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# MONITORING SYSTEM FOR YOUNG DIABETES PATIENTS

*The article describes the structures for monitoring the health status of patients with diabetes mellitus. Many systems are known for measuring and monitoring blood sugar levels. The list of tasks they solve includes monitoring blood glucose levels and physical activity, diet and insulin consumption. The capabilities of the Internet of Things (IoT), information and communication technologies and machine learning can help reduce the cost of healthcare and the organization of online medical services. Methods such as predicting blood glucose levels and simulating blood glucose dynamics are important in developing technologies for monitoring patients with diabetes. Increasing access to patient data has paved the way for the adoption of machine learning and its use in diabetes management. Machine learning's ability to solve complex problems has contributed to his success in the study of diabetes. The number of patients with diabetes mellitus among children is growing in the world, therefore, the observation of young patients is one of the hot topics. Therefore, this review aims to find the optimal structure for monitoring the health status of young patients with diabetes mellitus.*

***Keywords****: diabetes mellitus, glucose control, Internet of Things, machine learning.*

**Introduction.** The healthcare industry is constantly evolving and offers a wide range of research opportunities. Development is carried out using technologies and applications of the Internet of Things (IoT). They combine information and communication technologies (ICT), sensors, big data sets, machine learning techniques, and artificial intelligence. New technologies are used for continuous monitoring of patients with chronic diseases, the number of which has been increasing in recent years [1].

Machine learning methods allow with high accuracy to automatically determine mathematical models of these dependencies from the obtained arrays of interdependent quantities, as a result of which it is possible to predict the development of the disease and the patient's condition with high accuracy based on various psychological factors and parameters of vital activity. Models expose dependencies between inputs and outputs.

Chronic diseases require long-term treatment. Patients with chronic diseases usually spend long periods of time in the hospital for daily follow-up. Diabetes mellitus is a chronic disease associated with dysfunction of the pancreas that occurs when the correct levels of insulin are not produced (type 1 diabetes, T1D) or the body does not use insulin properly (type 2 diabetes, T2D) [1].

The main concern of a patient with diabetes mellitus is to constantly monitor blood glucose levels. Methods for controlling these levels are divided into three: invasive, minimally invasive and non-invasive [2]. The invasive method is one of the most used approaches because it provides the most accurate results in direct contact with the patient's blood. Finger pricking is a traditional procedure in this method. Measurements must be

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carried out in a strict cleaning regime, otherwise infections may occur [2, 3]. Body fluids such as saliva, urine, sweat, or tears have been studied as non-invasive glucose tests, but they cannot be used to continuously monitor glucose levels.

**Review of known technical solutions.** The article [4] describes a system of long-term monitoring of glucose levels in the subcutaneous tissue in a small group of people with diabetes. It uses a fully implanted first-generation sensor prototype / telemetry system. The devices remained implanted for 180 days, with signals transmitted every 2 minutes to external receivers. The proposed system demonstrates its ability for continuous long-term glucose monitoring.

The article [5] proposes a blood glucose monitoring system using a Wireless Body Area Network. One part of this network is the meter sensor, which measures the approximate concentration of glucose in the blood. The system uses an Arduino Uno board and a Zigbee module. The results of the study show that remote monitoring of patient glucose can be achieved using desktop, mobile and web applications. One of the disadvantages of the proposed system is that it is not energy efficient. This is due to the high power consumption of the Arduino Uno board and Zigbee module.

Three main components of an IoT-based health monitoring system: a network of sensors, gateways connected to the Internet, support for cloud and big data (Figure 1). The data collected by users from the connected sensors will be available to caregivers, family members and authorized persons, which will allow them to check the vital signs of the subject at any time from anywhere [6].


***Figure 1*** – General health monitoring system based on IoT [6]

The article [7] presents the architecture of the monitoring system for patients with diabetes mellitus. The system architecture consists of three main components: sensor modules, data acquisition module and database server. In this system, sensors collect information about the user's vital functions and transmit it via Bluetooth to a mobile application. The mobile app sends this data to the database via 4G or Wi-Fi. The monitoring system analyzes the data collected from the sensors. When the system detects an abnormal situation, the doctor will be notified to look at the mobile application and determine its cause.

The article [8] presents a deep learning model that is able to predict glucose levels with high accuracy. A multilayer convolutional recurrent neural network (CRNN) architecture was used to predict glucose levels (Figure 2). The architecture of a convolutional recurrent neural network consists of three parts: a multilayer convolutional neural network; recurrent

neural network (RNN) with long-term short-term memory (LSTM) cells and fully connected layers. LSTM shows good performance in forecasting time series with long time dependences [9]. The convolutional recurrent neural network model is implemented using the TensorFlow library.

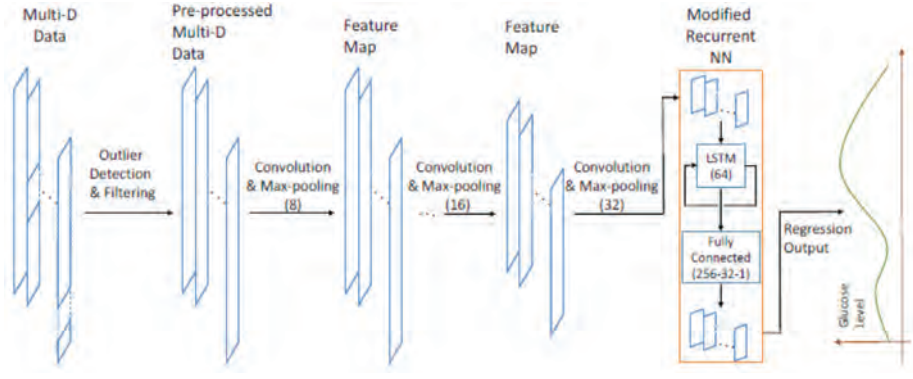



***Figure 2*** – CRNN architecture for glucose prediction [8]

The article [10] presents a mobile application showing data about a patient and indicators of his health. The patient receives consultations depending on the state of health.

**Proposed monitoring system.** Based on the study of the structures contained in the articles discussed above, it is possible to propose a generalized (universal) system for monitoring the health status of young (children and adolescents) patients with diabetes mellitus.

The monitoring system records various health-related actions of users. The main idea of the system is to collect data on the vital functions of patients with diabetes using sensors and analyze this data for an individual rehabilitation program. Machine learning methods can be used to predict future changes in health status.

It is proposed to take as a basis the structure of a general health monitoring system based on IoT in article [6] and the architecture of a monitoring system for patients with diabetes mellitus in article [7]. The system can be improved by adding other patient indicators (glycated hemoglobin level, blood fructosamine level) that can be useful in predicting blood glucose levels. The main stages of the proposed system can be divided into four stages (Figure 3).

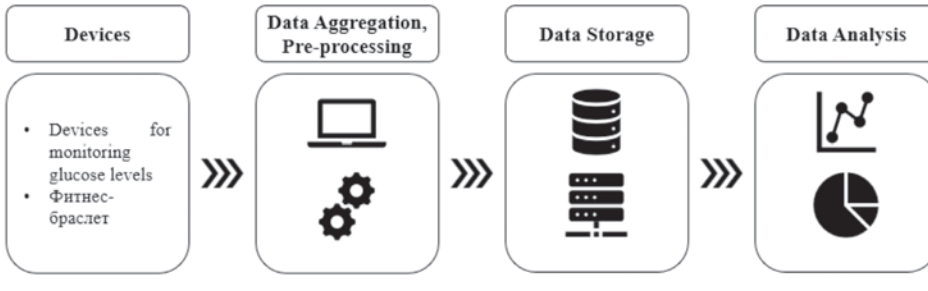


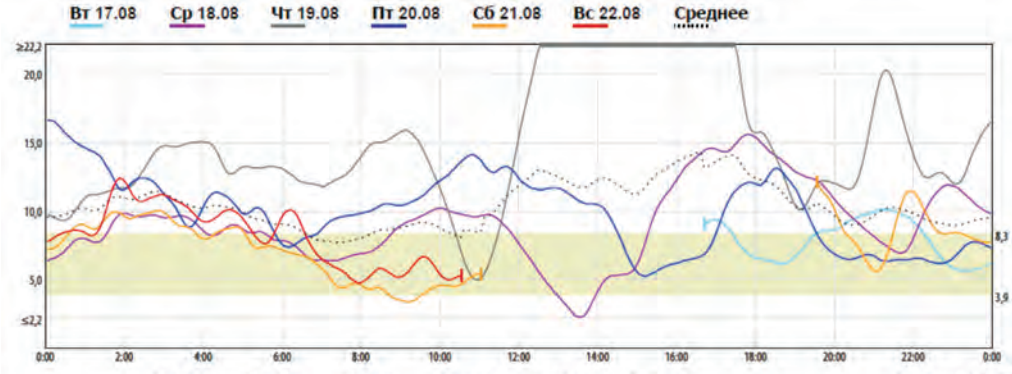

***Figure 3*** – Stages of the monitoring system

The authors recommend using the following sensors: a glucose meter for measuring glucose levels and a fitness bracelet for measuring physical activity. To measure the physical activity of the patients, the Xiaomi Mi Band 5 fitness bracelet was chosen, and to collect glucose data, the iPro2 MMT-7745WW continuous glucose monitoring system, the Enlite MMT-7008A glucose sensor, the Enlite MMT-7510 sensor insertion device and the dock will be used -station (Figure 4). The data from the sensors are transferred to a database and analyzed to compile an individual rehabilitation program.


***Figure 4*** – a) Enlite MMT-7008A; b); b) Docking station; c) Enlite MMT-7510; d) iPro2 MMT-7745WW; e) Xiaomi Mi Band 5

Fitness bracelet Xiaomi Mi Band 5 can measure the patient's pulse, activity (number of steps, calories), stress level (Figure 5). The data is stored in the Mi Fit mobile application with the ability to export for analysis. Figure 6 shows data from glucose monitoring devices.


***Figure 5*** – Data of the Mi Fit mobile application: a) heart rate; b) steps




| | Вт 17.08 | Ср 18.08 | Чт 19.08 | Пт 20.08 | Сб 21.08 | Вс 22.08 | В среднем / всего |
|---|---|---|---|---|---|---|---|
| # значений сенсора | 88 | 288 | 288 | 288 | 187 | 127 | 1 266 |
| Наибольший | 10,1 | 15,7 | 22,2 | 16,7 | 12,2 | 12,4 | 22,2 |
| Наименьший | 5,7 | 2,3 | 4,9 | 5,2 | 3,3 | 4,7 | 2,3 |
| Среднее | 7,9 | 9,1 | 15,0 | 10,0 | 7,4 | 8,2 | 10,2 |
| Станд. откл. | 1,5 | 2,9 | 4,5 | 2,7 | 2,2 | 2,2 | 4,1 |
| CAP % | 30,4 | 12,0 | 17,2 | 24,1 | Н/И | 3,9 | 18,2 |
| Корреляция | Н/И | Н/И | 0,95 | 0,37 | Н/И | Н/И | 0,78 |
| # действительных калибровок | 2 | 4 | 3 | 3 | 0 | 1 | 13 |
| Назначение | X | | | X | C | X | |

X: используйте клиническую оценку S: без данных сенсора C: без калибровки ГК

***Figure 6*** – Data from Medtronic iPro2

A prototype of a mobile application will be developed that allows receiving data on the user's vital functions from sensors, information entered by the user (gender, height, age, etc.) and a personalized rehabilitation program. Glucose prediction is based on a machine learning method. The mobile application serves as a tool for monitoring the health status of patients with diabetes.

A personalized rehabilitation program for patients with diabetes is physical activity and exercise. Children and adolescents with type 1 and 2 diabetes should engage in moderate to vigorous aerobic activity for 60 minutes a day or more to strengthen muscles and bones at least three days a week [11]. Weight loss reduces the risk of cardiovascular disease and improves glycemic control [12].

**Conclusion.** The article showed that by integrating sensor devices with a monitoring system, it is possible to collect and analyze a complete history of data on the user's vital functions (heart rate, number of steps and blood glucose level). Work continues to predict blood glucose levels based on the user's vital functions collected by sensor devices. The development of a new system is aimed at using it for the treatment and monitoring of the health status of young patients. It is expected that the results of this study will be used by patients with diabetes mellitus.

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## ҚАНТ ДИАБЕТІ БАР ЖАС ПАЦИЕНТТЕРДІ БАҚЫЛАУ ЖҮЙЕСІ

*Мақалада қант диабеті бар пациенттердің денсаулық жағдайын бақылаудың құрылымдары сипатталған. Қандағы қант деңгейін өлшеуге және бақылауға арналған көптеген жүйелер белгілі. Олар шешетін тапсырмалардың тізіміне қандағы глюкоза деңгейін және физикалық белсенділікті,*

*диетаны және инсулиннің қабылдануын бақылау кіреді. Заттар ғаламторының (IoT), ақпараттық-коммуникациялық технологиялардың және машиналық оқытудың мүмкіндіктері денсаулық сақтау мен онлайн медициналық қызметтерді ұйымдастырудағы шығындарды төмендетуге мүмкіндік береді. Қандағы глюкоза деңгейін болжау және оның динамикасын модельдеу сияқты әдістер қант диабеті бар пациенттерді бақылау технологияларын құрастыруда маңызды болып табылады. Пациенттер туралы деректерге қол жетімділіктің артуы машиналық оқытуды енгізуге және оны қант диабетін емдеуде қолдануға жол ашты. Машиналық оқытудың күрделі мәселелерді шешу қабілеті оның қант диабетін зерттеудегі жетістіктеріне ықпал етті. Әлемде балалар арасында қант диабеті бар пациенттердің саны артып келеді, сондықтан жас науқастарды бақылау өзекті тақырыптардың бірі болып табылады. Сондықтан, бұл шолу қант диабеті бар жас пациенттердің денсаулық жағдайын бақылау үшін оңтайлы құрылымды табуға бағытталған.*

***Түйінді сөздер**: қант диабеті, глюкоза деңгейін бақылау, Заттар ғаламторы, машиналық оқыту.*

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## СИСТЕМА МОНИТОРИНГА ЮНЫХ ПАЦИЕНТОВ С САХАРНЫМ ДИАБЕТОМ

*В статье описаны структуры контроля состояния здоровья пациентов с сахарным диабетом. Известно множество систем для измерения и контроля уровня сахара в крови. Перечень решаемых ими задач включает в себя контроль уровня глюкозы в крови и физической активности, диеты и потребления инсулина. Возможности интернета вещей (IoT), информационно-коммуникационных технологий и машинного обучения позволяют снизить затраты на здравоохранение и организацию онлайн-медицинских услуг. Такие методы, как прогнозирование уровня глюкозы в крови и моделирование ее динамики, имеют важное значение при разработке технологий для мониторинга пациентов с сахарным диабетом. Увеличение доступа к данным о пациентах проложило путь к внедрению машинного обучения и использованию его в лечении диабета. Способность машинного обучения решать сложные задачи способствовала его успехам в изучении диабета. В мире растет число пациентов с сахарным диабетом среди детей, поэтому наблюдение за молодыми пациентами является одной из актуальных тем. Поэтому данный обзор направлен на поиск оптимальной структуры для мониторинга состояния здоровья молодых пациентов с сахарным диабетом.*

***Ключевые слова**: сахарный диабет, контроль уровня глюкозы, Интернет вещей, машинное обучение.*