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A SOFTWARE SOLUTION FOR REAL-TIME COLLECTION AND PROCESSING OF MEDICAL DATA FOR EPILEPSY PATIENTS

The rapid development of computer technologies has significantly impacted various sectors, including healthcare. The ability to collect, process, and visualize medical data in real time is becoming increasingly important, especially for managing chronic conditions such as epilepsy. This paper presents a web-based application designed for real-time monitoring of health indicators, enabling healthcare professionals to track patient data efficiently. The system automates the process of collecting data from fitness trackers, transmitting it via a mobile device to a server, and visualizing it in a web application. Its architecture employs a thin-client model with Node.js for backend logic and React.js for the user interface, ensuring scalability and responsiveness. Key features include real-time data visualization, historical trend analysis, and the ability to export health metrics for further examination. The system architecture follows a modular approach, with a clear separation of concerns between the client-side, server-side, and database components. MongoDB is used as the database provider, offering flexibility in handling large volumes of health data. The system underwent extensive testing in two stages. During the first stage, real-world data collection demonstrated an average data transmission time of less than 112 ms, ensuring compliance with real-time requirements. In the second stage, stress testing with up to 100 simultaneous users showed an average server response time of 145.8 ms and a 95th percentile response time of 167.1 ms. These results confirm the system’s robustness and suitability for deployment in medical facilities. Future work aims to enhance the system by incorporating advanced real-time alert mechanisms and additional health metrics, such as oxygen saturation and activity levels, to provide comprehensive monitoring. The presented solution showcases the potential of integrating modern web technologies into healthcare, contributing to improved patient outcomes and more efficient workflows for medical professionals.

Keywords: real-time monitoring, medical data processing, automation, health indicators, software, system architecture, development technologies.

Introduction. The development of contemporary society is characterized by the substantial impact of computer technologies, which have found application across all areas of human activity. Information technologies facilitate the dissemination of information within society, thereby forming a global information space. Consequently, they have become a crucial driving force in the development of the global economy and other spheres of human activity. It is challenging to identify sectors where information technologies are not currently utilized. The primary domains of their implementation include construction, mechanical engineering, education, banking, and, notably, medicine. In numerous medical studies, the use of computers and specialized software is indispensable. In today’s context, proficiency in computer use is becoming one of the most vital professional skills for medical workers. Data collection and analysis methods, particularly in the realm of intellectual analysis, although relatively young among computer sciences, are gaining increasing relevance. This trend is driven by the growing volume of information and the enhancement of methods for its collection and processing. The relevance of this work lies in the ongoing development of the field of medical data collection and processing, especially in real-time scenarios.

Epilepsy is a highly significant issue within modern neurology and psychiatry. According to the World Health Organization (WHO), the lack of comprehensive epidemiological data on epilepsy across various countries results in notable deficiencies in the organization of medical care. Seizures associated with epilepsy may be attributed to brain trauma or hereditary factors; however, in many cases, the etiology remains unknown. Individuals with epilepsy frequently exhibit multiple seizure types and may also suffer from other neurological disorders. Recurrent epileptic seizures are often exacerbated by specific external and internal factors. For instance, it is well-documented that seizures can be triggered by sensory stimuli such as exposure to bright, flashing lights or cardiovascular stress. The management of these seizures presents significant challenges, and preventing their consequences without the employment of specialized (auxiliary, invasive) monitoring devices is virtually unfeasible.

Fitness trackers represent a cornerstone of trends within the field of healthcare web applications. The synchronization of these devices with mobile platforms and their integration into personalized dashboards significantly aids in the collection of patient data. These trackers facilitate the monitoring of variables such as heart rate, blood glucose levels, among others. Notably, 49% of the North American population utilizes smart devices, highlighting the remarkable proliferation of such trends within healthcare.

The primary objective of this work is to enhance the existing approach to data collection from fitness trackers, focusing on the analysis and presentation of final data to the physician of a specific patient.

Analysis of recent research and publications. The creation and maintenance of modern computer databases concerning patients' health status, disease progression, laboratory tests, and treatments no longer pose significant challenges for information technology specialists. However, a more complex issue is the lack of effective information technology for the processing and analysis of medical data, which would enable medical analysts to identify patterns and correlations between various medical indicators that are not immediately apparent. This, in turn, would enhance the efficacy of treatment by selecting therapy intensity that is adequate to the patient's condition, assessed based on a combination of identified risk factors [1]. The determination of specific features in the processing and analysis of statistical data from medical research, as well as the improvement of information technology that accounts for these features, remains critical. The application of traditional statistical methods in medical data analysis has a long history [2, 3]. Despite their significant utility and importance, it is essential to acknowledge their limitations concerning medical data. The specific nature of medical data used in causal relationship analysis does not allow for the correct application of many existing mathematical methods currently used for data processing and analysis. The primary reason for this is that classical statistical methods work well for testing pre-formulated hypotheses, which is rarely achievable in medical practice. Additionally, various limitations of statistical methods related to specific distribution laws of samples, data types, sample sizes, and other factors must be noted.

Methods of data mining developed in the late 1990s, such as neural networks of various types, fuzzy logic, genetic algorithms, etc., can address the limitations of statistical methods. Examples of versatile software systems based on these methods include Intelligent Miner (USA), Knowledge Studio (Canada), SAS (USA), MineSet (USA), Clementine (UK), ST: Neural Networks, among others. However, this versatility becomes a drawback in medical applications, as it does not account for all the specific characteristics of medical data. These characteristics include extremely large data volumes, the selection of the most informative features, the development of decision rules considering risks, and the evaluation of the validity of information.

Medical information systems (MIS) are employed to automate tasks at each stage of the diagnostic and therapeutic process. The creation of a medical information system serves several purposes:

- improving the quality of work of healthcare workers and institutions by organizing the comprehensive processing of medical information that aligns with the level of utilized technical means, including the enhancement of management and planning processes;
- facilitating the labor of healthcare workers by eliminating labor-intensive and inefficient manual processes of medical data processing and analysis;
- ensuring effective information exchange with other information systems.

Based on their purpose, MIS are classified into:

- systems whose primary function is data accumulation (automated data and/or information processing systems, automated information and reference systems);
- diagnostic and consultation systems;
- systems that provide medical services.

In Ukraine, public healthcare institutions can choose any medical information system provided that it has successfully passed testing, is connected to the central database of the Electronic Health System (EHS), has the necessary functionality, and meets the technical specifications defined by the Ministry of Health. Nowadays, medical information systems are a crucial means of establishing interaction between healthcare facilities and patients. Recently, the demand for acquiring information systems in hospitals has increased more than ever, leading to heightened competition among developers of medical information systems. Therefore, to compete with other MIS, developers must improve their systems or create them with a level of functionality that allows healthcare institutions to provide a better level of service to their patients [4].

Let us consider the most popular medical information systems operating in Ukraine.

"HELSI" is a modern, convenient, and reliable electronic medical system designed for both public and private medical institutions, doctors, and patients. The system features a data center certified by the State Service for Special Communication and Information Protection of Ukraine (SSSCIP) for comprehensive information security (CSIS).

The system automates the majority of processes within healthcare institutions, including the work of doctors and registration departments. It maintains electronic medical records for patients and manages doctors' schedules.

Additionally, the system ensures the accounting of payments and medications, the generation of statistics and reports, and includes a form constructor [5].

Among the advantages, it can be noted that the system automates numerous processes, records user actions, and sets access rights while maintaining data confidentiality.

However, the system has a very low rating in online surveys, with most negative reviews indicating that the system does not effectively interact with healthcare institutions. Appointments made in the system do not correspond to those in the hospital. The MIS also faces issues with patient registration, user interface convenience, and overall design.

The company "eLife" has been operating in the field of process automation for nine years. This company has developed a medical information system called "Medeir". Among its advantages, the system is noted for planning interactions with patients, optimizing the operations of healthcare institutions, and easily scaling data management. The MIS promises high reliability, optimization of staff working time, and cost optimization [6]. Reviews of the system are available only on its own website, making it difficult to evaluate its overall rating. By examining the system's images, the main disadvantages identified include inconvenient, complex, and outdated interface, making it challenging to assess the functionality in detail at this stage.

"Medstar Solutions" is a medical information system that automates medical processes, ensuring comfortable patient care. It is the first cloud-based MIS in Ukraine with a state security certificate for the protection of personal and medical data. The system has been operating in the market for nearly eight years, improving the patient care process [7]. The MIS has a decent rating, with approximately half of the reviews on social media being positive. Most negative reviews focus on the slow processing of requests and the creation of episodes, diagnoses, etc.

"Doctor Eleks" is the medical information system has been providing services for 17 years and has extensive experience working with over 1,400 healthcare facilities. The system automates all business processes within institutions and ensures the creation of reports based on the data entered into the system and their analysis. Among the advantages, it is noted that the MIS, due to its extensive experience in this field, has a better and more detailed understanding of all healthcare facility processes. Additionally, the MIS can store data both in cloud storage and on servers, ensuring data security in accordance with the comprehensive information security system (CSIS) [8]. Among the disadvantages are slow request processing, slow creation of medical leave documents, the presence of errors, a non-user-friendly interface, and unsatisfactory customer support service.

"Health 24" allows any patient to quickly make an appointment or consultation with any doctor without spending much time. To receive quality medical services, there is no need to stand in long queues at hospitals or clinics. The comprehensive service provides online doctor searches, selection of the best clinics, online registration, access to electronic medical records, and price comparison for services [9]. The majority of reviews about this product are positive, making this MIS the highest-rated among those listed. Customers highlight the convenience and clarity of the program, well-organized document flow, and the implementation of standardization in record-keeping. However, it faces challenges in working with multidisciplinary healthcare institutions.

Let us consider the most popular medical information systems operating abroad. England has developed systems such as NHS Director, which allows for advice and consultation directly from the National Health Service. The National Center for Emergency Medical Services performs numerous tasks related to patient treatment at home. However, the issue is that the work of these services is not integrated with the activities of other health services and the health management system throughout the United Kingdom.

The Danish automation of the healthcare system serves as an exemplary model. In 1994, Denmark established a healthcare network system, which was later portalized in 2004. Currently, Health Net is an essential resource for citizens, professionals, and general practitioners, facilitating home treatment. The system operates on three levels: national (National Health Board), primary (nursing homes, pharmacies), and secondary (hospitals). All levels are integrated into a unified portal infrastructure, enabling participants at any level to access all types of information.

The implementation of a hospital automation information system in Austria is exemplified by the project carried out at the Vienna General Hospital. One of the operational principles of this institution is the integration of therapeutic, educational, and research activities, necessitating the implementation of an information system that supports clinical processes as well as research and teaching activities, serving approximately 8,000 users. Consequently, the hospital introduced electronic medical records, a patient administration module, a content management system for the general clinical repository (including medical device data, multimedia data, scanned documents, videos), a planning and documentation module for operations, a data migration system, integration of existing subsystems, a clinical drug trial system, and a research integration platform (to combine clinical data and research data, such as phenotype and genotype) [10].

Electronic Medical System in Canada. The Ministry of Health of the Canadian province of Alberta decided to distribute medical information through a secure network to ensure informed decision-making by healthcare professionals regarding the provision of medical care. To implement this project, an integrated medical system (Wellnet) was developed. This system supports decision-making and ensures the availability of accurate and up-to-date information on population health and current medication information (including evidence-based medicine).

It is evident that the primary task of information and communication technologies in healthcare is to ensure patient safety. Based on this premise, healthcare informatization in European Commonwealth countries follows the path of creating decision support systems for physicians, establishing a new informational environment for their activities. This environment allows access to professional information resources (information and reference systems and thematic forums) and navigation between professional associations and recognized experts. It creates a continuous education environment for physicians through regular monitoring of the latest achievements in medicine and pharmacy. Computerized physician order entry systems can reduce medication errors by nearly 80% and adverse side effects by 55%. In some countries, physicians cannot obtain a license to practice without appropriate knowledge in information technology (e.g., in the Netherlands) [10].

Experts, based on many years of experience in creating and using medical information systems for working with visual images obtained from radiological, tomographic, mammographic, ultrasound, and other studies, assert that the benefits of automating instrumental diagnostics departments are evident. This automation significantly expands the professional capabilities of physicians across various specialties.

The automation of clinical laboratory studies is of great importance in improving the quality of medical care. It significantly enhances laboratory productivity and creates a unified database of research results, which, when integrated with the medical information system of healthcare facilities, becomes immediately accessible to all necessary medical professionals. According to most experts, the most adequate indicator of the system's organizational efficiency is the reduction of medical personnel's working time spent on preparing reporting documentation. The preparation of a large number of various documents and reports has become a bottleneck in the operation of healthcare facilities, which inevitably impacts the quality of treatment. Therefore, the benefit of automation is currently linked to solving this issue. As the MIS continues to develop, this aspect of work can be completely removed from the responsibilities of medical personnel. The system should automatically retrieve all necessary information from medical documentation and transmit it to specialists responsible for report preparation. The implementation of an MIS can be considered successful if, after a period of time – which may span months or years—practically all medical personnel at the healthcare facility are using the system, at which point the question of quantitatively evaluating efficiency arises [10].

Proposed solutions. The article examines a developed web application that allows physicians to monitor patient health indicators in real-time, thereby automating the data monitoring process, as well as the overall data control process through the use of a dashboard. The software product can be utilized in various medical institutions. The web application includes patient search, patient information, and infographics. The primary user of the software is the physician.

We have a device in the form of a fitness tracker that transmits user data via Bluetooth protocol to an Android operating system device, storing this data in local storage. There is also a server entity that receives real-time data from the mobile device and transmits this data to the web application through a WebSocket connection. The data flow diagram is shown in fig. 1.

Functional requirements for the software:

- the doctor has the ability to log into the system;
- has the ability to log out of the system;
- the doctor has the ability to create a new patient profile;
- the doctor has the ability to interact with patient data;
- has the ability to edit patient data;
- has the ability to delete patient data from the system;
- the doctor has the ability to view patient health indicators;
- display of indicators for a specific time;

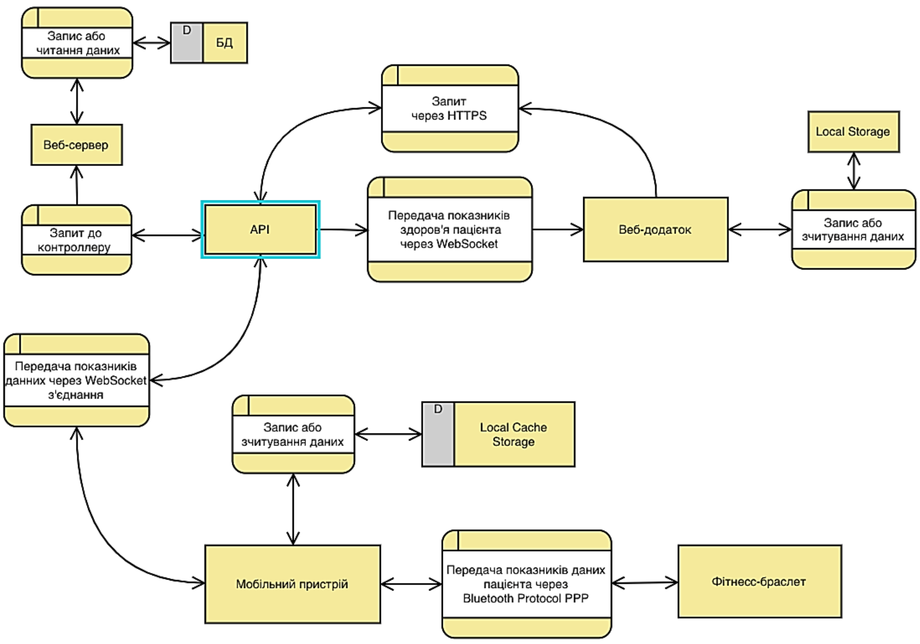

Fig. 1. Data Flow Diagram for proposed information system

- real-time display of indicators;
- real-time display of charts;
- display of indicators for the entire monitoring period;
- export of health indicator data for the entire period;
- export of health indicator data for a specific period.

The chosen architecture is a “thin client,” with information processing tasks performed on the server [11]. The deployment diagram is shown in fig. 2. Development technologies include NodeJS as the web application framework for user interaction with the website. The programming language is JavaScript (JS), with the React.JS library used for creating user interfaces. The platform utilized is Node.js. HTML5 is used for the external interface, and CSS3 is used for web page design.

The main components in the diagram are:

- “UserClient” – a computer or laptop used by a doctor or administrator.
- “Web Browser” – a browser installed on the computer or laptop used by the doctor or administrator.
- “Engine V8” – the browser engine for compiling and translating JavaScript code.
- “React.JS” – a component library for project initialization.
- “Client-Side-App” – a component for server-side rendering of application pages.
- “web-socket-client.js” – a component for initializing WebSocket connections.
- “webpack.js” – a component library for optimizing the project bundle during compilation.
- “WebServer/LocalServer” – a device or machine leased for deployment.
- “NodeJS” – a framework component for creating the server-side application.
- “ExpressJS Application” – a component library for additional functionality and handling application services.

For data management, we have chosen to utilize MongoDB, an open-source NoSQL database that offers flexible data modeling without the need for predefined table schemas. Its ability to efficiently handle large volumes of diverse medical data makes it particularly suitable for healthcare applications [12,13]. The data model is illustrated in fig. 3.

As a result of developing the software system, all necessary functionality was implemented, including the user interface and data retrieval from the mobile device.

The system was tested in two stages. In the first stage, data collection and analysis were conducted under real conditions.

A sample of the collected data, shown in fig. 4, includes key parameters such as pulse rate, number of steps, calories burned at specific moments, and an indicator of the presence of an episode based on sharp deviations in pulse rate from the patient’s historical data. System logs were also analyzed, revealing that the average data transmission time from the fitness tracker to the web application was less than 112 ms, meeting the best practice ranges of patient

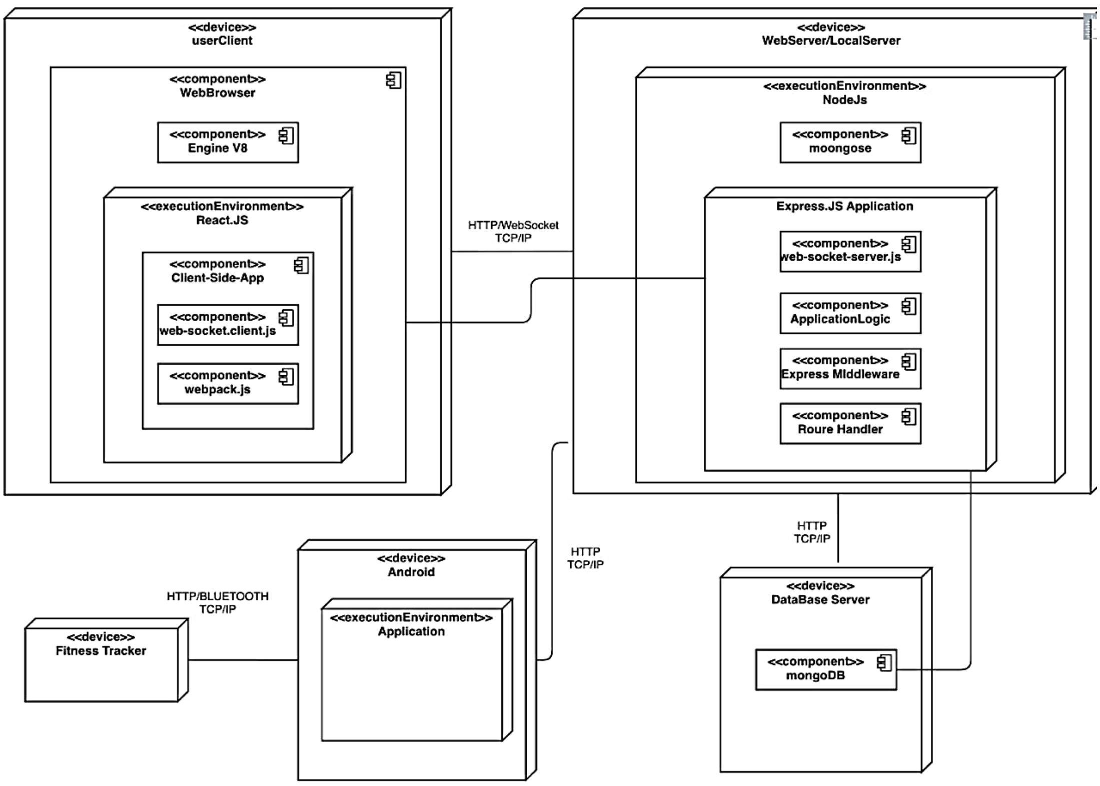

Fig. 2. Deployment Diagram for proposed system

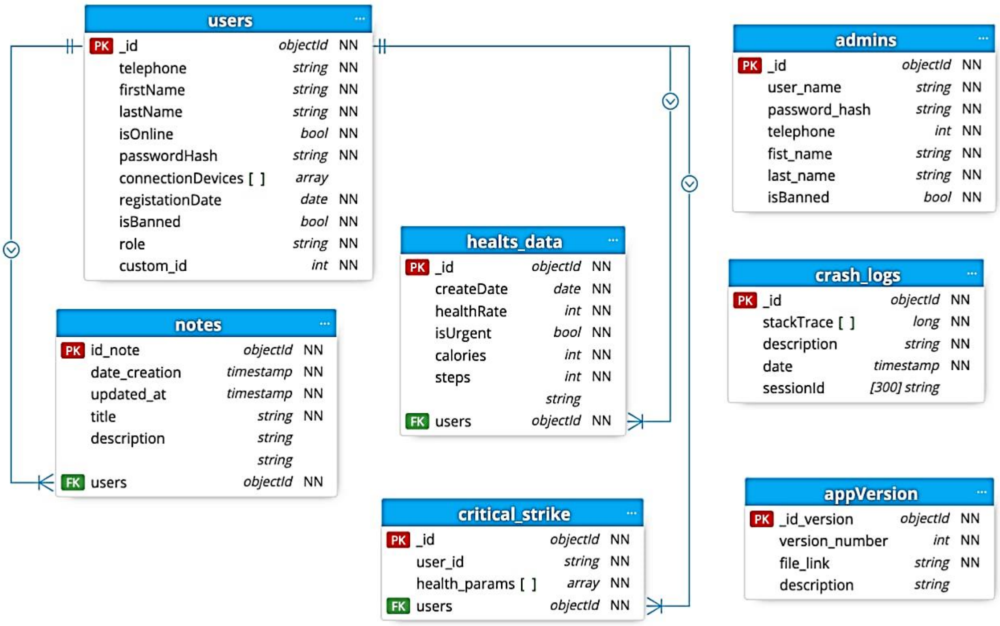

Fig. 3. Logical Data Model for proposed system

Report 834124(From-...

Файл Правка Вид Вставка Формат Данные Инструменты Расширения Справка Последнее изменение: только что

	A	B	C	D	E	F	G
1	Идентификатор	Пользователь	Приступ	Дата	Пульс	Кроки	Калорії
2	609c8b133b474100173f5784	834124	FALSE	13.05.2021, 5:12:35 GMT+3	72	860	1344
3	609c8b0e3b474100173f5783	834124	FALSE	13.05.2021, 5:12:30 GMT+3	75	860	1344
4	609c8b093b474100173f5782	834124	FALSE	13.05.2021, 5:12:25 GMT+3	76	860	1344
5	609c8b043b474100173f5781	834124	FALSE	13.05.2021, 5:12:20 GMT+3	78	860	1344
6	609c8aff3b474100173f5780	834124	FALSE	13.05.2021, 5:12:15 GMT+3	79	860	1344
7	609c8afa3b474100173f577f	834124	FALSE	13.05.2021, 5:12:10 GMT+3	79	860	1344
8	609c8af53b474100173f577e	834124	FALSE	13.05.2021, 5:12:05 GMT+3	80	860	1344
9	609c8af03b474100173f577d	834124	FALSE	13.05.2021, 5:12:00 GMT+3	80	860	1344
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11	609c8ae63b474100173f577b	834124	FALSE	13.05.2021, 5:11:50 GMT+3	79	860	1344
12	609c8ae13b474100173f577a	834124	FALSE	13.05.2021, 5:11:45 GMT+3	80	860	1344
13	609c8adc3b474100173f5779	834124	FALSE	13.05.2021, 5:11:40 GMT+3	80	860	1344
14	609c8ad73b474100173f5778	834124	FALSE	13.05.2021, 5:11:35 GMT+3	79	860	1344
15	609c8ad23b474100173f5777	834124	FALSE	13.05.2021, 5:11:30 GMT+3	76	860	1344
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19	609c8abe3b474100173f5773	834124	FALSE	13.05.2021, 5:11:10 GMT+3	72	851	1342
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25	609c8aa03b474100173f576d	834124	FALSE	13.05.2021, 5:10:40 GMT+3	78	837	1333
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27	609c8a963b474100173f576b	834124	FALSE	13.05.2021, 5:10:30 GMT+3	74	834	1327

Fig. 4. Generated report with collected data

monitoring systems [14]. The average server request processing time was less than 71 ms.

As a result, the system visualized heartbeat rate changes as an interactive chart, enabling the doctor to assess the patient's condition in real-time or over a specific period and identify potentially critical situations. fig. 5 presents the chart.

In the second stage of testing, load testing was conducted using the K6 Load Testing Tool, simulating up to 100 concurrent patient devices sending medical indicators. Under load, the average server request time was 145.8 ms, and the 95th percentile time was 167.1 ms. These metrics confirm the system's ability to operate stably even under high levels of concurrent requests, ensuring reliable performance in real-world medical settings.

Conclusions. The developed system provides real-time monitoring of health indicators for patients with epilepsy, enabling early detection of critical conditions and timely medical response. The system utilizes historical patient data to identify deviations in heart rate trends, which

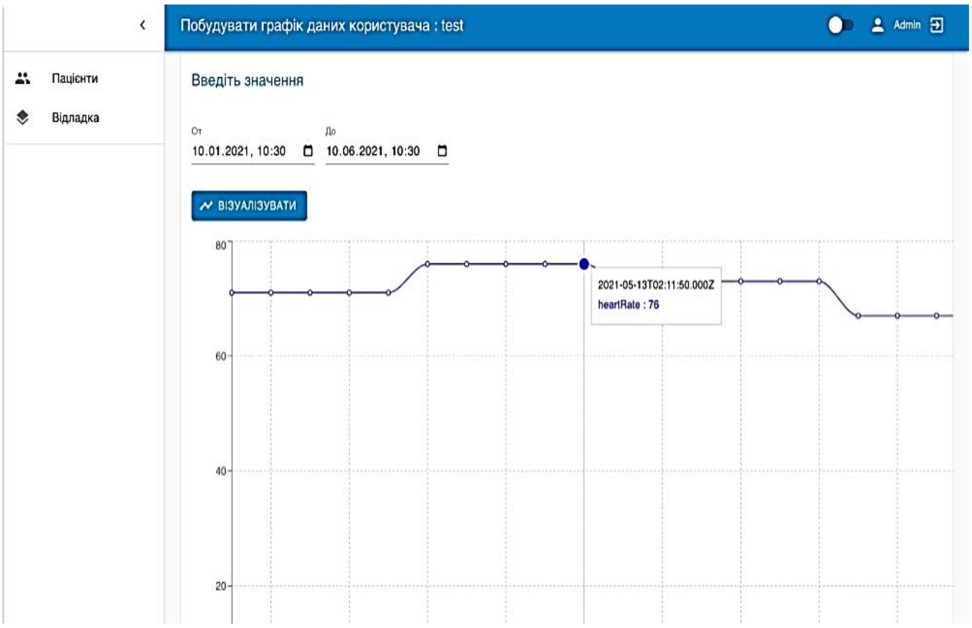

Fig. 5. Interactive chart of heartbeat rate changes for Real-Time patient monitoring

can serve as predictors of epileptic seizures. This functionality enhances the accuracy and efficiency of medical decision-making.

In the future, the system can be improved by implementing the following features:

- integration of advanced algorithms for predicting seizures based on heart rate variability and other parameters;
- support for real-time notifications to alert medical staff about potential critical conditions.
- expansion of data collection to include additional health metrics, such as oxygen saturation and activity levels, for comprehensive monitoring.

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ПРОГРАММЕ РІШЕННЯ ДЛЯ ЗБОРУ ТА ОБРОБКИ В РЕАЛЬНОМУ ЧАСІ МЕДИЧНИХ ДАНИХ ХВОРИХ НА ЕПІЛЕПСІЮ

Стрімкий розвиток комп'ютерних технологій суттєво вплинув на численні сфери суспільного життя, включаючи охорону здоров’я. Можливість збору, обробки та візуалізації медичних даних у режимі реального часу набуває дедалі більшого значення, особливо в контексті управління хронічними захворюваннями, зокрема епілепсією. У статті представлено веб-додаток, створений для моніторингу показників здоров’я у реальному часі, який дозволяє медичним працівникам ефективно відстежувати дані пацієнтів. Система автоматизує процес збору даних з фітнес-трекерів, їх передачі через мобільний пристрій на сервер та подальшої візуалізації у веб-інтерфейсі. Архітектура системи побудована на основі моделі тонкого клієнта, що використовує Node.js для серверної логіки та React.js для розробки користувацького інтерфейсу, забезпечуючи при цьому високу масштабованість і адаптивність. Основні функціональні можливості системи включають візуалізацію даних у режимі реального часу, аналіз історичних тенденцій та можливість експорту ключових показників здоров’я для їх подальшого дослідження. Архітектурна модель системи передбачає модульний підхід із чітким розмежуванням відповідальностей між клієнтською частиною, серверною стороною та компонентами бази даних. У якості бази даних використовується MongoDB, що забезпечує високу гнучкість в управлінні великими обсягами медичних даних. Система була піддана комплексному тестуванню у два етапи. На першому етапі збір реальних даних продемонстрував середній час передачі, що не перевищує 112 мс, що відповідає вимогам функціонування у реальному часі. На другому етапі, під час стрес-тестування за участю до 100 одночасних користувачів, було зафіксовано середній час відповіді сервера на рівні 145,8 мс, а 95-й процентиль часу відповіді склав 167,1 мс. Отримані результати підтверджують високу надійність системи та її готовність до впровадження у медичних установах. Подальший розвиток системи передбачає інтеграцію розширених механізмів сповіщення у реальному часі та додаткових показників здоров’я, таких як рівень насиченості киснем та рівень фізичної активності, що дозволить забезпечити комплексний моніторинг стану пацієнтів. Запропоноване рішення демонструє перспективи інтеграції сучасних веб-технологій в охорону здоров’я, сприяючи підвищенню ефективності медичних процесів та покращенню результатів лікування пацієнтів.

Ключові слова: моніторинг у реальному часі, обробка медичних даних, автоматизація, показники здоров’я, програмне забезпечення, архітектура системи, технології розробки.

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