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EVOLUTION OF INFORMATION TECHNOLOGY. OPPORTUNITIES AND CHALLENGES FOR DECISION SUPPORT SYSTEMS

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Анотація. *Стаття присвячена огляду історичного розвитку комп'ютерних технологій та їхнього застосування в різних сферах життя сучасного суспільства. Докладно розглядається еволюція обчислювальної техніки — від перших громіздких електронних комп'ютерів до сучасних ЕОМ і перспективних квантових систем. Особливу увагу в роботі приділено становленню та розвитку технологій штучного інтелекту, машинного навчання та великих даних, що привели до революції в інформатиці та відкрили нові можливості для автоматизації й підвищення ефективності в багатьох галузях. На основі аналізу сучасних досягнень у галузі ШІ, машинного навчання та кібербезпеки виявляються зміни в розвитку комп'ютерних технологій і передбачається їхній потенціал для майбутніх проривів. Крім того, у статті прогнозується подальший розвиток комп'ютерних та інформаційних технологій, а також пов'язаних із ними етичних та соціальних питань. Особлива увага приділяється забезпеченню впливу штучного інтелекту та робототехніки на військову сферу. Аналізуються застосування бойових роботів, безпілотних літальних апаратів та інших автономних систем у сучасних збройних конфліктах, а також тенденції розвитку технологій спільних дій об'єднаних груп дронів. Розглядається використання ШІ-систем у ситуаційних центрах і процесах ухвалення рішень. Остання частина статті присвячена розгляду можливості застосування генеративних моделей на основі трансформерів, таких як GPT, у ситуаційних центрах. Розкриваються способи використання цих технологій для автоматизованої аналітики, генерації тексту та створення інтелектуальних помічників, які можуть значно поліпшити роботу систем. У висновку статті обґрунтовуються ключова роль комп'ютерних технологій у сучасному світі та необхідність комплексного регулювання процесів управління з огляду на не тільки технічні, а й етичні та соціальні аспекти. Загалом, у статті подано всебічний аналіз історії та сучасного стану комп'ютерних технологій, а також їхньої діяльності в різних сферах життя суспільства. Описано досягнення в цій галузі та виявлено явища і тенденції, що становлять інтерес для фахівців у галузі інформаційних технологій, системної аналітики та управління.*
Ключові слова: *штучний інтелект, комп'ютерне навчання, великі дані, квантові обчислення, ситуаційні центри, системи ухвалення рішень, GPT-моделі.*

Abstract. *The article is devoted to a review of the historical development of computer technologies and their application in various spheres of life in modern society. The evolution of computing technology (from the first bulky electronic computers to modern computers and promising quantum systems) is studied in detail. Special attention is paid to the formation and development of artificial intelligence, machine learning, and big data technologies, which led to a revolution in computer science and opened new opportunities for automation and efficiency improvement in many industries. By analyzing current advances in AI, machine learning, and cybersecurity, the paper identifies some changes in the development of computing technologies and envisions their potential for future breakthroughs. In addition, the article predicts further developments in computing and information technology, as well as related ethical and social issues. Special attention is paid to ensuring the impact of artificial intelligence and robotics in the military sphere. The paper analyzes the use of combat robots, unmanned aerial vehicles, and other autonomous systems in modern armed conflicts, as well as some trends in the development of technologies for joint*

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actions of combined groups of drones. The use of AI systems in situation centers and decision-making processes is considered. The last part of the paper is devoted to the consideration of the possibility of applying generative models based on transformers, such as GPT, in situation centers. It reveals how these technologies can be used for automated analytics, text generation, and the creation of intelligent assistants that can significantly improve the performance of information systems. The article concludes by defining the key role of computer technologies in the modern world and the need for comprehensive regulation of management processes, taking into account not only technical but also ethical and social aspects. In general, the article presents a comprehensive analysis of the history and current state of computer technologies, as well as their activities in various spheres of society. The achievements in this field are described, and the phenomena and trends of interest to specialists in the fields of information technology, system analytics, and management are identified.
Keywords: *artificial intelligence, computer learning, big data, quantum computing, situational centers, decision-making systems, GPT models.*

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1. Introduction

The modern world is unimaginable without computer technology which penetrates all spheres of our lives. Every day we use computers, smartphones, tablets, and other devices, to interact with the digital world. The development of computer technology is one of the most important factors in modern society. Information technology permeates all spheres of human life, from household needs to complex scientific research. In this regard, the study of the history of computer technology development, its impact on various aspects of society, as well as predicting future trends is extremely relevant. Computer technologies enrich our lives, expand opportunities, and increase efficiency in many sectors — from science and medicine to manufacturing and education. This progress reflects continuous innovation that offers new solutions and approaches to complex problems. Scientific research on the development of computer technology plays a key role in shaping our understanding of the future. They make it possible to predict and analyze upcoming changes and create new opportunities to improve life and society as a whole. By analyzing the history of computer technology development and current advances in artificial intelligence, machine learning, cybersecurity, and other related fields, this article identifies trends in computer technology development and assesses its potential for future breakthroughs.

The aim of this study is not only to provide an overview of achievements but also to assess the impact of computer technology on our society, highlight the key areas of development, and present the possibilities of their application in the future.

2. History of the development of computers and artificial intelligence

The history of computers and artificial intelligence is an interesting field that spans many decades. Computers started to develop in the mid-20th century and continue to progress until today. Artificial intelligence (AI), in turn, has gradually become possible due to the improvements in the computing power of computers and the development of machine-learning algorithms and techniques. This section reviews the major milestones and achievements in the history of computers and artificial intelligence, leaving many details and particulars for more in-depth study.

2.1. The first electronic computers

In the 1940s, the first electronic computers were created, which were bulky and expensive devices. Their main characteristics were the following:

• bulky — computers were physically large and occupied a significant amount of space;

• expensive — the development and production of computers were complex and expensive processes;

• low performance — computers were slow compared to modern devices. They could only perform a limited number of operations per second and process small amounts of data;

• limited capabilities — at that time, computers were limited in functionality and could not perform complex operations or handle large amounts of data;

• high power consumption — computers required large amounts of electricity for their operation.

However, despite these limitations, the first electronic computers became a major building block in the development of computer technology, and their use allowed a great step forward.

In 1943, neuropsychologist, neurophysiologist, theorist of artificial neural networks, one of the founders of cybernetics Warren McCulloch (Fig. 1) and neurolinguist, logician, and mathematician Walter Pitts (Fig. 2) presented a model of an artificial neuron. This was the first attempt to create a simplified mathematical model that mimicked the basic principles of neurons in the human brain.

Figure 1 — W. McCulloch

Figure 2 — W. Pitts

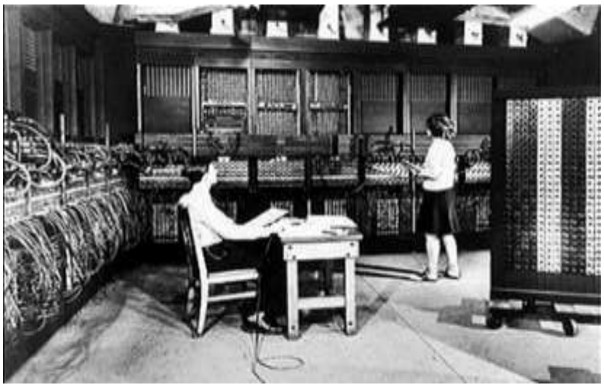

Figure 3 — ENIAC computer

The McCollock-Pitts model was used to explain simple operations that neurons perform in the brain such as classifying patterns and responding to external stimuli. Although the McColloch-Pitz model is simplistic and does not capture all aspects of biological neurons, it became the basis for the development of more complex models of artificial neural networks used in modern machine learning [1].

Figure 4 — A. Turing

In 1946, the first ENIAC computer (Fig. 3) was created in the USA. It was a general-purpose programmable computer developed during World War II in the United States. This project was led by John Mauchly, J. Presper Eckert, Jr. and their colleagues at Moore School of Electrical Engineering, University of Pennsylvania.

ENIAC was specifically designed to calculate artillery range tables, so it lacked other features that would have made it more versatile. The ENIAC complex included 17 468 lamps of various types, 7200 silicon diodes, 1500 relays, 70 000 resistors, and 10 000 capacitors. Computing power was 357 multiplication operations or 5000 addition operations per second. Power consumption was 174 kW. Weight — 27 tons. Subsequently, computers began to evolve, increasing performance and improving architecture. This was an important step in the history of computing [2].

Figure 5 — SECM

In 1950, Alan Turing (Fig. 4) published his famous article Computing Machines and Intelligence, which formed the basis for further research in AI. In it, he discussed the question of whether a machine could be considered intelligent and proposed a concept known as the Turing Test. This test was the first attempt to determine whether machines are capable of exhibiting intelligence by comparing their behavior to that of humans.

The official moment of the birth of Soviet computer technology is considered to be the end of 1948 when under the leadership of Sergey Aleksandrovich Lebedev, work began on the creation of the Small Electronic Counting Machine (SECM) (Fig. 5) in Feofaniia near Kyiv.

Figure 6 — S.O. Lebediev

In this project, independently from the works of John von Neumann, the principles of a computer with a program stored in memory were first put forward and implemented. This included the presence of arithmetic devices, memory, input/output and control devices, encoding and storage of the program in memory like numbers, binary number system for encoding numbers and commands, automatic execution of calculations based on the stored program, presence of both arithmetic and logical operations, hierarchical principle of memory construction, and the use of numerical methods to implement calculations. Design, assembly, and debugging of the SECM were realized in record time. The first trial run of the SECM machine took place on November 6, 1950 [3].

Figure 7 — LECM-1

Serhii Oleksandrovych Lebediev (Fig. 6), director of the Institute of Electrical Engineering, Academy of Sciences of the Ukrainian SSR, is the founder of domestic computer engineering. He was one of the developers of the first digital electronic computing machines with a dynamically variable program of calculations. Under the leadership and personal participation of this outstanding scientist, 18 computers were created, and 15 of them were mass-produced. S.O. Lebediev together with his colleagues from the Academy of Sciences of the Ukrainian SSR, such as Z.L. Rabinovich, Y.V. Blagoveshchenskyi, I.T. Parkhomenko, I.P. Okulova, R.Y. Chernyak, etc., created the first in Ukraine specialized electronic counting machine SECM, designed to solve systems of linear algebraic equations.

In 1953, scientists led by S.O. Lebediev created the first large computer — LECM-1 (Fig. 7). It was produced in one copy and created at the Institute of Precision Mechanics and the Computing Center of the USSR Academy of Sciences. LECM-1 had a high performance, reaching a speed of 8 000–10 000 operations per second. The electronic computer was equipped with a parallel floating-point arithmetic-logic device with 39 digits. The LECM-1 RAM was based on ferrite cores and had a capacity of 1024 words. In addition, this computer was equipped with a long-term memory device on semiconductor diodes also with a capacity of 1024 words. The ROM stored the most frequently used subroutines and constants. LECM-1 also had the ability to work with magnetic tapes to store information. There were four blocks of magnetic tapes with a capacity of 30 000 words each and two magnetic drums providing storage of 5120 words each. The data transmission speed from the drum reached 800 numbers per second, and from the magnetic tape — up to 400 numbers per second. The information was input through a photo-reading device on a punched tape, and output — on an electromechanical printing device. Later, after the improvement of RAM, its performance reached 10 000 operations per second — at the level of the best computers in the USA and the best in Europe [4].

In the years that followed, computers underwent significant development due to the use of transistors, miniaturization, and increased availability. During these years, transistors became a staple of electronics. They replaced the bulky and power-hungry tubes used in earlier computers. Transistors were small, energy efficient, and reliable, allowing for compact and faster computers. With the advent of transistors, computers were able to shrink in size, increase performance, and reduce power consumption. Computers became more affordable, both for large businesses and for universities and research centers. Advances in technology and the increased production of transistors led to lower prices for computers and made them more affordable for a wide range of users. The use of transistors significantly increased the performance of computers. They began to work faster, perform more operations per second, and process more complex tasks than before. Later on, the active development of programming languages began. This allowed for the simplification of the programming process, made it accessible to a wide range of developers, and expanded the capabilities of computers.

Although much more advanced than previous generations, computers were still expensive and available only to a limited number of organizations and specialists. However, they laid the foundation for the further development of the computer industry and paved the way for even more powerful and compact devices in the future in the field of automation and information processing.

In 1956, John McCarthy (Fig. 8), Marvin Minsky, and Claude Shannon organized a historic conference held at Dartmouth College. At this conference, John McCarthy introduced the term «artificial intelligence», which later became the key term for this field of science. The conference left a deep mark and became the starting point for many subsequent studies in the field of artificial intelligence [5].

In 1957, the asynchronous computer “Kiev” was created. It was the first computer in the world that had a universal purpose and was similar to modern computers. It had technical features unique for its time such as an asynchronous system of control transfer between functional units, ferrite RAM, external memory on magnetic drums, and many others. Its use and architecture strongly influenced the development of computer technologies and contributed to the expansion of computer applications. «Kiev» was ahead of foreign computers and was of great importance for the subsequent development of information technology. This computer was a significant improvement and development of the unique features of the SESM computer. The main development manager Borys Volodymyrovych Hnedenko (Fig. 9), manager responsible for the engineering part Lev Dashevskyi, and manager Kateryna Yushchenko, who was responsible for the command system and software development, made the greatest contribution to the creation of the «Kiev» computer [6].

In 1958, Frank Rosenblatt (Fig. 10), an American scientist in the field of psychology, neurophysiology, and artificial intelligence, created the first neural network on the basis of McCulloch and Pitts’ artificial neuron model and proposed a scheme of a device modeling the process of human perception, which he called “Perceptron”. Frank Rosenblatt’s work on the perceptron was indeed a turning point in the development of neural networks and artificial intelligence. He introduced the perceptron as a machine capable of pattern recognition. This work laid the foundation for what eventually became the field of machine learning. The cybernetic model of the brain (Perceptron), for the first time was realized in the form of an electronic machine “Mark-1”. “Mark-1” automatic calculator controlled by sequences was one of the first in the US computing machines with the possibility of programming [7].

In 1961, the semiconductor control machine “Dnepr” was created and accepted for serial production. This machine was developed in the Computing Center of the Academy of Sciences of the Ukrainian SSR (since 1962 — the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR) and was the first in the Soviet Union mass-produced from 1961 to 1971. Its purpose included monitoring and control of continuous technological processes, complex physical experiments, and the study of processes during their algorithmization. This computer was successfully used in many pioneering control systems for industrial and special purposes, as well as in scientific research. The machine was created jointly with specialists of NPO “Elektronmash” by Ukrainian scientists Borys Mykolaiovych Malynovskyi (Fig. 11) corresponding member of the Academy of Sciences of the Ukrainian SSR and the National Academy of Sciences of Ukraine, Doctor of Technical Sciences, Professor, Honored Worker of Science and Technology of Ukraine, A.G. Kukharchuk and V.M. Glushkov [8].

Viktor Mikhailovich Glushkov (Fig. 12) was a Doctor of Physical and Mathematical Sciences, Academician of the Academy of Sciences of the Ukrainian SSR, outstanding Soviet scientist, and one of the pioneers in the field of cybernetics and computer science. His work had a significant impact on the development of information technology in the Soviet Union and beyond. He created the theory of digital automata which became the foundation for the development of new computers. He developed a number of important software systems, including operating systems and programming languages. He made significant contributions to the development of artificial intelligence, machine translation, and pattern recognition. He is the author of more than 300 scientific works, including monographs and textbooks. Computers created under Glushkov’s leadership were used in various fields such as science, technology, production, education, and medicine. V.M. Glushkov and his team developed a number of new computer architectures, which formed the basis for the creation of subsequent generations of computers [9].


Figure 8 — D. McCarthy


Figure 9 — B. Gnedenko


Figure 10 — F. Rosenblatt


Figure 11 — B. Malinovskyi


Figure 12 — V. Glushkov

In 1962, V.M. Glushkov founded the Institute of Cybernetics of the National Academy of Sciences of Ukraine. In this institute, under the leadership of Victor Mikhailovich dozens of types of computers were created, many of which not only met world standards but also opened completely new directions in the development of computer technology.

In 1959, V.M. Glushkov formulated a program of work on machines for engineering calculations. Under the leadership of V.M. Glushkov and chief designer S.B. Pohrebinskyi, the idea of a personal machine for an engineer (now it would be called personal) was implemented in the Promin computer (Fig. 13). In 1963, the serial production of the Promin computer began at the instrument-making plant built in Severodonetsk.

Figure 13 — V. Glushkov and the developers of the Promin computer

The Promin machine and the Dnepr control machine started the industrial production of computer hardware in Ukraine. In 1968, the Institute of Cybernetics of the Academy of Sciences of Ukraine under the leadership of V.M. Glushkov created the MIR computer. MIR, a machine for engineering calculations was a family of small electronic digital computing machines designed to solve a wide range of engineering and design mathematical problems. MIR series machines became the prototype of personal computers on the basis of which many different control systems and complexes were designed. The institute became a flagship in the development and production of automated control systems [10].

The first computing machines designed for engineering calculations marked the beginning of computer intellectualization. At that time, intellectualization meant the schematic implementation of high-level languages in order to increase the efficiency of computer operation by simplifying human-machine interaction. This was a new, revolutionary direction that required theoretical justification, and it became one of the main vectors in the activities of the scientific school of V.M. Glushkov in the field of computer science.

Figure 14 — M. Minsky

But in 1969, Marvin Minsky (Fig. 14) and Seymour Peipert published a book called Perceptrons, which discussed the limitations of simple single-layer perceptrons. There was a widespread belief that neural networks were not capable of solving complex problems such as the logical function exclusive OR.

The limitations identified in the book have caused pessimism about the capabilities of neural networks, and this has led to a decline in interest and investment in this area of research. Funding for neural network projects decreased and researchers directed their attention to other machine learning techniques such as symbolic and expert systems. The period associated with the book Perceptrons by Marvin Minsky and Seymour Peipert was characterized as the «lull in the development of artificial intelligence» or the "winter of artificial intelligence" [11]. In 1982, however, a turning point in the history of neural networks occurred. A group of researchers from Carnegie Mellon University developed the first error back propagation network that was capable of learning on many levels and solving more complex problems than a perceptron. In 1986, David Rumelhart, Jeffrey Hinton, and Ronald Williams published a paper called Learning Internal Representations Using Error Back Propagation, which introduced the multilayer perceptron that is the basis of modern neural networks.

2.2. Personal computers, a revolution in computer science

With the advent of personal computers in the 1970s, there was a revolutionary shift in computer technology — computers became widely available. These computers were quite compact and relatively affordable, allowing computers to be used in homes, schools, and offices. Their main element was microprocessors. They combined the functionality of many electronic components on a single crystal wafer, which made computers more efficient, smaller, and cheaper to manufacture. Also at that time, various interfaces and operating systems were developed that made computers easier to use. The increase in their performance led to a revolution in computer science. People began to use computers to process data, store information, create and edit documents, and view multimedia content.

Dramatic increases in computing power have allowed scientists and researchers to apply more sophisticated algorithms and models to solve AI problems.

Figure 15 — Deep Blue computer

In 1997, a historic event took place. The Deep Blue computer (Fig. 15) created by IBM defeated the world chess champion Garry Kasparov. This was the first time that a computer defeated the reigning world champion in a classical chess match under tournament conditions. The match consisted of several games, and in the end, Deep Blue won with a score of 3.5 to 2.5. This event was a milestone in the history of artificial intelligence and chess, as it showed the capabilities of computers in solving complex intellectual problems and the ability of machines to learn and improve, competing with the best representatives of mankind in such fields as chess. The Deep Blue supercomputer made history as the first machine that managed to defeat a human grandmaster in chess [12].

Those years were also characterized by the development of computer networks, which allowed computers to communicate and exchange information with each other. This paved the way for the emergence of the Internet which in the future became a global communication system. Personal computers and the development of informatics had a huge impact on society and business, becoming the basis for further development of computer technology and expanding its use in many aspects of our lives.

2.3. Internet — global communication and information exchange

With the development of the Internet, a momentous breakthrough in communication and information sharing occurred. The Internet became a widespread network protocol that allowed computers to communicate and exchange information on a scale never seen before. This opened up new possibilities for global communication and data sharing:

• E-mail. In the 1980s, standards and programs for e-mail were developed. This allowed people to exchange messages instantly, overcoming geographical and time barriers.

• Websites and Hypertext. During this period, the HTML language was developed and the first websites appeared. Hypertext linking allowed cross-referencing between pages, making it easier to navigate and gather information. Virtual communities: social groups and communities began to form in the online environment. Forums, newsgroups, and chat rooms allowed people to socialize and share opinions and ideas.

• E-commerce. The 1980s saw the development of e-commerce. Online shopping and payment systems emerged that allowed people to make purchases and financial transactions over the Internet.

In the late 1980s, the Internet had already begun to penetrate all areas of life, transforming from a network for academic and scientific purposes into a powerful communication and information tool that shaped a new era in world history.

2.4. Cloud computing, artificial intelligence, big data

The 2000s saw a rapid development of the following:

• Cloud computing. This technology allowed data to be stored and processed in remote servers, making it easier to access and collaborate on information in real time.

• Big data analytics. With the advent of big data, processing and analyzing became a complex task. Powerful data analysis tools and techniques such as machine learning, clustering, and predictive algorithms emerged to extract valuable information and make predictions based on big data.

• Artificial Intelligence. This period saw significant progress in the field of artificial intelligence. Machine learning and deep neural networks became key techniques that allow computers to learn and adapt to new data and situations.

Between 1980 and 2000, scientists began to apply statistical methods, machine learning, neural networks, genetic algorithms, and other new techniques and approaches to create more complex artificial intelligence systems. These years were a period of recovery and revitalization of work in the field of artificial intelligence.

Figure 16 — Go champion Lee Sedol

In March 2016, AlphaGo, a computer program developed by Google DeepMind, battled with Lee Sedol, one of the best Go players, a 9th dan (top rank) professional (Fig. 16). And AlphaGo won with a resounding result 4:1! It was a significant advancement in the field of artificial intelligence. Go is an ancient strategy board game that originated in China over 3 000 years ago. The game is considered one of the most complex board games for computer modeling because of the sheer number of possible moves and positions. In Go, players take turns placing black and white stones at the intersections of lines on the board, aiming to surround as much territory as possible. The rules of the game are simple, but the strategic possibilities are almost limitless, making Go a game with a high level of strategy and minimal influence of chance. Unlike chess, where a computer can calculate the best move using an enumeration of all possible moves, in Go, the number of possible moves is so large that this approach becomes impossible. To successfully play Go, computer programs must use sophisticated machine learning algorithms that can evaluate positions and strategies based on previous experience, not just on hard analysis. This requires computer programs to be able to «learn» and adapt, which is a significant breakthrough in artificial intelligence. It was believed that winning required not only a sharp mind but also intuition, flair, and qualities inherent only to humans. But AlphaGo shattered these perceptions. These matches showed how far machine learning and artificial intelligence technologies have advanced. It was a true triumph of artificial intelligence [13]!

The 2000s were marked by a revolutionary leap in computer technology that profoundly affected all areas of life. Cloud computing, artificial intelligence, and big data analytics revolutionized the way information was stored, processed, and used, paving the way for countless innovative solutions and services. At the same time, a new era of quantum computing emerged, promising even more radical transformations.

3. Quantum computers and their prospects

At the turn of the 21st century, it became clear that the capabilities of traditional computers based on electronic circuits were limited. New challenges facing humanity require fundamentally new computing solutions. This has driven the explosive growth in the field of quantum computing, which exploits the unique properties of quantum mechanics. Unlike classical computers, which operate on bits that can only be in one of two states (0 or 1), quantum computers use qubits. Qubits are capable of existing in superposition, simultaneously being in both states which opens up enormous possibilities for parallel computing. In recent years, significant progress has been made in the field of quantum computing. Experimental quantum computers have been created that are capable of solving problems that are inaccessible to classical computers. Methods for managing and monitoring quantum systems have improved.

New algorithms have been developed that are specifically optimized for quantum computing.

Despite these advances, full-fledged universal quantum computers are still hypothetical devices. Creating such computers requires solving complex engineering problems. It is necessary to develop reliable methods for correcting errors that inevitably arise when working with quantum systems. However, quantum computers have enormous potential to revolutionize many fields such as artificial intelligence, cryptography, molecular modeling, new materials, and drug development.

In the upcoming years, we can expect further progress in the field of quantum computing, which could lead to the emergence of the first commercially available quantum computers [14].

3.1. Potential applications of quantum technologies

Potential applications of quantum technologies cover a wide range of fields. Quantum computers could revolutionize cryptography by providing more secure encryption and decryption methods, and solve complex optimization problems such as finding optimal routes or optimal resource allocation. Quantum computers can more accurately model molecular systems which is useful in pharmaceuticals, materials science, and other fields. Can improve machine learning and solve complex machine learning problems. Help with risk analysis, portfolio optimization and financial market forecasting, climate change modeling, and resource optimization. Quantum computers can accelerate research in physics, chemistry, biology, and other scientific fields.

It is important to note that while quantum technologies promise a lot, their practical realization is still in the development stage and requires additional research and engineering solutions.

3.2. Expected changes in the computing industry with the development of quantum computers

With the development of quantum computers, quantum supremacy is expected to be achieved — the point at which they will be able to solve problems that classical computers cannot process in a reasonable amount of time. This will change the paradigm of computing and lead to new methods of solving complex problems. Quantum computers may undermine existing cryptographic methods because they are able to break classical encryption algorithms. However, they also provide new security methods such as quantum keys. Quantum algorithms can improve machine learning and solve complex machine learning problems. This can lead to more accurate models and faster data processing. Quantum computers can model molecular systems more accurately, which is useful in pharmaceuticals. They can speed up the search for new drugs and optimize chemical reactions. Quantum computing can help in risk analysis, portfolio optimization, and financial market forecasting. Accelerate research in physics, chemistry, and biology and help model climate change. The development of quantum computers will require new knowledge and education. This will lead to the creation of new courses and programs for future professionals.

In general, the development of quantum computers will not only require new knowledge and education but will also stimulate related fields of research such as bioinformatics and bioengineering. This will lead to the creation of new courses and training programs, as well as to the emergence of new specialists able to work at the interface of these disciplines. Overall, the development of quantum computers will change the way we approach problem-solving and open up new opportunities in many areas. One of the promising directions, that can complement and accelerate progress in the field of quantum computing, is the creation of biocomputers.

4. Biocomputers

Biocomputing is a new field in computer science that uses biological materials such as DNA, RNA, and proteins to perform computations. This field is at an early stage of development, but it is already showing great potential that can be partially realized thanks to advances in quantum computing.

4.1. Advantages of biocomputers

Biocomputers have the following advantages:

1. Ultra-high information density. DNA can store disproportionately more information in a small volume compared to traditional storage media.

2. Ultra-low power consumption. Biocomputers consume significantly less power than traditional computers.

3. Self-repair capability. Biological systems are naturally capable of self-repair, which makes biocomputers more resistant to errors that are inevitable when working with quantum systems.

4.2. Tasks that can be solved by biocomputers

Biocomputers can solve such problems:

1. Genome decoding. Sequencing DNA more quickly and accurately.

2. Developing new drugs. Helping to model complex biological processes to speed up the development of new drugs.

3. Creating artificial intelligence. Biocomputers can be used to create a new type of artificial intelligence that is more similar to the human brain.

4.3. Limitations of biocomputers

However, biocomputers have certain limitations:

1. Difficulty of creation. Biocomputers are much more complex to design and manufacture than traditional electronic devices. Advances in quantum technologies can help solve this problem by providing new tools for creating and manipulating biological systems.

2. Instability. Biological materials are less stable than traditional electronic components. Quantum methods of error control and correction can be used to improve the reliability of biocomputers.

Despite these limitations, biocomputing has enormous potential to revolutionize computing.

The joint development of quantum and biocomputers can lead to the creation of fundamentally new computing systems that will have incomparably higher characteristics compared to modern computers. The interconnection of these two areas of research opens up new horizons for scientific progress and can lead to breakthrough discoveries in various fields such as medicine, materials science, artificial intelligence, and much more.

Overall, the future of computing lies with quantum and biocomputers, and their joint development could be the key to solving the most difficult problems facing humanity.

5. Artificial intelligence and machine learning

The rapid development of machine-learning (ML) technology and deep networks enables artificial intelligence to learn from data and identify complex patterns.

However, despite significant advances, artificial intelligence still has its limitations. Despite linguistic advances, GPT remains limited in aspects important for building strong AI. For example, it does not have the full capacity for general reasoning, emotional intelligence, or creative thinking which are the hallmarks of human intelligence. Most AI systems are limited in their capabilities to only what they have been trained for and are not capable of transferring knowledge between different tasks.

There are also ethical and social issues associated with the development and application of artificial intelligence. There are questions about the privacy of data, the potential threat of replacing human work, and the unpredictable behavior of artificial intelligence systems.

Thus, the current state of artificial intelligence is characterized by rapid progress and existing limitations that require further research and development.

5.1. The impact of machine learning on the development of computers

Machine learning has had a profound and significant impact on the development of computers. It gives computers the ability to learn and improve their performance without being explicitly programmed. Machine learning helps developers create more efficient and accurate algorithms. For example, classification and regression algorithms used in many fields such as medicine, finance, and signal processing become more accurate and more reliable by learning on large datasets. Machine learning plays an important role in the development of computer vision, which allows computers to analyze and understand images and videos. This has applications in areas such as facial recognition, self-driving cars, and medical image diagnosis. Allowing computers to understand and process natural language, which facilitates the development of voice assistants, machine translation, and automatic word processing. In robotics, machine learning is the basis for developing autonomous robots that can learn and make decisions based on their experience. This opens up new opportunities in industry, medicine, aviation, and other fields.

Machine learning plays a key role in the development of computers, providing them with new abilities and capabilities that previously seemed unattainable.

5.2. Examples of AI applications in various industries

Artificial intelligence and machine learning have applications in many industries. In healthcare, AI and ML are used for disease diagnosis and prognosis, medical image analysis (e.g., mammography screening and X-ray diagnosis), personalized treatment selection, and new drug development. In finance, AI is used to identify risk and fraud, predict market trends and stock prices, perform automated trading analysis, manage portfolios, and provide personalized financial advice. In commerce, AI is used to analyze customer data, provide personalized offers and recommendations, improve service levels, and optimize pricing and inventory. Robots and autonomous transportation systems are using AI to perform tasks without human intervention. In the energy industry, AI and ML help optimize energy production and consumption, predict consumption and equipment progression, manage power grids, and regulate load for optimal efficiency. AI is used for delivery route optimization, traffic management, automated driving, and license plate recognition. AI is also used in autopilot systems and the development of autonomous vehicles. These are just a few examples of the applications of AI and machine learning in various industries. The application areas of artificial intelligence continue to grow as its potential is unlimited.

5.3. Artificial intelligence in the armed forces

Artificial intelligence is playing an increasingly important role in military operations, enabling the automation and optimization of various functions and tasks. This includes battle planning, military resource management, battlefield prediction and analysis, and real-time decision-making. Through the use of AI, military operations are becoming more efficient and responsive. Computer algorithms can process and analyze huge amounts of data in the shortest possible time. Analyzing large amounts of data helps in faster processing and interpretation of situational and intelligence data which is important for decision-making. All this helps to quickly rethink the situation and make informed battle management decisions. AI is also used in the intellectualization of autonomous systems such as unmanned aerial vehicles and automated robotic systems. These systems are capable of performing various risky and dangerous tasks in place of humans, thereby reducing human involvement in combat and improving safety. The rapidity of learning and deploying new AI technologies is becoming critical to determining the contours of force balancing in military operations. Countries that are able to quickly adopt and apply AI technologies in combat operations gain a significant advantage in the struggle for military dominance. The pace of development and deployment of new technologies, including AI, are becoming serious security measures that determine military superiority and the contours of the changing balance of power in the international arena.

6. Robots in modern warfare

Combat robots play an increasingly important role in modern armed conflicts. Combat robots are remotely controlled or autonomous systems designed to perform a variety of combat tasks on the battlefield. They include unmanned aerial vehicles, ground robots, underwater drones, and other automated systems.

One of the main advantages of using combat robots is the ability to perform dangerous and risky tasks. Combat robots penetrate hazardous areas, scout the territory, and carry out missions with minimal risk to humans. This reduces casualties and improves the safety of your own forces. Additionally, combat robots can be equipped with advanced weaponry and technology, increasing their effectiveness on the battlefield. They can have unique abilities such as precision firing, rapid maneuvering, and penetration into hard-to-reach areas, allowing them to perform support roles and specific missions.

6.1. Some examples of combat robot applications

The use of combat robots in modern warfare is becoming increasingly common. Let us consider several aspects of their use.

- Monitoring and reconnaissance. Unmanned aerial vehicles are used to monitor territory, detect enemy positions, and gather intelligence.
- Delivery and evacuation. Robots can deliver ammunition and medical supplies, and even evacuate the wounded from the battlefield.
- Combat. Some robots are equipped with weapons and can engage in combat operations. They can perform tasks that are high-risk for humans.
- Autonomy. Although most combat robots require an operator, some models are capable of acting autonomously. The intellectualization of autonomous robots opens new perspectives for their applications.

Various countries are actively developing systems with AI and incorporating it into combat robots. For example, the Chinese People's Liberation Army (PLA) believes that "AI can fundamentally change the nature of warfare, leading to a shift from today's "informatized" warfare to a future "intellectualized" warfare in which AI will be critical to military power" [15].

The PLA plans to utilize AI technologies to enhance its capabilities in the future. This includes the use of intelligent and autonomous unmanned systems, as well as using AI to aggregate, process, and analyze intelligence data. China is currently funding various AI-related projects, including operations simulation, personnel training, command decision support, and the use of AI in defense, offense, and command in information warfare.

One example is Great Leap Forward, a program project that includes the development of autonomous combat systems such as unmanned undersea and surface ships. The goal of the project is to develop unmanned platforms with the ability to quickly process and utilize large amounts of information, thereby improving battlefield situational awareness and making better decisions. China is also actively working to improve the autonomy of its unmanned systems, takeoff, landing, terrain-based flight path planning, and target identification. Combining AI and unmanned systems technologies is a priority for China, which is committed to developing advanced capabilities on the battlefield and improving its force structures.

Figure 17 — Uran-9 multifunctional unmanned combat module

Other countries are also conducting research and development on combat robots and autonomous systems. The Russian Army is developing and using a variety of combat robots in military operations, including the FEDOR humanoid robot, the Uran-9 and Kurganets-25 heavy reconnaissance and strike robots, and the Armata combat robot. The Uran-9 multifunctional unmanned reconnaissance and fire support combat module (Fig. 17) was first demonstrated at the Alabino training range on March 24, 2016. Uran-9 is a ten-ton unmanned combat vehicle that can perform various combat operations. It is controlled via secure radio communication channels using pseudo-random frequency hopping at a range of up to 3 km. The range of the device can be extended by using UAV repeaters or integrating the control terminal into the attack helicopter control system. Uran-9 is capable of attack, defense, and reconnaissance operations within 3 km or farther, depending on the radio horizon, which is determined by the terrain and the height of the combat control point. It can perform various combat operations and transmit telemetry information and control via radio communication, but a serious disadvantage of the Uran-9 combat platform is the relatively low speed of the vehicle — 35 km/h and not the highest armor protection. This means that the armor protection may not provide reliable protection for the engine and other units from automatic cannons using armor-piercing shells of the latest generations [16].

Figure 18 — IAI ELTA REX MK II combat robot

Figure 19 — TALON V robot

Israel has a developed industry of combat robots, including unmanned aerial vehicles and robots for use on the battlefield. An example is the IAI ELTA REX MK II combat robot, ELTA REX MK II combat unmanned infantry support system (Fig. 18). It is an unmanned vehicle that can be operated by remote control, but is also capable of acting autonomously in the event of signal loss. The main purpose of developing this system is to patrol combat zones and border areas. The REX MK II has enhanced cross-country capability and maneuverability and can carry up to 1250–1300 kg of payload. If two such robots are used together with a squad of soldiers, it significantly reduces the weight that must be carried by a live fighter, improving the mobility and combat capability of the unit [17].

The British Army develops and uses a variety of combat robots, including demining and explosive device removal robots (e.g., TALON), as well as various autonomous systems to support combat operations. TALON (Fig. 19) is widely used by the military, law enforcement, and first responders for a variety of missions. It is used for improvised explosive device and munitions disposal, chemical, biological, radiological, and nuclear threat handling, security, reconnaissance, communications, heavy lifting, and defense and rescue missions. TALON has been used extensively around the world in a variety of situations, including Ground Zero after the 2001 attack on the World Trade Center, in Iraq and Afghanistan, searching for suspects in the Boston Marathon bombing and providing security at major sporting events. The TALON V is the first field robotic system to successfully pass the Army Test and Evaluation Command test. This confirms its effectiveness and reliability in combat environments [18].

In the United States, the Defense Advanced Research Projects Agency (DARPA) funds various programs to develop combat robots, such as Atlas, BigDog, and Spot from Boston Dynamics. Autonomous unmanned systems such as the Sea Hunter are also being developed. The Sea Hunter is the first unmanned ship of its class in the U.S. Navy. Its primary mission is to detect submarines in both autonomous and teleoperated modes. ACTUV Sea Hunter, developed under the Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) project, is a full displacement trimaran vessel with a length of more than 40 meters and a main hull width of about 3.35 meters. The Sea Hunter's design (Fig. 20) is highly seaworthy, allowing it to operate successfully at speeds up to 21 knots even in five to six-degree wave conditions and with retention of capabilities in heavy swell. The main advantage of the vehicle is its ability to detect and track submarines, for which it is equipped with various detection and surveillance equipment. The Sea Hunter is unarmed and is more suited to the role of a Sea Pathfinder. However, its design and submarine detection capabilities make it an interesting and promising tool for anti-submarine warfare activities [19]. The Sea Hunter is the first unmanned ship.

Figure 20 — Sea Hunter marine drone

6.2. Combat drones

An important part of modern armed forces, combat drones (unmanned aerial vehicles, UAVs) play a key role in various military operations. Let's take a look at some aspects of combat drones.

Types of combat drones

Reconnaissance drones are used to gather information about enemy positions, routes, and territory. Strike drones can drop bombs, fire missiles, and strike targets. Kamikaze drones dive to a target, blowing themselves and the enemy up. Long-range drones can stay in the air for long periods of time to perform reconnaissance.

Advantages of using attack drones

One of the main advantages of unmanned aerial vehicles (UAVs), especially small and medium-sized ones, is that they are economical to build and operate. Strike drones in this class are effective platforms for employing precision weapons and advanced reconnaissance and surveillance capabilities. They are capable of engaging multiple targets on the battlefield and behind enemy lines while remaining relatively simple to operate and maintain. These relative cheapness and simplicity of UAVs allow them to be built in significant numbers compared to manned vehicles. Such a concept, based on the use of low-cost platforms for modern weapons, is becoming increasingly popular. UAVs are armed with relatively inexpensive munitions which differs them from other modern weapons platforms. Technological advances allow the development of compact missiles and bombs capable of engaging a wide range of targets on the battlefield despite their relatively small size and cost. Another advantage of UAVs is the absence of a pilot on board. This makes them cost-effective and reduces political risks if the vehicle is lost. UAVs can conduct multi-hour missions due to the economical nature of their turbojet engines, allowing them to observe and attack targets on the battlefield for long periods of time. They are also an important part of the battlefield information network, sharing data with operators and other elements of the battle management system in real time.

Disadvantages of combat drones

UAVs are completely dependent on humans, and the operator may not always be able to see impending danger. There is also a problem of limited visibility. The operator only sees what the camera on the drone shows.

Nevertheless, it is important to note that combat drones are changing the nature of warfare and are becoming increasingly important in modern conflicts.

6.3. Technologies for coordinating multiple drones

A technology that enables the coordination of multiple drones to perform a common task involves the use of artificial intelligence and sophisticated control algorithms to synchronize the actions of a group of drones. They can target a single target or perform different functions within a single operation. This allows for efficient coordination of a large number of drones, which can be used for monitoring, reconnaissance, and search and rescue operations.

In addition, such systems can provide rapid detection of deviations from the agreed flight task, entry into prohibited areas, dangerous approaches between vehicles, and other critical situations. This opens up new opportunities for the use of drones in various fields, including military applications.

Figure 21 — Bayraktar TB2 drone

One prominent example of the use of drone coordination in combat is the Nagorno-Karabakh conflict in 2020. During this conflict, Azerbaijan used unmanned aerial vehicles (UAVs), including Turkish Bayraktar TB2 attack drones (Fig. 21) and Israeli Harop kamikaze drones, to strike Armenian air defense and other military targets. These drones were used for massive attacks and demonstrated a high degree of coordination, which allowed them to effectively engage targets and significantly impacted the course of hostilities.

There have also been cases of drones being used to deceive air defense systems, when An-2 corncrackers converted to UAVs were used as decoys, forcing the Armenian air defense to reveal their positions. This led to the loss of dozens of air defense installations and radars by the Armenian side, which significantly weakened its defensive capabilities. This example shows how drone coordination can be used to change tactics and strategy in modern military conflicts, making combat operations more effective and reducing risks to the lives of soldiers [20].

6.4. The future of fighting robots

Combat robots, including land, sea, and airborne drones, represent an important area of military technology development. The following trends can be expected in the future.

The development of artificial intelligence will enable robots to make real-time decisions based on analyzing data from various sources such as sensors, cameras, and radars, and provide autonomous combat systems that can perform tasks without direct operator control, reducing reaction time and increasing their effectiveness in combat applications.

The development of the Internet of Things (IoT) concept and information-sharing networks will allow combat robots to share data with other military platforms, including drones, tanks, ships, etc. This will provide a more complete and accurate picture of the situation on the battlefield, allowing for more informed decision-making.

Continued advances in miniaturization and technology will allow for smaller and lighter combat robots. This will improve their mobility and maneuverability, allowing them to penetrate hard-to-reach places and operate in a variety of environments.

An important aspect of the development of combat robots will be to ensure safety for both military and civilian populations. Issues related to the ethics of using autonomous systems for military purposes will require serious discussion and regulation.

Along with the development of combat robots, new methods and technologies for detecting and countering them will emerge. This includes the development of defense systems against aerial and ground drones, as well as countermeasures against enemy combat robots.

Overall, the future of combat robots will be driven by the desire to improve the effectiveness of military operations, minimize risks and threats to personnel and civilians, and strictly adhere to ethical standards and international law.

7. The role of situation centers and decision systems in combat operations

Situation centers and decision-making systems play a key role in modern warfare by providing commanders with information about the current battlefield environment and helping them make informed strategic and tactical decisions. Let's look at some of the key aspects of their operation.

Data collection and analysis

Situation centers receive data from a variety of sources such as reconnaissance drones, radar systems, reconnaissance squads, and even networks of spy agents. After that, this data is analyzed and structured to provide a complete picture of the situation.

Information visualization

Another important aspect of situation centers is the ability to visualize data for commanders and analysts. This can include creating three-dimensional models of an area, displaying troop and enemy locations, and other key parameters such as weather and terrain conditions.

Decision-making

Based on data analysis, situation centers help commanders make decisions concerning tactics and strategy. This may include identifying targets for attack, planning troop movement routes, and allocating resources to support military operations.

Communication and coordination

Decision-making systems also enable effective communication between different levels of command and units on the battlefield. This enables rapid response to changing conditions and coordination among different parts of the military.

Automation and artificial intelligence

Modern situation centers are increasingly using automation and artificial intelligence to improve the speed and accuracy of data analysis and to predict possible scenarios.

Overall, situation centers and decision-making systems play a critical role in ensuring the effectiveness and success of combat operations by providing commanders with relevant and reliable information and helping them make informed strategic and tactical decisions.

7.1. GPT technology is the key to effective and reliable decision-making systems

To significantly improve the effectiveness of situation centers and decision-making systems, it is advisable to apply GPT (Generative Pre-trained Transformer) technology. GPT is a generative artificial intelligence technology that uses a transformer model to generate text. It was developed by OpenAI and is one of the most popular chatbot technologies in the world. GPT-3 is a version of the model that was released in 2020 and has over 175 billion parameters. However, since then, newer models have been developed such as GPT-4 and GPT-5 which learn from a large number of different data sources including text, images, and audio to produce more accurate and varied results.

GPT-5 is a significant enhancement to previous versions that includes a number of revolutionary innovations. One of the key changes is the ability to process not only text but also images and video with a degree of accuracy and coherence comparable to text processing. This greatly expands the model's applications and makes it more versatile. In addition, the new features and capabilities of GPT-5 can significantly improve the interaction between humans and neural networks. AI will become more intuitive and able to understand and respond to queries and instructions in a more natural and human-like manner. All these new developments and applications of GPT-5 technologies open up new horizons in the use of artificial intelligence in various industries and fields of activity. The main component of GPT is a neural network that is trained on huge amounts of text data from various sources including the Internet. This allows the model to assimilate a lot of information and understand the context of different queries. Its answers are not limited to simple templates or pre-prepared phrases but can be creative and original, which makes it an ideal interlocutor and assistant in various situations. They can significantly improve and automate analysis and decision-making processes and provide new tools for work and research.

7.2. Perspectives on the use of GPT technologies

The use of GPT technologies will significantly improve analysis and decision-making processes and provide new tools for work and research.

1. Process automation. GPT technologies can automate the processing and analysis of large amounts of data. They can help in automatically classifying, summarizing, and analyzing textual information including reports, news, social media posts, and other sources. This will allow situation center operators to get information more quickly and make informed decisions.

2. Text analysis and sentiment analysis. GPT models can be trained on data to analyze text and determine tone or sentiment. This can be useful, for example, in monitoring social media to identify discussions and reactions to events, or in analyzing news sources to determine the impact and reactions to certain situations.

3. Text generation. GPT technologies can be used to automatically generate text, for example, to create reports, messages, or recommendations. This can assist situation center operators in compiling and formulating information that they can further communicate to stakeholders.

4. Virtual assistants and user support. GPT models can be trained to create virtual assistants that can answer user questions and offer recommendations and solutions. This can reduce the workload and help users to get prompt answers to their queries.

5. Interactive communication. GPT technologies allow systems to be built to interactively communicate with the user. They can handle complex queries and dialogs, provide clarifying questions, and help users achieve desired results.

6. Prediction and modeling. GPT models can be used to predict and simulate various scenarios. This can help situation center operators assess potential risks and opportunities, and develop contingency plans for various contingencies.

7. Personalization. GPT technologies allow the personalization of the experience of users of the situation room. This can be achieved by tailoring the interface and the information provided to the individual needs and preferences of each user.

8. Data fusion. GPT models can help in fusing data from various sources including structured and unstructured data. This allows situation center operators to gain a more complete picture of the situation and make more informed decisions.

9. Raising awareness. GPT technologies can be used to increase user awareness of various situations and events. This can be achieved by providing timely alerts, advisories, and analytical reports.

10. Improved communication. GPT models can help to improve communication between the various stakeholders involved in the situation center. This can be achieved through automatic translation, transcription, and text analysis.

11. Security. GPT techniques can be used to ensure the security of the situation center. This can be achieved by identifying potential threats and by controlling access to information and systems.

12. Cost savings. The use of GPT technologies can help reduce the cost of running a situation center. This can be achieved by automating various processes and also by reducing the number of staff required to run the center.

13. Increased efficiency. GPT technologies can help to increase the efficiency of the situation center. This can be achieved by speeding up the processing of information and also by improving the quality of decision-making.

14. Enhancement of capabilities. GPT technologies can help to enhance the capabilities of a situation center. This can be achieved by adding new features and capabilities that were previously unavailable.

15. Improved competitiveness. The use of GPT technologies can help to improve the competitiveness of an organization. This can be achieved by improving the quality of decision-making and also by speeding up the response to various events.

When using GPT technologies in situation centers and decision-making systems, it is important to consider the need to continually update and retrain models to achieve optimal performance and prevent the spread of inaccurate or misleading data.

Before implementing GPT technologies in situation centers and decision-making systems, a thorough assessment of the risks and potential benefits should be conducted.

8. Conclusions

In the course of studying the history of computer technology development and its impact on various spheres of society, it becomes obvious that computer science plays a key role in technological progress and changing the face of the modern world. The conducted analysis of the evolution of computer technologies and their application in various spheres of life of modern society allows us to draw the following conclusions:

1. The rapid development of computer technologies in recent decades has become one of the main driving forces of technological progress and social change. From bulky electronic machines of the early years to modern high-performance systems, computers have firmly entered all spheres of life in modern society.

2. Revolutionary advances in artificial intelligence, machine learning, and big data processing are opening new horizons for automating, improving efficiency, and empowering computer systems.

3. The application of transformational model-based technologies such as GPT has great potential to improve the efficiency of information systems, situation centers, and decision support systems.

4. Despite the obvious advances and promises, the development of computer technology presents a number of important social and ethical challenges that require careful analysis and a balanced approach to management.

5. The collection and processing of vast amounts of data raises issues of information protection and confidentiality.

6. Automation of routine tasks may lead to job losses in some industries.

7. AI-based systems may behave unpredictably, creating safety risks and ethical dilemmas. To ensure responsible and ethical development of computer technologies, an integrated approach that takes into account not only technical but also humanitarian aspects is necessary.

Analyzing the history and current state of computer technologies plays a key role in understanding the modern world. The further development of these technologies opens up new opportunities for humanity but requires a responsible and integrated approach to process management based on ethical principles and aimed at minimizing risks. Nevertheless, with proper management and a responsible approach to the development and use of computer and information technologies, we can expect further breakthroughs in automation, efficiency, and innovation that will benefit society as a whole.

REFERENCES

1. McCulloch & Pitts Publish the First Mathematical Model of a Neural Network. URL: https://www.historyofinformation.com/detail.php?entryid=782.
2. ENIAC computer. URL: https://www.britannica.com/technology/ENIAC.
3. History of computing in 10 subjects. URL: https://arzamas.academy/special/ cybernetics/timeline
4. Artificial intelligence has been invented at Dartmouth. URL: https://home.dartmouth.edu/about/artificial-intelligence-ai-coined-dartmouth.
5. Glushkov V.M., Yushchenko E.L. Mathematical description of the computer "Kiev". Kiev: State Publishing House of Technical Literature of the Ukrainian SSR, 1962. URL: https://www.sorucom.org/articles/materialy-mezhdunarodnoy-konferentsii-sorucom-2017/3219/.
6. Perseptron: the foundations of modern AI laid 60+ years ago. URL: https://medium.com/@danielbanales/perceptron-the-bases-of-modern-ai-settled-60-years-ago-a7218ae75af2.
7. Dnepr — the first domestic semiconductor control machine. URL: https://www.icfcst.kiev.ua/MUSEUM/GL_HALL2/COMPUTERS/Dnepr_param_r.html.
8. Viktor Mikhailovich Glushkov. URL: https://glushkov.su/.
9. Computer "MIR-2" (abbreviation from "Machine for Engineering Calculations"). URL: http://www.icfcst.kiev.ua/MUSEUM/PHOTOS/MIR2_u.html.
10. Principles of Neurodynamics: Perceptrons and the Theory of Brain Mechanisms. URL: https://libarch.nmu.org.ua/handle/GenofondUA/56396.
11. Kasparov vs. Deep Blue | The Match That Changed History. URL: https://www.chess.com/article/view/deep-blue-kasparov-chess.
12. Go: why it took so long for a computer to beat a human being. URL: https://alex-averyanov.livejournal.com/330217.html.
13. How a quantum computer works. URL: https://robotdreams.cc/blog/392-yak-pracyuyut-kvantovi-komp-yuteri.
14. Wong K. China's CASC Unveils D3000 Unmanned Oceanic Combat Vessel Concept. *Jane's International Defense Review*. 2017. July 2. P. 5.
15. BAE Systems has revealed its response to Russia's Uran-9 strike system. URL: https://military-informant.com/army/bae-systems-pokazala-otvet-na-rossiyskiy-udarnyiy-kompleks-uran-9.html.

16. A combat robot in service with the Israeli army, IAI ELTA REX MK II. URL: https://www.iai.co.il/iai-unveils-rex-mk-ii-multi-mission-unmanned-land-vehicle.
17. A medium-sized tactical robot. URL: https://www.epequip.com/catalogue/uncrewed-systems/uncrewed-ground-vehicles/talon-v/.
18. BEC Sea Hunter. The silent submarine hunter. URL: https://naukatehnika.com/ bezekipazhnyj-trimaran-sea-hunter.html.
19. After the Karabakh conflict, everyone is talking about the “drone revolution”. URL: https://meduza.io/feature/2020/11/19/posle-karabahskogo-konflikta-vse-govoryat-o-revolyutsii-dronov.

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