ONTOLOGICAL MODEL OF E-SCENARIO OF SCIENTIFIC RESEARCH AS A MEANS OF ORGANIZING OPERATIONAL RESEARCH KNOWLEDGE BASE

Serhiy Kalnoy,

Senior Researcher,
Junior Academy of Sciences of Ukraine (Kyiv, Ukraine)
E-mail: 13rom@ukr.net
ORCID: 0000-0001-5998-0339

The author reviewed the ontological aspects of developing the E-scenario model of scientific research as a means of organizing an operational research knowledge base. There have been analysed existing ICT systems as information support tools of scientific researches. The author has determined the methodological requirements for the development of knowledge bases for research purposes, and presented the conceptual, mathematical model for the generation of the ontological E-scenario of scientific research.

This article determines the general ontological structure for the organization of the E-scenario of scientific researches, and describes its functional characteristic. The author presented a general description of available ICT tool, which is intended to create a variety of E-scenarios of knowledge base in a given subject area. All above mentioned provides another promising direction for solving topical issues concerned with effectiveness of research activity information support based on application of modern ICT technologies.

Key words: research activities, operational knowledge base, information knowledge sources, ontological model, E-scenario of scientific research.

Introduction

The use of information and communication technologies (ICTs) is a prerequisite for innovative alternatives to traditional methods of information support of research, which creates opportunities for access to interactive classes and collaboration in computer networks, regardless of location. In such circumstances, the key point is the form of organization and access to information sources of knowledge generation, which are located in appropriate environments, and can be accessed from anywhere and at any time.

Nowadays, when developing network management systems of information sources that accompany the research process, the problematic issue is not the program aspect, but finding, formulating, structuring and presenting data and messages which will be used further for knowledge formation [Leech & Sutton, 2002; Pugh & Prusak, 2013; Smedley & Sutton, 2004; Wenger et al., 2002]. To solve this problem, we propose to create an ontologically structured and operationally oriented knowledge base, a key form of knowledge arrangement whereof is the E-scenario of scientific research.

Based on the above mentioned, the purpose of the article is to determine the principles and structure of the ontological model of E-scenario of scientific research as a means of organizing an operational research knowledge base.

Analysis of Recent ICTs Developments in Information Support of Scientific Research

Existing systems of information and communication technologies for development and management of knowledge bases in e-network have an extensive theoretical and practical research and use platform [Boland et al., 2001; Kogut, 2000; O;Leary, 1998; Manniche et al., 2017]. Recent theoretical studies and practical results in this area have been based on the formation of ontological models of knowledge bases and development of various ICTs based thereupon, such as: ”TODOS”, “Graph Editor”, “Linguistic Corpus”, Exalead, Protégé, KAON2, Sesame, IBM SHER, Joseki Jena, Oracle Spatial, etc. [Krótkiewicz & Wojtkiewicz, 2005; O’Leary, 2016].

Use of information and communication technologies (ICTs) as information support for scientific research purposes ensures the creation of a network environment supporting the mode of e-distance interaction between the participants of scientific research process. E-distance interaction is a network virtual environment, through which the participants of the research process interact mainly individually, both asynchronously and synchronously in time, mostly and principally using electronic transport systems for supply of scientific materials and other information objects.

One of the goals of activity in this environment is to provide conditions for the effective use of information resources by all participants in the scientific research process. For this purpose, the means of formalization of various informational sources of knowledge formation are created, taking into account the specifics of scientific research process. The process of scientific research knowledge formalization depends not only on the structure of the research object and its functional characteristics, but also on the means of research and operational activity of scientists studying the given object.

ICT software components ensure the development and use of knowledge bases for the realization of information support of scientific research process [Chandrasekaran & Linderman, 2015; Leitner & Warden, 2004]. ICT software has been applied for research activity with due consideration of the fact that the volume and variety of data and messages of different profiles of knowledge are so large now that it is necessary to classify them in terms of area of research, or the areas of interest of all participants of the research process, as well as the tasks they address. It is not just about data stored in specialized databases or information repositories but also about dynamic messages that are generated by specific sources, as needed. The application of these ICT software tools focuses on the following tasks:

- ensuring the possibility of prompt organization of access to information sources for the formation of knowledge related to one subject area of research, or having common interests of the fields of activity;
- supporting the interaction of all research process participants within a multiple set of subject areas with the possibility of expanding such set;
- providing an opportunity to expand the list of sources and consumers of heterogeneous information sources of knowledge formation taking into account the results obtained by the research process participants;
- limitation of access to scientific information resources within the scope of a specific subject area of research, or sphere of interest with the possibility of solving the previous task;
- providing the possibility for each subject of the research process to use scientific information resources in several subject areas;
- ensuring prompt search of required information source by research process participants, as well as sharing.

Ontological Approach to Formation of Network Base of Scientific Research Knowledge

The task to be tackled while forming the scientific research knowledge network base is not to accumulate disaggregated data but combine structured, formalized information sources, i.e. laws and principles, which will allow solving real-life issues during research. The ontological approach to the design of a network research knowledge base allows us to create systems, in which information sources of knowledge formation become ontologically structured and accessible to all research process participants. The main advantages of this approach are:

- ontological approach provides the user with a uniform, systematic view of a particular subject area of research;
- information sources on the subject area of scientific research are presented in the same way, which simplifies their perception;
- generation of ontology allows to restore promptly missing logical links of the subject area of research without breaking the overall structure of the knowledge base.

The importance of the ontological approach to creation of a network research knowledge base is proved by the fact, that if the information sources of knowledge formation are not described and duplicated, they will eventually become obsolete and out of date. On the contrary, information sources of knowledge formation, which are ontologically structured, networked and used, may generate new knowledge. The ontological approach makes it possible to present terms and concepts in such a way that they become suitable for computer processing, which brings scientific terminology to a formalized shape and promotes its understanding by all scientific research participants [Fridman & Hafner, 2000; O'Leary, 1998].

The ontological aspects comprise a wide range of issues, from the scope of application to the formal description of the components of computer ontologies in the subject areas of research. At the formal level, ontology is a system of multiple terms, statements about these concepts, being the basis for formation of classes, objects, links, functions and theories. Computer ontology of certain subject area of research may be considered as a general, open base of information sources of knowledge formation, which is represented by the generally accepted (formal) specification language. In the ontological classification scheme of artificial intelligence tools and methods, the ontological approach is treated as a kind of systematic approach based on knowledge formation [Krótkiewicz & Wojtkiewicz, 2009]. An ontological approach ensures effective design of components of any knowledge-centred information field of research.

Nearly all ontology models imply certain concepts (notions, classes), concepts properties (attributes, roles), relationships between concepts (dependencies, functions), and additional constraints defined by axioms. The concept may be a description of the task, function, action, strategy, thinking process, research process, etc. [Krótkiewicz & Wojtkiewicz, 2005]. Meanwhile the attention is paid to formalization of stages of development, structuring and presentation of information sources of knowledge formation, which allows the research process participants to effectively assimilate the theoretical material in combination with practical and laboratory researches. In its turn, effective implementation of these steps and generation of final results (libraries of ontology bases of information sources of knowledge formation) is impossible without a systematic ontological analysis of a given set of information resources of the chosen subject area of research.

Methodological Requirements for Development of Knowledge Base for Research Purposes

The concepts of ontology and ontological analysis have been incorporated into the procedures and standards for modelling ICT systems of knowledge bases for scientific research purposes [Chandrasekaran & Linderman, 2015; Leitner & Warden, 2004]. The description of such systems actually means structuring of information sources of knowledge formation. Implementation of these techniques requires taking into account different formal and methodological requirements, criteria and evaluations [Peffers et al., 2007; Greener, 2018]. Here are the basic ones:

1. Formation of information and functional models.
2. Need for structuring terms and concepts.
3. Rules of reliable statements and conclusions formation that describe terms and concepts.

At the initial stage of developing an ontological model, the following tasks must be performed:

- creating and documenting a glossary of terms;
- describing the rules, according to which and on the basis of applicable terminology, reliable statements characterizing the system state are

established;
- developing a model for formulating required additional statements based upon the existing assertions.

The ontological system is characterized by unity, logical interrelations and consistency of the concepts used [Gould & Mackaness, 2016].

Visual ontology design methods contribute to a faster and more complete understanding of knowledge structure of an area of scientific research. However, the objective circumstances, i.e. time and place of communication, not always meet the capabilities of their participants. The research program also does not reflect the process of its realization, research, consultative interaction and evaluation of results, but contains only general guidelines for its implementation. Therefore, there is a need to create e-remote information support system for scientific research. One approach that will ensure the effective functioning of such a system is to develop an ontological model for the E-scenario of scientific research. E-scenario of scientific research is a personalized ontological system for formalization of the process of information research support taking into account the subject area of research, the area of knowledge use and the operational area of research, which serves as a means of organizing an operational research knowledge base.

In line with the above, each modern model of knowledge base development has its own organizational structure, ensuring functional links between information objects of the knowledge base [Chao et al., 2017]. However, nearly all information objects of modern knowledge bases are fully integrated with their functional structures, resulting in large structural dimensions of such knowledge bases. Management of such systems of knowledge bases requires large computational resources that directly influences information processing time. In addition, systems are not focused on a personalized approach to their organization and management. To solve this problem, the author proposes to develop a structure of the knowledge base as a set of individual personalized E-scenarios, which, within the given ontological structure, are operationally formed in accordance with selected object and assigned task.

If a new E-scenario should be developed, which includes other E-scenarios stored in the knowledge base as xml-files, such scenarios should be linked to it either automatically through hyperlinks, or operationally by embedding its information structure in the underlying structure of E-scenario being created. The integrated E-scenario structure is then stored in xml-file. Thus, the knowledge base in this case has a file operating structure, which includes ontologically-structured E-scenarios in xml-file format. In our case, each E-scenario of scientific research, within the given ontological structure, is personally formed in accordance with the selected object of research and the task, and then stored in the knowledge base in the xml-format.

Conceptual Mathematical Model, Formation of Ontological E-scenario of Scientific Research

The process of forming the ontological model of E-scenario of scientific research involves presenting them in the form of objects by means of formation of ontology, using a description of certain concepts.

The general formula for formalizing this ontological model is as follows:

$S=\{O_a\{P_b\{T_d\{E_e\{C_q\{M_v\{Z_g\}R_h\{Z_g\}\}\}\}\}\}\}$, where:

- Objects of research: $O=\{O_a\}$, a=1,2,3, ….m;
- Subjects of study: $P=\{O_a\{P_b\}\}$, b=a1, a2, a3, ….. , an;
- Research topics: $T=\{P_b\{T_d\}\}$, d=b1, b2, b3, ….. , bn;
- Research stages: $E=\{T_d\{E_e\}\}$, e=d1,d2, d3, ….. , dn;
- Purpose of the research: $C =\{E_e\{C_q\}\}$, q=e1, e2, e3, ….. , en;
- Research Tools: $Z =\{C_q\{Z_g\}\}$, g=q1, q2, q3, ….. , qn;
- Research route: $M = \{C_q\{M_v\{Z_g\}\}\}$, v=g1, g2, g3, ….. , gn;
- Evaluation of results: $R=\{C_q\{R_h\{Z_g\}\}\}$ h=v1, v2, v3, ….. , hn.

Ontological model of the E-scenario of scientific research is presented in tabular form in Table 1.

***Table 1**. Conceptual ontological model of E-scenario of scientific researches*

Object Name	Class	Feature Name	Conditions for Identifying Trait: $\{x \mid F(x)\}$ [*)]
Objects of research	O	$\{O_a\}$	$\{O_a\|F(O_a)\}$
$\{O_a\}$	P	Subjects of research	
Subjects of research	P	$\{O_a\{P_b\}\}$	$\{O_a\{P_b\}\|F(O_a\{P_b\})\}$
$\{O_a\{P_b\}\}$	T	Research topics	
Research topics	T	$\{P_b\{T_d\}\}$	$\{P_b\{T_d\}\|F(P_b\{T_d\})\}$
$\{P_b\{T_d\}\}$	E	Stages of research	
Stages of research	E	$\{T_d\{E_e\}\}$	$\{T_d\{E_e\}\|F(T_d\{E_e\})\}$
$\{T_d\{E_e\}\}$	C	Purpose of research	
Purpose of research	C	$\{E_e\{C_q\}\}$	$\{E_e\{C_q\}\|F(E_e\{C_q\})\}$
$\{E_e\{C_q\}\}$	R	Means of research	
Means of research	R	$\{C_q\{R_g\}\}$	$\{C_q\{R_g\}\|F(C_q\{R_g\})\}$
$\{T_d\{E_e\}\}$	M	Route of research	
Route of research	M	$\{C_q\{M_v\{R_g\}\}\}$	$\{C_q\{M_v\{R_g\}\}\|F(C_q\{M_v\{R_g\}\})\}$
$\{C_q\{M_v\{R_g\}\}\}$	O	Evaluation of results	
Evaluation of results	O	$\{C_q\{O_h\{R_g\}\}\}$	$\{C_q\{O_h\{R_g\}\}\|F(C_q\{O_h\{R_g\}\})\}$

** Conditions for identifying a trait: {x|F(x)} - defines the set of all x, which equal to F(x). Example: $\{k \in K_a \mid k<5\} = \{1,2,3,4\}$.*

General Ontological Organisational Structure of E-scenario of Scientific Research

Based on the above it may be concluded that the ontological graph-structured model of E-scenario of scientific research,as a means of organizing an operational research knowledge base, has the following form (Fig. 1).

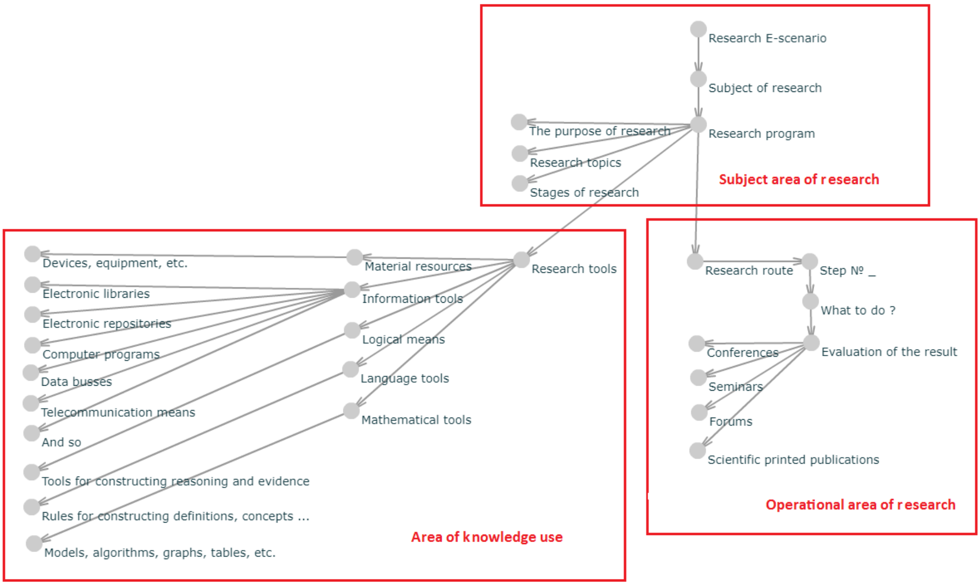

Fig. 1. The general ontological structure of organization of E-scenario of scientific research

The ontological model of E-scenario of scientific research presented (Fig. 1) comprises three system blocks. These blocks are as follows:

1. "Subject area of research" designed to formalize the links between research subjects and related research program, which in turn includes the research objective, research topics, and research stages.
2. "Knowledge Area" designed to formalize research tools into the knowledge base, which includes:
   - *Tangible resources*. These are, first and foremost, scientific research tools. Historically, the emergence of tangible resources is associated in time with the formation of empirical methods of research – observation, measurement, experiment. These tools are directly aimed at the investigated objects and play a major role in empirical testing of hypotheses and other results of scientific research, in the discovery of new objects, facts;
   - *Information tools* (computer technology, information technology, telecommunications equipment).
   - *Logical tools.* Means for drawing conclusions and formation of evidences to differentiate between true, objective arguments and false, intuitively

accepted ones. Examples of logical problems:

- What logical requirements must satisfy the considerations allowing drawing objectively true conclusions; how to control the nature of these considerations?
- What logical requirements should the description of empirically observable characteristics satisfy?
- In what way should the initial systems of scientific knowledge be logically analyzed, in what way should certain systems of knowledge be aligned with other ones (for example, in sociology and closely related psychology)?
- In what way should a scientific theory that allows for scientific explanations, predictions, etc. be developed?

- *Language tools* (rules for constructing definitions, concepts). In any scientific study, a scientist has to clarify the introduced concepts, symbols and signs, use the newset concepts and symbols. Definitions are always associated with language as a means of cognition and expressing knowledge. Rules for the use of languages, both natural and artificial, through which the researcher forms his reasoning and evidence, formulates hypotheses, draws conclusions, etc., are the starting points of cognitive activity. Knowledge thereof greatly affects the effectiveness of the use of linguistic cognition in scientific research.

- *Mathematical tools*. They allow considering objects abstractly from their contents in the form of numbers and sets, as well as to systematize empirical data, identify and formulate quantitative dependencies and patterns. Development of mathematical cognition tools has an increasing influence on the development of modern science; they also penetrate into the humanities, social sciences.

3. “Operational Research Area” designed to establish a research roadmap of step-by-step formalizing the procedure (“What to do”) for conducting research, and provides an “Outcome Assessment” of their implementation, which is discussed at various scientific meetings and in scientific publications.

General Characteristics of Available ICT tool for forming the E-scenario of Scientific Research

For the purpose of implementation in practice of a given E-scenario model of scientific research, ICT Knowledge Base Scenarios Editor has been developed.

Knowledge Base Scenarios Editor is a networked ICT designed to create a variety of knowledge base scenarios in a given subject area, which are stored in *xml*-files, enabling their local and personalized use. Created *xml* knowledge base scenarios can be merged into new information structures, thereby generating new E-scenarios of knowledge base, which in turn become objects for new E-scenarios, etc.

ICT Knowledge Base Scenarios Editor has a wide format of use, from the creation of simple personal information systems to complex operational object-oriented knowledge bases.

Conclusions

One of the promising directions for further improvement of the given model of E-scenario of scientific research is the development of methodological, ontological and logical bases of knowledge construction thereupon. Ontologies play a crucial role in describing the formation of such systems. This involves solving urgent problems associated with improved effectiveness of research. One of the perspective tasks of development of provided ICT is the creation of a system of ontological descriptions of various objects of scientific research in the process of research activities, which simultaneously becomes a means for mastering the methodology of scientific knowledge and formation of new research bases of knowledge.

The use of the proposed method of development of the ontological model of the E-scenario of scientific research allows making this process more personalized, and more mobile and unlimited in the format of electronic dissemination of knowledge. That is, the given system of knowledge formation allows forming both personal and collective knowledge bases. This task is accomplished as the researcher has the opportunity to use his/her own experience by elaborating the personal E-scenarios of knowledge formation and, if necessary, link them to other E-scenarios of knowledge of fellow researchers, or integrate their knowledge into their E-scenarios of knowledge, or deliver them personally to their colleagues, thereby sharing their knowledge in the professional field and creating creative scientific teams.

REFERENCES

Bera, Palash, Burton-Jones, Andrew and Yair Wand. Guidelines for Designing Visual Ontologies to Support Knowledge Identification. MIS Quarterly, 35(4), 2011: 883-908.

Boland, Richard J., Singh, Jahdip, Salipante, Paul, Aram, John D., Fay Sharon Y. and Prasert Kanawattanachai. Knowledge representations and knowledge transfer. The Academy of Management Journal, 44(2), 2001: 393-417.

Chao, Zhang, Guanghui Zhou, Qi Lu and Fengtian Chang. Graph-based knowledge reuse for supporting knowledge-driven decision-making in new product development. International Journal of Production Research, 55(23), 2017: 7187-7203.

Chandrasekaran, Aravind and Kevin Linderman. Managing knowledge creation in high-tech R&D projects: A multimethod study. Decision Sciences, 46(2), 2015: 267-300.

Fridman Noy, Natalya and Carole D. Hafner. Ontological foundations for experimental science knowledge bases. Applied Artificial Intelligence, 14(6), 2000:

565-618.

Gould, Nicholas and William Mackaness. From taxonomies to ontologies: formalizing generalization knowledge for on-demand mapping. Cartography and Geographic Information Science, 43(3), 2016: 208-222.

Greener, Sue. Methodological choices for research into interactive learning. Interactive Learning Environments, 26(2), 2018: 149-150.

Kogut, Bruce. The network as knowledge: Generative rules and the emergence of structure. Strategic Management Journal, (21), 2000: 405-425.

Krótkiewicz, Marek and Krystian Wojtkiewicz. Knowledge Acquisition in Conceptual Ontological Artificial Intelligence System. Human-Computer Systems Interaction. AISC, 60, 2009: 29–37.

Krótkiewicz, Marek and Krystian Wojtkiewicz. Conceptual ontological object knowledge base and language. Computer Recognition Systems Proceedings of the 4th International Conference on Computer Recognition, 2005, 227–234.

Leech, Stewart and Stephen G. Sutton. Knowledge management issues in practice: Opportunities for research. International Journal of Accounting Information Systems, 3(2), 2002: 69-73.

Leitner, Karl-Heinz and Campbell Warden. Managing and reporting knowledge-based resources and processes in research organisations: Specifics, lessons learned and perspectives. Management Accounting Research, 15, 2004: 33-51.

Manniche, Jesper, Moodysson, Jerker and Stefania Testa. Combinatorial Knowledge Bases: An Integrative and Dynamic Approach to Innovation Studies. Economic Geography, 93(5), 2017: 480-499.

O'Leary, Daniel E.. KPMG knowledge management and the next phase: Using enterprise social media. Journal of Emerging Technologies in Accounting, 13(2), 2016: 215-230.

O'Leary, Daniel E. Using AI in knowledge management: Knowledge bases and ontologies. IEEE Intelligent Systems, 13(3), 1998: 34-39.

Peffers, Ken, Tuunanen, Tuure, Rothenberger, Marcus A. and Samir Chatterjee. A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24(3), 2007: 45-77.

Pugh, Katrina and Luarence Prusak. Designing effective knowledge networks. MIT Sloan Management Review, Fall, 2013: 79-88.

Smedley, Georgia A. and Steve G. Sutton. Explanation provision in knowledge-based systems: A theory-driven approach for knowledge transfer designs. Journal of Emerging Technologies in Accounting, (1), 2004: 41-61.

Wenger, Etiene, McDermott, Richard and William M. Snyder. Cultivating Communities of Practice: A Guide to Managing Knowledge. Harvard Business School Publishing, 2002.