# Development of a system for monitoring health and patient care based on IoT technologies

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**Abstract**

The paper proposes an innovative hybrid architecture of a patient monitoring system that combines cloud technologies with local data processing to improve the efficiency and reliability of health monitoring. This solution enables real-time processing of critical data locally, reducing latency, while large data and long-term analysis results are transferred to the cloud for further processing and storage. For successful implementation of such systems, it is necessary to consider issues of data protection, standardization, ethical aspects, reliability, and training of medical personnel. The paper analyzes existing health monitoring systems, their strengths and opportunities for improvement. The proposed methods for developing such systems are described, including the use of various sensors, real-time data analysis, and patient condition classification. Data transmission scenarios and system operation algorithms are developed. Particular attention is paid to the benefits of integrating IoT devices for continuous health monitoring and their impact on patients and healthcare workers.

**Keywords**

Internet of Things (IoT), healthcare, biotechnology, health monitoring, personal health devices, electrocardiogram (ECG), health monitoring systems, big data processing, data security



## 1. Introduction

The world is developing daily and becoming more convenient for its inhabitants - talking about life inside the house or outside its borders. In comparison with our lives a hundred years ago and now, there has been a significant increase in technology that has allowed humanity to make huge steps forward in all areas. With the advent of smart devices, there has been development not only in the areas of industry or manufacturing, information technology or even trade, but also biotechnology and medicine, which is a significant leap forward. Thanks to scientific research in the field of biotechnology and medicine, it was possible to develop new methods of treating diseases, vaccines, genetic therapy and immunotherapy, which significantly increased the quality of life and increased the life expectancy of people.

Throughout our lives, we have encountered many innovations and their research, which each time aptly help and facilitate our lives. With the help of information technology, humanity has reached the "peak" in which it has become more comfortable and safer to live. Speaking about the growth of the development of medical research, which is carried out mainly using IoT technologies and even artificial intelligence technologies, it has become more convenient and faster to pass medical tests and conduct research tests; improved diagnostics that enable more accurate and faster detection of disease by analyzing medical images, biomedical data and patient symptoms; personalized treatment has become available, which allows you to develop personalized treatment

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approaches and select optimal treatment regimens; health monitoring has increased to a level that promotes early detection of deterioration and avoidance of complications; efficient management of medical resources allows optimizing the use of medical resources, for example, by automating the management of hospitals and medical institutions, etc.

Mankind for many decades worked on the development of information systems and technologies in order to improve the quality of life and facilitate various routine work, which, as it turned out, can be so easily automated. Thanks to the introduction of the Internet of Things into our lives, we can easily control the level of pollution in our region, receive real-time notifications on the phone, for example, regarding the flooding of an apartment, or, more importantly, control the blood sugar content, or monitor our heart rate hourly without using a tonometer. So, let's talk about one of the most important areas in which IoT is so necessary for humanity - medicine. It is thanks to medical IoT that all patients can be provided with a reliable and convenient way to track their health in real time, the level of accuracy of results or studies will increase significantly to higher percentage positions, and by automating the processes of data collection and analysis, it will be worth spending less time waiting for results and comments from doctors.

The widespread adoption of IoT, bio-devices, and E-health applications has significantly expanded the network of end-user devices. Within this framework, the substantial volume of data generated by sensors and healthcare wearables constitutes big data. Consequently, storage and processing tasks have transitioned to the cloud layer due to its cost-effectiveness and "pay-as-you-go" model, which simplifies computations and reduces system costs. This transition has led to the introduction of Cloud of Things (CoT) to further enhance the healthcare system.

IoT-enabled healthcare encompasses various applications such as clinical care, telemedicine, and remote patient monitoring. It involves continuous monitoring of patient data, which is processed and stored in the cloud for remote access by physicians. This facilitates prompt disease prognosis, thereby mitigating the risk of critical ailments and reducing treatment costs. Consequently, the integration of IoT with healthcare yields significant societal benefits [1].

## 2. Literature review

The development of a system for monitoring health and patient care based on Internet of Things (IoT) technologies is a relevant and promising topic in the modern medical field. This system can provide a reliable and convenient way to track the status of patients in real-time, which will allow you to respond faster to any changes and provide the necessary assistance [2]. Facing with unpredictable challenges in this area Speaking about certain challenges, the following aspects can be distinguished:

- Data privacy and security: With an increase in the amount of medical information that is transmitted through different networks, there is an increase in the importance of data security and privacy issues. Taking into account and implementing measures to protect patient's personal information and ensure data integrity is one of the most important tasks.
- Standardization and compatibility: The variety of medical devices and systems can easily cause integration or interoperability problems. The development of interface standards that will effectively combine different devices will contribute to the creation of coherent and coherent monitoring systems.
- Ethical aspects: When using IoT technologies in the medical field, several ethical issues can be distinguished, such as maintaining patient privacy, proper use of the collected data, and understanding the effectiveness and possible limitations of monitoring systems.
- Reliability and availability: In healthcare systems, reliability and continuity of operation are critical aspects. Restoring systems during emergency and unforeseen situations, such as equipment or network failure, requires high technical training.
- Attracting medical personnel: The introduction of new technologies usually requires a rethinking of the role and responsibilities of medical personnel. Interaction with doctors and other specialists is needed to effectively implement systems and maximize their potential.

Getting answers to these challenges is an important step in the development and implementation of IoT technology-based health monitoring systems, and addressing them will determine success in improving the quality of health care delivery and patient care. Needed aspects for the medical field To ensure the success of the built monitoring system, it is necessary to take into account important aspects that are guided by the following factors. First, we need to develop an integrated architecture, because the system must have a flexible and scalable architecture that allows you to effectively integrate a variety of medical devices and provide a continuous flow of data [3]. Another important step will be to ensure the security and confidentiality of information, namely: the introduction of modern encryption and authentication methods to prevent unauthorized access. The creation of communication standards and protocols will facilitate the integration of different medical devices and ensure their interoperability. In the end, after the above steps, training and training of users (including medical personnel and patients) for more effective use of the system can take place, using the example of pieces of training and lectures, or in an online format in the form of an article or video-acquaintance with the system. Analysis of existing analogs of health monitoring in Ukraine

The analysis of analogues of health monitoring and patient care systems based on medical IoT technologies revealed a variety of approaches and functionality on the market. The advantages and limitations of each system, the possibility of integrations, as well as the level of security and privacy were investigated. The findings will provide a basis for further improvement and adaptation of the developed system of monitoring and patient care based on IoT technologies. Avoiding combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally [4].

- Medical Information System "MedAir" is a comprehensive information solution aimed at improving the management and delivery of medical services. This system combines the functions of an electronic medical record, planning patient appointments, accounting for medical procedures, analyzing medical data, and ensuring interaction between medical personnel. MedAir is aimed at automating routine tasks, which allows medical personnel to focus on providing quality medical care. The system supports the efficient exchange of information between hospitals, polyclinics, and laboratories, facilitating the integration of various aspects of health care.
- Withings Health Solutions offers an innovative approach to monitoring health and improving it using advanced IoT technologies. The system reveals ample opportunities in the field of health and medicine. It allows not only to effectively monitor the physical condition of users but also to provide valuable data to medical professionals to support decision-making.
- The system provides an opportunity to become familiar with the health status of their patients thanks to accurate individually oriented data from Withings. The dashboard of this system will provide its users with a complete overview of patient health indicators, allowing doctors to enter and analyze all the necessary details regarding their condition.
- The MedM RPM Platform software solution is a fairly innovative example of a convenient and useful application for monitoring the blood pressure, blood sugar, weight, and body temperature of a patient doctor. This application allows you to collect data from more than 700 devices portable devices, and IoT sensors. The main difference and great advantage are that it is not limited to a specific hosting or platform, and can be used in emergency situations by medical specialists, sensor or device manufacturers, and system integrators. Recently, there has been significant development of MedM - authentication, and integration with Health Sync have been added. Evidence suggests that software is constantly being improved to provide more accurate results and open connectivity to the healthcare ecosystem.

Figure 1 shows the process of data transfer, first, there is a connection of various types of medical sensors to a person (there is an interaction and data reading), and - the data is transferred to the hub for automatic collection and transmission of state data and, in parallel with this, you can see the "Data reading" window in the application of your device (phone, laptop or tablet), data is transferred to the

server or the cloud, and only then goes to the portal for patients, doctors. Along with the transfer to the portal, the EHR/EMR integration APIs occur.

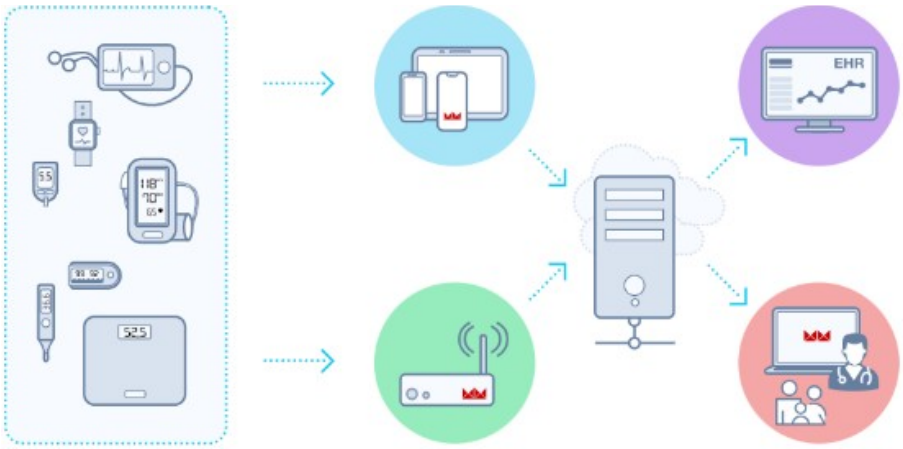


**Figure 1:** Data transfer process in a health monitoring and patient care system.

The article [5] examines the possibility of using radio frequency identification (RFID) systems in combination with the Internet of Things (IoT) to optimize the delivery of medical care in military conflicts. The authors explore how RFID tags can be integrated into medical protocols for:

- Rapid casualty identification: Accurate and immediate identification of patients, including their medical history and current condition.
- Patient movement tracking: Monitoring the movement of wounded from the battlefield to medical facilities.
- Medical resource management: Optimizing the distribution of medical resources and drugs.
- Improving the coordination of medical teams: Ensuring effective communication and coordination of medical personnel.

The goal of the study is to demonstrate how RFID technologies can improve the efficiency of medical care in extreme conditions, reduce response times and improve the chances of survival of victims. The authors suggest that the results of the study will help create new standards for the organization of medical care in conflict zones and other emergency situations [12]. RFID systems can become an integral part of a comprehensive solution to ensure medical safety and save lives.

The article [6] describes a motion detection and control system for fitness exercises based on the Internet of Things that can be relevant for monitoring the health of people involved in sports. Using such a system as a mobile application allows the user to receive an assessment of the technique of performing exercises, demonstrating them in front of the smartphone camera, as well as recommendations that can help improve the exercise performance and monitor health indicators. As a result, the effectiveness of exercises will increase and the health condition will improve. The Internet of Things system configures business rules and scenarios, the necessary artifacts for users, the exercises they perform, errors and deviations made when performing exercises, and analyzes video files. The Internet of Things solution is built using a neural network that can recognize the user's body posture during an exercise based on a video file shot on his or her own smartphone camera. Artificial intelligence, using mathematical calculations, will return the result of the video file analysis, where the user will be able to see their shortcomings in performing a certain task and receive recommendations. A special factor in pattern recognition is the individual initial anthropometric data of each user, which must be taken into account during the analysis. The use of an IoT system for monitoring and controlling medical indicators for performing fitness exercises will have a positive impact on the trend of a healthy lifestyle in the modern world without the involvement of personal fitness trainers.

The development of the IoT in healthcare opens up new opportunities to improve the quality of medical care. However, the widespread adoption of intelligent medical devices and their connection to wireless networks pose significant risks to the security of patient data. Threats such as unauthorized access, leakage of confidential information, and cyberattacks require a comprehensive approach to ensuring security in the medical field, as discussed in the article [7]. This study proposes the use of 5G security standards to protect data in IoT-based intelligent healthcare systems. By analyzing various types of threats (data forgery, unauthorized access, denial of service, etc.), the researchers identified the most vulnerable points in such systems. Key findings of the study:

- The need for reliable protection of patient data: The introduction of strict security measures is a critical factor in maintaining the confidentiality of medical information and patient trust.
- Application of 5G standards: 5G security standards offer effective data protection mechanisms such as strong encryption and device authentication.
- A Comprehensive Approach to Security: To ensure the security of intelligent healthcare systems, it is necessary to combine various security measures, including hardware, software, and organizational ones.
- The proposed approach allows:
- Reduce the risk of patient data leakage: By using reliable encryption and authentication protocols.
- Increase the resilience of systems to cyber threats: By using multi-factor authentication and anomaly detection.
- Ensure secure interaction between medical devices: By creating reliable and secure data transmission networks.

The results of the study demonstrate that the application of 5G security standards in combination with other security measures can significantly improve the security of intelligent healthcare systems and create a reliable foundation for the development of telemedicine and other innovative medical services. This study makes a significant contribution to the development of safe and reliable intelligent healthcare systems, which is an important step towards personalized medicine and improving the quality of life of patients.

## 3. Data and methods

To achieve high efficiency of this study, specific data and methods should be used that will help collect data in the resulting component. So, let's take a closer look at the list of data and methods that we consider in this article.

The data for processing and research will be collected using the following sensors: temperature sensor, blood pressure sensor, sensor for measuring neural activity of the brain and ECG machine. The sensors will be placed on the patient's body and will collect data on his well-being. The data will be transmitted to the patient's smartphone, where it will be visualized, analyzed and processed.

Speaking about the formula for calculating the heart rate, you can use the most common, but at the same time the most accurate. The rhythmic dance of the electrocardiogram (ECG) contains the key to deciphering this biological code [14]. One of the fundamental methods is the calculation of the heart rate (HR) by the R-R intervals of the ECG. Representing the time between successive depolarizations of the ventricles, these intervals open a window into the heart rate. The formula for deriving heart rate from these intervals is elegantly simple, yet profound in its implications:

$$HR = \frac{60}{RR} \tag{1}$$

Here, HR signifies heart rate in beats per minute (bpm), This metric represents the frequency at which the heart contracts and relaxes, reflecting the overall cardiac performance and physiological

state of the individual. While RR denotes the duration of the R-R interval in seconds. The R wave corresponds to the peak of the QRS complex, marking the onset of ventricular depolarization, which initiates the contraction of the heart's main pumping chambers, the ventricles. The numerator, 60, represents the number of seconds in a minute, converting the RR interval from seconds to minutes. By dividing 60 by the RR interval, expressed in seconds, we obtain the number of heartbeats occurring within one minute. This formula transforms the subtle language of cardiac electrical activity into a tangible metric, facilitating real-time monitoring and diagnosis. Alongside this cornerstone formula, myriad other equations and methodologies harmonize to compose the symphony of modern healthcare technology, each contributing its unique verse to the grand narrative of patient care and well-being. The following methods were used for the study:

- Experimental method: a prototype device will be developed that will include all the necessary sensors. The device will be tested on a group of volunteers who will wear it for a certain time.
- Data analysis method: the data obtained will be analyzed and processed using statistical methods. This will assess the effectiveness of the device and its potential for use in healthcare.
- Survey method: Surveys will be conducted among volunteers who will wear the device. This will allow you to get their feedback on the device and its usability.
- Machine learning classification and prediction method: Machine learning will be used to classify different patient conditions based on the data obtained. For example, determining cardiac arrhythmias using ECG signals or identifying abnormalities in brain activity based on signals from a neuronal sensor.

To understand how it works better, let's see how the system uses each element in Figure 2.

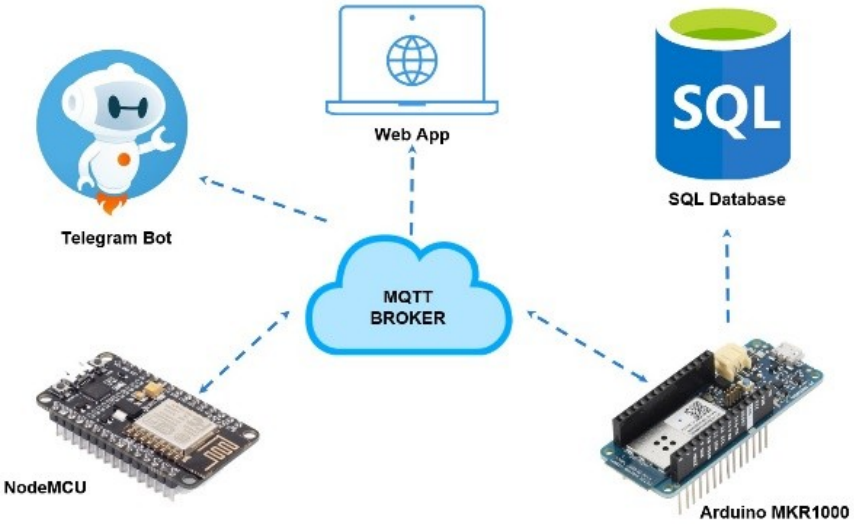


**Figure 2:** Elements of the patient health monitoring and care system.

This system uses a Telegram bot to control an Arduino MKR1000 via MQTT. The bot sends messages to the MKR1000, which then performs actions based on the messages. The MKR1000 can also send messages to the bot, which can then be used to update the web app. The SQL database is used to store data from the MKR1000.

Consider the proposed patient monitoring system diagram shown in Figure 3, using sensors and IoT devices that will read information from the human body, analyze and process it, transmitting visualized results to the device (phone) for easier perception by the user (doctor or patient). This system consists of sensors that measure temperature, blood pressure and neural activity in the brain, as well as an ECG device.

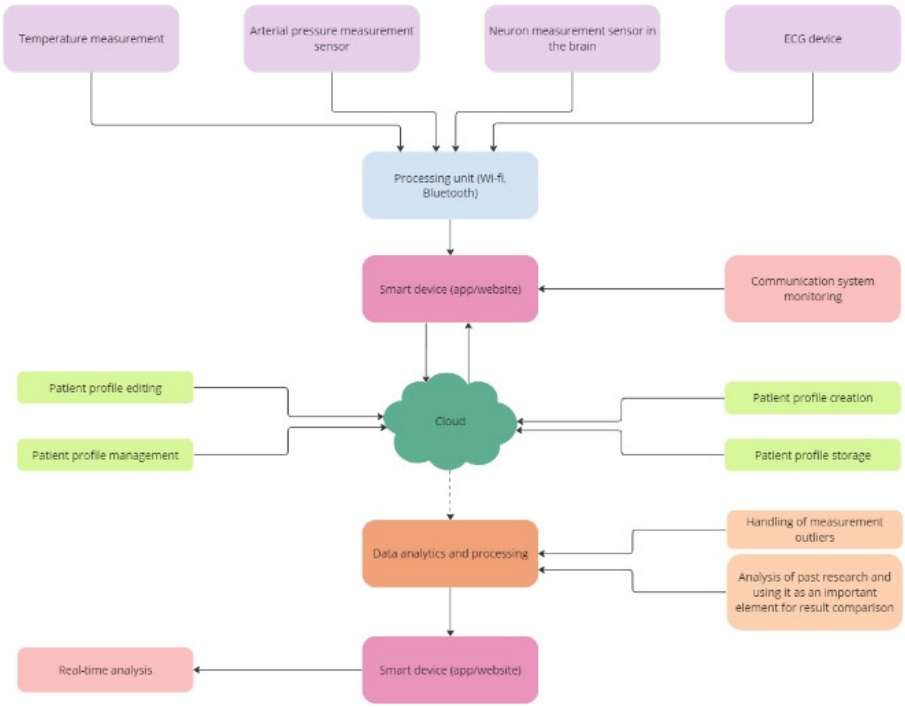


**Figure 3:** Structural diagram of the patient monitoring system.

Comprehensive data analysis encompasses various types of information, including photographs, such as X-rays, MRIs, and slides, as well as audio files with corresponding transcripts and text notes utilizing natural language processing (NLP). For instance, photographs can be utilized to analyze skin for signs of disease or to assess the condition of injuries. Moreover, image analysis can be employed to detect pathological changes in medical images, such as lung X-rays for identifying lesions or brain MRIs for detecting abnormalities or tumors. Centers like CMS [8] utilize payment data to enhance the quality of healthcare, while hospitals employ predictive artificial intelligence to identify high-risk patients for readmission. However, on this path, challenges such as issues with confidentiality, ethics, and legal matters arise.

In the realm of healthcare, big data analytics plays a crucial role in storing, analyzing, and managing vast amounts of electronic health data. Unlike traditional methods, the sheer size and complexity of this data make it challenging to handle using conventional software and hardware. Wearable devices, such as biometric sensors for monitoring blood pressure, heart rate, or body temperature, generate data at a much faster rate than older devices. This real-time data processing enables rapid analysis and insights. Big data analytics in healthcare provides a comprehensive understanding through detailed analysis [9], offering significant potential to tackle hidden issues and reduce processing time and costs associated with handling massive datasets.

The use of neural networks to predict environmental or medical processes has attracted considerable attention in recent years. In a study by [13], neural networks can effectively model complex relationships between medical factors and predict outcomes, providing more accurate outcome prediction for decision-making.

## 4. Results and analysis

The developed system consists of sensors, gateway, data storage, analytical module and applications for doctors and patients. Sensors collect data about the patient's health, such as temperature, blood pressure, and sensors installed inside the hospital, etc. This data is transferred to the gateway, which is responsible for transferring it to the data warehouse. The analytical module analyzes the data and provides recommendations for patient treatment. The application for doctors allows them to monitor the health status of patients and prescribe them treatment. The application for patients allows them to view data about their health and receive treatment recommendations.

The data path is as follows: first, the devices collect data about the patient's health. Data from the devices is sent to the gateway. The gateway transfers data to cloud storage. From the cloud storage, the data goes to the data warehouse. Data from the data warehouse is fed to the streaming data processor. A data streamer feeds data into a data lake. From the data lake, data is fed to the data analytics module. The data analytics module feeds the data to a machine learning expert. A machine learning expert feeds the data into a doctor's app. The application for the doctor transfers the data to the database. Data is sent from the database to the application for the patient.

To understand the likely scenarios of using the monitoring system, consider the scenario of the implementation of this system at the first stage - the use and configuration of devices by the user Figure 4.

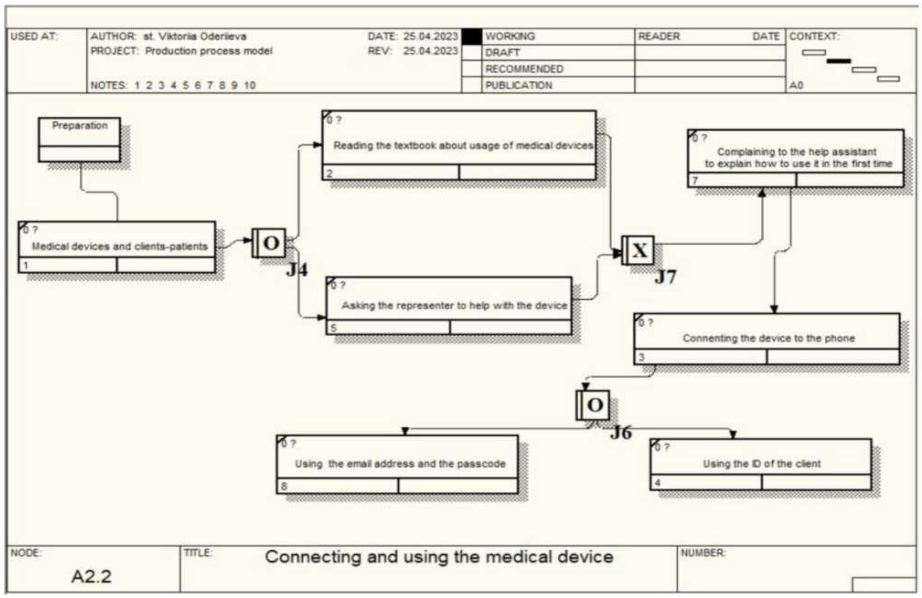


**Figure 4:** The project of the scenario of the start of use and configuration of devices by the user.

1. Registration of a new patient:a user (patient or healthcare professional) launches a health monitoring application on their device:he selects the option "New patient registration";t he system asks for basic personal data, such as name, surname, date of birth, etc;the patient enters the necessary data, after which a unique patient identifier is generated;information is stored in the system for future use.
2. Health monitoring: the patient securely fixes the health monitoring device on his body; device sensors constantly measure heart rate and ambient temperature; received data is automatically transferred to the IoT platform; the patient's health is monitored in real time.
3. Obtaining data by the doctor: the doctor enters the system using his account; he selects the patient whose statistics he wants to view; the system displays pulse and temperature dynamics, which the doctor can analyze; the doctor can make recommendations or prescribe treatment based on the collected data.
4. Reminder to the patient: the system can send reminders to the patient about medication or procedures; this can be done through a mobile application or email messages; the patient provides timely treatment and provides up-to-date data for the doctor's analysis.
5. Access to patient history: the patient or doctor can view the history of heart rate and temperature measurements; the system displays data in chronological order and can filter them by various parameters (for example, by date).

After considering the scenarios, we move on to collecting numerical data from sensors and research results. Data collected from patient-mounted sensors include heart rate, body temperature, room humidity, noise level, and lighting brightness, as listed in Table 1.

**Table 1**
The measured results of testing the study parameters at a certain point in time

| Heart Rate (bmp) | Temperature (C) | Humidity ($g/m^3$) | Sound (dB) | Light (lx) |
|---|---|---|---|---|
| 64 | 37,1 | 15 | 56 | 109 |
| 84 | 36,3 | 47 | 60 | 171 |
| 95 | 36,8 | 95 | 20 | 28 |
| 97 | 36,9 | 78 | 48 | 154 |
| 64 | 36,8 | 58 | 42 | 196 |
| 78 | 36,8 | 16 | 30 | 32 |
| 100 | 36,1 | 40 | 59 | 60 |
| 97 | 37,5 | 42 | 31 | 89 |
| 60 | 36,9 | 10 | 22 | 59 |
| 66 | 36,2 | 56 | 22 | 21 |
| 110 | 36,1 | 41 | 29 | 21 |
| 82 | 37,0 | 21 | 40 | 107 |
| 107 | 36,7 | 46 | 19 | 119 |
| 57 | 36,4 | 52 | 47 | 90 |
| 102 | 36,8 | 17 | 33 | 164 |
| 79 | 36,5 | 27 | 13 | 173 |
| 55 | 36,2 | 39 | 35 | 192 |

Let's examine the results of testing 20 patients who were added to the database of the developed system. We will present the research results in the form of graphs showing body temperature and heart rate per minute. The testing was conducted throughout the day, and all data were collected within this period for all patients. The red line on the graphs indicates the threshold values [10].

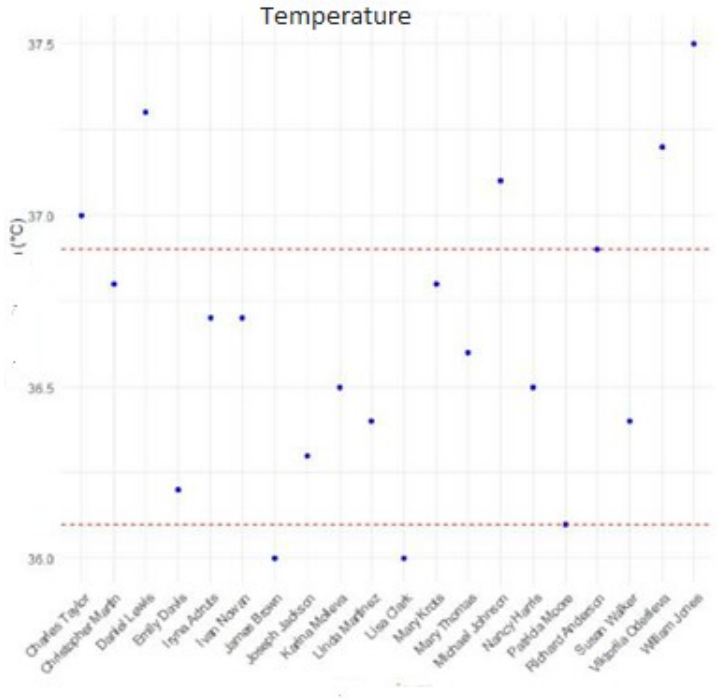


**Figure 5:** Patient's temperature chart.

As a result of the graph Figure 5, we see that some patients (C. Taylor, D. Lewis, M. Johnson, V. Oderiieva, W. Jones) have high temperatures, while others (J. Brown, L. Clark) have temperatures that are too low, which sets their values apart from those indicated by the red line.

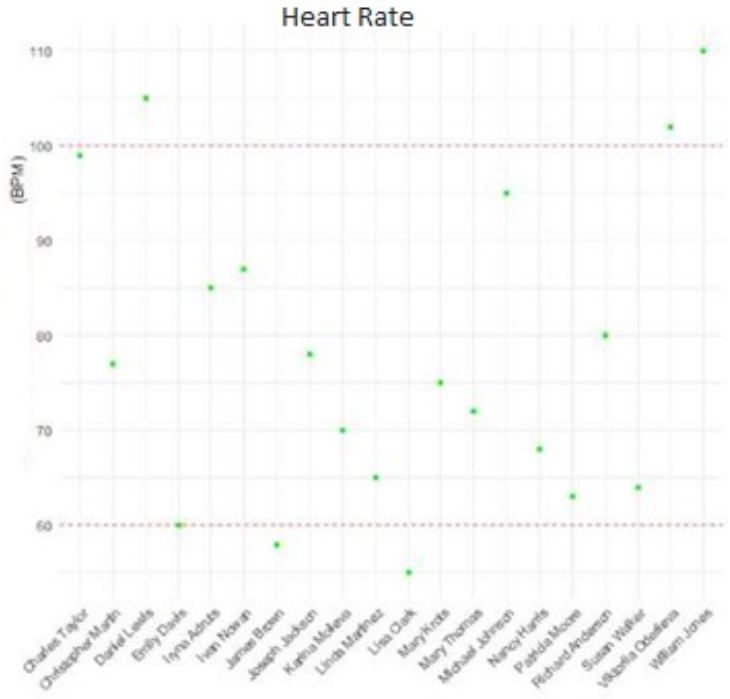


**Figure 6:** Patient's heart rate chart.

As a result of the graph Figure 6 we see that some patients (D. Lewis, V. Oderiieva, W. Jones) have too high a number of heart beats per minute, also some of them (J. Brown, L. Clark) are small, which distinguishes their values, indicated by the red line.

Testing of the developed health monitoring and patient care application has confirmed its correct operation. The system utilizes an Arduino microcontroller for collecting and transmitting data from

sensors to the server. The Arduino is equipped with sensors for temperature, humidity, sound, and light, which gather environmental condition data. After collecting the data, the Arduino sends it to the server. This distributed solution ensures the reliable and efficient operation of the health monitoring system, providing accurate data collection and processing, and its subsequent display on the web interface for users and medical staff.

Following the study [11], data analysis enables researchers to identify patterns and trends (for example, examining whether there is a link between physical activity levels and cardiovascular disease risk), test hypotheses (such as whether new technology is effective in preventing dementia), assess intervention effectiveness (such as evaluating whether a new preventive program improves cognitive abilities among adolescents), and identify risk and protective factors (such as determining if stress is a risk factor for heart attacks).

With this approach, researchers gain a deeper understanding of the impact of various factors on health and can more accurately predict the possible risks or benefits of certain interventions. This helps in the development of more effective prevention and treatment strategies, as well as in improving the general quality of life of the population.

The scientific novelty of the study lies in the proposal of an innovative hybrid architecture for patient monitoring that combines cloud technologies and local data processing to improve the speed and reliability of the system. This solution ensures fast local processing of critical data, minimizing delays, while large volumes of data and long-term analysis results are transferred to the cloud for storage and further analysis. One aspect of the study is the protection of patient data, implemented using dynamic adaptation mechanisms of the system, which allows it to effectively respond to changes in regulatory requirements and operating conditions.

## 5. Conclusion

The study shows that the integration of IoT technologies in the medical field can significantly improve the safety of patients and the protection of their data, as well as facilitate more effective monitoring and care. With the ability to collect, analyze and share data in real time, these systems can significantly improve the quality of healthcare services, improve the efficiency of healthcare and help healthcare professionals make informed decisions for early disease detection. However, for the successful implementation of such systems, it is necessary to take into account issues of data confidentiality, standardization, ethical aspects, system reliability and training of medical personnel.

The innovative hybrid architecture proposed in this paper, which combines local data processing and cloud technologies, demonstrates significant potential for improving patient health monitoring systems. By quickly processing critical information locally and transferring long-term data to the cloud for analysis, this system provides increased reliability and responsiveness.

This study provides valuable insights into the development of IoT-based health monitoring systems and highlights the importance of further progress in this field to unlock the full potential of IoT in healthcare.

## Declaration on Generative AI

The authors have not employed any Generative AI tools.

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