The standardization of intelligent computer systems as a key challenge of the current stage of development of artificial intelligence technologies

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***Abstract*—This work is devoted to the consideration of the most important factor providing semantic compatibility of intelligent computer systems and their components – standardization of intelligent computer systems, as well as standardization of methods and tools of their design.**

***Keywords*—intelligent computer system; integrated technology for the development of intelligent computer systems; knowledge base of an intelligent computer system; educational activities in the field of artificial intelligence; research activities in the field of artificial intelligence; development of artificial intelligence technologies; engineering activities in the field of artificial intelligence; convergence of scientific disciplines in the field of artificial intelligence; convergence of models for the representation and processing of knowledge in intelligent computer systems; general theory of intelligent computer systems; convergence of various methods and means of developing intelligent computer systems; semantic compatibility of intelligent computer systems and their components; hybrid intelligent computer system; semantic representation of knowledge; standard of intelligent computer systems.**

I. Introduction

The report at the OSTIS-2019 conference [1] examined the key problem for the current stage of development of artificial intelligence technologies: to ensure ***semantic compatibility*** of intelligent computer systems and *semantic compatibility* of various components of such systems (various types of knowledge that are part of knowledge bases, various problem solving models, various components of a multimodal interface).

This work is devoted to the consideration of the most important factor providing *semantic compatibility* of intelligent computer systems and their components – ***standardization of intelligent computer systems***, as well as standardization of methods and tools of their design.

The basis of the proposed approach to ensuring a high level of *learnability* and *semantic compatibility* of intelligent computer systems, as well as to the development of ***standard of intelligent computer systems*** is the unification of ***sense representation of knowledge*** in the memory of such systems and the construction of global ***sense space*** of knowledge.

II. The current state of artificial intelligence as a field of scientific and technical activities

artificial Intelligence
:= [An interdisciplinary (transdisciplinary) field of scientific and technical activity aimed at the development and application of ***intelligent computer systems***, which provide automation of various spheres of human activity]
:= [The field of human activity aimed at (1) building the theory of *intelligent computer systems* (2) development of technologies (methods and tools) for their design, (3) development of applied *intelligent computer systems*]
⇐ *decomposition**:
{
- *educational activities in the field of artificial intelligence*

- *research activities in the field of artificial intelligence*
- *development of integrated technologies in the field of artificial intelligence*
- *development of a set of intelligent computer systems*
- *business in the field of artificial intelligence*

}

⇒ *feature**:

[A feature of artificial intelligence as a field of scientific and technical activity is that it has a pronounced interdisciplinary, interdisciplinary, integration, collective character. Success here is largely determined by the consistency of actions and the level of compatibility of the results of these actions.]

Despite the presence of ***serious scientific results*** in the field of *artificial intelligence*, the pace of development of ***market of intelligent computer systems*** is not so impressive. There are several reasons for this:

- there is a big gap between scientific research in the field of *artificial intelligence* and the creation of industrial complex technologies for the development of *intelligent computer systems*. Scientific research in the field of *artificial intelligence* is mainly concentrated on the development of new methods for intelligent problems solving;
- these studies are fragmented and the need for their integration and the creation of a general formal theory of intelligent systems is not recognized, that is, there is a "Babylonian crowd" of various models, methods and tools used in *artificial intelligence* in the absence of awareness of the problem of providing their compatibility. Without a solution to this problem, neither a general theory of intelligent systems can be created, nor, therefore, an integrated technology for *intelligent computer systems* development, available to both engineers and ***experts***;
- the specified integration of models and methods of artificial intelligence is very complicated, because it is interdisciplinary in nature;
- intelligent systems as design objects have a significantly higher level of complexity compared to all the technical systems that humanity has dealt with;
- as a consequence of the above, there is a big gap between scientific research and engineering practice in this area. This gap can only be filled by creating an evolving technology for *intelligent computer systems* development, the evolution of which is carried out through the active cooperation of scientists and engineers;
- the quality of the development of applied intelligent systems to a large extent depends on the mutual understanding of experts and knowledge engineers. Knowledge engineers, not knowing the intricacies of the application field, can make serious mistakes in the developed knowledge base. The mediation of knowledge engineers between experts and the developed knowledge base significantly reduces the quality of the developed intelligent computer systems. To solve this problem, it is necessary that the language of knowledge representation in *knowledge base* be "convenient" not only for intelligent systems and knowledge engineers, ***but also for experts***.

The current state of ***artificial intelligence technologies*** can be characterized as follows [2]–[7]:

- There is a large set of particular *artificial intelligence technologies* with appropriate tools, but there is no general *theory of intelligent systems* and, as a result, there is no general *complex design technology for intelligent computer systems*;
- The compatibility of particular artificial intelligence technologies is practically not realized and, moreover, there is no awareness of such a need.

The development of *artificial intelligence technologies* is substantially hampered by the following socio-methodological circumstances:

- The high social interest in the results of work in the field of *artificial intelligence* and the great complexity of this science give rise to superficiality and dishonesty in the development and advertising of various applications. Serious science is mixed up with irresponsible marketing, conceptual and terminological sloppiness and illiteracy, throwing in new absolutely unnecessary effective terms, confusing the essence of the matter, but creating the illusion of fundamental novelty.
- The interdisciplinary nature of research in the field of *artificial intelligence* substantially complicates this research, since work at the intersections of scientific disciplines requires high culture and qualifications.

To solve the above problems of the development of *artificial intelligence technologies*:

- Continuing to develop new formal models for *intelligent problems* solving and to improve existing models (logical, neural networks, production), it is necessary to ensure **compatibility** of these models both among themselves and with traditional models for solving problems that are not among the intellectual tasks. In other words, we are talking about the development of principles for organizing *hybrid intelligent computer systems* that provide solutions to **complex tasks** that require sharing and in unpredictable combinations of a wide variety of types of knowledge and a wide variety of problem solving models.
- A transition is needed from the eclectic construction of complex intelligent computer systems using different types of knowledge and various types of problem solving models to their deep integration, when the same presentation models and knowledge processing

models are implemented in different systems and subsystems in the same way.
- It is necessary to reduce the distance between the modern level of *theory of intelligent systems* and the practice of their development.

artificial intelligence
⇒ *development trends**:
{
- [Erasing interdisciplinary barriers between different areas of research in *artificial intelligence*.]
- [Transferring the emphasis from scientific research aimed at studying the phenomenon of intelligence and building formal models of intelligent processes to creating of industrial complex technology for *intelligent computer systems* design.]

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⇒ *development problems**:
{
- [Lack of motivation among scientists to integrate their research results in the field of *artificial intelligence* within the framework of the general theory of intelligent systems.]
- [Insufficient level of motivation and consistency for the transition from the theory of intelligent systems to ***integrated technology for intelligent computer systems design***, ensuring their semantic compatibility.]
- [Lack of effective interaction between various activities that provide development of *artificial intelligence* (educational activities, research activities, technology development, engineering, the business in the field of artificial intelligence).]

}
⇒ *consequence**:
[The consequence of these problems is that the current state of artificial intelligence technologies does not provide the required development of the market for artificial intelligent systems.**]**
⇒ *what to do**:
[For the development of artificial intelligence technologies, close interaction between practical engineers, developers of new technologies and scientists in the field of artificial intelligence is necessary.**]**

artificial intelligence
⇒ *key development tasks**:
{
- [the convergence of various areas of scientific research in the field of artificial intelligence in order to create *general theory of intelligent systems*]
- [integration of the existing variety of models, methods and tools for developing various components of intelligent systems into *unified integrated technology*, providing intelligent systems development for automating various fields of activity]
- [ensuring of *semantic compatibility* of the developed intelligent computer systems]
- [integration and coordination of various activities that ensure the sustainable development of artificial intelligence:
  - educational activities aimed at training of specialists capable of effectively participating in the development of artificial intelligence;
  - artificial intelligence research activity;
  - activities aimed at the development of artificial intelligence technologies;
  - applied intelligent systems engineering;
  - of a business aimed at organizing and financially supporting all the above types of activities and, first of all, at introducing the developed systems.

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The problem of creating a fast-growing market for semantically compatible intelligent systems is a challenge addressed to specialists in the field of artificial intelligence, requiring overcoming the "Babylonian crowd" in all its manifestations, the formation of a high culture of negotiability and a unified, consistent form of representation of collectively accumulated, improved and used knowledge.

Scientists working in the field of artificial intelligence should ensure the convergence of the results of different areas of artificial intelligence and build a general theory of intelligent computer systems and *integrated technology for semantically compatible intelligent computer systems design*, including the appropriate ***standards of intelligent computer systems*** and their components.

Engineers developing intelligent computer systems should collaborate with scientists and participate in the development of integrated technology for intelligent computer systems design.

III. The convergence of different activities in the field of artificial intelligence

The further development of artificial intelligence affects all forms and directions of activity in this area. We list the main areas of convergence in the field of artificial intelligence [8]–[10]:
- The convergence of various disciplines in the training of specialists in the field of artificial intelligence in order to form a holistic picture of **problems** in the field of *artificial intelligence*;
- The convergence of various scientific studies in the field of *artificial intelligence* in order to build ***general theory of intelligent computer systems***;
- Convergence of development methods and tools for various *intelligent computer systems* to create ***integrated technology for intelligent computer systems*** development, available to a wide range of engineers;

- Convergence of engineering activities in order to build an ecosystem of semantically compatible and effectively interacting intelligent computer systems that support semantic compatibility in the process of operation and evolution;
- The convergence of all these types of activities among themselves, aimed at ensuring their consistency.

As an example of the integration of these types of activities, we can mention the organization of training for a modern engineer of intelligent systems.

How to teach an engineer to feel confident in such conditions of rapidly developing technologies? To do this, there is only one way – to immerse him in a problem field, teach him to see problems in the current state of technology, give him the opportunity to participate in eliminating these problems, to form appropriate skills and a sense of ownership in the development of technologies. If engineers who are users of relevant technologies do not participate in its development and provide feedback, the pace and quality of technology development will be significantly reduced.

But for this technology should be open so that anyone can contribute to their development, and should be protected from unskilled or malicious actions. Therefore, we need the organization of free examination, the development of harmonization rules and the possibility of the existence of points of view that are not universally recognized.

In fact, the convergence between different types of activities in the field of artificial intelligence will really be realized only when every specialist in this field will participate and sufficiently orient in all these types of activities, i.e. at the same time will be a teacher, a scientist, and a participant in the development of integrated technology, and an engineer, and a businessman. The idea of the impossibility of such a combination is clearly exaggerated and is the strongest brake on the implementation of convergence processes in the field of artificial intelligence.

IV. Semantic compatibility of intelligent computer systems, semantic representation of knowledge and its standardization

The key problem of the current stage of development of the general theory of intelligent computer systems and the technology for their development is the problem of ensuring *semantic compatibility* (1) of the various types of knowledge that make up the knowledge bases of intelligent computer systems (2) of various types of problem solving models (3) of various intelligent computer systems in general [11]–[13].

To solve this problem, unification (standardization) of the form of knowledge representation in the memory of intelligent computer systems is required. A logical approach for such unification is the orientation to ***sense representation of knowledge*** in the memory of intelligent computer systems.

In the development of knowledge-driven computer systems, a key role is played by the way knowledge is represented internally. The quality of knowledge representation of a computer system is determined by how close this representation is to sense (semantic) representation. Our approach to formalizing the *sense* of the knowledge presented is based on the following principles [14].

The sense of any information construction is a structure that includes:

- described objects that can be entities of any nature;
- links between the described objects, which can also be considered as these links themselves (it follows from this that there may be links between links, as well as links between links and objects that are not links);
- typology of relationships and non-relationship objects. This typology can be reduced to links that connect the described objects (including relations) with the classes to which the described objects belong. Moreover, these classes are also one of the types of described objects.

It is necessary to distinguish (1) sense as a sense structure of the above kind, and (2) ***sense*** as a semantic representation of information, as an information construct in which objects (entities) of the above sense structure are replaced by unique signs of these objects and which, respectively, is isomorphic to the sense structure indicated above, (3) ***sense**** as a relation connecting informational constructions with the corresponding sense structures.

sense
:= [sense model of information construction]
:= [sense representation of the information construct]
:= [sense structure]
:= [sense construct]
:= [sense representation of information]

sense*
:= [Binary oriented relation connecting informational constructions with semantic equivalent semantic structures]

Thus, in the final analysis, the sense of any informational construction is a configuration of links between the described objects (entities). In other words, the information is contained not in the signs (in particular, in the names) of the described entities, but in the configuration of the revealed links between these entities. Moreover, the links between the signs of the described entities are information models of the links between these entities themselves.

At the same time, we emphasize that entities are different (material, abstract). The described entities include links, and classes of entities (concepts), and structures.

Following the principle of Occam's razor, it is necessary to rid the form of internal representation of information in the memory of an intelligent computer system of parts that are not directly related to the *sense* of the information presented.

"It is necessary to bridge the gap between the syntactic data structures, on the one hand, and the *sense* (meaning) expressed by them, on the other" [15].

If the signs of the described entities have an internal structure (for example, are words or phrases), then the configuration of the links between the entities being described is not explicitly displayed, but is "camouflaged" against the background of explicitly and implicitly defined links between fragments of the signs used (between letters, words, phrases).

All known languages perform two functions – communicative (as a means of exchanging messages between subjects) and cognitive (as a means of representing the information model of the described World).

The language of the internal representation of knowledge in the memory of a computer system is not required to perform a communicative function. The language of the internal representation of knowledge is only required to ensure that knowledge is stored in a form convenient for processing. Convenience of processing knowledge stored in memory is determined by:

- simplicity of information retrieval procedures for fragments of a stored knowledge base that satisfy specified requirements;
- simplicity of the procedures for integrating new knowledge added to the knowledge base;
- ease of implementation of inference procedures.

Thus, everything that provides only the communicative functions of the language can be excluded from the language of the internal representation of knowledge. The language of the internal representation of knowledge in the memory of a computer system, based on the formalization of ***sense*** of this knowledge, should fulfill only a cognitive function – be a means of representing *internal information model* of some described World (including the external environment of the corresponding computer system).

The signs that make up the internal representation of knowledge should not have an internal structure, in particular, should not be represented in the form of some name of the corresponding (designated) entity. *Sense* of each sign is determined solely by its links with other signs that make up the internal representation of the knowledge base of a computer system. In contrast, semantic analysis and understanding of messages (external texts) requires structuredness and easy recognition of signs. By the similarity of structures representing signs (for example, character strings), the syntactic equivalence of signs is determined, although in informal languages it does not always coincide with their semantic equivalence (i.e. with their synonymy).

Within the framework of the internal semantic representation of the knowledge base of a computer system, *synonymy* (duplication) of signs is excluded. Internal signs denoting the same entity must be "glued", identified. As a consequence of this, within the framework of each knowledge base, *semantic equivalence* (duplication) of its constituent fragments is excluded, i.e. fragments that carry the same information. At the same time, the possibility of the existence of *logically equivalent* fragments of knowledge bases when one fragment is a logical consequence of the second and vice versa remains.

The texts of the language of the internal sense representation of knowledge should be non-linear in contrast to the usual texts, because the configuration of links between the entities of the described World in the general case is not linear. Each entity described can be associated with an unlimited number of links with other entities. Moreover, for any group of entities there always exists a link connecting them – everything in the World is interconnected. The question is which links are appropriate and which are impractical to explicitly represent in the knowledge base. The linearity of familiar texts is the result of projecting a nonlinear World onto a linear (one-dimensional) space, which requires additional special language tools that provide not a description of this World itself, but its projection onto a linear space. It should be noted that ***specialized non-linear languages*** are widely used, for example:

- circuit diagrams;
- flowcharts;
- blueprints.

Unlike these languages, the language of the sense representation of knowledge should be a universal non-linear language.

Powerful and simple means of transition from information to meta-information (in particular, from poorly structured data to related data) are introduced within the language of the internal sense representation of knowledge. For this, the texts that are part of the knowledge base are also considered as described entities, for the designation of which the corresponding signs are introduced, each of which is interpreted as a signs denoting the set of all the signs that make up the designated text, including the signs of all kinds of links that are included in it.

Since the language of the internal sense representation of knowledge should be universal, it should provide the representation of all kinds of knowledge:

- specifications of various entities;
- documentation of various technical systems;
- various subject domains (both static and dynamic);
- various types of domain ontologies;
- utterance texts;

- texts of proof of theorems;
- statement of tasks;
- formulations of task classes;
- texts of solutions to specific problems;
- ways to solve various classes of problems;
- descriptions of the evolutionary histories of various systems;
- descriptions of projects aimed at creating and improving various technical systems.

The use of the universal language of the internal representation of knowledge with the possibility of its unlimited expansion, if the need arises for the presentation of new types of knowledge, creates the conditions for the unlimited expansion of the fields of application of computer systems based on such an internal language.

Within the framework of the language of the internal sense representation of knowledge, the names, terms, designations used in the transmission and reception of external messages are also independent described entities that have their own internal signs, which are associated with the internal links of the internal signs of those entities that are called these external designations. All external languages are part of the external World described by it for the knowledge base.

Atomic fragments of the internal sense representation of the knowledge base are only signs. Moreover, each inner sign itself can be a described entity (meaning the sign itself, and not the entity denoted by this sign). In addition, each link between the described entities is also itself a described entity, which in its internal representation has its own internal sign and which is interpreted as a set, the elements of which are signs of entities linked by the described link. Thus, everything that is not related to the presentation of sense, but to the form of representation used, is excluded from the internal representation of knowledge. So, for example, in the internal representation of knowledge there are absent not only letters, words, phrases, but also delimiters, limiters, prepositions, conjunctions, pronouns, declensions, conjugations, etc.

The language of the internal sense representation of knowledge should not only be convenient for processing knowledge in a computer system, but should be understandable and "transparent" for both the developer of the computer system and its end user. For this, along with the development of the language of the internal semantic representation of knowledge, external languages close to it should be developed, which should be based on simple and quickly acquired procedures for translating texts from internal to external forms of their presentation. We emphasize that the principles of organizing the memory ***modern computers*** do not correspond to the principles of the semantic representation of information in their memory. Therefore, the level of compatibility of modern computer systems and their users, the level of their "mutual understanding" is clearly insufficient. The computer system should not be **"black box"** for users. To solve this problem, it is necessary to make the principles of organization, storage and processing of information in computer systems understandable and convenient for users by using the sense representation of information in the memory of a computer system.

The typology of signs that make up the internal sense representation of knowledge is completely determined by the typology of entities denoted by these signs. In this case, the basic typology of the described entities is distinguished, which defines the syntactic typology (alphabet) of internal signs.

Our proposed standard for the internal sense representation of knowledge in the memory of an intelligent computer system is called ***SC-code*** (Semantic Code) [16]. The signs included in the texts of *SC-code* are called ***sc-elements***. Each *sc-element* can be considered an invariant of the whole variety of presentation forms (in various languages and sign constructions) of the entity that is denoted by this *sc-element*. Such an invariant is only that the indicated sc-element denotes the corresponding entity. Therefore, *sc-element* has no form. In this sense, he abstracts from the form of his presentation within the framework of a particular sign construction.

SC-code
:= [Language of a unified sense representation of knowledge in the memory of an intelligent computer system]

Syntax of ***SC-code*** is determined by
- typology (alphabet) of ***sc-elements*** (atomic fragments of ***SC-code*** texts);
- rules for connecting (incidence) of sc-elements (for example, what types of *sc-elements* cannot be incident to each other);
- typology of configurations of *sc-elements* (links, classes, structures), links between configurations of *sc-elements* (in particular, set-theoretic)

SC-code denotational semantics is specified by
- semantic interpretation of *sc-elements* and their configurations;
- semantic interpretation of incidence of sc-elements;
- hierarchical system of subject domains;
- the structure of the concepts used in each subject domain (studied classes of objects, studied relations, studied classes of objects of relations from related subject domains, key instances of studied classes of objects);
- subject domain ontologies.

It should be emphasized that unification and the maximum possible simplification of ***syntax*** and ***denotational semantics*** of the internal language of intelligent computer systems are necessary because the overwhelming volume of ***knowledge*** stored in the knowledge base of an intelligent computer system are ***meta-knowledge*** describing the properties of other knowledge. Moreover, for the indicated reason, constructive (formal) development of the theory of intelligent computer systems is impossible without clarification (unification, standardization) and ensuring semantic compatibility of various types of knowledge stored in the knowledge base of an intelligent computer system. It is obvious that the variety of forms of representing semantically equivalent knowledge makes the development of a general theory of intelligent computer systems practically impossible. *meta-knowledge*, in particular, should include various kinds of logical statements and all kinds of programs, descriptions of methods (skills). Providing the solution of various classes of information problems.

We list the basic principles underlying ***SC-code***:

- The signs (notation) of all entities described in *sc-texts*, (SC-code texts) are represented in the form of syntactically elementary (atomic) fragments of *sc-texts* and, therefore, not having an internal structure, not consisting from simpler fragments of text, such as names (terms) that represent the signs of the described entities in familiar languages.
- Names (terms), natural-language texts and other informational constructs that are not *sc-texts* can be included in *sc-text*, but only as files described (specified) by *sc- texts*. Thus, the knowledge base of an intelligent computer system based on *SC-code* can include names (terms) that denote some described entities and are represented by the corresponding files. Each sc-element will be called internal (to indicate some entity, and the name of this entity represented by the corresponding file will be called the external designation of this entity. Moreover, each named (identifiable) *sc-element* is linked by an arc belonging to the relation "***be an external identifier***", with a node whose contents are an identifier file (in particular, a name) denoting the same entity as the above *sc-element*. An external designation may be not just a name (term), but also a hieroglyph, pictogram, voiced name, gesture. We especially note that the external designations of the described entities in an intelligent computer system based on *SC-code* are used only (1) to analyze the information received in this system from outside from various sources, and input (understanding and immersion) of this information into the knowledge base, as well as (2) for the synthesis of various messages addressed to various subjects (including to users).
- Texts of *SC-code* (*sc-texts*) generally have a non-linear (graph) structure, since (1) the sign of each described entity is included in the sc-text once and (2) each such sign may be incident to an unlimited number of other signs, since each described entity can be linked by an unlimited number of links with other described entities.
- The knowledge base, represented by the text of *SC-code*, is a graph structure of a special kind, the alphabet of elements of which includes set of nodes, set of edges, set of arcs, set of basic arcs – arcs of a specially selected type that provide structuring of knowledge bases, and there are also many special nodes, each of which has content, which is a file stored in the memory of an intelligent computer system. The structural feature of this graph structure is that its arcs and edges can connect not only a node with a node, but also a node with an edge or arc, an edge or arc with another edge or arc.
- All elements of the above graph structure are signs that are part of the text of *SC-code*. Those. all its nodes, edges and arcs are the designations of various entities. Moreover, an edge is a designation of a binary undirected link between two entities, each of which is either represented in the graph structure under consideration by a corresponding sign, or is this sign itself. An arc is a designation of a binary oriented link between two entities. A special-type arc (***base arc***) is a sign of link between a node denoting a certain set of elements of the considered graph structure and one of the elements of this graph structure that belongs to the specified set. A node that has content (a node for which the content exists but might not be currently known) is a sign of the file that is the content of this node. A node that is not a sign of a file can denote a material object, a primary abstract object (for example, a number, a point in some abstract space), some binary link, some set (in particular, a concept, structure, situation, event, process). At the same time, entities denoted by the elements of the graph structure under consideration can be permanent (always existing) and temporary (entities to which the period of their existence corresponds). In addition, entities denoted by the elements of the considered graph structure can be constant (specific) entities and variable (arbitrary) entities. Each element of the considered graph structure, which is a designation of a variable entity, is assigned a range of possible values of this designation. The range of possible values of each variable edge is a subset of the set of all kinds of constant edges, the range of possible values of each variable arc is a subset of the set of all possible constant arcs, the range of possible values of each variable node is a subset of the set of all possible constant nodes.
- In the considered graph structure, which is a representation of the knowledge base in *SC-code*, different elements of the graph structure can be, but should not exist, denoting the same entity. If a pair of such elements is detected, then these elements are glued together (identified). Thus, the synonymy of

internal designations in the knowledge base of an intelligent computer system based on *SC-code* is prohibited. In this case, the synonymy of external signs is considered normal. Formally, this means that several arcs belonging to the relation "***be an external identifier***" come out of some elements of the graph structure under consideration. Of all the indicated arcs belonging to the relation "***be an external identifier***" and emerging from one element of the considered graph structure, one (very rarely two) is selected by including them in the number of arcs belonging to the relation "***be the primary external identifier***". This means that the external identifier indicated in this way is not homonymous, i.e. cannot be used as an external identifier corresponding to another element of the considered graph structure.

- In addition to files representing various external symbols (names, characters, pictograms), files of various texts (books, articles, documents, notes, comments, explanations, can be stored in the memory of an intelligent computer system built on the basis of *SC-code* drawings, drawings, diagrams, photographs, video materials, audio materials).
- Any entity that requires a description can be designated as an element of the considered graph structure. We emphasize that the elements of the graph structure under consideration are not just the designations of the various entities described, but designations that are elementary (atomic) fragments of the sign structure, i.e. fragments, the detailed structure of which is not required for the "reading" and understanding of this sign structure.
- The text of *SC-code*, like any other graph structure, is an abstract mathematical object that does not require detailing (refinement) of its encoding in the memory of a computer system (for example, as an adjacency matrix, incidence matrix, list structure). But such detail will be required for the technical implementation of the memory in which sc-constructions are stored and processed.
- On the other hand, for the operation of intelligent computer systems based on *SC-code*, in addition to the method of abstract internal representation of knowledge bases (*SC-code*), several methods of external image of abstract sc-constructions convenient for users will be required and used in the design of the source texts of the knowledge bases of the indicated intelligent computer systems and source texts of fragments of these knowledge bases, as well as used to display to users various fragments of the knowledge bases user queries. *SCg-code* and *SCn-code* are proposed as such methods for external image of sc-constructions.
- The most important additional property of *SC-code* is that it is convenient not only for the internal representation of knowledge in the memory of an intelligent computer system, but also for the internal representation of information in the memory of computers specially designed for interpreting semantic models of intelligent computer systems. That is, *SC-code* defines the syntactic, semantic and functional principles of organizing the memory of new generation computers, oriented to the implementation of intelligent computer systems – the principles of organizing graphodynamic associative semantic memory.

V. From standardization of the semantic representation of knowledge in the memory of intelligent computer systems to the standardization of intelligent computer systems

After we have defined the standard of *universal* (!) internal language of the sense representation of knowledge in the memory of an intelligent computer system, we can proceed to refine the standard of intelligent computer systems based on the specified language. Since this language is universal, it is possible to describe the intellectual computer system itself with a sufficient degree of detail and completeness, in the memory of which the specified description is stored. The integrated set of knowledge stored in the memory of an intelligent computer system and *sufficient* (!) For the functioning of this system is called ***knowledge base*** of the specified system. *Knowledge Base* of an intelligent computer system includes:

- a description of the facts and laws of the external environment in which the intelligent computer system functions ("dwells") and, in particular:
  - a description of external actors (for example, users) with whom the system interacts (a description of their properties, a description of the situations and events associated with them, a description of protocols for direct interaction with them);
  - a description of the syntax and semantics of the languages of communication with external entities;
  - a description of the facts of the behavior of an intelligent computer system in the external environment;
  - a description of the rules (skills) of the behavior of an intelligent computer system in the external environment;
- a description of the rules of behavior of internal entities of an intelligent computer system that perform actions (information processes) in the memory of an intelligent computer system (we will call such entities internal agents of an intelligent computer system);
- a description of the information processes themselves, planned, executed, or executed in the memory

of an intelligent computer system (a description of the behavior of an intelligent computer system in the internal environment);
- a description of methods (skills) that provide solutions to the corresponding classes of information problems – a description of the rules of behavior of internal agents of an intelligent computer system in its memory, which is the internal environment of an intelligent computer system.

Thus, the standardization of intelligent computer systems is determined by language means of knowledge bases structuring, means of systematizing the various types of knowledge that are part of knowledge bases.

At the same time, the intelligent computer system itself is considered as a system consisting of two main components:
- knowledge base, which is a complete description of this intelligent computer system;
- universal interpreter of knowledge bases of intelligent computer systems, consisting of:
  - memory in which the processed knowledge base is loaded and stored;
  - a processor that provides a direct interpretation of the knowledge base stored in the above memory.

Note that in the hardware implementation of a universal interpreter of knowledge bases that have a sense representation, the line between memory and the processor of the interpreter can be blurred. Those. the knowledge base interpreter can be implemented as a processor-memory in which processor elements will be connected to memory elements.

The above *completeness* description of an intelligent computer system in the knowledge base of this system itself is determined by the following properties and capabilities of intelligent computer systems.

Intelligent computer system is ***knowledge-based computer system*** and controlled by its knowledge. Those, the basis of an intelligent computer system is its knowledge base, which is a systematic information picture (information model) of the world (environment) in which an intelligent computer system operates. This environment is understood as ***external environment*** of an intelligent computer system, and its ***internal environment***, which is the knowledge base stored in memory of intelligent computer system.

An intelligent computer system is a computer system that has a high degree of ***learnability***, which boils down to expanding the *external environment* of one's "habitat" (functioning), to expanding one's *internal environment* (of one's knowledge base) with new declarative knowledge and new skills, to an improved quality of one's knowledge base (improving the quality of structuring a knowledge base, observing the principle of Occam's razor, minimizing contradictions, information holes, information garbage).

The high degree of *learnability* of intelligent computer systems is determined by the high speed of almost unlimited expansion of knowledge and skills of the system (and, including, the expansion of the variety of types of acquired knowledge and the variety of types of acquired skills – types of problem solving models). Such learnability is provided by:
- semantic compatibility of the knowledge used (including knowledge of various types) – the presence of an automated method for various knowledge integration;
- semantic compatibility of the skills used – the possibility of associative use of any required knowledge (including the same) in interpreting (performing) any skills (including recently acquired);
- the high level of flexibility of an intelligent computer system —- the low complexity of intelligent computer systems modifying at all levels while maintaining the integrity of the system (in particular, the complexity of modifying stored knowledge and skills used);
- high level of stratification;
- a high level of reflectivity – the ability to introspection and, including, to reasoning.

Intelligent computer system is a social subject that is able to exchange information and coordinate with other intelligent systems (including people) in the direction of achieving corporate goals, as well as maintain a sufficient level of semantic compatibility (mutual understanding) with other entities to prevent the "Babylonian crowd" syndrome.

An intelligent computer system is a computer system capable of solving a *integral* (!) complex of tasks that ensure the effective functioning of a computer system in the corresponding "habitat" environment. This includes
- means of *perception* of the current state (situations and events) of the "habitat" environment,
- means of *analysis* of this state,
- means of *goal-setting* (generation of tasks to be solved, with the specification of their priority),
- means of solving initiated tasks (relevant skills and interpreters of these skills),
- tools of targeted impact on the environment "habitat", i.e. tools of changing the state of this environment.

The basis of our approach to ensuring semantic and logical (functional) compatibility of knowledge representation and processing models is based on the following principles:
- *universal* way of *sense* representation of knowledge – *SC-code*;
- hierarchical system of formal ontologies represented in *SC-code* and ensuring compatibility (consistency) of the concepts used;
- general abstract graphodynamic associative memory, integrating all the knowledge used by the intelligent

system;
- *hierarchical* system of agents over the specified memory;
- programming tools for these agents – tools for decomposing (reducing) agents to agents of a lower level (to interpreting agents).

We emphasize that the development of an intelligent computer system standard is a prerequisite not only for ensuring the semantic compatibility of intelligent computer systems, but also for the formation of a developing market of *industrial* (!) intelligent computer systems – i.e. for mass industrial development of intelligent computer systems in various fields [17], [18].

The standardization of intelligent computer systems that we propose is the basis for the technology of semantically compatible intelligent computer systems design that focus on the use of new generation computers specially designed for this purpose.

VI. Methodology for the development and continuous improvement of the standard of intelligent computer systems as a knowledge base of intelligent computer metasystem

The description of the standard of intelligent computer systems based on the semantic representation of knowledge, presented as a section of the knowledge base ***Intelligent Computer Metasystem*** (IMS.ostis) has the following structure:

- The subject domain and ontology of the internal language of the semantic representation of knowledge in the memory of an intelligent computer system (syntax and denotational semantics of the internal language).
- The subject domain and ontology of the external languages of the intelligent computer system, close to the internal sense language (syntax and denotational semantics of external languages).
- The subject domain and ontology of structuring the knowledge bases of intelligent computer systems.
- The subject domain and ontology of integrated problem solvers of intelligent computer systems.
- The subject domain and ontology of verbal and non-verbal interfaces of intelligent computer systems.

It is important not only to develop a standard of intelligent computer systems, but also to organize the process of permanent and rapid improvement and harmonization of this standard. If the standard of intelligent computer systems is presented in the form of a knowledge base of intelligent computer systems, which is specifically designed to automate the use and improvement of this standard and which *itself is built in strict accordance with this standard*, then the process of permanent improvement of the standard of intelligent computer systems becomes a process of permanent collective improvement of the knowledge base of the specified intelligent computer system.

This process is based on the following principles:

- According to the specified knowledge base, any user can carry out free *navigation*, asking a wide range of questions to the corresponding intelligent computer system.
- Any section of this knowledge base and even its entirety can be represented in the form of a semantically structured and "readable" source text.
- Anyone can become a co-author of the next version of the standard. To do this, he needs to register accordingly and comply with the relevant rules of interaction of the authors of the standard.
- Direct editing of the current *version of the standard* is carried out *automatically* by special internal agents for knowledge bases processing on the basis of a fully completed review process and coordination of the editorial editing proposed by one of the authors. A sufficiently representative group of authors should participate in each such procedure.
- Any proposal aimed at improving the current version of the standard is subject to review. Such a proposal may be a new fragment of the standard, an indication of a contradiction, an information hole, a garbage fragment, a dubious fragment, the proposed editorial revision.
- If the proposed new fragment of the standard is the result of eliminating a previously identified contradiction, or an information hole, or the result of processing a previously identified doubtful fragment, then in the specialization of the specified new fragment, this should be clearly indicated.
- All actions of each author are recorded in the knowledge base in the section of the stories of its evolution with automatic indication of the author and the moment the action was performed.
- Based on the history of evolution of the standard, the level of activity of each author and the level of value of his contribution to the development of the standard are automatically determined.
- The types of activities of the author of the standard include:
  - the construction of the proposed new fragment of the standard, together with the corresponding explanations, notes, examples, as well as with reference to some signs used by the current version of the standard (primarily to the concepts used);
  - building a specification of the contradiction (in particular, errors) found in the current state of the standard;
  - building a specification of the information hole detected in the current state of the standard;
  - building a specification of the garbage (excess) fragment detected in the current state of the

standard and expected to be deleted;
  - building a specification requiring revision of a dubious fragment of the current state of the standard indicating the directions of such revision;
  - building specifications of the proposed editorial revision in the current state (current version) of the standard (deletion, replacement);
  - building a review of the proposal made by another author, indicating his opinion ("I agree", "I agree in case the elimination of the relevant comments", "I disagree for the reasons indicated");
  - construction of a repeated review of the revised proposal made by other authors (after the elimination of comments);
  - building a revised version of your assumption after removing the comments made by reviewers.
- In the process of collective improvement of the standard, special attention should be paid to achieving consensus (consensus) on issues such as:
  - distinguished entities (primarily concepts) and their unambiguous basic formal **specifications** (for concepts – definitions);
  - *basic* terms attributed to selected entities (including concepts);
  - distinguished subject domains and their structural specifications (classes of objects of study, studied relations defined on objects of study).

To organize the coordination of work on the development and continuous improvement of the standard of intelligent computer systems and to build the appropriate infrastructure, it is necessary to create a Consortium for the standardization of intelligent computer systems, ensuring their semantic compatibility.

VII. Standards as a kind of knowledge

Standards in various fields are the most important type of knowledge, ensuring the coherence of various types of mass activity. But so that the standards do not inhibit progress, they must be constantly improved.

Standards must be used effectively and competently. Therefore, the design of standards in the form of text documents does not meet modern requirements.

Standards should be in the form of intelligent help systems that are able to answer a variety of questions. Thus, it is advisable to formalize the standards in the form of knowledge bases, corresponding intelligent reference systems. Moreover, these intelligent reference systems can coordinate the activities of standards developers aimed at improving these standards [19]–[21].

From a semantic point of view, each standard is a hierarchical ontology, clarifying the structure and concept systems of their respective subject areas, which describes the structure and functioning of either a certain class of technical or other artificial systems, or a certain class of organizations, or a certain type of activity.

Obviously, to build an intelligent reference system for the standard and an intelligent system for supporting collective improvement of the standard, formalization of the standard is necessary in the form of an appropriate formal ontology.

The convergence of various activities, as well as the convergence of the results of these activities, requires deep semantic convergence (semantic compatibility of the relevant standards), which also urgently requires formalization of standards.

It should also be noted that the most important methodological basis for formalizing standards and ensuring their semantic compatibility and convergence is the construction of a hierarchical system of formal ontologies and observance of the Occam razor principle.

VIII. Experience in integrating various types of knowledge and various problem solving models on the basis of their standardization

On the basis of the proposed standard for the semantic representation of knowledge, means have been developed that provide coordinated integration (the possibility of sharing when solving problems within the same intelligent system) of various types of knowledge and various problem solving models.

Integration of various types of knowledge is ensured by the presence of a model of hybrid knowledge bases, considered in [22] and, in turn, including a hierarchical family of top-level ontologies that provide semantic compatibility of various types of knowledge. Based on this model, it is supposed to integrate such types of knowledge as facts, specifications of various objects, logical statements (definitions, axioms, theorems), events, situations, programs and algorithms, processes, problem formulations, domain models, ontologies and others.

Integration of various problem solving models (knowledge processing models) is provided within the framework of the hybrid problem solver model considered in [23]. In the framework of this model, the solver is interpreted as a hierarchical model of agents interacting with each other by specifying the actions they perform in the general semantic memory. Based on this approach, the integration of such problem-solving models as logical (including clear, fuzzy, reliable, plausible, etc.), neural network models, genetic algorithms, various strategies for finding ways to solve problems is supposed. One of the components of the hybrid task solver model is a basic programming language oriented to the processing of semantic networks, on the basis of which it is proposed to develop programming languages of a higher level.

The considered approaches to the integration of various types of knowledge and problem-solving models have found application in a number of works, including joint ones:

- The paper [24] proposed an approach to the integration of neural network image processing models and logical inference models to build a decision support system in production;
- In the works [25] and other works of the authors, types of knowledge are considered, the presentation of which is necessary for building a comprehensive integrated knowledge base of an enterprise, examples of formalization of specific types of knowledge are given;
- The paper [26] proposed an approach to the integration of neural network and semantic models to improve the quality of image recognition;
- The paper [27] and other works of the authors considered approaches to improving the quality of recognition of voice messages due to the context described in the knowledge base;
- A number of prototypes of reference and training systems have been developed, within the framework of which various types of knowledge are integrated (facts, logical statements, programs, illustrations, examples, etc.) and various problem solving models within the framework of the corresponding subject domains are applied.

IX. From standardization of intelligent computer systems to standardization of their design technology and to the construction of an intelligent knowledge portal that ensures the efficient use and improvement of these standards

From the standard of intelligent computer systems built on the basis of the semantic representation of knowledge, from the intelligent computer metasystem discussed above that supports the operation and improvement of this standard, it is easy to move to the standard of integrated technology for designing an intelligent computer system based on a semantic representation of knowledge, which includes the specified standard of intelligent computer system, and the standard of methods for their development, and the standard of their development tools. Moreover, the standard for the specified integrated technology can be brought into line with the metasystem that supports the operation and improvement of the standard of this technology. We called this metasystem ***IMS.ostis Metasystem*** (Intelligent MetaSystem for Open Semantic Technology for Intelligent Systems).

IMS.ostis Metasystem
:= [Intelligent computer metasystem for design support of intelligent computer systems based on the semantic representation of knowledge]
:= [Intelligent knowledge portal that ensures the efficient use and improvement of the standard of intelligent computer systems, built on the basis of the sense representation of knowledge, as well as the standard of methods and design tools for these intelligent computer systems]

IMS.ostis metasystem knowledge base has the following structure:

- Description of the standard of intelligent computer systems based on the sense representation of knowledge (the structure of this standard was discussed above).
- Description of the standard design methods for intelligent computer systems based on the semantic representation of knowledge.
- Description of the standard design tools for intelligent computer systems based on the semantic representation of knowledge.

The considered knowledge base will be published in the form of the source text of this knowledge base, which, we hope, will be quite "readable" for a wide range of specialists due to the "transparent" formalized structuring of this text and the inclusion of informal information structures (explanations, notes, images) [1], [28].

X. Standardization of the global semantic space and prospects for the development of science, education, industry and the knowledge market

The structuring of *semantic space* of knowledge is determined by a system of interconnected *subject domains* and their corresponding *ontologies*.

Subject domains and, accordingly, ontologies specifying them are different.

The subject domain and ontology of a certain class of technical systems is one thing and the subject domain and ontology of project activities (including techniques) aimed at developing technical systems of a specified class, as well as the subject domain and ontology of tools used in the development of these technical systems, are another thing.

In addition, each class of technical systems can be associated with a subject domain and an ontology of actions that ensure the efficient operation of technical systems of this class.

Thus, on the set of subject domains and ontologies corresponding to them, a whole family of relations connecting them is defined. We list some of them:

- be a particular subject domain or ontology in the set theoretic sense (for example, the subject domain of planar figures and the subject domain of polygons and the subject domain of triangles are connected this way);
- to be a particular subject domain or ontology in a spatial sense, this provides a detailed description of the *spatial parts* of objects studied in a given subject domain;

- be a particular subject domain or ontology in the temporal sense, which provides a detailed description of the temporal parts (stages of existence) of objects studied in a given subject domain.

The list of types of links between subject domains and ontologies can be continued. We emphasize that

- each scientific-technical or educational discipline and each standard in the semantic space is represented in the form of a hierarchical system of interconnected subject domains and ontologies;
- the convergence of different disciplines ultimately boils down to *increase in the number of connections* between subject domains and ontologies that are part of different disciplines.

The experience of convergence of various activities in the field of artificial intelligence can be used to implement a transdisciplinary approach in the development of science as a whole.

Moreover, the design of knowledge bases of intelligent computer systems should be based on the results of scientific research of the whole complex of scientific and technical disciplines. The knowledge bases of intelligent computer systems should make full use of the results of scientific research, and not distort them with the hands of knowledge base engineers.

Of fundamental importance for the development of transdisciplinary research and the deepening convergence of various disciplines is the concept of *formalized* (!) ***global semantic spaces***, which is the result of the abstract integration of knowledge bases designed in the standard of sense representation of knowledge and included in the portals of scientific and technical knowledge corresponding to *all kinds* (!) of scientific and technical disciplines.

If each scientific and technical discipline will evolve not only within the framework of its formalized local sense space, focusing attention only on its class of objects of research and on its subject of research, but also simultaneously within the framework of the formalized *global semantic spaces*, then obviously interdisciplinary research will develop more intensively, constructively and accurately.

The system of evolving semantically compatible portals of scientific and technical knowledge is the basis of a new level of development of the organization of scientific and technical information and the organization of scientific activity in general. From a system of scientific books and articles, a transition to a system of semantically compatible databases of scientific and technical knowledge is necessary, in which duplication of knowledge is fundamentally excluded and in which the meaning (essence) of the contribution of each scientist to the development of the global semantic space of knowledge is clearly defined and localized.

Convergence, integration of the results of various scientific disciplines, transdisciplinarity of scientific research is the most important trend in the development of modern science:

"...the era of analyticism and its inherent differentiation of science and closed scientific theories is already behind us. It became apparent that the real problems facing human society are much more complicated than scientific ones, and science is not able to fundamentally solve them due to the fragmentation of scientific disciplines and their specialization, poor coordination of research teams and their subjects, lack of system monitoring and a common formalized language for representing knowledge." [8].

The most urgent is the need for the convergence of various disciplines:

- in the field of artificial intelligence to build a general theory of intelligent computer systems;
- in medicine for creating intelligent computer systems for integrated transdisciplinary diagnostics;
- in education for the formation and learners of a comprehensive picture of the world;
- in the integrated automation of enterprises to ensure semantic compatibility of all levels of enterprise management;
- in the complex informatization of scientific activity.

Problems that need to be solved at the stage of increasing the level of informatization of various areas of human activity, require the use of modern artificial intelligence technologies, are fundamental in nature and, therefore, for different areas of human activity are largely the same in the informatization of scientific activity and the informatization of education (Univercity 3.0), industry (Industry 4.0), healthcare.

Based on the use of the global semantic space of knowledge, it becomes possible to create a rapidly developing ***knowledge market***, within which

- the authorship of each action aimed at the development of global semantic space will be clearly fixed;
- will automatically (and therefore objectively) based on the analysis of the opinions of reviewers establish the fact of recognition (consistency) of each proposal aimed at the development of a global sense space;
- will automatically (and therefore objectively) evaluate the significance of the contribution of each author to the development of global sense space;
- will automatically (and therefore objectively) evaluate the practical relevance of knowledge created by each author recognized by the scientific community, based on an analysis of the frequency of use of this knowledge in problems solving, in the development of various intelligent computer systems;
- will be recorded even those points of view that are correctly framed, but did not receive the recognition of reviewers (over time, such recognition can be obtained).

XI. Prospects for the development of the market of intelligent computer systems based on their standardization

The main product of *OSTIS Technology*, focused on the design of semantically compatible intelligent computer systems based on the sense representation of knowledge in the memory of these systems, is not the intelligent computer systems themselves, but the sociotechnical ***OSTIS Ecosystem***, which is a self-organizing system consisting of interacting computer systems built using *OSTIS Technology* (*ostis-systems*), as well as their users (end users and developers), and constantly supporting compatibility and, as a result, a high level of "mutual understanding" between the indicated *ostis-systems*, as well as between these systems and their users.

Thus, the basis of *OSTIS Technology* is the constantly evolving standards that provide the specified compatibility and "understanding".

OSTIS Technology is a technology for the development of semantically compatible hybrid intelligent systems that have a high level of learnability and constantly maintain the specified compatibility both among themselves and with their users.

We emphasize that *OSTIS Ecosystem* is a *hierarchical* multi-agent system, since the components (agents) of this multi-agent system [29] can be not only individual *ostis-systems* and their users, but and teams consisting of *ostis-systems*, users, as well as other such teams. Moreover, each *ostis-system* or user can be a member of several teams at once.

The transition from individual intelligent computer systems to an ecosystem of intelligent computer systems requires the development of

- ***standards*** of intelligent computer systems;
- ***standards evolution support tools*** of intelligent computer systems;
- ***compatibility support tools*** of intelligent computer systems during their evolution and operation;
- ***compatibility support tools*** of intelligent computer systems in the process of changing (evolution) of intelligent computer systems standards;
- ***integration automation tools*** of intelligent computer systems;
- ***means of coordination*** the activities of intelligent computer systems within various teams.

XII. Conclusion

The creation of *OSTIS Technology* will allow to solve a number of significant problems considered in this paper, which, in turn, will radically change the capabilities of a developer of intelligent computer systems and expand the range of problems solved by such systems [30], [31].

To reduce the time needed to improve the quality of developed intelligent computer systems, it is necessary to organize *component* design of intelligent computer systems with a powerful and constantly expanding library of reusable components of intelligent computer systems, but for this it is necessary to provide ***semantic compatibility*** of the specified components.

For the implementation of cooperative purposeful and adaptive interaction of intelligent computer systems within the framework of automatically formed teams of intelligent computer systems, ***semantic compatibility*** of intelligent computer systems is required, and this, in turn, requires unification of intelligent computer systems. The unification of an intelligent computer system is possible only on the basis of ***general formal theory of intelligent computer systems*** and the corresponding ***standard of intelligent computer systems***, and this requires a deep convergence of different areas of research in the field of artificial intelligence.

Since the result of the development of artificial intelligence as a scientific discipline is the permanent evolution of the general theory of intelligent computer systems and the corresponding standard of intelligent computer systems, in order to increase the pace of development of artificial intelligence and, accordingly, the technology for intelligent computer systems development, it is necessary to create a portal of scientific and technical knowledge on artificial intelligence that provides coordination of the activities of specialists, as well as coordination and inter radio results of this activity.

To switch to a new technological structure in the field of artificial intelligence, which is based on ensuring the semantic compatibility of intelligent computer systems, a prerequisite for which is the standardization (unification) of intelligent computer systems, certain socio-psychological prerequisites are required – an appropriate motivation and a fairly high level of determination, as well as mathematical and systemic culture.

The key points of *OSTIS Technology* are:

- targeting at a new generation of computers specifically designed for the production of semantically compatible intelligent computer systems;
- compliance with the principle of Occam's Razor at all levels of intelligent computer systems and, first of all, on the verge between the software and hardware of computer systems using *semantic representation of information* in the memory of intelligent computer systems;
- convergence of various types of components of intelligent computer systems, as well as methods and means of their development;
- orientation to solving the problem of semantic compatibility of intelligent computer systems *at all levels* of the organization of their activities.

Very promising object of mathematical research is the concept of the global sense space represented in *SC-code*, which includes the signs of *all kinds* of entities and, accordingly, the signs of all kinds of links between these entities and/or their signs. The peculiarity of this space is that it has a unique combination of properties:

- property of objectivity (independence from the point of view of a particular subject);
- with topological properties, which allows it to be investigated using topology methods by specifying, in particular, the concept of semantic proximity;
- algebraic properties, which allows you to explore it using the theory of algebraic systems, category theory;
- graph-theoretic properties, which allows you to explore its structure using the methods and tools of graph theory.

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Стандартизация интеллектуальных компьютерных систем – ключевая задача текущего этапа развития технологий искусственного интеллекта

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Данная работа посвящена рассмотрению важнейшего фактора, обеспечивающего *семантическую совместимость* интеллектуальных компьютерных систем и их компонентов – ***стандартизации интеллектуальных компьютерных систем***, а также стандартизации методов и средств их проектирования.

Основой предлагаемого подхода к обеспечению высокого уровня *обучаемости* и *семантической совместимости* интеллектуальных компьютерных систем, а также к разработке ***стандарта интеллектуальных компьютерных систем*** является унификация ***смыслового представления знаний*** в памяти таких систем и построение глобального ***смыслового пространства*** знаний.

В работе рассмотрены текущие проблемы в области развития технологий искусственного интеллекта, в области автоматизации научно-технической и образовательной деятельности, а также в области развития информационных технологий в целом.

Описаны принципы, лежащие в основе ***стандарта интеллектуальных компьютерных систем*** и соответствующей технологии их разработки, рассмотрена структура базы знаний портала научных знаний, в рамках которой формально описывается указанный стандарт.

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