The Main Directions, Problems and Prospects of the Development of the Next-Generation Intelligent Computer Systems and the Corresponding Technology

Vladimir Golenkov, Natalia Gulyakina
Belarusian State University of Informatics and Radioelectronics
Minsk, Belarus
Email: golen@bsuir.by, guliakina@bsuir.by

***Abstract*—The paper considers the main directions, problems, and prospects for the development of next-generation intelligent computer systems and corresponding technologies, with a focus on the current state of work in the field of Artificial Intelligence. It highlights the problems and methodological challenges of the current stage of development, as well as the prerequisites for transitioning to intelligent computer systems of the new generation. The text also provides background and history of OSTIS Technology development, and outlines its features, advantages, and novelty. Additionally, it mentions current projects related to the development of OSTIS Technology in the current stage of work.**

***Keywords*—Next-generation intelligent computer system, self-learning intelligent computer system, interoperable intelligent computer system, individual subject, collective of subjects, hierarchical subject, social responsibility^, interoperability^, individual activity, collective activity, intelligence of a collective of subjects^, strategic problem of the subject*, subproblem*, Society, OSTIS Ecosystem .**

I. The feature of the current state of work in the field of Artificial intelligence — the transition to the next-generation intelligent computer systems

The epicenter of the modern stage of automation of human activity is a low level of automation and high overhead costs

- for the system integration of various computer systems, in other words, for the creation of complicated hierarchical computer complexes;
- for the modernization of computer systems during their operation [1].

Modern computer systems clearly lack the *intelligence* and *autonomy* to automate these aspects of human activity.

The necessity to move from modern *computer systems* (including modern *intelligent computer systems*) to *next-generation intelligent computer systems* is due to the necessity to move to automate more and more complex types and areas of *human activity* requiring the creation of whole complexes of *intelligent computer systems* that can independently evolve and interact effectively with each other in the *collective solution of complex problems*.

Computer systems with these abilities are the *new generation computer systems*. Since these *computer systems* cannot but have a high level of *intelligence*, they should also be referred to as *next-generation intelligent computer systems*. A high level of *intelligence* is necessary for next-generation computer systems:

- to adequately assessment their own competence and the competence of their partners;
- to ensure mutual understanding, contractual capacity and coordination (consistency) of their actions with the actions of partners in the course of *collective solution of complex problems* in the conditions of possible occurrence of unpredictable (non-standard) circumstances.

Obviously, the creation and operation of the *next-generation intelligent computer systems* requires:

- to develop a general formal theory of such systems;
- to develop a comprehensive technology for designing and supporting the subsequent stages of the life cycle of these systems;;
- to develop a general formal theory of the whole variety of types and areas of human activity that it is advisable to automate.

next-generation intelligent computer system
= (*self-learning intelligent computer system* ∩ *interoperable intelligent computer system*) *[2]*

self-learning intelligent computer system
:= [*an intelligent computer system* that has a high rate of self-realized evolution, which results in a significant reduction in the complexity (costs, overhead) of its modernization]

self-learning of an intelligent computer system
⇒ *suggests**:

- ability to monitor the state and dynamics of the environment and adjust their actions with appropriate environmental changes (adaptability);
- ability to analyze and improve the quality of your own knowledge base (structuring and analysis of contradictions, information holes, information garbage);
- ability to extract knowledge from external sources of information;
- ability to analyze and improve the quality of their own activities (including the ability to learn from their own mistakes);
- ability to analyze the quality of the activities of other subjects and benefit from it for yourself (learn from the mistakes of others).

high level of self-learning of an intelligent computer system

⇒ *is provided by**:
- high level of flexibility of an intelligent computer system
- high level of stratification of an intelligent computer system
- high level of reflexivity of an intelligent computer system
- high level of cognitive activity

interoperable intelligent computer system

:= [computer system capable of independent effective interaction with other systems]

interoperability of an intelligent computer system

⇒ *suggests**:
- ability to understand other systems and its users
  ⇒ *suggests**: semantic compatibility with interacting systems and users
- negotiability
- ability to coordinate their actions with the actions of partners

Our proposed approach to the construction of the next-generation intelligent computer systems is based on the following principles:

- semantic representation of knowledge stored in the memory of *next-generation intelligent computer systems*;
- ontological structuring and systematization of knowledge stored in memory;
- decentralized situational agent-oriented organization of *problem solving processes*;
- convergence and deep (diffuse) integration of various problem solving models and, as a consequence, the hybrid nature of *problem solvers*;
- semantic integration of input information entering an individual intelligent computer system from the outside through different sensory channels and in different languages by translating input information into a common universal *language of internal semantic representation of knowledge.*.

it should be distinguished*

∋ {
- *individual next-generation intelligent computer system*
- *collective next-generation intelligent computer system*

}

collective next-generation intelligent computer system

⇒ *subdividing**:

{
- *collective of next-generation individual intelligent computer systems*
- *hierarchical collective of next-generation intelligent computer systems*
  := [collective of next-generation intelligent computer systems, whose members can be both collective and *individual next-generation intelligent computer systems*]

}

individual next-generation intelligent computer system

⇒ *features**:
- *individual next-generation computer system* cannot be decomposed into subsystems that can be developed absolutely independently of each other and coordinated only by inputs and outputs, implementing the "black box" principle.
- In an *individual next-generation intelligent computer system*, convergence, compatibility and "meaningful" interaction of various types of knowledge and models of problem solving are necessary. That is, an *individual next-generation intelligent computer system* should be a *hybrid system*.

OSTIS Technology

:= [Our proposed Technology for developing and maintaining *next-generation intelligent computer systems*]

:= [Open Semantic Technology for Intelligent Systems [3]]

⇒ *requirements**:

- complexity — *OSTIS Technology* ensures the compatibility of all private *Artificial intelligence* technologies; compatibility, self-learning and interoperability of *intelligent computer systems* being developed, as well as support not only for the design of *intelligent computer systems*, but also for their entire life cycle
- universality — *OSTIS Technology* is focused on the development and maintenance of *next-generation intelligent computer systems* for any purpose
- self-learning — *OSTIS Technology* ensures the permanent evolution of the *OSTIS Technology* itself (itself) due to the fact that it is implemented in the form of the *next-generation intelligent computer system* that "knows" the *OSTIS Technology* and "knows" how to use it

ostis-system
:= [*intelligent computer system* based on *OSTIS Technology*]

OSTIS Ecosystem
:= [The main product of *OSTIS Technology*, which is a global network of *ostis-systems*]
∈ *hierarchical collective of intelligent computer systems of the new generation*

The main components of *OSTIS Technology* are:
- ***OSTIS Standard***
  := [The standard of next-generation intelligent computer systems as well as methods, methods and means of supporting their life cycle]
  := [*OSTIS Technology Standard*]
- ***OSTIS metasystem***
  := [The core of the *ostis-systems* lifecycle support automation system]
- ***OSTIS Library***
  := [Distributed library of typical (reusable) components of *ostis-systems*]

II. Problems of the current stage of development of the theory and technology of next-generation intelligent computer systems

The creation of *next-generation intelligent computer systems* requires answers to the following questions:

- What are the requirements for *intelligent computer systems* that provide the above complex automation of *human activities*;
- Why modern intelligent computer systems do not meet these requirements and, accordingly, why the transition to a fundamentally *next-generation intelligent computer systems* is necessary;
- What fundamental principles should underlie the *next-generation intelligent computer systems*;
- What principles should underlie the most automated technology for designing and supporting the entire life cycle of *next-generation intelligent computer systems*;
- What principles should underlie the structure and organization of various types and areas of *human activity* to ensure its comprehensive and maximum possible automation with the help of *next-generation intelligent computer systems* (as you know, before automating any *human activity*, it is necessary to put it in order — automating disorder leads to even greater disorder).

The current fundamental problems of creating the theory and technology of *next-generation intelligent computer systems* include:

- Development of a theory of *hierarchical multi-agent systems* in which agents are individual or collective *intelligent computer systems that are interoperable*.
- Unification and standardization of various models of knowledge representation and processing. The effect of this unification will not be visible immediately. But if this does not happen, we will never come to an effective comprehensive automation of *human activity*. The eclectic variety of automation methods and tools leads not only to unjustified duplication of the systems being developed, but also to an increase in the complexity of their use and maintenance.
- Convergence and integration of different areas of *Artificial Intelligence*.
  Currently, various areas of *Artificial Intelligence* have a fairly high level of development (signal processing, natural language processing, logical models, artificial neural networks, ontological models, multi-agent models, and many others). Integration of all these directions is a rather time-consuming problem, but it is quite a solvable one, which is based on the harmonization of related notions.
- Convergence of such activities in the field of *Artificial Intelligence* as:
  - training of specialists in the field of *Artificial Intelligence*;
  - engineering activities for the development of applied *next-generation intelligent computer systems*;
  - development of *technology* for designing and supporting the life cycle of *next-generation intelligent computer systems*;
  - research activities in the field of *Artificial intelligence*.
- In order to develop the Technology of *next-generation intelligent computer systems*, it is also necessary to converge this Technology with all

types and areas of *human activity* that are not part of the activities in the field of *Artificial Intelligence*. The development of the technology of *next-generation intelligent computer systems* has a pronounced interdisciplinary character. This means that all the knowledge accumulated by *human society* in various fields should be represented as part of the Global *Knowledge Base* of the Ecosystem of *next-generation intelligent computer systems* (using portals of scientific, technical, administrative and other knowledge), should be clearly stratified in the form of a hierarchical system of semantically compatible reusable *ontologies* and transformed into a hierarchical system semantically compatible *formal* components of knowledge bases of *intelligent computer systems* for various applications.

- Ensuring semantic compatibility of *next-generation intelligent computer systems* not only at the stage of their design, but also at all subsequent stages of their life cycle.
- Development of a model of collective behavior of *next-generation intelligent computer systems*, in other words, a model of decentralized collective problem solving at the level of:
  - *a multi-agent system* whose agents are internal agents of an *individual intelligent computer system* interacting through a common memory (through a common *knowledge base* stored in one memory);
  - *a multi-agent system* whose agents are *interoperable intelligent computer systems* interacting through a common *knowledge base* stored in the memory of a *corporate intelligent computer system* or in the memory of the coordinator of the activities of a temporary collective of *intelligent computer systems*.

Within the framework of the theory of *collective problem solving*, the following problem situations can be distinguished:

- a problem that can be solved by the *individual intelligent computer system* in which this task is initiated;
- a problem corresponding to the competence of the *collective of intelligent computer systems* within which this problem was initiated;
- a problem that goes beyond the competence of the *collective of intelligent computer systems* within which this problem was initiated. Such a problem requires the formation of a temporary team, the coordinator (but not the manager) of which becomes the *intelligent computer system* within which the specified problem was initiated. To do this, it is necessary to find those *intelligent computer systems* that together will provide the necessary competence. At the same time, note that each *interoperable intelligent computer system* (both individual and collective) must know its competence in order to determine whether it can or cannot solve a given (arisen) task. This, in particular, is necessary for the formation of temporary collectives of *intelligent computer systems*.
- Development of the principles underlying a powerful Library of reusable and compatible components of *next-generation intelligent computer systems*, which provides full automation of the integration of these components in the assembly process of the designed systems.
- Development of methods and means of permanent expansion of the Library of reusable components of *next-generation intelligent computer systems* in various fields of *human activity:*
- Scientific and technical activity in any field should be reduced to the development of *knowledge bases* of various *intellectual portals of scientific and technical knowledge*. At the same time, the *knowledge base* of each such portal should be decomposed into fragments included in the Library of reusable components of *knowledge bases* of *next-generation intelligent computer systems*, which can hierarchically fit into each other. To do this, the specified components must be specified accordingly.
- Developers of any *intelligent computer system* should decompose the developed system into a set of components included in the Library of components of *next-generation intelligent computer systems* — so that the development of any similar system is reduced to the assembly of components from this Library.
- All(!) developers should take care of expanding the Library of reusable (typical) components of *next-generation intelligent computer systems*, which will significantly reduce the complexity of developing new *next-generation intelligent computer systems* within the Ecosystem of such systems. At the same time, the authorship of the components of the specified Library should be encouraged, which is the fundamental basis for the development of the knowledge market, the knowledge economy.

If we competently develop and use the Technology of *next-generation intelligent computer systems*, then the development of any new *intelligent computer system* will mainly be reduced to its automatic assembly from the components of this system specified by the developer. Some components of the *intelligent computer system* being developed may be included in the current state of the Library of Components of *next-generation intelligent computer system*, and some of them will require additional development. But at the same time, each such new component is most often the result of modification of existing components from the specified

Library and must be specified and included in this Library. Thus, the developer of an applied *intelligent computer system* should develop not only this system, but also contribute to the development of a Library of Components of *next-generation intelligent computer systems*, as a result of which the next *intelligent computer system* he is developing can be assembled without additional components being developed, but only from components of the Component Library. If all developers of applied systems act in this way, then the rate of increasing the level of automation of *human activity* will increase significantly.

III. Methodological problems of the current stage of work in the field of Artificial intelligence

A. Social responsibility of specialists in the field of Artificial intelligence

The current stage of development of the theory and practice of *Artificial Intelligence* exposes a whole range of problems that hinder this development [4], [5]. Further development of *Artificial Intelligence* technologies

- on the one hand, it can and quite quickly make the transition of modern society to a fundamentally new level of its evolution, providing comprehensive automation of all types and areas of *human activity* subject to automation, as well as providing the maximum possible comfort and the maximum possible disclosure of the creative potential of each person;
- on the other hand, it can quite long and quite convincingly imitate the specified progress of automation of *human activity* for an illiterate layman — any even very worthy goal can be ruined by the imitation of its achievement;
- on the third hand, can quickly enough lead *human society* to degradation and self-destruction.

As a result, at the present stage of development of *Artificial intelligence* technologies, the level of social responsibility of specialists in the field of *Artificial intelligence* is a determining factor in the development of *human society*. The danger to *human society* does not come from *intelligent computer systems*, but from the motivation of specialists who develop these systems. It is obvious that the creation of *intelligent computer systems* designed for the deliberate infliction of any damage to *human society*, and requiring the creation of appropriate intellectual means of ensuring security, is a shortcut to self-destruction.

The efforts of specialists in the field of *Artificial intelligence* should be aimed at significantly increasing the level of intelligence of *human society* as a whole, the basis of which is the complex automation of all those types and areas of *human activity* that fundamentally makes sense to automate.

B. The global goal of Artificial Intelligence activities

Why the current stage of activity in the field of *Artificial intelligence* requires the formulation of the global goal of this activity and its permanent clarification.

The current state of *Artificial Intelligence* can be characterized as a deep methodological crisis caused by:

- the fact that scientific results in this area came out of scientific laboratories and began to have a real practical impact;
- the lack of understanding that obtaining serious scientific results in a particular field and the creation of technologies that ensure the effective practical use of these results are tasks commensurate in importance and complexity. This is especially true for *Artificial Intelligence*.

The latter circumstance leads to unjustified euphoria, the illusion of well-being and to a burgeoning eclecticism that completely ignores even the seemingly obvious laws of the general theory of systems.

Unfortunately, local implementation of the results of scientific research in the field of *Artificial intelligence*, local automation of business processes of any organization without taking into account the system organization of the entire complex of methods and automation tools of various types and areas of human activity leads to unjustified duplication of results.

If in the near future there is no awareness of the global (strategic) goal of work in the field of *Artificial Intelligence*, then activities in this area as a whole will be carried out in the style of "swan, cancer and pike" . Wasting effort will not lead to a holistic, practically meaningful result. The "vectors" of specific areas of this activity, the "vectors" of our efforts will not have the same focus, which will significantly reduce the overall productivity of all these activities and the quality of the overall (total) result.

What should be the *strategic problem* (super problem) that experts in the field of *Artificial intelligence* should solve. It is obvious that such a super task is the transition of the entire complex of *human activity* to a fundamentally new level of maximum possible automation, within which *creative* activity remains a fundamentally non-automated part of human activity, in particular, research activities, teaching and educational activities, permanent increase in the level of complex automation of *human activity*. The main goal of complex automation of *human activity* is not only to automate what can be effectively automated using *Artificial Intelligence* methods, but to automate all(!) "bottlenecks" of *human activity* that determine its overall performance in various fields.

As a result, at present, *Artificial Intelligence* technologies are on the threshold of transition to a fundamentally new level of development — on the threshold of transition from solving private (local) problems to solving the global problem of complex automation of all types and areas

of *human activity*, which requires automation of solving not only private urgent and important problems, but also automation of the solution more and more high-level problems, for which the problems that are being automated now become sub-problems. In other words, when automating the solution of complex problems (supervising problems), automation focuses on the development of methods and means of interaction between the means of solving local problems (particular problems).

Shifting the focus to automation of solving not just *intellectual problems*, but to automation of solving complex problems, the sub-problems of which are a variety of *intellectual problems*, not only takes *Artificial Intelligence* technologies to a fundamentally new level, but will also have a significant impact on all aspects of *human activity*:

- research and scientific and technical work should acquire a convergent mutually enriching character;
- the basis of education should be interdisciplinarity;
- the basis of global automation of *human activity* should be a general complex formal and permanently improved theory of *human activity*, which should be based on an interdisciplinary convergent methodology aimed at overcoming the eclectic approach.

Consequently, the main goal of complex automation of various types and areas of human activity with the help of *interoperable intelligent computer systems* is to significantly increase the *level of intelligence* of human society as a whole.

Modern *human society* — is a complex distributed multi-agent *cybernetic system*, the development of which is carried out, unfortunately, in violation of many laws of Cybernetics and, in particular, in violation of the criteria that determine the level of *intelligence* of hierarchical multi-agent systems. The level of *intelligence* of such systems is determined by a number of seemingly obvious factors:

- what is the volume and *quality of knowledge* accumulated by a *multi-agent system* and available to all agents (subjects) included in this system
  - how much of this *knowledge* is sufficient to organize the management of the activities of this system;
  - to what extent is this knowledge correct (consistent) and adequate;
  - how great is the convergence, compactness and purity of this *knowledge* (the presence of information garbage, information duplication is taken into account here);
  - how well structured (systematized) is the accumulated knowledge;
- how each agent of a *multi-agent system* has access to the knowledge stored in the shared memory of the entire *multi-agent system*;
- how this *knowledge* accumulates and evolves, how a multi-agent system learns itself
  - how a *multi-agent system* learns from its own mistakes,
  - how a *multi-agent system* improves the quality of its knowledge;
- how the *multi-agent system* as a whole and each agent in particular use the *knowledge* accumulated in the shared memory to solve various *problems*.

As a result, if we consider modern *human society* from the standpoint of the theory of *multi-agent systems*, which are communities of *intelligent systems* (not only artificial, but also natural intelligent systems), it is obvious that the next stage of its evolution requires:

- automation of accumulation, analysis and permanent improvement of the ***quality of knowledge*** accumulated by mankind;
- automation of the effective use of knowledge accumulated by mankind in solving problems of various levels that require the formation of various short-term or long-term ***communities*** of ***people and intelligent computer systems***. Each such community is intended either to solve any one specific problem, or to solve some set of problems in some area;
- increasing the level of ***convergence*** of knowledge, methods, actions, as well as new technical systems being created;
- improving the level of ***interoperability*** for both intelligent computer systems and people.

C. General requirements for specialists in the field of Artificial intelligence

⇒ *epigraph*:*

- The requirements for specialists in the field of *Artificial intelligence* at the new stage of development of this field are a reflection of the requirements for *next-generation intelligent computer systems* and related technologies
- The level of *intelligence* (including collective intelligence) of *intelligent computer system* developers cannot be lower than the level of *intelligence* of *intelligent computer systems* being created
- The level of *intelligence* of a team of agents is not always higher than the level of *intelligence* of its agents
- The development of *interoperable intelligent computer systems* can only be collective
- A collective of non-interoperable developers cannot create *interoperable intelligent computer systems*

The high level of *social responsibility* required of *specialists in the field of Artificial Intelligence* imposes on

them a number of obvious, but, unfortunately, often overlooked general requirements necessary for high-quality participation in complex collective socially significant projects. Such general requirements include:

- a high level of ***motivation*** to participate in the permanent evolution of an integral technological complex that provides the development of effective *interoperable intelligent computer systems*. A comprehensive and high-quality technology for the development and maintenance of *interoperable intelligent computer systems* should be considered as a key product of collective activity in the field of *Artificial Intelligence*. This motivation implies appropriate purposefulness, lack of selfishness, arrogance, individualism, isolationism, parasitism;
- high level of ***creative activity***, passionarity, courage;
- a high level of ***reflection*** — is the ability to analyze one's own goals and actions and correct one's own mistakes, as well as analyze the goals, actions and mistakes made by the team of which the specialist is a member. It is one thing to sincerely recognize the logic and expediency of observing certain rules (principles, requirements), and it is quite another thing to be able to see and correct your own violations of these rules. Without such reflection, the progress of collective creativity is impossible. Knowing how to do it and actually following — it is not the same thing.
- high level of ***own interoperability***:
  - the ability to *understand each other* and ensure *semantic compatibility*, which requires permanent monitoring of the current state and evolution of the technological complex;
  - *contractual capacity* — the ability to quickly coordinate their goals and plans, denotational semantics of concepts and terms, as well as decentralize the distribution of sub-problems of a collectively solved problem;
  - *ability to coordinate* and synchronize their actions with colleagues in conditions of possible occurrence of unpredictable circumstances.

Without a high level of developer interoperability, it is impossible to ensure:

- ***convergence***, unification, standardization of *interoperable intelligent computer systems*;
- formation of a powerful ***Library of standard components of next-generation intelligent computer systems***;
- a significant reduction in labor intensity and an increase in the level of automation of the development and maintenance of *next-generation intelligent computer systems*;
- building a general theory of the ***Ecosystem of the next-generation intelligent computer systems*** and, accordingly, a general theory of *human activity*.

As a result, in order to create *interoperable intelligent computer systems*, it is necessary that their creators themselves have a high level of *interoperability*. The problem of ensuring this is the main challenge that is addressed to specialists in the field of *Artificial intelligence* at the current stage of development of this field.

The main reason that prevents the formation of the necessary level of *interoperability* among specialists in the field of *Artificial intelligence* is the competitive style of relationships between specialists. This style of relationship is a widespread way to stimulate employee activity. But this is not the only way to stimulate creative activity in solving strategically important problems, which, in particular, is the problem of effective complex automation of all types and areas of *human activity* with the help of *interoperable intelligent computer systems*. Moreover, competition provokes selfishness and ignoring the interests of other subjects (including the interests of the collective of which the subject is a member). Thus, competition clearly contradicts the principles of *interoperability* and, accordingly, the principles of the organization of *intellectual communities*, intellectual creative teams and organizations.

It is necessary to move from a competitive style of relationships to mutually beneficial interaction between subjects of all levels of the hierarchy. This is the main essence of *interoperability* and the transition to *intellectual collectives* and an intellectual society.

It should be noted that the listed general requirements for specialists in the field of Artificial intelligence at the present stage of the development of *Artificial intelligence technologies* should be imposed not only on them, but also on all people who are ready to contribute to technological progress. It's just that at this stage, the main responsibility for this lies precisely with specialists in the field of *Artificial intelligence*.

D. Requirements for the fundamental training of specialists in the field of Artificial intelligence

The need to significantly increase the level of practical significance and efficiency of work in the field of *Artificial intelligence*, which requires a transition to the *next-generation intelligent computer systems* and to a fundamentally new technological complex, imposes on specialists in the field of *Artificial intelligence* not only general requirements necessary for effective participation in complex collective socially significant projects, but also high requirements for their fundamental professional training:

- a high level of system culture that allows you to "see" the hierarchy of complex systems, the

connections between different levels and hierarchies, the difference between tactical and strategic tasks;
- a high level of mathematical culture, culture of formalization;
- a high level of technological culture and technological discipline;
- a high level of self-learning in a rapidly changing technological infrastructure

E. Problems of the current stage of development of the theory and technology of next-generation intelligent computer systems

Let's list the main methodological problems of the current stage of work in the field of Artificial Intelligence, which hinder the solution of the fundamental tasks discussed above:

- An insufficiently high level of awareness by specialists in the field of *Artificial intelligence* of their social responsibility.
- The lack of a coordinated awareness of the global goal of work in the field of *Artificial intelligence*, which is to gradually increase the ***level of intelligence*** of *human society* by complex automation of all aspects of its activities using a network of interacting *intelligent computer systems*.
- The insufficiently high level of *interoperability* of specialists in the field of *Artificial intelligence* and the predominance of a competitive style of relationships. The consequence of this is an insufficient number of motivated specialists in the field of *Artificial Intelligence*, capable of effective creative interaction. In order for them to appear in sufficient numbers, a good system of their professional training is not enough. It should also be noted that good human relations, psychological atmosphere and Team Building in the development team, which many companies take seriously, is a necessary, but far from sufficient condition for the effectiveness of collective development of complex computer systems (especially for *next-generation intelligent computer systems*).
- Insufficiently high level of comprehensive fundamental training of specialists in the field of *Artificial intelligence*.
- The pronounced interdisciplinary nature of *Artificial Intelligence* as a field of human activity, requiring specialists to be able to work at the junctions of sciences.
- Lack of awareness of the need for deep *convergence* between various areas of *Artificial Intelligence* and the formalization of the entire complex of knowledge in the field of *Artificial intelligence* for their use in the *knowledge bases* of intelligent computer systems (first of all, instrumental *intelligent computer systems* that are part of the technological complex for the development and maintenance of *intelligent computer systems* for various purposes).
- The high level of complexity of the complex formalization of all knowledge accumulated by mankind (primarily in the field of mathematics and general systems theory) and their convergence with the complex of knowledge accumulated and formalized in the field of *Artificial intelligence*. This is necessary for the direct use of the knowledge accumulated by mankind in *intelligent computer systems* for various purposes.
- Lack of awareness of the need for deep *convergence* and consistency between
  - research activities in the field of *Artificial intelligence*;
  - activities aimed at the development of private *artificial intelligence* technologies, as well as integrated technology for designing and supporting the life cycle of *intelligent computer systems*;
  - engineering activities aimed at the development of specific *intelligent computer systems* for various purposes;
  - educational activities aimed at training specialists in the field of *Artificial intelligence*.
- The problem of ensuring ***semantic compatibility*** of *next-generation intelligent computer systems* not only at the stage of their design, but also throughout their life cycle in the conditions of permanent evolution of *intelligent computer systems* themselves during their operation, as well as the permanent evolution of complex technology of their development [6], [7].

The main part of these problems is the need to move to a fundamentally new style and organization of interaction between specialists in the field of *Artificial Intelligence*, without which it is impossible to move from private theories of *Artificial Intelligence* to a ***General theory of intelligent computer systems*** that ensures compatibility of all private theories of *Artificial Intelligence*, as well as the transition from private *Artificial intelligence* technologies to ***Complex Artificial Intelligence technology***, ensuring compatibility of all private *artificial intelligence* technologies. The transition to a new style of interaction of specialists in the field of *Artificial intelligence* is based on the transition from competition to synergetic mutually beneficial interaction aimed at convergence and deep integration of private (local) results, which will lead to the transformation of the modern community of specialists in the field of *Artificial intelligence* into an ***intellectual community***.(see [8]).

IV. Prerequisites for the transition to intelligent computer systems of the new generation

- An actively expanding variety of information resources and services, the efficiency of which has a low level due to the lack of their systematization and compatibility [9], [10]
- The emergence of formal ontologies as a means of ensuring semantic compatibility of information resources accumulated by mankind, Semantic Web
- Active development of the theory of multi-agent systems, their self-organization, emergence, synergy, theory of intellectual communities and organizations
- Development of the theory of decentralized situational management ("the orchestra plays without a conductor")
- Smart home, smart hospital, smart city
- Industry 4.0, University 4.0
- The appearance of works aimed at clarifying the cybernetic principles underlying Society 5.0

V. Background and history of OSTIS Technology development

- 1981 – Japanese and American fifth-generation computer projects
- 1984 – V.V. Golenkov defended his PhD thesis "Structural organization and processing of information in electronic mathematical machines controlled by the flow of complex structured data"
- D.A. Pospelov's advice: «Before designing computers focused on the implementation of intelligent computer systems, it is necessary:
  - to develop basic mathematical and software for such computers;
  - to develop the basics of technology for designing intelligent computer systems implemented on the basis of these computers;
  - to develop a software model (emulator) of a new generation computer being created on modern computers;
  - implement several specific *intelligent computer systems* based on the above technology and the specified software model of the future computer.

If all this is not done, then the developed computer of the new generation will be a brilliantly made "hardware", which is unclear how to use and which, therefore, will quickly become obsolete. That is why all fifth-generation computer projects were doomed.»

- 1992 – Prototype of a semantic computer on transputers
- 1995 – Opening of an educational specialty in BSUIR 'Artificial intelligence" and the creation of an appropriate graduate department
- 1996 – V.V. Golenkov defended his doctoral dissertation "Graphodynamic models and methods of parallel asynchronous processing of information in intelligent systems"
- 2010 – Creation of an open *OSTIS Project* aimed at creating an open integrated technology for designing *intelligent computer systems*, the implementation of which focuses on the use of *next-generation computers*
- 2011 – The beginning of the annual OSTIS conferences aimed at the development of the open *OSTIS Project*
- 2019 – On the basis of the educational institution 'Belarusian State University of Informatics and Radioelectronics", an educational and scientific association in the direction of 'Artificial Intelligence";
- 2021 – Publication of a prototype of the *OSTIS Technology Standard*, presented in the form of a formalized text, which is the source text of the knowledge base of the Meta-system for Supporting the Design of Intelligent computer systems developed using *OSTIS Technology* [11];
- 2023 – Publication of a collective monograph on *OSTIS Technology*, which is considered as the basis for further development and official recognition of the formalized *Standard of OSTIS Technology* and a significant expansion of the corresponding collective of authors

Summarizing our experience in the field of Artificial Intelligence, we can say the following:

- The requirements for *intelligent computer systems* of the next generation (a high level of *self-learning*, *interoperability*, *independence*, *universality*), involves the creation of a *fundamentally new integrated* technology that integrates, ensures compatibility of the entire variety of existing *private Artificial intelligence technologies* and which supports all stages of the life cycle of *intelligent computer systems* being developed;
- The complexity of the implementation of *next-generation intelligent computer systems* (due to the discrepancy between the basic principles of information processing in such systems and the principles of the von Neumann machine underlying modern computers) requires the creation of computers specifically focused on the implementation of *next-generation intelligent computer systems*. But it is necessary to create these new-generation computers on the basis of (or, more precisely, within) the above-mentioned integrated technology for designing and supporting the subsequent stages of the life cycle of *next-generation intelligent computer systems*.
- The epicenter of the creation and subsequent evolution of this complex technology for *next-generation intelligent computer systems* is:
  - training of a new generation of specialists in the field of *Artificial Intelligence*, who are initially

focused on convergence, on ensuring compatibility of their results with the results of their colleagues and on the specification of their results within the Library of standard (reusable) components;
  - permanent development of the *OSTIS Technology Standard*, presented in the form of a formalized text of the *knowledge base* of the Meta-system for supporting the design of *intelligent computer systems* developed using *OSTIS Technology*.

VI. Features, advantages and novelty of OSTIS Technology

The novelty of OSTIS Technology primarily consists of:

- the requirements for systems created and maintained with the help of this Technology (for *next-generation intelligent computer systems*) – hybridity, interoperability, self-learning.
- the requirements for the *OSTIS Technology* itself (for the methods used by it, automated methods and tools) – the complexity of the technology, its versatility and self-learning

Additional factors of the novelty of *OSTIS Technology* are:

- the fact that the intensive evolution of the *OSTIS Technology* itself (the transition to its new versions) does not lead to the moral aging of already operated *intelligent computer systems* (*ostis-systems*), since during the operation of these systems, their automatic modification (modernization) is possible in the direction of bringing them into line with the current version of the *OSTIS Technology*;
- the fact that permanent support of semantic compatibility of operated *intelligent computer systems* (*ostis-systems*) is provided during their own evolution, as well as during the evolution of the *OSTIS Technology* itself;
- the fact that the basis of the activity (functioning) of hierarchical collectives of *ostis-systems* is decentralized planning, initiation and situational management of collectively performed actions (processes) carried out within the framework of both long-term and temporarily existing *collectives of ostis-systems*;
- in a significant increase in the efficiency of expanding and using the Library of standard (reusable) components of *ostis-systems* (*OSTIS Libraries*) due to:
  - exclusion of semantic equivalence of components;
  - a significant reduction in the variety of logically and functionally equivalent components;
  - the presence of a simple and fairly easily automated procedure for integrating the components of the specified library and, accordingly, the procedure for assembling *ostis-systems* from ready-made components of the *OSTIS Library*;
- in the orientation to create an integrated model that ensures the coordination of the entire variety of types and areas of *human activity* and to develop the architecture of a global complex of *ostis-systems* that provides automation of this diversity (*OSTIS Ecosystem*).

VII. Current projects of the current stage of work on the development of OSTIS Technology

Let's list some projects of applied *next-generation intelligent computer systems* that are relevant at this stage and the means of their development:

- Development of a formalized ***Standard for next-generation intelligent computer systems***, presented as part of the *knowledge base* of the intellectual portal of scientific and technical knowledge on the theory of *next-generation intelligent computer systems* and providing *semantic compatibility of computer systems* of this class [11].
- Development of a formalized ***Standard of methods and tools for supporting the life cycle of next-generation intelligent computer systems***, presented as part of the *knowledge base* of the intelligent *Metasystem for automating the life cycle of next-generation computer systems* (*OSTIS Metasystem*).
- Development of a comprehensive ***Library of standard components of next-generation intelligent computer systems*** (*OSTIS Library*), providing compatibility of standard (reusable) components and full automation of their integration (connection) in the process of assembly (component) design of semantically compatible *next-generation intelligent computer systems*.
- Within the framework of the ***OSTIS Meta-system***, providing wide access to the current state of the *OSTIS Standard* and developing appropriate semantic visualization and navigation tools.
- Within the framework of the ***OSTIS Metasystem***, the development of automation and management tools for the process of collective improvement (modernization, reengineering) of the *OSTIS Standard*.
- Development of a ***software platform*** for the implementation of *next-generation intelligent computer systems*.
- Development of an ***associative semantic computer*** for the implementation of *next-generation intelligent computer systems*. This is a universal computer in which the hardware implementation of associative

reconfigurable (structurally tunable) memory is carried out, in which information processing is reduced to reconfiguration of connections between memory elements.

- Development of the architecture of the *next-generation intelligent computer system*, which is a ***personal intellectual assistant*** (secretary, referent) for each user, providing the maximum possible automation of the user interaction process with the entire Global ecosystem of*next-generation intelligent computer systems* (*OSTIS Ecosystem*). The *knowledge base* of each such *personal intellectual assistant* includes:
  - personal information of the corresponding user, access to which is provided to other *intelligent computer systems* by the personal intelligent assistant of this user, but necessarily with the permission of this user and with the notification of the relevant risk factors to the user. The user's personal information is his medical data, biographical data, personal photographs, unpublished intellectual property, generated or sent messages addressed to other users or various communities.
  - information about various communities of the *Global Ecosystem of next-generation intelligent computer systems*, of which the corresponding (assisted) user is a member, indicating the role (position, duties) that the specified user performs within each such community. There can be many of these communities — professional communities, friends, relatives, consumer-producer communities, administrative and civil communities, banks, medical service communities, etc.
  - information about your own plans and intentions (both strategic and immediate, including meetings, negotiations, meetings)

  Personal intelligent assistant *problem solver*
  - provides the maximum possible automation of various types of professional individual activities of the corresponding (serviced) user;
  - provides intellectual mediation (representation of interests) of the served user within all communities of which he is a member.

  User interface of a personal intelligent assistant
  - provides the user with the means to manage his individual activities carried out collectively with the corresponding personal intellectual assistant;
  - provides a unified nature of user interaction within the various communities to which it belongs. The simplest type of community is a one-time dialogue between two users.
- Development of a unified ***set of automation tools for individual design of fragments of knowledge bases***, which is part of each user's *personal intellectual assistant* and provides support for individual contributions to the development of both their own (personal) *knowledge base* and the *knowledge base* of other systems that are part of the *Ecosystem of intelligent computer systems*. The specified complex of automation tools includes
  - editor of the internal representation of knowledge (editor of *sc-texts*);
  - editors of various external forms of knowledge representation (*sc.g-texts*, *sc.n-texts*);
  - translators from the internal representation of knowledge to various external forms of representation;
  - translators from each form of external representation of knowledge to their internal representation;
  - means of syntactic and semantic analysis of the projected fragment of the *knowledge base*;
  - a translator that provides the transformation of the internal representation of knowledge (in *SC-code*) into a natural language representation in the format of the LaTeX markup language that meets the requirements for the design of articles in collections of scientific and technical materials. This translator will allow to concentrate the efforts of developers of various *intelligent computer systems* on the formalization of scientific and technical knowledge used in intelligent computer systems, and significantly reduce the complexity of the preparation and registration of publications of relevant scientific and technical results.

    In the future, various scientific and technical journals should be transformed into intellectual portals of collectively developed scientific and technical knowledge in various fields.
- Development of a set of textbf*tools for individual comprehensive permanent medical control and monitoring* of the corresponding (serviced) user within the framework of a personal intelligent assistant

- Development for each community of *next-generation intelligent computer systems* of a unified set of ***tools for the collective development of a common knowledge base*** of this community (*knowledge base* of the corporate system of the specified community), which includes:
  - means of assembly (integration) of the developed *knowledge base* from its individually developed fragments;
  - means of coordination of individually developed fragments (personal points of view, the epicenter of which is the coordination of the *concepts* used);
  - means of mutual reviewing;
  - means of coordinated adjustment of the *knowledge base*;
  - means of forming and agreeing on a plan for

improving a collectively developed *knowledge base*;
  - means of monitoring and managing the process of improving the collectively developed *knowledge base*.
- Expansion of the set of ***design automation tools*** for various types of components of *next-generation intelligent computer systems* (*ostis-systems*) and various classes of such systems.
- Development of the formal structure of the global complex of automated human activity and the corresponding architecture of the ***OSTIS Ecosystem***. A significant expansion of the areas of application of *OSTIS Technology* (medicine, industry, construction, law, and so on).
- Development within the framework of the *OSTIS Ecosystem* of a ***set of tools and techniques for training specialists in the field of Artificial intelligence*** (at the level of students, undergraduates and postgraduates).
- Development within the framework of the *OSTIS Ecosystem* of a ***complex of means of informatization of secondary education*** with the help of semantically compatible *next-generation intelligent computer systems*.
- Development within the framework of the *OSTIS Ecosystem* of a ***complex of informatization tools for higher technical education*** using semantically compatible *next-generation intelligent computer systems*.

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Основные направления, проблемы и перспективы развития интеллектуальных компьютерных систем нового поколения и соответствующей им технологии

Голенков В. В., Гулякина Н. А.

В статье рассмотрены основные направления, проблемы и перспективы развития интеллектуальных компьютерных систем нового поколения и соответствующих технологий с акцентом на современное состояние работ в области Искусственного интеллекта. Освещены проблемы и методологические вызовы современного этапа развития, а также предпосылки перехода к интеллектуальным компьютерным системам нового поколения. В тексте также представлены предыстория и история развития Технологии OSTIS, а также описаны ее особенности, преимущества и новизна. Дополнительно упоминаются текущие проекты, связанные с развитием Технологии OSTIS на текущем этапе работы.

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