Open Semantic Technology as the Foundation for New Generation Intelligent Systems

Mikhail Tatur and Anton Paramonov
Belarusian State University of Informatics and Radioelectronics
Minsk, Republic of Belarus
tatur@bsuir.by, a.paramonov@bsuir.by

***Abstract*—Issues of new generation intelligent systems development are discussed. A hypothesis is proposed: for the effective implementation of the OSTIS Ecosystem project, it is necessary to create a fundamentally new computer architecture (specialized computers)..**

***Keywords*—OSTIS technology, Ecosystem, Intelligent Systems, Specialized computers, Hardware Platform**

I. Introduction

Artificial Intelligence, like any young scientific direction, develops in leaps and bounds, replacing one generation of technical systems with others. Let's try to present an condition ontology of this direction, which reflects the subjective vision of the authors.

We will make a reservation right away that in this article we will try to use generally accepted statements and trends to avoid unnecessary controversy. We will use the generally accepted understanding of Artificial Intelligence, which stages of evolution are distinguished, at what stage of progress we are now, etc.

We will consider an intelligent system as a product obtained as a result of mathematical apparatus applying, developing algorithms and software and hardware implementation without specifying the application. The mnemonic scheme of the intelligent systems ontology can be represented as three components, as shown in Fig.1. It‘s no coincidence that in the figure the Mathematical Model (as a paradigm, in a broader sense) intersects with the Algorithms that implement it, and the Hardware Platform intersects with the Software.

In most cases, when creating intelligent systems, they use the mathematical apparatus of Neural Networks and Machine Learning - in Data Processing, as well as Semantic Networks, Inference and Ontologies – in Knowledge Processing (Knowledge Discovery). In addition, Evolutionary Design and Fuzzy Sets are used as extended tools for these paradigms to increase the efficiency of solving intellectual problems.

<u>Remark.</u> *In the context of this work, we will not refer to the role of Linguistics, Neurophysiology, and other fundamental disciplines. They, of course, influenced both the formation of Artificial Intelligence, and still influence its development, but are not the topic of the current discussion.*

For each mathematical direction, there is a wide range of technological software support to creating intelligence applications (Tensor Flow, Coffee, ScikitLearn Python, Keras, R, etc.). The hardware platform is traditionally presented as "universal" and "specialized". The universal platform includes conventional computers with GPUs, as well as supercomputers and computing clusters. A specialized platform is mainly neurocomputers and graphic computers (semantic, associative). It‘s easy to see that specialized "intelligent" computers correspond to the main artificial intelligence mathematical paradigms. If we trace the development chronology of this area of hardware platforms, we will notice obvious surges and falls in the interest of the scientific community and developers. You can also note a wide variety of architectures and technical solutions proposed at different times [1] [2] [3].

As an example, we can highlight one of the latest developments announced by the Moscow State Technical University named after N. E. Bauman – "Leonhard" [4]. As the author's state: " ... for the first time in the history of computing, a universal computing system with many instruction streams and one data stream (MISD) has been developed that implements the DISC (Discrete Mathematics Instruction Set computer) instruction set." There have been quite a few such statements in the past, but none of the specialized «intelligent computers» has found mass industrial use. In our opinion, this is explained by the simple victory of "universal" computers in competition with specialized processors. As a rule, intelligent computing algorithms are highly complex, and therefore require the appropriate performance of the hardware platform. Therefore, throughout the development of the intelligent computing direction, there have been periodic attempts to create specialized (problem-oriented) architectures, the so-called. neurocomputers, graphic computers, semantic computers, associative computers, focused on supporting the corresponding computing paradigm. However, over and over again, special processors were inferior in their characteristics to modern "universal" (multi-core and graphics) computers. In particular, the narrow application focus of specialized computers with large (even huge) development costs in terms of time and

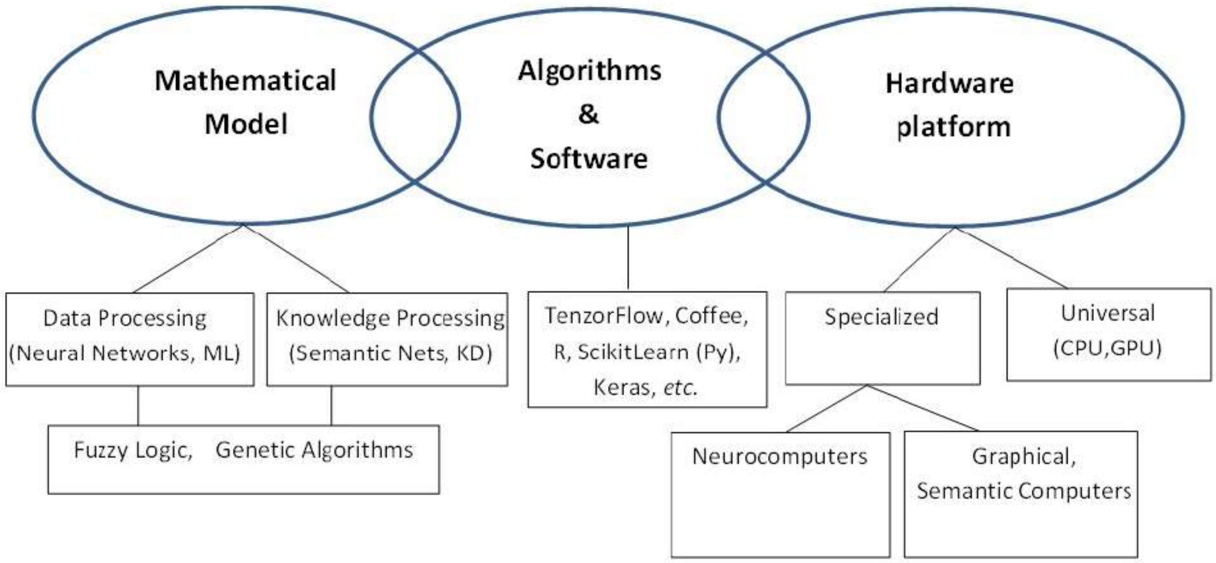

Figure 1. Ontology of intelligent systems

price offset the expected performance gain. In addition, general electronic technologies consistently improve the performance of «universal» computers. In general, a paradoxical situation has occurred in the Artificial Intelligence field. On the one hand, there is the possibility of a quick and relatively inexpensive (using existing libraries and universal software and hardware platforms) creation of highly specialized, commercially successful products with a formal manifestation of intellectual properties. On the other hand, this hinders the development of new (FUNDAMENTALLY NEW) intelligent systems with qualitatively new properties and higher technical characteristics.

The purpose of this presentation is to reflect on what it could be like a New Generation of Intelligent Systems, and what impact OSTIS will have in its emergence.

II. General trend in the development of Artificial Intelligence technologies

As a result of a series of industrial and information revolutions, society has moved into a qualitatively new stage of its evolution. Now the information sector occupies a decisive and important position in the context of the development of fundamentally new information technologies aimed at acquiring, processing, and storing knowledge. Currently, UNESCO is promoting the concept of the knowledge society as an antithesis of the concept of the Information Society, the success of which depends primarily on the development of the knowledge-based economy [5]. The indicated trends inevitably lead to digitalization, automation, and finally Digital Transformation of current business processes. It‘s important to highlight that the use of Artificial Intelligence technologies is one of the fundamental principles of the society digital transformation [6]. Today we can state certain successes and practical achievements in the implementation of commercially successful projects of intelligent computer systems. However, despite the apparent prospects, it can be assumed that with the development of the information society (with a further increase in the volume of information), the approaches underlying such systems will reach the limit of their capabilities, just as it happened before with many computer systems for data processing. Combining many intelligent services into Digital Platforms significantly increases the efficiency of solving a particular range of tasks. This is achieved by Distributing Computations and powers between resources that are available within the platform to all its participants (Fig. 2). The use of an architecture based on autonomous services (also known as Microservices) allows you to speed up the development process and organize the formation of various platform configurations. At the same time, the Knowledge Base of each such service is built autonomously and is often encapsulated within its implementation. This gives rise to multiple duplication of information and redundancy in the knowledge processing. In this connection, it should be noted that the problematic issues of metadata and ontologies of the modern information society are strongly connected with the problems of "conceptual plurality of information" and "data representation in subject areas of knowledge".

However, the most promising approach to building AI applications is the collaboration of intelligent systems, which forms a single complete ecosystem. This solution is projected to solve a wide class of problems in

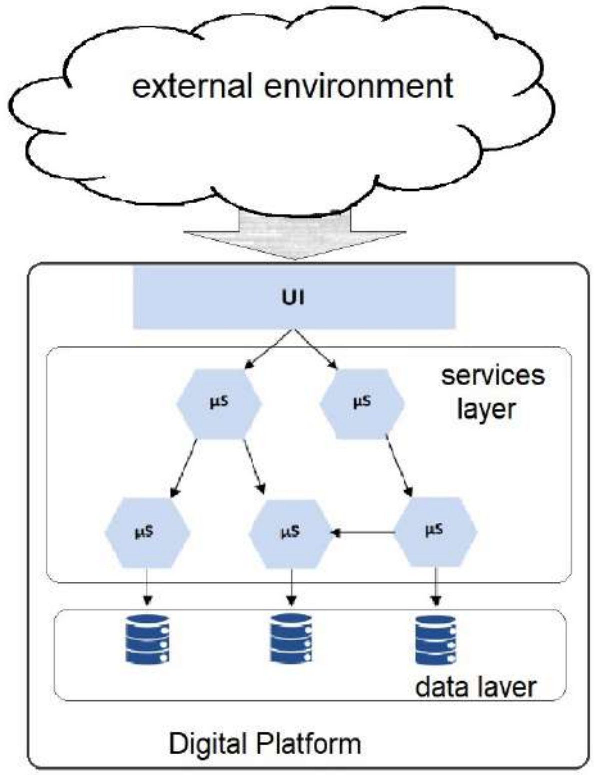

Figure 2. Generalized scheme of the Intelligent Services Platform

various sectors of the economy. Based on the Systems Theory by Ludwig von Bertalanffy, an ecosystem is commonly understood as «a complex open self-organizing, self-regulating and self-developing system». A Digital Ecosystem is often understood as a single common space in which many different services operate seamlessly, both from one company and several partner participants. Integration between them allows you to achieve maximum speed and transparency of processes, detect problems and improvement points in different business areas. An Intellectual Ecosystem implies a qualitative change in approaches to the creation of intelligent computer systems. The main goal is the formation of a common information space in the form of a general knowledge base and a general mechanism for the semantic compatibility of all intelligent agents of this system. Figure 3 shows the general principle of building an Intelligent Ecosystem.

The transition from data processing systems to knowledge management systems involves conceptually new approaches not only and not so much in mathematical and algorithmic support, but to a greater extent in the creation of hardware platforms. Various ideas have been put forward for a long time to achieve high real performance of a computing system by adapting its architecture to the structure of the problem being solved and creating a computing device that equally effectively implements both structural and procedural fragments of calculations [7] [8]. However, as a promising and comprehensive solution, the construction of new generation intelligent computers is considered. They will make it possible to remove a few issues that arise due to the technical limitations of existing computer architectures and bring the development of intelligent systems to a qualitatively new level.

III. Towards a new generation of intelligent computers

Let's define a new generation of intelligent systems through a description of their properties, distinguishing features and expected technical characteristics..

What can be expected from innovative mathematical models?

In terms of functional capabilities, intelligent systems should exhibit some (not necessarily all) qualitatively new properties, such as:

- semantic clustering;
- convergence (gradual blurring of the boundaries between data processing and knowledge processing);
- automatic knowledge acquisition;
- processing of fuzzy knowledge;
- generation (recreation) of images from patterns;
- modeling of cognitive functions and phenomena and so on.

In terms of applications, innovative mathematical models should be more versatile compared to neural and semantic networks.

In terms of technical characteristics, intelligent systems should provide:

- reduction of labor costs for the construction, operation, and development of new applied intelligent systems;
- increase in the level of intelligence (cognitivism) compared to known intelligent systems.

In terms of infrastructure, mathematical models and language tools for representing images and knowledge will be standardized and ensure cross-platform compatibility, meaning that high-level models, algorithms, and software will be portable across specialized, problem-oriented, and universal computers.

What to expect from specialized hardware platforms?

In terms of architecture, intelligent computers should support the infrastructure of mathematical models, possibly incorporating features of both neural and semantic computations.

In terms of technical specifications, specialized computers may have performance that exceeds that of general-purpose computers by several orders of magnitude.

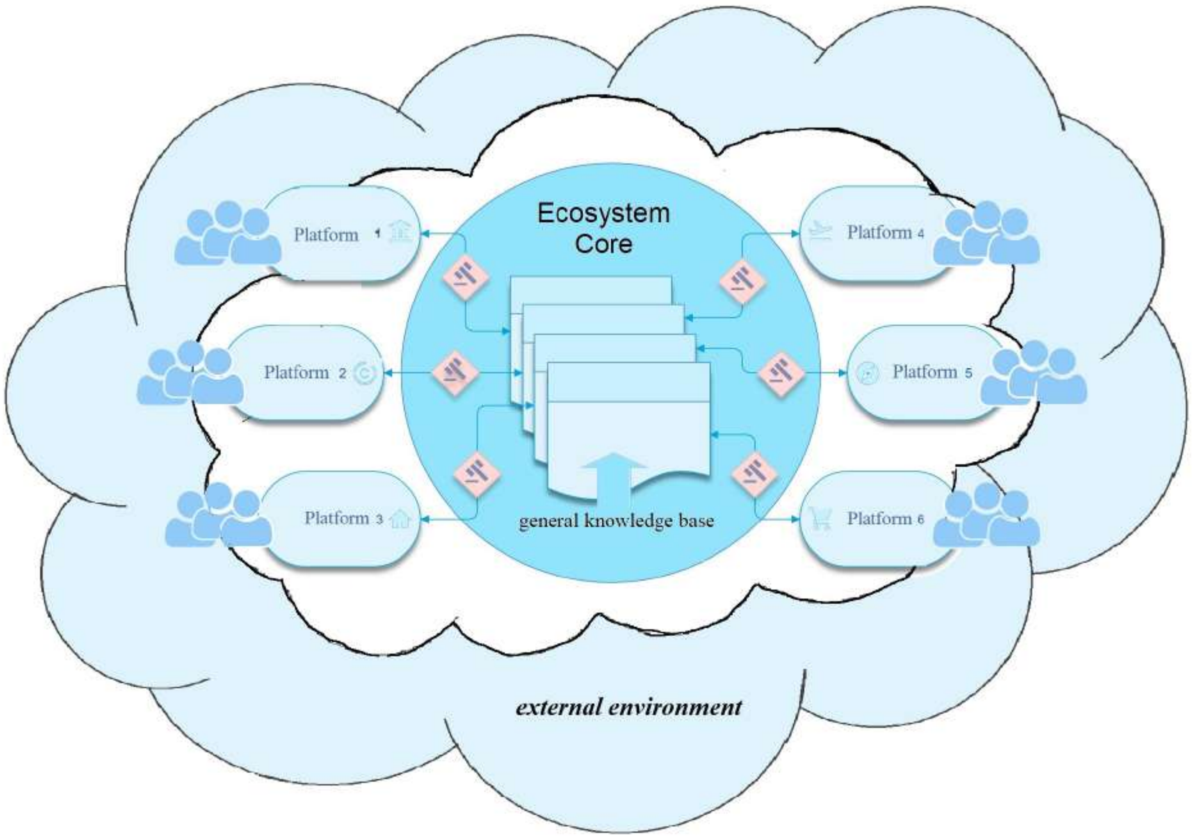

Figure 3. Generalized scheme of the Intellectual Ecosystem

In terms of the component base, modern electronic technologies, primarily FPGA and GPU, allow for the development and rapid prototyping of original technical solutions for innovative architectures of intelligent computers.

In terms of the structure and technical solutions topology, the architectures of modern neural networks, including convolutional ones, are tree-like schemes with re-convergent irregular connections, often with non-homogeneous functions in processor elements. The architectures of modern semantic networks also represent graph schemes with irregular connections and non-homogeneous functions of processor elements. Attempts to structurally implement such architectures "bluntly" usually encounter technological limitations of the component base and do not have any significant effect. Therefore, in both cases, developers strive to find "workarounds." One of the most common solutions is to map the irregular connections of architectures onto a structure with a regular topology of connections.

The simplest examples can be a bipartite graph, which is reduced to a technical solution in the form of a line of processor elements (Fig. 4), as well as lattice graphs, which are reduced to a technical solution in the form of a matrix of processor elements [2] [3].

In more complex implementation variants, one should expect more complex variants of mapping the architecture onto the topology of processor elements connections.

In terms of profitability, specialized computers may find their niche by unifying a wide range of intelligent computations and integrating into the overall infrastructure of artificial intelligence.

IV. OSTIS in the context of ambitious objectives

Over the past 10-15 years, as OSTIS began "to take shape", it has primarily been viewed as a tool for building applied intelligent systems. Examples of this include an information service system for employees and a decision-making module for the quality control system of PJC "Savushkin Product", a set of prototypes for intelligent learning systems in various disciplines of secondary and higher education, and intelligent dialogue systems for medical and educational purposes implemented on universal software and hardware platforms. Currently, OSTIS can be considered as an independent infrastructure [9], within which all prerequisites exist for the creation of innovative specialized processors. These specialized

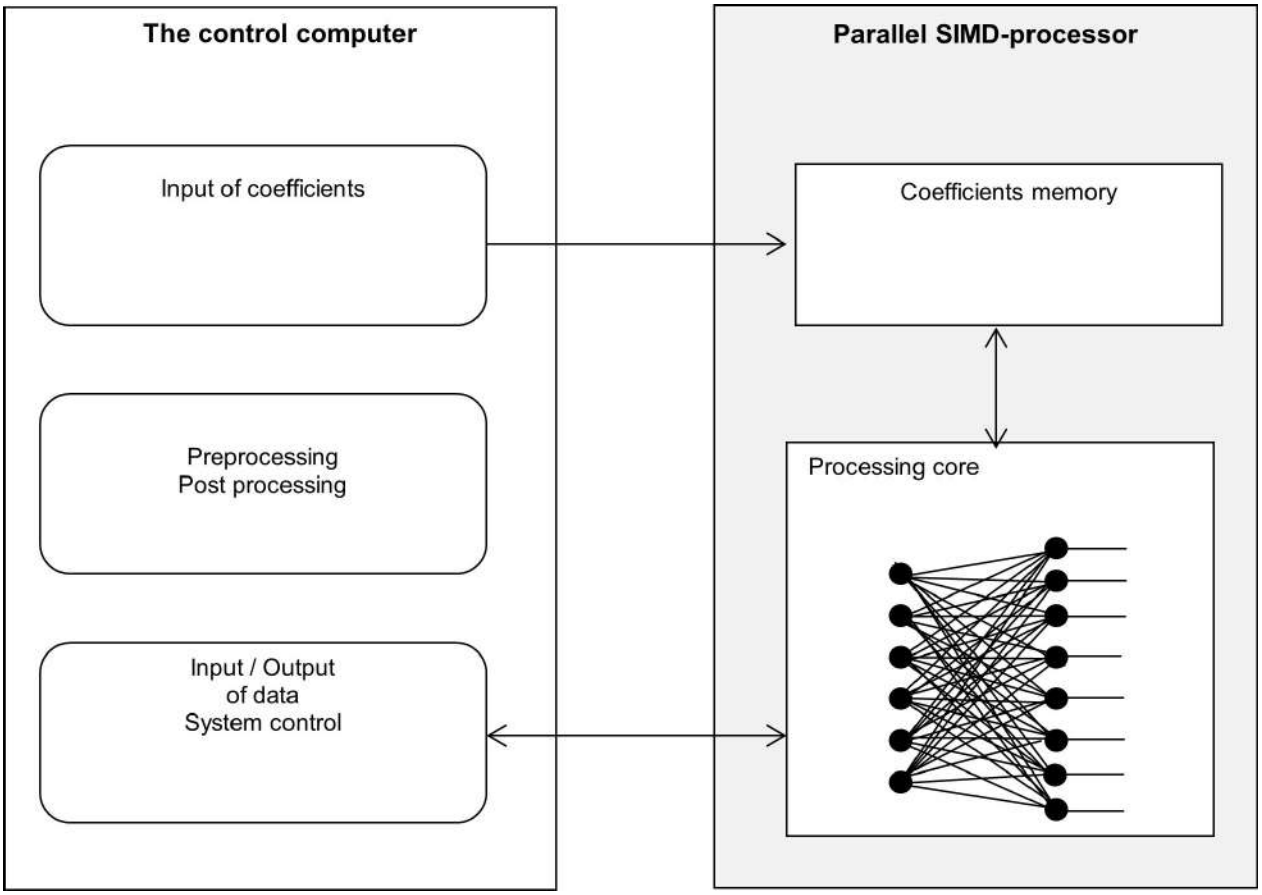

Figure 4. Simplified scheme of a computing system with a parallel processor core

processors within OSTIS are viewed as an option for interpreting computer system models developed based on OSTIS platforms [10]. One of the principles of OSTIS is to ensure platform independence of computer systems (OSTIS systems) developed on its basis. In other words, the development of such a system is reduced to the development of its model (including functional modules for solving tasks), described by means of a knowledge representation language and the subsequent loading of this model onto an OSTIS platform that meets certain requirements. Figure 5 illustrates a fragment of the OSTIS ecosystem, which is a comprehensive infrastructure for the interaction of OSTIS systems, users, and other computer information systems. As shown in the figure, specialized (associative semantic computers) developed under the infrastructure conditions will directly support distributed knowledge processing, significantly increasing their efficiency compared to universal computers.

Thus, in general, an OSTIS platform can be implemented either in hardware (e.g., as a specialized processor) or in software (e.g., as a virtual machine based on modern von Neumann computers). At the same time, there can be many implementation options for both hardware and software OSTIS platforms, and each such option may have its own advantages and disadvantages, considering the classes of tasks solved by specific OSTIS systems.

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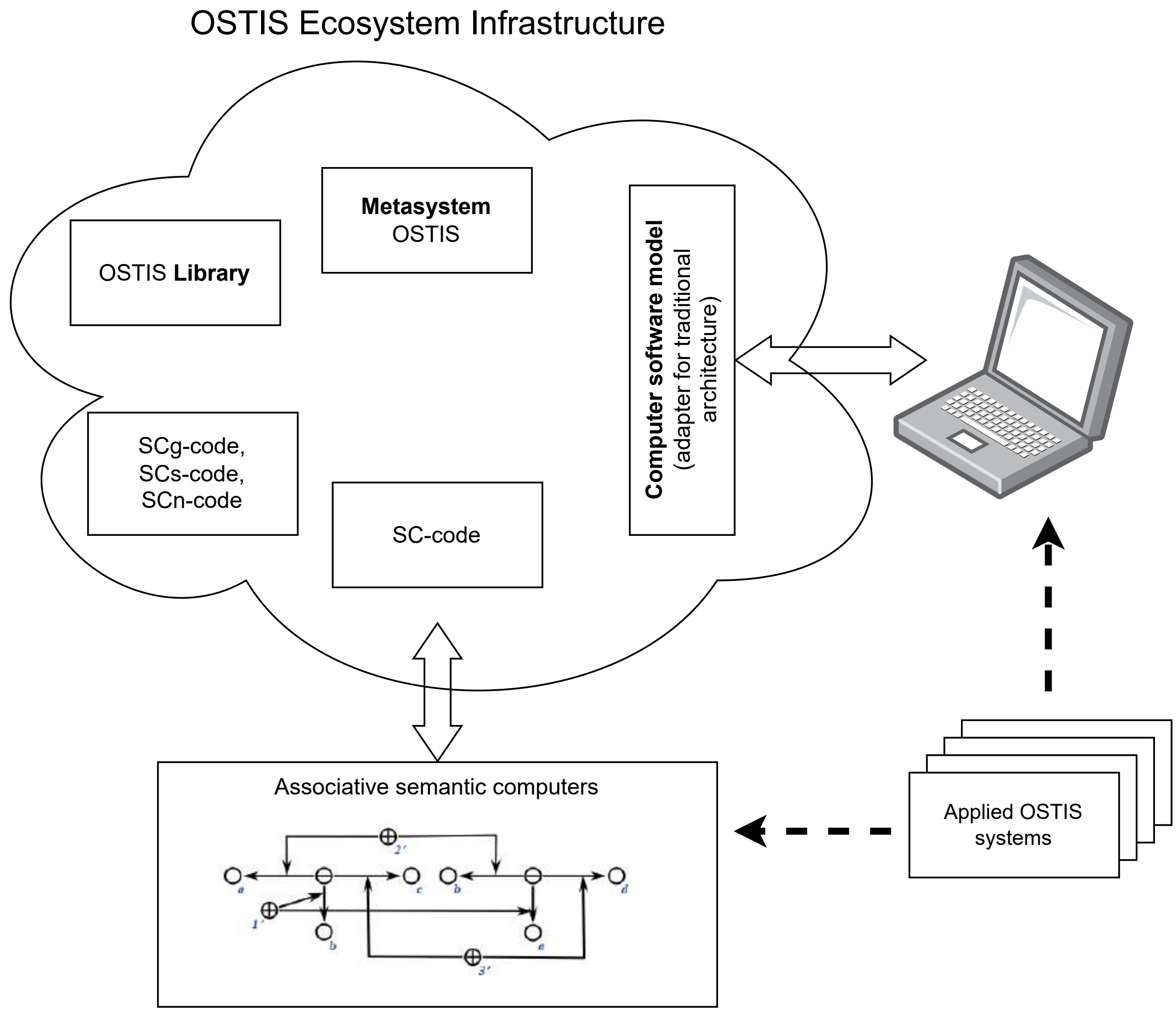

Figure 5. The OSTIS ecosystem and specialized computers place in it

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Открытая семантическая технология как фундамент нового поколения интеллектуальных систем

Татур М. М., Парамонов А. И.

Рассматриваются вопросы развития нового поколения интеллектуальных систем. Приводятся примеры известных практических экспериментов по созданию специализированных платформ для достижения высокой реальной производительности вычислительной системы. Выдвигается гипотеза о необходимости создания принципиально новой архитектуры вычислительной машины для эффективной реализации проекта экосистемы ostis-платформ. Предлагается концепт инфраструктуры OSTIS экосистемы на базе специализированных компьютеров.

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