Integration and Standardization in New Generation Intelligent Medical Systems Based on OSTIS Technology

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***Abstract*—The article discusses the integration of international medical standards in Russia, Belarus, and Kazakhstan using semantic technologies. It describes OSTIS (Open Semantic Technology for Intelligent Systems) — an open project for creating common semantic technologies for the component design of intelligent systems. An example of the integration of various medical records standards in intelligent medical systems is given. The advantages of such integration are the improvement of the exchange of medical information, simplification of the diagnosis and treatment process, and the possibility of creating a unified medical space within the region.**

***Keywords*—ontology modeling, OSTIS, medical information systems, standardization of medical data, integration of medical systems, International Classification of Diseases (ICD), flexibility and adaptability in healthcare systems.**

I. Introduction

The possibilities of application of new modern technologies in human life are growing day by day. Implementation of artificial intelligence in medical systems plays an important role in medical data processing. The huge amount of data processed in modern medical systems can be quickly analyzed and processed only using the artificial intelligence (AI) element that is being implemented in modern computer technologies. Processing medical data using AI enables the identification of diseases and the patterns and trends of their development, helps to identify pathologies and risks of disease, as well as forecasting the spread of infections and predicting epidemics. This helps doctors and healthcare organizations in general to make informed decisions [1]–[3].

The implementation of AI in medical systems can solve both complex and simpler problems. The complex challenges include the implementation of AI in robotic surgery. The application of AI in robotic surgery could significantly accelerate the development of surgical robots to perform complex surgeries with a high level of precision, which in turn will reduce risks and shorten patient recovery time after surgery. More straightforward challenges include the personalization of medicine, namely taking into account individual patient characteristics: genetic data and biomarker analysis, when developing personalized treatment plans and systematizing patients' medical histories [4], [5].

Electronic medical histories of patients, as well as digital data from medical examinations, patient monitoring data from medical devices, are part of a unified medical decision support system called a medical information system (MIS). MIS is a key element of the medical system. MIS providing automation of document flow and accounting in medical institutions has an important role in modern medicine. And the introduction of AI in MIS allows to move these systems to a new level of development.

II. Problematics of modern medical information systems

MIS is an information system designed for processing, accumulation, storage and retrieval of a patient's electronic medical record. MIS can be classified depending on the area of activity of medical institutions. For example, MIS for hospital usually collects and processes information from all blocks of the information system, including operating and resuscitation units. They may include modules for managing patients, staff, equipment, as well as for monitoring the performance of medical procedures and treatment. And MIS for outpatient clinics, in turn, usually focus on automating processes such as making appointments, working with waiting lists, and maintaining patient registries. They may also include functions for managing doctors' schedules, tracking patients' medical histories, and sharing medical information between different specialists and departments [6].

Thus, it can be concluded that MISs vary depending on the specific needs of the healthcare facility, but all systems will perform functions such as completing a patient's medical record and tracking medical history.

The first thing patients encounter when moving from one health care facility to another is the need to refill out their data for their medical records. Although personal data remains unchanged, the medical history may be incomplete because the patient cannot access all the data about all the examinations they have undergone.

This can make diagnosis difficult and distort the overall picture. It is worth noting that the more systems in which a patient enters their personal data, the greater the risk of this data being leaked.

Protection of patients' personal data is an important element of MIS operation. When implementing an information system, the staff of a health care institution should make certain efforts, for example, they should follow the algorithm of working with the selected information system, enter information into the system using available templates and forms and consistently maintain electronic medical records.

In 2020, during a roundtable discussion at the BELTA press center, representatives of the Ministry of Health and practical medicine discussed the promising directions of Belarusian e-health. And even earlier, in March 2018, the Concept of e-health development of the Republic of Belarus for the period until 2022 was developed and approved. The purpose of which was to develop e-health and create a centralized health information system (CHIS) for the formation of a unified information archive of patients and exchange of medical data [7].

The activity of the CHIS aims to improve the availability and quality of health care by assisting in clinical decision-making, improving the quality and efficiency of management decisions based on statistical and analytical data.

CHIS consists of functional and support subsystems and other subsystems. Supporting subsystems include software and hardware complexes, information protection system and subsystems that ensure proper technical functioning and interdepartmental information interaction of the CHIS. One of the subsystems included in the CHIS is the electronic medical record of the patient and the clinical decision support system.

Thus, we can conclude that the electronic medical record is a MIS, a subsystem of the CHIS. And the main obstacle to the creation of CHIS is the lack of standards in the field of e-health and regulations for the exchange of electronic medical information

As recommended by the World Health Organization and the International Telecommunication Union, a national eHealth system requires the following components: standards and interoperability (component); an enabling environment (role); and standards that will ensure the holistic and accurate capture and exchange of health information across all health systems and services (functional purpose).There are also a number of principles that should be considered when developing a CHIS:

- utilization of cloud computing technologies;
- use of open source software;
- service-oriented architecture, microservices, modularity, possibility to create additional services through open interfaces;
- elimination of duplication of engineering and telecommunication infrastructure;
- Web client technology;
- ensuring information security and information protection;
- scalability;
- simple and user-friendly interfaces, ergonomic and intuitive to use;
- single entry and repeated use of primary information;
- Interoperability of MIS with CHIS.

Thus, there is a need for technology that meets all the requirements for the realization of CHIS and, in particular, MIS.

The results of the implementation of the Concept in eHealth is the creation of the following systems:

1) National registers:
    - State Register "Diabetes Mellitus";
    - State register of persons exposed to radiation as a result of the Chernobyl catastrophe and other radiation accidents;
    - Belarusian Kancer Register;
    - Republican register of HIV-infected patients;
    - Republican register "Tuberculosis".
2) Medical information systems:
    - AIS "Electronic Prescription". This system is designed to automate the process of prescription writing and control over its fulfillment.
    - RSTMC (Telemedicine). Telemedicine system allows doctors to counsel patients from a distance using video, audio or messenger chat.
    - IAS "Zdravookhranenie". This system is designed to automate the recording and analysis of medical information, including data on the health status of patients.
    - IAS "Drug Supply". This system is designed to automate the process of planning and control of centralized procurement of medicines for healthcare organizations.

All these systems are aimed at improving the quality and efficiency of medical care through the use of modern information technologies. They also promote standardization and centralization of medical information, which facilitates data exchange and collaboration between different specialists and medical institutions. In addition, these systems help to ensure the security and confidentiality of medical data.

There are a number of foreign analogs of MIS. Here are a few MIS popular in Russia:

1) ArchiMed+ is a versatile medical software that is suitable for private physicians, medical centers, dental offices, and chain clinics. ArchiMed+ is easily scalable, offers many integrations including third-party labs, labeling system, telemedicine and more.

2) Medesk — this cloud-based medical information system is used in more than 20 countries around the world and in 72 regions of Russia. It is suitable for healthcare institutions of any size, from private clinics to networks. electronic medical records, CRM, telemedicine and solutions for managers and physicians are available in Medesk.
3) KMIS is a complex MIS suitable for automation of any medical institutions, the feature of which is integration with Federal systems.
4) MEDMIS is a relatively young MIS that entered the market in 2017. In 4 years, MEDMIS has been used by more than 200 medical organizations. MEDMIS is constantly evolving and gaining momentum: updates are released once a week.
5) MedAngel is an MIS with the possibility of individual customization for the specifics of the clinic's work. There is only a boxed version of the program with open code. The system is modular, you can assemble a personalized kit.

The list represents the most popular systems on the market. Each system has its own advantages and features, and the choice depends on the needs of a particular healthcare facility.

An Intelligent Medical System (IMS) is an information system that uses artificial intelligence techniques and approaches, including semantic technologies, to process, store and analyze medical data. Such systems represent a key element in modern healthcare, providing effective management of patient information, improved decision-making in medical practice and personalized patient care.

With the rapid development of artificial intelligence systems, IMS are becoming increasingly in demand. Their ability to analyze and interpret large amounts of data allows to reduce the workload of medical personnel, improve diagnostic accuracy and optimize treatment processes.

However, problems arise due to the variety of formats for storing medical data in different countries. Norms and legislation governing the processing and protection of medical information may differ from country to country. For example, the Republic of Belarus, Russia and the Republic of Kazakhstan have different standards and requirements for storing and processing medical data. This can create difficulties in integrating and sharing information between systems, as well as increase the risk of breaches of patient data privacy and security. For successful implementation of intelligent medical systems, it is necessary to take these differences into account and develop appropriate mechanisms for data standardization and interoperability.

III. Proposed approach

At the heart of any knowledge-based IMS is a formalized knowledge base, the quality and volume of which directly affects the effectiveness of the system. For uniform representation and unambiguous interpretation of knowledge bases, a common set of all terms used in practice is required. Terminology should be generally accepted and understandable to medical specialists, i.e. it should be the result of ontological agreement in the field of medicine.

Ontological modeling of the subject domain includes specification, conceptualization and formalization. At the specification stage, a glossary of terms is built, including all terms important for the subject area and their descriptions. In the conceptualization stage, important objects of the subject domain are identified. In this stage, the hierarchy and relationships between the objects of the subject domain are also defined. In the formalization stage, meta-objects and relationships between meta-objects are created that correspond to the objects and relationships between the objects of the subject domain. As a result, an ontology of the subject domain will be obtained. At the actualization stage, object parameters and their domains are defined (parameter domain is the area of acceptable parameter values), as well as values, classes, subclasses and class instances. Parameters, parameter domains, parameter values, classes, subclasses and class instances are realized as metaobjects (a metaobject is some text representing a definition, concept or some other description.) of appropriate types. After the work at the actualization stage, the ontology is turned into a knowledge base. The result of ontology modeling is the ontology of the subject area. To turn the ontology into a knowledge base, it is necessary to actualize it.

In MIS, the problem of incompatibility of data formats is a significant challenge that can hinder effective information sharing and interoperability between different healthcare systems. OSTIS (Open Semantic Technology for Intelligent Systems) is proposed to address this problem. OSTIS provides innovative tools and approaches for creating semantically interoperable medical systems that can efficiently process and store data, regardless of its original format and structure.

One of the key features of OSTIS technology is its ability to unify the representation of different types of knowledge in a single database. This enables the creation of centralized information repositories where medical data can be organized and structured according to common semantic standards, while ensuring a high degree of compatibility and interoperability.

OSTIS technology is also highly flexible and modifiable, allowing the system to be customized to meet the specific requirements and standards of each country, including the Republic of Belarus, the Russian Federation and the Republic of Kazakhstan. As a result, medical information systems based on OSTIS technology can easily adapt to various regulatory and legislative requirements, which ensures their seamless integration into the existing healthcare infrastructure.

One of the key benefits of using OSTIS technology is the ability to automatically convert and compare data from different formats. This helps eliminate interoperability issues and ensures seamless information exchange between different medical systems and institutions, which ultimately improves system efficiency and the quality of care provided.

Thus, the use of OSTIS technology is an effective and promising approach to solving the problem of incompatibility of data formats in medical information systems. It ensures the creation of modern and innovative healthcare systems capable of adapting to a variety of requirements and changes in the medical field, which is a key factor for improving the quality and accessibility of medical care in different countries.

As an illustrative example, let us give the possibilities of using OSTIS formalization technology for two subject areas related to intelligent medical systems.

Formalizing the subject matter of a patient's medical record using OSTIS technology demonstrates significant convenience and efficiency in processing and storing medical data. The formalization process allows describing various aspects of a patient's health, including medical history, diagnoses, treatments and symptoms of diseases.

One of the features of formalization on OSTIS technology is the ability to create a single semantic model that integrates different aspects of medical information in a unified format. For example, information about gastrointestinal (GI) diseases can be organized in the form of semantic entities such as disease type, symptoms, diagnosis and treatment methods.

The advantage of using OSTIS technology is that information on GI diseases can be stored in a single semantic format, making it easier to access and share data between different medical systems and institutions. In addition, thanks to the semantic approach, information about diseases and their symptoms can be structured and categorized for easy analysis and processing.

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IV. The subject area and ontology of a patient's medical record

Medical records are kept according to the order approved by the Ministry of Health. In the Republic of Belarus, this is Order No. 710 of the Ministry of Health of the Republic of Belarus of August 30, 2007 "On Approval of the Forms of Primary Medical Documentation in Outpatient and Polyclinic Organizations". The card of a patient receiving medical care in outpatient conditions must comply with the form 025/-07 "Medical card of an outpatient". In the Russian Federation it is the Order of the Ministry of Health of the Russian Federation from December 15, 20144 № 834n "On approval of the unified forms of medical documentation used in medical organizations providing medical care in outpatient settings, and procedures for filling out the form № 025/u "Medical card of a patient receiving medical care in outpatient settings". In the Republic of Kazakhstan it is the Order of the Acting Minister of Health of the Republic of Kazakhstan from October 30, 2020 № KR DSM- 175/200 "On approval of forms of record documentation in the field of health care" form № 052/u "Medical card of an outpatient". There are similarities and differences. There is a common part: full name, sex, date of birth, place of work, blood group and Rh. There are also differences, for example, in the RF there is a section SNILS, in the RK IIN, and in the RB personal number on the passport [9]–[11].

Based on OSTIS technology, it is possible to effectively formalize various concepts from a patient's medical record, taking into account the peculiarities of regulatory documentation in different countries. Despite the differences in the formats and structure of medical documents in the Republic of Belarus, the Russian Federation and the Republic of Kazakhstan, OSTIS technology can be used to create a universal model for data storage and processing, ensuring their standardization and flexibility.

The advantage of OSTIS technology lies in its graph-based approach to information representation, which allows for quick changes to the system without changing its structure, just modifying the knowledge base. This approach makes the system flexible and adaptable to new requirements and changes in legislation, which is especially important in the medical field, where requirements and standards are constantly changing.

Fig. 1 shows a fragment of a patient medical record ontology formalized using SCG language and including such basic concepts as:

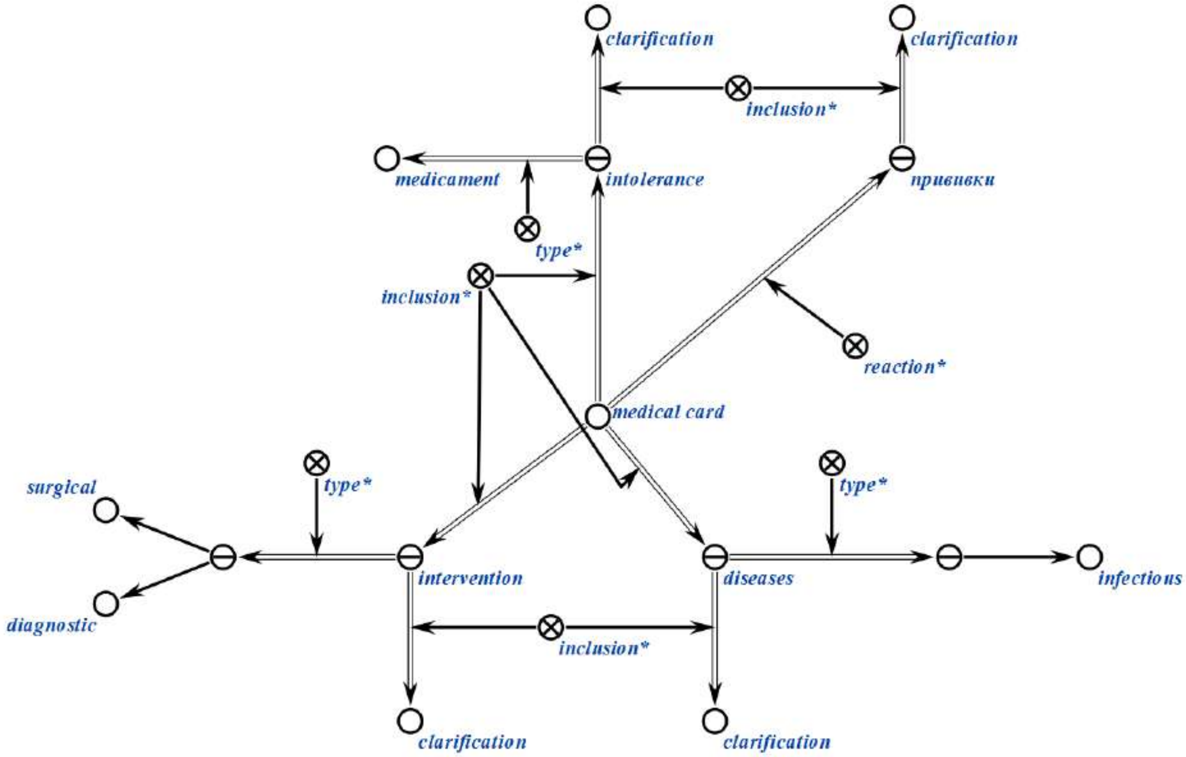

Figure 1. Fragment of medical record ontology

For example, patient information, including personal data and medical history, can be represented in graph structures where each node represents a different concept and the links between nodes reflect the relationships between the data. This approach makes it easy to add new data or modify existing data without having to redesign the entire system.

Using OSTIS technology, it is also possible to bring different formats and structures of data from medical documents to a common standard of presentation. For example, patient information from different countries may contain different fields and formats, such as SNILS in Russia, IIN in Kazakhstan, and personal passport number in Belarus. However, thanks to the flexibility and adaptability of OSTIS technology, these data can be standardized and combined into a common information model, providing a unified view and access to a patient's medical information regardless of where they live or where they are being treated.

In addition, with the help of OSTIS technology, meta-information can be added to the patient's medical data at the level of knowledge base, which allows its use by intelligent system agents in the process of processing and analysis. This makes it possible to create a more flexible and intelligent system of medical data processing than just adding comments in a classical medical information system. An example of a fragment of such data formalization is presented in Fig. 2.

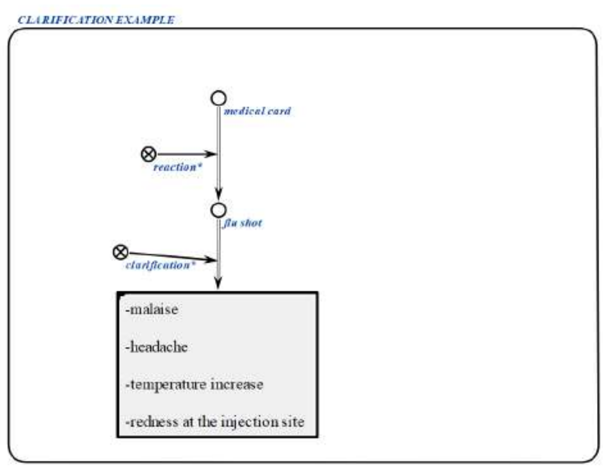

Figure 2. A fragment of the ontology of a medical record that allows you to store clarifying information

Thus, the use of OSTIS technology to formalize data from patients' medical records and information on GI diseases allows to create a flexible and adaptive system that can effectively take into account new requirements and changes in legislation, as well as standardize the presentation of information to simplify its analysis and processing.

V. The subject area and ontology of GI disease

Gastrointestinal (GI) diseases are one of the most common problems in medical practice worldwide. They cover a wide range of conditions, from functional disorders to serious pathologies such as peptic ulcers and cancer. According to the World Health Organization (WHO), GI diseases are the leading causes of death and disability worldwide.

GI disease statistics:

- according to the WHO, in 2020, GI diseases are the cause of death for more than 4 million people worldwide;
- according to studies conducted in different countries, GI diseases account for up to 25% of all reasons for visits to general practitioners;
- some of the most common GI diseases include peptic ulcer disease, gastric and duodenal ulcers, gastritis, colitis, irritable bowel syndrome (IBS), gallstones, pancreatitis, and GI cancer;

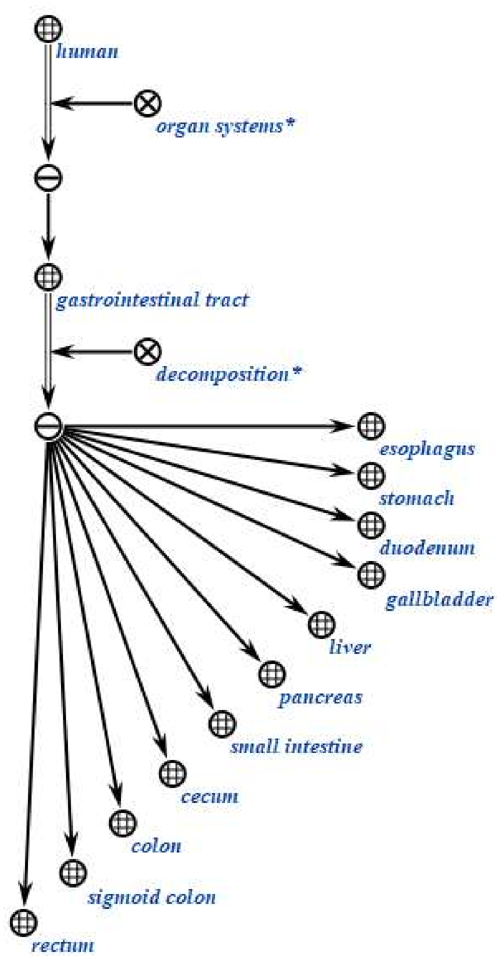

Figure 3. A fragment of the ontology of a medical record that allows you to store clarifying information

The International Classification of Diseases, 10th Revision (ICD-10) provides a coding system for diseases used in medical statistics and diagnosis. GI diseases are described in ICD-10 section K00-K93. This section includes a wide range of conditions, from dental problems to diseases of the liver, pancreas, and other GI organs. Diseases of this area include functional disorders, inflammatory processes, infections, tumors, and other pathologies specific to the GI tract. They can be manifested by various symptoms such as abdominal pain, diarrhea, constipation, nausea, vomiting and others. The definition and classification of GI diseases according to ICD-10 is important for statistical analysis, morbidity studies and health care planning.

Fig. 3 shows the formalization of the digestive organs domain using OSTIS technology. This formalization includes the development of an appropriate ontology structuring information about GI diseases according to the main sections of the International Classification of Diseases 10th Revision (ICD-10) [12].

The first section of the digestive organ ontology covers the anatomical structure and functions of organs including stomach, liver, pancreas, intestine and others. Each organ is presented as a separate entity described by its anatomical features and functions. The subject matter is further divided into various sections, including functional disorders, infections, tumors and other pathologies, in accordance with ICD-10. Each section contains the relevant classes of diseases and their associated medical conditions, symptoms and treatments.

In the context of the study of the subject area of digestive organs, special attention is paid to the stomach, considered on the example of gastritis in its usual and hyperacidic forms. Each disease corresponds to a reference marker set by the expert, which can be tissue or drug-specific. In addition, each disease has etiologic markers, which are multiple indicators that point to possible sources of the disease, such as bacteria, viruses, and other factors.

Organs in the digestive system can be in three states: disease state (more than 80% similarity), risk state (50% to 80% similarity), and non-risk state (healthy organ, less than 50% similarity). This approach allows the system to classify organs according to their current status based on analysis of user data.

The formalization of the ontology fragment and its corresponding knowledge base, presented in the figure, allows not only to treat diseases after their manifestation, but also to carry out the tasks of early diagnosis and prevention of the disease at early stages. This methodology allows integrating reference and etiological markers of diseases into the knowledge base, which provides the system with access to information for analyzing and processing medical indicators at a deeper level, which is discussed in the works of Rostovtsev V. N. [13]–[15].

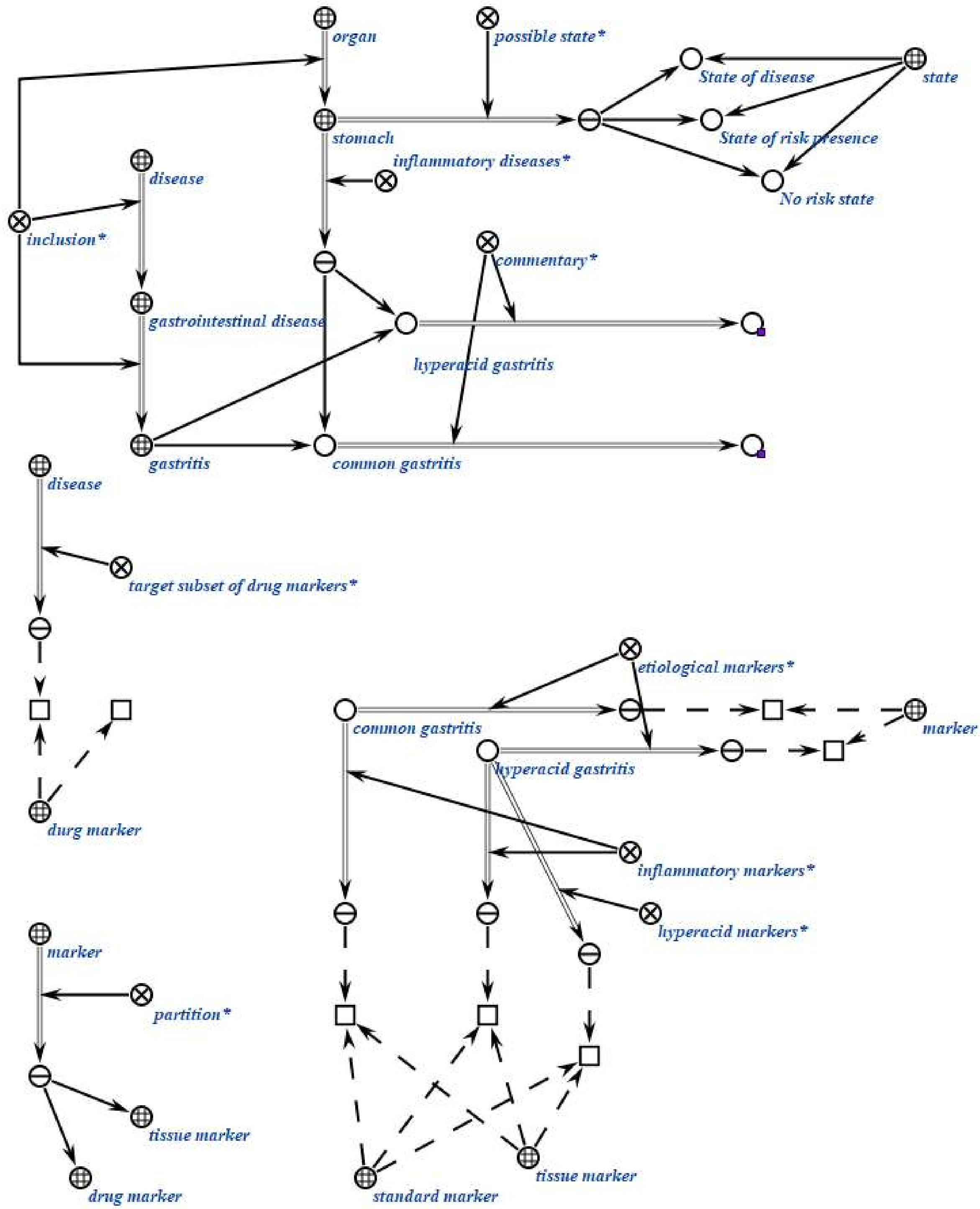

Figure 4. Fragment of medical record ontology

VI. Conclusion

The integration of Open Semantic Technology for Intelligent Systems (OSTIS) into medical information systems presents a promising solution to the challenge of data format incompatibility. OSTIS offers innovative tools and approaches for creating semantically compatible medical systems capable of efficiently processing and storing data regardless of their original format and structure.

One of the key features of OSTIS is its ability to unify various types of knowledge into a single database. This centralized approach allows for the organization and structuring of medical data according to unified semantic standards, ensuring high compatibility and interoperability.

Furthermore, the flexibility and adaptability of OSTIS enable the customization of systems to meet the specific requirements and standards of each country, including Belarus, Russia, and Kazakhstan. This adaptability facilitates seamless integration into existing healthcare infrastructures.

The automatic conversion and matching of data in different formats represent a significant advantage of OSTIS. This capability eliminates compatibility issues and facilitates smooth information exchange between various medical systems and institutions, ultimately enhancing system efficiency and the quality of healthcare delivery.

In summary, the application of OSTIS technology offers an effective and promising approach to addressing data format incompatibility in medical information systems. It fosters the creation of modern and innovative healthcare systems capable of adapting to diverse requirements and changes in the medical field, which is crucial for improving the quality and accessibility of healthcare in different countries.

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ИНТЕГРАЦИЯ И СТАНДАРТИЗАЦИЯ В ИНТЕЛЛЕКТУАЛЬНЫХ МЕДИЦИНСКИХ СИСТЕМАХ НОВОГО ПОКОЛЕНИЯ НА ОСНОВЕ ТЕХНОЛОГИИ OSTIS

Крищенович В. А., Сальников Д. А., Захарьев В. А.

В статье рассматривается интеграция международных медицинских стандартов в России, Беларуси и Казахстане с применением семантических технологий. Предлагается подход к интеграции и стандартизации медицинских данных на основе применения технологии OSTIS. Приводится пример разработки фрагмента онтологии на основе различных стандартов медицинских карт в интеллектуальных медицинских системах. Преимуществами такой интеграции являются улучшение обмена медицинской информацией, упрощение процесса диагностики и лечения, а также возможность создания единого медицинского пространства в рамках региона.

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