METHODOLOGICAL AND TECHNICAL BASIS FOR INTERDISCIPLINARY INVESTIGATION IN THE FIELD OF CYBER-PHYSICAL-SOCIO SYSTEMS

Boris Sokolov[(a)], Semyon Potryasaev[(b)], Karim Benyamna [(c)], Irina Sokolova [(d)], Dmitri Ivanov[(e)]

[(a),(b)]SPIIRAS — St. Petersburg Institute of Informatics and Automation, Russian Academy of Sciences, 14th line 39, St. Petersburg, 199178, Russia
[(a), (b), (c)]ITMO University — St. Petersburg National Research University of Information Technologies, Mechanics and Optics, 13 Gdanovskaya str., St. Petersburg, 197198, Russia
[(d)] St. Petersburg University, Universitetskayz emb., 7–9, St. Petersburg, 199034, Russia
[(e)] Department of Business Administration, Berlin School of Economics and Law, Badensche Str. 50–51, 10825 Berlin, Germany

[(a)]sokolov_boris@inbox.ru, [(b)]semp@mail.ru, [(c)] benyamna.karim@gmail.com,
(d) i_sokolova@bk.ru, [(e)]divanov@hwr-berlin.de

ABSTRACT
The main objects of our investigation are cyber-physical-socio space and systems (CPSS). The cyber-physical-socio space is the fusion of the physical space, the cyber space, and the socio space. The problem of CPSS complexity management and control is modern and current. The solution of this problem involves interdisciplinary research studies by specialists in mathematics, economics, sociology, biology, physics, and computer technologies. However, the founders of cybernetics imparted to its laws much more universality than is really considered in today's social and business systems. Therefore, the paper presents the results of the methodological and technical basis for interdisciplinary investigation and development in the field of CPSS, which are interrelated with a new scientific branch named neocybernetics.

Keywords: interdisciplinary research, cyber-physical-socio space and systems, neocybernetics, control and management, integrated modelling and simulation.

1. INTRODUCTION

As a result, of the continuing scientific and technical revolution, which began in the middle of the XXth century, a significant amount of complex objects appeared (nuclear power plants, space equipment, electronics, computers, etc.). Their research, description, design and management presents important difficulties and problems. Cyber-physical-socio space and systems (CPSS) are striking examples of complex systems. So today, we witness a transformation from industrial society, which is based on cyber-physical space to informational society, which is interrelated with cyber-physical-socio space and systems (Zhuge H. 2011; Zhuge H. and Xu B. 2010). The technologies to control this transformation need regulation and structuring at the macro and micro levels. This inspires a renewed interest in the theoretical background of control problems. Unfortunately, the logically relevant chain of fundamental notions: Cybernetics – Control – Informational processes – Universal transformer of information (computer, cybernetic machine) was split. The expansion of computer technologies created an illusion of their ability to solve any problem. Imperfections of these technologies have already caused catastrophes that led American and European scientists to proclaim establishment of "Risk society" rather than "Informational society" one (Gerasimenko V.A. 1993; Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006; Zhuge H. 2011).

Two main reasons stimulate the importance of the new cybernetics in the modern world. The first one concerns the problem of complexity, which has various applications and aspects (structural complexity, complexity of functioning, complexity of decision making, etc).

For example, (Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006), CPSS attributes are characterized by the following properties: high complexity and dimensionality with such features as redundancy; multi-functionality; distributed elements; unification; uniformity of main elements, subsystems and inter-relations; structure dynamics; non-linear uncertain behavior; hierarchical network structure; non-equilibrium; uncertainty of observer selection and interaction with them; dynamic rules and regulations; counteracting and amplifying relationships with self-excitation; possible chaotic behavior; no element has enough information about the whole system; selective sensitivity to input actions (dynamic robustness and adaptation); the response time is greater than the time between input actions, and it is greater than the time of supervention; the real object of control cannot have a complete and reliable description (in accordance with Bremerman's limit and Godel's theorem).

Moreover, if we want to interpret CPSS as a socio-humanitarian cyber-system, some media-culture attributes were proposed. Understanding the CPSS media as the objects and technologies providing transfer of experience by creating specific forms of interaction based on the transfer of culture mechanisms, we investigate media culture — as stages of evolution of various forms of mediation. The phenomenon of a media environment allows speaking about the formation of the new sociocultural and philosophical outlook based on the recognition of the special "reality" defining strategy of life, perception and understanding, reality of cyber-physical-socio systems.

Addressing the question of morphology of virtual art, it should be noted that prompt distribution digital, and, in particular, computer technologies of creation of virtual projects of reality, have received lighting in a set of the scientific directions and spheres of life, the majority of which are far outside the sphere of art. From the theory and history of art artists move in the direction of the analysis of "art science" (Gran O. 2003) as the practice of immersion to systems of communications of various media forming the existential grids catching fluctuations of the field of reality and turning them into elements of art projects. Such experiments become steps on the way of "a projection of computer ontology in culture" (Manovich L. 2002). The close interlacing of real-virtual-cultural-social under a common denominator media in the modern world gives a clear understanding of the expanding sphere of influence of art, its invasion into external and internal limits of the viewer (Manovich L. 2002).

The second reason is the lack of holistic (system) thinking in the IT industry. The problem of complexity control and management involves interdisciplinary research studies by specialists in mathematics, economics, biology, physics, and computer technologies. However, the founders of cybernetics imparted to its laws much more universality than is really considered in today’s social and business systems. Therefore, the paper presents the results of interdisciplinary research in the field of computer modeling and decision support systems in socio-cybernetics objects (Gerasimenko V.A. 1993; Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006; Zhuge H. 2011; Heikki and Hyötyniemi 2006).

At the beginning of the XXIst century, the specified objective circumstances, which are connected with CPSS resulted in need of a formation of a wide range of experts on system outlook and the relevant system branch of scientific knowledge.

It has been shown in many works (Gerasimenko V.A. 1993; Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006; Yusupov R.M. and Zabolotskii V.P. 2000) that when speaking about the interdisciplinary branch of system's knowledge, it is expedient to select in it two big sections (block) — the block of fundamental system info - cybernetic knowledge and the block of applied system info - cybernetic knowledge. In the first of the listed blocks, the defining role is played by three scientific directions — the general theory of systems, cybernetics and informatics.

General theory of systems (sistemologiya). This scientific direction sets the task to construct the general scientific bases for systems of any nature. The central concept of the general theory of systems is the concept of open system, i.e., the system, which is implemented by a two-sided interaction with the environment. Mathematical basics of the general theory of systems can be reasonably considered an interpretation of the bases of mathematics, mainly theories of the relations (the concept of the relation is fundamental both in mathematics, and in system researches), theories of mathematical structures, and the theory of categories and functor (Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006). However, except for a number of recognized general provisions in general for the present there is no uniform understanding of in what way this theory has to be submitted.

Informatics. This scientific direction connected with the development of methods and means of collecting, storage, transfer, representation, processing, and information security.

Speaking about processes of interaction of cybernetics with informatics, it should be noted, first, that historically the last one developed in a subsoil of traditional cybernetics, actually on a uniform technical base — computer facilities and means of communication and data transmission, and, secondly, cybernetics, being science about the general laws and regularities of management and communication. In recent years, the second round of rapprochement of cybernetics and informatics has been noted. There is an active terminological and substantial interpenetration of these scientific directions, issues of use of information for the benefit of management

Therefore, the methods, technologies and means developed in informatics actively take root in cybernetics within such new scientific directions as: information management, different types of intellectual management (situational, neuro-management, the management based on knowledge, on the basis of evolutionary algorithms, multi-agency management and control, etc.). These types of intellectual management are based on the appropriate intellectual information technologies (IIT) focused on symbolic information processing.

It is accepted to refer to the specified information technologies (Gorodetskii V.I., Kotenko I.V., and Karsaev O.V. 2000; H. Wong and K. Sycara, 2000; Yarushkina N.G. 2004; Omatu S., Khalid M., and Yusof R. 1996; Vasiliev S.N., Zherlov A.K., Fedosov E.A., and Fedunov B.E. 2000; Timofeev A.V. and Yusupov R.M. 1994): technologies of expert systems (Expert Systems) or systems based on knowledge (Knowledge-Based Systems); technologies of fuzzy logic (Fuzzy Logic); technologies of artificial neural networks (Artificial Neural Networks); technologies of displaying, based on precedents (Case Based Reasoning, CBR) CBR technologies; technologies of natural language systems and ontology; technologies of associative memory; technologies of cognitive mapping and operational coding; technologies of evolutionary modeling.

General theory of management (cybernetics). Initially, the founder of cybernetics, N. Winer, in 1948 in the book

"Cybernetics or Management and Communication in an Animal and the Car" emphasized that this science is science about management, communication and processing of information in systems of any nature (Wiener N. 1948, Wiener N. 1950). At the same time, the main goal of the research conducted within the specified science consisted in the identification and establishment of the most general laws of functioning to which the operated objects, and the corresponding managing directors of a subsystem irrespective of their nature are submitted. The classical cybernetics has reduced all earlier existing views of management processes in a uniform system and has proved its completeness and generality. In other words, it has shown in detail the raised power of system approach to the solution of complex problems. The most developed direction in cybernetics was the theory of management of dynamic technical systems within which numerous outstanding fundamental and applied scientific results have been received by domestic and foreign experts.

In turn, cybernetic terminology gets into informatics and computer facilities. Today, in particular, concepts and the strategies of adaptive and pro-active computer systems, adaptive management and the adaptive enterprise are very popular in the IT industry. These strategies are intensively developed by the companies IBM, Intel Research, Hewlett Packard, Microsoft, Sun, etc. (Chernyak L. 2003, Chernyak L. 2004, Dmitrov A. 2006). At the same time, the material basis for the realization of technologies of the operated self-organization is created. In the modern business systems (BS) only those organizations obtain success in which development of IT of architecture is focused on the Web services and technologies allowing effective decentralization of traditional systems of decision-making, turning them into self-regulating subsystems. Interaction of cybernetics (neocybernetics) and informatics with the general theory of systems is carried out in several directions. The first of these is directly connected with the generalized description of objects and subjects of management on the basis of the new formalistic approaches developed in a modern systemology to which it is possible to refer, for example, structural and mathematical and category-functor approaches (Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006). In this regard, it is also possible to note interesting scientific results, which have been received in a qualimetry of models and multiple-model complexes and can be used in informatics and cybernetics. The methods and algorithms of decomposition (composition), aggregation (disaggregation), and coordination developed in the general theory of systems in relation to objects of any nature are widely used in cybernetics and informatics also to solve problems of collecting, storage, transfer, representation, processing, information security, and also management of complex objects. On the other hand, it has been shown in several studies (Vasiliev S.N., Zherlov A.K., Fedosov E.A., and Fedunov B.E. 2000; Timofeev A.V. and Yusupov R.M. 1994) that the approaches developed in the classical theory of management and control of technical objects and also in modern informatics can be applied successfully to the organization of processes of management of quality of models and multiple-model complexes, and also their structural and parametric adaptation.

2. METHODOLOGICAL AND TECHNICAL BASIS OF NEOCYBERNETICS

The analysis of the neocybernetic fields has shown that this theory is an inter-disciplinary science oriented at analysis and synthesis of intellectual control systems for complex arbitrary objects (Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006; Zhuge H. 2011; Heikki and Hyötyniemi 2006). These systems operate with both deviation-counteracting and amplifying mutual casual relationships and are able to model the environment and themselves in the environment (the cybernetics of the observer enclosed in the system). The subject of neocybernetic investigation is scientific basics of structure-functional analysis, monitoring, and synthesis of adaptive self-organizing intellectual control and management technologies for cyber-physical-socio systems (CPSS).

A few words about neocybernetic history. The renovation of cybernetics has two sources. The first source lies in the attempts to revise methodological backgrounds of cybernetics. As early as in 1963 Magorah Maruyama focused on the systems in which the mutual causal effects are deviation-amplifying. Economic, social and biological examples were considered (Maruyama M. 1963). In contrast to Weiner's cybernetics with deviation-counteracting systems, the studies of deviation-amplifying mutual casual relationships were called "the second cybernetics" (Foerster, von H. 1987, Foerster, von H. 1974). In 1974, Heinz von Foester defined "the second-order cybernetics" with the awareness that an observer is an element of the system. The studies considered processes resulting in increased biological and social complexity (Heikki and Hyötyniemi 2006). Stafford Bear in his works starting in 1974 emphasized that investigations into complexity problems should evolve Ashby's law of requisite variety (Bir S. 1963).

The analysis of modern cybernetics has allowed proposal of several directions respecting this law and establishing concepts of neocybernetics (Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006; Sokolov B.V. and Yusupov R.M. 2008; Sokolov B.V. 2010) (see fig. 1).

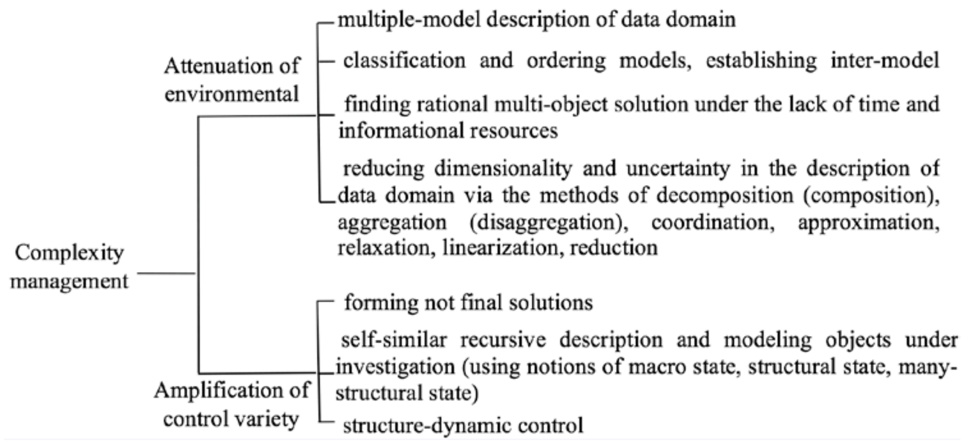

Figure 1: Directions For Realizing The Law Of Requisite Variety

The second source of renovation in cybernetics is the interaction with other scientific disciplines within the system concept. The leading role in establishing neocybernetics belongs to informatics and general systems theory.

In recent years, a new stage of convergence between informatics and cybernetics has occurred. Thus, methods, technologies, and tools of informatics are widely used within new branches of cybernetics such as informational control, evolutionary algorithms, multi-agent control, etc. In turn, cybernetic notions are widely used in the IT industry: adaptive and proactive computer systems; adaptive control and adaptive enterprise.

Now let us consider preliminary composition, structure, main objects, goals, tasks, unsolved problems, and subjects of the XXIst century cybernetics. The peculiarities of control systems, and environmental impacts require sufficiently new approaches to methodological basis of cybernetics. In order to emphasize this novation, the term neocybernetics should be used.

Goals of neocybernetics lie in the creation of cybernetic systems of new generation with the following features: proactive control; abilities of self-actualization, self-reconfiguration, self-perfection, self-optimizing, self-treatment, and self-preservation; public behavior; sociability; kindness; honesty.

The main notions of neocybernetics include complexity, structure dynamics, emergent property, macro states, structural states, many-structural states, proactive control, integrated modeling, and qualimetry of models and multiple-model systems.

The main tasks of neocybernetics are the following: Complexity management including attenuation of environmental variety; amplification of control variety; the tasks of decomposition (composition), aggregation (disaggregation), coordination, approximation, relaxation, linearization, reduction in modeling, analysis and synthesis of CPSS; structure dynamics control for CPSS; models qualimetry; traditional tasks of the first-order cybernetics.

The main unsolved problems of neocybernetics include organization and conducting interdisciplinary investigations for CPSS development; examining basic characteristics of for CPSS (self-configuring, self-service, self-optimizing, fault tolerance, self-preservation) and influences upon these characteristics; construction of methods, algorithms, and models for analysis and synthesis for CPSS; analysis of user interaction for CPSS; analysis of biological analogues for synthesis of CPSS.

Methodology and technique of neocybernetics for CPSS control and management are based on the concept of proactive monitoring and control, which assumes incident prevention through creating radically new forecasting and preventing opportunities when forming and implementing the control actions. Table 1 presents the main scientific results, which we have obtained in the field of neocybernetics by now (Kalinin V.N. and Sokolov B.V. 1995; Okhtilev M.Yu., Sokolov B.V., and Yusupov R.M. 2006; Sokolov B.V. and Yusupov R.M. 2006; Yusupov R.M. et al. 2011).

Table 1 presents opportunities of proposed methods and algorithms, which constitute the description of integrated intellectual decision support systems for proactive management and control of CPSS, as well as combined methods of operative synthesis of hierarchical network structures of decision support systems for proactive management of CPSS as part of managing complex organizational and technical objects.

Table 1: The Main Achievements of the Proposed Methodology and Technique

Achievements	Shortcomings	Opportunities
1. Dynamic multiple-model description of CPSS functioning at the different stages of their life cycle [	1. Different types of models (analytical-simulation, logical algebraic, logical-linguistic models) are used for the description and study of main CPS attributes.	1. Joint use of diverse models in the framework of poly-model systems, allows improvement of the flexibility and adaptability of CPSS, as well as compensation for the drawbacks of one class of models by the advantages of the others.
2. Combined methods and algorithms of models coordination and adaptation.	2. Now several procedures and techniques are proposed to arrange and conduct integrated modeling, which may be different in the methods of generating admissible alternative, solutions, the rules for testing constraints given in the analytical or algorithmic form, and the methods of transition from one step of interactive restriction of the set of admissible alternatives to another.	2. The adaptive plans (programs) of CPSS functioning include transition programs as well as programs of stable CPSS operation in intermediate multi-structural macro-states. One of the main opportunities of the proposed method of CPSS SDC program construction is that besides the vector of program control we receive a preferable multi-structural macro-state of CPSS at the end point of control interval. This is the state of CPSS reliable operation in the current (forecasted) situation.
3. Methodological and technical basis for the synthesis and intellectualization of monitoring technology and systems for complex technical objects.	3. Flow-oriented knowledge-representation models, methods, and algorithms for monitoring and control of CPSS are widely used in different applied areas now (power grid system, virtual enterprises, applied areas of space).	3. The proposed methods of monitoring automation and modeling allow switching from the heuristic description of telemetry analysis to a sequence of stages of monitoring program contraction and adaptation, from unique skills to unified technologies of software. These methods are based on the conclusion that a functional description of monitoring and control process is much less complicated than a detailed examination of software realizations.

3. EXAMPLE OF CPSS MODELLING AND SIMULATION

As an example of the integrated modeling and simulation based on the CPSS, we developed an analytical model for time-table of trains, a simulation program (Fig. 2) and an experimental stand (Fig. 3) with a transport network (for example, railroad); additionally, some production and warehouse facilities are currently under development. The railroad is provided with multiple sensors, for example the RFID, which provide information about the position and the speed of the bypassing locomotives. We note that the RFID experimental environment is not intended (at least, in its current version) for a full implementation of the developed models. It is much simpler as a modeling framework and serves to gather experimental data for the modeling complex. The modeling complex itself is implemented in a special software environment, which contains a simulation and optimization (analytical) engine of planning and execution control, a Web platform, an ERP system, and APS system, and a SCEM system (Morozov V.P. and Dymarskii Ya.S. 1984; Chernyak L. 2003; Chernyak L. 2004; Dmitrov A. 2006). The cornerstone of the computational framework is the decision modeling component, that is, the simulation and optimization engine. The schedule optimization is based on an optimal control algorithm that is launched by a heuristic solution, the so-called first approach.

The seeking for the optimality and the transport network control system (CS) scheduling level is enhanced by simultaneous optimizing and balancing of interrelated CS functional, organizational and information structures.

We note that the RFID experimental environment is not intended (at least, in its current version) for a full implementation of the developed models. It is much simpler than the modeling framework and serves to gather experimental data for the modeling complex. The modeling complex itself is implemented in a special software environment, which contains a simulation and optimization engine of CS planning and execution control, a Web platform, an ERP system, and APS system, and a SCEM system. The kernel of the computational framework is the decision modeling component, that is, the simulation and optimization engine. The schedule optimization is based on an optimal control algorithm that is launched by a heuristic solution, the so-called first approach. The search for the optimality and the CS scheduling level is enhanced by simultaneous optimizing and balancing of interrelated CS functional, organizational and information structures.

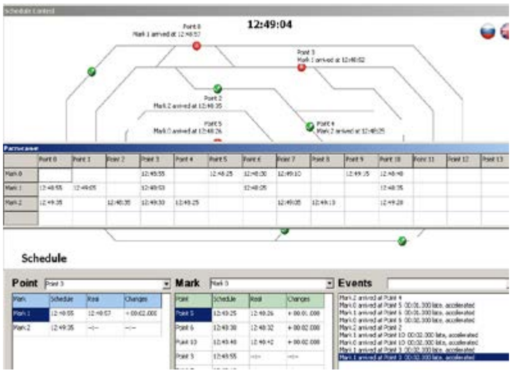

Figure 2: Screenshot from the Transport Network Simulation Program

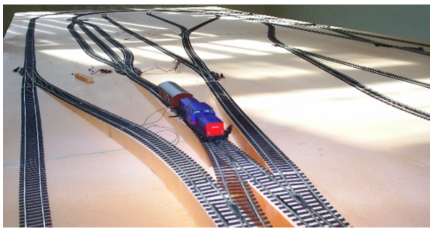
Figure 3: An Experimental Stand

The schedules can be analyzed with regard to performance indicators and different execution scenarios with different perturbations. Subsequently, parameters of the CS structures and the environment can be tuned if the decision-maker is not satisfied with the values of performance indicators. In analyzing the impact of the scale and location of the adaptation steps on the CS performance, it becomes possible to methodically justify the requirements for the RFID functionalities, the stages of a CS for the RFID element locations, and the processing information from RFID. In particular, possible discrepancies between the current needs for the wireless solution of CS control problems and the total costs of ownership regarding RFID can be analyzed. In addition, processing information from RFID can be subordinated to different management and operation decision-making levels (according to the developed multi-loop adaptation framework). Pilot RFID devices with reconfigurable functional structure are developed (Okhtilev, M.Yu., Sokolov, B.V., Yusupov, R.M. 2006). In order to simulate the RFID-based transport network, we have created a prototype of a simulation model that reproduces a real railway network. To do this, we could use different approaches, but the most suitable is the multi-agent system modelling (Gorodetskii, V.I., Kotenko, I.V., and Karsaev, O.V. 2000, H. Wong, K. Sycara, 2000). To realize the simulation model we could use different tools developed for modeling a multi-agent system (M.A.S) but most of them have a restrictive or a paid licensing policy. So, we managed to develop from the bottom a prototype of a simulation environment based on the C++ programing language and the M.A.S. approaches. The first step in creating a simulation model is to define the time framework, implemented in the form of the main event loop. In the loop, we have two functions; the first may or may not create a random disturbance in the locomotive speed and the maximum speed. The second function simulates the agent behavior. This system enables us to simulate a basic railroad network, and test the RFID infrastructure using a realistic model. Of course, as any system, this one has its advantages and disadvantages. As regards advantages, they include: the technologies used to create this model (C++ language), it provides us with a great flexibility in terms of functionality, allowing for modification and implementation of any kind of logic we want; agent based modeling is a powerful method allowing a large number of enhancements in the behavior of the system. Additionally, it enables us to define a logic of each individual locomotive, which is close to how decisions are made in a real system; define the system behavior by an independent entity allows great scalability, as the complexity of the system is linear to the number of entities.

4. CONCLUSION

Thus, summarizing the aforesaid, it should be noted, first of all, that one of the main tendencies in the development of information technologies and systems (IT and IS) in the XXIst century will be connected, in our opinion, with the solution of the problem of comprehensive integration of these technologies and systems with the existing and future industrial and socio-economical structures and the corresponding control systems. To solve successfully this interdisciplinary problem, it is necessary to solve a number of scientific-and-methodological and applied problems.

One of such urgent and interesting scientific-and-methodological problems arising at the turn of modern cybernetics and computer science, is the problem of justifying composition, structure, quantitative and qualitative characteristics of information that is necessary both for effective control of CPSS and for the control of information systems that provide for successful realization of business processes. In this connection, the following problems can be listed among primary tasks that need to be solved: formation and justification of a system of indices to measure information that is necessary for effective operation with adaptive CPSS (for various classes of customers and applications); development and justification of methods and algorithms for determining values of the information measure indices; development and justification of the structure of regular information measurement; development and justification of analysis and design methods for adaptive technologies and realization of processes of generation, registration, gathering, transmission, accumulation, storage, search, processing and release of information to end users with account for objective needs for information and objective prerequisites of the above-listed processes; development and justification of models, methods and algorithms of adaptive control of information quality.

Dynamic multiple-model descriptions of CPSS functioning at the different stages of their life cycle are proposed in the paper. Different types of models (analytical-simulation, logical algebraic, logical-linguistic models) are used for the description and study of the main attributes of CPSS. The joint use of diverse models in the framework of multiple-model systems allows for improved flexibility and adaptability of CPSS, as well as compensation for the drawbacks of one class of models by the advantages of the others.

ACKNOWLEDGMENTS

The research described in this paper is partially supported by the Russian Foundation for Basic Research (grants 15-07-08391, 15-08-08459, 16-07-00779, 16-08-00510, 16-08-01277,16-29-09482-ofi-i), Russian Humanitarian Found (grants 15-04-00400), grant 074-U01 (ITMO University), project 6.1.1 (Peter the Great St. Petersburg Polytechnic University) supported by Government of Russian Federation, Program STC of Union State “Monitoring-SG” (project 1.4.1-1), State research 0073–2014–0009, 0073–2015–0007.

REFERENCES

Bir S., 1963. Cybernetics and production control. Moscow: Fizmatlit.

Chernyak L., 2004. Adaptability and adaptation. Open Systems. 9 (May), pp. 30-35.

Chernyak L., 2003. SOA: a step beyond the horizon. Open Systems. 9 (May), pp. 34-40.

Chernyak L., 2003. From adaptive infrastructure to adaptive enterprise. Open Systems. 10 (Oct.), pp. 32-39.

Dmitrov A., 2006. Service-oriented architecture in modern business-models. Moscow.

Foerster von H., 1987. Cybernetics. Encyclopedia of Artificial Intelligence. New York: John Wiley and Sons.

Foerster von H., 1974. Cybernetics of Cybernetics, paper delivered at 1970 annual meeting of the American Society for Cybernetics. University of Illions. Urbana.

Gerasimenko V.A., 1993. Computer science and integration in engineering, science and cognition. Foreign radio electronics. 5 (May), pp. 22-42.

Gorodetskii V.I., Kotenko I.V. and Karsaev O.V., 2000. Intellectual agents for detecting attacks in computer networks. Proceedings of Conference on Artificial Intelligence. Moscow: FML Publishers, pp. 23-35.

Gran O. 2003. Virtual art: from illusion to immersion. Cambridge: MIT Press.

Heikki Hyötyniemi, 2006. Neocybernetics in Biological Systems. Helsinki University of Technology, Control Engineering Laboratory, Report 151 (August), 273 p.

Wong H., Sycara K., 2000. A Taxonomy of Middle Agents for the Internet. Proceedings of the 4th Int. Conf. Multiagent Systems, IEEE CS Press, 2000.

Ignatyev M.B., 2008. Semantics and selforganization in nanoscale physics. International Journal of Computing An- ticipatory Systems, vol.22, Edited by D.M.Dubois. Liege, Belgium: CHAOS. pp. 17-23.

Kalinin V.N., Sokolov B.V., 1995. Multi-model description of control processes for space facilities. Journal of Computer and Systems Sciences International, 1 (Jan.), pp. 149–156.

Maruyama M., 1963. The Second Cybernetics. Deviation Amplifying mutual causal process. American Scientist, 51.

Manovich L., 2002. The language of new media. Cambridge: MIT Press.

Morozov V.P., Dymarskii Ya.S., 1984. Elements of control theory for flexible manufacturing: mathematical support. Leningrad: Mashinostroenie.

Okhtilev M.Y., Sokolov B.V., Yusupov R.M., 2006. Intellectual Technologies of Monitoring and Controlling the Dynamics of Complex Technical Objects. Moskva: Nauka.

Omatu S., Khalid M., Yusof R., 1996. Neuro-Control and Its Applications (Advances in Industrial Control). New York: Springer Verlag.

Sokolov B.V., Yusupov R.M. 2008. Neo-cybernetics: possibilities and perspectives of progress. In Report made at general plenary session of the 5th scientific conference “Control and information technologies” (CIT-2008), pp. 1–15. October 14–16 (Russia, St. Petersburg,).

Sokolov, B.V., 2010. Dynamic models and algorithms of comprehensive scheduling for ground-based facilities communication with navigation spacecrafts. SPIIRAS Proceedings. 13(2), 7-44. doi:10.15622/sp.13.1

Timofeev A.V., Yusupov R.M., 1994. Intellectualization of automated control systems. Technical Cybernetics, 5 (May).

Vasiliev S.N., Zherlov A.K., Fedosov E.A. and Fedunov B.E., 2000. Intellectual control of dynamic systems. Moscow: Fizmatlit.

Wiener N. 1948. Cybernetics: Or the Control and Communication in the Animal and the Machine. MIT Press, MA.

Wiener N., 1950. The Human Use of Human Beings: Cybernetics and Society. Boston: Da Capo Press.

Yarushkina N.G., 2004. Theory of fuzzy and hybrid systems: a tutorial. Moscow: Finance and Statistics.

Yusupov R.M., Zabolotskii V.P., 2000. Scientific and methodological foundations of informatisation. Saint-Petersburg: Nauka Publishers.

Yusupov, R.M., Sokolov, B.V.,Ptushkin, A.I.,Ikonnikova, A.V.,Potryasaev, S.A., Tsivirko, E.G., 2011. Research problems analysis of artificial objects lifecycle management. SPIIRAS Proceedings. 16(1), 37-109. doi:10.15622/sp.16.2

Zhuge H., 2011. Semantic linking through spaces for cyber-physical-socio intelligence: A methodology. Artificial Intelligence, 175, pp. 988-1019.

Zhuge H., Xu B., 2010. Basic operations, completeness and dynamicity of Cyber Physical Socio Semantic Link Network CPSSocio-SLN. Concurrency and Computation. Practice and Experience, 9 (Sep.), http://onlinelibrary.wiley.com/doi/10.1002/cpe.1623/abstract/10.1002/cpe.1623.

5. AUTHORS BIOGRAPHY

BORIS SOKOLOV is a deputy director for research at Saint Petersburg Institute of Informatics and Automation the Russian Academy of Science. Professor Sokolov is the author of a new scientific lead: optimal control theory for structure dynamics of complex systems. Research interests: basic and applied research in mathematical modelling and mathematical methods in scientific research, optimal control theory, mathematical models and methods of support and decision making in complex organization-technical systems under uncertainties and multicriteria. He is the author and co-author of 9 books on systems and control theory and of more than 450 scientific papers. Professor B. Sokolov supervised over 90 research and engineering projects. Web-page can be found at http://litsam.ru.

SEMYON POTRYASAEV graduated from the Baltic State Technical University "VOENMEH" with a degree of control systems engineer and the Moscow Institute of International Economic Relations as an economist in finance and credit. Successfully defended his PhD thesis in 2004 at the Saint Petersburg Institute of Informatics and Automation of the Russian Academy of Science (SPIIRAS). Currently works as a senior Researcher at the Saint Petersburg Institute of Informatics and Automation of the Russian Academy of Science (SPIIRAS). Previously worked in commercial educational centers as a trainer and consultant on information security and web technologies. Research interests: applied research in mathematical modelling, optimal control theory, mathematical models and methods of support and decision making in complex organization-technical systems under uncertainties and multicriteria. Web-page can be found at http://litsam.ru.

IRINA SOKOLOVA graduated from the Herzen State Pedagogical University of Russia, St. Petersburg in 2006. Successfully defended her PhD thesis in 2009 at Herzen State Pedagogical University of Russia. She is the author and co-author of more than 15 scientific papers. Irina Sokolova has taken part in over 10 grants, conferences. Web-page can be found at http://www.culturalnet.ru/main/person/712.

KARIM BENYAMNA graduated from the State University of Information Technologies, Mechanics and Optics, specialty: Informatics Systems and Technology, Saint-Petersburg in 2015. Since 2015 he has been the postgraduate student of establishment of the State University of Information Technologies, Mechanics and Optics. He is the author and co-author of more than 5 scientific papers.

DMITRY IVANOV is a professor at the Department of Business and Economics at the Berlin School of Economics and Law and the Chair of the German-Russian Coordination Office for Logistics. He studied production management and engineering (2000). In 2002, he graduated in Saint Petersburg as a Ph.D. in economics on the topic of operative supply chain planning and control in virtual enterprises. In 2006, he received the Dr.rer.pol. degree at the Chemnitz University of Technology. He is an author of 6 scientific books and more than 70 papers published in international and national journals, books and conference proceedings. Since 2001, he has been involved in research and industry projects on supply chain management and virtual enterprises. Dr. Ivanov received a German Chancellor Scholarship Award in 2005.