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МИРОВОЙ РЫНОК ТЕХНОЛОГИЙ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА: СОВРЕМЕННЫЕ ТЕНДЕНЦИИ РАЗВИТИЯ

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Аннотация: Сегодня технологии искусственного интеллекта являются неотъемлемой частью жизнедеятельности каждого человека. Их использование влечет за собой появление более совершенного функционального оборудования и внедрение все более развитых информационных технологий и систем. Данные обстоятельства подтверждают высокую актуальность тематики статьи. Расширение сфер практического применения технологий искусственного интеллекта с каждым годом обостряет, с одной стороны, проблему доверия к их функциональным возможностям и полученным результатам, а с другой стороны, проблему безопасности и надежности их использования. Основная цель нашей статьи заключается в анализе основных тенденций развития мирового рынка технологий искусственного интеллекта и выявлении перспективных сфер для их практического применения. Решение этой задачи предполагает использование методов комплексного подхода и систематизации информации. В ходе проведенных исследований был выявлен ряд основных тенденций развития мирового рынка технологий искусственного интеллекта. К ним относятся расширение сфер практического применения и постоянный рост разработки новых технологий, функциональные возможности которых соответствуют постоянно появляющимся новым запросам общества. Сделан вывод о том, что в XXI веке развитие технологий искусственного интеллекта стало определяющим фактором становления нового информационно-цифрового уклада мировой экономики.

Ключевые слова: Искусственный интеллект, технологии, мировой рынок, тенденции развития.

WORLD MARKET OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES: MODERN DEVELOPMENT TRENDS

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Abstract: Nowadays, artificial intelligence technologies are an integral part of the life of every person. Their use entails the emergence of more advanced functional equipment and the introduction of increasingly advanced information technologies and systems. These circumstances confirm the high relevance of the topic of the article. The expansion of the areas of the practical application of the artificial intelligence technologies every year exacerbates, on the one hand, the problem of trust in their functionality and the results obtained, and on the other hand, the problem of security and reliability of their use. The main purpose of our article is to analyze the main trends in the development of the world market of artificial intelligence technologies and identify promising areas for their practical application. The solution of this problem involves the use of methods of an integrated approach and systematization of information. The research revealed a number of key trends in the development of the global market for artificial intelligence technologies. These include the expansion of the areas of practical application and the constant growth of the development of new technologies, the functionality of which corresponds to the constantly emerging new demands of society. It is concluded that in the XXI century, the development of artificial intelligence technologies has become a determining factor in the formation of a new information and digital way of the world economy.

Key words: Artificial intelligence, technologies, world market, trends of development.

Introduction.

Currently, artificial intelligence (AI) is commonly understood as the field of computer science, within which intelligent computer systems (ICS) are created. The functional capabilities of such systems are quite close to the thinking abilities of a person. They allow you to understand the language, contribute to the acquisition of new knowledge and their application to solve various problems. Today, AI also includes a large set of algorithms, application software (AS) and technologies that provide opportunities for practical solutions to a wide range of tasks at the level of human thinking abilities.

Therefore, today ICS have become an objective component in many areas of society's life. Even the simplest of them function on the basis of using and processing large amounts of information and are used to identify images, recognize language, and form forecasts. However, such ICS are not able to perceive objective reality at the level of human thinking and therefore cannot be used to develop strategic development plans and new models for the functioning of the objective reality surrounding a person. On the other hand, both simple and more advanced ICS allow you to organize large amounts of information. This makes it possible to use them to teach a person a new understanding of changes in the surrounding reality.

Research purpose.

The research purpose is to analyze the global market of artificial intelligence technologies and identify promising trends in its development in relation to various spheres of society.

Materials and methods.

AI technologies are commonly understood as a set of technological processes that improve the quality of processing large amounts of information at the level of understanding natural language, machine learning, expert systems, and virtual agents. This is achieved due to such properties of AI as the ability to learn and think, as close as possible to the intellectual capabilities of a person [1]. This definition is the most general and widespread, but for the same reason it does not reflect all the features of the development and practical application of AI technologies.

There is no clearer definition of AI technologies today, because almost every day there is an expansion of their application in various areas of society. However, even a brief analysis of the information over the past two decades suggests that AI technologies will become an important part of not only professional activities, but also the personal life of each person in the near future. AI technologies are now actively used in all sectors of the economy and, above all, in those enterprises that

produce high-tech products [2]. At enterprises that are specialized developers of various types of software, operating on the basis of AI technologies, the cost of its creation increases annually. At the same time, AI technologies themselves are high-tech products that are sold through their implementation in the production of specific high-tech products. This approach allows high-tech enterprises to gain additional competitive advantages by moving to a higher level of management of their production activities. The introduction of AI technologies in the production increases the stability of its information support, improves the organization of all business processes, helps to reduce costs and leads to an increase in enterprise profits through the optimization of the entire volume of management and computing operations.

Among the many areas of development of AI technologies, the creation of ICS and the number of tasks solved with their help, it is customary to distinguish two fundamental approaches: semiotic and biological. Within the framework of the first of them, expert systems, databases and logical inference systems are created that are as adequate as possible to the mental processes of a person. Within the framework of the second one, neural networks are developed, evolutionary calculations are carried out based on genetic algorithms and models of the development of biological systems, and progressive neuro - and bio - ICS are created.

Naturally, the directions of development of AI technologies and the creation of ICS are not limited only to these approaches. On the contrary, these approaches are constantly being improved, as well as new approaches that take into account the most recent achievements of the STP. So, since the beginning of the 1990s, an approach based on modeling the activities of intelligent agents has been actively developing. At the same time, ICS are considered as intelligent agents that can receive signals from the surrounding reality through sensors and influence its objects using various mechanisms. This approach mainly uses methods and algorithms of search and decision-making.

The development of this approach was a hybrid approach based on a combination of neural and symbolic models. The synergistic effect of their solution makes it possible to implement in practice the entire range of cognitive and computational capabilities of ICS. As a result, expert rules are generated in neural networks, and generating rules are formed through machine learning. The founders of this approach are convinced that hybrid ICS will significantly outperform ICS based on individual concepts.

The modern stage of development of AI technologies is characterized by a range of prospective trends. It comprises the following:

- 1) modernization of existing and development of new AI technologies, being in demand at the market in the competitive environment;
- 2) expanding the functionality of AI technologies, including adaptive and communicative ones, interactive interaction with humans, machine learning algorithmization, computing speed, perception of human activities, etc.;
- 3) search for new solutions to various kinds of problems in conditions of unlimited information arrays by using self-learning algorithms and algorithms with the involvement of a teacher in AI technologies;
- 4) creation of flexible and multifunctional AI technologies, used for the modernization of robot systems [3].

Dynamics of the implementation of prospective trends of the development of AI technologies are determined by the total influence of many objective and subjective factors, which revealing is not within frames of this research.

The information presented above allows us to conclude that in the XXI century, the development of AI technologies determines the formation of a trend for the formation of a new information and digital way of the world economy. So, according to experts of Frost & Sullivan, by 2022 the total market volume of AI technologies will increase to 52.5 billion US dollars. This is almost 4 times more than the level of 2017, which was 13.4 billion US dollars (see Figure 1[4]). It is expected that the annual growth rate of the AI technology market will remain at the level of 30%. According to the forecast of specialists of Frost & Sullivan and TAdviser [4, 5], the rapid expansion of the areas of AI technology implementation will ensure the growth of the global market of goods and services with their use to 15.7 trillion US dollars by 2030.

Fig. 1. Dynamics of the world market of AI technologies, 2013-2022

According to the Tractica analytical report on the development and implementation of AI technologies in 2018, the volume of the global software market amounted to \$ 8.1 billion and had all the prerequisites for the further growth. Analysts of this company estimated an increase in its volume by 2025 to 105.8 billion US dollars [6]. Due to the constant growth in the volume of information, the computing power of ICS and the improved performance of algorithms, the demand for the software used in AI technologies is also increasing. Today, AI technologies are used in almost all sectors of the economy. They allow the use of ICS for automated management decision - making. Moreover, the presence of many new options for their application reveals the potential for the development of existing businesses, helps to attract additional investment and optimize all business processes at enterprises that produce high-tech products.

According to a report by Tractica, at the end of 2018, AI technologies were used in 258 areas of the global community's life: from trade and advertising to transport and various types of communication. Most of the total revenue from the use of AI technologies is concentrated in markets with a narrow specialization that requires processing large amounts of information. The company's specialists have justified real-world applications of AI technologies and systematized forecasts of expected revenue generation from their use in relation to the industry structure of the economy. This report can be the basis for forming forecasts for the development of the AI technology market. In addition to the main areas of practical application of AI technologies, it provides a detailed analysis of individual options for using AI

technologies by industry. Figure 2 shows the ten areas of society where the use of AI technologies with elements of PPO is most in demand [6].

Fig. 2. Areas of life activities of the society with high demand for the use of AI technologies with software elements [6]

It comprises:

- video observation systems;
- systems for the monitoring and management of calculation operations in IT networks;
- client service and marketing;
- recognition of the human voice and objects (technique, cars etc.);
- study of patents;
- identification of photo and video images, medical images;
- automated processing of patients' data;
- control of periods of the periodical technical maintenance of the equipment [6].

Tractica analysts, together with Frost & Sullivan specialists, presented the results of the analysis of the software market used for the functioning of various AI technologies [4, 6]. The researchers of the two companies believe that the further growth of the global AI technology market will be achieved through the development

and implementation of a more advanced software. New promising areas of development of the AI technology market have been identified, namely: the development of cognitive computing (CC) systems, processing of large amounts of information, robotics, quantum and neuromorphic computing.

The introduction of a more advanced software for the functioning of various AI technologies is influenced by such an important area of society's life as ensuring the cybersecurity of network management systems. It is carried out by developing and implementing various innovative solutions to protect against information threats that cannot be detected in a timely manner by existing security systems. So, the specialists of the Israeli company Deep Instinct have created their own algorithms for timely detection of threats to the AI technology of deep learning. They allow you to quickly find anomalies in the operation of network management systems and identify targeted cyber attacks. Practice shows that existing security systems cannot withstand such cyber attacks [7].

Today, the information and communication technologies and communications, automotive, financial and banking, and entertainment industries have a significant impact on the introduction of more advanced software for the functioning of various AI technologies. The impact on the introduction of more advanced PPO for AI technologies in the defense, space, and energy industries, as well as in retail, is increasing.

Up to 40% of the cost of developing QC systems and AI technologies is accounted for by the software and cognitive platforms. They combine modern tools and high-speed technologies for conducting analysis, organizing access and providing other services based on processing large amounts of structured and unstructured information. It is obvious that in the near future this market segment will show high growth rates. According to experts' forecasts, the annual volume growth will be about 43.0%.

The global market for QC systems and AI technologies in 2018 was \$ 24 billion. This figure is expected to grow to \$ 77.6 billion by 2022. According to the forecast of IDC specialists, the market of QC systems and AI technologies will show an average annual growth rate of 37.3% [8].

The United States holds a leading position in terms of the number of transactions concluded in the market of investments in the development of AI technologies and their development. Behind them are China and the United Kingdom. However, in terms of the average cost of a single transaction, China is the undisputed leader. This figure for China has been over \$ 100 million for more than four years,

while similar figures for the United States and Great Britain are significantly inferior to it and are equal to \$ 15 and \$ 5.4 million, respectively (see Table 1 [4]).

Table 1

Leaders in the volume of investments at the market of AI technologies

Country	Volume of investments, mln. USD	Number of transactions
USA	6398,61	429
China	5505,22	53
Great Britain	569,49	124
Canada	285,17	34
Israel	278,40	42
Total:	13036,89	682

In China, there is a very active development of almost all areas of the use of AI technologies. In this regard, 2017 is a significant year, when the share of Chinese startups for the first time exceeded the share of American ones in the total volume of global investments aimed at the development of AI technologies. It was 48%. At the same time, it is necessary to take into account such an important factor as the total number of startups that purposefully develop AI technologies. In the US, 54% of such startups operate, and in China only 15% [4].

The rapid growth in demand for the development and implementation of technologies in China is also due to the fact that at all levels of management, the task of promoting of AI technologies in almost all sectors of the economy is successfully solved. With such a high growth rate of the market for the development and implementation of AI technologies, the United States may lose its position, and China has all the prerequisites to become a world leader in this market.

Chinese companies that specialize in the development and implementation of various technologies also take a leading position in attracting foreign investment. In this area of their activity, the leading American companies are already losing their leadership (see Table 2 [4]).

Table 2

Leaders in the involvement of investments in the development of AI technologies

Country	Company	Volume of attracted investments, mln. USD
China	SenseTime	1200
China	UBTech Robotics	820
China	Megvii Technology	600

USA	Dataminer	391
China	YITU Technology	300
USA	Pony.ai	214
USA	CrowdStrike	200

The research of the practical application of AI technologies in various areas of the information and digital economy is conducted in such world-known companies as Alibaba Group, General Atlantic, Fidelity International, IBM, Google, Affectiva, CloudMinds and many others [9].

The field of the human health protection is one of leading ones in terms of the practical application of various AI technologies. They are mainly used to improve the accuracy of making diagnoses of diseases. This allows to significantly reduce the cost of the direct treatment of patients. Among the large number of startups in this area, we should highlight the Russian project for the development of hybrid chips (neural coprocessors) based on memristor and optogenetic AI technologies, implemented at MIPT [10]. This project combines both the world-class fundamental research and the possibilities of their practical application in such areas as: neurobiology and neuropharmacology, prostheses and artificial organs integrated with the human nervous system.

The rapid development of AI technologies and their use for the solving of practical problems in a wide variety of areas of society's life has resulted from the uncertainty in many global markets. However, to overcome this kind of problems in the development of technologies the key factor is the equipment that operates on the basis of specialized devices, which are called chipsets or simply chips. It is in them that all computational processes, image and speech recognition, and processing of large amounts of information take place. In 2018, the global market for chips designed to use AI technologies in the field of deep learning was 164.9 million units [6].

The rapid expansion of the areas of practical application of technologies in the very near future will lead to the fact that in order to increase their efficiency, it will be necessary to accelerate the operation of functional applications. It is intended to use a set of chips for this purpose. Practice shows that the potential of AI technologies can be better realized if the chipsets are optimized to provide the required computing power with the minimal energy consumption as part of their use in specific AI applications. This trend in the development of technologies contributes

not only to the expansion of specialization, but also to the growth of the variety of chips.

According to experts' forecasts, in 2025, the production of chips intended for use in AI technologies for deep learning will amount to 2.9 billion units in the global economy, and in the value volume will exceed 72.6 billion US dollars (see Figure 3 [6]).

Among the leading manufacturers of chips used in AI technologies for deep learning there are Nvidia and Intel [6]. The existing potential of using AI technologies for the deep learning was implemented by creating fundamentally new models of equipment and algorithms used for pattern recognition. This made it possible to conduct self-training programs on tasks that do not have a well-defined code.

Fig. 3. Dynamics of chips' market, used in AI technologies for deep learning purposes

In 2018, AI deep learning technologies were widely used for the pattern recognition, text structuring, and preventing fraudulent transactions in the financial sector and other areas. According to analysts, the practice of using AI technologies for the deep learning will contribute to the development of new and more productive applications in the production of self-driving cars, various types of personal equipment, medical prevention, and others.

Tactica specialists have identified more than 200 areas of the real use of AI technologies and identified 27 major sectors in this market. It was found that such

sectors as image recognition, trade and algorithmic management of patient data in healthcare have significant potential for their development. However, there are other sectors whose development is still at a low level.

Tractica experts predict high dynamics of AI technologies development in six fundamental areas of their practical application: machine and deep learning, computer vision, the use of the natural language for the information processing, automation of calculations on large amounts of information, and strong AI. It is expected that in the next 10 years, AI technologies will have an impact on almost all spheres of society's life. At the same time, among the leading sectors of their development will be the personal consumption, the provision of services, the advertising business and the military-industrial complex. Revenues of the global AI technology market will increase to \$ 38.8 billion by 2025 (see Figure 4 [6]).

Fig. 4. Dynamics of incomes of the world market of AI technologies 2016-2025

According to some forecasts, the image recognition market is expected to grow annually at an average rate of 17-19%. In 2025, its volume will reach US \$ 30 billion. [[11]. AI technologies used for pattern recognition solve the problems of pattern recognition, optical images, code, objects, and digital photos. As a rule, they are used in integration with other AI technologies for security and surveillance, scanning and image creation, marketing and advertising, and image search by specified parameters.

The transition of all computing processes, both in real production and in personal consumption, to cloud-based information processing technologies, as well as the growing influence of the Internet, personal digital devices, and social networks, are becoming the defining directions of the image recognition market development. The key players in this market are well-known large corporations such as NEC, Google, Honeywell, Hitachi, Qualcomm, as well as many smaller companies such as LTU Technologies, Attrasoft, Blippar, SLYCE and others [9].

According to analysts of the company "Market & Markets", the market for AI technologies that use natural languages to process large amounts of information will increase to \$ 16.0 billion by 2022. At the same time, its average growth rate is expected to be in the range of 16-18% [11]. The key factors for this will be: increasing the demand of users for the more advanced software; focusing user preferences on the practical application of smart devices; increasing investments in the field of public health protection for the development of new and improving existing AI technologies; expanding the use of AI technologies that can perform calculations on large amounts of information in network and cloud business applications, increasing the need for the introduction of M2M technologies in the real production sector.

There are also forecasts for the growth of the global market for speech recognition technologies and technologies, according to which it is expected to increase its volume in value terms to 185 billion US dollars by 2022, with an average annual growth rate of 10-12% [12].

Results and discussion.

Main results of the research hereunder can be considered as follows.

1. Two fundamentally different approaches to the development of AI technologies and the creation of ICS for solving different classes of problems with their help as part of a variety of areas of their practical application – semiotic and biological have been determined. The main differences between them are revealed and the functional capabilities of the AI technologies developed with their help are determined.

2. Since the early 1990s, an approach based on modeling the activities of intelligent agents, focused on the primary use of methods and algorithms for the search and decision-making, has been actively developing. An alternative to this approach was the development of a hybrid approach, which is based on a combination of neural and symbolic models to obtain a synergistic effect from their

solution and practical implementation of the entire range of cognitive and computational capabilities of ICS.

3. It is established that AI technologies are still actively used today, first of all, by enterprises of industries that produce high-tech products. This allows them to gain additional competitive advantages by moving to a higher level of management of their production activities.

4. The results of the analysis of such characteristics of the global AI technology market as the overall dynamics, the growth dynamics of expected revenues, the dynamics of chip production, the growth dynamics of the markets for AI technologies designed for image recognition and speech, as well as using natural languages for processing large amounts of information are presented. In addition, the leaders of the AI technology market in attracting investment in the context of countries and individual companies were identified.

Conclusions.

Basing on results, obtained in the course of the performed research, following opinions can be formulated.

1. In the modern sense, AI is a field of computer science, within which ICS are created that are quite close in their functional capabilities to the thinking abilities of a human.

2. Was revealed a range of prospective trends of the modern stage of development of the world market of AI technologies.

3. The analysis of main trends of the global AI technology market shows its dynamic development and constant expansion of the areas of practical application of AI technologies. Therefore, in the near future, we should expect the emergence of new breakthroughs in the development of more efficient and fast-acting AI technologies in various spheres of life of the world community.

4. The introduction of AI technologies in the production makes its information support more stable, improves the organization of all business processes, helps to reduce costs and leads to an increase in enterprise profits by optimizing the entire volume of management and computing operations.

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