A CONCEPTUAL MODEL OF THE DATA ECOSYSTEM FORMATION IN THE HEALTH 4.0

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Abstract: Digitalization of health and medicine has become a global trend in recent years. The development of this trend is manifested in improving the quality of medical care, increasing access to medical services, and ensuring more effective health decisions. The global health trend is characterized by the transition from e-health to digital health, which is closely related to the formation and development of Industry 4.0. The projection of innovative approaches of Industry 4.0 into the health sector opens up great opportunities for creating a new healthcare paradigm (Health 4.0) by integrating modern technologies, analytical tools and smart medical devices. This article highlights Industry 4.0 technologies, the integration of which into healthcare has led to the generation of a huge amount of various data. Data collected through new technologies on the Health 4.0 platform, their types, structure, sources and capabilities are examined. It is shown that for the collection, transmission, storage, processing of heterogeneous data of a large volume, the introduction of new approaches and methods is required. In the environment of technological transformation, the evolution of the healthcare system at the data level and the conceptual model of the chain of formation of the Healthcare 4.0 ecosystem are proposed. The content of the components included in the Healthcare 4.0 data ecosystem is determined. Some problems arising in the formation of the data ecosystem on the Healthcare 4.0 platform and the processing of large health data are studied.

Keywords: health data, Health 4.0, data sources, ecosystem, conceptual model, IoT, Big Data.

1. Introduction

Modern information technologies have significantly changed our personal life and thinking. As a result of transferring the main part of human activity to the Internet, any behavior of an individual leaves certain traces, the total of which leads to a rapid increase in digital information. Thus, as a result of the transition of activities in the healthcare from traditional form to electronic (digital) one, various types of large amounts of data have been accumulated in health information systems and decision support systems in clinics, and this process lasts dynamically. The issues such as storing and managing a large amount of data and extracting useful information from it are currently becoming relevant.

Health is one of those areas where data is continuously generated in various formats, in large volumes and at high speed. The types of medical data include technical signals received from devices recording figures (analysis results, electronic health records, statistical data), video (ultrasound examination, radiological images), photo (tomography, radiography), electrical signals (electroencephalogram, electrocardiography) [1]. Different types of data are difficult, if not impossible, to process with traditional software. The main problem is the heterogeneity of medical data, that is, since the data come from different sources and in different formats, their indexing schemes also differ.

The bar-chart presented below shows the growth trend in the volume and speed of data collected from various sources in the health sector from 2012 to 2022. The data for 2022 was projected based on the results of previous years (**Fig. 1**).

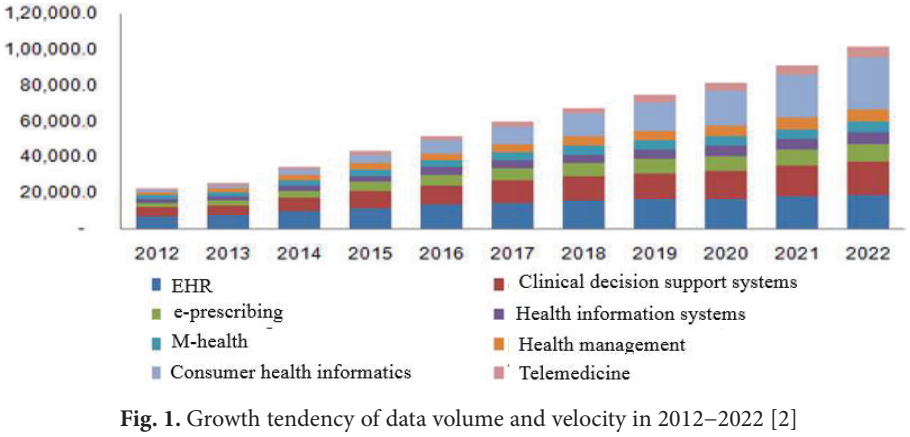

Fig. 1. Growth tendency of data volume and velocity in 2012–2022 [2]

Data analytics enables revolutionary changes in the health system. Improving the efficiency of medical services can help predict infectious disease epidemics and optimize health costs.

The basis of Health 4.0 is a system of medical services based on modern technologies such as wearable and implantable devices, the Internet of Things (IoT) and the Internet of Medical Things (IoMT), smart sensors for collecting, processing and transmitting health data, Wireless Sensor Networks (WSN), technologies for processing and storing big health data – Big Data, Cloud (Fog, Dew) Computing, Cyber physical systems, 5G. These technologies provide direct access to medical services regardless of time and place and reduce the high cost of provided medical services [3–8].

The aim of this research is to identify the sources and nature of health data in the Health 4.0 environment and explore new opportunities for collecting and sharing data, transferring, processing, analyzing and storing them by creating an ecosystem of data that expands the effectiveness of medical services.

2. Methods

This study is based on a review of the literature on the integration of Industry 4.0 technologies and tools into healthcare, as well as innovative digital technologies, which make it possible to identify priority areas for research in the Health 4.0 environment. From the most common and accessible databases (GoogleScholar, ScienceDirect, Scopus, ResearchGate, etc.), systematic reviews are identified, including a large number of articles on the problem under study, and research papers in this area. In the process of literature analysis, the publications with the most relevant through the prism of the aim were selected. The study of the literature identifies the multidimensional character of health data in the Health 4.0 environment and develops the authors' approach to the formation of a data ecosystem.

3. Results

As a result of the conducted research, let's propose below the conceptual model of the evolution of the healthcare system at the data level and the formation chain of the Healthcare 4.0 ecosystem in the environment of technological transformation (**Fig. 2**).

The content of each component that makes up the conceptual model of the Health 4.0 data ecosystem is presented in **Fig. 3**.

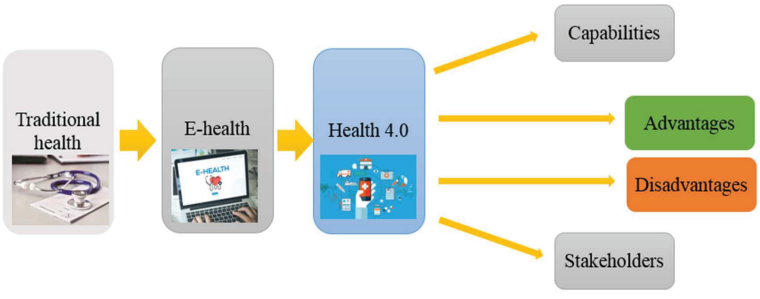

Fig. 2. A conceptual model of the healthcare 4.0 data ecosystem formation chain (Source: developed by the authors)

Traditional → E-health data source	E-health → Health 4.0 data source	Capabilities and tools	Stakeholders	Advantages	Disadvantages
• Clinical systems • Administrative systems • Scientific studies • EHR • Telemedicine • Public health • Health services • MRT • EKQ etc.	• İoT • Social media • Self-monitorinq wearables • Sensor apps • Mobile apps • Wellness • Fitness internet • Holography etc.	• Visualization • Integration • Prediction • Modelling • Synthesis insights • Artificial intelligence • Machine learning • Deep learning etc.	• Health providers • Citizens, consumers, patients • Research institutes • Health technology • Insurance • Pharmacy • Government etc.	• Real-time feedback • Effective health services • Improving the quality of the decision-making process • Expanding health research • Fast diagnosis • İncrease quality etc.	• Need security • Data confidentiality • Storage • Heterogeneous structure • Short time monitoring • Interoperability etc.

Fig. 3. Content of the components included in the Health 4.0 data ecosystem (Source: developed by the authors)

4. Discussion

As a result of the digitization of health, health data is currently distributed across the following three main standard sources:

– clinical systems: Health information system, emergency information system, hospital information system, medication management system, medical services quality management system, laboratory information system, physician's personal account, patient's personal account, etc.;

– administration systems: Resource management system, catalog management system, business process support system, single payment system, situation center, sanitary condition monitoring system, etc.;

– scientific research and scientific works: Medical publications, research reports, the result of R&D activities, surveys, etc.

Different types of data collected from these systems can be grouped into the following categories [9]:

– Structured health data;
– Unstructured health data;
– Health description data;
– Biomedical (genetic) data.

For diagnostic and treatment decisions, there is a need to integrate clinical information and biological data that are in different formats and generated from different heterogeneous sources. For example, medical information may be presented in the form of numerical values in arbitrary units, images, texts, handwritten notes and doctor's prescriptions, gene and protein sequences and so forth. Joint storage, comparison and conversion of different data types require solving very complex problems such as image recognition, data compression, etc. Here, medicine does not always take advantage of ready-made solutions from other areas [10].

Fig. 4, a modification of the figure given in [11], illustrates health data flow. Here, Data warehouse stores large volumes of digitized data obtained from various sources. This data is processed using analytical methods to make smarter and more appropriate healthcare decisions.

Electronic health records offer many advantages in data collection and management processes in modern health. The main advantage of EHRs is that medical professionals have access to the entire health history and data of the patient. This data includes medical diagnoses, prescriptions, information about certain allergic diseases, demographic information, and results from various laboratory tests.

Telemedicine increases the quality of service by combined analysis of information about patients received from different sources. The main advantage of telemedicine is that physicians can view the patient's data collected through smart devices in real time, monitor the chronic disease and prescribe treatment without visiting the hospital.

Data collection sources in the Healthcare 4.0: Internet of Things: One of the main sources for collecting health data in the Health 4.0 is the Internet of Things. The Internet of Things is a global network of "things" (sensors, transmitters, and information transmission devices ensuring data collection and sharing) equipped with physical devices connected to the Internet [12]. The integration of IoT technologies into health aims to continuously collect health data and send them to cloud by replacing outdated medical devices with smart devices, robotic surgical instruments, etc. IoT generates a continuous data flow while monitoring the health of people (or patients), which leads to the generation of Big Health Data [11].

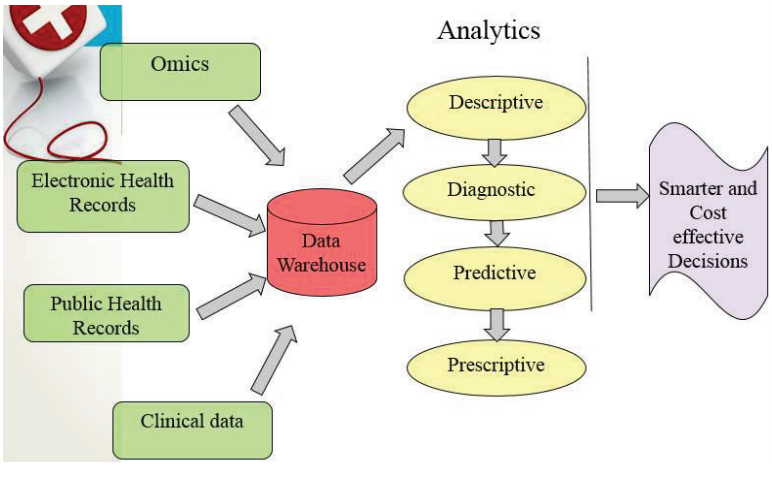

Fig. 4. Data Flow collected from e-health sources

Holography: Holography provides better communication for humans due to the extensive capability of 3D visualization of a patient's body with high resolution [13].

Mobile health (mHealth): In the present digital world, every individual can track fitness and health statistics using the devices as smartphones, smart watches, etc. Special platforms for data collection through connected sensors have been produced for the integration of devices and data [1].

Health data processing issues: the rapid growth of data in health creates a number of challenges along with great opportunities:

– Storage – storing large amounts of data is one of the main challenges. To overcome this problem, the introduction of cloud-based storage technologies is one of the best options for most health organizations;

– Data cleaning – once data is obtained, it must be cleaned to ensure its accuracy, correctness, consistency and relevance;

– Uniform format – health coding systems such as Current Procedural Terminology and International Classification of Diseases have been developed to represent key clinical concepts for the problem solution;

– Data reliability – data collected about patients are not completely accurate. This factor reduces the quality of big data;

– Image processing – improper handling of health images can lead to the modification of images, for example, the analysis of various unrelated structures instead of the real situation analysis;

– Security – data security is one of the highest priority issues for health organizations. Use of security tools, sensitive data encryption, and other security measures may solve this problem;

– Data sharing – in situations when patients get treatment at several hospitals, information needs to be shared with other health organizations. When the data is shared, since the health data systems of separate health organizations differ from each other, technical and organizational obstacles arise in the exchange of information.

5. Conclusions

The generation of large amounts of data in the Health 4.0 environment and the processing and analysis of this data with new analytical tools create opportunities for the formation of new strategies and goals for medicine.

In the article, a conceptual approach and model for the formation of the data ecosystem in the Health 4.0 environment is proposed.

The types, structures, sources and capabilities of data, which are the main elements of the Health 4.0 ecosystem, are explored. The medical data collected from the sources created by the innovative technological base of Health 4.0 were classified according to their heterogeneous nature and their main characteristics were analyzed. The problems that may arise during the management, analysis and processing of large volumes of health data were indicated.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has no associated data.

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