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BASIC COMPONENTS OF THE SOFTWARE MODULES CONSTRUCTION FOR OBTAINING, STORING AND EXCHANGING MEDICAL AND ENVIRONMENTAL INFORMATION

Introduction. *Currently, the exchange of medical information between healthcare facilities, data repositories, various mobile devices operating in a mobile medicine or telemedicine environment and patients is becoming increasingly important.*

Digital transformation in healthcare includes the use of electronic health records (EHR) in practical medicine, the information technologies creation for processing complex medical information using artificial intelligence, the telemedicine systems construction and the development of medical devices, software modules and mobile applications that completely change of the interaction between medical care providers, and the way of decisions regarding physicians plans for diagnosis, treatment, rehabilitation, and disease prevention.

Currently, in order to increase the effectiveness of preventive measures against a wide range of diseases, there is an urgent need to develop environmental control systems and devices built using modern wireless technologies, cloud services and mobile communication systems.

The purpose of the paper *is to analyze the main requirements and components of information flows for obtaining and exchanging digital medical and environmental data and implement them in information and software modules for obtaining, saving and exchanging this information for further analysis.*

The results. *Today, all health information operations directly depend on the level of interoperability in the healthcare industry, that is, the ability of different information systems, devices and applications to access, exchange, integrate and share data in a coordinated way to ensure timely and seamless information exchange and optimize the process of providing medical care.*

To ensure the appropriate level of interoperability, a set of characteristics has been formed for each subject/object of interaction, consistent with its role function in the process of medical data exchange. An adaptive architecture of the digital medicine ecosystem has been developed, which enables the integration of data exchange tasks between participants using web services.

According to the target function, several groups of information flows are identified, which are implemented during the interaction of the main participants in the provision of medical care: patient — physician, patient — health facilities, physician — physician. Based on taking into account the role and ways of transferring personal medical information between participants, an algorithm for the exchange of personal medical data was created.

The selected basic characteristics of the digital medical data exchange process and the requirements for the structure and functions of the information and software tools supporting this process are implemented in the information and software modules for saving and exchanging clinical information.

Conclusions. *Software modules should implement one of the main functions of the digital medicine ecosystem and environmental monitoring — obtaining, storing and exchanging digital medical data that circulates between ecosystem participants. The main feature of such exchange and storage is the implementation of the principles of interoperability, which makes it possible to quickly and efficiently perform similar functions.*

The developed information and software modules of various purposes implement the methodology of activities in the digital medicine ecosystem with various software applications to create a unified information environment with the placement of a database on the health status of patients on any storage, in particular, cloud storage.

Keywords: *digital medicine ecosystems, electronic medical records, disease risks, determination of concentrations of toxic chemicals, interoperability, information flows, data analysis methods, information and software modules, measurement sensors.*

INTRODUCTION

The quality of modern life largely depends on the development of digital technologies, which affect all sectors of the national economy, including medicine. Digital transformation is happening at different levels of the health care system, covering both the practice of medicine and the management of the industry.

The exchange of medical data and information between health care facilities, data repositories, patients and various mobile devices operating in a mobile medicine or telemedicine environment and patients is of great importance. Today, these processes are implemented with the use of medical information standards in the form of certain software tools adapted to the exchange of various types of medical data, which effectively affects the communication methods of the participants in the provision of medical care and, accordingly, the quality of this process.

Digital transformation in healthcare includes the introduction of electronic health records (EHR) in practical medicine, the creation of information technologies for processing complex medical information using artificial intelligence, the construction of telemedicine systems and the development of medical devices, software modules and mobile applications that completely change the way interactions with medical professionals, the way data is shared between providers, and the way decisions are made regarding plans for diagnosis, treatment, rehabilitation, and disease prevention.

Currently, in order to increase the effectiveness of preventive measures against a wide range of diseases, there is an urgent need to develop environmental control systems and devices built using modern wireless technologies, cloud services and mobile communication systems. Environmental monitoring systems are becoming widespread, which allow many devices to be connected via the Internet to remotely collect information about environment in order to share it with other systems and devices. In this direction, a significant step is the construction of systems for monitoring environmental objects and modeling environmental processes, such as the platform for research and education CPS/IoT Ecosystem (a joint project of the Wien Technical University, the Austrian Technology Institute and the Institute of Science and Technology), as well as research aimed at the use of hyperspectral portable photon sensors (for example, VIS-NMIR), which are actively developing in Europe and the USA.

PROBLEM STATEMENT

The implementation of digital transformation, the creation of a patient-oriented ecosystem of digital health care, which is based on information technology (IT), telemedicine and mobile medicine, is defined as one of the priority tasks in the Global Strategy of Digital Health Care for the period 2020–2025 [1]. Digital transformation (DT) is "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [2, p. 118].

The health care system covers a variety of services provided by medical professionals in the treatment, rehabilitation and prevention of public health disorders, and it is the need to ensure the efficiency of these processes that has led to a long-term interest in the implementation of digital transformation in this important industry [3, 4]. Studies devoted to various aspects of digital medicine have not lost their relevance for both scientists and practitioners in recent decades [5–8]. The directions of research and development related to digital medicine technologies are filled with new topics related to the processes of saving and sharing medical data, their further analysis to solve issues of individual and population health.

According to various researchers, digital technologies help engage patients in quality healthcare regardless of where they live, empower patients and their families to more easily obtain information about their health and treatment options, and facilitate access to healthcare facilities that meet their needs [8–10]. Telemedicine tools, IT analysis and prediction of patients' condition using artificial intelligence, as well as blockchain technologies, Internet of Things (IoT) and robotic services, which have been developed and used by various healthcare entities, are currently considered not only as infrastructure, but also as strategic asset [11, 12]. The use of sensors, wearable devices, virtual/augmented reality and robotics affect every medical specialty, causing the need for new skills for doctors and the field of medicine [13]. It is the wide and deep use of IT that is a vivid manifestation of the digital transformation in the healthcare sector, which fundamentally changes the provision of medical services [14]. They are actively discussing the issue of organizing the effective work of medical personnel, automating business processes; intelligent data processing and the

security of their exchange, etc [15]. The healthcare system is significantly influenced by digital innovations, in particular the entering of the Internet into the daily lives of consumers with disabilities. They can use the Internet to find information about doctors, book medical appointments etc., so target consumers or patients are connecting to the digital system of a healthcare facility (for example, easy access via smartphone) [12, 13, 16].

The analysis of the priority areas of digital medicine attracts increased attention. A large-scale study of the realities of digital healthcare transformation by Sebastian Hermes and co-authors, analyzing 1,830 healthcare organizations found on Crunchbase, allowed them to form a common value system of the digital healthcare industry. This system consists of eight new components of digital medicine, namely: information platforms, data collection technology, market intermediaries, remote and on-demand health care services, augmented and virtual reality provider, blockchain-based PHR, cloud service provider and intelligent analysis data for the provision of medical services [17].

As a result of the analysis of the effectiveness of the implementation of digital technologies among providers of medical services, Kraus S. and co-authors proposed an interesting model of the main forms of digital transformation in medicine. This model combines five clusters: operational efficiency of healthcare providers; patient-centered approaches; organizational factors and managerial implications; specific service practices; socio-economic aspects [18].

At the same time, the lack of proper understanding of the effectiveness of the use of digital medicine assets on the part of the management of healthcare facilities and physicians is noted. The problem of the use of Dig Data, security, privacy and data protection during their storage and sharing, the use of cloud computing systems are also issues that are quite complex and important for application in this field [4]. Healthcare professionals must be motivated to apply IT in healthcare management processes to realize optimal data integration on a national scale.

A correct understanding of how in practice different players (patients, pharmaceutical companies, health care institutions, government institutions etc.) use digital technologies and tools to improve the quality of interoperability in digital health care is important and crucial.

The purpose of the paper is to analyze the main requirements and components of information flows for obtaining and exchanging digital medical and environmental data and implement them in information and software modules for obtaining, saving and exchanging this information for further analysis.

SOURCES OF OBTAINING DIGITAL MEDICAL AND ENVIRONMENTAL DATA

For the information flows formation of the health care ecosystem, knowledge about the types of available data, sources, methods and means of its generation are important.

Types and sources of obtaining digital medical data. Peculiarities of the methods of obtaining medical information lead to the selection of two groups of personal health data. The first group is data verified by specialists. This group includes data obtained as a result of research using approved methods and clinical protocols. Such studies are carried out by specialists of diagnostic departments in hospitals and laboratories using certified devices that provide

data on various physiological and functional systems of the body according to modern recording standards and are suitable for storage in databases (DB) without prior processing. Such data make up the main share of digital medical information for intelligent information technologies.

Personal medical data of the II group is a characteristic feature of the rapid development of modern mobile technologies, which enable patients to determine health indicators on their own. First of all, let's note the numerous mobile devices and gadgets that provide information about the cardiovascular system (portable medical devices for ECG, pulse oximeters, a device for daily pressure monitoring etc.), wellness gadgets — to ensure the improvement of health, well-being and emotional state, system testing itself etc. The peculiarity of such measurements is that they are carried out according to the methods of personal, direct data collection and often require initial verification before being stored in various levels of storage.

From these two groups of data, different in terms of the source of their generation, different representative attributes for recording and storage technologies are formed: electronic health records (EMR) as digital versions of paper charts, electronic medical records (EHR), which collect extensive primary information about a patient from many medical institutions and the patient's electronic health passport — a personal health record (PHR) that contains information about the patient's health throughout life.

To create formalized electronic medical documents, it is necessary to take into account at what level of medical care this document will be used. Most often, these documents will be universal for each level (Figure 1).

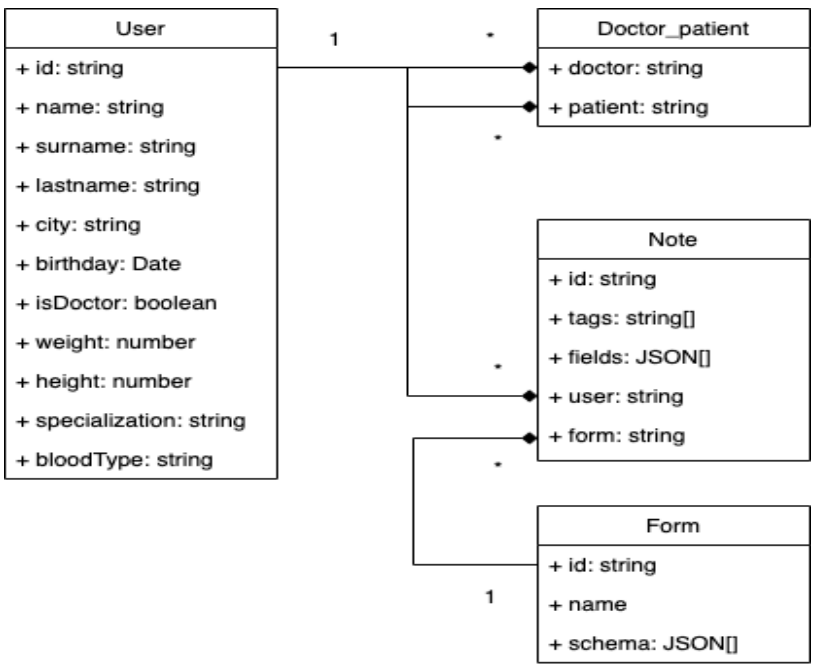

Fig. 1 Data description structure as a class diagram in UML notation

It is worth emphasizing that the PHR can provide valuable representative data for clinical course evaluating and provides a level of reliability that cannot be achieved by traditional patient surveys alone. This concept is the most important component of joint decision-making between the patient and his doctor [19]. Most users and patients receive care from multiple health care providers, and thus their health data are distributed across paper-based and EMR-based systems.

Methods and means of obtaining data on adverse environmental factors. The growth of industrial development and agricultural production under the conditions of non-compliance with environmental standards leads, accordingly, to a decrease in the ecological cleanliness of the environment due to the contamination of its components with heavy metals and harmful chemicals. Therefore, it is currently necessary to carry out constant monitoring of the quality of drinking water, food products and determine the ecological state of environmental objects in view of the increasing impact of their quality on human health.

The sanitary and hygienic regulation of Ukraine is based on the concept of maximum permissible concentrations (MPC) of harmful substances in drinking water and food products, i.e. such a concentration of a chemical element or its compounds, which during daily exposure to the human body for a long time does not cause pathological changes or diseases, which are established by modern research methods.

Electrochemical methods of analysis are widely used to determine concentrations of toxic elements in drinking water and other environmental objects. The method and technology for assessing the risks of drinking water consumption developed by us, one of the components of which is the "ICP Analyzer", ensure an express measurement of the concentration of 12 chemical substances (Pb, Cd, Cu, Zn, Se, I, K, Na, Ca, F, NO3, NH4) in water objects on site and eight toxic elements (Hg, As, Sn, Ni, Co, Mn, Cr, Fe) in the laboratory, which enables rapid analysis of toxic chemical elements to assess risks of health deterioration of a person in case of consumption of contaminated drinking water [20].

MAIN CHARACTERISTICS OF THE PROCESS OF STORAGE AND EXCHANGE OF DIGITAL MEDICAL DATA

In the ecosystem of digital medicine, different algorithms for the exchange and storage of medical data, which depend on the purpose of such applications, can be implemented. Therefore, data accumulation can be carried out in different storages according to the applied information technology. It should be noted that repositories can be located both in the "cloud" and on specific servers. But the storage technology depends on the type of information product — electronic records or documents, digital medical images or graphic files. We will not dwell on the description of each of them. The main thing is that more often the recording of medical data is carried out with the formation of databases to ensure their further exchange.

One of the main challenges for the healthcare sector is solving the problem of fast, convenient and secure exchange of information about the health of patients, in particular, their medical documents. As health care facilities (HCIs) increasingly use information technology tools and the scope of information processing operations expands, the need for effective patient data sharing becomes critical.

First of all, it is necessary to analyze who will be participants in the process of exchanging digital medical data, and the specifics of their interaction in the case of providing various medical services.

Define several levels of organization of interaction of participants in providing medical services [21].

The first level is the formulation of requirements for interconnection, taking into account the technical characteristics of a specific addressee system or software module for the safe transfer of data to another structure and the receipt of data from it.

Level II — definition of the data exchange format.

Level III — provision of common underlying models and data codification, including the use of data elements from standardized coding vocabularies, providing common understanding and meaning to the user.

Level IV is organizational, covering governance, policy, social, legal and organizational requirements for secure, seamless and timely communication and use of data both within and between organizations.

These components enable shared consent, trust, and integrated end-user workflows in a digital health infrastructure.

Today, all data and health information operations directly depend on the level of interoperability in the healthcare industry, as interoperability is known to mean the ability of different information systems, devices and applications to access, exchange, integrate and share data in a coordinated way to ensure timely and seamless exchange of information and optimize the process of providing medical care.

To ensure the appropriate level of interoperability, each subject/object of interaction has appropriate characteristics, consistent with its role function in the process of medical data exchange.

A common requirement for all participants in the process of providing data for their exchange is to ensure the quality of data in the electronic environment. In other words, in an electronic environment, everyone from administrative and support staff responsible for special programs to direct caregivers documenting patient records will be tasked with ensuring data quality [22].

Since Digital Medicine Ecosystems are developed on the basis of the main functions that are implemented during the exchange of information and data between various participants in the process of providing medical care, this is taken into account in the information model of medical data exchange in the digital medicine ecosystem that we have created. At the same time, it becomes extremely necessary to control access to stored data of various users: permanent or temporary service providers, laboratories, clinics and specialists of various profiles, in order to prevent accidental or malicious use of medical information [23], therefore, great attention is paid to compliance with the requirements of protected health information (PHI) [24].

We have developed a special adaptive architecture for the digital health ecosystem, which enables an integrated solution to the problems of data exchange between the participants of this system using web services. The data is uploaded in various formats (DICOM, WORD etc.) and transferred between medical information systems in real-time, at the user's request. The transfer pattern depends on the operating conditions or limitations of the digital health ecosystem.

The principles of healthcare data interoperability are of great value, which combine technical, syntactic, and semantic characteristics [25–27]. Technical interoperability mitigates the effects of remoteness through networks, interface specifications, interconnection services, data integration services, data representation, exchange etc. Syntactic interoperability concerns the mechanisms of data transmission and is the basis for semantic interoperability, which supports the main function, specifically, the binding to data values.

Therefore, the goal of achieving semantic interoperability can only be achieved when the meaning of shared information is implicit in the interacting applications and services or in the communication regarding the exchange of medical services information. These three types of compatibility are equally important for maintaining a consistent and accurate approach to health information exchange, and thus for achieving the primary goal of quality in healthcare. Information consistency often causes errors, and this becomes even more challenging as the system grows larger and more complex with an intense increase in information, which affects higher error rates. The solution to maintaining end-to-end integrity does not come from a single healthcare provider or hospital, but will necessarily be a collective and cost-effective effort by all healthcare providers across the industry. Thus, the distribution of health information in the form of electronic health records and the transfer of data to different healthcare organizations results in the requirement to apply standards for the exchange of patient data and help healthcare organizations effectively manage and share data.

Modules for the accumulation and exchange of digital medical data must be based on compliance with the HL7 standard for the registration of medical information services and their results, in accordance with the requirements of service-oriented architecture (SOA) for information exchange. It should be pointed out that in order to improve the provision of healthcare services, it is necessary to have technically reasonable interoperability standards, taking into account a common set of requirements for accessing information systems of all healthcare institutions.

To unify these processes, we used the international standard of the HL7 family — FHIR. The Healthcare Interoperability Resource is a draft data standard developed and maintained by HL7 International. FHIR was created considering the complexity of healthcare data and uses the Internet to connect various discrete elements [28].

CHARACTERISTICS OF INFORMATION FLOWS OF MEDICAL DATA EXCHANGE

Today, the creation and implementation of software modules for storing and exchanging clinical information is recognized as relevant by many developers of E-Health information and telecommunication system. The functionality of the software module for medical data exchange is aimed at creating a single information space in the digital health ecosystem to increase the efficiency of using the accumulated data in the diagnostic and treatment processes.

The integration of software modules and systems for diagnosing specific pathologies and organizing the effective exchange of received and stored medical information is based on ensuring the efficiency of E-Health information flows.

The definition of E-Health information flows takes into account the personal level of data handling, the level of a primary care and secondary care specialists. These levels also reflect roles and determine the ways of transferring personal medical information between participants in the process of providing medical care, which are taken into account in the created algorithm for exchanging personal medical data (Fig. 2)

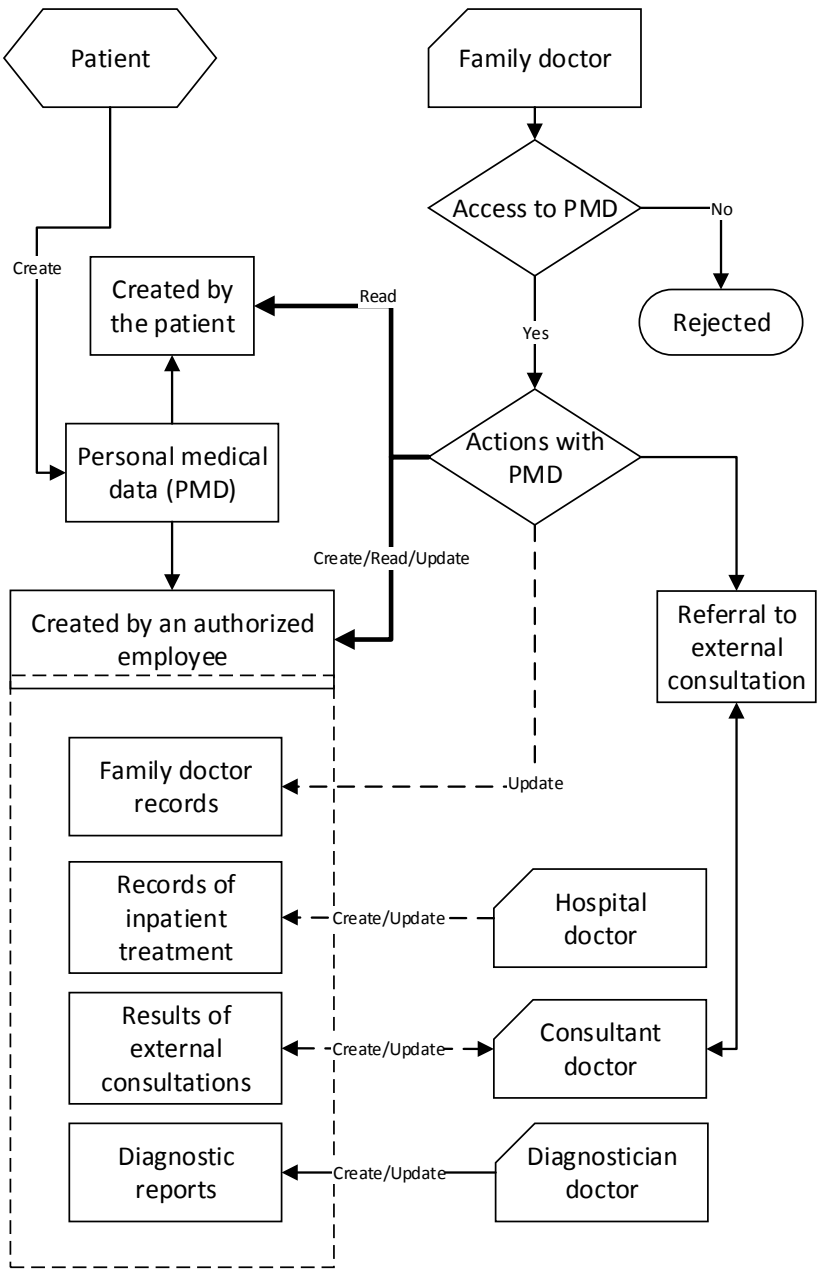

Fig. 2. Algorithm for exchanging personal medical data

It is important that in order to organize the effective exchange of digital medical data between patients, doctors, and other healthcare providers, the following requirements must be met: system interoperability and multi-platform capability, scalability, and a high degree of data encryption.

The transfer of technological information (identification and authentication data) to the central cloud storage is carried out from all the components shown in the diagram.

We built the cloud platform based on the Platform as a Service (PaaS) service model, and the deployment model is a private cloud or personal cloud, and the software consists of a server and client part. For the server part, one should install VirtualBox with Apache2, PHP, and MySQL on the Windows, IOS, or Unix platform and place the ownCloud software product (Univention-App-owncloud-virtualbox.ova).

INFORMATION AND SOFTWARE MODULES FOR STORING AND EXCHANGING MEDICAL AND ECOLOGICAL INFORMATION

Based on the defined requirements and basic characteristics of the processes of obtaining, accumulation and exchange of medical and ecological data, a group of information and software modules has been formed, which also have blocks for analyzing these data. Let's analyze two typical information and software modules with the function of mobile connection in the process of personal medical data transmission.

Information and software module ExchangeDMD-1. The purpose of the ExchangeDMD-1 is to ensure the exchange of digital medical data between different clinical units to improve the work of healthcare professionals, manage this data, and, subsequently, exchange data with the central database of the electronic healthcare system. The databases of these units contain information on the implementation of appropriate treatment and rehabilitation activities for patients with various diseases after stroke as well as diabetic patients.

The use of this module is also aimed at improving communication between healthcare professionals and patients and optimizing patient access to a wide range of medical data stored in various healthcare facilities, software devices, or mobile applications.

The diagram of information flows of the ExchangeDMD-1 module is presented in Figure 3.

Specialized module "ClinAss". Individualized medical care in a clinical environment is an important factor in improving the process of providing medical services. It focuses on clinical indicators and disease progression at the individual level, which makes it possible to understand the course of diseases and their treatment in various patients' conditions, in other words, it considers health problems at the population level (from a group of patients to each of them).

The specialized module "ClinAss" has advanced functionality, combining the processes of exchanging stored information about the patient's condition with a block for assessing and predicting changes in this condition based on clinical data (Fig. 4). The unit for analysis and prognostication was developed based on the information technology for determining the severity of patient's condition [29].

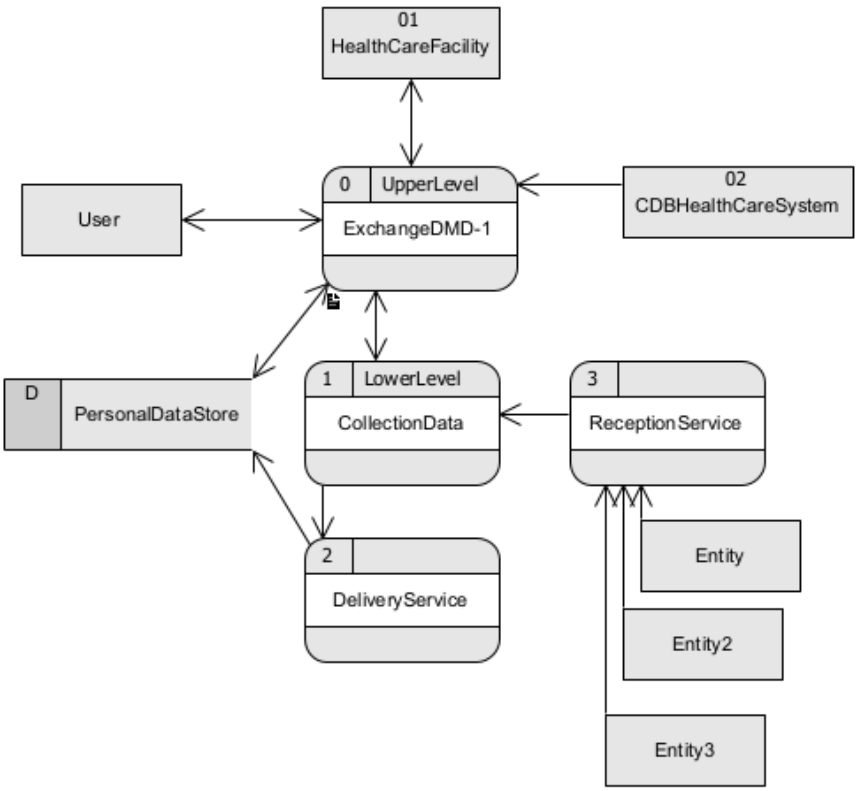

Fig. 3. Data flow diagram (DFD) of the ExchangeDMD-1 module

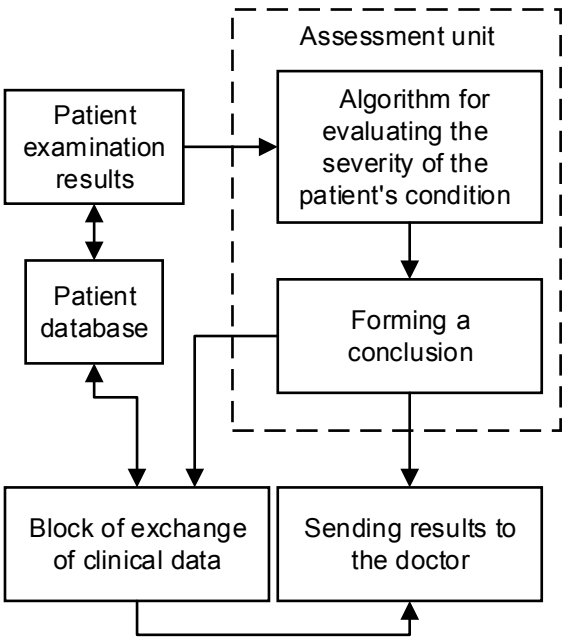

Fig. 4. Architecture of the software module "ClinAss"

According to the formalized business processes, patient data is stored in a database located in the cloud storage. To support the process of choosing treatment tactics, the clinical data of a particular patient is compared with the results of class prediction, which makes it possible to determine the severity of the disease. The results of the comparison aid the physician in determining the best treatment tactic, which are adjusted to some extent by the local protocol.

Software module for assessing the risks of disease in case of contaminated water consumption. The basic component of the software module integrated into the software of the "ICP Analyzer" device is the developed algorithm for predicting the risks of diseases in case of using contaminated drinking water. Assessment of the risks of the occurrence of diseases is carried out by the sequential implementation of three stages:

stage 1 — measurement of chemical elements concentrations in drinking water samples;

stage 2 — health risk assessment;

stage 3 — analysis of the results of the risk assessment of human diseases in case of consumption of contaminated drinking water.

The general computer system of the device consists of three independent subsystems: processing analytical data of chemical element concentration measurements separately for inversion chronopotentiometry and chronoionometry methods, as well as a module for assessing the risks of human disease in case of drinking water consumption (Fig. 5). The subsystems are united by a common information system with a database and a measuring device.

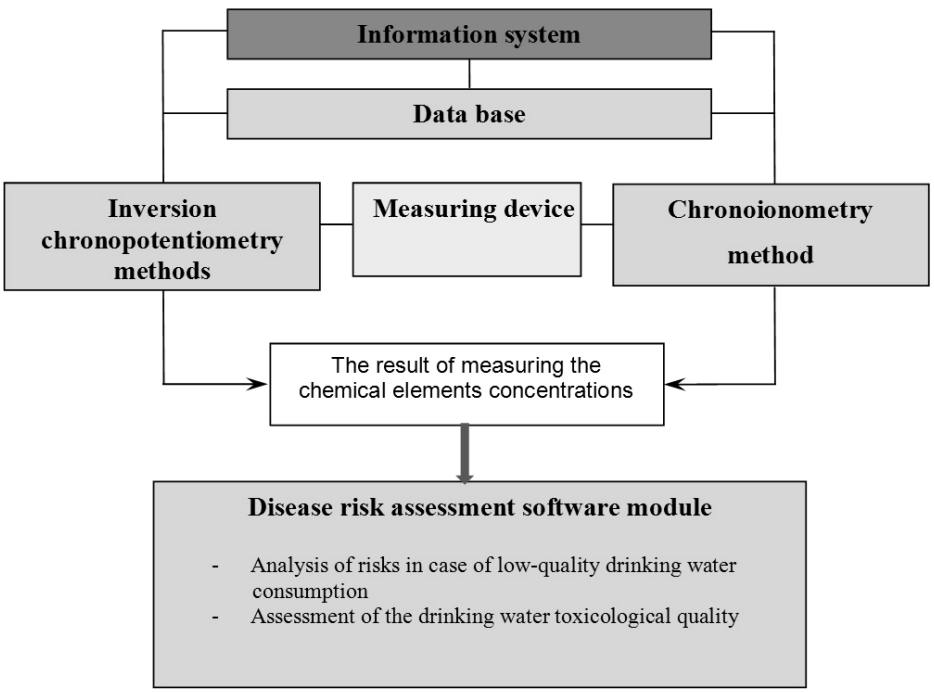

Fig. 5. The structure of the program module for the assessment of disease risks in case of consumption of contaminated water

Mobile applications that measure the chemical elements concentrations according to the specified methods and assess the risks of disease from the contaminated water consumption are aimed at using cloud technologies to store data on the chemical elements concentrations measurement obtained by devices such as "ICP Analyzer" and the results of assessing human risks in the case of drinking low-quality water.

Software of information and software modules. The software modules are client-server applications that handle data in conjunction with a database management system.

Server technologies used: the main programming language: PHP 8.0; server software: Apache 2.4.23 or Nginx 1.5.13; database management system: MySQL 8.0.17; an additional package of functions: NET_HL7 1.0.1. Client technologies: the main markup language of the project: HTML 5; the main language of the project styling: CSS 3 or CSS 4; additional libraries: jQuery 3.3.1, Bootstrap 4.0.

At the application (service) level, which provides interfaces to patients and healthcare professionals of different levels, the development technologies used are JavaScript React, ECMA 5 standard. These technologies make it impossible to interact asynchronously with authorization and workflow services, laboratory services, and objects in JSON format.

The client-side of the software runs on mobile devices with Android, IOS, or Windows Mobile platforms, and personal computers with Windows, IOS, or Unix platforms.

The exchange of digital medical data is primarily focused on the availability of information in full at any given time. For this purpose, in the proposed structure of information interaction, a doctor, using a mobile application or a stationary workstation, has access to the "Doctor's Personal Account", which provides access to the medical data of his patients. The specialist's workspace also has a module that allows the use of decision support algorithms. It is also taken into account that the doctor has limited access to the patient's medical data until the patient allows viewing a certain list of them.

To sum up, the information and software modules described above are developed to facilitate the main functions during the exchange of information and data between different participants of the researched processes, as determined by the analysis of the requirements and main characteristics of the obtaining, storing and exchanging digital medical data in the digital healthcare infrastructure and environmental monitoring.

CONCLUSIONS

Software modules implement one of the main functions of the digital health ecosystem and environmental monitoring — obtaining, storing and exchanging of digital health data circulating between ecosystem participants. The main specificity of such exchange and storage is the implementation of interoperability principles that allow for the fast and efficient performance of such functions.

The developed information and software modules serve diverse purposes and enable the creation of a common information environment in the digital healthcare ecosystem. Specifically, they allow for the creation of a patient health status database that can be stored on any storage, in particular, cloud storage.

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БАЗОВІ СКЛАДНИКИ ПОБУДОВИ ПРОГРАМНИХ МОДУЛІВ ДЛЯ ОДЕРЖАННЯ, ЗБЕРЕЖЕННЯ ТА ОБМІНЮВАННЯ МЕДИКО-ЕКОЛОГІЧНОЮ ІНФОРМАЦІЄЮ

Вступ. *Наразі велике значення набуває обмін медичними даними та інформацією, який здійснюється між закладами охорони здоров'я, сховищами даних, пацієнтами та різними мобільними засобами, які функціонують в середовищі мобільної медицини чи телемедицини, та пацієнтами.*

Цифрова трансформація в галузі охорони здоров'я охоплює запровадження електронних медичних записів (EHR) у практичну медицину, створення інформаційних технологій оброблення складної медичної інформації з використанням штучного

інтелекту, побудову телемедичних систем та розроблення медичних пристроїв, програмних модулів і мобільних застосунків, які повністю змінюють спосіб взаємодії з медичними працівниками, спосіб обміну даними між провайдерами та шляхи прийняття рішень щодо планів діагностування, лікування, реабілітації та профілактики захворювань.

Наразі з метою підвищення ефективності профілактичних заходів щодо широкого кола захворювань нагальною потребою є розроблення систем та приладів екологічного контролю, побудованих з використанням сучасних бездротових технологій, хмарних сервісів та систем мобільного зв'язку.

***Мета** проаналізувати основні вимоги та характеристика інформаційних потоків обміну цифровими медичними даними і реалізувати їх у інформаційно-програмних модулях для збереження та обмінювання клінічною інформацією.*

***Результати.** Сьогодні всі операції з медичною інформацією напряму залежать від рівня інтероперабельності в галузі охорони здоров'я, тобто від здатності різних інформаційних систем, пристроїв і застосунків отримувати доступ, обмінюватися, інтегрувати та спільно використовувати дані у скоординований спосіб для забезпечення своєчасного та безперебійного обміну інформацією та оптимізувати процес надання медичної допомоги.*

Для забезпечення належного рівня інтероперабельності для кожного суб'єкту/об'єкту взаємодії сформовано комплекс характеристик, узгоджених з його рольовою функцією в процесі обміну медичними даними. Розроблено адаптивну архітектуру екосистеми цифрової медицини, яка дає можливість інтеграційного розв'язання завдань обміну даними між учасниками з використанням веб-сервісів.

За цільовою функцією виділено декілька груп інформаційних потоків, які реалізуються під час взаємодії головних учасників надання медичної допомоги: пацієнт — лікар, пацієнт — заклад охорони здоров'я, лікар — лікар. На основі врахування ролі та шляхів передавання персональної медичної інформації між учасниками, створено алгоритм обміну персональними медичними даними.

Виділені базові характеристики процесу обміну цифровими медичними даними та вимог до структури та функцій інформаційно-програмних засобів підтримки цього процесу реалізовано у інформаційно-програмних модулях для збереження та обмінювання клінічною інформацією.

***Висновки.** Програмні модулі реалізують одні з основних функцій екосистеми цифрової медицини та екологічного моніторингу — одержання, збереження та обмін цифровими медичними даними, які циркулюють між учасниками екосистеми. Основною специфікою такого обміну та збереження є реалізація принципів інтероперабельності, які дає змогу швидкого та ефективного виконання подібних функцій.*

Розроблені інформаційно-програмні модулі різного призначення реалізують методику роботи в екосистемі цифрової медицини з різними програмними застосунками для створення загального інформаційного середовища з розміщенням бази даних про стан здоров'я пацієнтів на будь-якому сховищі, зокрема, хмарному.

***Ключові слова:** екосистеми цифрової медицини, електронні медичні записи, ризики захворювання, визначення концентрацій токсичних хімічних речовин, інтероперабельність, інформаційні потоки, методи аналізу даних, інформаційно-програмні модулі, вимірювальні сенсори.*