

## **Theoretical Approaches To The Definition Of "Cyber-Physical System" Concept**

**By**

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### **Abstract**

In modern conditions, the degree of a man and machine integration is quite high, and, according to a number of experts, this process is at the initial stage only. The consequence of this integration is the emergence of so-called cyber-physical systems. The lack of an unambiguous understanding of such terms content as "artificial intelligence", "robot", "intelligent robot", "robotics", "intelligent agent", etc., leads to terminological problems during regulation development. The article defines that a cyber-physical system is an integration of physical objects, software and communication networks. This concept has a significant volume, which includes many different objects of the material world, therefore, until the researchers come to a consensus on this concept, it is preferable to fix a set of CPS integral features, which will create a flexible approach to the associated field of public relations regulation.

**Keywords:** cyber-physical system, bio-cyber-physical system, robot, robotics, regulation, law, artificial intelligence, concept, term

### **Introduction**

The Decree of the Russian Federation Government (August 19, 2020) No. 2129-r approved the Concept for the development of relation regulation in the field of artificial intelligence technologies and robotics until 2024. This document is a set of legal perspectives, and also defines the areas of work within the framework of a multifaceted legal platform creation in the field of robotics and artificial intelligence.

The lack of an unambiguous understanding of such terms content as "artificial intelligence", "robot", "intelligent robot", "robotics", "intelligent agent", etc., leads to terminological problems during regulation development.

Considering the applied nature of these technologies application in different areas, it will be necessary to formulate different definitions depending on the industry of artificial intelligence technologies and robotics application<sup>1</sup>. For this reason, during the time period considered in the Concept, it is proposed to avoid, if possible, the introduction of a single regulatory definition of these terms for all industries into the legislation of the Russian Federation. At the same time, it is extremely important during this period to carry out the work

on the construction and harmonization of the subject area ontology by the expert community and specialized technical committees under the Federal Agency for Technical Regulation and Metrology. If it is necessary for the purposes of regulation subject determination of specific regulatory legal acts, it is proposed to use the definitions contained in standardization documents, or to give definitions relevant to a particular area of regulation.

All this applies equally to the concept of "cyber-physical system".

## **Materials and methods**

The methodological basis of the study is a systematic approach to the study of the theoretical aspects of "cyber-physical system" concept definition. When processing the factual material, they used such traditional scientific methods as dialectical, logical, the method of scientific generalizations, content analysis, comparative analysis and synthesis. Their application made it possible to ensure the validity of the performed analysis, theoretical and practical conclusions and developed proposals.

## **Results and discussion**

In modern conditions, the degree of a man and machine integration is quite high, and this process, according to a number of experts, is at the initial stage only. The consequence of this integration is the emergence of so-called cyber-physical systems (hereinafter referred to as CPS). At the same time, CPS integrate the cybernetic principle, computer hardware and software technologies, qualitatively new actuators built into their environment and capable of perceiving its changes, responding to them, self-learning and adapting. The key idea of such systems is the integration of the physical and information space<sup>2</sup> The ability to perceive the environment and adapt to it is another feature of CPS.<sup>3</sup>

The history of the term CPS origin is controversial among researchers. It is believed that German specialists were the first ones who introduced this concept.<sup>4</sup> Other authors believe that the term CPS comes from the USA: already in 1948, N. Wiener introduced the term "cybernetics", which formed the basis of the subsequent concept – CPS.<sup>5</sup>

The approaches to CPS definition also have a different nature. According to the specialists of the US National Institute of Standards and Technology, cyber-physical systems are the smart systems that include computational and efficiently integrated physical components that closely interact with each other.<sup>6</sup> Also, the result of another study was the rationale for the presence of the following important characteristics in such a system:

- 1) it is a hybrid system, since it integrates calculations with physical processes;
- 2) CPS combines computing and communication capabilities with monitoring and control of the objects in the physical world;
- 3) it consists of physical objects, sensors (sensors and actuators) and information systems.<sup>7</sup>

One of the most common definitions of CPS is the definition offered in Wikipedia. It sounds like this: "Cyber-physical system (English cyber-physical system) is an information technology concept that implies the integration of computing resources into physical processes. In such a system, sensors, equipment and information systems are connected throughout the

entire value chain that goes beyond a single enterprise or business. These systems communicate with each other using standard internet protocols to predict, self-adjust and adapt to changes<sup>8</sup>.

Taking into account the very nature of the CPS term, we believe it is necessary, first of all, to consider the CPS definitions, enshrined in a number of foreign standards, regulatory documents, as well as studies in the framework of public funding. These definitions are presented in table 1.

**Table 1:** Definitions of CPS, fixed in foreign standards and regulations, as well as in the studies within the framework of public funding

Name of the document or research program	CPS definition
Research of expert group on the Future of Science and Technology (STOA) <sup>9</sup>	CPS is a system of interacting computational elements that control physical objects, including humanoid robots, artificial intelligence (AI), the Internet of things (IoT) and any device or machine that is connected to an information network
Industry 4.0 Research <sup>10</sup>	CPS are the systems that consist of software embedded in hardware, such as sensors, processors and communication technologies, and can autonomously exchange information, trigger actions and control each other independently
Study of the group of experts in the direction "Ethical aspects of cyber-physical systems" <sup>11</sup>	CPS are intelligent robotic systems connected to the Internet of things, or technical systems of networked computers, robots and artificial intelligence that interact with the physical world.
The Grant Program Cyber-Physical Systems (CPS) NSF 18-538	CPS are technical systems in which networked computers and robots interact with the physical world. By 2050, these systems can interact with us in many areas, move along our roads, move with us in our daily lives and work in our industries.
US National Institute of Standards and Technology (NIST) Framework Standard <sup>12</sup>	CPS are engineered systems that are built and depend on the seamless integration of computing and physical components. CPS closely integrates computing devices, management, network infrastructure and the physical world perception. The system may include human interaction with or without human control. CPS may also include several integrated system components operating on a wide variety of spatial and temporal scales.
European Strategy for the Development of CPS <sup>13</sup>	CPS are smart systems that include designed (engineering) interactive networks consisting of physical and communication components.
	CPS consists of computing, communication and control components, closely interacting with physical processes of various nature (mechanical, electrical and chemical)

Some authors note that the sphere of creation and CPS use includes a number of concepts, the definition of which is fundamentally important for research in this area. Most often, such categories as "robot", "artificial intelligence", "cyber-physical system"<sup>14</sup> are included in circulation. However, a significant spread of opinions in the field of understanding

related concepts leads to difficulties regarding differences in the understanding of a particular category. For example, within the framework of a direct cyber-physical system, such concepts as “robot” and “robotics”, “intelligent robot”, etc. can be combined. Besides, these concepts can act as autonomous entities<sup>15</sup>. Difficulties in interpreting these concepts are also related to the fact that each of these terms has its own specific understanding in relation to different areas of research or even the branches of law<sup>16</sup>. That is why the indicated team of authors is of the opinion that there is no single legal definition of CPS today.

Other researchers understand CPS as an integration of three elements: physical objects, software, and communication networks. At the same time, autonomy is not a mandatory characteristic of CPS.<sup>17</sup>

In foreign studies, there is also the term "bio-cyber-physical system", which includes both a biological and a physical component.<sup>18</sup> The biological principle of this system will make it possible to multiply the level of mutual understanding and interaction between a person and such a system, since it will be closer to a person by its nature. Unlike cyber-physical systems, cyber-biological systems involve the interconnection of a biological element, software, and communication networks.<sup>19</sup>

There is also an opinion that CPS should be studied from the standpoint of a mixed approach, involving the simultaneous study of physical processes, software and network interaction. The challenge for the researchers of the cyber-physical system is to synchronize the time of events occurring in the real world with the time of events in the virtual space.<sup>20</sup>

The researchers A.V. Neznamov, and B.U. Smith understand a cyber-physical system as a software and hardware complex capable of operating in the physical environment and influencing it. Accordingly, the CPS is presented here as an active participant in public relations.

A special place in the literature is given to the study of CPS safety. It is known that CPS include various interconnected systems that can monitor and control real objects and processes. They are closely related to the systems of the Internet of things, except that the CPS focuses on the interaction between physical, network and computing processes. In the process of integration of these two entities, a new aspect of the CPS was formed - the Internet of Cyber-Physical Things.

## **Conclusions**

The intensive development of CPS affects various aspects of people's lifestyle and allows the use of a wider range of services and applications, including e-health, smart homes, e-commerce, etc. However, the combination of the cybernetic and physical worlds reduces the level of CPS security. A number of studies are devoted to the analysis of vulnerabilities, threats and attacks on the CPS security, as well as to the proposals for their overcoming.

CPS is a network of embedded systems that interact with physical input and output.<sup>21</sup> In other words, the CPS consists of a combination of various interconnected systems with the ability to monitor and control real objects and processes associated with the Internet of things.

## Summary

CPS includes three main central components: sensors, aggregators and actuators. Moreover, CPS systems can sense the environment with the ability to adapt and manage the physical world.<sup>22</sup> This is mainly due to their flexibility and the ability to change the execution time of system processes through real-time computing.<sup>23</sup>

In fact, CPS systems are used in many professional areas, they allow to ensure the stability of production processes in a number of industries.

Thus, a cyber-physical system is an integration of physical objects, software and communication networks. This concept has a significant volume, which includes many different objects of the material world, therefore, until the researchers come to a consensus on this concept, it is preferable to fix a set of integral features of the CPS, which will create a flexible approach to the associated spheres of public relations regulation.

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