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CONCEPT FOR PHYSIOLOGICAL FUNCTION MONITORING WITH WEARABLE SENSORS

Urgency of the research. *Modern trends in the automation focus on the implementation of new technologies in people's daily lives, regardless of whether they are healthy or not. The overall health status monitoring became easier nowadays by developing intelligent wearable devices.*

Target setting. *Wearable devices must be non-invasive, comfortable, very light, and with unobtrusive design. The latest technological solutions in microcontroller, communication and sensing technologies provide significant advantages in terms of wireless monitoring of various parameters.*

Actual scientific researches and issues analysis. *When preparing this article, various publicly available journals, datasheets and experimental solutions were analyzed. Conclusions of other experiments were used to create the knowledge base on this research topic as well.*

Uninvestigated parts of general matters defining. *There are many technologies for sensing various physiological parameters and for communication that work online and offline from various vendors. This paper is not enough to describe and analyze them.*

The research objective. *In this article, the design factors and concepts of wearable monitoring systems were analyzed. The results of the article form the basis for further development of an integrated complex wearable device with an identification system.*

The statement of basic materials. *People should be monitored to predict future infections or prevent the spread of the disease. The use of compact solutions in health monitoring, such as sensors, microcontrollers with integrated communication technologies, provide a good basis for solving such problems as necessary monitoring of physiological condition.*

Conclusions. *The proposed paper deals with the properties that need to be assumed when designing a carrier device. The proposed system can provide useful information about the user's health, and the aim of the design was to find the cheapest solution for university environment.*

Keywords: *automated monitoring, sensing, physiological parameters*
Fig.: 4. References: 8.

Introduction. Systems with non-invasive and unobtrusive sensors can be used in many applications. They can be diagnostic tools for healthcare professionals who monitor patients remotely or for people who are interested in monitoring their own physiological functions, for example, during real-time physical activities. These devices can consist of various types of flexible sensors, which can be integrated, for example, into textile fibers, clothing, elastic patches or are directly connected to the human body. Sensors can measure physiological signals such as electrocardiogram, electromyogram, heart rate, arterial oxygen saturation (SpO_2), blood pressure, and respiratory rate. In addition, the micro-electro-mechanical systems MEMS include miniature motion sensors such as accelerometers, gyroscopes, that sense signals related to human movements. Continuous monitoring of physiological signals was primarily intended for the diagnosis and early detection of several cardiovascular, neurological and pulmonary diseases in the initial stages. Therefore, it is understandable, that wearable sensors play an important role in monitoring systems [1, 2].

Intelligent devices with information and communication technologies lead to developing smart cars, houses, cities, which are a trend of the present and a vision of the future. There is a wide range of innovative devices in this area that make people's lives easier. Especially for patients who suffer from chronic diseases, as their remote monitoring helps healthcare professionals to apply the necessary treatment in a timely or daily physiological parameters monitoring.

The current situation of the COVID-19 pandemic requires the necessary measures to be taken to protect society and oneself. Wearing protective drapes, thorough hygiene and compliance with mandatory quarantine are the basic steps for protection against the virus. The main symptoms are high fever, dry cough and breathing difficulties. The virus itself in the early stages behaves as a common flu, but its consequences can be fatal.

The design of the device is created to help schools in the daily prevention of students' infection and in monitoring their presence. The main physiological parameter under analysis when students enter the school area is their body temperature.

Internet of Things (IoT). The Internet of Things refers to the large number of "things" that are connected to the Internet. Their main task is to share data with other things such as Internet applications, connected devices, industrial machines, etc. Devices connected to the Internet use built-in sensors to collect data, and in some cases respond to collected data. IoT can improve the way we work and live. Examples of the real Internet of Things range from a smart home that automatically adjusts heating and lighting to a smart factory that monitors industrial machinery, which performs real-time diagnostics and the necessary optimization to prevent failures [2, 3].

IoT in healthcare. Health services are more expensive than before, the world's population is ageing, and the number of chronic diseases is rising. We are approaching a world where basic health care would be inaccessible to most people. While technologies cannot prevent the population from ageing, chronic diseases, they can at least facilitate health care in terms of access. IoT technology can move routine medical examination from the hospital to the patient's home. Very often proper diagnosis will also reduce the need for hospitalization. The full implementation of IoT in healthcare allows healthcare centers to be more competent and the patient to receive better treatment. The use of this technology-based medical method has many advantages that could improve the quality and effectiveness of treatment and improve patients' health accordingly.

Choice of connection technology. Choosing the most appropriate connection technology is one of the most important decisions to be made in IoT deployment strategy, as connectivity is an integral part of the final IoT solution for end-users. The choice of an appropriate communication method is based on several factors, including the distance or range of the connection, the connection rate, and the power consumption level of the device. The ratio of distance and connection speed for different wireless communication technologies is shown on Fig.1.

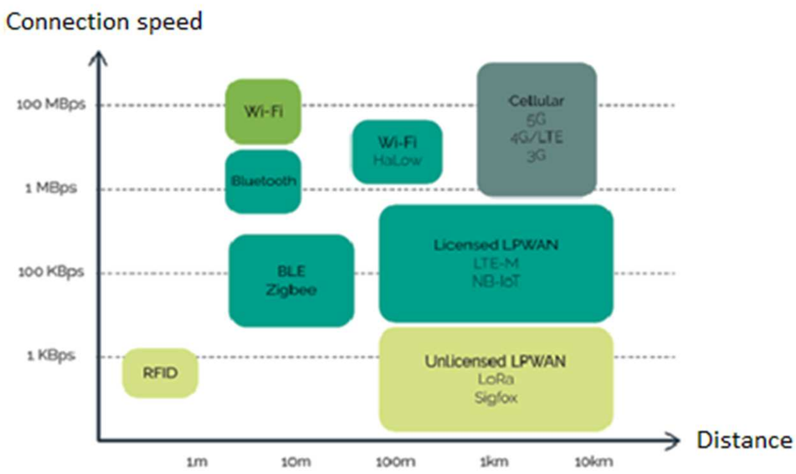

Fig. 1. Comparison of communication technologies

Cloud. The concept of Cloud when it comes to technology or computer science is nothing new. If we imagine the Internet as a virtual space that connects users from all over the world, it is a cloud. It shares resources, software, and information over a network. Information and data are stored on physical or virtual servers that are maintained and controlled by the cloud provider. The user accesses his information via an Internet connection. Cloud offers several services, the most well-known include cloud storage and cloud computing [4].

Cloud computing is used to work and complete specific projects. It's necessary to move data to the cloud before using cloud systems. However, after moving the data to the cloud, it can be processed into useful material and send back. An example of cloud computing is a software as a service (SaaS) where software data is entered and this data is then remotely transformed via a software interface without the process being connected to your computer. For example, remote application programming. Today, this technology is widespread in the digital and business world.

It ensures better cooperation, transparency, efficiency and innovation of solutions. It also reduces communication barriers and allows access to a wider audience, including customers and suppliers. Cloud computing pushes higher computing power than cloud storage. Cloud computing services enable the immediate delivery of the computing infrastructure, databases, repositories, and applications needed to process and analyze data points generated by hundreds of on-demand IoT devices. And with the emergence of similar services like Amazon Web Services, Google Cloud Platform, Microsoft Azure and IBM Cloud, the growth of the Internet of Things is even more so.

Design conditions for wearable devices Wearable devices are miniature electronic devices worn on the body, often integrated or intended to replace existing accessories, such as watches. This market segment is in progress, which is made possible by IoT technology. The need for smaller and intuitive devices is therefore growing rapidly. Current trends include smart watches, smart glasses and surveillance devices for sports and fitness activities. In addition to the consumer market, the medical industry is also creating demand for devices that monitor physiological parameters and functions.

The most important electronic component of wearable devices is the microcontroller (MCU). Because these MCUs must be small and contain multiple functions at once, integration is another important factor [5, 7].

Requirements for wearable equipment. The design of the wearable device should fit into various fashion accessories, such as watches, glasses, jewelry and the like. Aesthetics are so important that top semiconductor companies like Intel are working with the fashion industry to increase demand for their manufacturing. Capacitive touch sensing is a key technology that also helps to improve aesthetics. The user interface must be functional for a variety of shapes, including curved surfaces, must be fluid resistant, and can be scanned even when overlapped. Thanks to Capress and TrueTouch technologies from Cypress, these requirements are met. New equipment must be as small as possible so that it can be worn comfortably. At the same time, however, they must integrate multiple functions into one space. Technologies such as System-on-Chip (SoC) and Chip Packages (CSP) can help reduce size.

Energy consumption. Wearable devices are battery-powered, so each power consumption poses a challenge for these devices. Unlike other mobile devices, these wearable devices must always be switched on and always connected, because of which they are monitoring devices. For example, a smart watch must always display the time and must be connected to a mobile phone via a wireless connection, such as Bluetooth, in order to receive notifications, as in the case of pedometers and heart rate monitoring. Battery capacity is necessarily limited due to the need to reduce all dimensions. Therefore, these devices must operate with very low power consumption for the battery to last as long as possible [5, 6].

Wireless communication. A wireless connection is important for wearable devices because they must communicate with one or more devices. Depending on the type and features offered, the device must provide different wireless protocols, such as Wi-Fi, ANT +, Bluetooth Low Energy (BLE), and an IEEE 802.15.4-based protocol.

The choice of main processor depends on the type and characteristics of the device. Advanced information and entertainment devices that include an application processor are equipped with an MCU processor, which is processed in a carrier-type manner. The latest microcontrollers integrate function control into a single chip. This is important in reducing the total amount of carrying equipment and the cost per piece.

Wearable device components. Depending on the type of main processor used, multiple peripheral functions can be integrated into a single processor chip. For example, most PSoC devices integrate capacitive sensing functions, which eliminates the use of a separate touch controller and similar display functions. An important subsystem of the wearable device is the sensor data acquisition subsystem. Depending on the type of device, this could be a simple system with only a few MEMS sensors or complex with a dedicated sensor hub for connection to the sensors. MEMS sensors play a key role in fitness and wellness areas and monitor the movement of the human body in all dimensions. These sensors are also called motion sensors. Actually, all these sensors provide motion information in digital mode via the I2C / SPI communication interface [7, 8].

Design of an innovative solution. The aim of this innovative solution is to design a device that will be able to identify students, school staff and monitor physiological functions. The measured parameter will be body temperature. The overall concept of the device consists of two parts. The first part is the identification module, whose task is to register people in the cloud system with the current time of arrival. This module is closely connected with the main point of the solution, which is the design of the wearable device. The system structure is shown on Fig. 2.

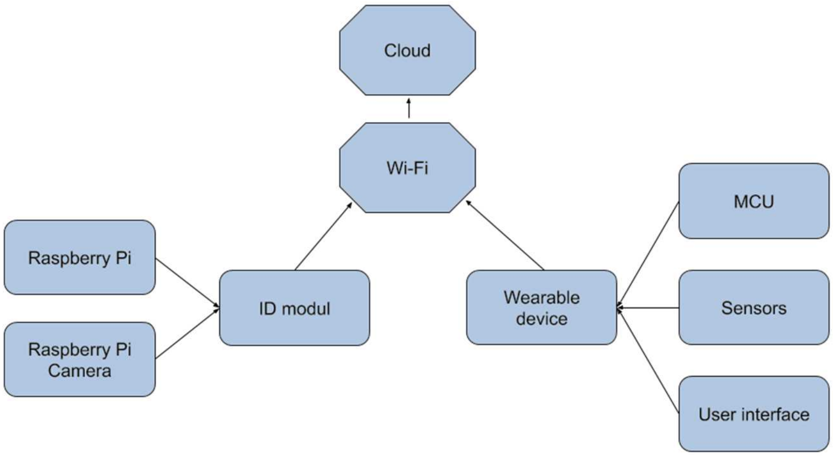

Fig. 2. System structure

Design of wearable device. To make the device as comfortable to wear as possible and to meet the aesthetic trends of today, it will be designed as a bracelet. Thus, it will also suit sensor applications that need the best possible contact with the human body. The main functions of the wearable device are a measurement of body temperature, pulse, QR code display function, Wi-Fi connection, power saving mode capability and sending of measured data to the cloud.[7]

Microcontroller selection. There are many different development boards and microcontrollers available from different companies: TI, Samsung, Arduino, Raspberry Pi and more. The choice of the most suitable depends on several factors, which vary depending on the nature of the application: Compatibility, Architecture, Memory, Availability, Price.

The overall set of components of the wearable device consists of a microcontroller that controls the processes of the device, the sensor that measures body temperature and pulse with high accuracy. In order to communicate with the device, it must be equipped with a display. The whole device is powered by a battery that offers 3.7 V.

The MAX30205 temperature sensor is selected to measure the temperature of the human body. The digital temperature sensor has an accuracy of 0.1°C in the measuring range of 37°C to 39°C. This device converts temperature measurements to digital form using a high-resolution analog-to-digital converter (ADC). The accuracy meets the ASTM E1112 clinical thermometric specification. Communication takes place via the I2C serial interface. The sensor has a supply voltage range of 2.7 V to 3.3 V and a low supply current of 600 µA. It is available in compact dimensions of 3x3 mm. These sensors are suitable for wearable fitness and medical applications [8].

In general, wearable devices such as smartwatches, bracelets offer almost the same basic functions. The best known include monitoring physiological functions, counting steps, calculating calories burned, monitoring sleep activity and compatibility with a mobile device that is used to visualize the measured data. Most of the special functions are not needed for this solution. The basis is the identification and measurement function of physiological parameters. In the future, the device may be equipped with innovative features that will add more application value to the device. The components of the system are shown on Fig. 3.

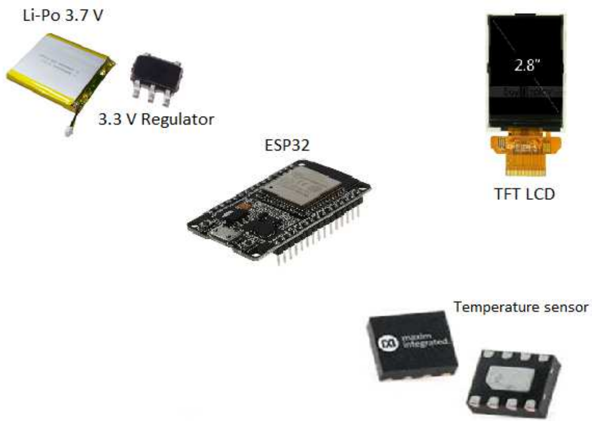

Fig. 3. Components of proposed system

Identification module. By combining a camera from Raspberry Pi and the control unit itself, we get a fully functional identification module. The camera will be used to scan the QR code of wearable devices. Subsequent recognition and identification is the responsibility of the microcontroller. This process requires the fast computing features that the Raspberry Pi offers with its computing power. It also includes a Wi-Fi wireless module, so sending data to the cloud is no problem.

The process of identification and measurement of physiological functions. On the entrance of the school facility, there is a gate that contains an identification module. Log in the system is done by scanning the QR code, which is unique for each student and employee. The wearable device contains a login function, the activation of which triggers two functions. The first function is to display the QR code on the display of the wearable device, which is scanned by the camera module. At the same time, the body temperature and pulse measurement function is run for 60 seconds to get the most accurate measurement values. After scanning the code, the control unit compares the Raspberry Pi identification module to see if the identification number is entered in the registry and if yes, the unit turns on Wi-Fi and then writes it along with the current time to the cloud. After 60 seconds, the resulting value of the measured body temperature and the averaged value of the measured pulse are written to the output. The control unit of the ESP32 wearable device switches on the Wi-Fi mode and sends the measured values to a common cloud. In the cloud, the assignment function of the identification numbers takes place together with the devices and their measured values. After the assignment, a final check of the measured values occurs, which verifies that an individual has a temperature above 38°C. In this case, the cloud function initiates an alarm mode and notifies the competent persons of the current higher temperature of the student.

The measurement cycle has repeated in total for ten times during the day, every half hour. This is to obtain the most accurate data and to detect fever, infection, and the like as soon as possible. To save battery life as much as possible, the implementation of the device's sleep modes is necessary. After each measurement and sending data to the cloud, after 30 seconds, the device enters a power-saving mode that turns off Wi-Fi, measurement functions and completely dims the contrast on the display.

The flowchart briefly describes the process of identifying and monitoring physiological functions. After experimental measurements and tests, it would be necessary to optimize the process and look for possible system errors. In addition, the power regulations should be reevaluated to save the battery as much as possible. It was not analyzed the process in the cloud in detail, but its functions are showed in Fig.4.

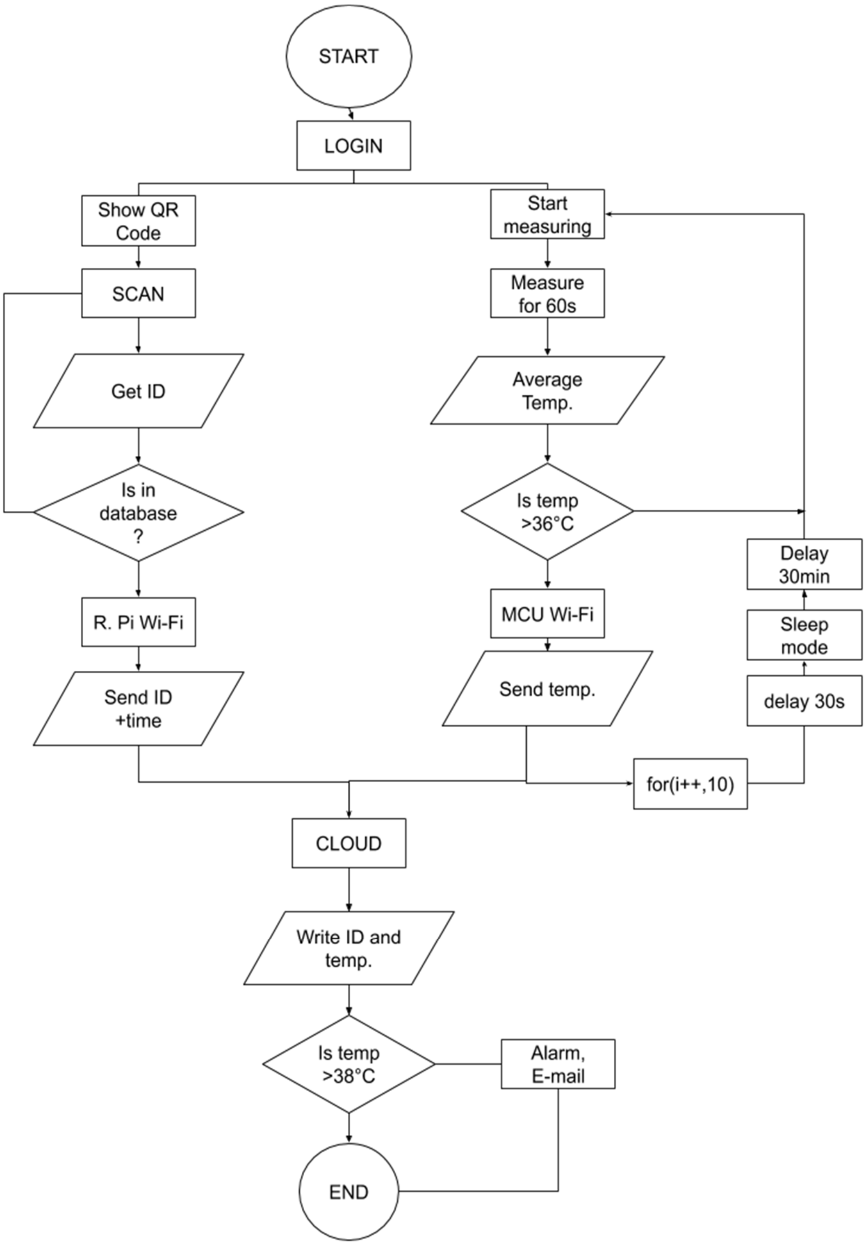

Fig. 4. Functional principle of the proposed system

Conclusion. This paper describes the concept of physiological condition monitoring system. The modern monitoring systems are implementing sensing, communication, and visualization operations without interrupting the normal life of people. The proposed monitoring system finds application in the monitoring of the health of the user. The integrated sensors can be used to monitor the temperature and other parameters and if it is necessary, it can warn the responsible staff to take action. The article aims to introduce the essential aspects of the system design and describes a functioning principle of the proposed device. Internet of Things, cloud technologies, hardware components and the design requirements were described. The most important design aspect was to find the cheapest solution for a university environment where the student and the staff can benefit from using such system.

As the proposed system solves a complex task, it was divided into two main units. In the first part of the system, the identification of the person is performed, while in the second part, various physiological indicators are monitored. These parts communicate in parallel via a Wi-

Fi connection with the master cloud. Data recording and processing is performed here. In the case of critical values, an alarm message is sent. The proposed system can be used as a basis for further development.

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КОНЦЕПЦІЯ МОНІТОРИНГУ ФІЗІОЛОГІЧНИХ ФУНКЦІЙ ЗА ДОПОМОГОЮ НОСИМИХ СЕНСОРІВ

Актуальність теми дослідження. *Сучасні тенденції автоматизації орієнтовані на впровадження нових технологій в повсякдення життя людей, незалежно від того, здорові вони чи ні. В даний час моніторинг загального стану здоров'я став простішим завдяки розробці інтелектуальних носимих пристроїв.*

Постановка проблеми. *Носимі пристрої повинні бути безпечними, зручними, дуже легкими і мати ненав'язливий дизайн. Новітні технологічні рішення в області мікроконтролерів, сенсорів та зв'язку забезпечують значні переваги з точки зору бездротового моніторингу різних параметрів.*

Аналіз останніх досліджень і публікацій. *При підготовці статті були проаналізовані різні загальнодоступні публікації, довідникові матеріали та експериментальні рішення. Результати інших експериментів також були використані для створення бази знань по цій темі дослідження.*

Виділення недосліджених частин загальної проблеми. *Існує безліч технологій для вимірювання різних фізіологічних параметрів і зв'язку, які працюють онлайн і офлайн від різних виробників. Даної статті недостатньо для їх опису та аналізу.*

Постановка завдання. *У цій статті були проаналізовані конструктивні особливості та концепції носимих систем моніторингу. Результати статті є основою для подальшої розробки інтегрованого складного носимого пристрою з системою ідентифікації.*

Виклад основного матеріалу. *Стан людини потрібно моніторити для того, щоб мати можливість передбачити майбутні інфекції або запобігти поширенню хвороби. Використання компактних рішень для моніторингу здоров'я, таких як датчики, мікроконтролери з вбудованими комунікаційними технологіями забезпечує гарну основу для вирішення таких завдань як моніторинг фізіологічного стану людини.*

Висновки відповідно до статті. *У запропонованій статті розглядаються особливості, які необхідно враховувати при проектуванні носимого пристрою. Запропонована система може надати корисну інформацію про здоров'я користувача, метою розробки було знайти найбільш дешеве рішення для університетського середовища.*

Ключові слова: *автоматизований моніторинг, сенсор, фізіологічні параметри*

Рис.: 4. Бібл.: 8.

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