Methodological problems of the current state of works in the field of Artificial intelligence

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***Abstract*—The article describes the strategic goals of Artificial intelligence and the main problems of scientific and technological activities in this field. The problems relevant for the development of the main directions and forms of its activity are defined. Approaches to their solution based on a new technological wave are suggested and issues important for the successful development of this research and practical discipline as a whole are discussed.**

***Keywords*—OSTIS, ostis-system, ontological approach, intelligent computer system, General theory of intelligent systems, knowledge base, problem-solving model, semantic representation of information, SC-code**

I. Introduction

The paper describes the strategic goals of *Artificial intelligence* and the main problems of scientific and technological activities in this field. The problems relevant for the development of the main directions and forms of its activity are defined. Approaches to their solution based on a new technological wave are suggested and issues important for the successful development of this research and practical discipline as a whole are discussed.

The main ones among others are the following:

- what will the complex automation of various types of *human activity* look like, built on the basis of new *Artificial intelligence technologies*?
- how will the interaction *between humans* be organized in this case, i.e., what will the architecture of a modern *smart society* look like?
- is the current level of semantic compatibility sufficient for mutual understanding between virtual computer systems, intelligent computer systems and their users and what needs to be done to improve it?

For a deeper consideration of methodological problems, it is proposed to divide them into the following basic parts.

Problems that hinder the development of Artificial intelligence as a scientific and technical discipline:

- the development of scientific research in the field of *Artificial intelligence*;
- the development of technologies for building and forming the market of *ICS* (*intelligent computer systems*, artificial intelligent systems);
- educational problems in the field of *Artificial intelligence*;
- the development of business in the field of *Artificial intelligence*.

Problems of automation of complex activities:

- research activities in various scientific disciplines;
- the creation of *technologies* for developing complex technical systems [1], [2];
- engineering activities for the development of complex technical systems;
- *educational* activities in research-intensive technical specialties;
- the definition of construction principles of the *OSTIS Technology* (Open Semantic Technology for Intelligent Systems), designed to solve the above problems.

The structure of the Ecosystem, built using the OSTIS Technology and that provides complex automation of all types of human activity.

Let us first specify the structure of scientific and technological activities in the field of *Artificial intelligence* as a scientific discipline.

Artificial intelligence is a field of human activity, the main purposes of which are:

- the building up of the theory of *intelligent systems*;
- the creation of the technology for the development of *ICS*;
- the transition to a new level of complex automation of all types of *human activity*, based on the mass usage of *ICS*.

The last assumes the presence of *ICS* that can understand each other and coordinate their activities. It is also necessary to build up a General theory of *human activity*, carried out in the conditions of a new level of its automation (the theory of activity of a *smart society*). Such an activity requires a significant rethinking of its organization and should be “understandable” to *intelligent computer systems*.

II. Current state and main tendencies of development of *Artificial intelligence*

A. Research activities

Most directions of *Artificial intelligence* are characterized by the inconsistency of the concept system and, as a result, the lack of their semantic compatibility and convergence [3], [4], [5]. All this hinders the building up of a general (with a high level of formalization) theory of intelligent systems.

This is due to the lack of understanding and motivation in a convergence between different directions. And since there is no urgent practical need, there is also no movement aimed at building up of the *General theory of intelligent systems*.

B. Development of the basic complex technology for the design of ICS

Modern technology of *Artificial intelligence* is a family of particular technologies. They are usually focused on the development and maintenance of various types of *ICS* components. At the same time, they implement various models of representation and processing of information as well as various problem-solving models focused on the development of various classes of *ICS*. As a result:

- the complexity of development increases, which requires highly qualified performers;
- complex technologies and tools for the development of *ICS* are missing;
- there is no syntactic and semantic compatibility of particular technologies and system integration of certain components.

C. Development of technology for building up designed intelligent computer systems

Traditional *(von Neumann) computers* are not able to effectively interpret the all variety of models used in *ICS*. Attempts to develop new generation computers focused on *ICS* were unsuccessful. The development of specialized *computers* focused on the interpretation of a single model does not solve the problem.

D. Specialized engineering in the field of Artificial intelligence

The development and production of *ICS* based on existing models, methods and tools face the following problems:

- there is no clear systematization of the all variety of *ICS*, that corresponds to the systematization of automated types of *human activity*;
- there is no convergence of *ICS* involved in the process of automating one type of *human activity*;
- there is no semantic compatibility, unification and mutual understanding of *ICS*;
- the semantic "unfriendliness" of the user interface and the lack of a built-in help system lead to a low rate of usage of the *ICS* capabilities.

Further automation of *human activity* requires increasing the level of *intelligence* of the corresponding *ICS* and implementing their ability to perform the following actions:

- to establish semantic compatibility (mutual understanding) between *computer systems* and their users;
- to maintain semantic compatibility during the evolution of users and other *computer systems*;
- to coordinate their activities with users and *computer systems* in the collective solving of various *problems*;
- to participate in the allocation of work (subproblems) in the collective solving of various *problems*.

The implementation of these capabilities will create an opportunity for full automation of the processes of system *integration* of *ICS* (into complexes of interacting systems) and their reengineering. This:

- will enable the complexes of cybernetic systems to adapt independently to solving new problems and will improve the efficiency of the operation of such complexes;
- will significantly reduce the number of errors compared to the "manual" system integration.

Thus, the next level of automation of human activity requires the creation of *ICS*, which could independently unite with the complexes necessary for solving complex problems [6].

E. Educational activities in the field of artificial intelligence

Any activity in the field of *Artificial intelligence* combines a high degree of research intensity and complexity of engineering work. Therefore, the training of specialists in this field requires the simultaneous formation of their research and engineering-practical skills, culture and thinking. The combination of fundamental scientific and engineering-practical training of specialists is a complex educational-pedagogical problem, since:

- there is no systematic approach to training young specialists in the field of *Artificial intelligence*;
- the lack of *semantic compatibility* between academic subjects leads to a "tesselation" of information perception;
- there is no personification of training and an attitude to the identification and development of individual abilities;
- there is no purposeful formation of motivation for creativity and skills of working in real development teams;
- there is no adaptation to real practical activities.

Any modern technology should have a high rate of development and requires highly qualified executive human resources.

Therefore, educational activities in the field of *Artificial intelligence* and the corresponding technology should be deeply integrated into all activities in the field of *Artificial intelligence*.

F. Business activities in the field of Artificial intelligence

There is an urgent need to increase the level of automation in many areas of human activity (in industry, medicine, transport, education, construction activity and many others). In addition, the development of *Artificial intelligence technologies* has led to a significant expansion of work on the creation of *applied intelligent computer systems*. All this, in turn, has led to the setting up of many commercial organizations focused on the development of such applications. Currently, there are the following problems here:

- it is difficult to ensure a balance of tactical and strategic directions for the development of all forms of activity in the field of *Artificial intelligence*;
- there is no deep convergence of forms of activity, which complicates the development of each of them;
- the high research intensity of works requires highly qualified performers and their ability to work as part of creative teams.

For advanced training of employees and ensuring a high level of development, business needs active cooperation with various scientific schools and departments that train young specialists in the field of *Artificial intelligence* as well as active participation in the preparation and holding of corresponding conferences, seminars and exhibitions.

III. Modern problems of artificial intelligence

Based on the problems listed above, two main problems can be distinguished:

A. *Building up and permanent development of the general (formal) theory of intelligent systems, **which includes**:*
   - the clarification of the requirements and features of *ICS* that determine the level of their intelligence;
   - convergence and integration of various types of knowledge and problem-solving models within each *ICS*;
   - a focus on the development of unified semantically compatible formal models and their universal interpreters;
   - ensuring a clear stratification and independence of the processes of evolution of formal models and their interpreters;
   - ensuring communication compatibility that allows *ICS* to independently form groups of *ICS* and their users, independently coordinate activities within groups when solving complex problems in unpredictable conditions.

B. *Creation and permanent development of a complex technology for the design and production of semantically compatible ICS that can independently coordinate their activities. **To do this, it is necessary to take into account**:*
   - the description of the standard of *ICS*, which ensures their semantic compatibility [7];
   - the development of libraries of semantically compatible and reusable components;
   - a low threshold for users and developers to enter the technology of the design of *ICS*;
   - high rates of technology development due to the active involvement of authors of various applications;
   - the development of new generation computers focused on the production of high-performance *ICS* of various purposes;
   - the creation of a global *ecosystem* that provides complex automation of all *types of human activity*;
   - the creation and permanent development of a global *sociotechnical ecosystem* (*ICS* and users), which provides complex automation of all *types of human activity*;
   - the transition from the eclectic building up of complex *ICS* to their deep **integration** and unification, when the same models of representation and processing of knowledge are implemented in the same way everywhere;
   - the reduction of the distance between the ***theory of ICS*** and the practice of their development.

Let us consider this in more detail. The epicenter of modern problems of development of activities in the field of *Artificial intelligence* is the *convergence* and *deep integration* of all forms, directions and results of this activity. The level of interrelation, interaction and *convergence* between various forms and areas of activity in the field of *Artificial intelligence* is insufficient. This leads to the fact that each of them develops separately, independently of the others. The question is about the *convergence* between such directions of *Artificial intelligence* as the representation of knowledge, the solution of intellectual problems, intelligent behavior, understanding, etc. as well as between such forms of *human activity in the field of Artificial intelligence* as scientific research, technology development, application development, education, business. Why, when contrasted with the long-term intensive development of scientific research in the field of *Artificial intelligence*, the market of *intelligent computer systems* and the complex technology of *Artificial intelligence*, which provides the development of a wide range of *intelligent computer systems* for various purposes and is available to a wide range of engineers, have not yet been created? Because the combination of a high level of research intensity and pragmatism of this problem requires for its solution a fundamentally new approach to the organization of interaction between *scientists* who work in the field of *Artificial intelligence*, *developers* of facilities for design automation of *intelligent computer systems*, *developers* of tools for implementing intelligent computer systems, including hardware support tools for intelligent computer systems, *developers* of applied *intelligent computer systems*. Such purposeful interaction should be carried out both within the framework of each of these forms of activity in the field of *Artificial intelligence* and between them. Thus, the basic tendency of further development of theoretical and practical works in the field of *Artificial intelligence* is the convergence of both the most different types (forms and directions) of *human activity* in the field of *Artificial intelligence* and a variety of products (results) of this activity. It is necessary to eliminate barriers between different types and products of activity in the field of *Artificial intelligence* to ensure their compatibility and integrability. The problem of creating a rapidly developing market of semantically compatible *intelligent systems* is a challenge addressed to specialists in the field of *Artificial intelligence*, which requires overcoming "the Babel" in all its occurrences, the formation of a high culture of negotiability and a unified, coordinated form of representation of collectively accumulated, improved and used knowledge. Scientists, who work in the field of *Artificial intelligence*, should ensure the convergence of the results of different directions of *Artificial intelligence* [8], [9] and build up:

- the general theory of intelligent computer systems;
- the general technology for designing semantically compatible intelligent computer systems, which includes the corresponding standards of intelligent computer systems and their components. Engineers, who develop intelligent computer systems, should cooperate with scientists and participate in the development of the technology of the design of intelligent computer system.

IV. OSTIS Technology (Open Semantic Technology for Intelligent Systems)

To solve the above problems, the *OSTIS Technology* is proposed – a complex open semantic technology for the design, production, operation and *reengineering* of hybrid, semantically compatible, active and negotiable *intelligent computer systems* [10], which is focused on:

- the development of *intelligent computer systems* that have a high level of *intelligence* and, in particular, a high level of *socialization*. The specified systems developed by the *OSTIS Technology* we will call ***ostis-systems***;
- the complex automation of all types and areas of *human activity* by creating a network of interacting and coordinating their activities *ostis-systems*. The specified network of *ostis-systems* together with their users will be called an ***OSTIS Ecosystem***;
- the support of the permanent evolution of *ostis-systems* during their operation;
- convergence and integration based on the semantic representation of knowledge of various research areas of *Artificial intelligence* (in particular, all kinds of basic knowledge and skills for solving intellectual problems) within the framework of the *General formal semantic theory of ostis-systems*;
- the development of new generation computers that provide effective (including productive) interpretation of logical-semantic models of *ostis-systems*, which are represented by knowledge bases of these systems that have a semantic representation.

The *OSTIS Technology* is implemented as a network of *ostis-systems*, which is part of the *OSTIS Ecosystem*. The key *ostis-system* of the specified network is the ***IMS.ostis*** *(Intelligent MetaSystem)* metasystem that implements the ***Core of the OSTIS Technology***, which includes basic (subject-independent) methods and tools for designing and producing of *ostis-systems* with the integration of typical embedded subsystems for supporting operation and reengineering of *ostis-systems* into their composition. The other *ostis-systems*, which are part of the network under consideration, implement various specialized *ostis-technologies* for designing various classes of *ostis-systems* that provide automation of any areas and *types of human activity*, except for designing *ostis-systems*.

The storage of information in the memory of the *ostis-system* focuses on the semantic representation of information – without synonymy and homonymy of signs, without semantic equivalence of information constructions. An abstract memory of the *ostis-system* is dynamic graph (i.e., nonlinear (graph) and restructurable). Information processing in the memory of the *ostis-system* is reduced not so much to changing the state of memory elements (this happens only when changing the syntactic type of elements and when changing the contents of those elements that denote files) as to changing the configuration of the relations between them. The organization of problem solving in the memory of the *ostis-system* is based on the *agent-oriented model of information processing*, controlled by situations and events that occur in the processed information (more precisely, in the processed *knowledge base*). From the point of view of architecture, the *ostis-system* is a hierarchical multi-agent system with shared memory (i.e., with memory that is available to all agents of the *ostis-system*).

Note that the shared memory of most of the *multi-agent systems* currently being studied is not common but distributed, i.e., it is an abstract (virtual) integration, which includes the memory of each agent of a multi-agent system. Coordination of the activities of agents of the *ostis-system* when performing complex *actions in the memory of the ostis-system* is also implemented through the *memory of the ostis-system* with the help of *methods* for solving various *classes of problems* as well as with the help of *plans* for solving particular problems, stored in memory. Based on this, it is possible to build up an unbound hierarchical system of *agents of the ostis-system* – from atomic agents that ensure the performance of basic actions in the memory of the *ostis-system* to non-atomic agents that are communities (groups) of atomic and/or non-atomic agents that provide the solution of various typical problems using appropriate methods and plans.

An important element of such a system is the implementation of decentralized situational control of the operation of *ostis-systems* not only at the level of internal information processes but also at the level of organization of individual activities in the environment and even at the level of participation in collective activities within various communities of *ostis-systems*. The organization of the performance of actions in the environment is carried out by the *ostis-system* as follows:

- classes of *atomic actions in the environment* are distinguished, for the implementation of each of which *effector agents of the ostis-system* are introduced;
- coordination of the activities of *effector agents of the ostis-system* when performing *complex actions in the environment* is carried out through the *memory of the ostis-system* with the help of *methods and plans* for solving various problems *in the environment*, stored in memory, as well as with the help of *receptor agents of the ostis-system* that provide feedback and, accordingly, sensorimotor coordination.

In the *ostis-system*, the basic set (basic system) of the used *concepts* is unified, which is the basis for ensuring *semantic compatibility* of all *ostis-systems*. The structuring of information (*knowledge base*) stored in the memory of the *ostis-system* is based on the hierarchical system of *subject domains* and their corresponding *formal ontologies*. **As a result, the ostis-system has the following features:**

- the ability for semantic immersion (semantic integration) of new acquired knowledge (including new skills) into the current state of the *knowledge base*;
- the ability for *semantic convergence* (detection of similarities) of new acquired knowledge (and, in particular, skills) with knowledge that is part of the current state of the *knowledge base of the ostis-system*;
- the ability for integration of different types of knowledge;
- the ability for integration of various problem-solving models;
- the ability of *ostis-systems* for understanding each other as well as any of its users by coordinating the system of used concepts (by terms and by denotational semantics);
- the ability of the *ostis-system* for providing and maintaining a high level of its *semantic compatibility* (a high level of mutual understanding) with other *ostis-systems* in the process of its evolution as well as the evolution of other *ostis-systems*, which leads to the extension and/or correction of the system of used concepts;
- the ability of *ostis-systems* for correlating, coordinating their activities with other systems in solving problems that cannot be solved either in principle or in a reasonable time by the efforts of one (individual) intelligent computer system;
- a high degree of individual learnability of *ostis-systems*, provided by a high degree of their flexibility, stratification, reflexivity as well as the universality of the facilities for the representation and creation of knowledge;
- **a high degree of collective learnability of *ostis-systems***, provided by a high degree of their semantic compatibility.

The listed features of *ostis-systems* demonstrate that they have a significantly higher *level of intelligence* and, in particular, a higher *level of socialization* compared to modern *intelligent computer systems*.

A. Semantic representation of information

Each syntactically elementary (atomic) fragment of the represented information is an indication of some entity, which can be real or abstract, concrete (fixed, constant) or certain (variable), permanent or temporary, coherent (reliable) or fuzzy (unreliable, with possible additional clarification of the likelihood degree). It follows herefrom that the semantic representation of information cannot include letters (they do not denote entities), words, word combinations (they are not elementary fragments), separation and limit symbols (they do not indicate entities).

Within the framework of the semantic representation of information, there is no synonymy (pairs of synonymous signs), homonymy (homonymous signs), semantic equivalence (pairs of semantically equivalent information constructions), i.e., there is no duplication of information as well as the ambiguity of the correlation between signs and their denotations. **Therefore**, the semantic representation of information cannot look like a linkage (string, sequence) of syntactically elementary fragments, since each described entity and its sign that mutually identically corresponds to it can be connected not with two but with any number of described entities. In other words, the semantic representation of information is a nonlinear (graph) information construction. It follows that if the internal representation of information in the memory of a computer system is a semantic representation, then the information processing in such memory is dynamic graph and is reduced not to changing the state of memory elements but to changing the configuration of relations between them.

As already noted, the key problem of the current stage of the development of the general theory of intelligent computer systems and the technology of their development is the problem of ensuring ***semantic compatibility*** of various types of knowledge that are part of *knowledge bases* of *intelligent computer systems*; various types of *problem-solving models*; various *intelligent computer systems* in general.

To solve this problem, it is necessary to unify (standardize) the form of representation of knowledge in the memory of intelligent computer systems. Our proposed approach for such unification is the orientation to the ***semantic representation of information*** (knowledge) in the memory of intelligent computer systems. The basis of the approach to ensuring a high level of learnability and semantic compatibility of intelligent computer systems as well as to developing a standard for intelligent computer systems is a unification of the semantic representation of information (knowledge) in the memory of intelligent computer systems and the creation of a global ***semantic space*** of knowledge. **It should also be noted that** the information in the sign construction is generally contained not in the signs themselves (in their structure) but in the relations between them. At the same time, these relations (syntactic relations) must have a coherent semantic interpretation.

B. Semantic network

We consider the semantic network not as a beautiful metaphor of complex structured sign constructions but as a formal clarification of the concept of semantic representation of information, as a principle of representation of information that underlies a new generation of computer languages and computer systems themselves – graph languages and graph computers.

A semantic network is a sign construction that has the following features:

- it is not necessary to take into account the "internal" structure (construction) of the signs included in the semantic network during its semantic analysis (understanding);
- the meaning of a semantic network is determined by the denotational semantics of all the signs included in it and the configuration of the incident relations of these signs;
- one of two incident signs included in the semantic network is a sign of linkage;
- the lack of synonymy, homonymy.

C. Standardization of ostis-systems

Standardization of *ostis-systems* includes:

- standardization of the language of the internal representation of information in the memory of *ostis-systems*;
- standardization of the principles of decentralized control of information processing in the memory of *ostis-systems*;
- standardization of the language for describing situations and events (in the memory of *ostis-systems*), which are the conditions for initiating various information processes in the memory of *ostis-systems*;
- standardization of the base language for specification (description, programming) of agents that perform the corresponding information processes in the memory of *ostis-systems*;
- standardization of base languages for input/output of information to/from the memory of *ostis-systems*.

The standard is a *knowledge base* being permanently improved, the evolution of which is supported by the corresponding portal.

D. Convergence, integration of knowledge and problem-solving models

For the convergence of knowledge, a universal base language of the internal semantic representation of knowledge in the memory of *ostis-systems (SC-code)* is introduced, according to the structure of which all internal languages focused on the representation of knowledge of various types (logical languages, languages for the representation of problem-solving models (in particular, programs), the language of problem definition, ontological languages and many others) are *sublanguages of the SC-code*, the syntax of which completely coincides with the syntax of the *SC-code*. **As a result**, the convergence of different knowledge is reduced to the coordination of systems of concepts used to represent different types of knowledge. Such coordination is focused on increasing the number of common concepts used in the representation of various knowledge.

Let us consider the convergence of ***problem-solving models in the ostis-system***. It is based on the following core principles:

- the syntax of the language for representing the corresponding class of problem-solving methods in memory is the syntax of the *SC-code*;
- the denotational semantics is described in the form of a corresponding ontology and is represented as a text of the *SC-code*;
- the operational semantics of each problem-solving model is a group of agents; it can be hierarchical based on different solver models, but there is a basic model for interpreting any methods:
  - *SCP language*:
    - the syntax is coincident with the syntax of the *SC-code*;
    - the denotational semantics is a procedural programming language in dynamic graph memory;
    - the operational semantics is implemented at the level of a software or hardware platform;
  - *sc-agents* work in a common environment (*sc-memory*) in parallel, asynchronously, based on a number of rules that allow them not to "hinder" each other.

The integration of knowledge in the memory of *ostis-systems* is reduced to the pasting together (matching) of synonymous signs. Since the problem-solving model used by the *ostis-system* is represented in the memory of the *ostis-system* as the corresponding type of knowledge, the integration of various problem-solving models can occur in the *ostis-system* in the same way as the integration of any other types of knowledge. In addition, when the question is about the integration of different problem-solving models, the possibility of simultaneous usage of different problem-solving models when processing the same knowledge and, in particular, when solving the same problem is supposed. This possibility in the *ostis-system* is provided by the *agent-oriented model of information processing* in the memory of the *ostis-system*. Thus, this kind of integration of various problem-solving models for *ostis-systems* is trivial.

Let us list the key advantages of the *ostis-system*:

- a high level of the ability of the *ostis-system* to perform semantic integration of knowledge in its memory (in particular, when immersing new knowledge in the current state of the knowledge base) is provided by the semantic nature of the internal encoding of information stored in the memory of the *ostis-system* and, in particular, by the fact that homonymous signs and pairs of synonymous signs are improper in the internal code of the knowledge base of the *ostis-system*;
- a high level of ability to integrate various types of knowledge in *ostis-systems* is ensured by the fact that each language focused on the representation of knowledge of the corresponding type is a sublanguage of the same base language of the *SC-code*;
- a high level of ability to integrate various problem-solving models in *ostis-systems*, which is ensured by the fact that all these models are focused on processing information represented in the *SC-code*; the same fragment of the knowledge base of the *ostis-system* (i.e., the same construction of the *SC-code*) can be simultaneously processed by several different problem-solving models; all problem-solving models in *ostis-systems* are integrated using the same basic problem-solving model – an *scp-model of problem solving*;
- a high level of learnability of the *ostis-system*, which is provided by a high level of semantic flexibility of information stored in the memory of the *ostis-system*, since each deletion or addition of a syntactically elementary fragment of stored information as well as the deletion or addition of each incident relation between such elements has a coherent semantic interpretation; by a high level of stratification of stored information, which is provided by the ontologically oriented structuring of the knowledge base of the *ostis-system*; by a high level of reflection of the *ostis-system*, which is provided by the powerful metalanguage capabilities of the language of the internal representation of information (knowledge) in the memory of *ostis-systems*. As a result, each *ostis-system* has a high *level of learning* (the ability to quickly extend their *knowledge and skills*) and a high *level of socialization* (the ability to effectively participate in the activities of various communities – ones that consist of ostis-systems and ones that consist of *ostis-systems* and humans.

E. Level of semantic compatibility

There are sharply defined formal notions that determine the *level of semantic compatibility* (level of semantic convergence) of various knowledge, skills, entire *ostis-systems* (more precisely, the knowledge bases of these systems). It is obvious that the *level of semantic compatibility* is primarily determined by the number of “adherent points” in the compared *knowledge, skills* ***and*** *knowledge bases* – ***there are signs*** that are present in different compared objects, but that have the same denotations (i.e., that denote the same entities). At the same time, among such signs that denote the same entities and are present in different objects being compared, the signs that denote *concepts* are of prime importance. The number of such common *concepts* in the compared *knowledge*, *skills*, *knowledge bases* determines the level of semantic compatibility (level of coherence) of the systems of the used *concepts* in the compared specified objects. An increase in the number of signs that denote the same entities and are present in different compared objects can lead to the fact that not only semantically equivalent signs but also whole semantically equivalent fragments (entire information constructions) will be present in different specified compared objects. It is important to emphasize that semantically equivalent sign constructions represented in the internal language of *ostis-systems* (in the *SC-code*), in the memory of different *ostis-systems*, are always syntactically isomorphic graph constructs, in which the isomorphism correspondence connects signs stored in the memory of different *ostis-systems*, but that denote the same entities (more precisely, the same entity). Note also that within the memory of each *ostis-system*, the synonymy of signs and, accordingly, the semantic equivalence of sign constructions are improper.

Due to the constantly developing semantic standards of the *OSTIS Technology*, which are represented by a system of formal ontologies for a variety of subject domains, the *ostis-systems* being developed initially have a sufficiently high *level of semantic compatibility* with all other *ostis-systems*. Moreover, in the *OSTIS Technology*, an entire core of all *ostis-systems* is allocated, that contains fundamental basic knowledge and basic skills that are the same for all *ostis-systems* and that allows each copy of this core to develop (communicate, specialize) in any direction.

Each *ostis-system*, interacting with humans (users) or with other *ostis-systems*, can increase the level of semantic compatibility (mutual understanding) with them as well as maintain a high level of such compatibility in the conditions of (1) its evolution, (2) the evolution of other *ostis-systems* and *users*, (3) the evolution of semantic standards of the *OSTIS Technology*. This interaction is generally focused on coordinating changes in the system of concepts used, i.e., adjustment of the corresponding fragments of ontologies.

V. Conclusion

Due to the high level of semantic compatibility of *ostis-systems* and the semantic representation of knowledge in the memory of *ostis-systems*, the complexity of semantic analysis and understanding of information received (reported, transmitted) to the *ostis-system* from other *ostis-systems* or users is significantly reduced and its quality is improved. Each *ostis-system* is able:

- to independently or by invitation join the *ostis-community* (community of *ostis-systems*) or the *ostis-group* that consists of *ostis-systems* and humans. Such communities and groups are created on a temporary (one-time) or permanent basis for the collective solution of complex problems;
- to participate in the distribution (including coordination of the distribution) of problems – both "one-time" and long-term ones (responsibilities);
- to monitor the state of the entire process of collective activities and coordinate own activities with the activities of other members of the group in case of possible unpredictable changes in the conditions (state) of the corresponding environment.

The high level of intelligence of *ostis-systems* and, accordingly, the high level of their independence and purposefulness allow *ostis-systems* to be full members of a wide variety of communities, within which *ostis-systems* gain the right to independently initiate (based on a detailed analysis of the current situation and the current state of the community action plan) a wide range of actions (problems) performed by other members of the community and thereby participate in the coordination of the activities of community members. The ability of the *ostis-system* to coordinate its activities with other *ostis-systems* as well as to adjust the activities of the entire group of *ostis-systems*, adapting to various changes in the environment (conditions), in which this activity is carried out, allows automating the activities of the system integrator both at the stage of assembling the group of *ostis-systems* and at the stage of its updating (reengineering).

The advantages of *ostis-systems* are provided by:

- the advantages of the *SC-code* – the language of internal encoding of information stored in the memory of *ostis-systems*;
- the advantages of the organization of *sc-memory* – the memory of *ostis-systems*;
- the advantages of *sc-models* of knowledge bases of *ostis-systems* – by means of structuring such knowledge bases;
- the advantages of *sc-models of problem solving* – agent-oriented problem-solving models used in *ostis-systems*.

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Список литературы

[1] A. Kolesnikov, *Gibridnye intellektual'nye sistemy: Teoriya i tekhnologiya razrabotki [Hybrid intelligent systems: theory and technology of development]*, A. M. Yashin, Ed. SPb.: Izd-vo SPbGTU, 2001.

[2] G. Rybina, "Dynamicheskye integrirovannye expertnye systemi: tekhnologiya avtomatizirovannogo polucheniya, predstavlniya i obrabotki temporalnykh znani [dynamic integrated expert systems: technology for automated acquisition, presentation and processing of temporal knowledge]," *Informatcionnye izmeritelnye i upravlyayuschye systemi [Information measuring and control systems]*, vol. 16, no. 7, p. 20–31, 2018.

[3] V. Taranchuk, "Vozmozhnosti i sredstva wolfram mathematica dlya razrabotki intellektual'nykh obuchayushchikh sistem [opportunities and means of wolfram mathematica for developing intelligent tutoring systems]," *«Nauchnye vedomosti Belgorodskogo gosudarstvennogo universiteta. Seriya: Ekonomika. Informatika» [«Scientific statements of Belgorod State University. Series: Economy. Computer science»]*, vol. 33, no. 1 (198), pp. 102–110, 2015.

[4] A. E. Yankovskaya, A. A. Shelupanov, A. N. Kornetov, N. N. Ilinskaya, and V. B. Obukhovskaya, "Gibridnaya intellektual'naya sistema ekspress-diagnostiki organizatsionnogo stressa, depressii, deviantnogo povedeniya i trevogi narushitelei na osnove konvergentsii neskol'kikh nauk i nauchnykh napravlenii [hybrid intelligent system of express diagnostics of organizational stress, depression, deviant behavior and anxiety of violators based on convergence of several sciences and scientific directions]," in *Trudy kongressa po intellektual'nym sistemam i informatsionnym tekhnologiyam «IS&IT'17». Nauchnoe izdanie v 3-kh tomakh. [Works of congress on intelligent 17 scientific publication in 3 volumes]*, ser. T. 1. Stupin A. S. publishing House, Taganrog, 2017, pp. 323–329.

[5] A. Palagin, "Problemy transdisciplinarnosti i rol' informatiki [problems of transdisciplinarity and the role of informatics]," *Kibernetika i sistemnyj analiz [Cybernetics and Systems Analysis]*, no. 5, p. 3–13, 2013.

[6] M. Kovalchuk, "Konvergencija nauk i tehnologij – proryv v budushhee [convergence of science and technology - a breakthrough into the future]," *Rossijskie nanotehnologii [Russian nanotechnology]*, vol. 6, no. 1–2, p. 13–23, 2011.

[7] V. Golenkov, N. Guliakina, V. Golovko, and V. Krasnoproshin, "Artificial intelligence standardization is a key challenge for the technologies of the future," in *Open Semantic Technologies for Intelligent System*, V. Golenkov, V. Krasnoproshin, V. Golovko, and E. Azarov, Eds. Cham: Springer International Publishing, 2020, pp. 1–21.

[8] A. F. Tuzovsky and V. Z. Yampolsky, "Integracija informacii s ispol'zovaniem tehnologij semantic web [integration of information using semantic web technologies]," *Problemy informatiki [Problems of Informatics]*, no. 2, p. 51–58, 2011.

[9] V. Haarslev, K. Hidde, R. Möller, and M. Wessel, "The racerpro knowledge representation and reasoning system," *Semantic Web*, vol. 3, no. 3, p. 267–277, 2012. [Online]. Available: https://doi.org/10.3233/SW-2011-0032

[10] 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.

Методологические проблемы современного состояния работ в области Искусственного интеллекта

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В работе описаны стратегические цели Искусственного интеллекта и основные задачи научно-технической деятельности в этой области. Обозначены проблемы, актуальные для развития основных направлений и форм его деятельности. Предлагаются подходы к их решению, основанные на новом технологическом укладе, и обсуждается вопросы, важные для успешного развития данной научно-практической дисциплины в целом.

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