СЕКЦИЯ «АКТУАЛЬНЫЕ ВОПРОСЫ В ОБЛАСТИ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ И ЭЛЕКТРОННОЙ КОММЕРЦИИ (НА ИНОСТРАННЫХ ЯЗЫКАХ)»

UDC 001.8:111

1. AN ONTOLOGY-BASED APPROACH AS FOUNDATION FOR MULTIDISCIPLINARY SYNTHESIS IN MODERN SCIENCE

Zotov N.V.[1], Master's degree student, group 326401

Belarusian State University of Informatics and Radioelectronics[1], Minsk, Republic of Belarus

Subotkina I.G. – Assistant professor

Annotation. This paper explores semantic methods and technologies to solve the problem of interdisciplinary organization in modern science. It presents the rationale for using an ontology approach based on semantic technologies to integrate knowledge from different fields of science. The relevance of using such methods and technologies is due to the increasing amount of complex structured knowledge and areas for their application.

Keywords. interdisciplinarity, interdisciplinarily organized science, ontologies, knowledge bases, semantic networks, semantic technologies.

At the present stage, various rapidly changing areas of human activity face problems related to solving complex problems that require the use of different types of knowledge from various fields of modern science. One of the key methods of overcoming these problems is interdisciplinary synthesis, which involves deep integration of knowledge from different scientific fields to create a more complete and comprehensive approach to solving existing problems. Despite the active recognition of the importance of interdisciplinary approach, there are a number of problems that hinder its successful implementation.

The problem of interdisciplinary synthesis in science is becoming more and more relevant in the context of increasing complexity of scientific issues and the need for an integrated approach to their solution [1, 2, 3]. The existing boundaries among traditional scientific disciplines limit the full understanding of many phenomena that often cross these boundaries. This in turn makes it difficult to develop effective solutions for existing problems such as environmental, energetic, demographic, medical, and inhibits the development of new interdisciplinary-organized fields of knowledge.

The object of the research in this paper is the process of interdisciplinary synthesis in the modern scientific community. The subject of the research is the scientific problems faced by modern scientists in the application of interdisciplinary approach. The objective of this research is to study the problem of interdisciplinary synthesis in science by identifying key aspects that hinder the successful integration of knowledge from different fields of human activity and considering existing technologies and methodologies that allow solving this problem [2, 3]. This work is aimed at identifying the fundamental problems associated with the application of interdisciplinary synthesis in science and finding methods and means to solve them.

Despite the fact that the history of interdisciplinarity goes back to the past, and the term became widely used in scientific fields only at present [4]. The view of science as clearly delimited fields of knowledge began to change in different historical periods under the influence of various factors.

At the beginning of the history of science, knowledge often included multiple fields: philosophy, mathematics, astronomy. However, as time went on, there was an increasing specialization of common knowledge. It led to the division of knowledge into disciplines and eventually to the formation of narrow specializations. The Enlightenment period in Europe in the 17th and 18th centuries saw the beginning of a change in attitudes towards scientific inquiry. Rationalism and empiricism promoted a broader view of the world, and the introduction of the scientific research method emphasized experimentation and observation. In the 19th century, new fields of knowledge began to emerge with the development of scientific methods and technology. For example, physics and chemistry began to interact closely, leading to the creation of physical chemistry. In the 20th century, scientific and technological progress accelerated, which required an integrated approach to solving complex problems.

Interest in studying the disciplinary organization of science emerged in the 1950s, forming the idea of scientific discipline and science as a system of disciplines. Today in science, a discipline is understood as a specific field of knowledge. Disciplinary organization facilitates intra-scientific communication, control, and training. Each scientific discipline has its own object of study, tools, expert community, and its own publications. Disciplinary organization changes science into an organized social mechanism that requires discipline of a researcher.

The disciplinary organization of science is also justified by the increasing volume of information and the complexity of research methodology. Professionalization and specialization lead to the fragmentation of disciplines and the creation of complexes. Science is presented not as separate disciplines, but as complexes that include fundamental and taxonomic disciplines [4].

Interdisciplinarity in science plays a key role in the modern world for several reasons:

- Many contemporary problems require an integrated approach. Interdisciplinary research allows scientists to combine their knowledge and methods from different fields to solve complex problems such as sustainable development issues (ecosystem sustainability, poverty alleviation, food security). Interdisciplinary research helps develop sustainable strategies by taking into account different aspects of the problems.
- Combining knowledge and methods from different disciplines contributes to new ideas, innovation and technological progress.
- Interdisciplinary research helps scientists look at problems from different perspectives and enrich their knowledge, which contributes to a deeper understanding of fundamental principles and phenomena.
- Interdisciplinary-organized teams facilitate better knowledge sharing among scientists from different fields. It can accelerate the adoption of new ideas and methods in the scientific community.
- Applying an interdisciplinary approach in education contributes to students' broader horizons and problem-solving abilities by combining knowledge from different fields.

Modern technologies and practical developments play an important role in scientific research, allowing scientists from different disciplines to collaborate and integrate their knowledge and skills. They allow scientists to process and analyze large amounts of data, use advanced modeling, and simulation techniques, and share information and collaborate with colleagues online [5]. For example, information technology and the Internet provide access to a large amount of information and research from different fields of science. It allows scientists from different disciplines to investigate problems from different perspectives and find new approaches and solutions. Virtual and augmented reality technologies make it possible to create many visual and interactive models and simulations, which can be used to explain complex concepts and principles from various scientific fields. It is worth noting the development of biotechnology, genetics, and nanotechnology, which has led to the emergence of new fields of research such as molecular biology, nanomedicine, and bioengineering. These technologies allow scientists from different disciplines to work together to solve complex problems and create innovative solutions.

Knowledge bases are becoming more and more popular in modern scientific and technical research emphasizing the problems of interdisciplinary synthesis [6, 7]. It is due that interdisciplinary interaction in modern scientific research is impossible without the formation of a unified formal categorical and conceptual apparatus. Such an apparatus can be realized with the help of ontologies of subject areas.

Ontology is a formal model of a subject domain that describes concepts and relations among objects in this area using the language of formal logic which is known knowledge representation language [8, 9]. The use of ontologies in interdisciplinary knowledge synthesis and integration has several advantages [10-12]:

- Ontologies allow organizing and classifying knowledge from different disciplines, establishing links among them, thus making knowledge more structured and usable.
- Ontologies allow knowledge integration by combining information from different sources and with different representations, which helps to eliminate semantic incompatibility among different systems and facilitates information sharing.
- Ontologies allow knowledge to be represented in the form that computers can understand. Thus systems can automatically analyze and make decisions based on the knowledge in ontologies.
- Ontologies provide a formal basis for developing expert systems that can provide guidance and advice in complex and multidimensional problems.

The use of ontologies for interdisciplinary knowledge synthesis and integration simplifies the collection and analysis of information from different domains and ensures that it is properly understood and used in practice [10]. It contributes to better knowledge utilization and more informed decision making. Based on a hierarchy of formally described subject areas and their ontologies, a unified knowledge base is formed [11]. The aggregate of knowledge bases forms a unified information space for solving information tasks of different complexity level.

The main advantage of the ontological approach to design is a significant increase in the flexibility of design activity due to the clear separation of those design actions that can be performed locally within the relevant subject areas and do not require any coordination by design actions in other subject areas and those design actions that must be coordinated between different subject areas, but whose coordination procedure is clearly defined. Flexibility and clarity of decomposition of ontological models of designed systems is the basis for effective organization of collective design activities [12].

Ontologies are used as a tool for structuring knowledge from different information sources. There is an extensive set of languages and standards for representing and working with ontologies, such as OWL (Ontology Web Language), RDF (Resource Description Framework), USC (Universal Semantic Code), SC-code (Semantic Computer code) and others.

The basis for describing ontologies are semantic networks. In most cases semantic networks are represented as graphs. There are several reasons for using graphs in describing ontologies [13-16]:

- Graph data models have tremendous expressive power. Graph databases offer a flexible model of data and a way to represent it. Graphs are additive, in providing the flexibility to add new data relationships, new nodes and new subgraphs to an existing graph structure without compromising its integrity and connectivity.
- The diversity of data representation forms is minimized by reducing the number of syntactic aspects considered when storing data and using them in databases, since graph data models allow to record different types of knowledge to be recorded in the same way.
- In order to understand the meaning of knowledge, it is necessary to represent this knowledge in an understandable form for everyone: both human and system. Speaking of unifying the representation of all kinds of knowledge, it is considered important to use graph databases not just as a means for storing structured data, but for storing semantically coherent, and interconnected knowledge.
- Data processing performance is increased by one or more orders of magnitude when data is represented as graphs, which is due to the properties of the graph itself. Unlike relational databases, where query performance degrades with increasing query intensity as the dataset grows, the performance of the graph data model remains constant even as the dataset grows. It is because data processing is localized in some part of the graph. As a result, the execution time of each query is only proportional to the size of the portion of the graph traversed to satisfy that query, not the size of the entire graph.
- Graph databases provide efficient semantic search, in finding data and information based on the relationships among data, which improves the quality and accuracy of search queries and provides a deeper understanding of these relationships and dependencies among data.

One of the key problems in the field of interdisciplinary research is the diversity of knowledge description and representation forms, as well as the lack of semantic compatibility and coherence of conceptual systems of different knowledge domains. It hampers the exchange of information among scientists and complicates the creation of integrated approaches for solving complex scientific problems [16].

The utilization of ontologies simplifies the collection and analysis of information, contributing to better knowledge utilization and informed decision-making. Through the creation of unified knowledge bases, ontologies offer a coherent information space for solving tasks of varying complexity levels. The flexibility and clarity provided by ontological approaches enhance the organization of collective design activities, promoting effective coordination among different subject areas. Furthermore, the use of graph databases for representing ontologies offers several advantages, including increased data processing performance, efficient semantic search capabilities, and the ability to store interconnected knowledge in a coherent manner.

To solve these problems, existing technologies and tools to support interdisciplinary research were investigated. It was found that the use of semantic technologies can significantly facilitate the process of interdisciplinary synthesis and promote more effective knowledge exchange among scientists.

References:

1. Bammer, G. Expertise in research integration and implementation for tackling complex problems: when is it needed, where can it be found and how can it be strengthened? / G. Bammer [et al.] // Palgrave Communications. – 2020. – T. 6. – №. 1. – p. 1-16.
2. Specht, A. Interdisciplinary collaboration from diverse science teams can produce significant outcomes / A. Specht, K. Crowston // Plos one. – 2022. – T. 17. – №. 11. – 57 p.
3. Palagin, A. V. Development and Formation of Transdisciplinary and Interdisciplinary Research and the Role of Informatics / A. V. Palagin, N. G. Petrenko // Computer Modeling: Analysis, Management, Optimization. - 2018. - No. 1. - pp. 46-70.
4. Mirsky, E. M. Interdisciplinary Research and Disciplinary Organization of Science. - Moscow: Nauka, 1980. - 304 p.
5. Alexeeva, I. S. Information Technologies in Interdisciplinary Research / I. S. Alexeeva, E. M. Migacheva, E. V. Zavartseva // Scientific Interdisciplinary Research. - 2020. - No. 8-1. - pp. 26-31.
6. Evgenyev, G. B. Industry 5.0 as Integration of the Internet of Knowledge and the Internet of Things // Design Ontology. - 2019. - Vol. 9. - No. 1 (31). - pp. 7-23.
7. Palagin, A. V. Problems of Transdisciplinarity and the Role of Informatics / A. V. Palagin // Cybernetics and Systems Analysis. - 2013. - No. 5. - pp. 3-13.
8. Yang L., Cormican K., Yu M. Ontology-based systems engineering: A state-of-the-art review / L. Yang, K. Cormican, M. Yu // Computers in Industry. – 2019. – T. 111. – C. 148-171.
9. Gavrilova, T. A. Knowledge Bases of Intelligent Systems. / T. A. Gavrilova, V. F. Khoroshevsky. - Saint Petersburg: Piter, 2000.
10. Golenkov, V. V. Ontology-based Design of Intelligent Systems / V. V. Golenkov // Open Semantic Technologies for Intelligent Systems (OSTIS-2017): Proceedings of the International Scientific and Technical Conference (Minsk, February 16-18, 2017) / Ed. by V. V. Golenkov (Ed.-in-chief) [et al.]. - Minsk: BSUIR, 2017. - Pp. 37-56.
11. Rubashkin, V. Sh. Ontological Semantics. Knowledge. Ontologies. Ontology-oriented Methods of Textual Information Analysis / V. Sh. Rubashkin. - Moscow: Phismatlit, 2012. - 348 p.
12. Smirnov, S. V. Ontologies as Semantic Models / S. V. Smirnov // Design Ontology. - 2013. - No. 2. pp. 12-19.
13. Ryen, V. Building semantic knowledge graphs from (semi-) structured data: a review / Ryen V., Soylu A., Roman D. // Future Internet. – 2022. – T. 14. – №. 5. – C. 129.
14. Barnaghi, P. From data to actionable knowledge: Big data challenges in the web of things [Guest Editors' Introduction] / Barnaghi P., Sheth A., Henson C. // IEEE Intelligent Systems. – 2013. – T. 28. – №. 6. – C. 6-11.
15. Robinson, I. Graph databases / Robinson, I. — O'Reilly Media, Inc., 2015.
16. Han, J. Semantic networks for engineering design: state of the art and future directions / Han J. et al. // Journal of Mechanical Design. – 2022. – T. 144. – №. 2. – C. 020802.