

A SYSTEM OF COGNITIVE MONITORING OF A PATIENT'S CONDITION IN A TELEMEDICINE NETWORK

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СИСТЕМА КОГНІТИВНОГО МОНІТОРИНГУ СТАНУ ПАЦІЄНТА В МЕРЕЖІ ТЕЛЕМЕДИЦИНИ

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СИСТЕМА КОГНІТИВНОГО МОНІТОРИНГА СОСТОЯНИЯ ПАЦИЕНТА В СЕТИ ТЕЛЕМЕДИЦИНЫ

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Abstract. The paper proposes an approach to the creation of a network of cognitive monitoring of a patient's condition in a telemedicine network. According to the World Health Organization, there are a large number of patients in the world who require constant monitoring of their condition. It is practically impossible to ensure control over the condition of these people through constant visits to medical institutions. However, today, thanks to the use of information and communication technologies, the concept of the Internet of things, it has become possible to solve this problem by creating a telemonitoring system. An urgent issue for this telemedicine monitoring system is not only monitoring the patient's condition, but also the ability to predict changes in his condition, which can be solved by combining modern ICT and cognitive technologies. The article identifies the main tasks of the cognitive network monitoring system and its proposed architecture. A model of prognostic analytics is developed, and procedures for cognitive monitoring of indicators of the patient's condition are formalized. The proposed approach to cognitive monitoring allows not only the ability to monitor the current state of the patient, but also to predict his condition in order to prevent the occurrence of emergency situations. An algorithm for choosing the optimal IoT platform for the implementation of a cognitive network monitoring system in telemedicine is presented. The solution proposed in this work is a relevant example of the fact that cognitive technologies are able to significantly change a number of functioning processes of modern information and communication networks.

Key words: telemedicine, cognitive technologies, Internet of things, IoT-platform, telemonitoring.

Анотація. У статті запропоновано підхід до створення системи мережного когнітивного моніторингу стану здоров'я пацієнта в мережі телемедицини. За даними всесвітньої організації з охорони здоров'я у світі є значна кількість пацієнтів, які потребують постійного нагляду, контролю їхнього стану. Забезпечити постійний контроль стану цих людей шляхом їх постійного відвідування медичних закладів практично неможливо, але сьогодні, завдяки використанню інформаційно-

комунікаційних технологій та концепції Інтернет речей (IoT) з'явилась можливість вирішити цю проблему шляхом створення системи медичного телемоніторингу. Актуальним питанням для даної телемедичної системи моніторингу є не тільки контроль стану здоров'я пацієнта, а й можливість прогнозування змін стану пацієнта, що вирішується за рахунок поєднання сучасних ІКТ та когнітивних технологій. У статті визначені основні завдання системи мережного когнітивного телемоніторингу, запропоновано її архітектуру. Розроблено модель прогностичної аналітики і формалізовані процедури когнітивного моніторингу показників стану пацієнта. Запропонований підхід когнітивного моніторингу дозволяє не тільки відображати поточний стан показників, що спостерігаються, а й прогнозувати їх зміни з метою своєчасного попередження про можливість появи позаштатних ситуацій. Наведено алгоритм вибору оптимальної IoT-платформи для реалізації системи мережного когнітивного моніторингу в мережі телемедицини. Пропоноване в статті рішення є актуальним прикладом того, що когнітивні технології здатні істотно змінити низку процесів функціонування сучасних інформаційно-телекомунікаційних мереж.

Ключові слова: телемедицина, когнітивні технології, Інтернет речей, IoT-платформа, телемоніторинг.

Аннотация. В статье предложен подход к созданию системы сетевого когнитивного мониторинга состояния пациента в сети телемедицины. По данным Всемирной организации здравоохранения, в мире есть большое число пациентов, которые требуют постоянного контроля их состояния. Обеспечить контроль состояния этих людей за счет постоянного посещения ними медицинских учреждений практически невозможно. Однако сегодня, благодаря применению информационно-коммуникационных технологий, концепции Интернет вещей появилась возможность решить эту проблему путем создания системы телемониторинга. Актуальным вопросом для данной телемедицинской системы мониторинга является не только контроль состояния пациента, а и возможность прогнозирования изменения его состояния, что может быть решено за счет объединения современных ИКТ и когнитивных технологий. В статье определены основные задачи системы когнитивного сетевого телемониторинга, предложена её архитектура. Разработана модель прогностической аналитики и формализованы процедуры когнитивного мониторинга показателей состояния пациента. Предложенный подход когнитивного мониторинга позволяет не только контролировать текущее состояние пациента, а и прогнозировать его состояние с целью упреждения появления внештатных ситуаций. Приведен алгоритм выбора оптимальной IoT-платформы для реализации системы когнитивного сетевого мониторинга в сети телемедицины. Предложенное в статье решение является актуальным примером того, что когнитивные технологии способны существенно изменять ряд процессов функционирования современных информационно-коммуникационных сетей.

Ключевые слова: телемедицина, когнитивные технологии, Интернет вещей, IoT-платформа, телемониторинг.

The current trend in the development of information and communication technologies (ICT) is the introduction of intellectualization functions - the creation of cognitive systems. One of the main areas of application of intellectual and cognitive technologies is healthcare. Modern ICTs allow the creation of so-called telemedicine networks which allow patients to receive quality and timely medical care in all circumstances, regardless of any factors (long distance, difficult weather conditions, etc.). According to WHO, there are a large number of people in the world who need constant monitoring and control of their condition. The vast majority of these are people suffering from cardiovascular disease or diabetes [1, 2]. Previously it was practically impossible to have constant monitoring of the conditions of these people, but today, thanks to the use of ICT and the concept of Internet of Things (IoT), it has become possible to create telemonitoring medical systems. Telemonitoring is a medical service that allows the patient to be constantly monitored and to transmit the data to the medical facility in real time [1-3]. In this way, modern ICTs allow the creation of a telemedicine networked system for the remote monitoring of the health of patients who are not able to be permanently under the supervision of a qualified healthcare professional but who need constant monitoring. A topical issue for this telemedicine system is not only the control of the patient's health, but also the ability to predict changes in the patient's condition. The solution to this problem is possible through the use of modern ICT and IoT technologies.

The purpose of the work is to develop a telemedicine network system for remote monitoring of the patient's health which is not able to be constantly monitored by a qualified medical professional.

To implement such a telemedicine monitoring system, it is necessary to combine the capabilities of modern ICTs, IoT technologies, and cognitive technologies. Such a symbiosis of technologies forms the Cognitive Internet of Things (CIoT) technology. The concept of the cognitive Internet of Things assumes the existence of IoT with "reasoning" mechanisms. The fundamental difference between cognitive technologies is that they allow modeling of the cognitive abilities of the human brain to solve specific applications such as: pattern recognition (languages, signals, images, etc.), detection and identification of patterns in data sets; decision making in a predictably changing environment [4, 5].

The process of creating a telemedicine health telemonitoring network system is a complex task that is based on a comprehensive assessment and analysis of many different factors. First of all it is necessary to formulate requirements for the telemonitoring system. To be effective, the system must have these features:

Monitoring the patient's condition by definite indicators.

Determining the trends of changes in monitored indicators.

Regular transmission of monitoring indicators to the telemedicine center.

Notification to the patient about the necessity of taking medicine, the necessity of changing the dosage scheme of the prescribed medicine and identifying the trend component of monitoring indicators.

Prognostication of the possibility of a critical emergence in patient's condition and taking appropriate measures to prevent the onset of a critical condition - calling for emergency medical care, notifying the patient, doctors, etc.

The solution of the listed above tasks requires implementation in the telemonitoring system of cognitive functions, such as: the ability to predict and recognize the deterioration or improvement of the patient's condition and recognition of the patient's critical condition. For implementation of this system it is advisable to use CIoT service platforms which elements can give a certain idea about the state and conditions of functioning of the surrounding objects, perceive knowledge about the surrounding objects, produce logical conclusions from the accumulated knowledge, and take actions to adapt to external and internal conditions. Accordingly, there are cognitive nodes CN or cognitive elements CE in the CIoT architecture that are capable to autonomously optimize, for example, technical specifications of the network according to certain conditions. As structural components of the cognitive telemonitoring system, it is proposed to use smart devices: CE – sensors for medical monitoring of the patient's condition indicators; CN – central controller which is capable of independent establishment or using predetermined rules of interaction between objects (Internet of Things); special gateway that interacts with smart-device domain elements with external information and communication objects (telemedicine center, e-Health electronic cloud database) (Fig. 1).

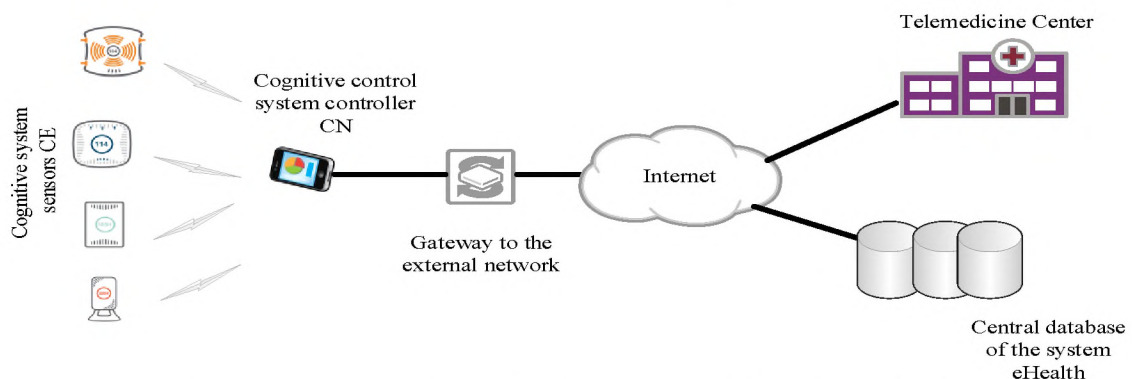


Figure 1 – Structural components of a cognitive telemonitoring system

The processing of medical monitoring data in order to assess and predict changes in the patient's condition, as well as to convert the data into a form that is necessary for their transmission to external objects, requires special procedures, the methods of implementation of which are discussed below. Fig. 2 shows the architecture of the cognitive telemonitoring system.

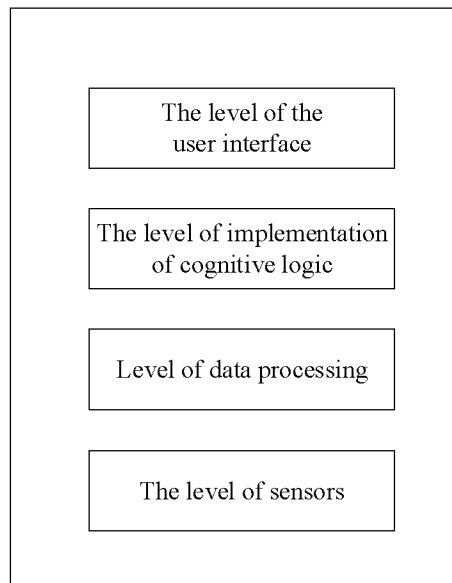


Figure 2 - Architecture of a cognitive telemonitoring system

The cognitive telemonitoring system monitors the patient's condition to prevent deterioration of his condition and prevent emergencies. Depending on the type of disease, different medical parameters may be monitored. For example, for patients with cardiovascular disease there is a high risk of myocardial infarction. The main signs of a heart attack are a significant drop of blood pressure, disturbance of heart rate, shortness of breath (respiratory rate). The system tracks these indicators:

- Continuous non-invasive blood pressure;
- Heart rate;
- Respiratory rate.

The determination of the trend component of the changes in the indicators that are monitored makes it possible to predict and recognize the deterioration of the condition of the patient with a predetermined warning period during which can be taken actions to reduce negative effects. Therefore, such telemonitoring system can be defined as cognitive system [4].

Cognitive monitoring is performed by a system consisting of two functional subsystems - subsystems of cognitive analysis and subsystems of interpretation of results. It is proposed to introduce cognitive monitoring procedures using statistical analysis of time series and statistical forecasting methods [5-7].

The initial data are:

- forecast bias periods LK, LC, LD (short-term, situational and long-term, respectively), which are set based on the doctor's recommendations;
- parameter to be monitored. Y is a set of parameters with power m that describe the dynamic characteristics of the monitoring object.

Thresholds $y_{kP} \in Y_P \forall y_k(i) \in Y (k = \overline{1, m})$. Y_P is the set of limit values. A number of peripheral meters $\{M_w\} (w = \overline{1, l})$ with power 1 provide the subsystem with the corresponding $\{y_k(i)\}$ parameter values $y_k(i) \in Y (k = \overline{1, m})$ that it accumulates and stores to further generate the required size n_{\min}^K, n_{\min}^C for short-term and situational forecasting.

Further, statistical analysis is used to search for patterns in the data. Procedures for short-term and situational forecasting of each parameter $y_k(i) \in Y (k = \overline{1, m})$ are implemented by a separate “plane” of the subsystem of analysis. The results interpretation subsystem compares the results of the situational prediction $y_k(i + L_C^k) \in Y (k = \overline{1, m})$ with the corresponding thresholds $y_{kP} \in Y_P (k = \overline{1, m})$, in order to determine the time points $t_k^{kP} \forall y_k(i) \in Y (k = \overline{1, m})$ and calculate the current value $F(j)$ over a given T_F observation period.

In Fig. 3 shows the architecture of the cognitive monitoring module.

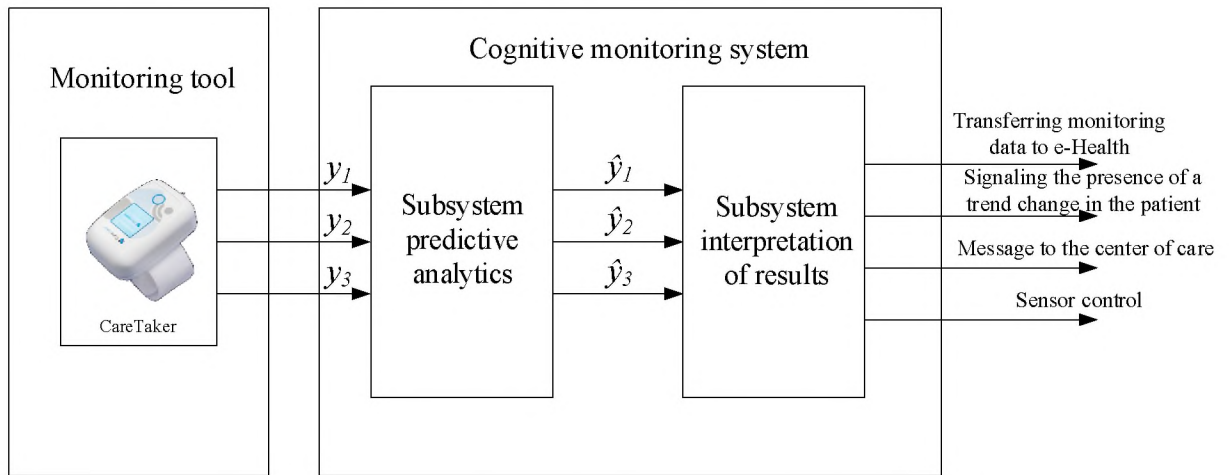


Figure 3 - Architecture of the cognitive monitoring module

In [8] it is stated that today there are a large number of IoT platforms on the market, upon which it is possible to implement a system of cognitive monitoring in a telemedicine network. Each of the IoT platforms is described by a feature vector whose elements take on values:

$$cr_i = \begin{cases} 1, & \text{if, the platform has the } i\text{-th characteristic;} \\ 0, & \text{otherwise,} \end{cases} \quad (1)$$

$$i \in [1, n].$$

Each characteristic is matched by a set of functions that defines functionality Funct_i :

$$\text{Funct}_i = \frac{F_i^T}{F_i^0}, \quad i \in [1, n], \quad (2)$$

where F_i^T - the number of functions corresponding to the declared; F_i^0 - total number of declared functions.

Then the function of choosing the IoT platform to create a system of cognitive monitoring in the telemedicine network, subject to cost constraints, can be written in the following form:

$$\gamma = \sum_i w_i \cdot \text{Funct}_i + \frac{1}{C_i} \rightarrow \max_{i \in [1, n]}, \quad (3)$$

$$C_i \leq C_{\max},$$

where C_i is the cost of the i -th IoT platform; C_{\max} - the maximum permissible cost of the platform; w_i is the element of the matching vector \overline{W} and takes on the value

$$w_i = \begin{cases} 1, & \text{if the } i\text{-th characteristic is needed;} \\ 0, & \text{Otherwise,} \end{cases} \quad (4)$$

$$i \in [1, n].$$

CONCLUSIONS

The paper proposes an approach to the creation of a network of cognitive monitoring of a patient's health in a telemedicine network. The proposed solution is a relevant example of cognitive technologies that are able to significantly change the number of processes of modern information and telecommunication networks. The main tasks of the network cognitive telemonitoring system are defined and its architecture is proposed. A model of prognostic analytics has been developed and formal procedures for cognitive monitoring of patient's state parameters have been formalized. The proposed cognitive monitoring approach not only reflects the current state of the observed parameters, but also predicts their changes in order to promptly warn about possible emergencies. The algorithm of choosing the optimal IoT platform for implementation of the network of cognitive monitoring in the telemedicine network is presented.

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