Information Technology as the Basis for Transformation into a Digital Society and Industry 5.0

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***Abstract* — Currently, the industry is transforming the physical world of real things into their "virtual copies". This transformation is a key element of industry 4.0. Due to the high requirements of end users to the individualization of the purchased product industry 5.0 is becoming increasingly popular concept, which implies the penetration of artificial intelligence into the human life to increase the level of human capabilities. The article discusses the state and prospects of development of technologies that contribute in the process of the transition from industry 4.0 to industry 5.0. The conditional pyramid of technologies which Association is capable to provide this transition is presented. New types of distributed computers, Internet of everything, multi-agent systems and technologies, ontology and knowledge bases, theory of complex adaptive systems, emergent intelligence, evergetic and enterprise architecture are considered as the main components for the transition. Boundary calculations in the context of management of data coming from the Internet of things will affect almost all companies in the economy and the public sector. They will cover the scope of activities from the automation of throughput control and data collection on the quality of goods, monitoring of vehicle traffic and ending with the robotization of factories. The article presents an analysis of modern and promising technologies necessary for the organization of the digital industry in enterprises, and determining the set of necessary technologies that ensure the transition from the current state of the industry to Industry 4.0 and then to Industry 5.0. It also presents a formal description of industry 4.0 and industry 5.0, which makes it possible to present the problem as a mathematical problem that has a solution. Complex formal description of the enterprise, based on the methodology of its architecture, allows to increase the efficiency of business information support in the industry 5.0. This is necessary for the organization of the digital industry in enterprises and to determine how to ensure the transition from the current state of the industry to industry 5.0. Applying this approach to industry 4.0, then to Industry 5.0, will measure the cost of this transition and make it effective.**

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Keywords — industry 4.0; industry 5.0; artificial intelligence; Internet of things; multicomponent technologies; complex adaptive systems; enterprise architecture

I. INTRODUCTION

The development of new information technologies has allowed the world to move into Industry 4.0. The technology of designing and manufacturing complex technical products changes dramatically during the implementation of the concept of Industry 4.0. The view on the role of computers in enterprise management is also changing. The view on the methods and means of industrial automation is changing, from sensors and automation of technological processes to integration and visualization of data and intellectual support.

Industry 4.0 is defined in the sources as “a concept used to describe related technological advances that provide the foundation for increasing the level of digitization of industrial and business environments.” Usually, when speaking about the development of Industry 4.0, four key components are distinguished: Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), smart factory and 6 core technologies: additive technologies - 3D printing, Industrial Internet of Things (IIoT) and CPS, big data, Artificial Intelligence (AI), Collaborative Robot (CoBot) and virtual reality[1]. At the same time, the focus is on the technical aspects of their implementation. The mental, creative and volitional abilities of a person are not part of this ideology. Such a situation does not suit society, which is reflected in a large number of articles devoted to this concept. It is noted that Industry 4.0 will continue to be impossible without a human being.

Despite the fact that Industry 4.0 will be able to show its results, and achievements no earlier than in 2020-2025, researchers are already starting to talk about Industry 5.0, which will be based on self-learning machines, copying the humans actions or other robots and continuous optimization of production algorithms. The concept includes the penetration of artificial intelligence into human life.

The term Industry 5.0 was firstly introduced on December 1, 2015 in an article published by Michael Rada with the

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reference to the social network LINKEDIN. Industry 5.0 is the efficient use of machines and people labor in a synergistic environment [2].

In this regard, Industry 5.0 refers to the integration of physical and virtual space to solve not only production problems, but also social problems. The point is that all advanced information technologies, artificial intelligence, augmented reality, robots are used in everyday life, industry, healthcare and other areas of human activity.

The report discusses modern technologies - from the Internet of things to enterprise architecture. The convergence of these technologies will ensure the transition from Industry 4.0 to Industry 5.0.

The article Sc. P. O. Skobelev and P. S. Yu. Borovik give a description of the technology Industry 4.0 and Industry 5.0[3]. We agree with the authors on the basic terms of these concepts and in order to determine the path of transition to enterprise architecture in the concepts of Industry 4.0 and Industry 5.0 we will briefly give the main technologies of these concepts.

II. On the Way to the Society 5.0: Directions and Prospects

The combined application of the technologies listed in Figure 1 will help society come to the concept of Industry 5.0.

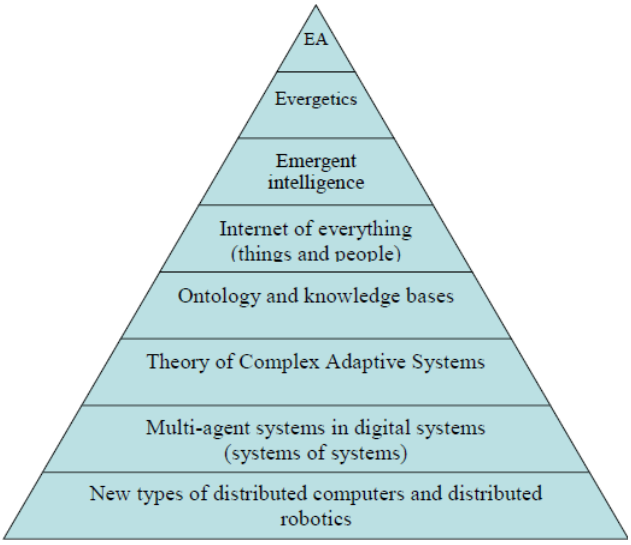

Fig. 1. The convergence of science and technology in Industry 5.0

A. New types of distributed computers

These technologies are the hardware base for creating an intelligent self-organizing system of various types. Distributed computer networks allow you to expand the computing resources and to provide multi-threading and asynchronous computations.

B. Internet of things and people

IoT (including the industrial Internet of things, IIoT) is an intensively developing technology that complements the traditional and familiar Internet, and it is also the basis of automation in Industry 4.0 and Industry 5.0.

IoT refers to the global infrastructure for the information society, providing the interconnection (physical and virtual) of things based on existing and developing ways of information and communication technologies.

Cisco proposed the term “Internet of Everything” in 2013. It is considered to be wider than IoT. Cisco defines IoE as the network connection of people, data, processes and things.

The implementation of IoT obviously requires the development of a number of promising technologies, including smart sensors, smart dust (self-organizing tiny devices (group robots) exchanging wireless signals and working as a single system), RFID tags (etc. it will allow “intellect” to be invested in a “thing” at the stage of its production. IoT in Industry 5.0 (as, indeed, in Industry 4.0) should not be technology for the sake of technology. IoT should be aimed at improving the quality of human life[4].

Unique solutions arise after Big Data is applied to these technologies. Big Data, IoT, and IoE are perhaps the key components of Industry 5.0. All information collected in the physical space in the form of Big Data during production is sent to cyberspace. The technology of artificial intelligence (AI) can help: to analyze this data, to find the optimal solution from the point of view of AI for the production or financial process and to send it back to the physical space [5]. The difference between Industry 4.0 and 5.0 is in the scale of implementation of the latest digital technologies.

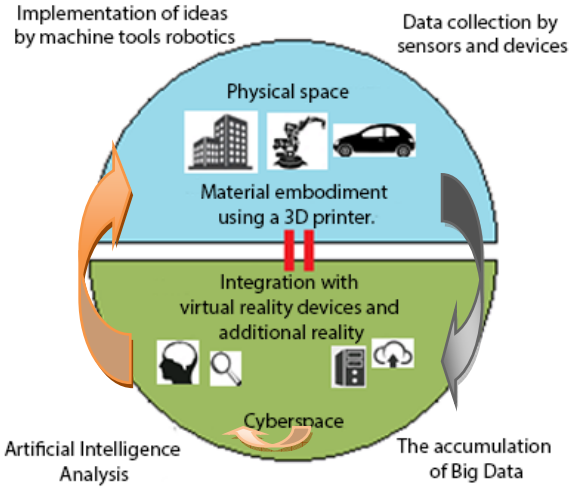

Fig. 2. The diagram of work in "Industry 5.0"

Figure 2 shows that Industry 5.0 will improve both the role of mechanical components and the human role in manufacturing. It will leave monotonous, repetitive tasks for robots and will reveal the creative side to humans. This will allow staff to take on greater responsibility and to strengthen systems oversight to improve the quality of manufactured products in all areas [6].

C. Multi-agent systems and technologies

The use of multi-agent technologies allows solving problems that are difficult to solve with the help of classical mathematical methods. The introduction of IOT technologies

(Iot) assumes that any thing will be equipped with a miniature sensor that will allow you to transfer data from it to the Internet. This will uniquely identify each thing, get the necessary data from it and, if there is a certain intelligence, even manage it. Data transfer to the Internet space will allow to create virtual models of real objects, such as production, the work of which can be controlled in real time. Intelligent agents are used to communicate between virtual and real worlds [7].

A multi-agent system is defined as a network of related agents that solve particular problems that exist in a common environment and interact with each other to achieve certain goals of the system. Communication between agents in a multi-agent system can be carried out in different ways. Their interaction can be organized by direct transfer of data from one agent to another, or by analyzing changes in the state of other things in the system.

The use of Internet of things technology will help to solve global problems that require a large amount of information and computing resources, such as resource planning and even modeling of entire ecosystems. The Internet of things increases the value of network connections to an unprecedented level. Its use allows to expand the user experience and creates favorable conditions for the development of countries, companies and users.

D. Ontology and knowledge bases

There is still no single definition of ontology. Ontology is knowledge formally presented on the basis of conceptualization. Formally, ontology consists of terms organized into a taxonomy, their definitions and attributes, and associated axioms and inference rules. [8]. An ontology is usually defined as some general vocabulary of concepts used as a building brick in an information processing system. Typically, an ontology describes a hierarchy of concepts that are interconnected by categorization of relationships.

Multi-agent systems effectively apply the ontological approach. All knowledge of agents is stored in the form of ontologies. They form a knowledge base that includes concepts, knowledge of the subject area and methods of solving problems. All this allows agents to share the accumulated information and helps in the decision-making process.

At the same time, three qualitatively different methods can be chosen to integrate the ontology approach:

- knowledge and ontologies formed by agents are available only to agents themselves;
- knowledge and ontologies formed by agents are combined and stored by one of the agents;
- some knowledge and ontologies are stored centrally, and some are distributed among agents.

Note that the use of ontologies in multi-agent systems will ensure the standardization of knowledge, which will simplify the exchange of information between agents, and will also allow, to predict the behavior of another agent based on a known part of its ontology if communication between agents is impossible.

E. Theory of complex adaptive systems

The theory of complex adaptive systems appeared in the 90s of the 20th century. The point is that irregular forms of living systems arise from adaptive behavior, and adaptive behavior can be reduced to a sequence of interactions with the environment to determine the dynamics of a more complex structure.

A comprehensive adaptive system has properties of aggregation (a hierarchy of elements in which lower-level elements form upper-level elements - aggregates), of non-linarites, of resource flows, of diversity (lack of equilibrium status).

Therefore, it can be argued that the basis of multi-agent systems is the theory of complex adaptive systems. It establishes a connection between multiagent and nonlinear systems.

F. Emergent intelligence

Emergent intelligence (intellectual resonance, swarm intelligence) is a manifestation of unexpected properties that a system possesses, but does not possess any of its individual elements. the dynamics and unpredictability of the decision-making process is a key feature.

Emergent behavior follows various patterns; it is unpredictable, but not accidental. The variability and stochasticity of the decision-making process with the help of the number of interactions that are almost not traced is a key feature of emergent intelligence. Therefore, the property of emergent intelligence is often associated with multi-agent technologies that implement the interaction of simple elements in their self-organization to solve specific problems.

G. Evergetics

Evergetics is a developing science of intersubjective management processes in society. It focuses on “good actions” in the management process. Classical management science is invariant to any values and this is the main its difference from evergetics[9].

Evergetics is an interdisciplinary science, which should be based both on the humanities, social sciences, and on control theory, computer science and some other disciplines. The multidisciplinary characteristic of evergetics is caused by the fact that a person in evergetics is, a subject that has ways and resources of resolving conflicts and decision-making, and also is an object of education, upbringing, creation of worldview and ability to interact with other subjects, etc. However, evergetics does not deny classical “systemic” approaches to management in socio-technical systems, but adds and widens their capabilities.

The basis of evergetics is the theory of intersubjective management. Within this theory all active subjects could be regarded as a heterogeneous "actor" who has "plunged" into some kind of problematic circumstances and is ready to solving

it collaboration with other actors. Moreover, the decision is made on the basis of agreement, with collaborative conviction, compromises, concessions, etc. It prevents the manifestation of violence, evil, aggression and other defects, because in the process of negotiation and decision-making, there is a “smoothing" of the negative phenomenon.

H. Enterprise architecture

An enterprise planning a transition to Industry 4.0 and subsequent to Industry 5.0 should do everything possible to make this transition as effective as possible. To do this, it is necessary to provide business implementation processes with the necessary support, while avoiding unnecessary costs. The enterprise will be successful within the framework of the concept of Industry 4.0 and Industry 5.0 if it has a rational architecture. The introduction of a rational enterprise architecture will also help to effectively transfer it to the digital industry.

The classic EA management cycle (Fig. 3) is closely intertwined with the ideas of improving and reengineering business processes and in the most simplified form consists of the following steps [10]:

- description of an existing EA (“as is” model, current EA, etc.);
- analysis of current EA, strategic requirements and problems / capabilities of the organization;
- designing a promising EA (“as it should” model);
- planning the transition to a perspective state from the existing one (project portfolio and development program);
- monitoring and control of ongoing changes, allowing to close the EA control cycle.

Rational EA design technology for the digital industry will improve the efficiency of information support for business in Industry 4.0 and 5.0.

Fig. 3. Classic control loop

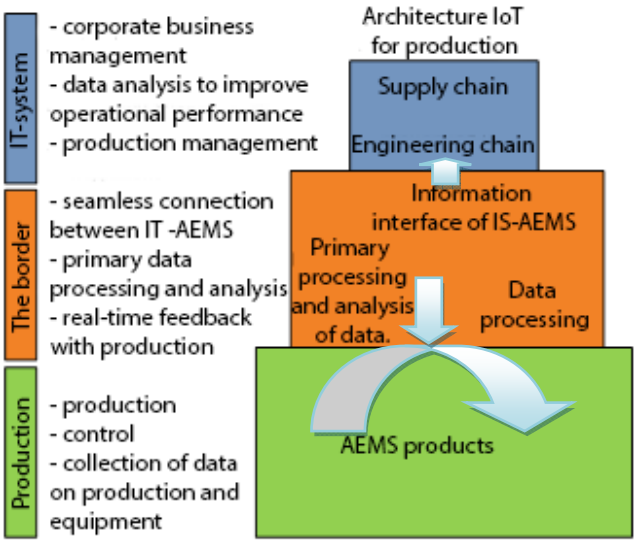

Fig. 4. Enterprise architecture

The use of boundary computing as a key element increases the productivity of the entire enterprise by integrating a wide range of production elements into a single IT system, which is facilitated by optimal EA. Figure 4 shows the general scheme of the production architecture, where the IoT Architecture is at the head of the processes, as the connecting link of this EA section with the data section [11].

I. Industry 5.0: Formal Description

Boundary computing in terms of managing incoming IoT data will affect almost all companies in almost every industry and public sector. They will cover all areas of activity, from automation of access control and data collection on the quality of manufactured goods, monitoring the movement of vehicles and ending with the robotization of factories.

We denote the concept of Industry 4.0 as I4. In general, it can be represented as follows (1):

$$I4 = IIoT + 3DP + BD + AI + CoBot + VR + EA, \quad (1)$$

where *IIoT* - industrial internet of things, *3DP* - additive technology (3D printing), *BD* - big data, *AI* - Artificial Intelligence, *CoBot* - collaborative robots and *VR* – the virtual reality, *EA* - enterprise architecture.

We denote the concept of Industry 5.0 as I5. Then, taking into account the technologies considered above, it is also possible to write in a general form(2):

$$I5 = K + IoE + M + O + T + EI + E + EA, \quad (2)$$

where *K* - new types of distributed computers, *IoE* - Internet of things and people, *M* - multi-agent systems and technologies, *O* - ontology and knowledge base, *T* - theory of complex adaptive systems, *EI* - emergent intelligence, *E* - evergetics.

Effective information support of the enterprise within the framework of the concept of Industry 5.0 can be provided using

a comprehensive formal description of the architecture of the enterprise according to the Zahman methodology. To ensure an optimal transition from the current state of the industry to Industry 5.0, it is necessary to introduce a digital industry in enterprises.

With the integration and end-to-end digitization of all parts of production and business processes, ICT systems, it becomes possible to form a complete (or partial) digital copy of production (digital twin). Thereby, on the one hand, a reflection of all real physical processes in a virtual (digital) production model is achieved; on the other hand, the results of digital modeling can provide feedback and create a control effect on real production processes, which is an integral part of the concept of Industry 5.0.

III. Conclusion

The analysis of modern and promising technologies has been determined that are necessary for the organization of the digital industry at enterprises. The study identified a set of technologies that will allow the industry to move from the concept of Industry 4.0 to the new concept of Industry 5.0.

The analysis shows that the increasing interest to the digital economy and the large fields of practical applications of this technology have establish a solid foundation for the implementation of Industry 4.0 and in the future can be the basis for the establishing of Industry 5.0.

The development of an optimal enterprise architecture and the construction of its formalized description will improve the quality of information support provided to the enterprise. An effective transition from the current state of the industry to Industry 5.0 cannot be imagined without the introduction of an optimal enterprise architecture.

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