Systems of Systems Concept in Knowledge Management

Alexander Petrovich Kamyshanov
Accounting and Audit Department
Plekhanov Russian Economic University
Moscow, Russian Federation
e-mail: a_kamyshanov@rbcmail.ru

Peter Ivanovich Kamyshanov
Accounting and Audit Department
Plekhanov Russian Economic University
Moscow, Russian Federation
e-mail: a_kamyshanov@rbcmail.ru

Abstract — **The development of new acquisition technologies is important function of knowledge management. They are realizing via powerful computer tools such as the Internet interactive hypermedia or the Large Knowledge Collider. But except powerful tools new cognitive concepts and procedures should be synthesized for knowledge evolution. The Systems of Systems approach gives the possibility to design knowledge bases network. In the framework of this concept meta-level knowledge base construction procedures are described for some problems solutions.**

Keywords-Systems of Systems; knowledge acquisition technologies

I. INTRODUCTION

Knowledge management (KM) appeared and developed as the new research area in computer science in dialectical conjunction with philosophy, epistemology, and theory of management. In modern economy KM is based on information technologies and cognitive science. Key concepts of KM are knowledge and education that can be treated as the business educational and innovative intellectual products and services, which can be transferred for a high value return. Otherwise they are looked as the productive assets for high competitive enterprise. Research methods of KM such as the construction of ontology for representing the main categories and entities in particular scientific domain, the rules formalization for logic inference to acquire new knowledge, and others give the possibility to get the new insight on already formed fundamental knowledge bases of the physics and the chemistry. The design of models for the knowledge evolution and development is one of the items in knowledge management. Spreading Piaget cognitive development theory for knowledge bases the two components model was proposed in [1]. One component is presented by ever changing content and structures as the other is realized by unchangeable functions.

II. THEORETICAL BACKROUND AND TOOLS FOR KNOWLEDGE ACQUISITION

The discovering of sources for stable and unchangeable true knowledge with the aim to incorporate them into ontology is one of the main problems in knowledge management. Inherently concepts in every area of research resulted democratic discussions of scientists with equal rights for the truth. However, every time it is not possible to consider the positions of different scientific schools via creation stable and unchangeable functions in ontology. Next example illustrates this thesis. In financial management and accounting the main categories and entities are defined by national legislations and standards. On the contrary in nature sciences such as the physics and the chemistry there are now laws and rules signed by the head of one or another state. Analysis has shown that in these cases most truthful, reliable, and confirmed by experiments knowledge are published in the textbooks for universities and encyclopedias. This statement is based as on multistage reviewing processes, numerous qualified readers, and free access for upper pointed publish sources, so on the great editors' responsibility before the future generations of students and researchers. No one can deceive the future.

On other side, in many problem domains ever changing content and structures of the ontology are representing by e-textbooks and various Wiki systems in the Internet hypermedia space [2]. The characteristic feature of these knowledge acquisition tools is the cooperative creation of new knowledge and paradigms by realizing every user possibility to change the content and items relations.

In the Internet hypermedia space knowledge are coming through Socialization, Externalization, Combination, Internalization (so-called SECI-process), which consider a spiraling evolution interaction between explicit and tacit knowledge resulted by their synergy [3]. But the young students with non formed stable knowledge component can be overloaded with information.

Following the new knowledge development paradigm, in which everyone is creating hypermedia content and information for Wikipedia and other bases, a learner or researcher has millions of information pieces at his fingertips varying in quality and relevance to the actual scientific work. Great amount of information may lead to the inability to discern between facts and concepts. The reason is the significant number of conflicting positions. Nevertheless the appearance of new Internet tribune for scientific discussions was the greatest achievement in democratization of science that accelerates the knowledge evolution. New research projects and programs are developing with the aim to raise the efficiency of knowledge acquisition systems. In European Union (EU) Framework Program 7 manages and coordinates the activity for creation the Large Knowledge Collider (LarKC). It is determined as

 ISBN: 978-1-61208-121-2

a platform for massive distributed incomplete reasoning directed to remove the scalability barriers of currently existing systems for Semantic Web [4].

So in our days two approaches for knowledge acquisition and development are realizing simultaneously. One is based on the Internet interactive multimedia hyperspace, while other is presented by LarKC technologies.

Thus the procedures synthesis for acquisition new knowledge by utilizing the potentials of LarKC and the Internet becomes extremely important item of agenda. Epistemology methods and the history of science have demonstrated that new knowledge appears as the results of hard experimental work that causes the evolution of insight within the problem domain of particular science. Otherwise the emergence of new paradigm gives the possibility to develop new theories. In some sciences, for example in mathematics, new knowledge results the hard theoretical work with already existing knowledge bases.

III. SYSTEMS OF SYSTEMS CONCEPT FOR KNOWLEDGE BASES

A. *Systems of Systems Engineering*

Every science can be looked as a complex system composed of subsystems. Each is characterized by hierarchy of interacting and networking components formed by concepts, laws, entities, and atomic terms described in ontology and united via logic inference constrains. Knowledge system of particular science is operating and coordinating as in conjunction with multiple objectives, so to evolutional perspectives. In the physics a hierarchy or continuum of laws as distinct systems or disciplines that are cooperating and interdependent was investigated in [5]. In biology system approach was introduced at the end of 1960th decade by the fundamental works [6][7]. The philosophy of systems engineering applied to real world had been developed in [8].

Traditionally every science was the logically separate knowledge system with little interdependence with others. The progress in knowledge management and information technologies is rapidly changing our world. Close relationship of different sciences and their interactions are the topics of current agenda.

Systems of Systems (SoS) engineering (SoSE) and analysis had appeared and developed in conjunction with space operations as well as large scale information systems and software design for them [9][10]. Research envisioned for SoS includes investigation oriented to the creation of new systems engineering methodologies to cope with SoS evolution and emergent knowledge associated with it.

Meta-model design is one of the powerful tools worked out in the framework of systems research [11]. Creatively applying it to SoSE for knowledge management we can describe the problem in the form of monotonous knowledge base for particular scientific domain.

Knowledge base KB constructed from logic declarations is considered monotonous, if for every declaration α and β the following statements are correct:

$$if\ KB \models \alpha\ then\ KB \wedge \beta \models \alpha. \quad (1)$$

In the case when declaration β breaks the KB monotonous property, in the ontology this declaration is considered as the new atomic term. The no contradiction logic is the main property for every scientific problem domain. It is ensured by collective efforts of researchers working all over the world in the various sciences.

As the problem knowledge base has been constructed, new scientific domains necessary for the solution should be investigated. In these domains monotonous segments of knowledge bases related to the problem should be determined. After that all segments are united in new monotonous meta-level knowledge base. Finally solution of the problem can be defined in the form of theorem proving by resolution method.

To illustrate the knowledge evolution model for the chemistry and the physics we can look at the category of the atomicity or the valence. The atomicity is important as for creation of semiconductor devices, so for determination the molecular structure of chemicals. It appeared at 1425 in the framework of medieval hermetic art. Later this category got the development in the chemistry and in the physics. In our days valence has found final formalization in quantum mechanics, where complex mathematical instruments and semantic phenomenological Pauli principle define it [12]. In this case, Pauli principle may be considered as an example of construction the meta-level knowledge base for description the atomicity properties.

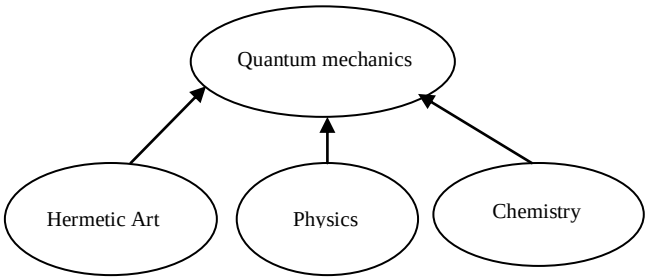

Figure 1. Knowledge bases network for definition the atomicity.

At the same time most other alchemy concepts modern chemists and physicists regard as pseudoscience.

B. *Systems of Systems Knowledge Engineering in Cardio Physiology*

There is one more example. At 1560th in Spain the great Renaissance doctor Andreas Vesalius tragically had discovered that human heart could operate independently from other systems of organism. Nevertheless, in this case the laws of hydromechanics for blood flow had to be realized.

In quite mode the minute blood flow volume over the man healthy heart is about $3 \sim 4 \times 10^{-3}$ m^3. The blood density (ρ) is approximately $1050 \sim 1064$ kg/m^3. The frequency of the cardiac rate at quite mode is near 72 strikes

per minute. Under hard physical load the frequency of the cardiac rate may increase till 210 strikes per minute and the minute blood flow volume rises up to 40×10^{-3} m^3. The square of the aortic valve, over which blood leaves the heart, is about 3×10^{-4} m^2. If the circle with the same square approximates valve's form, then the diameter of the circle d will be equal

$$d = 2 \times (S / \pi)^{0.5} \approx 2\times10^{-2}\, m\,. \quad (2)$$

Under this condition the blood flow (BF) over heart equals 3.6×10^{-3} m^3 and the initial velocity of the flow V_0 will be

$$V_0 = BF / S = 3.6\times10^{-3} / 3\times10^{-4} = 1.2\ m\ p.s. = 720\ m\ p.\ h. \quad (3)$$

For the minute blood flow volume equals 40×10^{-3} m^3, V_0 will be 8000 m p. h.

In the vessels blood liquid flow is considered to be continuous. At the aorta, by which arterial vascular system begins, the mean value of the hydrodynamic pressure for healthy heart is about 100 mm hg. col. According cardiology data in the right heart atrium, where venous loops are ending, the hydrodynamic pressure approximately equals 0 mm hg. col.

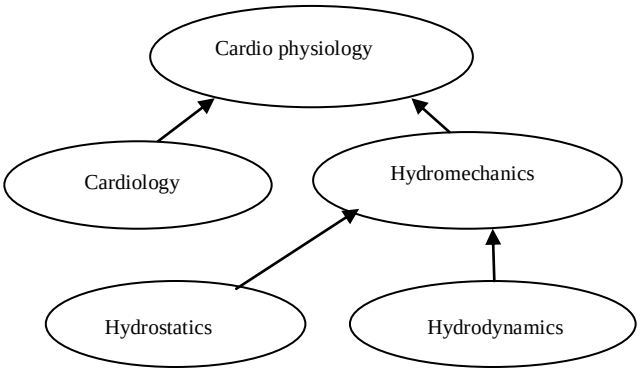

Figure 2. Knowledge bases topology for venous loop hydromechanics in blood circulatory system.

In [13] the theorem had been proved that in the venous loop of blood circulatory system the flow's pressure is defined by the laws of hydrostatics realizing in pulse mode.

As the consequence from the theorem, the continuity of blood flow over different organs in the body is provided by the venous valves operating in the definite way. Errors in the algorithm controlling the valves activity or their damage can cause the diseases of venous system, the heart failure, and trophic ulcer.

IV. META LEVEL KNOWLEDGE BASE AS HIDDEN VARIABLE

A. *Knowledge Base Engineering for Brain-Computer Interface*

At the beginning of 1990th IBM, Hewlett Packard, and Sony corporations started the sales of color monitors for the personal computers. These devices experimentally and publicly had demonstrated that human nerve fiber in optic track can transmit visual information (VI) with bit rate more than $135\ 109 \times 10^{12}$ bit/sec.

There are 1280 pixels over monitor horizontal and 1024 over vertical. Machine word in 32 bits executes the colors and brightness code. It is known from physiology, that more than 24 Hertz frame frequency is required to create illusion of moving picture. Thus

$$VI \geq 24 \times 1280 \times 1024 \times (2^{31} + 2^{30} + 2^{29} + ... + 2^{0}) \approx$$
$$\approx 31\ 457\ 280 \times 4.3 \times 10^{9} \approx 135\ 109 \times 10^{12}\ bit/sec. \quad (4)$$

From physics is known, that visual signals are transmitting in frequency spectrum spreading from 4×10^{14} till 8×10^{14} Hertz [14][15]. In common case healthy man and woman can get visual information traffic with lowest probability magnitudes of the first and second type errors.

At the same time, in [16] was pointed out that current brain–computer interface (BCI) had maximum information transfer rate up to 10 - 25 bits/min. This limited capacity could be valuable for people, whose severe disabilities prevent them from conventional communication method. There were declared, that future progress in multimedia neurophysiology interface development will be possible via involving neurobiology, engineering, mathematics, and computer science.

It is interesting fact that significant number of neurophysiologists has quite reliable visual systems providing lowest probability magnitudes of the first and second type errors for visual perception. Nevertheless they are persisting in following the concepts that nerve signals are transmitting by electrical impulses with voltage in few mill volts and maximum frequency in 500 Hertz. There is no one computer or telecommunication engineer, who can provide reliable transmission of the electrical signals with such parameters.

To solve this problem in [17] the next network with meta-level knowledge base as hidden variable was proposed [18].

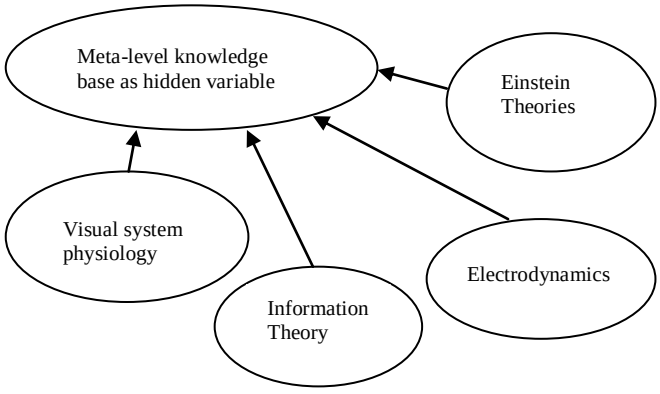

Figure 3. Cognitive model for visual system with meta-level knowledge base as hidden variable.

The investigation of the Internet hypermedia space had shown that to overcome the emergent difficulties new knowledge bases of biochronotopology and psychronotopology should be executed as hidden variable [19]. Concepts and categories defining by these knowledge bases could be very important for new research.

 ISBN: 978-1-61208-121-2

Examination of bio chronotopology category had led to new problems.

B. *The Problems of the "Time" Category*

Three dimensions of space and one dimension time had formed human perception of environmental world. "Time-dimension" is directed from past to present and from present to future. It is regarded, that such "time" direction is determined by "cause-effect" relation between events in physical world [20][21]. At another side the physical approach to the "time" category is not predetermined. In this science the "time" category has several different meanings.

First of all, "time" is looked at as independent continuous parameter in mathematical equations describing evolutions of physical systems.

The next, "time" is presenting the scale for determination the consequence of physical events. There are several types of such scales utilizing now. Astronomic scale is the main one. It defines the time intervals through the consequence of astronomic events, such as the rise and the setting of the Sun, consequent, following one after another two culminations of the observed star over the Earth particular meridian. Produced on the base of quantum frequency generators atomic "time scales" are also wide spread.

Additional meaning of the category "time" was realized in quantum mechanics, where the "fifth", the "sixth" and so on "time-dimensions" were introduced for "space-time continuum" [22][23]. These additional "time parameters" were orthogonal to traditional linear "time", and so the attempts were done to overcome the quantum uncertainty relation. However, as this aim had been reached, new approach had born out uncertainty in Einstein relativity theories [24]. Under the condition of "three-dimensional time" there wasn't presented any formula for the speed of light c determination. The speed of light c is considered as one of the fundamental physical constants. For authors' opinion, these scientific ideas have a great potential for development [25].

While in mathematical equations "time" is continuous variable, "time" determined by various physical scales has a discreet property.

Quantum physics characterizes atom as the system composed by nucleus with electrons' shells. Atomic systems can be united into complex molecular systems (Systems of Systems) existing in volatile SoS environment.

If the atomic quantum frequency standard determines the category "time" in molecular SoS, then serious problems can appear in description of molecular SoS evolution. Following N. Bohr postulates the frequency of the emitting radiation υ is equal to the quantity $(E_i - E_j) / h$ [26].

Here E_i , E_j - are the total energies of the stable electron's orbits, h – is Planck constant.

Under such approach, for physical "time" scale determined by atomic quantum frequency generator is impossible to define the "time" parameter characterizing evolution of the electron in atom at the stable energy state. Following modern quantum mechanics paradigm in the coordinate system connected with this electron it has neither past, nor future only present continuous. Moreover, in atom, for electron existing on the stable energy level the "cause-effect" relation is undetermined. In our days there are no technical tools defining category "physical time" for electron in a stable atom system.

Physical indetermination of "time" parameter for stable electrons' orbits put forward the question about physical meaning of parameter t in Schrödinger equation for wave function $\Psi(x, y, z, t)$ [27]

$$\left(-\frac{\hbar^2}{2m}\times\Delta + W(x, y, z, t)\right)\times\Psi(x, y, z, t) = i\times\hbar\frac{\partial}{\partial t}\Psi(x, y, z, t). \quad (5)$$

Here Δ - is Laplace operator, x, y, z, m – are electron's coordinates and mass, $W(x, y, z, t)$ – is the potential energy of electron in atom, $\hbar = h/(2\times\pi)$; $i = \sqrt{-1}$.

Chemical elements with significant atom numbers and protein macromolecules with complex three-dimension architecture have electrons' shells with complex topology. Schrödinger equations should be integrated for them [28]. The problem is that in modern textbooks for universities the "time" scales construction procedures for quantum objects don't determine. In control science this case is describing by fuzzy system paradigm [29][30][31].

V. PERSPECTIVES FOR KNOWLEDGE BASES SYSTEMS OF SYSTEMS CONCEPT

A. *Knowledge Management for Bio Cybernetics*

Bio cybernetics had demonstrated the possibility to model the complex biological system activity on the base of physical, chemical, hydromechanics' laws and the theory of automatic control. The results exhibited the experimental proofs for modeling human blood circulation at the definite range of environmental parameters were published in [32] [33][34] at 1970. There were shown that circulatory system dynamic could be modeled by the system of linear differential equations

$$\dot{X} = A(t)\times X + B\times u. \quad (6)$$

The research work for modeling cardio system activity continued in the next decades [35][36]. The electro-chemical model for the cardiac cell utilizing the system of differential equations with more than 50 parameters was proposed in [37]. The software tool to simulate cardiac cell activity was described and demonstrated in [38].

But as 40 years had passed no experimental results were published concerning the biological organs or the systems of any animal or human providing the integration of differential equations demanded for the blood circulation control.

The problem is extremely important for modern physiology. Several hundred millions of people are suffering from diseases of heart and circulatory system. To overcome the emergent difficulties the knowledge bases network is proposed, see Figure 4.

For authors' opinion, in nature the control algorithm for blood circulatory system is constructed on the base of fuzzy rules [30] in conjunction with multilevel qualitative

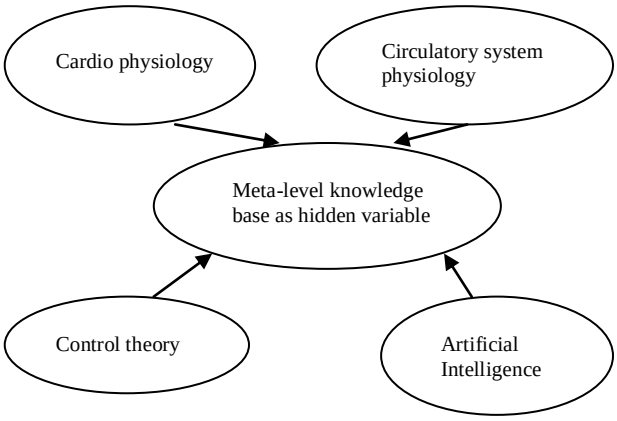

Figure 4. Cognitive model for circulatory system control with meta-level knowledge base as hidden variable.

reasoning trees [39] and qualitative induction logic inference [40]. Control signals are realizing as by bioelectrical impulses so by biochemical agents. With sufficient details they are described in the textbooks for medical universities.

B. *The Elementary Particles Physics Problems*

One more fundamental problem is studying in the modern textbooks for the chemistry and the physics. It is known from these sources that as hydrogen atom so neutron can be split on proton and electron. But while a hydrogen atom is considered to be a stable physical or chemical system, on the contrary, a free neutron has half life period about 10 minutes. The problem is that the properties of hydrogen atom are investigated by the chemistry or by the atomic physics, while properties of neutron are the subject of the elementary particles physics. This case also can be described by the network with monotonous meta-level knowledge base as hidden variable.

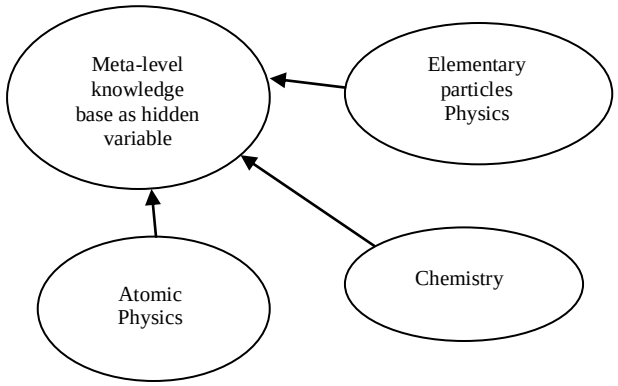

Figure 5. Cognitive model for hydrogen atom stability.

It was written in [41] that over the 20th century electronics had exhausted completely the atom model consisting of electrons orbiting the nucleus. New ideas are wanted to improve the matter structure model. Modern powerful computer tools such as the Internet interactive hypermedia space and LarKC can be utilized in the framework of SoSE concept to solve this problem. Scientific community has the real opportunity to estimate experimentally the efficiency of these acquisition tools and approaches.

New computer technologies provide the possibility to get new insights, which are determining as the new type of knowledge. So they give a chance to modify the current theoretical bases in various sciences. New insights have to be represented in explicit symbolic form [42]. Therefore, for authors' opinion, the Internet interactive hypermedia space is more suitable for discovering new scientific concepts than LarKC operating in the frame of monotonous logic formalism.

VI. Conclusion and Future Work

In general knowledge acquisition should be resulted by the development of new theories and their public recognition. Thus SECI processes will get their logical final. Modern computer technologies give the possibility to accelerate them. Systems of Systems engineering for construction the new knowledge bases can be applied for complex problems yet not solved.

In knowledge management SoSE concept has not only the advantages but the difficulties as well. For example, there are very few cardiologists realizing that the existence of the correct elements is not sufficient condition for reliable, correct operation of the control system. Stable functioning automatic control system can be designed from unstable units. It is necessary to know that blood circulatory system is referred to nonlinear, multi loops control systems, in which auto oscillation and sliding modes can exist. Under these conditions the stable operation of the cardiovascular system is determined not by electrocardiogram signals registration, the arterial pressure and pulse frequency measurement but by the methods of control theory.

On the other side, no more than one hundred researchers in the automatic control domain possess the knowledge about the structure of blood circulatory system, the peculiarities of the arterial and the venous vascular loops, about biophysical and biochemical processes in the blood. So in the case, when, for example, high level ontology in cardiology with great efforts and expenses will be created, none scientist will be able to work with full-scale version. To great concern, this statement is true for the problems of the Elementary particles physics and the fuzzy logic systems.

Practice has shown, the collective research work is the most effective way for unification the ontology of different sciences. As the result, new knowledge management methods will appear. These methods must be published in the textbooks for universities.

Now Systems of Systems engineering is intensively executed in financial management. For authors' opinion, in this area international cooperation will be very fruitful.

References

[1] C. Stickel, M. Ebner, and A. Holzinger, "Useful oblivion versus information overload in e-learning elxamples in the context of Wiki systems," Journal of Computing and Informational Technology, vol. 16, Dec. 2008, pp. 271-277.

 ISBN: 978-1-61208-121-2

[2] H. Maurer, "Web-based knowledge management," IEEE Computer, vol. 31, (3), 1998, pp. 122-123.

[3] I. Nonaka and H. Takeuchi, The Knowledge Creating Company. Oxford: Oxford University Press; 1995.

[4] M. Witbrock, "Acquiring and using large scale knowledge," Proc. 32nd Int. Conf. on Information Technology Interfaces (ITI2010), Univ. Comp. Centre, Univ. of Zagreb, Jun. 2010, pp. 37-42.

[5] R. Feynman, The Character of Physical Law, Cambridge, Massachusetts: MIT Press, 1965.

[6] M. Mesarovic (Ed.), Systems Theory and Biology, New York: Springer-Verlag, 1968.

[7] M. Mesarovic, D. Macko, and Y. Takahara, Theory of Hierarchical, Multilevel Systems, New York: Academic Press, 1970.

[8] A. Gheorghe, Applied Systems Engineering, New York: John Wiley & Sons, 1982.

[9] A. Sage, Systems Engineering, New York: John Wiley & Sons, 1992.

[10] A. Sousa-Poza, S. Kovacic, and Ch. Keating, "System of Systems engineering an emerging multidiscipline," Int. J. System of Systems Engineering, vol. 1, Jan. 2008, pp.01–17.

[11] A. Hall III, Metasystem Methodology: A New Synthesis and Unification, New York: Pergamon Press, 1989.

[12] J. Bell, Speakable and Unspeakable in Quantum Mechanics, Cambridge: Cambridge University Press, 1987.

[13] A. Kamyshanov, "Semantic model design for veins' loop by the logic formalism of Artificial Intelligence," Proc. 16th IASTED Int. Conf. on Applied Modelling and Simulation (AMS2007), ACTA Press, Aug. 2007, pp. 336-341.

[14] J. Seleznev, The Bases of the Elementary Physics, Moscow: Nauka, 1974.

[15] S. Palmer, Vision Science: Photons to Phenomenology, Cambridge, Massachusetts: MIT Press, 1999.

[16] J. Wolpaw, N. Birbaumer, D. McFarland, G. Pfurtscheller, and T.Vaughan, "Brain-computer interfaces for communication and control," Clinical Neurophysiology: Official Journal of the International Federation Neurophysiology, vol. 113, Jun. 2002, pp. 767 – 791.

[17] A. Kamyshanov, "Meta-model design for Internet multimedia neurophysiology interface," Proc. of 3rdAMS2009, Asia International Conference on Modelling and Symulation (AMS2009), IEEE Com. Societ. CPS, May 2009, pp. 632-636.

[18] S. Russell, J. Binder, D. Koller, and K. Kanazawa, "Local learning in probabilistic networks with hidden variables," Proc. of 14th International Joint Conference on Artificial Intelligence (IJCAI-95), Montreal: Morgan Kaufmann, 1995 pp. 1146-1152.

[19] A. Dubrov, Symmetry of Biorythms and Reactivity, New York, London, Paris: Gordon and Breach Science Publishers, 1988.

[20] J. Dorling, "The Dimensionality of time," American Journal of Physics, vol. 38, (4), 1970, pp. 539-540.

[21] Yu.Vladimirov, N. Mitskievich, and J. Horsky, The Space, Time, and Gravitation, Moscow: Mir Publishers, 1987.

[22] F. Tangherlini, "Atoms in higher dimensions," Nuovo Cimento, vol. 14, (27), 1963, pp. 636-651.

[23] Xiadong Chen, "A New Interpretation of Quantum Theory | Time as Hidden Variable," Department of Physics, University of Utah, Salt Lake City, UT-84112, 1999. Available on: *http://authors.aps.org/eprint/files/1999/Feb/aps1999feb10_004/auxiliary/New_Interp.ps*

[24] A. Einstein, The Collected Scientific Works, v. 1-4, Moscow: Nauka, 1965-1967.

[25] R. Penrose, The Large, the Small and Human Mind, Cambridge: Cambridge University Press, 1997.

[26] N. Bohr, The Three Articles about Spectrums and Atom Structure, translated from German, Moscow, 1923.

[27] Available on: http://hyperphysics.phy-astr.gsu.edu/HBASE/quantum/

[28] M. Lockwood, Mind, Brain, and the Quantum, Oxford: Basil Blackwell, 1989.

[29] L. Zadeh, Fuzzy Sets and Application, New York: John Wiley & Sons, 1987.

[30] R. Yager and L. Zadeh, An Introduction to Fuzzy Logic Applications in Intelligence Systems, New York: Kluwer Academy Publishers, 1991.

[31] L. Zadeh, "Fuzzy logic, neural networks, and soft computing," Comm. ACM, vol. 37, (3), 1994, pp. 77-84.

[32] B. Petrovskij, V. Shumakov, V. Novoselcev, E. Shtengold, V.Baikovskij, L. and A. Dartau, "Vital important human organism functions providing is the base of Artificial Heart automatic control," Proc. IFAC 1st Int. Symp. Technological and Biological Problems of Control, 1968, Erevan, USSR, Bioelectrical Control. Man and Automatic Systems, (Moscow: Nauka (Science), 1970, (in Russian), pp. 278-287.

[33] J. Krasner, P. Nardella, and P. Voykydis, "Cybernetic problems of the device for physiological control of Artificial Heart," Proc. IFAC 1st Int. Symp. Technological and Biological Problems of Control, 1968, Erevan, USSR, Bioelectrical Control. Man and Automatic Systems, (Moscow: Nauka (Science), 1970, (in Russian), pp. 265-275.

[34] W. Pickering, P. Nikiforuk, and J. Merriman, "The Use of analog computer for analysis of control mechanism in cardio vascular system," Proc. IFAC 1st Int. Symp. Technological and Biological Problems of Control, 1968, Erevan, USSR, Bioelectrical Control. Man and Automatic Systems, (Moscow: Nauka (Science), 1970, (in Russian), pp. 408-421.

[35] C. Luo and Y. Rudy, "A Dynamic model of the cardiac ventricular action potential," Part I, II, Circulation Research, vol. 74, (6), 1994, pp. 1071-1113.

[36] Y Lecarpentier, C. Coirault, and D. Chemla, "Regulation cellulaire et moleculaire de la contruction cardiaque," Medecine Therapeutique, vol. 2, (2), 1996, pp. 113-122

[37] R. Roche, R. Lamanna, M. Delgado, F. Rocaries, and Y. Hamman, "Calcium homestasis and membrane potential in cardiac myocite: an electrochemical model," Proc. of 5th EUROSIM Congress on Modelling and Simulation, France, Paris, 2004.

[38] R. Roche, R. Lamanna, M. Delgado, F. Rocaries, Y. Hamman, and F. Peker, "A Software tool for the simulation of a cardiac cell," Proc. 16th IASTED Int. Conf. on Applied Modelling and Simulation (AMS2007), ACTA Press, Aug. 2007, pp. 336-341.

[39] B. Kuipers, Qualitative Reasoning: Modeling and Simulation with Incomplete Knowledge, Cambridge, Massachusetts: MIT Press, 1994

[40] D. Šuc, "Machine reconstruction of human control strategies," Frontiers Artificial Intelligence Appl., vol. 99, Amsterdam: IOS Press, 2003.

[41] D. Packard, The HP Way. How Bill Hewlett and I Built Our Company, Cambridge, Massachusetts: Harvard Business School Press, 1995.

[42] I. Bratko, "An Assesment of machine learning methods for robotic discovery," Journal of Computing and Informational Technology, vol. 16, Dec. 2008, pp. 247-254.

 ISBN: 978-1-61208-121-2