Scientific Activities in Digital Environment: Relevant Problems

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Abstract – **The proposed approach to increasing scientific productivity is considered a conceptual basis for determining the functionality of scientific and educational online services designed to cooperatively solve infrastructure educational and research problems in the digital environment. The functionality of cooperation is designed to create updated knowledge systems, methodologies for solving scientific problems, encyclopedic resources, and other similar resources. The rules for the operation of online services cooperation are considered a methodological basis for creating and upgrading electronic encyclopedic services, libraries, scientific journals, and other scientific and educational online services.**

Keywords – **evaluation of research productivity, S-modeling, information resources, S-model of knowledge system, infrastructural educational and research S-problems, cooperative solution of S-problems, architecture of scientific and educational online services, S-environment.**

I. Introduction

Improving educational and research processes, choosing research projects worthy of funding, and evaluating the results of educational and research activities are closely related and continually relevant problems. Their solutions depend on the technologies for creating scientific and educational resources, their registration, publication, discussion, and assessment of significance [1– 5].

The abilities to invent, accumulate in the external environment, transmit and apply *symbolic systems* (visual, audio, etc.), and message languages based on them, systems of concepts and knowledge – these abilities are keys in research and educational activities [6–7].

Nowadays, the use of mobile and stationary programmable machines in *symbolic modeling of arbitrary objects* (*S-modeling*) is increasing at an accelerating pace [6]. The improvement of *the symbolic-code-signal environment for solving problems* (*S-environment*) [7] is accompanied by enormous changes in importance and dynamics in technologies for building, storing, accumulating, transmitting, and searching information resources (including technologies of neural networks with computer vision, machine learning, *digital twins*, etc.) [8–9].

The near future of the digital environment will be shaped by the intensive development of various services (including scientific and educational ones). The processes of convergence of digital communication technologies, mass dissemination of messages (television, radio) and *S-machine* technologies for solving various tasks (including scientific ones) that are gaining momentum will transform the digital environment and make it an even more powerful means of supporting scientific and educational activities [6–7].

In today's era of intensive development of cloud computing and *online services*[1] for various purposes (navigation, education, etc.), researchers and IT developers are increasingly attracted to the idea of integrated service-based automation of various activities. Since the mid-1990s, the importance of successful implementation of this idea (called the *digital economy*)[2] has steadily grown and associated with the competitiveness of corporations and countries[3].

Since the beginning of the 21st century, the role of mobile devices has been steadily growing in the implementation of these technologies. A generational change in digital cellular communication technologies serves as an indicator of this growth: [3G: speeds up to 3.6 mbit/s, Internet access in cellular communication networks became possible, in use since 2002; 4G: up to 1 gbit/s, live streaming video became possible, in use since 2010; 5G: up to 20 Gbit/s, enabling UltraHD and 3D video, artificial intelligence and Internet of Things, in use since 2018].

The use of 5G technologies, particularly VR and AI, in scientific and educational processes is expected to significantly alter the technological arsenal supporting cognitive processes via mobile devices.

In the *S-environment*, information resources are represented by messages (text, audio, video, etc.) in formats designed for storage (files of articles, books, films, etc.), as well as for accumulation, processing, and presentation to users engaged in the construction and application of knowledge. Being *S-objects* used to build knowledge systems, information resources serve as initial constructive elements for building new information resources [7].

Knowledge system models published in scientific papers recognized by the scientific community serve as the source material for the creation of encyclopedias and textbooks.

Regardless of the content or field of the scientific result, its fate depends significantly on how the description is compiled, how quickly and in which publications it is published, and how the processes of discussion, assessment of significance, and dissemination are organized.

Nowadays, the answers to such questions largely depend on the architecture of scientific publications' online services. The need to unify descriptions stored in the *S-environment* has been clearly demonstrated by the successful development of computer-aided design across various subject areas, including software and hardware design for *S-machines* [6–7].

Of course, artificial intelligence and virtual reality technologies, or some other technologies created on the

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[1] Trumba Corporation. 2007. Five benefits of Software as a Service. Available at: http://www.trumba.com/connect/knowledgecenter/pdf/Saas_paper_WP-001.pdf (accessed September 12, 2024).

[2] Christensen, C. M. 1997. The innovator`s dilemma: when new technologies cause great firms to fail. Boston: Harvard Business School Press. Available at: http://www.hbs.edu/faculty/Pages/item.aspx?num=46 (accessed September 12, 2024).

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basis of research on mental and sensory mechanisms, will not add ingenuity to researchers. However, they can radically transform message input and output technologies, online access to information resource repositories, and online discussions and publications in scientific community networks, etc.

Writing formulas and semantic markup of the text. To write formulas, highlight definitions, remarks, and examples, the tools of the *TSM complex language* (TSM: Textual Symbolic Modeling), developed for the form-oriented description of textual S-models, are further used [6–7].

Semantic text markup tools used in the article:

□ < text fragment > □ ≈ definition or statement (the symbol ≈ replaces the word "means");

◊ < text fragment > ◊ ≈ remark;

∘ < text fragment > ∘ ≈ example.

The first occurrences of the names of concepts and fragments of the description to which the author wants to draw attention are highlighted in italics.

II. Production of Research and Educational Activities

□ *The main types of scientific research production* are:

– the published models of the systems of concepts and knowledge (presented in articles, monographs, reports on completed research projects);

– the physically implemented models of invented objects; the reviews on descriptions of published research products;

– the results of educational and expert activities;

– the educational products (encyclopedic articles; sites dedicated to the popular presentation of scientific results, etc.). □

□ *Scientific materials* – articles, monographs, reports on completed research, and other documents containing descriptions of the results of scientific research, discussions, meetings, and other components of scientific activity; physical models, models of scientific and technical facilities, etc. □

□ *Scientific result* – a new or improved model of the knowledge system, describing a set of objects, including the object being studied, and the connections between them. The description of the model is presented in the form of a message designed for interpretation by the scientific community. □

The value of the result depends on the predictive power, reproducibility, and applicability of the model, as well as on the properties of the message containing its description.

◊ A justified indication of the model's inadequacy or clarification of its applicability area is also a scientific result. ◊

□ *S-model of the knowledge system* is considered as a triad <ca, set^{lng}, set^{intr}>, where ca is the s-model of the concept system Sc; set^{lng} is the s-model of the set lng of message languages interpreted on ca; set^{intr} is the s-model of the set $intr$ of the message interpreters on ca (the messages in languages from set^{lng}). *S-model ca of the concept system Sc* is the pair <mem^{sc} , $rel(mem^{sc})$ >, where mem^{sc} is the model memory corresponding to the set of Sc concepts; $rel(mem^{sc})$ is the family of relations defined on this set [6–7]. □

□ The type $ts[A[at,op]]$ of concept systems corresponds to a set of A concepts for which a set of at attributes and a family of op allowed operations are defined. □

The specialization of $ts[B<A[at,op]]$ *of the type* $ts[A[at,op]]$ will be called a subset $B<A[at,op]$ of concept systems with a set of attributes $at[B]$ ($at[B] > at[A]$ and a family of valid operations on $op[B]$ ($op[B] > op[A]$). The type $ts[A[at,op]]$ we will call a *generalization of the type* $ts[B<A[at,op]]$.

□ *The definition of a concept system* is a description of its s-model, followed by an indication of the scope of applicability. The description is presented in the form of a message designed for interpretation by the scientific and educational community, and presentation, storing, distribution, accumulation, and search in the s-environment.

The definition of a concept system must satisfy the following requirements of constructiveness:

– representation in the form of a pair <s-model of the concept system>, <description of applicability area>;

– the system must not include concepts that have no definitions (and at the same time are not concepts-axioms) [6–7]. □

□ *Determining the s-model applicability area:*

– description of the types of model correspondents (to whom it is addressed);

– goals, for which the model makes sense (classes of problems, in the study of which the model may be useful);

– the stage at which it is appropriate to use the model (conception, solution methodology, etc.). □

◊ The applicability of the model may lie in areas where natural objects are studied, or in areas where invented objects are studied. ◊

Interpreting a message on the model ca:

1. Constructing the output message (information retrieval) from the given input one (the messages are in languages from set^{lng}).

2. The output message analysis: are changes of the ca model required?

3. If required, then the model correction; if not, completion.

◊ In science and techniques, special attention is focused on s-models, where families of relations $rel(mem^{sc})$ are presented in the form of solvable problems (after setting the values of a certain subset of the memory mem^{sc} elements, the values of other elements can be calculated). ◊

∘ The elementary example of a concept system with solvable relations between memory elements – the concept system "circle" (in the s-model of this system, the number π, the radius r, the circumference cc and the circle area ac are the memory elements, and the relations $cc = 2\pi r$ and $ac = \pi r^2$ are the elements of the problems relations family). ∘

A programmatically implemented task stored as an information resource is the aggregate {*Formul*, *Rulsys*, *Alg*, *Prog*}, where *Formul* is the problem statement (which includes the concepts and relations between them); *Rulsys* – the set of systems of mandatory and orienting requirements for solving the problem; *Alg* is the union of algorithms sets, where each set corresponds to one system from *Rulsys*; *Prog* is the union of programs sets, where each set corresponds to one algorithm.

A description of applicability is given for each element of *Rulsys*, *Alg* and *Prog*.

Descriptions of applicability of the *Rulsys* elements include the specification of the problem solver type (stand-alone computer, network computer cooperation, human-computer cooperation, etc.); the requirements for information security, etc.

Descriptions of applicability of the *Alg* elements include data on the permissible modes of the problem solver work (automatic local, automatic distributed, interactive local, etc.), requirements for the result, etc.

Descriptions of the program's applicability include data on implementation languages, operating systems, etc. [6–7].

A. *Engineering models*

□ *A model invented by an engineer* is a description of the operating principle of a set of devices or systems, which can be symbolic or physically implementable constructions. □

◊ Important: not a singular device or system, but a set (type). Additionally, the author's participation is not required for the interpretation and implementation of the model. ◊

If a model satisfies the necessary requirements for a scientific result, and if the expediency of implementing the devices or systems described by the model is justified, then the model is certainly considered a scientific result.

◊ The scientific nature of the model does not depend on the field of knowledge to which it relates (whether communications, electrical engineering, mathematics, physics, biology, or another field). ◊

⚬ Theories of materials resistance, electrical engineering, communications, and many other fields are the scientific foundation of engineering, which is of paramount importance. Computing methods for various purposes are based on this foundation. These methods have been tested by generations of engineers designing bridges, buildings, electrical machines, power lines, airplanes, ships, radio and TV systems, spacecraft, and satellite communication systems. This list could easily be extended by anyone observing the world of things we rely on today. All artificial structures used by modern society are invented and designed by engineers. ⚬

◊ The study of invented objects is as well important as the study of natural ones: after all, studies of natural objects are carried out using invented methods of S-modeling, mathematical modeling, etc. ◊

III. EVALUATION OF THE USEFULNESS OF THE SCIENTIFIC RESULT

The widespread use of scientometric indicators related to citation, particularly the *h-index* [10], which has been heavily promoted by commercial companies such as Thomson Reuters and Elsevier, and the reverence for citation indices and their linkage to scientific productivity, has had a destructive impact that is difficult to quantify.

The activity of corrupt groups is growing, which, without hiding, undertake for a fee to ensure the publication of articles in scientific journals indexed by Scopus, included in the list of the Higher Attestation Commission, etc. There is a struggle for the markets for the sale of such services.

Even the applied usefulness of a scientific result cannot be quantified in all cases. Some estimates may be represented by the values of the cost of saved resources or some other (depending on the area and method of application of the result). It is hardly possible to quantify the usefulness of a scientific result for the advancement of research in the field to which the result relates [or for advancement in other fields of research (for example, in related fields)]. The possibility of quantifying the usefulness of a scientific result in education and enlightenment is no less doubtful.

The productivity of a researcher's scientific activity at any stage is evidenced by published scientific works.

If the reader of a scientific article (book or report) is engaged in research in the same field, he will be interested in:

– the essence and argumentation of the significance of the result;

– the connection with the previously published results of the author and other researchers (represented by the elements of the list of references);

– the audience to which the publication is addressed [to the professional community or some others (engaged in educational activities or technology developers, etc.)].

The scientific and educational usefulness of the authorship object is associated with its role in improving the system of scientific knowledge, and engineering – with the role in creating new technologies, devices or something else that is endowed with applied value and can be manufactured.

What type of thing authors are worthy of a status upgrade? Who and in what way should determine the types of things that it is advisable to consider as objects of authorship? Which objects of authorship should be considered as a national treasure, and their description as an important part of state information resources? Guided by what systems of rules can professional communities of authors carry out the examination of authorship objects applying for registration and placement in state repositories (libraries, archives, etc.)?

□ *Rationalization* is a model that improves (in a certain sense) one or more recognized models of some well–known research object. □

The improvement of an existing invention (⚬ a method for solving a problem or an information technology⚬) is considered a rationalization.

□ *An invention* is a model of a certain well–known object that is fundamentally different from previous models of this object and surpasses them in basic characteristics.

⚬ Methods of solving problems are being invented, task specification languages, and programming languages. ⚬

□ *A discovery* is a model of an object that was either not known or not investigated, or, if it was investigated, but was not represented by the model described in the published works. □

⚬ A certain element has been discovered (previously missing from the periodic table) – this is a discovery. ⚬

□ The object of authorship recognized by the state (*the object of authorship*) is a thing created by the author [an article, a book (electronic, paper or other medium), an audio recording, a video recording, etc.], to which copyright can be claimed in accordance with the form established by law. □

The subject of authorship (author) may be an individual or several individuals. The authorship object must be registered, and its specified description must be placed in the state repository.

In each state repository of objects of authorship, there should be an electronic catalog of stored descriptions of objects of authorship, and the description of each of them should be represented by a standard (for each type of objects of authorship) hypermedia specification containing an image of the stored object.

The significance of the objects of authorship registered in state repositories is determined by scientific and educational communities in the processes of public discussion (on community websites).

The document confirming authorship is a certificate of registration of the object of authorship in the state repository. It contains a legally prescribed description of the object of authorship (specification of the object of authorship) and the subject of authorship.

Each of the professional communities that have recognized the object of authorship puts up at least one of three assessments of the significance of the object of authorship (*rationalization*, *invention*, *discovery*). An object whose importance is recognized in several fields of knowledge may receive more than one assessment. In the field "By whom the significance of the authorship object is determined", the descriptor of the professional community, the date of the decision, hyperlinks to the decision protocol, and the database of discussion of the evaluated authorship object are entered.

◊ The obligation of the state to protect copyright must arise from the moment of registration of the object of authorship in the state repository (∘ in the Russian State Library ∘).

IV. Scientific results in a digital environment

The hypermedia form makes it possible to update the stored message relatively easily (additions, deletions of some fragments, changes in design, bug fixes, etc.). If the message (∘ scientific article ∘) is posted on the website, then the update process is quite simple. Immediately after its completion, users have the opportunity to familiarize themselves with the updated work (with an exact indication of the content of the completed update). The existence of a work in the form of a hypermedia message allows the author to choose the disciplines of commenting, forums and reviewing acceptable to him (if he posts the works on his website).

If there is a community or scientific publication on the site, then all this must comply with the rules of the community or scientific publication. ∘ The author posted the work on the community website. The received message is automatically registered (an electronic card is opened for it). Any update is registered on this card. It is much more difficult to hide evidence of theft than in the case of a paper form. ∘

□ *A hypermedia scientific publication* is an electronic publication in which materials are presented as hypermedia documents. □

Navigation features (hyperlinks and cross-references), the ability to see color illustrations, video messages from the author and thematic presentations – all this makes the material of a hypermedia document not only more expressive, but also more voluminous in meaning.

V. Online services

□ *The website of a hypermedia scientific publication* should have a set of services necessary for:

– registration of those who wish to participate in the work of the publication (these include authors, reviewers and those who intend to publish comments, ratings, suggestions for improving the work of the publication);

– management of databases containing appeals from participants, published materials, reviews, etc.;

– hypermedia presentation materials (including presentations and video messages). □

□ *Accredited scientific and educational institutions* (research institutes and universities) must have the right to register hypermedia scientific publications. □

The researcher should be able to immediately publish his products in hypermedia scientific publications [articles and monographs; reviews (necessarily signed) and comments; notes and assessments; educational materials]. For publication, it is sufficient that the submitted material corresponds to the subject of the publication and is designed in accordance with the requirements of this publication. The material posted on the publication's website is publicly reviewed and discussed by the community.

Registered scientific publications place in repositories those materials that are considered to be approved. State repositories of published scientific articles, monographs, research reports, abstracts of the successful applicants for academic degrees, etc. should accept materials in hypermedia form.

◊ Paper printouts, etc. non-multimedia forms of presentation of accepted materials – on request. ◊

The services of each repository must ensure the transfer of materials in an interactive mode: the bibliographic card of the material being sent for storage is filled in → the robot program of the repository checks it and, if everything is in order, reports readiness to accept the material → after successful completion of the reception of the material, the robot completes filling in the fields of the bibliographic card, certifies it with a digital signature (EDS) of the repository administrator and sends the material to the submitter.

◊ It is recommended to provide two types of services for storing and distributing scientific materials: paid and free. ◊

□ *Researcher's websites* are both the workshop of the inventor of S–models of knowledge, and a means of presenting and promoting them. □

VI. Conclusion

I. It is proposed to consider four main classes of scientific results: *discoveries*, *inventions*, *rationalizations*, and *discussions*.

II. The specified descriptions of scientific results are considered as *information resources registered in state repositories*.

III. In the modern digital environment, articles, monographs, scientific reports, conference proceedings and other materials should be presented as multimedia documents.

IV. It is advisable to create a set of online services designed to save and register articles, monographs, scientific reports and other materials considered as state information resources.

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