Principles for enhancing the development and use of standards within Industry 4.0

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***Abstract*—In this paper, we propose an approach to automating the processes of creating, developing and applying standards based on OSTIS Technology. The problems of modern approaches to the organization of these processes are considered, the role of standards in the framework of the Industry 4.0 concept is shown, examples of formalization of standards within the framework of the proposed approach are given.**

***Keywords*—Standards, Ontologies, Industry 4.0, OSTIS, ISA-88**

I. Introduction

Each developed sphere of human activity is based on a number of standards formally describing its various aspects – a system of concepts (including terminology), a typology and sequence of actions performed during the application process of appropriate methods and means, a model of a production facility, type and composition of project documentation accompanying activities and more.

The presence of standards allows us to solve one of the key problems that is relevant for any technology, especially for rapidly developing computer information technologies, the **compatibility problem** [1]. Compatibility can be considered in various aspects, ranging from the consistency of terms in the interaction of process participants and ending with the consistency of actions performed in the process the technology application, which, in turn, ensures that the result coincides when the same actions performed by different performers.

Despite the development of information technology, at present the vast majority of standards are presented either in the form of traditional linear documents, or in the form of web resources containing a set of static pages linked by hyperlinks. This approach to the presentation of standards has a number of significant drawbacks, which finally lead to the fact that the overhead costs of maintaining and applying the standard actually exceed the benefits of its application [2].

II. Problems and proposed approach

Let's list the most important and general problems associated with the development and application of modern standards in various fields [2], [3]:

- duplication of information within the document describing the standard;
- the complexity of maintaining the standard itself, due, among other things, to the duplication of information, in particular, the complexity of terminology changing;
- the problem of internationalization of the standard – in fact, translating the standard into several languages makes it necessary to support and coordinate independent versions of the standard in different languages;
- inconvenience of applying the standard, in particular, the complexity of the search for the necessary information. As a result, the complexity of studying the standard;
- inconsistency of the form of various standards among themselves, as a result – the complexity of the automation of processes of standards development and application;
- the complexity of the automation of checking the conformity of objects or processes with the requirements of a particular standard;
- and others.

As an example, consider the standard ***ISA 88*** [4] – the fundamental standard for batch production. The standard is widely used at enterprises in America and Europe, it is actively implemented in the territory of the Republic of Belarus, however, it has a number of disadvantages due to the above problems:

- the American version of the standard – *ANSI/ISA-88.00.01-2010* – is already updated, the third edition from 2010;
- at the same time, the European version adopted in 1997 – *IEC 61512-1* – is based on the old version *ISA-88.01-1995*;
- Russian version of the standard – *GOST R IEC 61512-1-2016* – is identical to *IEC 61512-1*, that is, it is also outdated;
- Russian version of the standard - *GOST R IEC 61512-1-2016* - also raises a number of questions related to the not very successful translation of the original English terms into Russian;
- when translating, meaning is lost due to poorly written text, failed translation, difficulty in understanding;
- and many others.

Another popular standard in the context of industry 4.0 is ***PackML*** (Packaging Machine Language) [5]. ***PackML*** is an industry standard for describing control systems for filling machines. Its main purpose is to simplify the development of such systems, abstract from hardware implementation and provide a single interface for interaction with the SCADA and MES levels. This standard defines both software elements (software modules for industrial controllers) and general principles for the development of packaging lines.

These and other standards are currently distributed in the form of documents that are inconvenient for automatic processing and, as indicated above, are highly dependent on the language in which each document is written.

These problems are mainly related to the presentation of standards. The most promising approach to solve these problems is the transformation of each specific standard into a knowledge base, which is based on a set of ontologies corresponding to this standard [1]–[3]. This approach allows us to significantly automate the development processes of the standard and its application.

The task of any standard in the general case is to describe a agreed system of concepts (and related terms), business processes, rules and other laws, methods for solving certain classes of problems, etc. *ontologies* are successfully used to formally describe this kind of information. Moreover, at present, in a number of areas, instead of developing a standard in the form of a traditional document, the corresponding ontology is being developed [6]–[9]. This approach provides obvious advantages in terms of automating the standards agreeing and application processes.

However, the problem that remains relevant is not with the form, but with the essence (semantics) of standards – the problem of inconsistency of the system of concepts and terms between different standards, which is relevant even for standards within the same field of activity.

To solve this problem and the problems listed above, it is proposed to use OSTIS Technology, one of the key tasks of which is to solve the problem of syntactic and semantic compatibility of computer systems [1], in particular, the compatibility of various types of knowledge [10] and various problem solving models [11].

As part of this work, we will consider the experience of using this technology in building an information and reference system for the standard for batch production ISA-88 [4] together with employees of JSC "Savushkin Product". Initially, this system was considered as a reference and training system for employees of the enterprise, however, it is currently being transformed into an international open-source project, the purpose of which is to create an up-to-date, constantly developed and user-friendly knowledge base that describes the specified standard. Work [12] considered the initial version of the formal description of the standard in question using the OSTIS Technology, as well as fragments of the formal description of the departments of the enterprise taking into account the requirements of the standard.

Subsequently, part of the descriptions presented, not directly related to the enterprise, was allocated to the above-mentioned separate system dedicated to the ISA-88 standard. The current version of the system is available online at http://ostis.savushkin.by.

III. ISA-88 STANDARD

The ***ISA-88*** (short for ANSI/ISA-88) standard is based on the previously developed standard NAMUR N33 and helps in solving several fundamental problems, such as the lack of a single model of batch production, the difficulty of requirements agreeing, the complexity of integrating solutions from various suppliers, the complexity of the management of batch production. To solve these problems, it was necessary to define common models, terminology, data structure and process description language. The structure of the standard corresponds to the mentioned tasks and includes four parts:

- ANSI/ISA-88.00.01-2010, Batch Control Part 1: Models and Terminology – defines standard models and terminology for formalizing requirements for batch production control systems, its equivalent is IEC 61512 1;
- ANSI/ISA 88.00.02 2001, Batch Control Part 2: Data Structures and Guidelines for Languages – defines data models for production management, data structures for information exchange, as well as a form for recording recipes;
- ANSI/ISA 88.00.03 2003, Batch Control Part 3: General and Site Recipe Models and Representation – defines models for presenting generalized recipes and exchanging such recipes between departments of the enterprise, as well as between the enterprise and its partners;

- ANSI/ISA 88.00.04 2006, Batch Control Part 4: Batch Production Records – defines data models and an indicative system model for recording, storing, retrieving and analyzing data on the progress of periodic production.

IV. System architecture and use cases

It is proposed to use OSTIS Technology and the corresponding set of models, methods and tools for developing semantically compatible intelligent systems as a basis for automating the processes of creating, developing and applying of standards. The basis of OSTIS Technology is a unified version of the information encoding language based on semantic networks with a basic set-theoretic interpretation, called the SC-code [1].

The use of SC-code and models for the presentation of various types of knowledge built on its basis will provide such opportunities as:

- automation of standardization processes by a distributed team of authors;
- the ability to fix conflicting points of view on the same problem in the discussion process and even in the process of applying the developed standard;
- the possibility of evolution of the standard directly in the process of its application;
- lack of information duplication at the semantic level;
- independence of the system of concepts from terminology, as a result – from the natural language in which the standard was originally created;
- the ability to automate standard verification processes, including identifying inconsistencies, information holes, logical duplications, etc.;
- improving the efficiency of using the standard, providing the ability to solve various problems without the need to convert the standard to any other format, in particular, the ability to automate the process of verifying compliance with anything necessary standards;
- and others.

The architecture of each system based on OSTIS Technology (ostis-system) includes a platform for interpreting semantic models of ostis-systems, as well as a semantic model of ostis-system described using SC-code (sc-model of ostis-system). In turn, the sc-model of ostis-system includes the sc-model of the knowledge base, the sc-model of the problem solver and the sc-model of the interface (in particular, the user interface). The principles of organization and designing of knowledge bases and problem solvers are discussed in more detail in [10] and [11], respectively.

Let us consider in more detail the composition of each of the above components in the framework of the system under the ISA-88 standard.

A. System knowledge base

The sc-model of the knowledge base of any ostis-system is based on a hierarchical system of subject domains and corresponding ontologies. Within the framework of this system, the core of sc-models of knowledge bases is distinguished, including the family of top-level subject domains [10]. This approach provides the compatibility of various types of knowledge in any ostis-system, as well as significantly reduce the time to develop a specific knowledge base.

Within the framework of the system under consideration, the following set of subject domains that correspond to the ISA-88 standard (Fig. 1) is distinguished:

Each subject domain has a corresponding structural specification, which includes a list of concepts studied within this domain (Fig. 2):

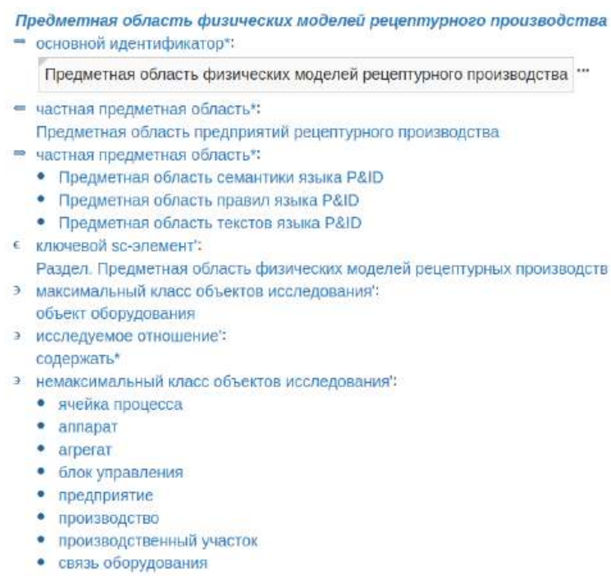

Figure 2. Subject domain specification.

In turn, each concept of the standard is described with the necessary level of detailing (Fig. 3):

In addition, an important advantage of using OSTIS Technology to develop this kind of system is the availability of methods and tools for the collective development of knowledge bases [10], which support the development of a standard presented in the form of a knowledge base distributed by a team of developers.

B. System problem solver

The problem solver of any ostis-system is a hierarchical system of agents interacting with each other exclusively through the semantic memory of this ostis-system (sc-agents) [11]. This approach provides the modifiability of the solver and the possibility of integrating various problem solving models within the solver.

In the context of the system according to the ISA-88 standard, an urgent task is to search for necessary

Figure 1. ISA-88 standard subject domains hierarchy.

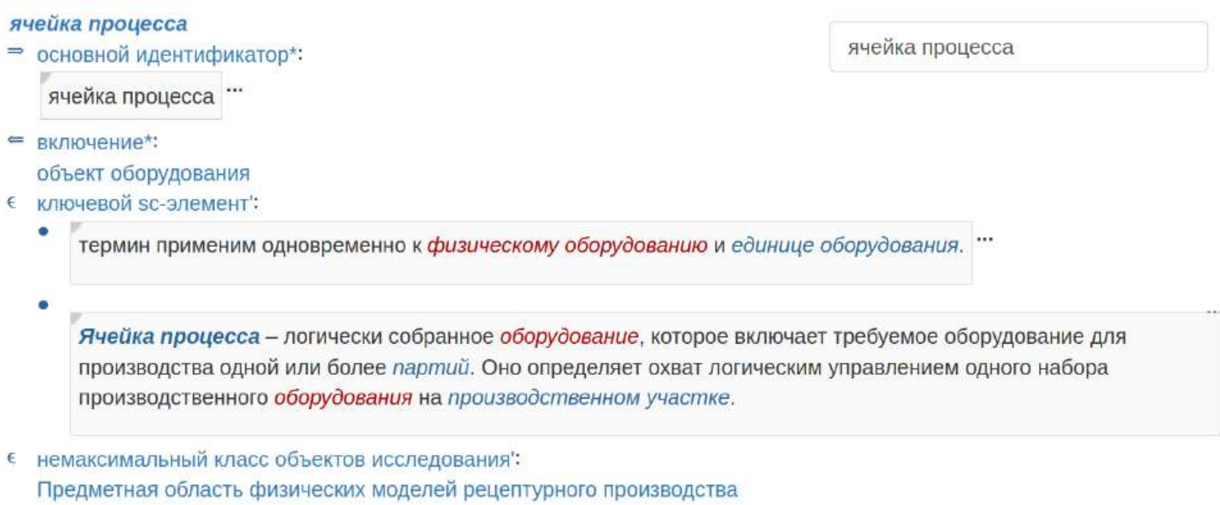

Figure 3. Concept specification within the standard.

information by the employees of the enterprise, from the definitions of certain concepts to the establishment of similarities and differences between the indicated entities. This task is relevant for both experienced employees and new employees who are first acquainted with the standard. An important aspect is the ability to ask questions in a way that is understandable to a user who is not necessarily familiar with the internal structure of an ostis system.

The approach used to build knowledge bases and problem solvers makes it possible to unify the principles of information processing, and, as a result, reduce the number of necessary sc-agents. So, for example, questions of the form

- "What subclasses does the given class have?";
- "What components is the specified entity divided into?";
- "What parts does the given object consist of?";
- "What are the varieties of a given entity?";
- etc.

can be reduced to the generalized question “What entities are particular with respect to a given entity?”, for the processing of which, therefore, it is enough to implement only one sc-agent. However, this does not prohibit having within the user interface a set of more specialized commands with names that are understandable to the end user, but within the framework of the system implemented in a universal key.

C. System user interface

The most important component for a system that describes a standard is the user interface, the quality of which largely determines the efficiency of using the system. Most often, users of the system are employees who are far from semantic technologies, and often information technologies in general, in connection with which the task of building an interface is urgent, which, on the one hand, would be easy to use and visual, on the other hand, would be universal (able to display different types of knowledge).

By default, system responses to the user are displayed in SCn-code, which is a hypertext version of the external representation of SC-code texts and can be read as linear text.

The information in the above figures is displayed as SCn-texts in a mode intended for the end user. For a more experienced user, a mode with a more detailed display of information is also provided.

An important feature of SC-code is a clear separation of the internal sign denoting some entity and the term or other external identifier corresponding to this entity. Due to this feature of each entity, an arbitrary number of external identifiers can be mapped, which, in turn, can easily provide a multilingual standard without the need for duplication of information.

So, for the current version of the system according to the ISA-88 standard, it turned out to be relevant to have versions of the system in Russian, English, Ukrainian and German. Fig. 4 presents the start page of the system in English. As can be seen from the presented examples, only the displayed terms change, the structure of the information remains unchanged.

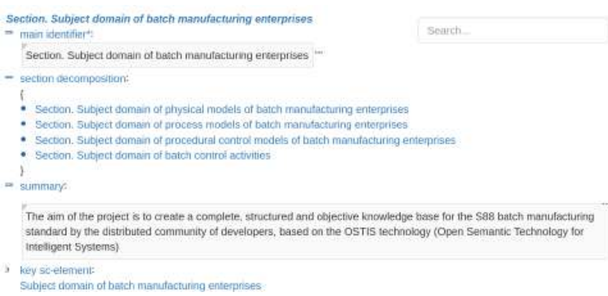

Figure 4. Start page in English.

Thus, the proposed approach also allows us to describe the syntax and semantics of external languages, which makes it possible to construct unified visualization tools not only for universal languages (variants for external representation of SC-code texts), but also for specialized languages, such as PFC. The figure 5 shows an image of a chart in PFC language, to the elements of which you can ask various questions, as well as to any other elements within the knowledge base.

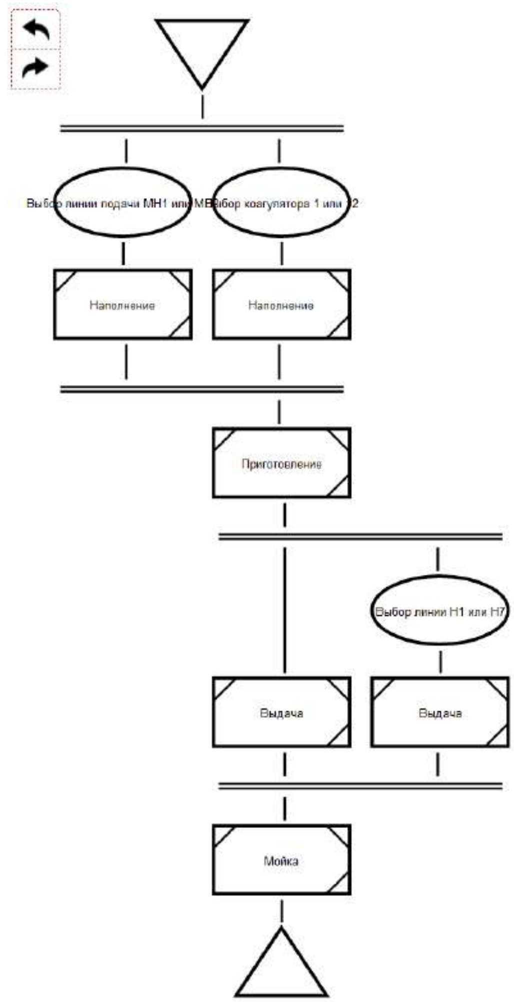

Figure 5. An example chart in PFC

In addition, the OSTIS Technology means allow to store and, very importantly, specify any external files, for example, images, documents, etc. within the framework of the knowledge base. The figure 6 shows the description in the knowledge base of the procedure image in the PFC language, which is part of the ISA-88 standard.

V. Integration of third-party solutions with a knowledge base

A standard system built on the basis of OSTIS Technology can be easily integrated with other systems in the workplace. To integrate the ISA-88 standard system with other systems running on JSC "Savushkin Product", a web-oriented approach is used – the ostis-system server is accessed with the use of the following queries:

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http://ostis.savushkin.by?sys_id=procedure
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where "sys_id=procedure" defines a term (the name of an entity) whose value we want to find out (in this example, in fact, the answer to the question“ What is a “procedure”?). This approach makes it relatively easy to

Figure 6. Image specification in the knowledge base.

add support of the knowledge base for current control systems projects, for this it is enough to indicate the names corresponding to the entities in the knowledge base within the control system. Thus, an interactive intelligent help system for control systems projects is implemented, allowing employees to simultaneously work with the control system and ask questions to the system directly during the work.

Fig. 7 shows an illustration of the display of information in the form of a mimic diagram of the HMI (from the control system project).

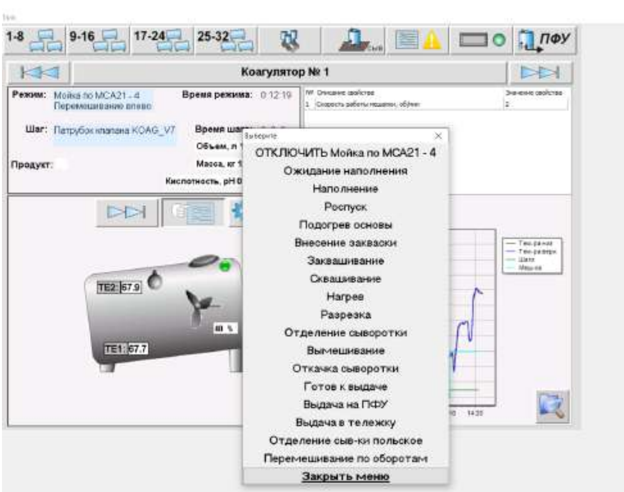

Figure 7. Example HMI from SCADA [12].

Fig. 8 shows a web page that displays the same information as a PFC chart (from the knowledge base).

VI. Conclusion

The paper considers an approach to automating the processes of creating, developing and applying standards based on OSTIS Technology. Using the example of the ISA-88 standard used at the Savushkin Product enterprise, the structure of the knowledge base, the features of the problem solver and the user interface of the support system for these processes are considered. It is shown that the developed system can be easily integrated with other enterprise systems, being the basis for building an information service system for employees in the context of Industry 4.0.

The approach proposed in the work allows us to provide not only the ability to automate the processes of creation, agreeing and development of standards, but also allows us to significantly increase the efficiency of the processes of applying the standard, both in manual and automatic mode.

As part of the further development of the obtained results, the authors plan to attract the international community to the development of the knowledge base and the entire prototype of the system according to the ISA-88 standard, for which the tools of collective development of knowledge bases proposed in the framework of OSTIS Technology will be used.

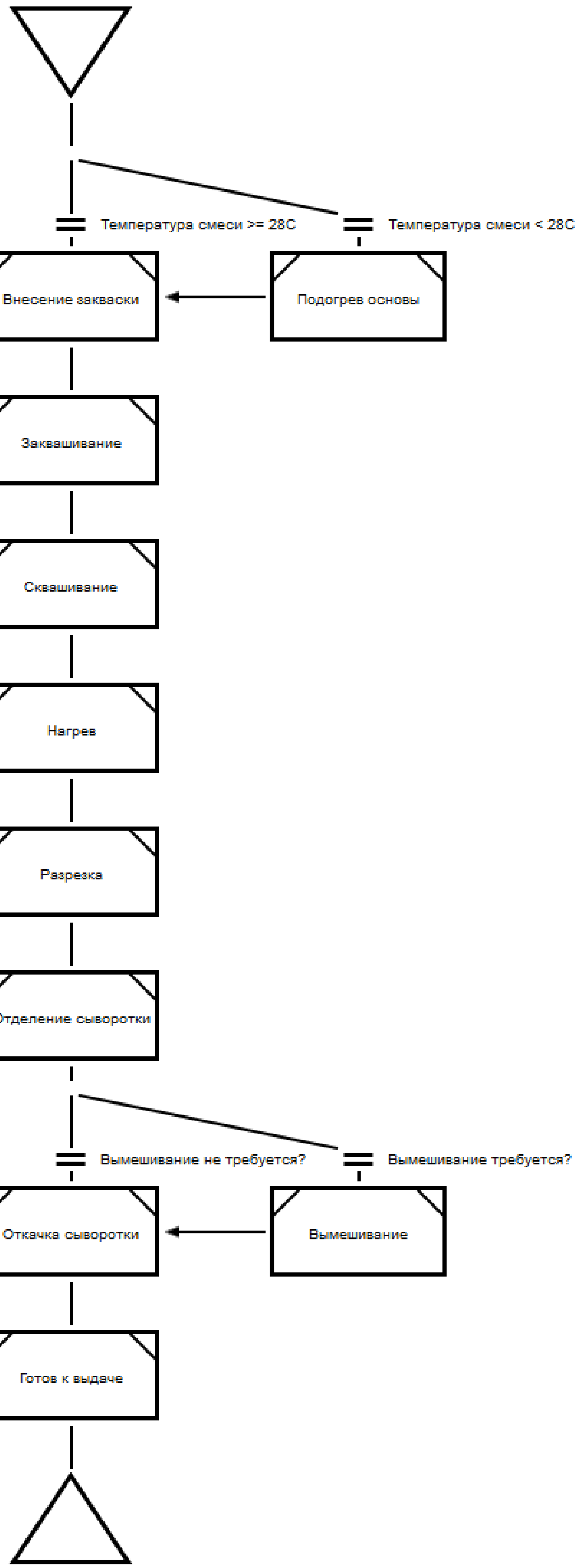

Figure 8. Corresponding PFC chart from OSTIS.

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References

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

[2] P. Serenkov, V. Solomaho, V. Nifagin, and A. Minova, "Koncepcija infrastruktury standartizacii kak bazy znanij na osnove ontologij [the concept of a standardization infrastructure as an ontology-based knowledge base]," *Novosti. Standartizacija i sertifikacija. [News. Standardization and certification.]*, no. 5, pp. 25–29, 2004.

[3] V. Uglev, "Aktualizacija soderzhanija standartov proektirovanija slozhnyh tehnicheskih ob'ektov: ontologicheskij podhod [updating the content of design standards for complex technical objects: ontologic approach]," *Ontologija proektirovanija. [Ontology of designing]*, no. 1, pp. 80–86, 2012.

[4] "ISA-88 standard," Available at: https://www.isa.org/isa88/, (accessed 2020, Jan).

[5] G. Mušič, "A low-cost PackML-based control solution for a modular production line," *IFAC-PapersOnLine*, vol. 48, no. 10, pp. 184–189, 2015. [Online]. Available: https://doi.org/10.1016/j.ifacol.2015.08.129

[6] B. R. Heravi, M. Lycett, and S. de Cesare, "Ontology-based standards development: Application of OntoStanD to ebXML business process specification schema," *International Journal of Accounting Information Systems*, vol. 15, no. 3, pp. 275–297, Sep. 2014. [Online]. Available: https://doi.org/10.1016/j.accinf.2014.01.005

[7] S. El-Sappagh, F. Franda, F. Ali, and K.-S. Kwak, "SNOMED CT standard ontology based on the ontology for general medical science," *BMC Medical Informatics and Decision Making*, vol. 18, no. 1, Aug. 2018. [Online]. Available: https://doi.org/10.1186/s12911-018-0651-5

[8] S. Schulz, R. Stegwee, and C. Chronaki, "Standards in healthcare data," in *Fundamentals of Clinical Data Science*. Springer International Publishing, Dec. 2018, pp. 19–36. [Online]. Available: https://doi.org/10.1007/978-3-319-99713-1_3

[9] S. Schulz and C. Martínez-Costa, "How ontologies can improve semantic interoperability in health care," in *Lecture Notes in Computer Science*. Springer International Publishing, 2013, pp. 1–10. [Online]. Available: https://doi.org/10.1007/978-3-319-03916-9_1

[10] I. Davydenko, "Semantic models, method and tools of knowledge bases coordinated development based on reusable components," in *Open semantic technologies for intelligent systems*, V. Golenkov, Ed. BSUIR, Minsk, 2018, pp. 99–118.

[11] D. Shunkevich, "Agent-oriented models, method and tools of compatible problem solvers development for intelligent systems," in *Open semantic technologies for intelligent systems*, V. Golenkov, Ed. BSUIR, Minsk, 2018, pp. 119–132.

[12] V. V. Taberko, D. S. Ivanjuk, V. V. Golenkov, I. T. Davydenko, K. V. Ruseckij, D. V. Shunkevich, V. V. Zaharov, V. P. Ivashenko, and D. N. Koronchik, "Ontologicheskoe proektirovanie predprijatij recepturnogo proizvodstva na osnove ontologij [ontological design of prescription production enterprises based on ontologies]," in *Open semantic technologies for intelligent systems*, ser. 1, V. Golenkov, Ed. BSUIR, Minsk, 2017, pp. 265–280.

Принципы повышения эффективности процессов разработки и использования стандартов в рамках концепции Industry 4.0

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В данной работе предлагается подход к автоматизации процессов создания, развития и применения стандартов на основе Технологии OSTIS. Рассмотрены проблемы современных подходов к организации указанных процессов, показана роль стандартов в рамках концепции Industry 4.0, приведены примеры формализации стандартов в рамках предлагаемого подхода.

На примере стандарта ISA-88, применяемого на предприятии ОАО "Савушкин продукт рассмотрена структура базы знаний, особенности решателя задач и пользовательского интерфейса системы поддержки указанных процессов. Показано, что разработанная система легко может интегрироваться с другими системами предприятия, являясь основой для построения системы информационного обслуживания сотрудников предприятия в контексте Industry 4.0.

Предложенный в работе подход позволяет обеспечить не только возможность автоматизации процессов создания, согласования и развития стандартов, но и позволяет значительно повысить эффективность процессов применения стандарта, как в ручном, так и в автоматическом режиме.

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