Immersive media in simulators of complex ergatic systems

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Abstract. This paper shows a change in the paradigm of medium-oriented training of complex systems operators on simulators using high-precision models of real control systems and their application environments. Evolution of the technogenic environment leads to an increase in the complexity of professional activity, which hinders the implementation of simple algorithmic learning technologies. Forecasts to reduce the role of man in ergatic systems are not justified. New ergatic systems using artificial intelligence technologies require from operators qualities that exceed human capabilities, which requires an examination of projects and an assessment of user control complexity. The reasons for the non-classical “complex learning” methodology, which takes into account the student’s self-organization and orientation in a complex dynamic context, are shown. Promising methodological approaches to the development of simulators that implement symbiotic medium-oriented learning are considered.

1. Introduction

Historically, the emergence of simulators was a reaction of technology developers to the need to use when working with new machines and mechanisms unusual forms of human experience, which arose from systems of mediated control and information presentation. Natural adaptation mechanisms and habitual sensorimotor forms of response for real-time control of artificial dynamic systems turned out to be insufficient, and the task was to form special experience, structures of professionally important qualities, knowledge, skills and abilities [1]. This problem was solved on simulators by actively immersing future operators in simulated conditions psychologically and perceptually similar to the conditions of real activity [2]. A training direction has been formed associated with repeated training of typical control algorithms in teaching tasks and conditions which showed the main features of the professional environment of work [3].

In different years, well-known Russian scientists, mainly representing the Moscow and Leningrad scientific schools of psychology, dealt with the problems of psychological support of professional activity. Their works revealed the classical content of professional activity as a subject of psychology, its features were investigated (K.A. Abulkhanova-Slavskaya, V.A. Bodrov, A.K. Gastev, S.G. Gellerstein, M.A. Kotik, N.D. Levitov, V.N. Myasishchev, A.P. Nechaev, G.S. Nikiforov, O.G. Noskova, K.K. Platonov, V.F. Rubakhin, I.M. Sechenov, V.A. Tolochev, I.N. Shpilemin). The methodology and theory of professional activity were developed (B.G. Ananiev, V.A. Bodrov, A.V. Brushlinsky, A.I. Galaktionov, L.G. Dikaya, E.M. Ivanova, A.V. Karpov, B.F. Lomov, V.I. Medvedev, G.V. Sukhodolsky, V.D. Shadrikov), the development directions of the professional character were investigated, the problem of professional suitability was developed (L.I. Antsyferova, M.A. Dmitrieva, A.L. Zhuravlev, D.N. Zavalishina, E.F. Zeer, A.M. Zimichev, E.A. Klimov, G.L. Koroteev, A.A. Krylov, A.I. Naftulev, A.A. Oboznov, Yu.P. Povarenkov, N.S. Pryazhnikov, A.A. Rean, I.L. Solomin, Y.I. Filimonenko), methods and technologies of engineering-psychological design and operator activity were created (V.F. Venda, Yu.Ya. Golikov, G.M. Zarakovsky, V.P. Zinchenko, A.N. Kostin, B.F. Lomov, V.M. Munipov, G.V. Sukhodolsky, Y.K. Strelkov, D.A. Oshanin), the problems of professional
selection and training were solved using technical means of training and simulators (V.A. Bodrov, V.N. Druzhinin, V.N. Zankovsky, G.L. Koroteev, V.N. Sokolov, A.A. Frumkin, V.E. Shukshunov).

As a result, by the eightieth years of the last century, a stable opinion was formed in the engineering environment about the need for accurate modeling of the conditions of real activity in order to achieve the required levels of professional readiness [4]. A whole branch of simulator engineering appeared, using the latest achievements of science and technology of modeling and presenting information for simulating on the simulator all aspects of the perceptual experience of operators practically indistinguishable for a subject from the experience he gets in real activity [5].

Training on simulators began to be reduced to the repetition of algorithms of real activity in standard conditions and formation of forms of operator behavior appropriate to typical situations [6]. To imitate the conditions of activity, computer technologies are now widely used that implement models of variable realism, covering the Milgrem continuum from complete artificial virtual and augmented reality to the physical in-situ conditions of real activity [7]. At the same time, the modeling of immersive environments that provide the formation of a sense of presence and a full multimodal immersion of the student in the learning environment [8, 9, 10] has become technologically available.

However, all the achievements in this area of simulator development end there, since the methodological, psychological and pedagogical, side of simulator training is still based on a simple repetition of training tasks that do not take into account the specifics of individual training and self-study of a person. The world of problems solved in modern ergatic systems, in its complexity has gone far from the implementation of primitive sensorimotor coordination and algorithmic operations, the development of which focused the first simulators [11, 12].

2. The challenges of complex learning in training environments

Despite the fact that all levels of human psyche organization are included in the operator's activity, the methods of simulator training are still based on the didactic formula “Repetitio est inaer studiorum” (Latin) known to us as “Repetition is the mother of learning”. As a result of repetition, according to the adherents of this trend, all professional skills and abilities arise and improve [13].

Revolutionary changes in the design of controlled machines associated with the evolution of man-made environment and means of network electronic communications radically change the formulation and solution of the problem of taking into account the human factor in training [14]. The simple repetition of elements of professional tasks is not enough to effectively include the operator in solving problems related to the symbiotic relationship of a person with the technogenic world, requiring the development of complex forms of intellectual activity [15, 16].

Over the last 20 years, processes of intensive introduction of automation technologies when executing control algorithms for complex technical systems are observed. This created among designers an illusion that a person would soon be removed from the control circuit of the machine. In their opinion, it became possible to replace the operator with systems and means of automation and robotization [8]. A rapid decline in the significance of the human operator was expected when working with complex systems, up to its complete exclusion in connection with the transition to automatic control. This was facilitated by the intensive development of electronic communications systems and artificial intelligence methods that promised to completely replace a person at the point of “technological singularity” [17, 18, 19]. The methodological basis of the design also included the philosophy of materialism prevalent in the engineering environment, which simplified man to the level of a complex machine.

However, these predictions for reducing the role of man in ergatic systems have not yet come true. Moreover, the inclusion of a person in various forms of orienting and controlling communication circulating in control systems is more intense than before. New tasks appeared, such as the formation of missions for robots, copying control in virtual environments, the control of automatic devices [20, 21, 22].

In the field of professional training, for the first time we faced with the paradoxical fact that developers of technology presented requirements for the professional qualities of operators, exceeding the capabilities of their psychophysiological system for processing and interpreting the information necessary for making adequate decisions. This means that no operator, in principle, under any circumstances, will be able to work effectively with such a system. However, simulators for these systems are produced with the hope that methodologists and instructors will still be able to teach the operator the desired behavior. This does not happen, and we are faced with a potentially dangerous, in terms of the human factor, systems with currently unsuitable operators. At the same time, the latter may not be aware of their professional inadequacy, focusing on false conceptual models of the reflexive
consciousness. The current situation requires developers to estimate the limit level of operator activity in the future system. It is necessary to determine the potential for mastering its algorithmic and cognitive components. One requires to perform works on adaptation the equipment to the operator serving it, which differs from the classical human adaptation to the equipment.

In contrast to the classical task of professional selection, which implies the absolute presence in the general population of the required volume of potentially eligible applicants, in this case there may not be any of them at all. Only controlling the level of complexity of an operator’s activity in an ergatic system can create conditions for error-free control and decision-making. This is a new task of ergonomic and technical design requiring the creation of activity models with variable functional load on the operator.

The intellectualization of the technogenic management environment is accompanied by the emergence of technologies for modeling almost all aspects of perceived professional and educational experience, which removes the problem of similarity in simulators for a long time considered basic when creating systems for professional training of operators of complex technical systems. Instead of the question “How to model?” the questions “What to model?” and “Why model?” were raised. Engineers do not yet have an answer to these questions, as they lie in the plane of pedagogy and psychology of education.

Education in the traditional concepts of classical pedagogy is considered as an active interaction of the two systems - the teacher and the student through the educational content. The teacher is the source of knowledge (structured information), and the student is its consumer, to a certain extent a passive element. By virtue of this, all teaching methods are aimed at presenting information and training tasks to the student with the subsequent implementation of activities in modeling environments containing essential elements and algorithms of real activity. Such a scheme of the educational process underlies all e-learning methods, but it is not effective in learning how to work with modern complex control systems. In them, the operator should set the task of management himself, and not be a passive conductor of standard ideas. With the increasing complexity of the technogenic environment of human civilization, it became necessary to change the paradigm of professional training, the transition to complex learning, by which we understand the use of representations of non-classical and post-non-classical psychology and pedagogy, considering the processes of directional orientation and coordination of the student’s self-organizing cognitive system in the environment of his experience [23, 24].

3. Pedagogical prolegomena of complex learning

In complex learning, a controlled technological environment must provide the user with the capabilities available to him, allowing him to solve control problems and not limit his field of action. There are questions of distribution of operator functions in the management environment of the ergatic system, which are considered in the context of self-organization of a particular subject in the process of influencing him on self-organizing communication. The appearance of a managed order in the final system is a special topic of complex learning, distinguish from the classical concepts associated with the use of the category of knowledge.

Classical models of teaching in the form of a didactic triangle, including a student, a teacher and educational content, reflect a number of didactic principles widely used in pedagogy, which are considered as the main active element of the teacher’s learning environment which implements teaching methods. The pupil is to a certain extent passive and is the object and subject of pedagogical influence. It is the attitude of the teacher and the student that determines the quality of the pedagogical process. Consequently, in the opinion of designers of the methodical component of electronic learning systems and simulators, in order to create an effective e-learning system, it is sufficient to simulate the working environment, functions and logic of the teacher’s actions using technology.

This largely controversial point of view of classical psychology and pedagogical psychology is widely replicated in the engineering and pedagogical environment and is the basis of e-didactics, which is a complex discipline about teaching methods in the new pedagogical reality of the century of technology. The main problem of this approach is that it reflects, within the framework of classical rationality, the engineering understanding of learning as an externally controlled information process associated with transfer of knowledge considered as portions of structured information. This contradicts modern scientific data from the field of human learning, according to which the learning process is of communication nature, orienting the student in the area of educational content [25, 26]. At the same time, the categories “knowledge” and “learning” reflect the processes of self-organization of the human cognitive system in the learning environment [27].
In complex learning, communication plays a special role in professional and learning environments. The concept of orienting communication is proposed, which allows explaining the learning processes in self-organizing systems [25].

The main provisions of the concept are the following:

- The brain is a physical system of autopoietic type which is capable, together with human sensorimotor systems, to create and maintain the integrity of the mental content generated in it in the form of subjective world with a subject acting in it, receiving and using conscious experience in the process of creating chains of orienting relationships in recursive cycles of self-reproduction and communication.

- A person, through orienting communication, continuously assimilates into the structures of his constructive experience, which he assesses as the positive aspects of interactive contacts of perceptual systems with the world, giving the subject potential for self-preservation and the continuation of biological and social evolution.

- In the process of learning, interconnected information processing cycles and formation cycles of information processing tools occur. The process of searching and creating efficient cognitive tools that allows one to explore the world in the course of creating a personal history of a person is continuous at all time levels.

- Learning is intervening in the cycles of experience and cognitive tools through the communication orientation of a subject and the introduction of relevant information.

- Self-learning of a person is built on the basis of reflexive self-orientation, proceeding in the form of the process of internal communication of the subject with himself and his inner world. Consciousness at the same time is an instrument of social and ego communication, involving a person in the autopoiesis processes of one’s self.

- Knowledge as a result of the pedagogical process is formed on the psychological and neurobiological levels and is a systematic, inseparable from a person property of his psychobiological organization embodied in it.

- The subject works with his subjective world through the exchange and interpretation of the information circulating in it, and the brain works with the physical world by fixing the changes that occur at the inputs of perceptual systems [25].

In accordance with the concept of orienting cooperation, learning systems are systems that organize and maintain the information environment in the form of a dynamic system in which communication processes orient the cognitive and personal mechanisms of a student in the area of educational content aimed at generating (designing) a learning result.

In the process of pedagogical communication, a self-organizing social system arises, producing in the course of its evolution directional changes in the cognitive and personality systems of a person. Note that such self-organizing metasystems arise during the course of any communication. The specificity of the learning communication metasystem is its focus on obtaining a pedagogical result. The role of the teacher is to maintain the vector of educational communication in the direction of ensuring the learning effect. At the same time, we note that the teacher creates the conditions for the emergence of educational communication, and in this he is independent. However, in the implementation of communication, his freedom and activity are limited by the properties and mechanisms of self-organization that arise and operate in a particular learning situation.

4. Non-classical medium-oriented education

The development of modeling technologies has led in the last decade to the widespread use of technology and methodology of medium-oriented education, its classical version postulating the special role of the similarity of the real activity model. Practically, the simulators have turned into high-precision models of real activity. Learning in the environment is a variant of the trial and error methodology transferred to complex activities. However, the classical approach exaggerates the value of external means of activity, leaving in the shadow the internal determinants of a professional formation. As a result, the quality of education suffers, internally inefficient structures and knowledge systems are formed. The effect of an amateur, sharply narrowing the range of effective professional activity appears. It can be said that classical medium-oriented education engenders middle-level professionals en masse.

Designing of training systems for training operators of complex technical systems required new post-non-classical ergonomics of simulator engineering [28, 29], which considers the learning process as a
process of autopoietic self-organization and orientation of social communication and the organism [30, 31].

The main theses of the hypothetical scheme of this direction are the following:

- The concepts of “teaching environment” and “learning environment” are introduced, which separate the formal model of activity and the technology of its creation (learning environment) from the learner’s cognitive-mental and personal structures, included in the teaching communication (teaching environment);
- The environment of the ergatic training system is a product of the constructing activity of the human operator psyche and cannot be considered outside its mental content;
- Environment reflects the phenomenon of dynamic integrity of cyclically formed chains of a person’s relationship with physical and social reality in the process of ensuring his life activity. The environment appears before the subject at the same time in the form of subjective reality and as an external objective, objective structure of the world in which the subject operates;
- The teaching environment in terms of content always arises as a dynamic process of forming a network of relationships in the subject of training, in which he personally (not always consciously) selectively engages the most diverse elements of the external and/or internal environment in order to ensure: autopoiesis of the organism, consciousness, personality stability and the continuity of its history.

In the environment agents (actors) of various physical nature can act. They can be a machine or a person, or both people or both machines. Elements of network can be of different nature. All education actors accumulate or use knowledge to generate new knowledge or distribute existing knowledge among carriers with different levels of knowledge. This is the main function of education - the distribution of knowledge in the teaching environment. Note that education does not create new knowledge, although in the process of distributing knowledge, elements of new may arise [32]. Using the experience of successfully trained for the creation of training procedures can be an effective direction for improving simulators.

5. Symbiotic environment-oriented learning

Symbiotic learning is the use of artificial intelligence technologies to enhance the capabilities of the operator, which becomes an element of the communication association of a person with an artificial or distributed intelligent controlled system in the form of an intelligent symbionte [15]. Intellect manifests itself only in an organized environment and is associated with the search, creation and use of tools that harmonize the system’s relationship with the structured environment. Intellectual symbiontes include various types of integration of the intellectual and cognitive systems of a person with various kinds of organized physical entities, which make it possible to increase the efficiency of the emerging system in solving intellectual problems.

When a student is included in interaction with complex systems (simulator, control environment), various forms of inter-system associations arise in which active forms of transformation and structuring of the learning environment manifest themselves, which can be useful in real activity. One can speak about the formation and development of symbiotic conceptual models of activity, which, unlike classical mental conceptual models, are not fixed, by largely an algorithmic product of the human psyche stored in his memory, but is the result of the joint work of the operator and the artificial intelligence of the machine.

The problem of adaptability is central while creation of technical means for training operators of complex ergatic systems of all types. It shows the general property of the living to adaptation by developing new flexible cognitive and executive structures and underlies all teaching methods. Practically all parameters of a learning task can be used to include and improve those or other professionally important functions, knowledge and skills of a person.

The recursive nature of complex learning is associated with cyclic processes of self-reproduction, operating in the human body, which makes it possible to single out recursive repetition as one of the main methods and methodological principles of learning in artificial environments.

The artificial learning environment in the simulator, presented to the student in the form of the world of his activity, should include all types of training leading to the emergence of effective professional behavior.

When creating a learning environment in the simulator, it is necessary to take into account the effects of self-organization arising in the system “learning environment - student”. It is important to ensure the activity of the student in the process of incorporation into the learning environment, which ensures
further activity in the professional environment. The main problems arising in the synthesis of simulators as systems of adaptive and symbiotic information interaction are the following:

- Search for patterns of stochastic determination of human behavior by a controlled object and environment, by means of machine learning;
- Creation of a data logging network for qualitative and quantitative analysis of factors and criteria for the complexity of solving professional tasks in the course of the life cycle of a controlled object and simulators;
- Selection of optimal models, levels, methods and means of adapting the structure and means of interaction in normal and extreme conditions for various functions;
- Development of models of adaptive communication interaction of the operator with artificial intelligence systems;
- Study of the psychological patterns of perception of thought, mnemic and perceptual processes in the conditions of cyclic self-organization of the structures of professional experience;
- Using the history of the operator's interactions with the simulator and real technology for its optimization and improvement [32].

6. The technogenic world, its educational and modifying properties

Observations on the speed of civilization evolution show that it is continuously accelerated, it acquires a global character and obeys a simple logarithmic law. The point at which this function goes to infinity is the point of singularity. At this point, qualitative changes in the content and forms of human development should occur [33, 34, 17]. According to the author of the term "technological singularity" Vernor Vinge by 2030, humanity will have technological means to create superhuman intelligence, namely:

- Large computer networks (and their combined users) will be able to “realize themselves” as superhuman intelligent entities;
- The human-machine interface will become so close that the user's intelligence can reasonably be considered superhuman;
- Biology will provide us with the means to improve the natural human intelligence [18].

Belief in scientific and technological progress is supported by other researchers. Thus, according to A.P. Nazaretyan “Among the conditions for the optimal development of civilization in the coming decades is the inevitable “denaturalization” of the human body and mind, the accelerated formation of man-machine complexes and the artificial restructuring of the material substrate of mind” [33, p. 276]. The world is becoming more organized and predictable [35]. The formation of the techno-biode has begun which is a single self-organizing planetary unity that unites man and technology [36, 37].

The evolution of the technogenic world, and appearance of a global intellectual environment, lead to a change in the fundamental human values which are the basis of the stability of the human person. The technogenic environment involves almost the whole of humanity in all spheres and forms of its life activity in the logic of its evolution. A parallel digital virtual world of total connectedness of mankind is being formed. It can be assumed that the technogenic environment will have the properties of a global distributed learning system that forms all the elements necessary for self-reproduction. This will be the solution to the problem of simulator training.

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