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Methodology of Evaluation of Evolving Sociotechnical Systems with Artificial Intelligence

Abstract

Evolution of the technogenic world, the development of networked and cyber-physical systems includes mechanisms of socio-environmental self-organization of techno-society through the transformation of human experience within the cycles of autopoietic self-organization of the techno-environment. An essential role in the issues of creating new forms of emerging socio-technical systems that include artificial intelligence technologies at the stages of formation and implementation of a technical project is played by the concept of including mechanisms of self-organization and system development, which is related to the methodology of assessing the ergonomic properties of the systems being created. Ergonomic assessment plays a unique harmonizing and corrective role in creating man-machine socio-technical systems. The determining role in the formation of ergonomic assessment of socio-technical systems is shown to be played by reduction mechanisms, which determine the evolution of these systems in the required direction. A socio-technical system with artificial intelligence does not have a priori predetermined, clearly known and intelligible to authors and user's properties, and displays them only in a working context, which does not allow applying the usual methods of ergonomic assessment used in assessing the permanent qualities of a socio-technical system concerning a human user. We noted the unique role of symbiotic relations in maintaining the effective operation of socio-technical systems with distributed artificial intelligence considered to the processes of coherence-decoherence, influencing the change of forms of organized complexity, and determining the system's viability in the environment. We pointed to the problem of inactivating technologically generated elements of the techno-environment into the socio-technical system's evolving part. Using the Internet as an example, we show that the free evolution of the techno-environment associated with excessive information diversity of the social component of the network leads to acceleration of its evolution but reduces its social stability and sustainability.

Keywords: *sociotechnical system, artificial intelligence, self-organization, evolution, cycles of autopoetic embodiment, ergonomics, evaluation of social systems*

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Методология оценки эволюционирующих социотехнических систем с искусственным интеллектом

Эволюция техногенного мира, развитие сетевых и киберфизических систем включают механизмы социально-средовой самоорганизации технообщества за счет трансформации человеческого опыта в рамках циклов аутопоэтической самоорганизации техносреды. Важную роль в вопросах создания новых форм возникающих социотехнических систем, включающих технологии искусственного интеллекта на этапах формирования и реализации технического проекта, играет принятая разработчиками концепция включения механизмов самоорганизации и развития системы, связанная с методологией оценки эргономических свойств создаваемых систем. Эргономическая оценка играет особую гармонизирующую и корректирующую роль при создании человеко-машинных социотехнических систем. Показано определяющее значение в формировании эргономической оценки социотехнических систем механизмов редукции, которые определяют направление эволюции данных систем в требуемом направлении. Социотехническая система с искусственным интел-

лектом априорно не имеет заранее заданных, четко известных и понятных авторам и пользователям свойств, их она проявляет только в рабочем контексте, что не позволяет применять привычные методы эргономической оценки, используемые при оценке постоянных качеств социотехнической системы по отношению к человеку-пользователю.

Отмечена особая роль симбиотических отношений в поддержании эффективной работы социотехнических систем с распределенным искусственным интеллектом. Рассматриваются процессы когеренции-декогеренции, влияющие на смену форм организованной сложности, определяющие жизнеспособность системы в среде. Поставлена проблема энактивации порождаемых технологиями элементов техносреды в эволюционирующую часть социотехнической системы. На примере сети Интернет показано, что свободная эволюция техносреды, связанная с избыточным информационным многообразием социального компонента сети, ведет к ускорению ее эволюции, но снижает ее социальную устойчивость и стабильность.

Ключевые слова: *социотехническая система, искусственный интеллект, самоорганизация, эволюция, циклы аутопоэтического воплощения, эргономика, оценка социальных систем*

Introduction

The intensive formation and development of the technogenic environment of human civilization observed in recent decades is accompanied by an increase in the complexity of the technogenic environment, the development of technologies, gadgets, machines, and mechanisms that combine into network structures controlled by artificial intelligence technologies. These processes lead to developing a global evolving planetary techno-biological unity [1], which exhibits the properties of self-organization and self-development inherent in its system basis only on living organisms and social communication.

The primary mechanism causing the processes of global self-organization, development, and constitution of the new systemic essence of the technogenic civilization of Planet Earth is electronic communication, which forms virtual interfaces connecting users with artificial worlds of different degrees of virtuality [2].

Human users and artificial intelligent systems and agents, including mobile robots and "smart environments," become participants of social network communications. Hybrid and artificial socio-technical systems of evolving types are emerging.

The network complexity world is developing. Communication of observers, including artificial agents forming a digital dynamic copy of the world, plays a unique role in the logic of its functioning.

The probabilistic, quantum-like nature of interactions in the emerging techno-biotic environment of the self-organizing world includes mechanisms of coherence and decoherence, ensuring the emergence and collapse of complex forms of techno-environment organization. "Technologically, a human-dimensional network-centric scenario of anthropo-technosphere evolution is built" [3, p. 55]. There is a world of organized complexity, manifested in the intensive development and implementation of computer technologies of management and control in all spheres of human activity, including technologies of artificial intelligence and virtual reality. It can be said that the technogenic civilization is entering the post-natural stage of its development, characterized by increasing complexity and intellectualization of the environment, intersystem integration, and the appearance of multilayer virtual control environments, in general digitalization and hybridization of real and virtual worlds.

In methodological terms, there is a change in the forms of thinking of researchers and designers of technogenic environment towards the application of forms of post-non-classical rationality [4], the main features of which in this context are:

— Socio-cultural determination of scientific and design activity;

— Formation of the designer-researcher in the process of learning and communication with other project participants;

— The emergence of heterogeneous, including different scientific specializations, research, and design communities;

— The design team's consideration as an evolving, self-organizing human-dimensional system within the current variant of technogenic culture.

Application of methodological principles of post-non-classical rationality is expedient in case of considering research and design objects as complex self-developing systems possessing cyclic causality, differentiation of external and internal space and time, taking into account the factor of system evolution and history within some cultural environment. Socio-technical systems with artificial intelligence arising within the evolving technogenic environment can be referred to as design objects.

Post-nonclassical methodology for the design of complex systems

The creation of complex systems is associated with the design of their composition and structure sufficient for the emergence of self-organization processes; but the methodology and tactics of research and conduct of the design process are changing. The active role of artificial intelligence technologies in solving design problems shifts the emphasis from the defining role of humans in the design of the technological environment to cooperative and mutually oriented communication interactions with the intelligent environment, which are carried out in computer-aided design systems. Virtual reality interfaces implementing induced environments are used. The designer's activity

in such a virtual environment, which simulates the design reality, allows effectively translating a person's creative abilities into a product. However, the design of complex systems differs from classical design.

Old mechanistic ideas about designing as the joint implementation of an engineering project execution algorithm that meets the technical assignment are replaced by holistic models and concepts.

They reflect the world's complexity in the process of autopoietic self-organization of the environment.

The development of cyber-physical technologies and flexibly networked machine design systems, the introduction of industrial robots, and automation tools bring new technological and production capabilities to create a complex technogenic environment. A distributed technological socio-technical environment emerges, generating an elemental diversity of components from which new machines and mechanisms are created.

The developer of a complex system cannot be outside the process of the evolution of the design environment. Submitting to its development logic, it gives the system the required properties, but it often does not understand the latent strategic goals and the direction of the development of the system being created. The designer is also not aware of the consequences of the future of the negative impact on a person the results of the functioning that arise the self-organizing elements of the technosphere.

The use of symbiotic forms of interaction of the person and intellectual environment of designing [5] demands new approaches for the creation of effective socio-technical systems.

As a variant of human inclusion in the design processes, a number of authors suggest "imagination technologies," which are understood as methods that allow users to discuss potential socio-technical worlds from different points of view, imagining how the development of new technologies can affect their lives and the future of society as a whole [6, p. 233]. According to E. G. Grebenshchikova, socio-technical imaginaries play a unique role in designing the future — mental constructs constructing the present and future of science and technology, postulates the development of social technologies focused on a proactive approach, proactive management, openness to criticism, and active inclusion of social actors in the discussion of potential socio-technical worlds [7]. As applied to design activity, it is possible to speak about the emergence of a hybrid techno-cultural environment in the design organization, which determines the effectiveness of the project team activity.

Designing is local in space and distributed in time, simultaneously being additional to the world. The process of selective inactivation of the project through technology and production in the evolving technogenic environment, which may not be ready to introduce innovations containing potential danger for the human elements of the techno-social organism, is essential.

Sociotechnical Systems with Artificial Intelligence (Complex Sociotechnical Systems)

A unique role in creating socio-technical systems considered in this article is played by the issues of symbiotic mutually beneficial association of man and technology within the evolving techno-environment.

A socio-technical system is a dynamic self-organizing element of a hybrid technogenic environment, arising and developing due to interaction and communication between humans, technical infrastructure, and technology.

Eric Trist and Fred Emery, who worked as consultants at the Tavistock Institute of Human Relations [8], proposed this term in 1960.

Examples of such techno-social organisms are airports, energy, transport, and other systems that contain and implement computerized network forms of cyclic communication, in which the group activities of members of the labor collective are carried out.

Currently, socio-technical systems use artificial intelligence technologies to optimize intra-system processes by automating work with big data and typical procedures. Such systems can be called complex socio-technical systems. Two types of communication processes work synergistically: self-organizing communication in the human part of the system and information circulating in the machine part of the system. In their interaction, there may be problems of ensuring effective and comfortable human interaction with the self-organizing communicative techno-environment, the evolution, and autopoiesis, which can lead to the emergence of stressogenic and destructive states in users and actors.

Complex socio-technical systems should be considered in the concepts of multiplicity, dynamic diversity, non-linearity, non-uniformity, the complexity of self-organizing systems. The concept of complexity of self-organizing systems reflects the continuous dynamics of the world in all its fundamentally unknowable quantitative-qualitative manifestations. General intellect as a form of assessment of the capabilities of a complex system is its emergent property that allows the latter to effectively solve the problems of active (formation of the artificial environment, creative activity) and passive (adaptation, adaptation to the environment) existence in the world.

E. N. Knyazeva generalizes the existing views on complexity and complex systems, formulating and detailing the characteristic properties of complex systems within the framework of synergetic paradigm:

— Complexity is a multitude of system elements connected in a nontrivial way by original links. Complexity is a dynamic network of elements connected by definite rules;

— Complexity is the internal diversity of a system, the diversity of its elements or subsystems that makes it flexible and capable of changing its behavior depending on the changing situation;

— Complexity is a multilevel system (there is an architecture of complexity);

— Complex systems are open systems, i.e., exchanging substance, energy, and/or information with the environment. The boundaries of a complex system are sometimes difficult to define (seeing its boundaries depends on the observer's position);

— Complex systems are systems in which emergent phenomena (phenomena, properties) occur, which cannot be "subtracted" from analysis of the behavior of individual elements;

— Complex systems have a memory; they are characterized by the phenomenon of hysteresis, with a change in the mode of functioning processes being resumed on the old traces (previous tracks);

— Complex systems are regulated by feedback loops: negative, which ensures restoration of equilibrium, return to the previous state, and positive, which is responsible for rapid, self-stimulating growth, in the course of which complexity flourishes [9].

Obviously, the definitions given by E. N. Knyazeva's complex systems are also applicable to socio-technical intelligent systems. In this case, the intelligence embodied in the symbiotic form in the system is a function of the complexity of the self-organizing system.

Methodology for ergonomic assessment of complex socio-technical systems

A special harmonizing and corrective role in creating man-machine socio-technical systems is played by ergonomic evaluation, carried out in the process of ergonomic expertise, carried out at different stages of design and operation. This verifies the degree of implementation in a ergonomic requirements project that determines the quality and efficiency of man-machine interaction in the system. However, the use of this procedure in a socio-technical system with artificial intelligence is complicated because it does not have a priori predetermined, is clearly known, and is understandable to authors and users properties. They manifest themselves only in a working context, which prevents the application of the usual ergonomic assessment methods used in assessing the permanent qualities of a socio-technical system concerning a human user. They can change continuously at different stages of the socio-technical system's existence and manifest themselves only in forms accessible to interpretation by the observer.

Only a human expert, including elements of creativity, aesthetics, group and individual professional experience, and at the same time subjectivity and randomness, carries out being a complex interdisciplinary procedure, ergonomic assessment.

In essence, any subjective evaluation, created by man, is an attempt of reduction of his experience, the essence and form of reality reduction performed by consciousness within the limits of subjective reality (which itself is a form of reduction performed by consciousness, while objective evaluation is a result of processed data reduction in the information system. Both assessments are forms of statistical evaluation, data processing, and optimization.

Evaluation is always associated with measurement and interpretation. The latter reflects the designer's dynamic picture of the world and is mainly subjective. Attempts to automate the processes of interpretation formation with the help of artificial intelligence algorithms rely on big data processing and deep learning technologies [10]. However, the replacement of natural intelligence by its technical counterpart artificial intelligence is currently impossible due to the difference in their nature — active but probabilistic in humans and passive, but deterministic in a computer system despite their fundamentally joint information base [11]. V. A. Lectorsky holds a similar position and view, supplementing them with the notion of postclassical logic derived from the process of metaphysics, which proceeds from the fact that things and other objects can and should be understood as a kind of clots of processes [12].

When evaluating something, people traditionally try to implement the principle of objectivity, which requires excluding the subject from any evaluation process because the latter does not allow to formalize evaluation and leads to its division into external objective and internal — subjective. At the same time, measurement and evaluation are always a process of reduction carried out by an observer, in which we understand something and someone (including a person) making a distinction. In essence, evaluation is the simplest model of the system being evaluated. Generating models of the world is the primary function of consciousness, which tries to create and verify the most effective and minimal models of reality [13].

Mathematical modeling is most often used in design as a discipline that works with models derived from formalizing the results of reduction, but the intuition and experience of the designer play a considerable role. In socio-technical systems, there are processes of reducing the system's world into evaluations, which participate and are used to create directions and forms of their further evolution. Each new state of a socio-technical system is also the result of a continuous reduction of its past states into simple models and then evaluations. The reduction-evaluation-correction cycles are fundamental for all socio-technical systems.

Observation plays a decisive role in evaluation procedures (local reductions) and is connected with the emergence of a system of distinguishing (observer) and systems of processing and interpreting data, transforming them into comprehensible (inconsistently interpreted) results. The observer plus the memory interpreter form a subject. Being a subject, an observer of the future, the designer always

deals with reduced forms of the world represented in his subjective world. His task is to make a distinction, which is always a reduction. In this case, the quantum holistic nature of the world comes into contradiction with concrete results of the reality world represented in consciousness. Resolution of this contradiction is possible only within social relations and social evaluations formed in them.

Social evaluation is some integrity composed of, but not reducible only to, reduced evaluations of collective members. Due to the autopoietic and probabilistic-random nature of emergent social interactions in the collective, a social system cannot be reduced to an object because any description would be incomplete and represent some interpretation, which is always inherently inherent a reduction of the actual social system. Multiple evaluations in a nonlinear sum of unit reductions lead to confusion and restoration of interpretation as wholeness, which again becomes quasi-quantum-mechanical.

Thus, design is the process of constructing some wholeness from local reductions created by designers based on evaluations obtained in collaborative work. The project is the reduced part of the future growing out of the past. Implementation is the process of transforming the project into reality. The result is the local realization of the project, which has acquired the force of reality. Subjective reduction transforms the project into reality and vice versa.

According to V. P. Zinchenko, a genome of spiritual development arises, which cyclically combines and complements the real and ideal forms of reality, forming a spiral of evolution [14, p. 338]. The subject and technology are a tool and mechanisms for transforming the reduced subjective forms of consciousness into reality.

Designing is creating a product with given properties and multiple evaluations of its impact on the world as a whole. Anything, in reality, is infinitely more diverse than its design. It is an evolving complexity, growing from an ideal form in the minds of the project's authors and realized in a variety of technological and social relations and forms into a real product.

In 1972 Austin O. Roche, Phil Ray, and John Frassanito were granted Patent No. 224,415 for the Datapoint 2200 desktop personal computer, making them the first personal computer [15]. They had no idea how effective technology they had released into the world, how significant the consequences of what they had done for the progress of humanity would be. The consequence of this was the total computerization of all spheres of human existence and activity and the independence of the technical environment itself from man. There appeared cyber-physical systems based on evolutionary principles of development [16], including key characteristics:

— Independence of functioning of system components;

— Managerial independence of the system components;

— Geographic distribution;

— Evolving behavior;

— Evolving development processes.

Technology has gained the ability to replicate human information behavior, create a digital picture of the world, and change it. This picture may be unfriendly and dangerous for humans, but at the same time, it may help ensure effective technosymbiosis in socio-technical systems.

Mechanisms of self-organization of evaluation activity in socio-technical systems with artificial intelligence

The design of complex computer and communication networks and environments requires an examination of the impact of global effects of changes occurring in the technogenic environment, especially in its interface elements that provide intersystem relationships and integration of humans into the technobiotic environment [17].

Let us note the dynamic nature of the development of human-dimensional systems whose very existence is a continuous change of the environment in the process of which there is a continuous entanglement of macroscopic systems and the disintegration of systems of interactions. Mechanisms that form the system and its environment in the form of a superposition of macrosystems — coherence process and destroy its entangled state — decoherence processes, as a result of which classical interaction systems appear before the observer [18]. The entangled states create the subtle matter of the real world, and the reduction leads to the definite classical world. At the same time, only creativity in the broad sense of the word integrating different points of view on the evolution of a complex system can overcome the deadening force of reductionism preventing the development of the formed version of the complex world.

We must admit that effective ergonomic assessment of socio-technical systems is possible only with multidimensional analysis, which includes multiple perspectives on the system from internal and external observers, allowing us to give an objective forecast of the system's development. This is possible with the emergence of a process of self-organization in the evaluation mechanism during the creation and functioning during the operation of the socio-technical system.

Self-organization in the formation of assessments in socio-technical systems

A number of conditions in the evaluation mechanisms and multiple feedbacks are necessary for the

inclusion of self-organization mechanisms in an open socio-technical system:

— Multiple diversity of elements of the evaluation system being at the first stage of its development under disorganization, weak mutual connectivity;

— Non-equilibrium, leading to the system deviations from the thermodynamic equilibrium of the evaluation system;

— Non-linearity and instability of relations and states between elements of the system lead to multiple variants of its development, the appearance of new forms with insignificant changes in parameters.

The inclusion of artificial intelligence algorithms in the work of the socio-technical system allows reducing the diversity of its final structures and optimizing the possible variants of development and resource provision.

Conclusion

The modern view of socio-technical systems with artificial intelligence considers them as complex self-organizing elements of the developing technogenic environment. The primary mechanism of their emergence and evolution is connected with the processes of coherence — decoherence of the guided processes of self-organization of technogenic environments with the active influence of the human link and the system of evaluations generated by the technical part, optimizing the structure and functions of the system. The emergence of multiple evaluations of the external and internal state of the socio-technical system leads to possible forms of its realization and evolution. Evaluation can be considered as a form of reduction of actual and potential states of the system within the framework of post-nonclassical rationality describing self-developing systems.

The system's computer (technogenic) world generates local digital reductions composed of external observations of the system. They are subject to formal laws and, as such, acquire the property of computability and, consequently, can be realized in digital form. The total digitalization of socio-technical systems attempts to use the reductions of the real, holistic world to organize them. Diversity, stability, and stability of the flow of self-organization processes in socio-technical systems with artificial intelligence give social communications and choice of development directions by symbiotic interactions between artificial and natural intelligence.

An example of a global socio-technical system is the Internet. In the process of its evolution, turning into a dynamic digital copy of the real world leads to its destruction because it is incapable of managing the future, which is peculiar only to active systems involving humans. It is necessary to take a cautious approach to the total digitalization of society because the multiple assessments arising in the environment lead to the appearance of destructive copies of the world outwardly indistinguishable from reality, but leading to the destruction of the social mechanisms of self-organization of society. The dominance of artificial intelligence distributed in the Internet environment leads to the degradation of human society and the displacement of a person losing moral and ethical reference points from productive and creative activity.

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