The role of big brain science in the development of artificial intelligence technologies

El papel de la gran ciencia del cerebro en el desarrollo de tecnologías de inteligencia artificial

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Abstract

The article establishes a link between fundamental brain science and the development of artificial intelligence technologies. A comprehensive analysis of existing national projects in the field of brain research is proposed: Human Brain Project (European Union), BRAIN Initiative (USA), Brain / MINDS (Japan), Australian Brain Alliance (Australia), Korea Brain Initiative (South Korea), Canadian Brain Research Strategy (Canada), China Brain Project (China). Their key features, goals, and main research priorities are analyzed in detail. Strategic directions common to national projects are identified: new medical technologies for diagnostics and treatment of a wide range of diseases; technologies of deep machine learning and artificial intelligence, which are considered as the most promising in the XXIs century in terms of investment attractiveness and the impact they can have on human life and society in the context of the fourth industrial revolution.

Keywords: Brain Research Programs, Artificial Intelligence, Machine Learning, Big Brain Science, Science Diplomacy, Industrial Revolution 4.0, Global Leadership, International Relations.

Resumen

El artículo establece un vínculo entre la ciencia fundamental del cerebro y el desarrollo de tecnologías de inteligencia artificial. Se propone un análisis exhaustivo de los proyectos nacionales existentes en el campo de la investigación del cerebro: Human Brain Project (Unión Europea), BRAIN Initiative (EE.UU.), Brain/MINDS (Japón), Australian Brain Alliance (Australia), Korea Brain Initiative (Corea del Sur), Canadian Brain Research Strategy (Canadá), China Brain Project (China). Se analizan en detalle sus características clave, objetivos y principales prioridades de investigación. Se identifican direcciones estratégicas comunes a los proyectos nacionales: nuevas tecnologías médicas para el diagnóstico y tratamiento de una amplia gama de enfermedades; tecnologías de aprendizaje automático profundo e inteligencia artificial, que se consideran las más prometedoras del siglo XXI en términos de atractivo de inversión y el impacto que pueden tener en la vida humana y la sociedad en el contexto de la cuarta revolución industrial.

Palabras clave: Programas de Investigación del Cerebro, Inteligencia Artificial, Aprendizaje Automático, Big Brain Science, Diplomacia Científica, Revolución Industrial 4.0, Liderazgo Global, Relaciones Internacionales.

Introduction

The dominant direction in the development of information technologies at the present stage is developments in the field of artificial intelligence (AI) and their application to solving an increasingly wider and more complex range of problems in the field of medicine, education, business, science, the military sphere, household issues, and entertainment[1-3]. The orientation of the economy towards long-term innovative development is the foundation of its sustainable growth, technological sovereignty, and strengthening of the state's position in world politics[4-6]. On this occasion, in a speech at the opening of the 49th Davos Economic Forum on January 22, 2019, Klaus Schwab noted: "Artificial intelligence, big data and the possibility of creating technological platforms for mass use are beginning to determine the national power of states"[7-9]. According to experts from the European Commission, AI in the 21st will be the main engine of economic growth and productivity and will also contribute to the sustainability and vitality of the industry[9]. In this sense, the mastery of AI technologies, their introduction into production promises the states significant economic benefits and leading positions in the world system of division of labor.

At the current level of technological development, artificial intelligence is usually understood as the field of scientific research aimed at creating programs and devices that simulate human cognitive functions and are capable of learning from many verified examples. Unlike classical directive programming, which is based on the logic "If, then", artificial intelligence technologies can operate, classify, and learn on patterns - groups of properties of objects, combined at different levels of abstraction[10-12]. For example, computer vision technology does not need an algorithm for comparing all possible differences between two animals to solve the problem of distinguishing a cat from a dog, which involves considering millions of conditions. A set of images of cats and dogs is presented to the artificial neural network in advance, based on which the program forms its pattern of properties corresponding to a specific animal and uses it to distinguish a specific cat from a specific dog[13-15]. This process is very similar to how the human brain does it. That is why, since its inception, AI technologies have been fundamentally inspired by the advances in neuroscience, as well as by research on the human brain. For example, one of the pioneers in the field of artificial intelligence, Minsky[7], outlined the main goal of one of his famous works as follows: "To develop theories about how the human brain works, and to develop a mechanism capable of feeling and thinking. Then the ideas obtained can be tried to be used both for studying ourselves and for developing artificial intelligence"[17,18]. As AI models evolve, they become more demanding in terms of computing power and energy consumption. Currently, many experts associate breakthroughs in the field of creating high-performance and energy-efficient microprocessors for AI with the discoveries of the fundamental principles of the brain and the creation on their basis of technologies for "neuromorphic computing[19-22]."

Currently, a circle of countries has been identified that has developed and started to implement national projects for the study of the brain. Let's consider their main features from the point of view of applied technological guidelines.

Human Brain Project (European Union).

In January 2013, the European Commission launched the Human Brain Project (HBP) as part of the EU's ambitious Future and Emerging Technology (FET) initiative. The main goal of FET is to transform the scientific base of a united Europe into a competitive advantage in the international arena. Today HBP brings together about 500 scientists and engineers from more than 140 universities, training, and research centers throughout Europe. Also, four organizations from Israel and one from Turkey have joined the program.

The main thematic blocks of the project are brain modeling, neuromorphic technologies, consciousness studies, brain medicine, robotics, computer technology for brain research[15]

The direction associated with the development of neuromorphic technologies is of direct importance for the development of AI technologies. Within the framework of it, work is underway to reproduce the basic principles of the operation of biological neural networks on electronic circuits. For this, two large-scale neuromorphic computers have been created: SpiNNaker, located in Manchester (UK), and BrainScaleS, located in Heidelberg (Germany). Their main feature lies in the speed of computation, which, when simulating biological processes, is many times greater than the capabilities of modern supercomputers. It is expected that neuromorphic technologies in the near future will significantly surpass modern computers in solving problems such as speech and image recognition, will make it possible to identify cause-and-effect relationships in science, finance, and management, as well as, on this basis, make high-precision forecasts at various time scales.

Another area of HBP closely related to AI is developed in the field of robotics. It is with this direction that some scientists associate the main vector of scientific and technological progress in the 21st century, calling it the "era of robots"[4]. The specially developed Neurorobotics platform allows to give any brain model its own "body" for studying feedback with the external environment, which allows to virtually create and test robots, and provides ample opportunities in the field of machine learning even before the physical implementation of the product.

In general, the Human Brain Project provides a framework for the collaboration of researchers from different countries, scaling, and practical implementation of ideas and scientific developments. In this sense, it is noteworthy that some researchers emphasize the characteristic feature of the EU's Greater Science, which is the emergence of politically motivated large-scale research projects closely intertwined in a wide integration context.19

Overall, the main goals of HBP are to:

- Develop a scientific infrastructure for brain research and cognitive neuroscience.

- Gather and disseminate data describing the brain and related diseases.
- Simulate the brain and Build theories and models of the brain.
- Develop brain-inspired computing, data analytics, and robots.

BRAIN Initiative (USA)

On April 2, 2013, US President Barack Obama presented a research initiative aimed at revolutionizing the understanding of the human brain, called BRAIN (Brain Research through Advancing Innovative Neurotechnologies) at an event at the White House. Thereafter, the US National Institutes of Health (NIH) formed a working group to elaborate on this initiative. In June 2014, the Working Group prepared the BRAIN 2025: A Scientific Vision report, which outlined the scientific objectives of the initiative and developed a multi-year plan to achieve them.

The overarching goal of the BRAIN Initiative is to combine modern research and conceptual frameworks into an integrated science of cells, circuits, brain, and behavior, which should serve as the foundation for further scientific and technological progress and the creation of new technologies. The report cites technological advances in machine learning and artificial intelligence as priority areas where progress is most needed: "The BRAIN initiative is likely to bring practical economic benefits to AI and smart machines. Our brains can quickly solve vision, speech, and motor coordination problems that the most powerful supercomputers cannot handle. As we learn more about the principles the brain uses to solve these problems, new computing devices may be developed based on the cognitive architectures found in the brain."[2]

For the development of broad interdisciplinary cooperation, the BRAIN Initiative Alliance was created, the mission of which is to coordinate efforts between the participants of the BRAIN initiative and to involve the widest possible range of stakeholders in the project. At the same time, the main priority of the BRAIN Initiative is the development of the relevant scientific field and relations between research teams within the United States, and, as K. Brose emphasizes: "On this basis, the establishment of coordination and cooperation with other countries that have similar projects: the EU, China, Japan, South Korea ...[5]

In general, the BRAIN Initiative promotes the establishment of open science within the United States, which should serve as the basis for creating serious groundwork in the most promising and technological areas, including in the field of AI.

Over the course of the study, it has been attempted to analyze and evaluate the terms below:

- Discovering diversity: identify different brain cell types and determine their roles in health and disease.
- Maps at multiple scales: generate circuit diagrams with varying resolutions from the synapses to the whole brain.
- The brain in action: produce a dynamic picture of the functioning brain through large-scale monitoring of neural activity.
- Demonstrating causality: link brain activity to behavior with precise interventional tools that change neural circuit dynamics.
- Identifying fundamental principles: produce conceptual foundations for understanding mental processes by developing new theoretical and analytical tools
- Advancing human neuroscience: develop innovative technologies to understand the human brain and treat its disorders, and create and support human brain research networks.
- From BRAIN Initiative to the brain: apply new technological/conceptual approaches to discover how neural activity patterns transform into cognitions, emotions, perceptions, and actions.

Brain / MINDS (Japan)

In May 2013, Japan's largest research organization RIKEN, at a meeting at the Institute of Brain Sciences, made a presentation on brain research programs in the EU and the United States, which initiated a Japanese project called Brain Mapping by Integrated Neurotechnologies for Disease Studies (Brain / MINDS) ... By September 2014, the composition of the project participants was determined, which included 22 leading specialized research, clinical and technological organizations in Japan. RIKEN was selected as the lead organization for the project.

The main goal of Brain / MINDS "is to study the neural networks that control higher brain functions in monkeys to gain new insights into information processing and diseases in the human brain"[15].

The Japanese program was initially focused on entering an international research consortium, and on allowing the country in the future to equally cooperate and compete in this area of Big Science in the international arena. To achieve this goal, the Strategic International Program for the Advancement of Brain Research (Brain / MINDS Beyond) was launched in June 2018. This initiative aims to foster the global diffusion of brain research through increased collaboration with domestic projects in other countries around the world. In the present study, it was attempted to use the marmoset, a small primate with a short life cycle, for functional and structural brain mapping and genetic studies, and to develop innovative tools to monitor and manipulate different aspects of neural activity , and finally establish biomarkers for brain disorders.

Australian Brain Alliance (Australia)

In February 2016, the Australian Academy of Sciences created the Australian Brain Alliance (ABA), with a focus on coordinating brain research across the country. Since its inception, ABA has brought together more than 28 organizations, including most of the major Australian universities and research institutes conducting research in neuroscience and behavioral science.

ABA offers a new vision of brain research and the development of intelligent technologies, including several main areas, among which are directly related to developments in the field of AI: neuromorphic computing - research to develop ways to create computer microcircuits that mimic the structures and processes of the brain to achieve unprecedented leaps in storage memory and processing power; deep learning algorithms inspired by the brain - the development of computational algorithms based on understanding the functioning of the brain.[13]

ABA pays significant attention to the issues of translating fundamental scientific research into practical results. To this end, a new approach is proposed that stimulates and facilitates a collaborative process of discovery between industry, universities, and other research institutions.

Korea Brain Initiative (South Korea)

In line with the global trend of several countries launching large, long-term research projects to revolutionize knowledge of the human brain, on May 30, 2016, the Korean government announced the launch of the Korea Brain Initiative. The project is based on expectations about the dominant role of brain science in the fourth industrial revolution.

The Korea Brain Initiative includes a series of strategic goals that fit within the broader context of current thinking about scientific and technological progress. In particular, the initiative aims to stimulate the development of technologies that connect the physical, digital, and biological worlds and play an important role in the development of convergent projects. In addition, brain science is seen as the key to the development of next-generation computer technology. It is expected that through the advancement of related research and development between natural and artificial intelligence, advanced algorithms and models of artificial intelligence will be developed, which will create a scientific and technological platform for the implementation of the fourth industrial revolution.[3]

The creation of a neuroindustry and the commercialization of developments are receiving increased attention. Korean authors also point to this aspect of the project: "The Korean Brain Initiative creates the basis for the industrialization of neuroscience discoveries. To this end, it is necessary to develop programs for the transition from laboratory to testbed and create clusters of neuroindustry, where the research and business sectors can work together. "[11]

Like the programs for studying the brain of other countries, since its inception, the Korea Brain Initiative has focused on the development of broad international cooperation to firmly gain a foothold in the number of countries developing Big Science.

Canadian Brain Research Strategy (Canada)

In 2015-2016, Canada hosted a series of seminars with the country's leading scientists, at which the concept of the Canadian Brain Research Initiative was widely discussed. As a result, a working group was formed, which began to develop the key components, scientific objectives, and guidelines for the Canadian strategy for the study of the brain. And in February 2017, the Canadian Brain Research Strategy (CBRS) project was presented, which was subsequently widely discussed with the Canadian scientific community. As conceived by the creators, CBRS rests on four pillars:

1. Understanding how a normal brain develops and functions, and how it develops throughout life.
2. Transforming fundamental new knowledge about the brain into new strategies for the prevention and treatment of brain disorders.
3. Using new knowledge to make new discoveries in other areas, especially in information and communication technologies, economics, complex systems, the social behavior of people, and education.
4. Stimulating the development of new tools for visualizing and measuring the brain, computational methods for understanding its complexity, and brain-inspired technologies, including advanced artificial intelligence, which will find wide applications in healthcare, education, and other fields.[6]

Although discussions about creating a Canadian brain research strategy began in 2015, it wasn't until June 2020 that a group of researchers received a grant from the Canadian Institutes of Health Research to develop a strategy that positions brain research as a national research priority and supports the creation of Canadian Brain Research Strategy Network. The latter should take upon itself the support of Canada's participation in the International Initiative for the Study of the Brain and, on this basis, unite around itself the intellectual and financial resources in the field of the study of the brain within the country.

China Brain Project (China)

In March 2016, the National People's Congress of the People's Republic of China approved the 15-year China Brain Project (CBP) initiative, including it in the XIII Five-Year Plan and an extensive program for the development of science and technology until 2030. CBP aims to advance fundamental knowledge about how the brain works and, at the same time, to meet some pressing social needs through

the application of neuroscience knowledge to the medical field and the development of new technologies.

The organizers described the main ideology of the project with the formula "One body two wings", where the body is the understanding of the fundamental foundations of cognitive functions and the development of technological platforms for brain research, and the wings are the development of artificial intelligence technologies and the development of methods for early diagnosis and treatment of brain diseases.[8] This formula is one of the main features of the Chinese project, which highlights the application of the main achievements of neuroscience to the creation of artificial intelligence and machine learning technologies. In this regard, the director of the Institute of Neurology and the head of the Center of Excellence in Brain Science and Intelligent Technology of the Chinese Academy of Sciences, Mu-min Po, notes the following: "CBP puts research on brain disorders and artificial intelligence as immediate high priority areas, not as distant goals. after we better understand how the brain works. In fact, neuroscience can make useful contributions to these two areas today. "[20]

With the creation of its brain research project three years after the emergence of major national projects in the EU and the United States, China was able to assess its own scientific capabilities in this area and identify priority research areas to achieve the best results and form the basis for international cooperation. In this sense, the choice of the development of artificial intelligence technologies as the main priorities of CBP is fully consistent with the "jigongjinli" trend (striving to achieve success and benefit as quickly as possible) of the country's scientific culture. Chinese researchers closely follow what is happening in the West, and when a promising direction appears, all resources are concentrated on its development. Therefore, CBP is a good tool for developing cooperation with foreign researchers and gradually improving its own technologies.

China has long supported the development of AI technologies, and the CBP project aims to bring a new level of convergence between scientists and industry within the country and allow China to become one of the world leaders in the field of AI.

Russia Project

In December 2017, at a meeting of the world's largest brain research projects in Canberra, representatives of Japan, South Korea, the EU, the United States, and Australia signed the Declaration on the International Brain Initiative, later joined by China and Canada. [16]This event marked the formation of global brain science, which can be characterized by the words "big" (claims to be fundamental discoveries that will largely determine the vector of scientific and technological progress in the 21st century), "open" (unites international efforts to achieve the goals, provides all participants with open access to databases and research infrastructure), "convergent" (involves a large number of stakeholders in the research process, aims at diffusion of technologies and implementation of results in various industrial sectors).

It should be mentioned that many Russian experts emphasize the high importance of brain science for the development of AI technologies. So, for example, ~~K.V.~~ Anokhin in one of his directly pointed out that the creation of new artificial intelligence systems is largely due to fundamental research in neurophysiology. [1]In 2019, in Russia, by Decree of the President of the Russian Federation No. 490, the National Strategy for the Development of Artificial Intelligence for the period up to 2030 was approved, which consolidated this thesis at the political level. In the document, one of the main directions of increasing the availability of hardware necessary for solving problems in the field of AI is the conduct of fundamental scientific research aimed at developing promising architectures of computing systems (including neuromorphic computing systems built on the principle of similarity to biological neural systems). Despite this, Russia still lacks a comprehensive national program for the study of the brain, although discussions about its need have been going on for several years. According to the latest data, the Russian Academy of Sciences and the Ministry of Education and Science have proposed to create a program of fundamental brain research, which includes not only biological and medical issues but is also closely related to the promising development of AI technologies. In September 2020, the President of the Russian Academy of Sciences A.M. Sergeev presented the draft of this program to the President of Russia. [17]However, after a year, no political decisions were made in this regard.

Conclusions

There are currently seven large-scale national brain research programs in the world. Each of them has its own characteristics and priorities. However, in the most general terms, all programs include two interrelated strategic directions: the creation of new medical technologies for the diagnosis and treatment of a wide range of diseases and, above all, the brain; development of deep machine learning and artificial intelligence technologies. Both areas are considered by most experts as the most promising in the 21st century in terms of investment attractiveness and the impact they can have on the life of a person and society.

For example, according to the World Health Organization, in 2015, the global expenditure on dementia alone was estimated at US $ 818 billion, and these costs are projected to increase significantly. The number of people with dementia is expected to reach 82 million by 2030 and 150 million by 2050.[18]

Data on the development of the market for artificial intelligence technologies look no less impressive. According to analysts at Stanford University's Center for the Study of Artificial Intelligence, total global investment in AI increased 40% in 2020 compared to 2019 to $ 67.9 billion and will only grow.[7]

Thus, today the circle of countries that have created a serious groundwork in the field of fundamental scientific research, which is of priority importance for the development and implementation of AI technologies, is more and more clearly defined. This makes it possible to take a forward path of development in the field of key technologies of the fourth industrial revolution and take a leading position in the global system of division of labor in the 21st century.

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