Next-generation intelligent computer systems and technology of complex support of their life cycle

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***Abstract*—The paper considers the principles of building next-generation intelligent computer systems, as well as the principles of building a comprehensive technology for their development and life cycle support - OSTIS Technology. Semantic compatibility and interoperability are highlighted as the key properties of the next-generation intelligent systems. The paper considers an approach to providing these properties, realized within the framework of OSTIS Technology.**

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

I. Introduction

The most important direction of increasing the level of *intelligence* of *individual intelligent cybernetic systems* is the transition to *individual intelligent cybernetic systems collectives* and further to *hierarchical intelligent cybernetic systems collectives*, whose members are both *individual intelligent cybernetic systems* and *individual intelligent cybernetic systems collectives*, as well as *hierarchical intelligent cybernetic systems collectives*. Similarly, it is necessary to increase the level of intelligence and *individual intelligent computer systems* (artificial *cybernetic systems*). But at the same time, we must remember that not every association of *intelligent cybernetic systems* (including *computer systems*) becomes an *intelligent collective*. For this, it is necessary to comply with additional requirements imposed on all members of *intelligent collectives*. The most important of them is the requirement of a high level of ***interoperability***, in other words the ability to interact effectively with other members of the team. The transition from modern *intelligent computer systems* to *interoperable intelligent computer systems* is a key factor in the transition to the ***next-generation intelligent computer systems***, providing a significant increase in the level of automation of human activity.

II. Next-generation intelligent computer systems

The creation of various complexes of interacting *intelligent computer systems* requires improving the quality of not only these systems themselves, but also the quality of their interaction. *Next-generation intelligent computer systems* should have a high level of ***interoperability***, in other words, a high level of ability to effectively, purposefully interact with their own kind and with users in the process of collective (distributed) and decentralized solution of complex problems [1], [2], [3], [4], [5], [6]. The level of ***interoperability*** of *intelligent computer systems* is, figuratively speaking, the level of their "socialization", usefulness within the framework of various a priori unknown communities (collectives) of *intelligent systems*. The level of ***interoperability*** of *intelligent computer systems* is the level of their communication (social) compatibility, which allows them to independently form collectives of *intelligent computer systems* and their users, as well as independently coordinate and coordinate their activities within these collectives when solving complex tasks in partially predictable conditions. Increasing the level of *interoperability* of intelligent computer systems determines the transition to the ***next-generation intelligent computer systems***, without which it is impossible to implement projects such as smart-enterprise, smart-hospital, smart-city, smart-society [7], [8].

intelligent computer system
:= [intelligent artificial cybernetic system]
⇒ *decomposition**:
{• *individual intelligent computer system*
• *intelligent collective of intelligent computer systems*
}

Let's take a closer look at the concept of intelligent collective of intelligent computer systems.

intelligent collective of intelligent computer systems

:= [intelligent multi-agent system, whose agents are intelligent computer systems]

⇒ *note**:

[Not every collective of intelligent computer systems can be intelligent, because the level of intelligence of such a collective is determined not only by the level of intelligence of its members, but also by the efficiency (quality) of their interaction.]

⇒ *decomposition**:

{
- *intelligent collective of individual intelligent computer systems*
- *hierarchical intelligent collective of intelligent computer systems*
  - := [intelligent collective of intelligent computer systems, at least one of whose members is an intelligent collective of intelligent computer systems]

}

next-generation intelligent computer systems

⇒ *requirements**:
- high level of *interoperability*
- high level of *learning*
- high level of *hybridity*
- a high level of ability to solve *intelligent problems* (in other words *problems*, which solution *methods* and/or the background information required for their solution are priori unknown)
- high level of *synergy*

interoperability^

:= [ability to effectively (focused) interaction with other independent subjects]

:= [ability to the partnership in solving *complex problems*, that require *collective activity*]

:= [ability to work in collective (in a team)]

:= [level of socialization]

:= [social skills]

high level of interoperability

⇒ *provided by**:
- high level of *understanding*
  - ⇒ *provided by**:
    - high level of ***semantic compatibility*** of a given subject with other subjects of a given collective
    - high level of *ability to understand* the messages and behavior of partners
    - high level of *ability to be understandable* for partners:
      - ability to clearly and reasonably formulate their suggestions and information useful for solving current problems;
      - ability to act and comment on their actions so that they and their motives are clear to partners;
    - high level of ability to increase the level of semantic compatibility with their partners
- high level of *negotiability*, in other words the ability to coordinate with partners their plans and intentions in order to ensure timely high quality of the collective result
- high level of *ability to decentralize coordination* of their actions with the actions of partners in unpredictable (abnormal) circumstances
- high level of *ability to minimize the negative consequences of conflict situations* with other subjects
  - ⇒ *provided by**:
    - high level of *ability to prevent the occurrence of conflict situations*
    - *compliance with ethical standards* and rules that prevent the occurrence of destructive consequences of conflict situations
    - high level of *ability to share responsibility* with partners for timely and high-quality achievement of a common goal

semantic compatibility^

:= [degree of coherence (coincidence) of systems of *concepts* and other *key entities*, used by specified interacting entities]

⇒ *note**:

[Provision of *semantic compatibility* requires formalization of the *semantic representation of information*]

ability to share responsibility with partners, which is a necessary condition for decentralized management of collective activity

⇒ *provided by**:
- *ability to monitor* and analyze collectively performed activity
- *ability to promptly inform partners* about adverse situations, events, trends, as well as initiate appropriate collective actions

learning^

:= [ability to quickly and efficiently acquire new *knowledge* and *skills*, as well as improve already acquired *knowledge* and *skills*]

high level of learning

⇒ *provided by**:

- high level of *flexibility of the information* stored in the memory of the intelligent system
- high level of *quality* of *stratification of information*, stored in the memory of the intelligent system by the stratification of *the knowledge base*
- high level of *reflexivity* of intelligent system
- high level of *ability to correct its mistakes* (including to eliminate contradictions in its *knowledge base*)
- high level of *cognitive activity*
- absence of *restrictions on the type of acquired knowledge and skills* (the absence of such restrictions means the potential *universality* of the intelligent system)

hybridity^

:= [degree of diversity of the *types of knowledge* and *models of problem solving* used and the level of efficiency of their sharing]

:= [individual ability to solve *complex problems* that require the use of different *types of knowledge*, as well as various combinations of different *models of problem solving*]

high level of hybridity

⇒ *provided by**:

- high degree of diversity of the *types of knowledge* and *models of problem solving* used
- high degree of *convergence* [9], [10] and deep *integration* (degree of interpenetration) of various *types of knowledge* and *models of problem solving*
- ability to indefinitely expand the level of its *hybridity*

We emphasize that the *hybridity* and *interoperability* of *intelligent computer systems* of the next-generation implies the rejection of the well-known paradigm of "black boxes", since:

- all the variety of problem solving models of *a hybrid intelligent computer system* should be interpreted on one common *universal platform*;
- availability of information about how each method used, the model of problem solving, each subject significantly improves the quality of their *coordination* when *solving complex tasks together*;
- it becomes possible to use some methods, models of problem solving and entire subjects (for instance, *intelligent computer systems*) to improve (improve the quality) of other methods, models and subjects.

It is especially necessary to note the following characteristics of *intelligent computer systems of the next-generation*:

- ***degree*** of ***convergence***, unification and standardization of *intelligent computer systems* and their components and the corresponding ***degree of integration*** (integration depth) of *intelligent computer systems* and their components;
- ***semantic compatibility*** between *intelligent computer systems* in general and *semantic compatibility* between the components of each *intelligent computer system* (in particular, compatibility between different *types of knowledge* and different *models of knowledge processing*), which are the main indicators of the degree of ***convergence*** (convergence) between *intelligent computer systems* and their components.

The feature of these characteristics of *intelligent computer systems* and their components is that they play an important role in solving all the key tasks of the modern stage of *artificial intelligence* development and are closely related to each other.

It should also be noted that the listed requirements for the *next-generation intelligent computer systems* are aimed at overcoming the curse of *Babel* [11] both within *intelligent computer systems of the next-generation* (between internal *information processes* for solving various problems) and between interacting independent *next-generation intelligent computer systems* in the process of collective solution of *complex problems*.

At the present stage of evolution of *intelligent computer systems* for a significant expansion of their application areas and a qualitative increase in the level of automation of human activity:

- It is necessary to move to the creation of <u>semantically</u> <u>compatible</u> ***intelligent computer systems of the <u>next-generation</u>***, focused not only on individual, but also on <u>collective</u> (joint) solution of *complex problems* requiring coordinated activity several independent intelligent computer systems and the use of various models and methods in unpredictable combinations, which is necessary to significantly expand the scope of application of *intelligent computer systems*, for the transition from automation of local types and areas of *human activity* to complex automation of larger (combined) types and areas of this activity;
- It is necessary to develop a ***General formal theory and standard for the next-generation intelligent computer systems***;
- It is necessary to develop a ***Technology for integrated support of the life cycle of the next-generation intelligent computer systems***, which includes support for the *engineering* of these systems (as the initial stage of their life cycle) and ensuring their *compatibility* at all stages of their life cycle;
- ***Convergence*** and ***unification*** of the *next-generation intelligent computer systems* is necessary;
- It is necessary to implement "seamless", "diffuse",

interpenetrating, ***deep integration of semantically adjacent components of intelligent computer systems***, in other words, integration in which there are no clear boundaries ("seams") of the integrated (connected) components, and which can be carried out automatically. This means moving to ***hybrid intelligent computer systems***;
- It is necessary to observe the ***Occam's razor principle*** – maximum possible structural simplification of *intelligent computer systems of the next-generation*, exclusion of eclectic solutions;
- It is necessary to focus on potentially ***universal*** (in other words, capable of quickly acquiring any knowledge and skills), ***synergetic*** *intelligent computer systems* with "strong" intelligence;

next-generation intelligent computer systems
⇒ *underlying principles**:
- *semantic representation of knowledge* in the memory of *intelligent computer systems*, assuming the absence of *homonymic signs*, which in different contexts denote different entities, as well as the absence of *synonymy*, in other words pairs of synonymous *signs*, which denote the same entity. The semantic representation of the information structure in general has a nonlinear (graph) character and is called *semantic network*
- use of a common for all intelligent computer systems *universal language of semantic representation of knowledge* in memory *intelligent computer systems*, having the simplest possible *syntax*, providing the representation of any *types of knowledge* and having unlimited possibilities of transition from *knowledge* to *meta-knowledge*. The simplicity of the syntax of *information constructions* of the specified *language* allows us to call these constructions *refined semantic networks*
- *structurally tunable (graphodynamic) memory organization* of intelligent computer systems, in which knowledge processing is reduced not so much to changing the state of stored *characters*, as to changing the configuration of the connections between these *characters*
- *semantically unlimited associative access to information* stored in the memory of *intelligent computer systems*, according to a given sample of arbitrary size and arbitrary configuration
- *decentralized situational management of information processes* in the memory of *intelligent computer systems*, realized using *agent-oriented model of knowledge base processing*, in which *initiation* of new *information processes* is not carried out by transferring control to the corresponding a priori known procedures, and as a result of the occurrence of the corresponding *situations* or *events in the memory of an intelligent computer system*, because «The main problem of computer systems is not the accumulation of knowledge, but the ability to activate the necessary knowledge in the process of solving problems» (Pospelov D.A.). Such a multi-agent process of information processing is a *activity* performed by some collective of independent *information agents* (information processing agents), the condition for initiating each of which is the appearance in the current state of *knowledge base* corresponding to this agent *situation* and/or *events*.
The choice of multi-agent technologies is explained by the fact that currently any complex production, logistics or other system can be represented by a set of interactions of simpler systems to any level of detail, which provides a fractal-recursive principle of building multi-tiered systems built as open digital colonies and AI ecosystems. Multi-agent technologies are based on a distributed or decentralized approach to problem solving, in which dynamically updated information in a distributed network of intelligent agents is processed directly from agents along with locally available information from "neighbors". At the same time, both resource and time costs for communication in the network are significantly reduced, as well as time for processing and decision-making in the center of the system (if there is one).»
⇐ *quotation**:
Barinov I.I.. DevelSFoftheConAI-2021/p. 270 [12]
- Transition to *semantic models of problem solving*, which are based on taking into account not only syntactic (structural) aspects of the processed information, but also semantic (semantic) aspects of this information – "From data science to knowledge science"
- ***ontological model of knowledge bases*** of *intelligent computer systems*, in other words the ontological structuring of all information stored in memory of *intelligent computer system*, assuming a clear *stratification of the knowledge base* in the form of a hierarchical system of *subject areas* and the corresponding *ontologies*, each of which provides a semantic *specification* of all *concepts* that are key within the corresponding *subject area*
- ***ontological localization of problem solving***

in *intelligent computer systems*, assuming localization *scope* of each stored in memory *method* and each *information agent* in accordance with *ontological model* processed by *knowledge base*. Most often, such a *scope* is one of *subject areas* or one of *subject areas* together with its corresponding *ontology*

- ***ontological model of the interface*** *intelligent computer system* which includes:
  - ontological description of *syntax* of all *languages* used by *intelligent computer system* for *communication* with external *subjects*;
  - ontological description of *denotational semantics* of each *language* used by *intelligent computer system* for *communication* with external *subjects*;
  - family of *information agents* providing *syntactic analysis*, *semantic analysis* (translation into an internal semantic language) and *understanding* (immersion in *knowledge base*) of any entered *message* belonging to any *to an external language*, the full ontological description of which is in the knowledge base of *intelligent computer system*;
  - family of *information agents* providing the *synthesis of messages* that (1) are addressed to external subjects with whom an *intelligent computer system* communicates, (2) are *semantically equivalent* to the specified *fragments of the knowledge base* of an intelligent computer system that determine the *meaning* of the transmitted *messages*, (3) belong to one of the *external languages*, the full ontological description of which is in the *knowledge base* of an intelligent computer system;
- *semantically friendly nature of the user interface*, provided by (1) a formal description in the knowledge base of the user interface management tool and (2) the introduction of the corresponding help subsystems into the *intelligent computer system*, providing a significant reduction in the language barrier between users and *intelligent computer systems*, which will significantly increase the efficiency of *operation of intelligent computer systems*
- *minimizing the negative impact of the human factor* on the efficiency of *operation intelligent computer systems* thanks to the implementation of an interoperable (partner) style of interaction not only between *intelligent computer systems* themselves, but also between *intelligent computer systems* and their users. Responsibility for the quality of joint activities should be distributed among all partners
- ***multimodality*** (hybrid character) *intelligent computer system*, which assumes:
  - variety of *types of knowledge* included in the *knowledge base* of an intelligent computer system;
  - variety of *problem solving models* used by the *problem solver* of an intelligent computer system;
  - variety of *sensor channels* that *monitor* the state of the *external environment* of an intelligent computer system;
  - variety of *effectors* that *affect* the *external environment*;
  - variety of *languages of communication* with other subjects (with users, with intelligent computer systems);
- ***internal semantic compatibility*** between the components of an *intelligent computer system* (i.e., the maximum possible introduction of common, matching *concepts* for various fragments of the stored *knowledge base*), which is a form of ***convergence*** and *deep integration* within an *intelligent computer system* for different types of *knowledge* and different *models of problem solving*, which ensures the effective implementation of the *multimodality of an intelligent computer system*
- ***external semantic compatibility*** between various *intelligent computer systems*, expressed not only in the commonality of *concepts* used, but also in the commonality of basic *knowledge* and is a necessary condition for ensuring a high level of *interoperability* of intelligent computer systems
- orientation to the use of *intelligent computer systems* as *cognitive agents* in ***hierarchical multi-agent systems***
- ***platform independence*** **of intelligent computer systems**, assuming:
  - clear *stratification* of each *intelligent computer system* (1) to a logical-semantic model represented by its *knowledge base*, which contains not only *declarative knowledge*, but also knowledge having *operational semantics*, and (2) to a *platform* providing *interpretation* of the specified *logical-semantic model*;
  - universality of the specified *platform* of interpretation of the *logical-semantic model of an intelligent computer system*, which makes it possible for each such *platform* to provide interpretation of any *logical-semantic model of an intelligent computer system*, if this model is presented in the

same *universal language of semantic representation of information*;
  - variety of options for implementing *platforms* for *interpreting logical and semantic models of intelligent computer systems* - both options that are programmatically implemented on *modern computers*, and options that are implemented in the form of *new-generation mainframe computers* focused on use in intelligent computer systems of a new generation (such computers we called *associative semantic computers*);
  - easily implemented possibility of transferring (reinstalling) the logical-semantic model (*knowledge base*) of any *intelligent computer system* to any other *platform for interpreting logical-semantic models*;
- initial orientation of *intelligent computer systems of the new generation* to the use of ***universal associative semantic computers*** (computers of the new generation) as a *platform for the interpretation of logical-semantic models* (knowledge bases) of *intelligent computer systems*

Currently, a large number of different types of *problem solving models*, models of representation and processing of knowledge of various types have been developed. But different combinations of these models may be in demand in different *intelligent computer systems*. When developing and implementing various *intelligent computer systems*, appropriate methods and tools should guarantee the *logical and semantic compatibility* of the components being developed and, in particular, their ability to use common *information resources*. For this, obviously, the *unification* of these models is necessary.

The variety of different types of intelligent computer systems and, accordingly, the variety of combinations of knowledge representation models and problem solving used by them is determined by:

- variety of the purpose of intelligent computer systems and the type of their environment;
- variety of different types of stored knowledge; a variety of knowledge processing models and problem solutions;
- variety of different types of interfaces (signal processing, audio, video, effector means).

The following aspects of the *compatibility* of knowledge representation and processing models in *intelligent computer systems* should be highlighted:

- syntactic;
- semantic (consistency of systems of concepts);
- functional (operational).

It should also be distinguished:

- *compatibility* between components of *intelligent computer systems*;
- *compatibility* between the upper logical-semantic level of the knowledge representation and processing models used and various levels of their interpretation up to the hardware level;
- *compatibility* between individual intelligent computer systems;
- *compatibility* between individual intelligent computer systems and their users;
- *compatibility* between teams of intelligent computer systems.

III. Semantic representation of information

semantic representation of information
:= [recording (representation) of the information structure at the semantic level]
:= [information construct whose syntactic structure is close to its meaning, i.e. close to the described configuration of connections between the described entities]
:= [semantic representation of the information structure]
⊂ *semantic network*
  ⊃ *refined semantic network*

refined semantic network
⇒ *the underlying principles**:
  - Each element (syntactically atomic fragment) of a refined semantic network is a sign of one of the described entities
  - Each entity described by a refined semantic network should be represented by its own sign, which is an element of this network
  - Within each separate refined semantic network, there is no synonymy of different signs, and there are also no homonymous signs
  - The variety of entities described by refined semantic networks is not limited by anything. Accordingly, the semantic typology of the elements of refined semantic networks is very rich
  - A special type of elements of refined semantic systems are signs of connections between other elements of these networks. At the same time, connected elements (i.e. elements that are incident to the specified signs of connections) there may also be signs of other connections. Most often, the sign of the connection between the elements of a refined semantic network is a reflection of the connection between entities that are designated by these elements. But in some cases, the sign of the connection between the elements of a refined semantic network can

be a reflection, for example, of the connection between one described entity and the sign of another described entity

IV. Multi-agent models of problem solving based on the semantic representation of information

next-generation intelligent computer systems problem solver

⇒ *requirements**:

- problem solver of intelligent computer systems of a new generation should be able to solve intellectual problems, which include the following types of tasks:
  - poorly formulated problem
    := [problem whose formulation contains various non-factors (incompleteness, vagueness, inconsistency (incorrectness),..)]
  - problem for which, in addition to the formulation of the problem itself and the corresponding method of solving it, additional, but a priori unknown, information about the objects specified in the formulation (statement) of the problem is needed. At the same time, the specified additional information may or may not be present in the current state of the knowledge base of intelligent computer systems. In addition, for some tasks, the area of the knowledge base can be specified (specified), the use of which is sufficient to search for or generate (in particular, logical output) the specified additional required information. Such an area of the knowledge base will be called the area of solving the corresponding problem
  - problem for which the appropriate method of solving it is not currently known. reformulate the problem, in other words generate (logically output) a logically equivalent formulation of the original problem for which the method of its solution is currently known; To solve such a problem , you can:
    * reformulate the problem, in other words generate (logically output) a logically equivalent formulation of the original problem for which the method of its solution is currently known;
    * reduce the original problem to a family of subtasks for which the methods of their solution are currently known.
- process of solving problems in intelligent computer systems of a new generation is implemented by a team of information agents processing the knowledge base of intelligent computer systems
- management of information processes in the memory of intelligent computer systems of a new generation is carried out in a decentralized manner according to the principles of situational management

situational management

:= [situational and event management]

⇒ *explanation**:

[managing the sequence of actions, in which the condition ("trigger") for initiating these actions is:

□ occurrence of some situations (conditions, states);

□ and/or the occurrence of some *events*

]

situation

:= [structure describing some temporarily existing configuration of relationships between some entities]

:= [description of the temporarily existing state of some fragment (some part) of some dynamic system]

event

⊃ *emergence of a temporary entity*
  := [appearance, birth, the beginning of the existence of some temporary entity]

⊃ *disappearance of a temporary entity*
  := [termination, termination of the existence of some temporary entity]

⊃ *transition from one situation to another*
  ⇒ *note**:
  [It takes into account not only the fact of the emergence of a new situation, but also its background - i.e. the situation that immediately precedes it. So, for example, reacting to an abnormal value of a parameter, it is important for us to know:

  □ what is the dynamics of the change of this parameter (it increases or decreases and at what rate);

  □ what measures were taken earlier to eliminate this anomaly.

  ]

V. Ontological models of interfaces of intelligent computer systems based on the semantic representation of information

interface of the next-generation intelligent computer system
⇒ *underlying principles**:
- interface of an *intelligent computer system of a new generation* is considered as a solver of a particular type of problems - *interface problems*, the main of which are:
  - problems of understanding verbal information acquired by an intelligent computer system (syntactic analysis, semantic analysis and immersion in the knowledge base of an intelligent computer system)
  - problems of understanding nonverbal information perceived by sensory subsystems of an intelligent computer system (image analysis, audio signal analysis, immersion of analysis results into the knowledge base of an intelligent computer system)
  - problems of synthesizing messages addressed to external entities (cybernetic systems)
- fact that the interface of an *intelligent computer system of a new generation* is a solver of a particular type of *problems of an intelligent computer system of a new generation*, the properties underlying the *problem solvers of intelligent computer systems of a new generation* are inherited by the interfaces of *intelligent computer systems of a new generation*. It follows from this that the basis of *intelligent computer systems of the new generation* is:
  - semantic representation of accumulated (acquired knowledge);
  - interpretation of semantic analysis of acquired verbal information as a process of translating this information into the internal language of the semantic representation of knowledge, followed by immersion (input, integration) of the result of this translation into the current state of the knowledge base of an *intelligent computer system of a new generation*;
  - interpretation of the synthesis of messages addressed by external entities as a process of reverse translation of some fragment of the knowledge base from the internal language of the semantic representation of information into an external language used to communicate with a given subject;
  - agent-oriented organization of interface problem solving, implemented by the respective teams of internal agents of the interface of *intelligent computer systems of a new generation* interacting through the knowledge base of an *intelligent computer system of a new generation* that is publicly available to them
- interface of an *intelligent computer system of a new generation* is interpreted as a specialized integrated *intelligent computer system of a new generation*, which is part of the above-mentioned intelligent computer system, the knowledge base of which includes:
  - ontology of the syntactic internal language of the semantic representation of information;
  - ontology of denotational semantics of the internal language of semantic representation of information;
  - syntax ontology of all external languages used to communicate with external entities;
  - ontologies of denotational semantics of all external languages used for communication with external subjects (each such ontology from a formal point of view is a description of the correspondence between the texts of external languages and semantically equivalent texts of the internal language of the semantic representation of information.

    At the same time, we emphasize that all of these ontologies, which are part of the knowledge base, interfaces of intelligent computer systems of a new generation, as well as all other information included in this knowledge base, are presented in the internal language of the semantic representation of information, which, accordingly, is used in this case as a meta language.

Conversations about a friendly and, in particular, adaptive *user interface* have been going on for a long time, but this most often concerns the form ("syntactic" side) of the *user interface*, and not the semantic content of interaction with users. Currently, *user interfaces* of computer systems (including *intelligent computer systems*) for a wide contingent of users are not semantically (meaningfully) friendly (semantically comfortable). The organization of user interaction with computer systems (including *intelligent computer systems*) is a "bottleneck" that has a significant impact on the efficiency of *automation of human activity*. The modern organization of user interaction with a computer system is based on the paradigm of a competent user who knows what he wants from the tool he uses and is fully responsible for the quality of interaction with this tool. This paradigm underlies the activities of a logger in interaction with an axe, a rider in interaction with a horse, a car driver, a pilot in interaction with a corresponding vehicle, an operator of a nuclear power plant, a railway dispatcher, and so on.

At the present stage of the development of *Artificial intelligence*, in order to increase the efficiency of interaction, it is necessary to move from the paradigm of competent management of the tool used to the paradigm of equal cooperation, partnership interaction of an *intelligent computer system* with its user. An *intelligent computer system* should turn "face" to the user.

Semantic friendliness of the user interface should consist in adaptability to the peculiarities and qualifications of the user, the exclusion of any problems for the user in the process of dialogue with an *intelligent computer system*, in permanent care of improving the user's communication skills.

VI. Advantages of the proposed approach to the creation of intelligent computer systems of a new generation what measures were taken earlier to eliminate this anomaly

The ***semantic representation of information*** in the memory of *intelligent computer systems* ensures the elimination of duplication of information stored in the memory of an *intelligent computer system*, i.e. the elimination of a variety of forms of representation of the same information, the prohibition of the appearance in one memory of *semantically equivalent information structures*, including synonymous *signs*. This significantly reduces complexity and improves quality:

- development of various *models of knowledge processing* (because there is no need to take into account the variety of forms of representation of the same knowledge);
- *semantic analysis* and *understanding* of information received (transmitted) from various external entities (from users, from developers, from other *intelligent computer systems*);
- *convergence* and *integration* of different types of knowledge within each *intelligent computer system*;
- ensuring *semantic compatibility* and *mutual understanding* between various *intelligent computer systems*, as well as between *intelligent computer systems* and their users.

We consider the concept of *semantic network* not as a beautiful metaphor of complexly structured *sign constructions*, but as a formal refinement of the concept of *semantic representation of information*, as the principle of representation of information underlying a new generation of *computer languages* and *computer systems* themselves - *graph languages* and *graph computers*. A *semantic network* is a nonlinear (graph) *sign construction* with the following properties:

- all elements (in other words syntactically elementary fragments) of this *graph structure* (nodes and bundles) are *signs* of the entities being described and, in particular, *signs of connections* between these entities;
- all *signs* included in this *graph structure* do not have *synonyms* within this structure;
- "internal" pattern (structure) of the *signs* included in the *semantic network* does not need to be taken into account in its *semantic analysis* (understanding);
- meaning of a *semantic network* is determined by the *denotational semantics* of all the *signs* included in it and the configuration of the *incidence relationships* of these signs;
- of the two *incident signs* included in the *semantic network*, at least one is a communication sign.

A *refined semantic network* is a *semantic network* having a simple *syntactic structure* in which, in particular,

- finite *alphabet* of *semantic network* elements is used, in other words a finite number of syntactically distinguished types (syntactic labels) attributed to these elements;
- external identifiers (in particular, names) attributed to *semantic network* elements are used only for information input/output.

An *agent-oriented model of information processing* combined with *decentralized situational control of the information processing process*, as well as with the *semantic representation of information* in the memory of an *intelligent computer system* significantly reduces the complexity and improves the quality of integration of various *models of problem solving* in the processing of a common *knowledge base*. This refers to the simultaneous use of different *models of problem solving* when processing the same *knowledge*, in particular, when solving the same *problem*.

A high level of *semantic flexibility of information* stored in the memory of an *intelligent computer system of a new generation* is ensured by the fact that each deletion or addition of a syntactically elementary fragment of stored information, as well as the deletion or addition of each *incident relationship* between such elements has a clear semantic interpretation.

A high level of *stratification of information* stored in the memory of the *next-generation intelligent computer system* is provided by the ontologically oriented structuring of the knowledge *base of the next-generation intelligent computer system*.

A high level of *individual learning* of the next-generation intelligent computer systems (in other words their ability to rapidly expand their *knowledge* and *skills*) is provided:

- *semantic flexibility of the information* stored in their *memory*;
- *the stratification* of this information;
- *reflexivity* of intelligent computer systems of the new generation.

A high level of *collective learning* of the next-generation intelligent computer systems is ensured by a high level of their *socialization* (i.e. the ability to effectively participate in the activities of various collectives consisting of the *next-generation intelligent computer systems* and people) and, above all, a high level of their *mutual understanding*.

The high level of *interoperability* of intelligent computer systems of the new generation fundamentally changes the nature of the interaction of *computer systems* with people whose activities they automate - from the management of these automation tools to *equal partner meaningful relationships*.

Each *next-generation intelligent computer system* is capable of:

- independently or by invitation to join a team consisting of *intelligent computer systems of a new generation* and/or people. Such teams are created on a temporary or permanent basis for the collective solution of complex *tasks*;
- participate in the distribution (including coordination of the distribution) of *tasks* – both "one-time" tasks and long-term tasks (responsibilities);
- monitor the state of the entire process of collective activity and coordinate their activities with the activities of other members of the team in case of possible unpredictable changes in the conditions (state) of the relevant environment.

The high level of *intelligence of the next-generation intelligent computer systems* and, accordingly, the high level of their independence and purposefulness allows them to be full members of a wide variety of communities within which *next-generation intelligent computer systems* receive the right to initiate independently (based on a detailed analysis of the current state of affairs and, including, the current state of the community action plan) a wide the range of actions (problems) performed by other members of the community, and thus participate in the coordination and coordination of the activities of community members. The ability of the *next-generation intelligent computer system* to coordinate its activities with other similar systems, as well as to adjust the activities of the entire *collective of the next-generation intelligent computer systems*, adapting to various types of changes in the environment (conditions) in which this activity is carried out, allows you to significantly automate the activities of a *system integrator* both at the stage of creating a *collective of the next-generation intelligent computer systems*, and and at the stage of its updating (reengineering).

The advantages of *intelligent computer systems of the new generation* are provided by:

- advantages of the language of internal *semantic encoding of information* stored in the memory of these systems;
- advantages of the organization of graphodynamic associative semantic memory of *intelligent computer systems of a new generation*;
- advantages of *semantic representation of knowledge bases* of intelligent computer systems of a new generation and *means of ontological structuring of knowledge bases* of these systems;
- advantages of *agent-oriented problem solving models* used in *intelligent computer systems of a new generation* in combination with decentralized control of the information processing process.

VII. Technology of integrated life cycle support for intelligent computer systems of the next generation

life cycle of the next-generation intelligent computer system

$\Rightarrow$ *includes**:
- designing the next-generation intelligent computer system
  $\Rightarrow$ *includes**:
  - designing the knowledge base of the next-generation intelligent computer system
  - designing the next-generation intelligent computer system problem solver
  - designing the interface of the next-generation intelligent computer system
- realization of the next-generation intelligent computer system
- initial training of the next-generation intelligent computer system
- quality monitoring of the next-generation intelligent computer system
- restoring the required level of the next-generation intelligent computer system
- reengineering of the next-generation intelligent computer system
- ensuring the security of the next-generation intelligent computer system
- operation of the next-generation intelligent computer system by end users

The construction of a *technology* for *integrated support of the life cycle of the next-generation intelligent computer systems* involves:

- Clear description of the current version of the *next-generation intelligent computer systems standard*, which ensures semantic compatibility of the systems being developed;
- Creation of powerful libraries of semantically compatible and reusable components of developed *intelligent computer systems*;

- Clarification of the requirements for the integrated technology being created and caused by the features of the *next-generation intelligent computer systems* developed and operated using this technology.

Creation of an infrastructure that provides intensive permanent development of *Technology* for *integrated support of the life cycle of the next-generation intelligent computer systems* involves:

- Ensuring a low threshold of entry into the *technology of designing intelligent computer systems* for both technology users (i.e. developers of applied or specialized intelligent computer systems) and developers of the technology itself;
- Ensuring high rates of *technology* development by taking into account the experience of developing various applications by actively involving application authors to participate in the development (improvement) of *technology*.

At the heart of the creation of the ***technology*** we offer ***for integrated support of the life cycle of intelligent computer systems of the next generation***, are the following provisions:

- implementation of the proposed *technology* for the development and maintenance of *intelligent computer systems of the next generation* in the form of an ***intelligent computer metasystem*** that fully complies with the *standards* of the proposed *intelligent computer systems of the next generation* developed by the proposed *technology*. The structure of such an *intelligent computer metasystem* implementing the proposed technology includes:
  - formal ontological description of the current version of the *standard for intelligent computer systems of the next generation*;
  - formal ontological description of the current version of *methods and tools for designing, implementing, maintaining, reengineering and operating intelligent computer systems of the next generation*.

  Due to this, the technology of designing and reengineering intelligent computer systems of a new generation and the technology of designing and reengineering the technology itself (i.e. intelligent computer metasystem) are the same thing;
- ***unification*** and ***standardization*** **of intelligent computer systems of the next generation**, as well as *methods* of their *design, implementation, maintenance, reengineering and operation*;
- permanent evolution of the ***standard of intelligent computer systems of the next generation***, as well as *methods* of their *design, implementation, maintenance, reengineering and operation*;
- ***ontological design*** **of intelligent computer systems of the next generation**, assuming:
  - clear coordination and operational formalized fixation (in the form of *formal ontologies*) of the approved *current state* of the hierarchical system of all *concepts* underlying the permanently evolving *standard of intelligent computer systems of the next generation*, as well as at the heart of each developed *intelligent computer system*;
  - fairly complete and prompt documentation of the current status of each project;
  - using the *"top-down"* design *methodology*.
- ***component design*** of intelligent computer systems of a new generation, i.e. design focused on the assembly of *intelligent computer systems* from ready-made components based on constantly expanding libraries of *reusable components*;
- ***complex nature*** of the proposed *technology* that performs:
  - support for *designing* not only *components* of *intelligent computer systems of the next generation* (various *fragments of knowledge bases, knowledge bases* in general, various *methods of problem solving*, various *internal information agents, problem solvers* in general, formal ontological descriptions of various *external languages*, *interfaces* in general), but also *intelligent computer systems* in general as independent *design objects* taking into account the specifics of those classes to which the designed *intelligent computer systems* belong;
  - support not only for the *integrated design* of *intelligent computer systems* of the *next generation*, but also support for their implementation (assembly, reproduction), maintenance, reengineering during operation and operation itself.

To create a *technology* for integrated design and comprehensive support for the subsequent stages of the life cycle of *intelligent computer systems of the next generation*, it is necessary:

- Unify the formalization of various models of representation of various types of used information stored in the memory of *intelligent computer systems* and various models of solving intelligent problems to ensure *semantic compatibility* and simple automated integrability of various types of *knowledge* and *models of solving problems* in *intelligent computer systems*. To do this, it is necessary to develop a basic *universal* abstract model of knowledge representation and processing, which provides the implementation of various models of problem solving.
- Unify the structuring of *knowledge bases* of intelligent computer systems in the form of a hierarchical system of ontologies of different levels.
- Unify the system of *concepts* used, specified by the corresponding *ontologies* to ensure *semantic compatibility* and *interoperability* of various *intelligent computer systems*.

- Unify the architecture of *intelligent computer systems*, providing *semantic compatibility*:
  - between *intelligent computer systems* and their users;
  - between *individual intelligent computer systems*;
  - between *collective intelligent computer systems*,

  as well as ensuring the *interoperability* of communities consisting of:
  - *individual intelligent computer systems*;
  - *collective intelligent computer systems*;
  - users of intelligent computer systems
- To develop a *basic model of interpretation* of various formal models of problem solving in intelligent computer systems with a focus on the maximum possible simplification of such interpretation in *next generation computers* that are specifically designed for the implementation of individual *intelligent computer systems*.
- To develop the *next generation of computers*, the principles of functioning of which are as close as possible to the basic abstract model, which ensures the integration of all kinds of knowledge representation models and problem solving models. At the same time, the basic information processing machine underlying these computers should differ significantly from the von Neumann machine and should be close to the basic model of problem solving in intelligent computer systems in order to significantly reduce the complexity of interpreting the entire variety of problem solving models in intelligent computer systems.

The implementation of all these stages of the development of *Artificial Intelligence technologies* represents a transition to a fundamentally new technological order, which provides a significant increase in the efficiency of practical use of the results of work in the field of *Artificial intelligence* and a significant increase in the level of automation of *human activity*.

We have called the proposed *technology of integrated support of the life cycle of the next-generation intelligent computer systems* the ***OSTIS Technology*** (Open Semantic Technology for Intelligent Systems). Accordingly, *intelligent computer systems of the next generation* developed using this technology are called ***ostis-systems***. The *OSTIS technology* itself is implemented by us in the form of a special *ostis-system*, which we call the ***OSTIS Metasystem*** and the *knowledge base* of which contains:

- Formal theory of *ostis-systems*;
- Standard of *ostis-systems*
  - Standard for *ostis-systems* knowledge base
    - Standard of the internal universal language of semantic representation of knowledge in the memory of *ostis-systems*
    - Standard for the internal representation of top-level ontologies in the memory of *ostis-systems*
    - Standard for the presentation of the source texts of knowledge bases of *ostis-systems*
  - Standard for *ostis-systems* problem solvers
    - Standard of the *ostis-systems* basic programming language
    - Standard of high-level programming languages for *ostis-systems*
    - Standard for the representation of artificial neural networks in the memory of *ostis-systems*
    - Standard of internal information agents in *ostis-systems*
  - Standard for *ostis-systems* interfaces
    - The standard of external languages of *ostis-systems* close to the internal universal language of semantic representation of knowledge
- Standard for ostis-systems and the OSTIS Technology (***OSTIS standard***) [13];
- The core of the Library of reusable components *ostis-systems* (***OSTIS Libraries***);
- Methods and *tools to support the life cycle* of *ostis-systems* and their components.

ostis-system
⇒ *subdividing**:
  {• *ostis-subject*
    := [independent *ostis-system*]
    ⇒ *subdividing**:
      {• *individual ostis-system*
       • *collective ostis-system*
         := [multi-agent system, which is a collective of individual and collective *ostis-systems*, whose activities are coordinated by the corresponding corporate *ostis-system*]
         ⇒ *note**:
           [*The ostis-systems* collective may include individual *ostis-systems* may include individual *ostis-systems* of any kind – including corporate *ostis-systems* representing the interests of other *ostis-systems* teams]

}

- *built-in ostis-system*
  := [*ostis-system*, which is part of some individual *ostis-system*]

}

individual ostis-system
:= [minimal independent *ostis-system*]
⇒ *subdividing**:
{• *personal ostis-assistant*
  := [*ostis-system*, which provides comprehensive adaptive service to a specific user on *all* issues related to his interaction with any other *ostis-systems*, as well as representing the interests of this user in the entire global network of *ostis-systems*]
• *corporate ostis-system*
  := [*ostis-system* that coordinates the joint activities of *ostis-systems* within the framework of the corresponding *ostis-system* collective, monitors and reengineers the corresponding set of *ostis-systems* and represents the interests of this collective within other *ostis-system* collectives]
• *individual ostis system that is neither a personal ostis assistant nor a corporate ostis system*
}

VIII. Conclusion

Let us briefly list the main provisions of this work:

- The main practically significant direction of the development of modern *intelligent computer systems* is the transition to *interoperable intelligent computer systems* capable of effective interaction with each other and with users, which
  - provides automation of solving complex problems that require the creation of temporary or permanent collectives
  - turns *intelligent computer systems* into independent active *subjects* capable of initiating various complex problems and, in fact, initiating for this purpose workable collectives consisting of people and *interoperable intelligent computer systems* of the required qualifications
- Collectives consisting of independent *interoperable intelligent computer systems* and people have good prospects of becoming synergetic systems.
- The *interoperability of intelligent computer systems* is ensured
  - a high level of mutual understanding and, accordingly, semantic compatibility
  - a high level of contractual capacity, in other words. the ability to pre-coordinate their actions with the actions of other subjects
  - a high level of ability to quickly coordinate their actions with the actions of other subjects in the course of their realization
- Among the principles underlying the construction of *interoperable intelligent computer systems* are:
  - semantic representation of knowledge in the memory of *intelligent computer systems* in the form of refined semantic networks
  - using the universal language of the internal semantic representation of knowledge
  - graphodynamic organization of knowledge processing
  - agent-based problem solving models
  - structuring and stratification of knowledge bases in the form of a hierarchical system of formal ontologies
  - semantically friendly user interface
- To develop a large number of interoperable semantically compatible *intelligent computer systems* that ensure the transition to a fundamentally new level of automation of *human activity*, it is necessary to create technologies that ensure the mass production of such *intelligent computer systems*, participation in which is available to a wide contingent of developers (including developers of intermediate qualifications and novice developers). The main provisions of this technology are
  - standardization of interoperable *intelligent computer systems*
  - widespread use of *component design* based on a powerful library of semantically compatible reusable (typical) components of *interoperable intelligent computer systems*
- Effective operation of *interoperable intelligent computer systems* requires the creation of not only the *technology of designing* such systems, but also a family of technologies to support all other stages of their life cycle. This is especially true of the technology of permanent support of*semantic compatibility* of *all* interacting *interoperable intelligent computer systems* during their operation.

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Интеллектуальные компьютерные системы нового поколения и технология комплексной поддержки их жизненного цикла

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В работе рассмотрены принципы построения интеллектуальных компьютерных систем нового поколения, а также принципы построения комплексной технологии их разработки и поддержки жизненного цикла – Технологии OSTIS. В качестве ключевых свойств интеллектуальных систем нового поколения выделяются их семантическая совместимость и интероперабельность. В работе рассматривается подход к обеспечению указанных свойств, реализуемый в рамках Технологии OSTIS.

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