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ARTICLE

CYBER-PHYSICAL SYSTEMS AT THE INTERSECTION OF HUMAN AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

The era of the global deployment of the fourth industrial revolution and the transition to cyber-physical systems, experienced by society in the 21st century, globally raised the question of the role and place of artificial intelligence in the emerging digital economy. At the same time, the question arose about the relationship between artificial and human intelligence, managerial artificial intelligence and managerial human intelligence, human individual management intelligence and human command and control intelligence. Modeling and analysis of the relationship between the evolution of artificial intelligence and the transformation of human and managerial human intelligence have acquired particular importance. This article presents a study of the interdependencies between the historical progress of technical resources in social production and human intellectual development, as well as the interrelationships between the development of artificial and human intelligence, managerial artificial and managerial human intelligence in the transition to cyber-physical organizations.

KEY WORDS
cyber-physical systems, cyber-physical organisations, artificial intelligence, human intelligence, managerial human intelligence

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INTRODUCTION

The technical and economic basis of the fourth industrial revolution, which takes place in modern industrial countries, is objectively connected with the transition of these countries' economies to cyber-physical systems that form a qualitatively new material and technical basis of social reproduction.

Cyber-Physical Systems (CPS) are systems consisting of various natural objects, artificial subsystems and operating controllers that allow representing these elements as a whole. CPS provides a close communication and coordination between computing and physical resources. Computers monitor and control physical processes using a feedback loop where events in physical systems affect computation and vice versa» [1]. Technically, the transition of social reproduction to using cyber-physical systems is based on the expansion of the integrated development in digital technologies, automatic electromechanical devices (robots), the Internet and artificial intelligence. As a result, this assimilation and spread of cyber-physical systems in the economies of industrial countries objectively stimulates deep structural changes in them - first, production-technological and spatial-sectorial, and then socio-economic and institutional-managerial. Historically, industrial and technological structural shifts are of a worldwide universal nature and are directed by global industrial and technical development. This development happens in several stages and is manifested in the transition of all countries and territories from manual tool labor to machine mechanical one. The first stage took place in the XIX century and consisted in the transition to steam-mechanical labor. The second stage showed first the transition to electromechanical labor (XX century), and then - to the automated electromechanical one with the widespread use of the information technology (last quarter of XX - first half of XXI century). Production and technological structural shifts (and the subsequent spatial and sectoral economic changes) at first, historically stimulate the changes in the technical equipment and organization of social labor, then – quantitative and qualitative social and personal transformations – the development of human intelligence. It resulted in the shifts in social and economic system of social reproduction.

Consequently, the transition to cyber-physical systems of reproduction, which use artificial intelligence, should be objectively accompanied not only by the transformation in the organization of social labor and socio-economic relations, but also by the corresponding development of human intelligence, coupled with the evolution of artificial intelligence.

THE INTERRELATION OF TECHNICAL RESOURCES OF PRODUCTION AND INTELLECTUAL DEVELOPMENT OF A PERSON

The evolution of the technical resources of production

Socio-economic systems are the social relations systems of people as participants in joint production, and the human's role in these relations is to act as subjects of individual complexes, possessing the corresponding intelligences. Qualitative changes in the social economy's means of production influence both the development of socio-economic systems of human interaction and their personalities with their inherent human intelligences. In prehistoric times, the industrial and technological shifts in social economy (the development of primitive tools of labor - sticks, stones, bones) influenced the transition from savagery

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to primitive appropriating production (hunting and gathering). Industrial and technological structural shifts associated with the domestication of animals and plants led to the transition to primitive reproduction (primitive agriculture and animal husbandry). The emergence of metal tools gave impetus to the transition of human society to instrumental reproduction. The appearance of steam and electric engines led to the transition of mankind to machine reproduction.

In the first half of the 21st century, the humanity made a transition to cyber-physical reproduction thanks to the creation of electronic computing technology. The development of this technology led to the emergence of artificial intelligence, which later caused the integration of artificial intelligence with electromechanical technology and the Internet. It is historically inevitable that changes in the organization of social labor and in the structure of social reproduction as a socio-economic system give impetus to the progress of human personalities as key elements in the socio-economic system of social production and the development of their human intelligence as a necessary resource for participation in social production. The transition of humanity to primitive appropriating production objectively forced primitive man to master the skills and abilities, the elements of intelligence necessary for rational public participation in joint hunting and gathering in the primitive herd conditions. The development of primitive reproduction (primitive agriculture and animal husbandry) gave an impulse to developing in people the elements of both individual and group intelligence, which are necessary for planning and coordinating joint agricultural activities in the context of the tribal organization of social management and cyclically changing natural environment. The advent of metal tools gave impetus to the development of human intelligence, necessary to ensure the effective use of instrumental technology and rational participation in the intensively deepening division and expanding cooperation of social labor. The transition to machine production and the increase in the share of the mental labor there in the structure of social labor costs forced the intensive development of educated and creatively oriented human intelligence, which ensures that the complex machine technology has the economically efficient use in the conditions of periodically changing industrial cycles and technological modes of industrial production.

The need to develop human intelligence

In the first half of the XXI century the mankind made a transition to the sixth technological order of industrial production, to cyber-physical technical systems of reproduction, that use artificial intelligence. This should require the corresponding development of human intelligence. Industrial countries expand the development of cyber-physical systems and digital technologies of the sixth technological mode of industrial production. In its economic essence, this development represents their historical transition from automated electromechanical production to cyber-physical (using artificial intelligence) social labor and production. This transition is related to the ongoing qualitative leaps in the economic content of two interrelated aspects of social labor - technical and technological (the system of human influencing the objects of labor with tools of labor) as well as social and personal (the system of interaction between people in the labor process). Production and technical systems are beginning to form in the technical and technological content of labor (impact on nature). They integrate not only electromechanical tools, high-tech materials, electric motors, means of transmitting electricity over distances, automated control systems, but also controllers through the Internet and information technologies, physical and technical formations of artificial intelligence. In turn, the progress of the social labor's technical and technological content should objectively determine the transformation of its social and personal content (human interaction). Qualitative changes are observed in the systems of economic, organizational and managerial relations, in the nature of work, in the competencies and intelligence of workers. In this case, the intellectual and creative competences of employees are of particular importance.

Thus, it is becoming critical that the transition to a social economy based on the expanding use of cyber-physical systems is conditioned by the development of artificial intelligence in production and technical systems, and by the development of intellectual and creative abilities in workers in socio-organizational ones.

The interrelation between the two categories

The development of the social labor content (impact on nature) consistently determines, structural changes in social reproduction, followed by systemic transformations at enterprises and in the national economies of individual countries and, as a consequence, in the world economy as a whole. Cyber-physical trends and processes are driving «a gradual blurring of the boundaries between the industrial and service sectors. Hybrid industrial and service corporate giants are emerging. They simultaneously produce physical products, maintain powerful network and computer infrastructure, and at the same time, develop software products and services, sell services and serve customers [2]. Industries and enterprises undergo cyber-physical technological integration based on expanding the implementation of digital technologies. This process will objectively give an impetus to developing full life cycles chains of science-intensive products within industrial complexes, including science-intensive services, extraction of raw materials and production of construction materials, manufacturing finished products, after-sales service and conventional services, waste disposal and environmental service.

This should give a corresponding impetus to the transformation of small and medium-sized businesses, which are developing under the influence of integration into these cyber-physical full life cycles chains of science-intensive reproduction.

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Production systems of individual economic entities accumulate structural changes which inevitably gives an impetus to the growth of structural and systemic transformations in national economies. This is manifested in an increase in the share of science-intensive goods and services in the reproduction structure of the gross national product. A highly educated middle class transforms into the main social stratum in the structure of labor resources reproduction. It is engaged in knowledge-intensive innovative labor, based on the widespread use of cyber-physical production means.

The transformation processes of property relations will play the leading role in the structure of economic relations reproduction as well as in institutional and managerial organizational forms of social production. As a result, socio-organizational systems are beginning to be of key importance for economic growth, providing cost-effective and competitive cyber-physical integration of industries and enterprises based on the expansion of the implementation of digital technologies, Internet capabilities, artificial intelligence, as well as the development of creative and intellectual competencies of workers. The development of structural and systemic changes in national economies causes qualitative changes in the structure of the world market economy, in the system of global market economy and in global competition. Gradually, the development and implementation of cyber-physical strategic competitive competencies are becoming the key factors of global competitive success. As a result, the transformation of monocentric globalization is growing and it turns into a polycentric one. The latter is aimed at balancing the development of the world and national economies on the basis of successes in the competitive development of cyber-physical systems and industries. The course of this structural and systemic development in society (as a social system) and in its basic elements (organizations) consistently transforms the corresponding interrelated and interacting components (internal systems).

- First, it transforms the material and technical system (technological links) of interaction between the means of production.
- Secondly, it changes the reproduction system of personal social and labor resources in social systems (organizational and personal relations), providing intellectual development of new material and technical capabilities of social production.
- Thirdly, it modifies the socio-economic system (economic relations and institutions), which ensures the socio-economic interaction between the subjects of production activity (workers and organizations).

These systems are interconnected in each organization (social structure). They interact and develop continuously, acting as subsystems of a controlled social system.

At the same time, according to the system approach, these systems act as correspondingly interconnected and interacting subsystems in the structure of the organization as a social system. Thus, theoretically, a cyber-physical organization represents a specific form of a social system. The corresponding production and labor processes are carried out within this organization, and they form its internal dynamic content. As it was already mentioned, there are two main components in the content of social labor as a result of the interaction between technical and human factors of production. The first is technical and technological, the second one is social and personal.

These components develop dialectically in the context of public economy transition to cyber-physical systems and digital technologies. This objectively generates dialectically interconnected qualitative changes in them. On the one hand, artificial intelligence organizations emerge and develop in the production and technical systems. On the other hand, creative human intelligence emerges and develops in the social and labor systems.

In the first half of the XXI century, the social system that originated in primitive society resulted in the emergence and development of the components of the system, where people interact with nature and with each other in the production process. These components are interconnected and play the key role in the cyber-physical management. This historical development is based on socio-economic progress, which is the result of the dialectical interaction between technical and human factors of production. The content of the technical (materialized) factor distinguishes such interrelated components as tools of labor, objects of labor and the technology of the tools of labor influence on objects of labor. The content of the human (living) factor distinguishes such interrelated components as systems of socio-economic relations, forms of labor organization, institutional methods of coordination (management) of labor and human intelligence as the basis of purposeful social interaction in the labor process. The interrelated historical development of the technical (materialized) and human (living) factors of social reproduction is ultimately aimed at the historical development of man.

Human development represents the essence of the historical process. Therefore, the ontological (anthropological) basis of socio-economic development is the irresistible tendency of human development in accordance with their universal generic essence [3]. In turn, an increase in the scale and culture of consumption determines the historical development of a man. This increase is due to a rise in the production scale, and it manifests itself densely in new rounds of cultural and intellectual development of the personalities of people employed in social production. The transition to cyber-physical systems using artificial intelligence should require the corresponding development of human intelligence.

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CYBER-PHYSICAL ORGANIZATIONS, ARTIFICIAL AND HUMAN INTELLIGENCE

The formation of cyber-physical systems

The transition of the modern economy to cyber-physical systems using artificial intelligence historically acts as the next stage in the expansion of social reproduction on a qualitatively new technological basis. This expansion of social reproduction is determined by the action of the corresponding economic laws and patterns, which determine the direction and nature of the trends in modern economic development.

Theoretically, certain economic laws and regularities define the dynamics of the production scale growth and the improvement in the structure of social production. Among these laws one can single out the laws of the rise in needs, the necessity to satisfy needs, and the growth of labor productivity.

The economic law of the rise in needs reflects a deep internal relationship between production and needs. Human development forms the basis of the society progress; whose economic basis is the satisfaction of people's growing needs. Satisfaction of needs, in turn, stimulates the growth of production, the expansion of which leads to an increase in human needs [4]. The economic law of the necessity to satisfy needs is the first precondition of life itself. This law operates due to the driving force contained in the need and determining the necessity to produce material and spiritual goods for its satisfaction. Ultimately, the need visibly appears in the results of labor as specific products that directly satisfy specific needs. The law of necessity to satisfy needs determines the manifestation nature of most market phenomena. It underlies the exchange interactions of market relations participants [5]. The law of growth in labor productivity expresses internally necessary, stable and significant links between the progress of the technological production mode (production technologies and their individual elements) and the efficiency of production activities in the process of creating goods and services (or the amount of labor to manufacture a unit of production).

Taking into account the synergistic effect, all factors affecting labor productivity can be divided into the following main groups. They are factors associated with living labor, factors connected with the means of labor, factors associated with the introduction of the latest forms in organization of production and labor, factors connected with the improvement of technical and economic relations, factors associated with the improvement of labor objects, factors involving structural changes in the national economy [6]. The factors under consideration are characterized by their functional and labor essence, manifesting materialized and living labor. Each of them has a specific content that includes the corresponding elements, components and connections. Moreover, historically, their content is in continuous and interconnected development.

The impact of technological progress on social progress

The technological production mode (techniques and production technologies) is an integral part of the social production mode - the socio-economic form (system) of combining direct producers with the means of production, where technical production means dialectically interact with human resources.

Consequently, technical progress should determine the social progress in production, which manifests itself in the development of organizational forms of interaction between workers and their human intelligence, interconnected with it.

The resources associated with the use of technical labor means (materialized labor) dialectically interact with the resources associated with the use of living human labor in the process of expanding social reproduction. In the author's opinion, this interaction should be considered as an objective economic law.

This regularity reveals the mechanism for the growth of labor productivity and production, followed by the possibilities to satisfy the rising needs, because of the systemic (interdependent) interaction between material, technical, social, and personal factors (elements) of the growth in social labor productivity and reproduction volumes.

The connection of different intelligences

Quantitative and qualitative changes in the evolution of material and technical factors (resources) should be dialectically ensured by corresponding quantitative and qualitative changes in the development of social and personal (human) factors (resources) for the growth of labor productivity and the scale of social production. The content of material and technical factors allows to single out such developing components as labor tools, technical energy sources (engines), electronic computing means for automated engine control (ACS), technical means of transferring energy from engines to tools (transmissions), intellectual means (artificial intelligence) of programming and optimizing the ACS operation, technologies and means of information transfer from AI to ACS.

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According to modern scientific approaches, artificial intelligence is the ability of a digital computer or computer-controlled robot to perform tasks normally associated with intelligent beings. The term is often applied to a project for the development of systems endowed with human-specific intellectual processes, such as the ability to reason, generalize, or learn from experiences. In addition, the definition of the AI (artificial intelligence) concept is reduced to a description of a set of related technologies and processes, such as machine learning, virtual agents and expert systems [7].

Artificial management intelligence presents a specific type of artificial intelligence

Artificial management intelligence is an intelligent management system for organizations. It is based on the construction of a rational labor relations model, which makes it possible to equate the interests of the company (employer) and employees. According to modern researchers, the main tool for creating Artificial Management Intelligence is a rational model of labor relations. This is a personnel management system that changes the organizational culture in the company and equates the interests of the company (employer) and employees by changing the imperfect system of labor relations. After implementing the model, each employee gets the opportunity to satisfy their own interests through a high-quality work for the benefit of the company [8].

The content of social and personal factors allows singling out several developing components. They are a socio-economic component that implements the possibilities of division, cooperation and coordination of people's joint work, an institutional and managerial component that provides goal-setting and rational coordination of interaction between people and technology as well as among people themselves; social and labor component - people with their human intelligence, knowledge, skills and abilities. According to modern scientific literature, human intelligence is the mental ability of the human body, expressed in its ability to solve various challenges, cope with problems, carry out cognitive activities, adapt to changing environmental conditions and control them. Human mental intelligence is a set of accumulated knowledge, the ability to apply it correctly, as well the ability to think broadly and to find logical solutions.

From the author's point of view, rational intelligence can be distinguished in the structure of human intelligence. This is the ability to identify structure, formalize problem situations, factor in and predict logical solutions to problems of social development.

In addition, according to modern researchers, a person has a certain level of emotional intelligence. This is the ability to identify subtexts, hidden meanings, the interlocutor's manipulations by reading their emotions, facial expressions, gestures, and posture. Modern science also singles out social intelligence. This is the ability to understand people's behavior correctly. It is essential for effective interpersonal interaction and successful social adaptation. Human intelligence develops in society when people interact with other each other, exchange experiences, and adopt cultural traditions [9].

Managerial human intelligence is a specific form of human intelligence

According to the results of modern scientific research, managerial human intelligence has a narrow and a broad meaning. In the narrow sense, it is the intellectual ability to effectively develop and make optimal management decisions and organize public (joint) production and labor activities of subordinates to implement these decisions, i.e. to plan, delegate, motivate, control and coordinate fulfillment of the tasks assigned to them. In the broad sense, managerial human intelligence is a special combination of several properties of social and general intelligence, an alloy of logic and intuition, predominantly synthetic, analytical and practical style of thinking.

These special properties include the ability to identify cause-and-effect relationships and the main link, grasping which you can solve various problems in the interests of your organization. They also involve the ability to build processes, anticipate the development and consequences of situations associated with the activities of the organization, and make adequate managerial decisions. One more property is the understanding of the people's interests, motives and psychology, the ability to select personnel for key positions, unite and direct their efforts to solve the problems that the organization is facing. Another factor is the ability to operate with a large number of variable factors, plan the organization's work for both short and long terms.

The most important properties of managerial human intelligence are critical self-assessment, the ability to learn from one's own mistakes, understanding the essence of management principles. Most of the management abilities are given to humans by nature, while the rest of them are acquired through training and work experience. If a person does not possess natural abilities, acquired ones are not able to compensate for them [10]. The latest studies of managerial human intelligence note that the relative predominance of the 1st or 2nd signaling system (right or left hemisphere of the brain) objectively determines different types of thinking. As a result, the individual characteristics of managers' thinking are reflected in different relationships between different types of thinking, which must be taken into account when selecting and placing management personnel.

In this connection, cyber-physical organizations (the ones using cyber-physical production systems) must take into account the specifics of the division, cooperation and coordination of intellectual managerial labor. In particular, modern research note, that such circumstances must be taken into account that

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workers with visual-effective or concrete-sensory abilities must command machines, things, mechanisms; workers with visual-figurative (speculative-specific) abilities are more suitable for leading people; workers capable of abstract modeling are more appropriate for design and engineering work [10]. As the organization of social labor is developing in the context of spreading cyber-physical systems in general and artificial intelligence in particular, it will urgently require deep consideration of the levels of the individual's intellectual actions.

Modern psychology also knows the concept of levels of intellectual activity and intellectual actions

Researchers distinguish three levels of intellectual activity. The first one is the stimulus-productive level, when mental activity is conditioned only by the influence of external factors. The second level is the heuristic one, which means a spontaneous cognitive activity leading to the discovery of a number of regularities. The third level is the creative one representing the highest level of mental activity, where there is a full penetration into the essence of the things being studied, the solution of existing problems and the setting of new tasks.

Two levels of intellectual actions are also distinguished. The first one comprises personal actions at the level of the social individual, where the human activity is determined by the task and the desired results. The second level includes the actions of a creative person. In this case, the result turns out to be wider than the set goal and it generates new tasks [11].

These levels of personal actions determine the employees' differentiation into leaders and performers

Appearing in material and technical production systems, such component as artificial intelligence stimulates qualitative changes in the content of production processes. This inevitably affects the human factor of production, which is revealed in the corresponding requirements for improving managerial work, increasing its efficiency. As a result, the development of human managerial intelligence is put on the agenda. At the same time, this is not only the issue of individual managerial intelligence, but also a purposeful increase in the efficiency of managerial work based on the development of command-managerial human intelligence. The importance of teamwork and, as a consequence, of team (group) intelligence increases significantly in the context of expanding cyber-physical integration between industries and economic entities, the increase in complexity and urgency for management problems, the scale of processing the necessary management information. The provision of intellectual productivity and efficiency of team management work becomes particularly important.

Consequently, the problem arises how to develop and implement models of optimal interconnection and interaction systems between artificial intelligence of technical systems and the human intelligence of both individual workers and the group intelligence of teams that implement the corresponding projects and strategies for the competitive and economic development of controlled organizations. The controlled organizations management brings the issue of developing organizational models and schemes (division, cooperation and coordination) of social labor to the agenda. Including intellectual and managerial labor, these systems must correspond to the requirements of cyber-physical production systems and the expanding use of artificial intelligence most adequately. They must as well provide coordinated interdependent development of artificial and human intelligence, artificial managerial and human managerial intelligence. At the same time, the problem raises in the management systems of cyber-physical organizations how to develop modeling and rational structuring of the human individual-managerial and human command-managerial intelligences ratio, their relationship with the evolution of artificial intelligences. This should consist in an increase in the productivity of social labor in general and an increase in the efficiency of managerial labor in particular.

CONCLUSION

Thus, if we proceed from the economic regularity of the growth in labor productivity and production as a result of the systemic (interdependent) interaction between material-technical (including artificial intelligence) and social-personal factors (including human intelligence) of social labor and reproduction, we can draw the following conclusion. Among other reasons, the growth of labor productivity and production is largely the result of the dialectical interaction of artificial intelligence and human intelligence. In their interaction, these factors induce and optimize production and labor processes within social systems. In modern economy, the Industry 4.0 passes on to cyber-physical systems and the increasing use of artificial intelligence. This requires the development of research on ways to modernize human intelligence, primarily managerial human intelligence, as well as ways to combine it with the evolution of the artificial intelligence implementation. There is a need to intensify the development of theoretical and methodological principles, scientific methods and methods of managing the functioning of organizations using cyber-physical systems, the processes of interaction between material-technical (cyber-physical) and social-personal factors of production in them. We also should develop human intelligence adequately to expanding opportunities of artificial intelligence.

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CONFLICT OF INTEREST

There is no conflict of interest.

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