# DEVELOPMENT OF DIGITAL TWIN ECOSYSTEM AND ONTOLOGY IN MEDICINE

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**Summary:** Providing citizens with high-quality and safe medical services, providing information support for medical research and continuous medical education, making both doctor's decisions and management decisions necessitated the provision of tools to ensure complex digitization of healthcare. To achieve these goals, a wide range of modern technologies have emerged. One such technology is digital twin technology.

Modern medicine, being formed in the environment of Health 4.0, includes not only the treatment of patients, but also the management of healthcare, the prevention of diseases and the processes of health restoration. With the increasing popularity of information communication technologies, people's demand for health services is shifting from offline service to new online models. Currently, the field of online medicine is not developed enough to serve the elderly, chronically ill people and the people with infectious diseases. Using the advantages of digital twins in solving these problems can give positive results.

The article describes the nature, capabilities and applications of digital twin technology. The principles of the formation of the medical digital twin ecosystem are developed to ensure citizens' accessibility to medical services and to make both medical and managerial decisions. The architecture and structural components of the digital twin ecosystem providing the connection between physical medical objects (patient, hospital, doctor, etc.) and their virtual images are shown. An ontological model for the staged construction and functionalization of the general DT of healthcare is proposed and its hierarchical architecture is established.

**Keywords:** medicine, real object, physical object, digital twin, virtual object, architecture, ecosystem, visualization system, ontology, medical exchange.

## 1. Introduction

Currently, the fourth industrial revolution, i.e., Industry 4.0, is taking place in the world, smart factories, smart devices and the Internet of Things are replacing humans in production. The capabilities of the technologies provided by industry 4.0, which ensures the digitization of healthcare, have enabled the widespread use of the intelligent and self-regulating paradigm of the "Internet of Things" connected to a dynamic network infrastructure. These technologies have also led to the emergence of new medical mobile applications and the rapid integration of quality mobile devices into clinical practice [1]. Today, digital technologies are applied in a complex and targeted manner in almost all areas of medicine. The generation, collection and joint processing of heterogeneous medical data previously took a lot of time and was implemented offline, whereas now, there are opportunities for real-time processing of this information and research in this direction is being deepened day by day.

The acceleration of the trends in the use of digital technologies expands its boundaries and possibilities, and as a result, the phenomenon of "digital transformation" emerges. Digital transformation ensures the transformation of data into information and knowledge and its use for effective decision-making based on the new knowledge gained [2]. One of the basic technologies of digital transformation, the Digital Twin (DT) acts as a digital copy of the physical object or process they represent, enabling the monitoring and evaluation of the process in real time regardless of the location.

There is no uniform definition of DT. Many definitions depend on the purpose and potential application area of DT technology. For example:

1) DT can be expressed as a virtual digital copy of an animate or inanimate physical object [3].

2) Combining sensor data, computer modeling and artificial intelligence algorithms, DT can be defined as a digital mirror of the created real world [4].

DT tests and predicts the effects of the implementation of certain options, solutions, as well as to visualize the obtained results in a convenient form [5]. A connection between the DT and its equivalent in real-life that ensures a continuous and reliable flow of information is a prerequisite.

## 2. Methods

This study is based on a literature review of digital twin technologies and tools emerged in the digital transformation environment, as well as the integration of those digital technologies into healthcare. Systematic reviews from the most common and accessible databases (Google Scholar, Science Direct, Scopus, Research Gate, etc.), including a large number of articles on the studied topic and research articles in the field are identified. During the analysis of the literature, the most relevant publications are selected from the perspective of the goal. The literature review made it possible to determine the functions of the general architecture and structural components of the digital twin ecosystem, which provide the connection between physical medical objects (patient, hospital, doctor, etc.) and their virtual images, and to build an ontological model for the creation of a general DT of healthcare.

## 3. Results

As a result of the conducted research, an architecture of the DT ecosystem in medicine is proposed and it is depicted in **Fig. 1**.

The architecture of the DT includes physical and virtual objects, technologies ensuring the connection between them, a unified database of medical data, a centralized management system and visualization systems. A virtual object is software consisting of a set of applications that explain the behavior of a medical object on a computer. Applications are used as a real-time monitoring system for the object's activity, and this system operates throughout the entire life cycle of the object.

Medical digital twins regularly collect sensor data from relevant real-world physical objects (patient, hospital, doctor, medical devices, organs, etc.) via 4G/5G, IoT, IoMT. As the volume of this data increases, digital twins also develop and enable effective and smarter decision-making using AI and Big data technologies [6]. Developing a visualization system to see the effectiveness of the decisions made is one of the important processes. Visualization system represents data management models in various fields of medicine, information received from various sources and results visually. This enables effective monitoring, control and management of processes occurring in a medical physical facility.

Machine learning (ML) methods, one of the leading fields of artificial intelligence, are used for training, validating and optimizing the digital model. ML ensures the construction of the most suitable models by applying methods on datasets formed on the basis of past experience.

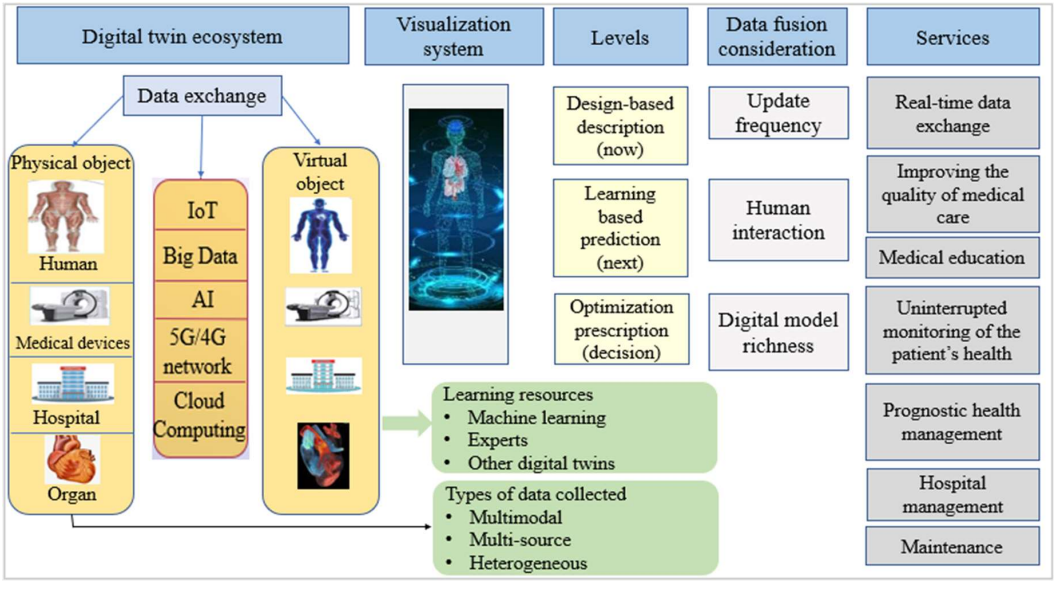


**Fig. 1.** Architecture of the medical digital twin ecosystem

In the healthcare sector, being heterogeneous, medical data is collected from various sources, and there is a need to understand the common semantics of this data. A possible solution to this semantic interaction problem is possible through applying an ontological approach. Ontology is a hierarchically structured set of general and specific terms used to describe and present a subject area [7]. The task of ontologies is to maximally represent the semantics, properties and inter-word relations of terms. Standardized ontologies have recently been developed in many fields. However, each ontology depends on the subject area, its specific components and the semantic relations between them. Taking these into account, let's build an ontological model of the health system. **Fig. 2** illustrates the hierarchical architecture of the ontological model.

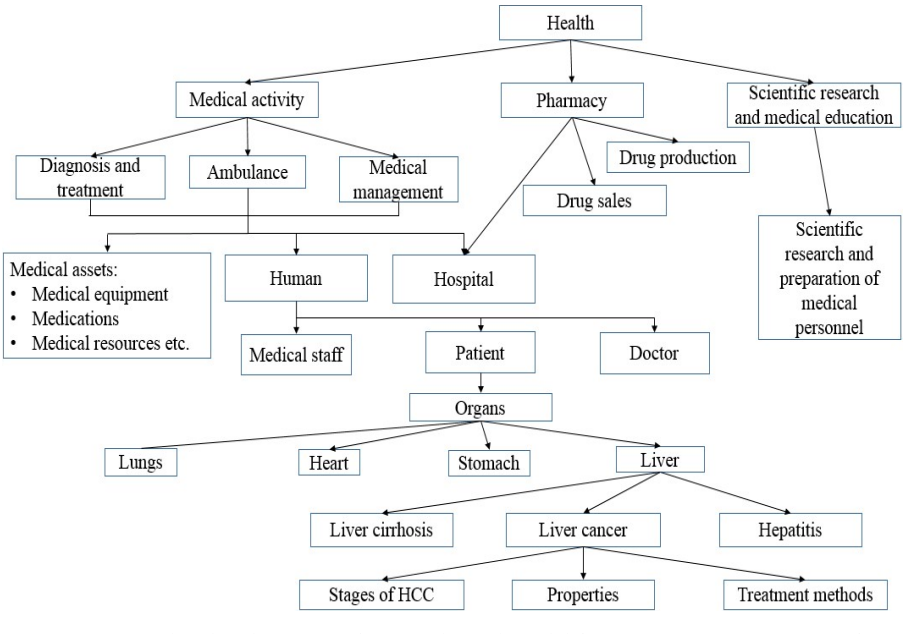


**Fig. 2.** Hierarchical architecture of an ontological model for creating a common DT of a healthcare system

While to agree with researchers who welcome the concept of a digital twin, it is also recognized that creating a complete healthcare DT is a long-term and step-by-step process. Through the ontological model described above, a common digital twin of the healthcare system can be created in stages. With the help of digital twin technology, research is already being done in the field of creating a digital twin for each individual human organ and diseases related to these organs.

## 4. Discussion and scope of application

Healthcare is considered to be one of the promising areas where DT technologies may have a revolutionary impact. DT is designed to provide more effective medical interventions and help physicians and medical technologies understand the patient's health status [8]. One of the main conditions for the application of DT in medicine is the availability of its physical object in the real world. A medical DT is a dynamic digital model that contains all the input data about a physical object or medical system. Medical digital twins can be used to solve many problems in healthcare. They may include early diagnosis of any disease in the initial stag e and monitoring of subsequent development trajectories, optimization of the time of medical assistance, development of personalized medicine, identification of drug effect mechanisms, etc.

According to the proposed general ontological model, a virtual DT can be created by collecting certain data from a large number of physical objects in the healthcare system [9]:

– patient: genetic data, laboratory results, medical images, biomedical signals, personal data, social determinants;

– hospital: medical resources (equipment, medicines, etc.), personnel resources, operational information within the hospital, building layout;

– data collecting medical devices – sensor data, quality indicators, environmental data.

Along with the physical objects mentioned above, the digital twins of certain parts and organs of the human body can also be

created. Currently, a digital twin of the human heart is created using data collected by medical devices to simulate the physiological processes of a real human and tested to solve multiple medical problems [10]. It should be noted that the heart of each person is individual, consequently universal anatomical models based on population data are useless here. In contrast, the digital twin of the heart represents the individual characteristics of each patient.

Presently, the possibilities of digital twins of the human heart to increase their effectiveness in the diagnosis, prognosis and treatment of various heart diseases are investigated and their practical applications are analyzed. The positive results obtained, the processes and technologies applied for the creation of the cardiac DT can be used as a blueprint for the creation of other medical DTs.

## 5. Conclusions

This article analyzed the essence of digital twins, which are one of its basic technologies formed as a result of digital transformation, and explored the formation of the digital twin ecosystem and its possibilities in medicine. The architecture of the medical digital twin ecosystem was developed and its components were described. Moreover, the hierarchical architecture of the ontological model was established for the staged construction and functionalization of the general DT of healthcare.

## 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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The study was performed without financial support.

## Data availability

Manuscript has no associated data.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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