A.V. Palagin, Dr Sci. (Tech.)
V.M. Glushkov Institute of Cybernetics,
National Aacademy of Sciences of Ukraine
(palagin_a@ukr.net)

Ontology Conception of Transdisciplinary Scientific Research

One of the highest priority directions of modern community development is building a knowledge-oriented society (as a type of stage of information community development), in which most working people are in the line of work related to creation, saving, processing and implementation of information, especially its (information's) highest form — knowledge. Among other important problems, which are resolved at the current point of societal development, the problem of providing scientifically grounded, effectively presented and complete informational resources is especially worth emphasizing.

Одним из наиболее приоритетных направлений развития современного сообщества является построение общества, ориентированного на знание как стадию развития информационного сообщества, в котором большинство трудящихся занимаются работой, связанной с созданием, сохранением, обработкой и использованием информации, особенно ее высшей формы — знания. Среди других важных проблем, решаемых на современном этапе общественного развития, следует отметить проблему обеспечения научно обоснованными, эффективно представленными и полными информационными ресурсами.

K e y w o r d s: knowledge, subject domain, ontological approach, transdisciplinary (TD) research, unified network of TD-knowledge.

Intelligent Computer Systems. The theory and practice of knowledge-based system building and usage is the most important direction of Computer Science, one which is being developed intensively. This direction enables enhancing the effectiveness of computer technologies building and usage as well as applied systems and development tools.

The given problem is complex because it demands the construction, organizing and usage of the big formal knowledge bases and involving of a range of the scientific theories, which are to contribute to solving the know- ledge extraction problem, formal representation problem, and the problem of processing and system integration by providing the conceptual and methodolo- gical basis of the TD-research theory.

The building of ontology-driven Intelligent Computer Systems (ICS) for this type of research is closely linked with the theoretical foundations and methodology of design development, which include the fundamental principles of generalized system architecture and structure, the formal model and methodology for subject domain (SD) ontology designing as a whole, generalized algorithms for procedure of knowledge processing etc. In turn every listed component of generalized methodology of design is tied into complex research-applied problem solving.

For example, the development of SD-ontology determines the conceptualization of ontological categories, hierarchical structures of entities development and improvement at all levels, building of the formal system of axioms and limitations. The complex solution of the given design tasks is obvious to increase the role of ontological knowledge while solving the particular problems in applied fields [1].

TD-research integrates the essential basics of separate disciplines and corresponding technologies, creating clusters of their convergence on the basis of their high-powered mutual synergistic influence, and above all else appeals to the holistic picture of the world (in all its diversity) [2, 3], the creation of which has become the highest priority direction of the world scientific development.

One of the main tasks of TD-research is providing efficient TD-cooperation during all stages of the life cycle, solving the fundamental and applied scientific problems based on their comprehensive methodological support, integration process support, convergence and unified formal knowledge representation of TD-knowledge processes ensuring its effective computer processing.

Thus, the building of TD interaction systemology as a standalone area of knowledge has gained extreme import; this sphere is directed towards the discovery of new patterns as the result of system integration of existing scientific theories, forming of new concepts, categories and scientific theories, which enlarge the range of transdisciplinarity in the direction of the global integrated knowledge system and provide on the one hand the solution to the current scientific and technical tasks, and on the other hand the development of the knowledge system itself [3].

The implementation of the TD-research conception provides for a range of scientific research and research-related projects aimed at the development of the following [4]:

the systemology of TD interaction;

the TD-research process control systems (subsystems of monitoring, knowledge management, scientific and technical program management);

tools and systems of formal knowledge representation, methods for their processing, saving, integration and service support;

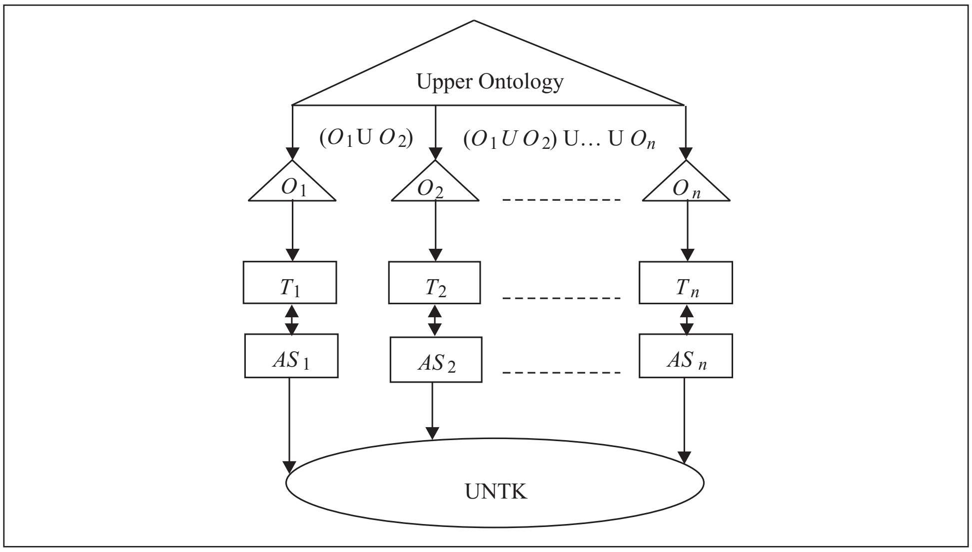

Fig. 1. The Architecture of the UNTK: O_1 — O_n — the ontology of SD; T_1 — T_n — formal scientific theory presentation; AS_1 — AS_n — corresponding applied systems

problem-oriented systems, including automated workstations for scientific researchers at all rank;

knowledge saving and intellectual property support systems;

applied systems of varied purposes (science, economy, sectors of the management, creating of scientific and innovation centers and virtual organizations, medical and economic monitoring, e-courses, personalized knowledge bases of researchers, etc.).

All of the developments listed appear to be focused in one way or another on the solving of the global task — creation of the Unified Network of Transdisciplinary Knowledge (UNTK). It was prepared by modern Internet in the form of the Semantic Web.

The network of TD-knowledge. The modern tools of information technologies with text processing, semantic analysis and generalization of semantic content greatly enable automation of the SD-knowledge description process. Every such description is represented by the following type of link "ontology — formal scientific theory presentation — applied system". Thus the architecture of the UNTK can be represented by Fig. 1.

The role of category-level ontology is to provide the interdisciplinary cooperation on the general language principle level. The role of the SD-ontology (in addition to the traditional functions of scientific theory conceptualization and specification) is to realize the ontological control on the ICS or SNTK-level.

The UNTK does not exist physically at the moment; it is in fact a superstructure above the existing Web which in turn keeps evolving in the Semantic Web direction.

The ontological approach to TD-research conception implementation. The ontological approach to information processing and knowledge representation was developed as an attempt to create a single standard of knowledge formalization in different fields of the study [3].

The basic ontological principles are given below:

1. The application of ontological approach to terminology superstructure building of knowledge system of SD;
2. The automation of knowledge extraction processes in the concept form, their ontological structuring and construction of SD-ontology. In the process methodology of automated design of the ontology of the SD (provided in [1]) is used;
3. The transition from "syntax" knowledge representation given by the classical explanatory dictionaries to their "semantic" and ontological representation;
4. The implementation of computer component ontological model, which enables the building of generally important knowledge representation of SD.
5. The system integration of ontologies of different SD to support complex research.

The ontological method development has made it possible to create the efficient tools for ICS-building, and most importantly, the technological basis for TD interaction and ontological engineering systemology as a part of modern Artificial Intelligence theory.

The ontological approach gives the user the whole systemic view of the field of study or the cluster of SDs, which make up the complex project. The ontological knowledge models enable the building of classes, objects, functional procedures and, finally, the formal theories; and the ontological technologies guarantee the scientific research and corporate information-analytical system building, starting with multivariate analysis of initial information resources and ending with collective decision-making and knowledge management systems.

The specific part of the modern stage of science development is the fact that the process of scientific world view and UNTK still falls behind the complex system TD project demands both in TD-research progress management terms (support for all stages of life cycle of the scientific research (SR)) and in knowledge management (procedures of knowledge formalization, generalization, actualization and assessment).

There is a lack of efficient methods of knowledge integration for different subject areas. In spite of this, the process of clustering (forming of convergence clusters) of scientific disciplines and technologies, which are united by joint development objectives, impact factors and feedbacks, has began and is continued presently (the well-known NBIC-cluster (nano-bio-information science-cognitive science) [2, 3]).

This process is accompanied by forming new scientific theories and disciplines and it appeals to the canonical form of concept definitions that allows creation of new concepts by performing the logic operations on the concepts (and in parallel with their definitions). The definition of the main part of a concept looks like the process of assignment of the conditional concept of species to the closest concept of genus, this process is based on genus-creating features (significant and distinctive): $X_{ij} = A_j X_i$, where X_i and X_{ij} — genus (decisive) and species (conditional) concepts, A_j — a set of species features.

The genus-species definition is the biggest representative, but not the only one. There are other sorts of definitions: genetic, operational, axiomatic, contextual, inductive and other ones. Let us point out that the correctness of the concept definition directly influences the quality of knowledge and therefore the completeness of the description of the subject areas and scientific theories. The forming hierarchy of basic categories (categorial stratification) plays the main role in TD-knowledge systems, because it is a system-building hierarchy.

Today there exist a number of onto-editors and onto-languages for traditional ontological approach to description of SDs or clusters compiled of them. The most widespread one is Ontological Web Language (OWL), which is the formal language for representation of ontological knowledge and it is possible to describe the onto-graph of SD-ontology using this language.

The standard of *e*-representation of SR results. One of the main stages of SR performance is the stage of efficient result generalization and representation. Its main goal is building the formal knowledge system, that on the one hand forms the structure of the problem scientific theory and provides the effective implementation of SR-results, on the other hand; i.e. the implementation of the chosen innovation-strategy. Such a wide integral representation of SR-results is to make them more available to the potential users. It makes sense to use a single standard for *e*-representation of knowledge gained as a result of SR.

Fig. 2 shows that the *e*-representation of SRW-results is an open information system in terms of IEE POSIX 1003.0 with open interface specifications and functions of extensibility, scalability, interoperability and portability of applications (from one computer system to another).

The development of the specified standard of representation of SRW results is an important step in *e*-Science paradigm development direction, where knowledge is represented explicitly using a constructive unified form, ready for specific solving of applied tasks, and the process of scientific research demands the collective effort of a number of teams of scientists with shared resources among them and the intensification of the processes of exchange of scientific results,

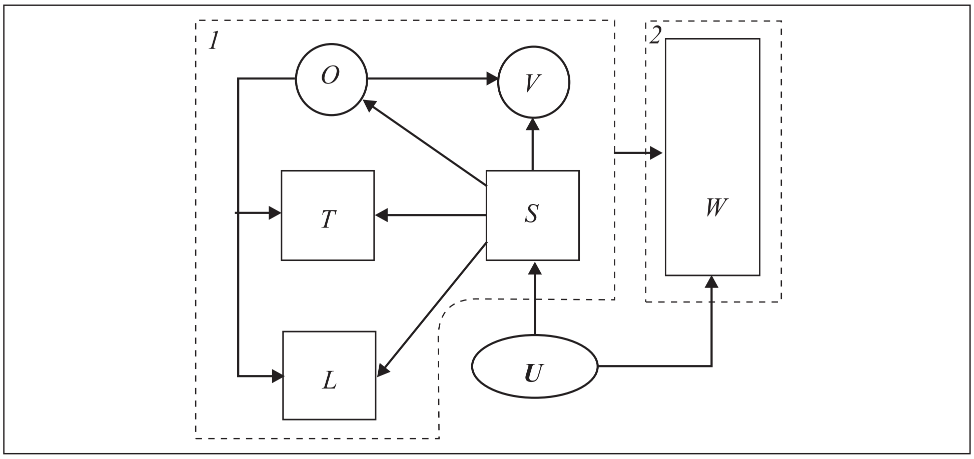

Fig. 2. The standard of e-representation of SRW-results: *O* — the ontological description of SD (ontograph, thesaurus of terms, the system of logic conclusion); *V* — figured component of ontological description (3D graphics, multimedia presentation of the surrounding reality objects); *T* — the SD representation on formal theory level; *L* — the full linguistic corpus, which represents the SD; *S* — subsystem of service-oriented architecture, the set of services which are provided to the users (taking into account the user's type); *W* — corporate Web-portal with a certain number of services; *U* — the user; *1* and *2* — subsystem of *e*-representation of knowledge

when traditional approaches cannot effectively support these processes and the corresponding information volumes.

Such union of resources and effective support on the main information infrastructure level on the scale of the field of science (including the academic field) leads to the opening of job positions for researchers connected via the local and global networks and supported on the level of communication environment as well as personal workstation.

The ontological paradigm. Today the computer ontologies are a quickly growing section of both theoretical and applied computer science. The relevance of this direction of research is made clear by these two main circumstances.

The first one concerns the fact that computer ontology technologies are at the same time the result of knowledge-engineering development as well as the tool of knowledge-engineering, meaning that they serve as the tool for scientific theory conceptualization as well as the field of study database specification and formalization, all the while executing the functions of classification, structuring, sorting and integrating and serving as a tool for knowledge usage.

The second circumstance is connected with the functions of ontology in modern knowledge space. It concerns the building of an effective mechanism for an information search using the information relevant to the user's request based on the user's primary knowledge system of the relevant field of study and on the adequate reflection of the object of his interest by using the structured semantic models, which connect the basic concepts with order-relations (genus — species, class — subclass, part — whole, object — property etc.), steady constructions organized using the more complex way of getting Internet requests and forming the answers with “well” defined semantics as well as semantic marking of resources.

The general objective of ontology is to compensate for the absence of knowledge representation standards during the user’s interaction with information systems and of the latter between each other.

The ontology of the real ontology-driven ICS in a general case contains three hierarchically linked components: meta-ontology, which deals with common concepts (in a broader case it is a language-ontological world view), domain ontology and the ontology of implementations.

The system-ontological approach. Common principles of building the ontology models with the goal of their practical application are provided below [1].

The system approach to knowledge points the analyst towards any SD from the viewpoint of the regularity of the system as a whole and the interaction between its sections. The knowledge consistency comes from the multi-level hierarchical organization of any essence, it means that all of the objects, processes and effects could be considered a number of smaller subsets (features, details) and, conversely, any object can (and should) be considered part of higher grade classes of generalizations.

The one of the main ideas behind the system-ontological approach is to develop the ontological tool to support solving of applied tasks — the multifunctional ontological system.

It is a well-known fact that the ontological approach does not have any limitations and every expert can understand this approach in accordance with his professional views. Except for one — it is necessary to represent the ontology model of the SD in an explicit form and to substantiate the necessity of using this particular model, which meets the requirements of the specific use.

Let us look at the provided computer model of SD-ontology, having paid especial attention to the distinctive features of such an ontology compared to the generally accepted ontological model. In a general case, the ontological model of a SD is described by the ordered triple [1]:

$$O = < X, R, F >,$$

where X, R, F are finite sets of concepts, semantic relations between the concepts and the functions of concept and/or relations interpretation.

Conclusion. The computer ontology is a formal expression of conceptual knowledge concerning the SD and its importance can be compared to the intellectual knowledge base of the computer system. Only the formal (computer) ontology of the SD allows the realization of all the functions listed above and the realization of knowledge-oriented information systems with ontology-driven architecture [5].

Одним з найприорітетнійших напрямків розвитку співтовариства є побудова суспільства, орієнтованого на знання як стадію розвитку інформаційного співтовариства, в якому більшість працюючих, зайняті роботою, пов'язаною із створюванням, збереженням, обробкою та використанням інформації, особливо її найвищої форми — знання. Серед інших важливих проблем, вирішуванним на сучасному етапі суспільного розвитку, слід відзначити проблему забезпечення науково обґрунтованими, ефективно представленими і повними інформаційними ресурсами.

REFERENCES

1. Palagin, A.V., Kriviy, S.L. and Petrenko, N.G. (2012), *Ontologicheskie metody i sredstva obrabotki predmetnykh znaniy. Monografiya* [Ontological methods and tools for field of subject knowledge processing. Monograph], The V. Dal Publishing House of the NEU, Lugansk, Ukraine.
2. Palagin, A.V. (2014), "Transdisciplinarity, computer science and the development of modern civilization", *Visnyk NAN Ukrainy*, no. 7, pp. 25-33.
3. Palagin, A.V. (2013), "The problem of transdisciplinarity and the role of computer science", *Cybernetics and Systems Analysis*, no. 5, pp. 3-13.
4. Kurgaev, O.P. and Palagin, A.V. (2015), "On the subject of information support for scientific research", *Visnyk NAN Ukrainy*, no. 8, pp. 33-48.
5. Palagin, A.V. and Yakovlev, Y.S. (2005), *Sistemnaya integratsiya sredstv obrabotki sistemnykh znaniy* [System integration of means of computer technology], UNIVERSUM-Vinnitsa, Vinnitsa, Ukraine.

Received 11.05.16

PALAGIN Alexandr V., Dr. Sc. (Techn.), Professor, Member of the National Academy of Sciences of Ukraine, Deputy Director of V.M. Glushkov Institute of Cybernetics of NAS of Ukraine. A. Palagin graduated from Kiev Polytechnic Institute in 1961. Scientific interests: intellectual computer systems.