Examples of Integrating Wolfram Mathematica Tools into OSTIS Applications

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***Abstract*—Within the concept of convergence and unification of intelligent computer systems of the new generation, technical solutions are discussed, examples of development and modernization, integration of Ecosystem OSTIS tools with Wolfram Mathematica (WM) computer algebra system (CAS) are provided.**

On the example of integration with specialized complex of intellectual educational resource for the discipline "Computer Systems and Networks" the possibilities of using WM tools in ostis-system are discussed when solving problems related, in particular, to topology of info-communication networks. The application of WM tools for visualization of network topology, as well as emulation of the search for the optimal route for data transmission is shown.

***Keywords*—technological production process, adaptive control, neural network, reinforcement learning, Industry 4.0, standard**

I. INTRODUCTION

Following the assessment of the current state of work in the field of Artificial Intelligence (AI), it is possible to affirm active local development of various directions (non-classical logics, formal ontologies, artificial neural networks, machine learning, soft computing, multi-agent systems, etc.), however, a comprehensive increase in the intelligence of modern intelligent computer systems does not occur [1].

The key reasons of methodological problems of current state of Artificial Intelligence, as well as a number of actions required to solve them are outlined in [1]. What actions are needed to improve the current state? First of all, it is necessary to converge and integrate all directions of Artificial Intelligence and corresponding construction of a general formal theory of intelligent computer systems (ICS), the transformation of modern variety of frameworks for development of different ICS components into a single technology of complex design and support of the full life cycle of these systems, which guarantees the compatibility of all developed components, as well as the compatibility of the ICS as independent subjects, interacting between each other. Convergence and unification of new generation of intellectual computer systems and their components is required.

Convergence and unification of new generation intelligent computer systems and their components is necessary. At the same time, convergent solutions basically mean optimized complexes that include everything necessary to solve AI tasks, organized and configured for efficient use of information resources, simplification of implementation processes, meeting the requirements of maximum performance, availability of intelligent interface, simple and understandable for all categories of users.

Supporting the outlined concepts, we note that such problems can be effectively solved by developing, improving, regularly updating the content of intelligent systems by incorporating CAS means. Below are a few methodological and technical solutions for integration of different types of knowledge, implemented by inclusion of Wolfram Mathematica functions in the ostis-system of support and maintenance of the teaching process of one of the basic disciplines in high school, illustrated by examples.

II. CONCRETIZATION AND VARIANTS FOR INTEGRATING THE ECOSYSTEM OSTIS WITH CAS

Integration of the Ecosystem OSTIS with any service means the ability to use the functionality of the service to change the internal state of the system's knowledge base. Within Ecosystem OSTIS full and partial integration levels are acceptable.

According to the Technology, full integration of the Ecosystem OSTIS with any service implies the possibility of executing service's function at platformindependent level using SCP language. That is, the task of integration of such a service is reduced to allocation of a graph structure processing algorithm and its implementation within a system's knowledge base. As a result of such integration there is no need to use a third-party service, in fact, an Ecosystem component is used.

Partial integration means changing the state of the system's knowledge base at the stages of service function 225 execution. The depth of integration can vary. In some cases, a service can refer to the knowledge base to get additional information or to record intermediate results. In the simplest case, a knowledge base can change only once, after a result of the service's function is received. In case of partial integration it is supposed that particular ostis-systems are to play the role of system integrators of included resources and services of other computer systems, as the level of intelligence of ostissystems allows them to specify the computer systems being integrated to a sufficient degree of detail and, consequently, to "understand" adequately what each of them knows and/or can do.

Separately, let us note that following the Technology, ostis-systems are capable (and it should be used) to coordinate the activities of a third-party resource and service sufficiently well, to provide a "relevant" search for the required component. The systems themselves can also perform the role of intelligent help-systems – assistants and consultants for efficient operations with functional capabilities, when the user interface is implemented with non-trivial semantics in the unique tasks of complex subject areas. Such help systems can be made intelligent intermediaries between the relevant computer systems and their users.

The systems themselves can also act as intelligent help systems. Their relevance is dictated by the high complexity of subject areas and the non-triviality of some unique tasks. Such conditions require the design of appropriate unique and nontrivial user interfaces with additional information support for their use. Such help systems can be made intelligent intermediaries between the relevant computer systems and their users, and the homogeneity of the technologies used ensures seamless integration with the existing system.

Solving the issues of data format coordination. A tedious problem of functional service integration when forming a digital ecosystem of multiple interacting services is the difference in data formats that participants of this Ecosystem work with. Two services, which imply data processing from one subject area, are likely to have different data formats. The problem of coordinating the data format of different services significantly complicates the development of the services themselves and leads to an increase in time costs. Such issues can be effectively solved using CAS import and export functions, such as in Wolfram Mathematica, which supports more than 100 data formats, including graphics, video, and more.

At the current stage of development and usage of the Ecosystem OSTIS, one of the priority areas appears to be the integration of the capabilities of computer algebra systems and intelligent learning systems constructed in ostis-application. The importance of this is due to the relevance, the requirements of the intellectualization of educational resources on the one hand, and on the other – contents of computer algebra systems, which have an undoubted advantage and great opportunities for solving problems relevant to educational systems for virtually all natural-science and technical disciplines, involving the use of complex mathematical apparatus.

It can be stated that, despite the popularity of topics related to automation and intellectualization of educational activities in science disciplines and the development of appropriate computer systems, at the moment the market is practically lacking tested intellectual educational systems capable of self generating and solving various problems, and verifying the correctness of the solution provided by the user. As prototypes, there are some systems that consider non-trivial problems, such as geometry [2], [3] and graph theory [4]. But, to be fair, it should be noted that there is no intelligence in the mentioned systems (in fact, only a specific set of actions is implemented, the tasks are not generated in the applications themselves), there is no means of verification of solutions with even minor deviations of the design rules.

One of the variants for interaction between Ecosystem OSTIS and CAS can be approaches similar to the integration of artificial neural networks in ostis-systems (see [5]).

Developing the aforementioned implementations, the following methodological and technical solutions can be considered:

- Black-box integration, when the knowledge base of the ostis-system contains the specification of the used kernel function of the computer algebra system, as well as the specification of the method of calling this function (for example, specifying through which software interface the interaction with this external system is performed). This integration variant is the easiest to implement and generally has the advantages listed below. At the same time, this variant has a disadvantage that the ostis-system does not contain means of analysis and explanation of how a certain step of solving a problem that is realized by a used CAS function was taken.
- A tighter integration, in which a particular function is still a part of a third-party CAS, when not only the result of its performance is loaded to the knowledge base of ostisystem, but also all possible specification of it, e.g. explanation of the problem solution step, indication of particular algorithms and formulas which can be involved in the solution, description of possible alternative solution variants, evaluation of solution efficiency and so on. In this variant of integration, the ostis-system gets more opportunities of analysis

and explanation of the problem solution process. (Note that this doesn't apply specifically to CAS Wolfram Mathematica, because it always has detailed explanations for all solutions, and allows 226 for step-by-step execution.)

- Full integration, which translates computer algebra functions in use from this system's internal language into the ostis-system. This variant is the most labor-intensive and complicated in terms of updating the capabilities of computer algebra systems in the corresponding ostis-systems taking into account their constant development. At the same time this integration variant, in comparison with the two previous ones, has an important advantage: it ensures platform-independent solution and allows using all the advantages of the approaches proposed within the OSTIS Technology in solving a concrete problem, in particular the possibility of multi-user parallel knowledge processing and the possibility to optimize a problem solution plan or its fragments directly during the solution.

The approach to solving the problems of intellectualization of educational activity, based on the integration of ostis-systems and computer algebra systems, has several advantages:

- When developing ostis-systems, the need to program many functions that have already been implemented and tested in CAS is eliminated. This is fundamental because computer algebra systems are developed by highly qualified specialists in the relevant fields, the implementation of similar functions in ostis-systems may require significant financial and time expenditures.
- A concrete ostis-system using individual functions of CAS, due to the approach to the development of hybrid problem solvers in OSTIS Technology, gets the possibility to self plan the course of problem solving provided that some of its steps are implemented by means of the attached functions. From the point of view of the approach proposed within the framework of OSTIS Technology, each function of the computer algebra systems, computer mathematics systems (CMS) becomes a method for solving problems of some class. This class of problems is described in the knowledge base of the ostis-system and allows it, when solving a concrete problem, to independently draw a conclusion about the expediency of applying one or another CAS function. Such integration with ostis-systems will make it possible to eliminate a possible disadvantage of individual computer algebra systems noted earlier (determined by which CAS are used – explained below in the overview of computer mathematics systems, conditions of their application and access to individual components).

We emphasize that these integration variants are not mutually exclusive and can be combined. In addition, integration can be deepened step by step taking into account the above advantages and disadvantages as well as the relevance of using certain functions of computer algebra systems in solving specific tasks within the Ecosystem OSTIS and corresponding ostis-systems.

In general case, step-by-step integration of CAS with the Ecosystem OSTIS implies, as a minimum, description of the specification of the basic functions of the selected computer algebra system by means of the OSTIS Technology, in other words – development of the ontology of external functions. In case of Wolfram family systems, the process of developing such ontology can be automated due to the presence of the Wolfram Language formal language and good documentation of system functions.

Summarizing the above, we state: the integration of educational systems developed on the basis of OSTIS Technology and computer algebra systems will allow us to create systems with intelligent properties in a shorter time, and with the use of carefully developed (mathematically, algorithmically) and repeatedly tested tools.

III. FUNDAMENTALS, TERMINOLOGY. COMPUTER MATHEMATICS SYSTEMS, COMPUTER ALGEBRA SYSTEMS

In the mid-twentieth century, at the junction of mathematics and computer science, a fundamental scientific trend, computer algebra, the science of efficient algorithms for calculating mathematical objects, emerged and intensively developed. Synonyms for the term "computer algebra" are: "symbolic calculations", "analytical calculations", "analytical transformations", and sometimes "formal calculations". The field of computer algebra is represented by theory, technology, software tools. Applied results include developed algorithms and software for solving problems using a computer in which the original data and results take the form of mathematical expressions, formulas. The basic product of computer algebra became software computer algebra systems (CAS). The range of mathematical problems solvable with the help of CAS is constantly expanding. Considerable effort is devoted to developing algorithms for computing topological invariants of varieties, nodes, algebraic curves, cohomology of different mathematical objects, and arithmetic invariants of rings of integers in the fields of algebraic numbers. Another direction of modern research is quantum algorithms, which sometimes have polynomial complexity, while existing classical algorithms have exponential complexity.

Research and development of theoretical foundations and technologies for implementing methods and software implementations of computer algebra tools continues. Terms, definitions, names in descriptions of functions and tools of these systems also undergo changes, some formulations earlier given in separate manuals, reviews of tool capabilities are being not only refined, but also