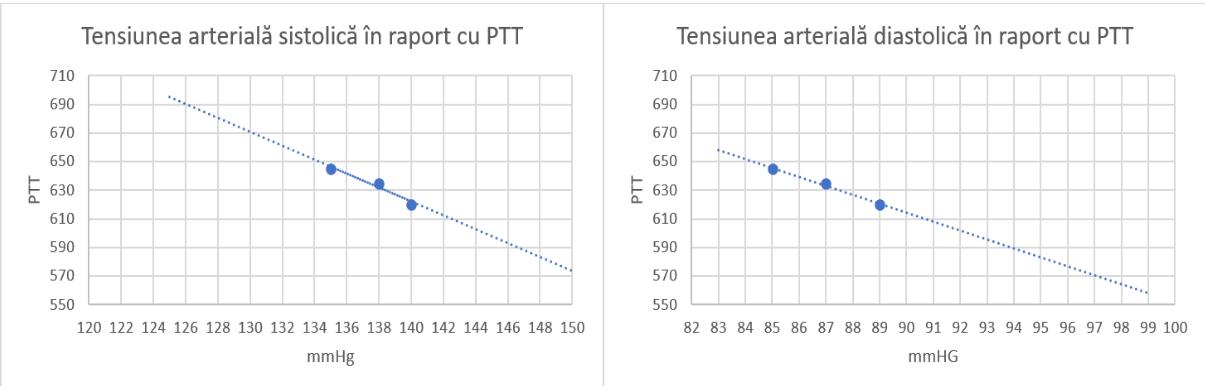

Fig. 3.9. The graph of linear regression of blood pressure dependence on pulse propagation time (Pulse Transit Time)

Based on the obtained graph, the correlation coefficients A and B are established, which form the dependence between the pulse propagation time (Pulse Transit Time) and the blood pressure. The linear regression formula is determined using the Microsoft Office Excel statistical analysis program in the linear regression graph. In the final stage, the results obtained by comparing the data between the value of blood pressure determined by the pulse propagation time algorithm and the value obtained with the OMRON M2 Classic Intellisense automatic tonometer were validated.

Data were taken from a sample of 10 volunteers at the Medical Service of the Ministry of Internal Affairs. The mathematical algorithm determines the time between the two characteristic points and then assesses which of the values are viable. The data is recorded in the memory of the microcontroller and then the average value is determined for every 100 values, so the determination time is 1-2 minutes. Based on the arithmetic mean by mathematical formula, the numerical values for systolic and diastolic blood pressure were calculated.

The first three measurements are taken to extract the values of the coefficients, as well as the formula for calculating the linear regression for the correlation curve between the pulse propagation time and blood pressure. The following 3 measurements are taken to analyze the accuracy of the algorithm, from which the average value is extracted. Based on the data, the average, standard deviation and error were calculated. According to the prototype, the average error recorded is 3.8%, with a mean deviation of ± 4.5 mmHg, with a standard deviation of 3.2 for systolic blood pressure. For diastolic blood pressure, the mean error is 3.6%, with a mean deviation of ± 0.8 mmHg, with a standard deviation of 3.3. The overall accuracy is about 96.3%, so the algorithm proves to be accurate compared to the oscillometric method.

In order to evaluate the veracity between the two measurement techniques, the Bland-Altman diagram was developed for the interval 60 - 150 mmHg (fig. 3.10).

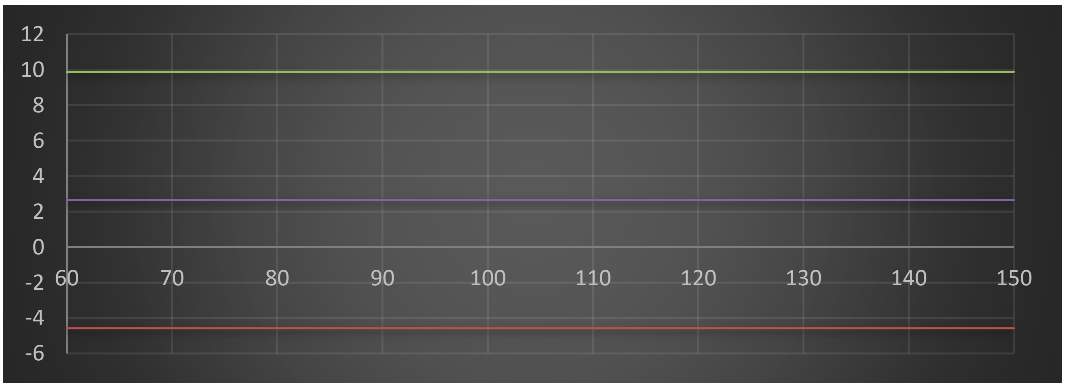

Fig. 3.10. Bland-Altman diagram for blood pressure, determined by the pulse propagation time method

The pulse propagation time method used was shown to have an overall average of the experimental sample of 2.6, with a standard deviation of 3.7 and a standard error of 0.8%. Due to the use of the linear regression method, some shortcomings can also be identified that cannot expose the regulation of the cardiovascular system, so it is recommended to introduce additional parameters such as heart rate.

A correlation curve was made between the two methods of determination used in this study in order to represent the dependence of blood pressure determined with the help of the automatic tonometer, compared to the one estimated with the help of the prototype (fig. 3.11). The analysis of the obtained data shows that the blood pressure values, measured using the automatic tonometer, using the oscillometric method, in relation to the method of estimating blood pressure by correlating with the pulse propagation time, extracted from the physiological signals of electrocardiography and photoplethysmography, using the prototype, has an approximately linear correlation.

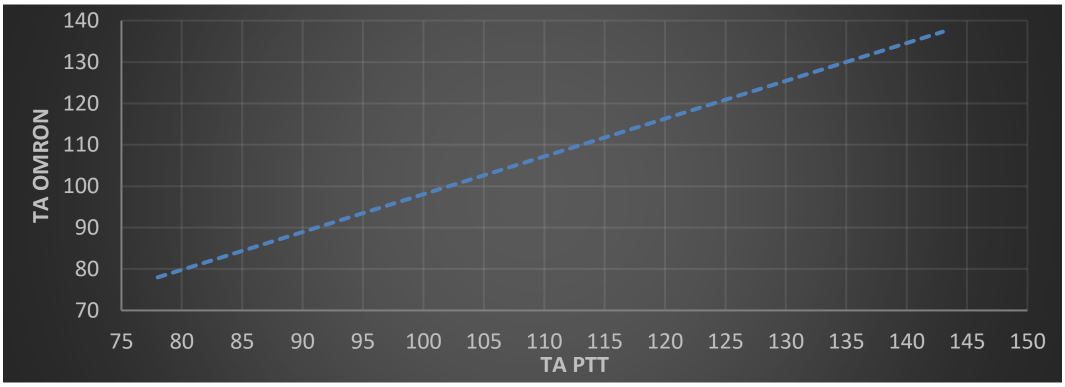

Fig. 3.11. Correlation diagram between the pulse propagation time and the oscillometric method

Thus, the effectiveness of using the method of determining blood pressure was demonstrated using the cuffless method (pulse propagation time), implemented on the prototype. This method has the advantages of a clearly superior ergonomics compared to the oscillometric method, which is positively reflected on the patient-system relationship, due to a reduced portability and size of the prototype [5].

The implemented pulse propagation time method has a lower accuracy compared to the cuff method, while it is suitable for dynamic monitoring. From the point of view of measurement accuracy, it is necessary to perform the calibration not less than once in 30 days but it is recommended to perform the calibration weekly, due to changes in the optical properties of tissues and differentiations between individuals, in terms of curve to calibrate the pulse propagation time versus blood pressure.

An advantage of the developed system is the avoidance of compression of the arm, which leads to stagnation of blood circulation and can cause discomfort and pain. Therefore, the algorithm, implemented on a prototype compared to the oscillometric method, is valid for monitoring blood pressure using the method of determining the pulse propagation time. This is a key element in the development of this system, due to the innovation of introducing SoC systems and biosensors in the daily lives of people with chronic diseases, to ensure good management of chronic diseases.

3.6. Conclusions in Chapter 3

1. The mobile prototype for remote monitoring of functional parameters of the vital-cardiovascular and respiratory physiological systems and the relative state of somato-vegetative health was developed and created according to a concept in conformity with the collection, processing, extraction of information from biomedical signals and transmission They are carried out on the basis of digital bioengineering methodology and at the expense of electronic devices, sensors, translators and embedded systems, adequate, high-performance, state-of-the-art, low energy consumption, small size, which adequately and preventively reflects the functional state of the systems. appropriate and relative to somato-vegetative health.
2. It was shown that the data obtained using the developed prototype showed an average variation of ±2 beats per minute with a standard deviation of 1.4 and a standard error of 0.2%. The average value of accuracy is about 98.3%, which indicates that the Pan-Thompkins algorithm implemented on the developed device detects quite correctly the frequency of cardiac cycles and is consistent and close to the value displayed by medical equipment.
3. The respiration rate determined using the developed prototype recorded a standard deviation of 0.9, a variation of 0.8 and an error of 0.3%. The overall accuracy of respiration is 95.5%. The respiration rate determined using the developed prototype recorded an overall accuracy of 95.5%.
4. It was found that the values of oxygen saturation sampled using the prototype developed against medically certified industrial devices deviated by ± 1%, the standard margin of error was 0.3% and the accuracy of detection of blood oxygen saturation varied between 98% ÷ 100%.
5. There was an average temperature difference of 0.4 ºC ± 0.1ºC with the prototype developed based on MAX30205 compared to the forearm infrared thermometer
6. It was established that the data collected using the developed prototype recorded an average error of 3.8%, an average deviation of ± 4.5 mmHg and a standard deviation of 3.2 for systolic blood pressure. For diastolic blood pressure, the mean error is 3.6%, the mean deviation is ± 0.8 mmHg, and a standard deviation is 3.3. The overall accuracy is about 96.3%, so the algorithm proves to be accurate compared to the oscillometric method.

CHAPTER 4. DEVELOPING AND IMPLEMENTING THE WIRELESS COMMUNICATION ALGORITHM, GRAPHIC INTERFACE AND TESTING THE FUNCTIONAL CAPABILITIES OF THE CONTINUOUS MONITORING PROTOTYPE

4.1. Wireless communication systems and the IoT platform

The development of digital signal processing systems and biosensors will lead to a change in the ideology of the medical system. The use of wireless communication technologies is a key element in the application of continuous monitoring of a person's health.

The architecture of the prototype communication system consists of 6 main elements: bio signals, biosensors, TTGO TM sampling, processing and remote transmission module, Wi-Fi access point, Cloud service and computer (fig. 4.1).

A wireless access point-based system in the form of a router and an HTTP machine-to-machine communication protocol have been implemented. Hypertext Transfer Protocol (HTTP) is a text-based protocol that can be used to transmit information to a remote computer or web address.

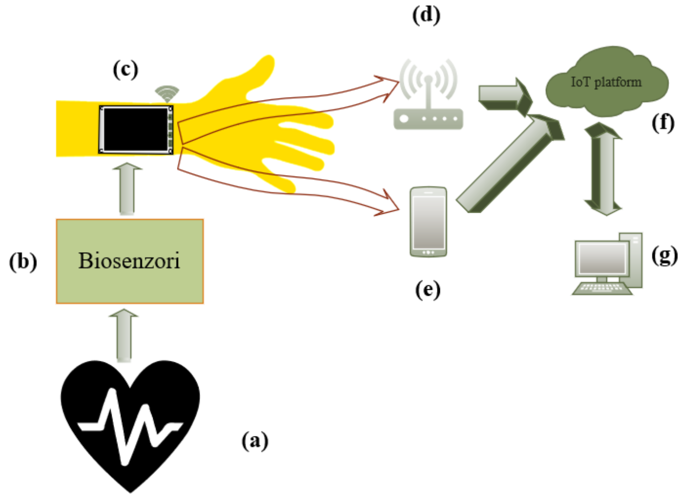

Fig. 4.1. Architecture of the remote communication system of the developed system
(a) - bio signals, (b) - biosensors, (c) - TTGO TM module, (d) - Wi-Fi Router, (e) - optional Smartphone, (f) - IoT platform, (g) - computer.

The AskSensor.com IoT platform is a Cloud system that can be connected to sensors, microcontrollers and embedded systems, receiving real-time data, which can be statistically analyzed and have the ability to generate alarm signals when needed. The platform allows communication based on the TCP / IP protocol, which offers the possibility of mass dissemination.

You need to register an account under which only one user can log in to view data in the Cloud. The asksensor.com IoT platform will generate for each group of sensors a special key called API key (Application Programming Interface). This is a unique identifier used to authenticate an account or data, and provides a specific set of priorities / rights for the account associated with this key.

A communication channel has been created with a unique API key, with which the received data has been collected and stored. The API key plays the role of data protection and communication channel, thus ensuring the cyber security of the data. A unique API key is assigned to each sensor group that directs transmitted data to only one recipient.

Six different modules have been allocated for each group of sensors, where the data can be displayed graphically. You can also view the data stream received with the API key in tabular form where the received data is displayed.

For the transmission we used: the API key and modules with the respective values which, once transmitted, will be displayed in the graph of each module. The advantages of such a communication channel are the ease of implementation and the high level of security

4.2. Evaluation of physiological parameters values, which preventively reflect the sanogenous and dysanogenous state of the cardiorespiratory system using the prototype.

The ability to dynamically analyze the changes of vital parameters was verified in order to demonstrate the degree of performance of the developed prototype and to establish the functionality of the system as a whole. As a result, a certain protocol was implemented to detect variations in vital parameters and to establish their sanogenic / disanogenic limits.

The C-language coded program generates this link at a given time interval for all data (heart rate, respiration rate, body temperature, blood oxygen saturation, systolic blood pressure, diastolic blood pressure, GPS coordinates).

Fig. 4.2. Graphical evolution over time of vital parameters

The interface consists of 6 graphs that represent the evolution of the parameters heart rate, respiration rate, body temperature, blood oxygen saturation, systolic blood pressure, diastolic blood pressure (fig. 4.2.). From the above, it has been shown that the use of the graph that represents the dynamic evolution of a vital parameter presents the optimal option to quickly render the information on the user's screen.

The advantage of using a Cloud IoT system is the simplicity of the graphical interface and the remote data transmission. Thus, an efficient and fast communication system has been created that exposes the information in the shortest time and maximum security. The formation of a history of vital parameters is an appreciable advantage for establishing the anamnesis and diagnosis.

This ensures the access of the doctor who monitors from the terminal the evolution of vital parameters to the latest available data that appear on the web page interface, which positively influences the dynamics of the patient's health.

Therefore, an efficient and secure communication system has been developed, which ensures the real-time transmission of vital parameters at a distance, using specialized communication channels. Communication channels are interconnected using special API keys, which increases security. An enormous advantage is also the use of internet infrastructure as a field of information dissemination, so, due to its universality and global spread, no specialized communication equipment is needed.

You can visualize in real mode the dynamic evolution of vital parameters and you can make quick decisions to provide first aid in case of need using the graphical interface. Aiming to trigger alerts in dysanogenic cases, an activation condition has been established for each vital parameter if the received value is outside the preset range. In case the current value that is received is less than or greater than the sanogenic range of each parameter, the alarm is triggered and an alert message is sent to the predefined email address. The IoT Cloud platform is displayed with the coordinates of the prototype indicating the current location of the subject to reduce the time required for localization and first aid (fig. 4.3.).

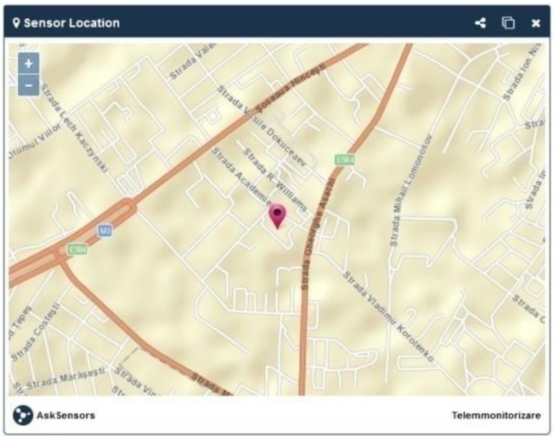

Fig. 4.3. Geo-location system integrated in the IoT platform

The data packet is transmitted with an interval of 2 minutes (the interval for determining the blood pressure), for each being assigned a point on the graph. The alert is in the form of a mail message that has been sent to the default address. The message specifies the date and time of detection, the critical values and the value that triggered the alert (fig. 4.4.).

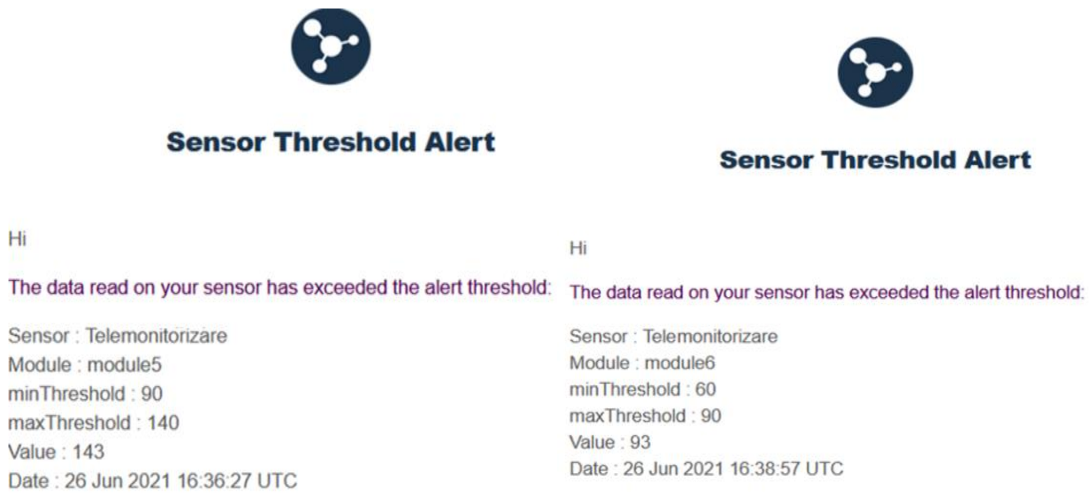

Fig. 4.4. Critical alert for systolic and diastolic BP

The alert message is sent as an e-mail message specifying the reasons for triggering the alert. The data includes the name of the module, the determined value and are transmitted within a certain time frame. Transmitted parameters are stored in the memory of the IoT platform, if necessary, the data can be downloaded to the computer's memory and subjected to a thorough analysis.

Therefore, a telemonitoring system of vital parameters has been obtained which, based on the algorithms for analyzing data from biosensors, transmit information using special communication channels that contain a unique identifier to the Cloud platform. A graphical machine-user interface has been created, with the help of which the dynamic evolution of the vital parameters, the numerical values and the modification of the sanogenic limits can be visualized.

Alert systems are introduced which are activated in case the monitored parameters exceed the sanogenic limits. These parameters can be customized for the optimal condition of each patient, thus ensuring maximum effectiveness of the therapy. Such an automatic detection / alerting system and adequate analysis of vital signals with storage capacity in the database, has a major impact on the medical system.

Information and medical technology are harmoniously combined in vital monitoring systems, a possible "aspiration" of 21st century technologies, which is an extremely useful tool in the management of cardiovascular disease.

4.3. Conclusions in Chapter 4

1. The use in the elaborate prototype of the Wireless communication system, of the specialized communication channels, interconnected with special API keys, of the IoT platform and the use of the internet infrastructure as a way of propagating information, ensures the adequate real-time remote transmission of physiological parameters. vital.
2. The testing of the functional capacities, as a whole, of the prototype, by evaluating the sampling, storage and analysis of the values of physiological parameters in dynamics, detection / alerting of sanogenic and disanogenic signals, efficiency of the information communication system through internet infrastructure demonstrated continuously, at a distance, of vital physiological parameters.

5. GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The analysis of the bibliographic data allowed to confirm the decisive role of the cardiovascular and respiratory physiological systems not only in ensuring the basic vitality of the organism and in carrying out daily activity, but also in highlighting the significance of these systems for capitalizing emotional-cognitive-behavioral reactions. of defense through the phylogenetic training determining these systems, and in the formation / maintenance of somato-vegetative health. Therefore, it has been demonstrated the need to use the physiological parameters of these systems (heart rate, respiration rate, body temperature, blood oxygen saturation, systolic blood pressure, diastolic blood pressure) in order to monitor them remotely as indicators for obtaining information about the relative state of health in the operative organization of restoring the homeostasis of disordered functions and maintaining the relative level of somato-visceral health.

2. The architecture of selecting and combining the constituent elements of the prototype portable remote telemonitoring of physiological parameters was developed based on signals of the functions of vital physiological systems - cardiovascular and respiratory (heart rate, respiration rate, body temperature, blood saturation with oxygen , systolic blood pressure, diastolic blood pressure), which reflects the preventive functional state of the appropriate and relative systems of somato-vegetative health.

3. The mobile prototype for remote monitoring of functional parameters of vital physiological systems - cardiovascular, respiratory and relative somato-vegetative health was developed and created in accordance with a concept according to which the collection, processing, extraction of information from biomedical signals and their remote transmission is performed on the basis of high-performance embedded systems, digital sensors with low energy consumption and small size,

which adequately and preventively reflect the functional status of the appropriate systems and, relatively, the state of somato-vegetative health.

4.Testing the overall functional capabilities of the prototype by evaluating the sampling, storage and analysis of the values of physiological parameters in dynamics, detection / alerting of sanogenic and disanogenic signals, streamlining the communication system of information through internet infrastructure, at a distance from vital physiological parameters.

5. The authentic and efficient level of telemonitoring of the physiological parameters collected with the help of the developed prototype was obtained based on bio signal sampling, analysis and automatic wireless data transmission, by using special communication channels interconnected with special API keys, algorithms for analyzing data from biosensors, Wireless connections, for the transmission of numerical values of parameters, using the Internet infrastructure, as a field of information propagation. Being stored in the memory of the IoT platform, all these can be downloaded to the computer's memory for further analysis. The system integrates a graphical interface to visualize the evolution of physiological parameters, under the alert management menu in case of exceeding the sanogenic numerical values and the transmission of the alert to a healthcare center.

PRACTICAL RECOMMENDATIONS

1. It is necessary to organize the production of the elaborated telemonitoring system for the timely provision of medical assistance in order to telemonitor the functional state of the most important and vulnerable physiological-cardiorespiratory system.

2. Having as purpose the maintenance of the somato-vegetative health, it is necessary to develop and implement in high school biology classes an algorithm for reading and recognizing the critical limits of the main functional indicators of the cardiorespiratory system and providing first aid to patients with this system.

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LIST OF SCIENTIFIC PAPERS PUBLISHED ON THE THESIS TOPIC

2. Articles in scientific journals

2.3. in journals in the National Register of journals (Cat. B, C)

1. **BOTNARU, N.M.** Telemonitorizarea sănătății – solicitarea incontestabilă a zilei. *Buletinul Academiei de Științe a Moldovei. Științele vieții*. 2017, nr. 2(332), 38-49. ISSN-1857-064X. (Cat. B) https://ibn.idsi.md/sites/default/files/imag_file/38_49_Telemonitorizarea%20sanatatii %20-%20solicitarea%20incontestabila%20a%20zilei.pdf.
2. **BOTNARU, N. M.** Telemedicina: impactul economic şi social. *Buletinul Academiei de Științe a Moldovei. Științele vieții*. 2019, nr. 2(338), 62-73.ISSN 1857-064X. (Cat. B) https://ibn.idsi.md/sites/default/files/imag_file/62-73_0.pdf.
3. **BOTNARU, N. M**. Telemonitorizarea în dinamică a funcțiilor și stării sistemului cardiorespirator la om. *Buletinul Academiei de Științe a Moldovei. Științele vieții.* 2020, nr. 3(342), 79-95. ISSN 1857-064X. (Cat. B) https://ibn.idsi.md/sites/default/files/imag_file/79-95.pdf.
4. **BOTNARU N.** O nouă metodă de determinare și transmitere la distanță a valorilor tensiunii arteriale utilizând sisteme cuffless (pulse transit time). *Studia Universitatis Moldaviae. Științe Reale și ale Naturii.* 2021. nr.6(146), 44-48, ISSN 1814-3237. (Cat. B) https://ibn.idsi.md/vizualizare_articol/143834

3. Articles in scientific journals

3.2. in international scientific conferences (Republic of Moldova)

5. ФУРДУЙ, Ф. И., ЧОКИНЭ, В. К., ГЛИЖИН, А. Г., ФУРДУЙ, В. Ф., ВРАБИЕ, В. Г., ГЕОРГИУ, З. Б., БЕРЕЗОВСКАЯ, Е. С., КУЦУЛАБ, А. М., **БОТНАРУ, Н. М**., ШАВДАРИ, Л. В., БУЛАТ, О. В., ВУДУ, В. Г., ГОЛОВАТЮК, Л. Б. Санокреатология – новая биомедицинская наука, призванная решить проблему здоровья. В: Сборник научных статей по материалам Международной научно-практической конференции „*Современные достижения науки и пути инновационного восхождения экономики региона, страны*”. 18 мая 2017. Комрат: „Прогресс”, 2017, с. 385-392. ISBN 978-9975-83-055-3. https://ibn.idsi.md/vizualizare_articol/138116.

3.3. in the proceedings of national scientific conferences with international participation

6. **BOTNARU, N.M.** Telemedicina – medicina viitorului. Conferința științifică cu participare internațională „*Învăţământ superior: tradiţii, valori, perspective*”.29-30 septembrie 2020. Chişinău: UST, 2020, Vol. 1,c. 82-86. ISBN 978-9975-76-312-7. https://ibn.idsi.md/vizualizare_articol/114408.

ADNOTARE

Botnaru Nicolai: „Elaborarea unui sistem de monitorizare a stării sănătății sistemului cardiorespirator", teza de doctor în științe biologie, Chișinău, 2022.

Structura tezei: introducere, 4 capitole, concluzii și recomandări, bibliografie din 273 de surse, anexe, 127 de pagini text de bază, 7 tabele, 53 figuri. Rezultatele obținute au fost tipărite în 6 publicații științifice.

Cuvinte cheie: parametri fiziologici, tensiune arterială, frecvența respirației, frecvența contracțiilor cardiace, saturația oxigenului din sânge, temperatură corpului, sănătate somato-vegetativă, monitorizare la distanță.

Scopul: fundamentarea utilizării unor indici fiziologici reprezentativi ai sistemelor vitale cardiovascular și respirator în calitate de indicatori ai unui dispozitiv (prototip) de telemonitorizare în dinamică a activităților funcționale preventive a stării sănătății somato-viscerale a organismului.

Obiective: Analiza practicii utilizării tehnologiilor de monitorizare la distanță a unor funcții ai sistemelor cardiovascular și respirator; estimarea parametrilor fiziologici (tensiunea arterială, frecvența respirației, frecvența contracțiilor cardiace, saturația oxigenului din sânge, temperatură corpului), utilizarea cărora, într-un sistem de telemonitorizare, ar permite evaluarea preventivă a activității funcționale a sistemului cardiorespirator și a stării relative a sănătății somato-vegetative la distanță; elaborarea unui sistem de monitorizare a unor indici reprezentativi ai funcțiilor sistemului cardiorespirator în scopul evaluării la distanță a activității funcționale a acestuia și a stării relative a sănătății somato-vegetative; elaborarea unei interfețe specializate de vizualizare și analiză a informației fiziologice despre activitatea sistemului cardiorespirator; elaborarea modulului de transmitere a informației cu ajutorul rețelelor de comunicare, în caz de necesitate; testarea capacităților funcționale în ansamblu cu sistemului de telemonitorizare în continuu la distanță.

Noutatea și originalitatea științifică: rezidă în argumentarea unui concept privind identificarea unor sisteme fiziologice și a parametrilor funcționali ce ar reflecta starea lor funcțională relativă și a sănătății somato-vegetative și ar putea servi ca indicatori de telemonitorizare, elaborarea unui prototip original de monitorizare la distanță.

Originalitatea rezultatelor: constă în crearea unui sistem inedit de monitorizare la distanță a unor parametri vitali în baza componentelor structurale constitutive performante, specializate, care, cu ajutorul unor algoritmi speciali, calculează parametrii corespunzători. În cazul dereglării acestora are loc declanșarea alarmei și transmiterea unui mesaj pe adresa de email predefinită.

Problema științifică: fundamentarea și efectuarea studiilor interdisciplinare în fiziologie (sanocreatologie) și inginerie biomedicală în scopul elaborării și creării unui sistem de telemonitorizare la distanță în continuu a unor parametri vitali.

Importanța teoretică: constă în realizarea noilor posibilități de a studia derularea mecanismelor constituirii, maturizării și stabilizării în ontogeneză a funcțiilor sistemelor fiziologice vitale – cardiovascular și respirator și rolul acestora în formarea și reglarea sănătății somato-vegetative.

Valoarea aplicativă: este determinată de solicitările științelor: fiziologia omului și animalelor, sanocreatologia, medicina, bioingineria, de a studia modificările funcțiilor sistemelor fiziologice vitale în dinamică la distanță și la timp a întreprinde acțiuni de prevenție și recuperare.

Implementarea rezultatelor: rezultatele obținute sunt utilizate în cadrul Serviciului Medical al M.A.I. și în Institutul de Fiziologie și Sanocreatologie. Totodată rezultatele obținute pot fi utilizate și în cercetări științifice ce țin de analiza datelor, studierea eficienței reprezentării informației în diminuarea morbidității și mortalității persoanelor monitorizate la distanță.

ANNOTATION

Botnaru Nicolai: „Elaboration of a monitoring system of the health of the cardiorespiratory system", PhD thesis in biology, Chisinau, 2022.

Thesis structure: introduction, 4 chapters, conclusions and recommendations, bibliography from 273 sources, annexes, 127 pages of basic text, 7 tables, 53 figures. The obtained results were printed in 6 scientific publications.

Keywords: physiological parameters, blood pressure, frequency of respiration, heart rate, oxygen saturation in the blood, body temperature, somato-vegetative health, remote monitoring.

Purpose: to substantiate the use of some representative physiological indices of the vital cardiovascular and respiratory systems as indicators of a device (prototype) for dynamic telemonitoring of preventive functional activities of state somato-visceral health of the body.

Objectives: Analysis of the practice of using technologies for remote monitoring of cardiovascular and respiratory system functions; estimation of physiological parameters (blood pressure, respiration rate, heart rate, blood oxygen saturation, body temperature), the use of which, in a telemonitoring system, would allow the preventive assessment of the functional activity of the cardiorespiratory system and the relative state of somato-vegetative health at distance; elaboration of monitoring system of some representative indices of the functions of the cardiorespiratory system in order to remotely evaluate its functional activity and the relative state of somato-vegetative health; elaboration of a specialized interface for visualization and analysis of physiological information about the activity of the cardiorespiratory system; elaboration of the information transmission module with the help of communication networks, in case of need; testing the overall functional with continuous remote monitoring system.

Scientific novelty and originality: consist in argumentations of a concept regarding identification of some physiological systems and their functional parameters that would reflect their relative functional state and somato-vegetative health and could serve as indicators of telemonitoring and elaborations of an original prototype of remote monitoring.

Originality of the results: it consists in the creation of a unique system for remote monitoring of some vital parameters based on high-performance, specialized which, with help of special algorithms, calculate the corresponding parameters. In the event of their failure, the alarm is triggered and a message is sent to the predefined email address

The scientific problem: the substantiation and conduct of interdisciplinary studies in physiology (sanocreatology) and biomedical engineering in order to develop and create systems of continuous remote monitoring of some vital parameters.

Theoretical importance: it consists in realizing the new possibilities to study the development of the mechanisms of constitution, maturation and stabilization in ontogenesis of the functions of vital physiological systems - cardiovascular and respiratory and their role in the formation and regulation of somato-vegetative health.

The applicative value: is determined by the demands of the sciences: human and animal physiology, sanocreatology, medicine, bioengineering, to study changes of the functions of vital physiological systems in remote dynamics and in time to take preventive and recovery actions.

Implementation of results: the obtained results are used within Medical Service of Ministry of Internal Affairs and in the scientific researches from the Institute of Physiology and Sanocreatology. At the same time, the results obtained can be used in scientific researches related to data analysis, studying the effectiveness of information representation in reducing the morbidity and mortality of remotely monitored people.

АННОТАЦИЯ

Ботнару Николай: "Разработка системы мониторинга состояния здоровья кардиореспираторной системы", кандидатская диссертация по биологии, Кишинев, 2022.

Структура диссертации: введение, 4 главы, выводы и рекомендации, библиография из 273 источников, приложения, 127 страниц основного текста, 7 таблиц, 53 рисунка. Полученные результаты напечатаны в 6 научных публикациях.

Ключевые слова: физиологические параметры, артериальное давление, частота дыхания, частота сердечных сокращений, насыщение крови кислородом, температура тела, соматовегетативное здоровье, дистанционный мониторинг.

Цель: обосновать использование репрезентативных физиологические показателей жизнедеятельности сердечно-сосудистой и дыхательной систем в качестве индикаторных компонентов устройства (прототипа) для их динамического теле мониторинга с целью профилактических оперативных мероприятий поддержанию состояния сомато-висцерального здоровья организма.

Задачи: Анализ практики использования технологий дистанционного мониторинга функций сердечно-сосудистой и дыхательной систем; идентификация физиологических параметров (артериальное давление, частота дыхания, частота сердечных сокращений, насыщение крови кислородом, температура тела), использование которых как индикаторы в системе теле мониторинга позволило бы на расстоянии проводить оценку функциональную активность кардиореспираторной системы и относительное состояние сомато-вегетативного здоровья организма; разработка системы мониторинга некоторых репрезентативных показателей функций кардиореспираторной системы для дистанционной оценки ее функциональной активности и относительного состояния сомато-вегетативного здоровья; разработка специализированного интерфейса для визуализации и анализа физиологической информации о деятельности кардиореспираторной системы; разработка модуля передачи информации с помощью сетей связи, в случае необходимости; тестирование функциональных возможностей в связке с системой непрерывного дистанционного мониторинга.

Научная новизна и оригинальность: заключается в обосновании концепции идентификации физиологических систем и их функциональных параметров, которые бы отражали их относительное функциональное состояние и соматовегетативное здоровье и могли бы служить индикаторами теле мониторинга и создание оригинального прототипа мониторизации на расстояние.

Оригинальность результатов: заключается в создании уникальной системы дистанционного мониторинга жизненно важных параметров на основе высокопроизводительных, специализированных составных структурных компонентов, которые с помощью специальных алгоритмов рассчитывают соответствующие параметры. В случае их сбоя срабатывает сигнализация и отправляется сообщение на заранее заданный адрес электронной почты

Научная проблема: обоснование и проведение междисциплинарных исследований в области физиологии (санокреатологии) и биомедицинской инженерии в целях разработки и создания систем непрерывного дистанционного мониторинга жизненно важных параметров.

Теоретическая значимость: заключается в реализации новых возможностей изучения развития механизмов конституции, созревания и стабилизации в онтогенезе функций жизненно важных физиологических систем - сердечно-сосудистой и дыхательной и их роли в формировании и регуляции соматовегетативного здоровья.

Прикладное значение: определяется потребностями наук: физиологии человека и животных, санокреатологии, медицины, биоинженерии, изучать изменения функций жизненно важных физиологических систем в динамике для своевременного принятия профилактических и оздоровительных мер.

Внедрение результатов: полученные результаты используются в Медицинской службе МВД и в научных исследованиях Института Физиологии и Санокреатологии. В то же время полученные результаты могут быть использованы в научных исследованиях, связанных с анализом данных, изучением эффективности представления информации в снижении заболеваемости и смертности людей, мониторинг которых осуществляется дистанционно.

BOTNARU NICOLAI

ELABORATION OF A MONITORING SYSTEM OF THE HEALTH OF THE CARDIORESPIRATORY SYSTEM

165.01 - HUMAN AND ANIMAL PHYSIOLOGY

Summary of the doctoral thesis in biological sciences

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