Implementation principles of the training subsystem for end-users and developers of intelligent systems

Natalia Grakova
Belarusian State University of Informatics and Radioelectronics
Minsk, Belarus
Email: grakova@bsuir.by

Maria Koroleva, Georgiy Bobrov
Bauman Moscow State Technical University
Moscow, Russian Federation
Email: maria.svyatkina@gmail.com, bobrov.georgij@yandex.ru

***Abstract*—In the article, an approach to solving the problem of training end-users and developers of intelligent systems is proposed, which involves the supplement of each intelligent system with a module that is an intelligent training subsystem, the purpose of which is to train the end-user and the developer of the main system in the principles of working with it, its operation and development. As a foundation for the implementation of this approach, it is proposed to use an Open Semantic Technology for Intelligent Systems (OSTIS Technology).**

***Keywords*—OSTIS, intelligent system, intelligent learning system, ontological approach**

I. Introduction

Currently, artificial intelligence technologies are being rapidly developed and are being used in various spheres of human activity. Unfortunately, the question is increasingly about systems that contain elements of artificial intelligence, rather than about intelligent systems, to which much higher requirements are imposed. The most important of these requirements is the *learnability* of the system, that is, its ability to acquire new knowledge and skills, and, in particular, *unlimited learnability*, that is, such a degree of learnability, when no constraints are imposed on the typology of this knowledge and skills. In other words, a system with *unlimited learnability* can, if necessary, acquire any knowledge and the ability to solve any problem over time. Let us clarify that this does not mean that one particular system will be able to solve any problem; it means that the system can acquire the ability to solve the required problem, while there are no fundamental restrictions on the class of such problems [1].

At the same time, intelligent computer systems are complex technical systems, the development and even usage of which often require high professional qualities. In particular, the following problems are relevant:

- the lack of efficiency of using modern intelligent systems, the complexity of their implementation and maintenance, which are largely determined by the high threshold of entry of end-users into intelligent systems;
- the user often does not use a significant part of the functions of even traditional computer systems simply for the reason that they do not know about their availability and do not have a simple mechanism to find out about them. For intelligent systems, this problem is even more pressing;
- there are high costs for training developers of intelligent systems, their adaptation to the features of the organization of a particular intelligent system.

These difficulties are connected not only with the inherent complexity of intelligent computer systems compared to traditional computer systems but also with the low level of documentation for such systems, the inconvenience of using such documentation, the complexity of localization of tools and the scope of solving a particular problem both for the end-user and for the developer.

II. Proposed approach

Within the framework of this article, an approach to solving these problems is proposed, involving the supplement of each intelligent system with a module that is an intelligent training subsystem, the purpose of which is to train the end-user and the developer of the main system in the principles of working with it, the principles of its operation and development.

In other words, the main idea of the proposed approach can be exemplified as follows: regardless of what problems an intelligent system is being developed for, it must have some of the functions of a training system, even if the system is not initially a training one. So, the end-user should be able to study both the principles of working with an intelligent system and gain new knowledge about the subject domain, for which an intelligent system is being created. In turn, the developer of intelligent systems should be able to study the principles of the internal organization of the system, the principles of its operation, the functions of specific components of the system, have the opportunity to localize the part of the system, on which they must gain insight for making changes to the functionality of the system.

To implement this idea, an intelligent system must contain not only knowledge about the subject domain, for which it is designed, but also

- knowledge about itself, its architecture, components, functions, operating principles, etc.;
- knowledge about the user, their experience, skills, preferences, interests;
- knowledge about the problems that the system solves independently at the moment and the problems that are planned to be solved in the future;
- knowledge about current problems in the development of the system and its maintenance.

The representation and processing of all of the above require a common formal foundation for the representation of knowledge of various types as well as a common foundation for various types of means of processing this knowledge.

As such a foundation, it is proposed to use an Open semantic technology for intelligent systems (*OSTIS Technology*) [2], which allows integrating any type of knowledge and any problem-solving model. The systems being developed on the basis of this technology are called *ostis-systems*.

The usage of the OSTIS Technology gives the following advantages for solving the specified problem:

- The technology is based on the *SC-code* – a universal and unified language for encoding information in the dynamic graph memory of computer systems. The SC-code allows representing any information in a unified (similar) form, which will make the proposed approach universal and suitable for any class of intelligent systems;
- The OSTIS Technology and, in particular, the SC-code, can be easily integrated with any modern technology, which will allow applying the proposed approach to a large number of already developed intelligent systems;
- The SC-code allows storing and describing in the ostis-system knowledge base any external (heterogeneous) information in relation to the SC-code in the form of internal files of ostis-systems [3]. Thus, the knowledge base of the training subsystem can explicitly contain fragments of existing documentation for the system, represented in any form;
- Within the framework of the OSTIS Technology, models of the ostis-system knowledge bases [4], ostis-system problem solvers [5] and ostis-system user interfaces [6] have already been developed, asserting their full description in the system knowledge base. Thus, for ostis-systems, the proposed approach is implemented much easier and provides additional advantages, which are discussed in more detail in this article [7];
- One of the main principles of the OSTIS Technology is to ensure the flexibility (modifiability) of systems developed on its basis. Thus, the usage of the OSTIS Technology will provide an opportunity for the evolution of the intelligent learning subsystem itself.

Further, let us consider in more detail the possibilities of using the OSTIS Technology for the development of intelligent learning systems.

III. Intelligent learning systems

Intelligent learning systems (ILS) are an important class of intelligent systems. Such systems, in comparison with traditional e-learning systems (for example, electronic textbooks), have a number of significant advantages [8]. At the same time, the issue of intellectualization of the learning process remains relevant [9]–[11], including with the usage of semantic technologies [12]. At the same time, as can be seen from the above papers, the relevance of this issue is realized by specialists in the field of education and not only by specialists in the field of intelligent system development.

In the case of the implementation of ILS based on the OSTIS Technology, additional features appear, which include the following:

- The semantic structure of the studied educational material and the studied subject domain is explicitly presented to the user. At the same time, visualization of any level of the specified semantic structure is enabled;
- The user gains access to sufficiently complete information about the studied subject domain; all its aspects are reflected thanks to the explicit placement of all subject conformities and interrelations of concepts in the knowledge base;
- In addition to the ability to read texts and illustrative materials of the textbook, it is possible to navigate through the semantic space of the subject domain;
- The user is allowed to ask the system any questions and set problems on the studied subject domain. This is achieved by including a problem solver in the ILS, which can solve problems according to their formulations, including those input by the user. At the same time, the specified problem solver can find a way to solve the problem even if the corresponding solution method (for example, an algorithm) is unknown to it;
- The user is given the opportunity to train (acquire practical skills) in solving a variety of problems in the studied subject domain under the control of the system. At the same time, the system
  - performs a semantic analysis of the correctness of solving problems both according to freely generated answers (results) and the solution protocols;

– localizes the errors made by the user in solving problems, determines their cause and gives appropriate recommendations to the user.

- The ILS has an intelligent user interface with computer (virtual) models of various objects of the studied subject domain, which allows the system to "understand" the meaning (analyze the semantics) of user actions on the transformation of these objects. All this significantly increases the level of the interactive virtual laboratory environment of the electronic textbook;
- When communicating with the system, the user is given free hand in choosing any of the many synonymous terms (identifiers) registered in the system knowledge base. At the same time, these terms may belong to different natural languages;
- There is a principal possibility of implementing a natural-language interface with the user (thanks to the wide possibilities of semantic analysis of user messages and the possibilities of synthesis of messages addressed to users at the semantic level);
- It is quite easy to reorient the ILS to serve users with a different natural language (since the major part of the ILS knowledge base, which directly describes the semantics of the corresponding subject domain, is independent of the external language including the natural one);
- The user can choose the sequence of studying the educational material (the route-based navigation through the educational material), but relevant recommendations are given;
- The user can choose the problems being solved (in the book of problems and laboratory-based works), but the appropriate recommendations are given. These recommendations are aimed at minimizing the number of solved problems that ensure the acquisition of the required practical skills;
- The system does not have a special mode for control (verification, testing) of knowledge. Such control is carried out seamlessly for the user by monitoring and analyzing user actions when solving various problems in the studied subject domain. To do this, the ILS knowledge base contains information about what types of problems and laboratory-based works should be completed by the user for satisfactory, good and excellent assimilation of the educational material, respectively;
- It is quite easy to integrate several independent ILS in related disciplines into a single textbook, which, in particular, provides an opportunity to ask questions and set problems at the intersection of these disciplines;
- The ILS user works under the supervision and control of an intelligent helper, which helps the user master the capabilities of the system quickly and effectively. In fact, this is nothing more than an ILS user's guide designed as a semantic electronic textbook;
- When designing the ILS knowledge base, there is a unique opportunity to check the semantic correctness of the information resource being formed:
  – correctness of definitions and statements;
  – correctness of the usage of various concepts;
  – correctness of algorithms;
  – correctness of proofs of theorems;
  – etc.

Some of these opportunities (in the limiting case, all of them) can be implemented within the framework of the subsystem for training users of an intelligent system. Next, let us consider in more detail the architecture of the proposed subsystem.

IV. ARCHITECTURE OF THE SUBSYSTEM FOR TRAINING USERS OF INTELLIGENT SYSTEMS

Figure 1 shows the architecture of the proposed *subsystem for training users of intelligent systems*. To implement the interaction of the *subsystem for training users of intelligent systems*, implemented on the basis of the OSTIS Technology, with the main intelligent system, it is planned to develop an interface component, which is also part of the subsystem. It is important to note that for different intelligent systems, such components will be largely overlapping, which is due to the features of the OSTIS Technology itself, which, in turn, will reduce the cost of integrating the training subsystem and the main intelligent system.

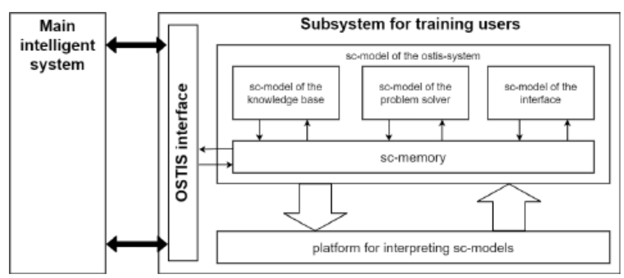

Figure 1. The architecture of the subsystem for training users of intelligent systems

If the intelligent system under consideration is an ostis-system, its integration with the *subsystem for training users of intelligent systems* is carried out more deeply, and the architecture of the resulting integrated system can be represented as follows (fig. 2). As can be seen from the figure, the components of the *subsystem for training users of intelligent systems* solely complement the already existing in the main ostis-system components, which allows minimizing the cost of integrating the *subsystem for training users of intelligent systems* and the main ostis-system.

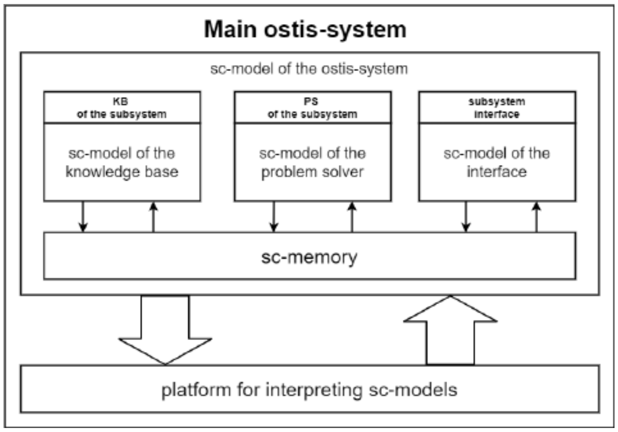

Figure 2. The architecture of the subsystem for training users of intelligent systems as part of another ostis-system

V. Examples of the representation of various types of knowledge within the framework of the subsystem for training users of intelligent systems

Let us consider a number of examples that illustrate the possibilities of the approach proposed within the framework of the OSTIS Technology to the development of knowledge bases when describing various types of knowledge in the subsystem for training users of intelligent systems. For the illustrations, the SCg- and SCn-codes [3] will be used, which are the languages for the external representation of SC-code constructions.

Figure 3 in the SCg-code shows various information about a particular user of the intelligent system. This example shows how using the knowledge base structuring tools developed within the framework of the OSTIS Technology [4], it is possible to describe various types of information about the same entity in the knowledge base, in particular, the current employment and professional skills of the user. Any other information about the user can be described in the same way.

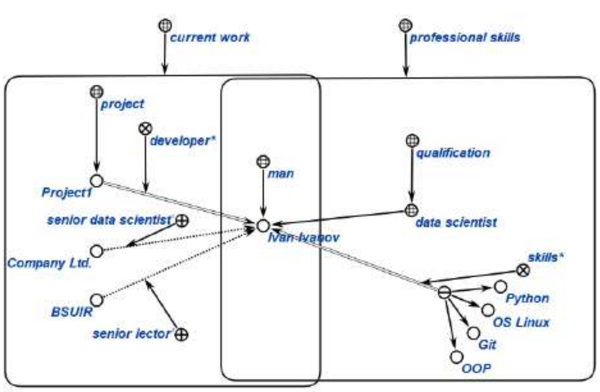

Figure 3. The description of the user of the intelligent system

The ostis-system knowledge base can be structured according to various features [4]. Within the framework of this article, the structuring of the knowledge base from the point of view of its development process is of the greatest interest. Let us consider a variant of such structuring in the SCn-code:

semantic model of the knowledge base
⇒ *abstract basic decomposition**:
{
- *history and current processes of computer system operation*
  ⇒ *abstract basic decomposition**:
  {
  - *history of computer system operation*
  - *current processes of computer system operation*
  }
- *computer system documentation*
- *context of the subject part of the knowledge base within the Global knowledge base*
- *subject part of the knowledge base*
- *history, current processes and development plan of the computer system*
  ⇒ *abstract basic decomposition**:
  {
  - *current processes of computer system development*
  - *history of the computer system development*
  - *structure and organization of the computer system project*
  - *computer system development plan*
  }
}

Figure 4 in the SCg-code shows an example of describing information about the performers of a certain project who take on various roles in it. From the point of view of the knowledge base structure, this information is part of the *structure and organization of the computer system project* section.

Figure 5 in the SCg-code shows an example of a description of project tasks and their performers, taking into account the qualifications of each performer. From the point of view of the knowledge base structure, this information is part of the *current processes of computer system development* section.

According to the approach proposed within the framework of the OSTIS Technology to the development of problem solvers, the basis of the solver is a hierarchical system of agents over semantic memory (sc-agents) [5]. The structure of the solver can also be described in the ostis-system knowledge base. Next, in the SCn-code, the structure of the problem solver of the labeling quality control system for the formulating enterprise is presented:

Problem solver of the labeling quality control system
⇒ *decomposition of an abstract sc-agent**:

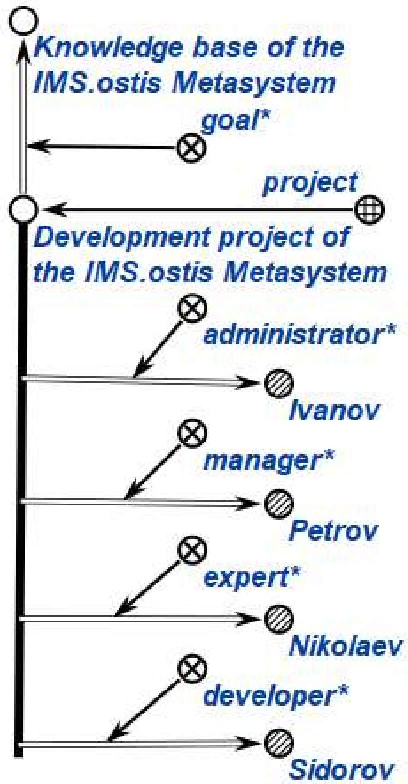

Figure 4. The description of the performers of the project for the development of some intelligent system

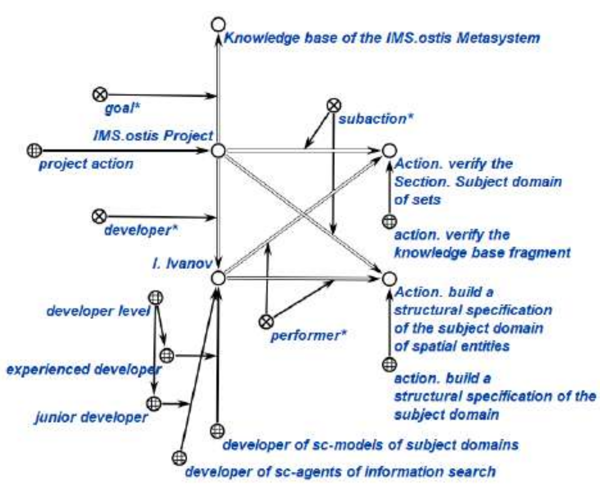

Figure 5. The description of the project tasks

{• *Atomic abstract sc-agent of labeling recognition based on a neural network*
• *Non-atomic abstract sc-agent of decision-making*
  ⇒ *decomposition of an abstract sc-agent**:
  {• *Atomic abstract sc-agent that implements the concept of a software package*
  • *Non-atomic abstract sc-agent of certain inference*
  • *Non-atomic abstract sc-agent of reliable inference*
  }
• *Non-atomic abstract sc-agent of content-addressable retrieval*
• *Non-atomic abstract sc-agent of interpretation of control programs for a robotic installation*
  ⇒ *decomposition of an abstract sc-agent**:
  {• *Atomic abstract sc-agent of interpretation of the movement action*
  • *Atomic abstract sc-agent of interpretation of the acquisition action*
  }
}

Non-atomic abstract sc-agent of certain inference
⇒ *decomposition of an abstract sc-agent**:
{• *Atomic abstract sc-agent that implements a certain inference strategy*
• *Non-atomic abstract sc-agent of logical rules interpretation*
}

Non-atomic abstract sc-agent of reliable inference
⇒ *decomposition of an abstract sc-agent**:
{• *Atomic abstract sc-agent that implements a reliable inference strategy*
• *Non-atomic abstract sc-agent of logical rules interpretation*
}

Non-atomic abstract sc-agent of logical rules interpretation
⇒ *decomposition of an abstract sc-agent**:
{• *Atomic abstract sc-agent of applying implicative rules*
• *Atomic abstract sc-agent of applying equivalence rules*
}

VI. CONCLUSION

As part of the further development of the proposed idea, models and tools for improving the efficiency of training users of intelligent systems will be developed in the form of an appropriate set of ontologies that describe knowledge about the intelligent system itself, its users and tasks for its development, models of the subsystem for training users of intelligent systems, a corresponding set of software agents, which implements the functionality of the subsystem considered in the article.

The implementation of the proposed idea will allow:

- reducing the threshold of entry of end-users into intelligent systems as well as significantly improving the efficiency of using such systems;
- reducing the time for training developers of intelligent systems, their adaptation to the features of a particular intelligent system, development and refinement of the intelligent system. All of the above will also solve the problem of employee turnover at enterprises engaged in the development of complex intelligent systems as well as reduce the cost of developing and maintaining intelligent systems and, as a result, make them more available to the end-user.

Acknowledgment

The authors would like to thank the Department of Intelligent Information Technologies of the Belarusian State University of Informatics and Radioelectronics for the help and valuable comments.

The work was carried out with the partial financial support of the BRFFR and RFFR, project numbers F21PM-139 and 20-57-04002.

References

[1] V. Golenkov, N. Guliakina, N. Grakova, I. Davydenko, V. Nikulenka, A. Eremeev, and V. Tarassov, "From training intelligent systems to training their development tools," *Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems]*, pp. 81–98, 2018.

[2] V. Golenkov, N. Gulyakina, I. Davydenko, and D. Shunkevich, "Semanticheskie tekhnologii proektirovaniya intellektual'nyh sistem i semanticheskie associativnye komp'yutery [Semantic technologies of intelligent systems design and semantic associative computers]," *Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems]*, pp. 42–50, 2019.

[3] (2021, Jun) IMS.ostis Metasystem. [Online]. Available: https://ims.ostis.net

[4] I. Davydenko, "Semantic models, method and tools of knowledge bases coordinated development based on reusable components," in *Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems]*, V. Golenkov, Ed., BSUIR. Minsk , BSUIR, 2018, pp. 99–118.

[5] D. Shunkevich, "Agentno-orientirovannye reshateli zadach intellektual'nyh sistem [Agent-oriented models, method and tools of compatible problem solvers development for intelligent systems]," in *Otkrytye semanticheskie tekhnologii proektirovaniya intellektual'nykh system [Open semantic technologies for intelligent systems]*, V. Golenkov, Ed. BSUIR, Minsk, 2018, pp. 119–132.

[6] A. Boriskin, D. Koronchik, I. Zhukau, M. Sadouski, and A. Khusainov, "Ontology-based design of intelligent systems user interface," in *Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems]*, V. Golenkov, Ed., BSUIR. Minsk , BSUIR, 2017, pp. 95–106.

[7] 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.

[8] V. Golenkov, V. Tarasov, and O. Eliseeva, *Intellektual'nye obuchayushchie sistemy i virtual'nye uchebnye organizatsii [Intelligent Learning Systems and Virtual Learning Organizations]*, V. Golenkov and V. Tarasov, Eds. Minsk. BSUIR, 2001.

[9] G. Y. Yalamov and T. S. Shikhnabieva, "Adaptivnye obrazovatel'nye informatsionnye sistemy: podkhody k intellektualizatsii [adaptive educational information systems: approaches to intellectualization]," in *Chelovek i obrazovanie [Human and education]*, no. 4 (57), 2018, pp. 84–90, (in Russ).

[10] Y. A. Vagramenko and G. Y. Yalamov, "Analiz napravlenii intellektualizatsii sovremennykh informatsionnykh sistem uchebnogo naznacheniya[analysis of the directions of intellectualization of modern information systems of educational appointment]," in *Upravlenie obrazovaniem: teoriya i praktika [Education management: theory and practice]*, no. 4(24), 2016, pp. 44–57, (in Russ).

[11] V. M. Trembatch, "Elektronnye obuchayushchie sistemy s ispol'zovaniem intellektual'nykh tekhnologii[e-learning systems using intellectual techniques]," in *Otkrytoe obrazovanie [Open education]*, no. 4, 2013, pp. 52–62, (in Russ).

[12] T. S. Shikhnabieva, "Adaptivnye semanticheskie modeli avtomatizirovannogo kontrolya znanii [adaptive semantic model of automatic knowledge control]," in *Pedagogicheskoe obrazovanie v Rossii [Pedagogical education in Russia]*, no. 7, 2016, pp. 14–20, (in Russ).

[13] V. Golenkov, V. Tarasov, and V. V. Emelyanov, "Virtual'nye kafedry i intellektual'nye obuchayushchie sistemy [virtual department and intelligent tutoring systems]," *Novosti iskusstvennogo intellekta [News of Artificial Intelligence]*, no. 4, pp. 3–13, 2001, (in Russ).

[14] V. Tarasov and V. Golenkov, "Sinergeticheskie uchebnye organizatsii v sfere vysshego obrazovaniya [synergistic organizations in the field of higher education]," in *Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems]*, V. Golenkov, Ed., BSUIR. Minsk , BSUIR, 2017, pp. 221–228, (in Russ).

Принципы реализации подсистемы обучения конечных пользователей и разработчиков интеллектуальных систем

Гракова Н.В., Королева М.Н., Бобров Г.С.

В работе предложен подход к решению проблемы обучения конечных пользователей и разработчиков интеллектуальных систем, предполагающий дополнение каждой интеллектуальной системы модулем, представляющим собой интеллектуальную обучающую подсистему, целью которой является обучение конечного пользователя и разработчика основной системы принципам работы с ней, принципам ее функционирования и развития. В качестве фундамента для реализации данного подхода предлагается использовать открытую семантическую технологию проектирования интеллектуальных систем (Технологию OSTIS).

Received 03.06.2021