Integration of Third-Party Functional Services on a Unified Semantic Basis

Alexandr Zagorskiy
Belarusian State University of Informatics and Radioelectronics
Minsk, Belarus
Email: alexandr.zagorskiy.research@gmail.com

***Abstract*—In the article, a digital ecosystem structure that utilizes semantic representation of information and investigates the integration principles for heterogeneous services is proposed. An example of this approach is demonstrated using the OSTIS Technology. The results obtained highlight the potential benefits of using semantic representation to enhance interoperability and adaptability of digital ecosystems. This research has significant implications for the design of more efficient systems that better match the user needs and preferences.**

***Keywords*—Digital ecosystem, interoperability, integration, semantics**

I. Introduction

To increase the level of automation of more and more broad types of human activities, a qualitative transition to the development of whole complexes of independently interacting intelligent computer systems is required [1]. The central problem of the next stage of information technology development is the problem of semantic interoperability of computer systems and their components [2]. The solution to this problem requires a transition from traditional computer systems and modern intelligent systems to semantically compatible computer systems [3], [4].

Semantic computer systems are next-generation computer systems that eliminate many of the shortcomings of modern computer systems. Nevertheless, the mass development of such systems requires appropriate technology, which should include:

- methods and design tools for semantic computer systems;
- methods and tools for continuous improvement of the technology itself.

The purpose of the work is to develop methods and tools for integrating various services into intelligent systems as one of the stages for designing a unified ecosystem of semantic computer systems. In the article, the problems of forming digital ecosystems using traditional approaches are considered, an approach to creating a digital ecosystem of semantically compatible computer systems is proposed, and an example of integration of functional services with the existing intelligent dialog system is demonstrated.

II. Problem definition

The concept of a *digital ecosystem* is a complex and dynamic system that consists of many components, including technologies, processes, users, enterprises, etc. In the context of digital technologies, the transition to the *digital ecosystem* is a key aspect for achieving business and societal goals through more flexible and sustainable management: “Society 5.0”, “Industry 4.0”, “Smart Home”, “Smart City”, “Knowledge Market” [5].

The concept of the *digital ecosystem* can be defined as a set of digital products and services that interact with each other and with the external environment, forming a single habitat. Implementation of the *digital ecosystem* is strongly related to the formation of a *distributed system*. This principle of implementation has both advantages (high level of adaptability, stability, connectivity) and disadvantages (non-optimality, uncontrollability, unpredictability of behavior) [6], [7], [8], [9].

In traditional approaches to the problem of forming a *digital ecosystem*, there are problems associated with the low level of *interoperability* of such systems [10]. Traditional approaches to solving this problem are often ineffective, since each of the systems has its own specialized application interface and data format for interaction. This leads to additional costs to eliminate the shortcomings of such problems. Life-cycle support and modification of existing systems may also require additional time and resources.

The use of open standards and interoperability protocols can greatly simplify the problem of ensuring *interoperability* between different systems. This improves the efficiency and cost-effectiveness of digital transformation projects and reduces the time and cost for developing and maintaining the *digital ecosystem* [11].

Thus, in order to create a successful *digital ecosystem*, many problems need to be solved to ensure a high level of interoperability between independently operating systems. The Semantic Web idea aims to solve these problems [12], but it also raises other problems or limitations that need to be considered [13], [14], [15].

In *integration* of *services* into such a *digital ecosystem*, several problems arise that can hinder the *integration* process and reduce the efficiency of the ecosystem [10], [16]. Some of these problems may include:

- different data formats and exchange protocols that can lead to errors in *information exchange*, which makes it difficult to communicate between *services*;
- *incompatibility* of application versions, which can lead to conflicts in *information exchange*;
- different security levels, which can lead to leaks of confidential information;
- lack of a single control point, which makes it difficult to monitor and manage the integration process;
- lack of mechanisms for analyzing and managing information, which makes it difficult to control *integration* processes.

These problems significantly complicate the development of the *services* themselves and lead to a significant increase in time and material costs. To solve these problems, various approaches and technologies are used to integrate *digital ecosystems* with various *services* and *resources* [17], [18]. Some of them may include:

- using standard protocols and data exchange formats, such as XML, JSON, and others, to make *information exchange* more reliable and universal;
- development of a unified data schema and access rules to make *integration* simpler and more manageable;
- implementation of mechanisms for automatic error and conflict handling, which reduces errors and improves reliability of the *digital ecosystem*;
- use of tools and technologies for information analysis and management, such as business analysis and information management systems, which allows controlling *information exchange* processes and optimizing their performance.

A possible solution is to move to universal communities of individual *intelligent cybernetic systems*, which are integrated into *multi-agent systems*, thus forming a single digital ecosystem. The general principles for *integration* of modern *services* with such a digital ecosystem may look as follows [10], [16]:

- *standardization* and *compatibility*, which is achieved by using standardized protocols and data exchange formats;
- openness and accessibility of the digital ecosystem to various stakeholders through open and user-friendly interfaces;
- security and confidentiality, which is achieved through the use of cryptographic methods of data protection and access control to resources;
- *automation* and *scalability*, which will ensure the efficiency and productivity of the *digital ecosystem* when dealing with a large number of *services* and *resources*;
- analysis and data management to help determine the effectiveness of *integration* and improve it further.

III. Proposed approach

Within this article, it is suggested to use the OSTIS Technology as the foundation [19]. The OSTIS Technology comprises a range of technologies that facilitate the creation, management, operation, and improvement of intelligent computer systems aimed at automating various human activities. This Technology is built on semantic representation and ontological systemization of information and agent-oriented knowledge processing.

The principles of the OSTIS Technology can be summarized as follows:

- Focus on developing highly intelligent and socialized computer systems called ostis-systems.
- Focus on automation of various types and areas of human activities by creating a network of interacting and coordinating ostis-systems, referred to as the OSTIS Ecosystem.
- Implementation of the OSTIS Technology as a network of ostis-systems, which includes the OSTIS Metasystem as a key ostis-system. The Metasystem implements the OSTIS Technology Core, which consists of subject-independent methods and tools for designing and producing ostis-systems, along with built-in support subsystems for operation and reengineering. Other specialized ostis-systems within the network use various ostis-technologies to automate different areas and types of human activities.
- Focus on developing next-generation computers capable of efficiently interpreting the logical-semantic models of ostis-systems, represented by the knowledge bases of these systems with semantic representation.

Within this article, fragments of structured texts in the SCn-code [20] will be used, which are simultaneously fragments of the source texts of the knowledge base, understandable both to human and machine. This allows making the text more structured and formalized, while maintaining its readability.

IV. OSTIS Ecosystem: a network for interacting and coordinating intelligent systems

The *OSTIS Technology* is a powerful tool for designing and implementing digital ecosystems that can integrate with various services and information resources. The realization of such a universal community of interoperable *intelligent cybernetic systems* can be implemented as a global *OSTIS Ecosystem* [21]. The *OSTIS Ecosystem* is a socio-technical ecosystem, which is a collective of interacting *semantic computer systems*, providing permanent support for evolution and semantic compatibility of all its constituent systems, throughout their entire life cycle.

A system built in accordance with the requirements and standards of the *OSTIS Technology* is defined as an *ostis-system*.

The *OSTIS Ecosystem* is a collective of:

- *ostis-systems* themselves;
- users of those *ostis-systems* (both end-users and developers);
- some *computer systems* that are not *ostis-systems* but are considered by them as additional *information resources* or *services*.

Within the *OSTIS Ecosystem*, the *ostis-systems* are able to communicate with each other and form specialized collectives to jointly solve complex problems. This approach not only increases the intelligence level of each *individual cybernetic system* but also ensures more effective interaction between them within a single *digital ecosystem*. This provides a significant development for a number of properties of each *computer system*, allowing a significant increase in the *level of intelligence* (and, above all, their *level of learnability* and *level of socialization*).

The members of the *OSTIS Ecosystem* are characterized as:

- *semantically compatible*;
- constantly evolving individually;
- constantly maintaining its compatibility with other members in the course of its individual evolution;
- capable of decentralized coordination.

The *OSTIS Ecosystem* is a transition from *single ostis-systems* to *collective ostis-systems*, that is, to distributed *ostis-systems*.

ostis-system
⇒ *subdividing**:
{• *stand-alone ostis-system*
• *build-in ostis-system*
• *collective of ostis-systems*
}

The purpose of the *OSTIS Ecosystem* is to ensure the *compatibility of computer systems* that are part of the *OSTIS Ecosystem* both during their development and operation. One of the problems is the implementation of various changes to the systems, that are part of the *OSTIS Ecosystem*, during their operation, which can cause compatibility to be compromised.

OSTIS Ecosystem
⇒ *objectives**:
• *operational implementation of all agreed changes of the ostis-systems standard (including changes to the systems of concepts used and their corresponding terms)*
• *permanent support for a high level of mutual understanding of all systems included in the OSTIS Ecosystem and all their users*
• *corporate solution of various complex problems requiring coordination of several ostis-systems and, possibly, some users*

The OSTIS Ecosystem is the next stage in the development of human society, providing a significant increase in the level of public (collective) intelligence by transforming human society into an ecosystem consisting of humans and semantically compatible intelligent systems. The OSTIS Ecosystem is a proposed approach to the implementation of a smart society, or Society 5.0, built on the basis of the OSTIS Technology.

The super-purpose of the OSTIS Ecosystem is not just a comprehensive automation of all types of human activities (only those activities whose automation is appropriate) but also a significant increase in the level of intelligence of various human (more precisely, human-machine) communities and the entire human society as a whole.

V. Support of compatibility between ostis-systems that are part of the OSTIS Ecosystem

Each system that is part of the OSTIS ecosystem must:

- train intensively, actively, and purposefully, either with the help of teacher-developers or independently;
- inform all other systems about proposed or finally approved changes in ontologies and, in particular, in the set of concepts used;
- accept proposals from other ostis-systems for changes in ontologies, including the set of concepts used, for agreement or approval of these proposals;
- implement approved changes in ontologies stored in its knowledge base;
- ensure maintaining a high level of semantic compatibility not only with other ostis-systems that are part of the *OSTIS Ecosystem* but also with its users (train them, inform them about changes in ontologies).

The *stand-alone ostis-system* that is part of the *OSTIS Ecosystem* has special requirements:

- it must have all the necessary knowledge and skills for messaging and purposeful interaction with other *ostis-systems* that are part of the *OSTIS Ecosystem*;
- in the context of constant change and evolution of the *ostis-systems* that build-up the *OSTIS Ecosystem*, it must itself monitor its compatibility (consistency) with all other *ostis-systems*, that is, it must maintain this compatibility by coordinating all changes with other *ostis-systems*, which require coordination in itself and in other systems.

To ensure high operational efficiency and high rate of evolution of the *OSTIS Ecosystem*, it is necessary to constantly improve the level of information compatibility (level of mutual understanding) not only between the computer systems that are part of the *OSTIS Ecosystem* but also between these systems and their users.

One of the ways to ensure such compatibility is the striving to ensure that the knowledge base, the picture of the world of each user, becomes part of the unified knowledge base of the *OSTIS Ecosystem*. This means that each user must know how the structure of each scientific and technical discipline is arranged (objects of research, subjects of research, definitions, patterns, etc.), how different disciplines can be interconnected.

The interoperability support requirements were taken into account when designing the OSTIS Ecosystem structure [21].

VI. Principles for integrating the OSTIS Ecosystem with heterogeneous services

In the first stages of the transition to Society 5.0, there is no need to convert all modern automation systems of some types and areas of human activities into *ostis-systems*. Systems based on the principles of the *OSTIS Technology* can take on a coordinating and interconnecting role due to their high level of *interoperability*. Such systems must learn either to perform the mission of an active interoperable superstructure over various modern automation tools or to task modern automation tools with feasible problems for them, ensuring their direct participation in solving complex problems and organizing the interaction management for various automation tools in the process of collectively solving complex problems.

In the context of integration of the *OSTIS Ecosystem* with heterogeneous *services*, the *services* refer to applications, programs, *web-services*, and other *information systems* that provide a certain functionality, a mechanism for transforming information according to a given function. Frequently, such an application can provide an *application interface* that can be used with a certain format of inputs to which certain formats of outputs will correspond.

The *integration* of the *OSTIS Ecosystem* with the *service* should be understood as the ability to use the functionality of the *service* to change the internal state of the *knowledge base* of the *OSTIS Ecosystem*. Several levels of *integration* are distinguished, which allow interaction with various *information resources* and *services*.

Full *integration* implies executing the finction of the *service* on a platform-independent level, where the entire program is executed in the *knowledge base* of the *OSTIS Ecosystem*. That is, the problem of integration of such a *service* is reduced to allocation of the graph structure processing algorithm and its implementation within the *knowledge base*. Within the *OSTIS Technology*, interpretation of such a processing program can be implemented with the help of the SCP Language [22]. As a result of such a full integration, the need to use a third-party *service* is eliminated.

Partial *integration* involves the implementation of interaction and state changes for the *knowledge base* of the *OSTIS Ecosystem* at the stages of executing the function of the *service*. The degree of *integration* depth can vary: in some cases the *service* may refer to the *knowledge base* for additional information, in others — for immersing intermediate results of execution into the *knowledge base* of the system. In the simplest case, changing the *knowledge base* of the *OSTIS Ecosystem* can take place once, after receiving the result of executing the function of the *service*. The interaction with the *knowledge base* in this case will be performed by a special *sc-agent* using a third-party *service*.

To ensure the *integration* of a functional *service*, the following minimum requirements must be met:

- specification of the input construction in the system *knowledge base*: defining the structure in the system *knowledge base* that will be converted to a data format compatible with the *service*;
- specification of the output construction in the system *knowledge base*: defining the structure in the system *knowledge base*, which will be formed from the original structure after the transforming the data of the *service* into knowledge;
- implementation of the *sc-agent*, which converts the construction of the *knowledge base* into a format that can be used in the *service*, as well as immerse the results of the *service* operation back into the system *knowledge base* in accordance with the specification.

Meeting these requirements will allow for effective *integration* of the functional *service*, which, in turn, will allow the data and functionality of the *service* to be used in various *ostis-systems*.

The generalized algorithm of the *sc-agent* using a third-party *service* for *integration* of functionality can be described as follows:

- extracting the necessary knowledge structures from the *knowledge base*, that meet the requirements of a functional *service*;
- converting the extracted knowledge into the format required for input to the functional *service*;
- forming a request for a functional *service* and waiting for its response;
- forming knowledge structures based on the data received from the functional *service*;
- immersing new knowledge structures in the *intelligent system knowledge base* in order to ensure their further use.

It should be noted that during the *integration* of functional *services*, it may be necessary to carry out additional data processing and transformation, for example, to ensure their *compatibility* with data formats or to ensure the security of data transmission and storage.

Thus, the introduction of the possibility to use a third-party *service* in the *OSTIS Ecosystem* assumes the following steps:

- analysis of the requirements for the integrated *service*, determining the necessary functionality, input and output data formats, and other characteristics of the service;
- development of the *integration* specification, which will define data formats and rules of interaction between the *knowledge base* of the *OSTIS Ecosystem* and a third-party *service*;
- development of an *sc-agent* that will provide interaction between the *knowledge base* and the third-party *service* in accordance with the *integration* specification;
- testing and debugging;
- embedding in the *OSTIS Ecosystem*, which will allow using the capabilities of the integrated third-party *service* in various *ostis-systems*.

The use of the described approach is considered in the work [23] on the example of the integration of computer vision services with the dialog ostis-system [24]. Similarly, other data processing models can be implemented: natural language processing systems [25], large language models such as ChatGPT [26], etc.

The most important feature when developing ostis-systems is that the development of an ostis-system actually boils down to the development of its knowledge base. When developing the components of the problem solver and the interface, their features are taken into account [27], however, the general mechanism for making any changes to the ostis-system becomes unified [28]. It follows from this that integrated tools can also affect both the system interface and the algorithm for solving certain problems.

Various approaches are used to enable the *sc-agent*, one of which is to connect the *sc-agent* within the already existing, main *ostis-system*. From the point of view of scalability when implementing this approach, the *monolithic architecture* of the resulting *ostis-system*, which simplifies the process of introducing new *services* and *sc-agents* into the *ostis-system*, should be noted.

The advantage of this approach is a simpler and more convenient introduction of new *services* and *sc-agents* into the *ostis-system*, as well as simplification of the dependency management process. Using the ostis-system implementation with *monolithic architecture* can be applied in cases where the functional *service* does not need frequent modification and has a fairly simple structure. In addition, *monolithic architecture* may be more convenient in cases where access to the *service* occurs via an internal network and requires low latency and high performance. In this way, both *services* for obtaining knowledge from external sources (obtaining weather forecasts, processing statistical information, etc.) and functional *services* (processing audio information and immersing the processing results in the *knowledge base*, obtaining a syntactic analysis of the sentence) can be integrated. An alternative implementation option is the implementation of a separate *ostis-system*, within which the function of the *service* will be integrated. This allows switching to the use of *microservice architecture*, which is characterized by distributed interaction of *ostis-systems*.

The advantages of this approach are greater *flexibility* and *scalability*. The approach is characterized by a high degree of distribution, decentralization, and availability of new functionality. The system goes beyond technical limitations, the functionality can be distributed on different hardware. The resulting functionality can be used by various *ostis-systems* within the *OSTIS Ecosystem* to achieve their goals. The disadvantages of such a system are the complexity of development, as well as the increase in time spent on communication of systems with each other over network protocols.

It is preferable to use the *microservice architecture* of ostis-systems in cases where the functional *service* has a complex structure, as well as in cases where scaling and flexibility of the entire system is required. An example is a *service*, which interacts with external data sources and may be prone to frequent changes. As examples of *integration* based on *microservice architecture*, *services* for reading the emotional state of the user, natural language processing, classification, and identification problems, etc. can serve.

Thus, the selection of the approach to *integration* of functional *services* depends on the specific requirements and conditions of the project. Using the *OSTIS Technology* allows creating flexible and efficient systems that can be adapted to different needs and requirements of users.

VII. Conclusion

To increase the level of automation of human activities, it is necessary to automate more complex problems. The solution of such problems is reduced to the requirement to increase the level of intelligence of individual cybernetic systems. However, the individual intelligence of cybernetic systems has its limitations. It is possible to achieve a significant increase in the level of intelligence by forming collectives of cybernetic systems, i.e. by moving to multi-agent systems [29]. Within such systems, the possibility of communication of each agent with each one is provided, as well as the possibility of forming specialized collectives for the solution of complex problems.

The possibility of *integration* of traditional *services* and *information resources* with a single platform of semantically compatible computer systems is an essential element for promoting technological innovations in the modern world. As the demand for efficient, reliable, and affordable systems continues to grow, it is very important to have a comprehensive and integrated platform capable of meeting various needs.

The *OSTIS Technology* provides the basis for the development of complex systems and their seamless *integration* with existing services and *resources*. Systems developed within an integrated ecosystem together provide opportunities to use a wide variety of functionality: information management, data analysis, decision-making, automation, etc.

Acknowledgment

The author would like to thank the research group of the Department of Intelligent Information Technologies of the Belarusian State University of Informatics and Radioelectronics for its help in the work and valuable comments.

References

[1] V. Golenkov, N. Guliakina, I. Davydenko, and A. Eremeev, "Methods and tools for ensuring compatibility of computer systems," *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, pp. 25–52, 2019.

[2] F. W. Neiva, J. M. N. David, R. Braga, and F. Campos, "Towards pragmatic interoperability to support collaboration: A systematic review and mapping of the literature," *Information and Software Technology*, vol. 72, pp. 137–150, 2016.

[3] P. Lopes de Lopes de Souza, W. Lopes de Lopes de Souza, and R. R. Ciferri, "Semantic Interoperability in the Internet of Things: A Systematic Literature Review," in *ITNG 2022 19th International Conference on Information Technology-New Generations*, S. Latifi, Ed. Cham: Springer International Publishing, 2022, pp. 333–340.

[4] Hamilton, Gunther, Drummond, and Widergren, "Interoperability – A Key Element for the Grid and DER of the Future," in *2005/2006 IEEE/PES Transmission and Distribution Conference and Exhibition*, 2006, pp. 927–931.

[5] M. Tsujimoto, Y. Kajikawa, J. Tomita, and Y. Matsumoto, "A review of the ecosystem concept — towards coherent ecosystem design," *Technological Forecasting and Social Change*, vol. 136, pp. 49–58, 2018.

[6] K. Kelly, *Out of Control: The New Biology of Machines, Social Systems, and the Economic World*. USA: Addison-Wesley Longman Publishing Co., Inc., 1995.

[7] H. Boley and E. Chang, "Digital ecosystems: Principles and semantics," in *2007 Inaugural IEEE-IES Digital EcoSystems and Technologies Conference*, 2007, pp. 398–403.

[8] G. Briscoe and P. D. Wilde, "Digital ecosystems: Self-organisation of evolving agent populations," *CoRR*, vol. abs/0803.2675, 2008. [Online]. Available: http://arxiv.org/abs/0803.2675

[9] T. Burstrom, T. Lahti, V. Parida, M. Wartiovaara, and J. Wincent, "Software ecosystems now and in the future: A definition, systematic literature review, and integration into the business and digital ecosystem literature," *IEEE Transactions on Engineering Management*, 2022.

[10] W. Li, Y. Badr, and F. Biennier, "Digital ecosystems: challenges and prospects," pp. 117–122, 2012.

[11] M. Mohseni, M. Sohrabi, and M. Dorrigiv, "A model-driven approach for semantic web service modeling using web service modeling languages," *Journal of Software: Evolution and Process*, vol. 33, 06 2021.

[12] T. Berners-Lee, J. Hendler, and O. Lassila, "The semantic web," *Scientific american*, vol. 284, no. 5, pp. 34–43, 2001.

[13] S. Kirrane, S. Villata, and M. dAquin, "Privacy, security and policies: A review of problems and solutions with semantic web technologies," *Semantic Web*, vol. 9, no. 2, pp. 153–161, 2018.

[14] R. McCooI, "Rethinking the semantic web. part 2," *IEEE Internet Computing*, vol. 10, no. 1, pp. 93–96, 2006.

[15] H. Nacer and D. Aissani, "Semantic web services: Standards, applications, challenges and solutions," *Journal of Network and Computer Applications*, vol. 44, pp. 134–151, 2014.

[16] O. Valdez-De-Leon, "How to develop a digital ecosystem: A practical framework," *Technology Innovation Management Review*, vol. 9, no. 8, 2019.

[17] E. G. Caldarola, A. Picariello, and A. M. Rinaldi, "An approach to ontology integration for ontology reuse in knowledge based digital ecosystems," pp. 1–8, 2015.

[18] D. Bork, R. Buchmann, D. Karagiannis, M. Lee, and E.-T. Miron, "An open platform for modeling method conceptualization: the omilab digital ecosystem," 2019.

[19] V. Golenkov, N. Guliakina, and D. Shunkevich, *Otkrytaya tekhnologiya ontologicheskogo proektirovaniya, proizvodstva i ekspluatatsii semanticheski sovmestimykh gibridnykh intellektual'nykh komp'yuternykh sistem [Open technology of ontological design, production and operation of semantically compatible hybrid intelligent computer systems]*. Minsk: Bestprint [Bestprint], 2021.

[20] (2022, Nov) Ostis Metasystem. [Online]. Available: https://ims.ostis.net

[21] A. Zagorskiy, "Principles for implementing the ecosystem of next-generation intelligent computer systems," *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, pp. 347–356, 2022.

[22] V. V. Golenkov, N. A. Guliakina, and O. E. Eliseeva, *Opisanie yazika SCP: Materialy po matematicheskomu obespecheniu EVM [Description of the SCP language: Computer Software Materials]*. Minsk : Instityt tech. kibernetiki Academii nauk Belarusi, 1995, (In Russ.).

[23] A. Kroshchanka, V. Golovko, E. Mikhno, M. Kovalev, V. Zahariev, and A. Zagorskij, "A Neural-Symbolic Approach to Computer Vision," in *Open Semantic Technologies for Intelligent Systems*, V. Golenkov, V. Krasnoproshin, V. Golovko, and D. Shunkevich, Eds. Cham: Springer International Publishing, 2022, pp. 282–309.

[24] V. Zahariev, D. Shunkevich, S. Nikiforov, and E. Aarov, "Intelligent voice assistant based on open semantic technology," in *Open semantic technologies for intelligent systems*, V. Golenkov, V. Krasnoproshin, V. Golovko, and E. Azarov, Eds. Cham. Springer, 2020, pp. 121–145.

[25] A. Goylo and S. Nikiforov, "Means of formal description of syntax and denotational semantics of various languages in next-generation intelligent computer systems," *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, pp. 99–118, 2022.

[26] "Introducing ChatGPT," Available at: https://openai.com/blog/chatgpt, (accessed 2023, March).

[27] D. Shunkevich, "Agent-oriented models, method and tools of compatible problem solvers development for intelligent systems," *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, pp. 119–132, 2018.

[28] V. V. Golenkov, D. V. Shunkevich, I. T. Davydenko, and N. A. Grakova, "Principles of organization and automation of the semantic computer systems development," *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, pp. 53–90, 2019.

[29] A. Zagorskiy, "Factors that determine the level of intelligence of cybernetic systems," *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, pp. 13–26, 2022.

Интеграция сторонних функциональных сервисов на унифицированной семантической основе

Загорский А. Г.

В работе представлены принципы, модели и средства интеграции различных сервисов в цифровую экосистему, основанную на смысловом представлении информации. Продемонстрирован пример реализации данного подхода с использованием Технологии OSTIS. Полученные результаты свидетельствуют о потенциальных преимуществах использования семантического представления информации для увеличения интероперабельности и адаптивности компьютерных систем в рамках единой цифровой экосистемы.

Received 29.03.2023