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AN OVERVIEW OF THE EVOLUTION OF ARTIFICIAL INTELLIGENCE AND ITS ROLE IN HIGHER EDUCATION

Abstract. The article provides a comprehensive overview of the evolution of artificial intelligence and analyses its role in the development of modern higher education, offering a structured synthesis of its evolutionary trajectory and highlighting its growing significance as a transformative factor in contemporary higher education systems, contributing to the enhancement of learning processes and educational outcomes. Artificial intelligence is understood as a field of computer science that develops systems capable of independently performing tasks traditionally associated with human intelligence through the acquisition, analysis and processing of information from the environment. Artificial intelligence has undergone continuous development, attracting increasing scientific interest and evolving from early theoretical concepts to advanced technological systems. The article examines the evolution of artificial intelligence by identifying five key stages of its development, ranging from symbolic systems and expert programs to machine learning, deep neural networks and transformer-based architectures. Each stage is characterized by the emergence of new approaches and methodologies that have contributed to the formation of modern artificial intelligence. Particular attention is given to its role in higher education, where artificial intelligence contributes to the transformation of educational practices and the development of adaptive and accessible learning environments.

The study emphasizes that contemporary advancements in higher education are increasingly associated with the integration of artificial intelligence into the educational practices of higher education institutions. In this context, artificial intelligence enhances the efficiency and flexibility of the educational process, supports personalized learning and expands access to educational resources. As a result, artificial intelligence is becoming an essential component of the modern educational landscape.

Keywords: artificial intelligence; digital learning; higher education; information technologies.

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Махатілов Антон Ігорович здобувач вищої освіти третього (освітньо-наукового) рівня 1-го року навчання кафедри педагогіки, іноземної філології та перекладу Харківського національного економічного університету імені Семена Кузнеця, Харків

ОГЛЯД ЕВОЛЮЦІЇ ШТУЧНОГО ІНТЕЛЕКТУ ТА ЙОГО РОЛІ У ВИЩІЙ ОСВІТІ

Анотація. У статті здійснено комплексний огляд еволюції штучного інтелекту та проаналізовано його роль у розвитку сучасної вищої освіти, запропоновано структурований синтез його еволюційної траєкторії та підкреслено його зростаюче значення як трансформаційного чинника сучасних систем вищої освіти, що сприяє підвищенню ефективності навчальних процесів та освітніх результатів. Штучний інтелект розглядається як галузь комп’ютерних наук, у межах якої створюються системи, здатні самостійно виконувати завдання, традиційно властиві людському інтелекту, шляхом отримання, аналізу та обробки інформації з навколишнього середовища. Штучний інтелект зазнав безперервного розвитку, привертаючи зростаючий науковий інтерес і еволюціонуючи від ранніх теоретичних концепцій до сучасних технологічних систем. У статті розглянуто еволюцію штучного інтелекту шляхом виокремлення п’яти ключових етапів його розвитку, від символічних систем і експертних програм до машинного навчання, глибинних нейронних мереж і трансформерних архітектур. Кожен етап характеризується появою нових підходів і методологій, які сприяли формуванню сучасного штучного інтелекту. Особливу увагу приділено його ролі у вищій освіті, де штучний інтелект сприяє трансформації освітніх практик і розвитку адаптивних та доступних освітніх середовищ. У дослідженні наголошується, що сучасні зміни у сфері вищої освіти дедалі більше пов’язані з інтеграцією штучного інтелекту в освітні практики закладів вищої освіти. У цьому контексті штучний інтелект підвищує ефективність і гнучкість освітнього процесу, підтримує персоналізоване навчання та розширює доступ до освітніх ресурсів. У результаті штучний інтелект стає невід’ємною складовою сучасного освітнього середовища.

Ключові слова: вища освіта; інформаційні технології; цифрове навчання; штучний інтелект.

Formulation of the problem and analysis of recent research and publications.

Information technologies have been developing for many decades and today they have spread across all spheres of human life. Moreover, their importance continues to grow with every day and their role in various spheres of human activity is undeniable. This trend is particularly evident in the field of higher education, where information technologies have acquired special importance in recent years.

Information technologies have become an integral part of the educational process, actively utilized by both teachers and students. These technologies serve as valuable tools that enhance learning outcomes, simplify the educational experience, provide access to a vast amount of information, create interactive educational environments, which fosters greater engagement and motivation among learners. In contemporary settings, they play a crucial role by facilitating distance learning, enabling students to study online and acquire knowledge from anywhere in the world, regardless of their own residence and the location of their educational institutions.

The rapid development of artificial intelligence has attracted considerable attention from the scientific community, resulting in a wide range of studies addressing its theoretical foundations, technological advancements, and practical applications. A number of scholars have focused on defining the nature and scope of artificial intelligence, proposing various approaches to its interpretation and classification [13; 14; 23].

Other researchers have examined the evolution of AI technologies, including machine learning, deep neural networks and transformer-based models, emphasizing their rapidly expanding capabilities [8; 9; 10; 27]. At the same time, increasing attention has been paid to the application of artificial intelligence in education, particularly in higher education, where it is associated with the development of adaptive learning systems and digital learning environments [1; 5].

However, despite the significant body of research, the issue of systematically analysing the evolution of artificial intelligence in conjunction with its role in higher education remains insufficiently explored, which determines the relevance of this study.

The aim of the research. This paper aims to examine the evolution of artificial intelligence and to analyse its role and significance in the context of higher education.

The aim of the research is achieved through the following objectives:

– to analyse the main stages in the development of artificial intelligence;

– to examine the transformation of scientific approaches to understanding artificial intelligence;

– to identify key technological advancements that have shaped modern artificial intelligence;

– to explore the application of artificial intelligence in education;

– to assess the role of artificial intelligence in the development of higher education.

Presentation of the main material.

One of the most dynamic and rapidly developing areas of information technologies, gaining increasing popularity nowadays, is artificial intelligence. Within this study, artificial intelligence is interpreted as a field of computer science concerned with the creation of systems capable of autonomously performing tasks inherent to human intelligence through the acquisition, analysis and processing of information from the environment. Within higher education, its integration creates strong prerequisites for improving the quality of learning, driving modernization, expanding access to diverse educational resources and enables higher educational institutions to adopt innovative approaches, which strengthens their role in preparing learners for the demands of a knowledge-based society.

Before artificial intelligence took the shape we recognize today, it passed through a series of developmental stages, each bringing new improvements and greater sophistication. In his article "Computing Machinery and Intelligence," Turing posed the fundamental question of whether machines could think. To investigate this, he introduced the "imitation game," an experiment designed to test whether a machine could demonstrate intellectual behaviour comparable to that of a human [25]. This idea became the foundation for later debates on artificial intelligence and marked the first major stage in its development.

In 1955, McCarthy, Minsky, Rochester and Shannon proposed the Dartmouth Summer Research Project on Artificial Intelligence, introducing the term "artificial intelligence" for the first time. The initiated research was based on the assumption that "every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it" [14, p. 2]. An attempt was made to explore how machines can use language, form abstractions and concepts, solve problems and improve their own performance **[14].**

The Dartmouth Conference took place in 1956, during which Newell and Simon presented the Logic Theorist, an information processing system, relying on heuristic methods that resemble human problem-solving behaviour [17]. The Logic Theorist is widely regarded as the first artificial intelligence program, as it was specifically designed to model human reasoning and demonstrated that machines could perform tasks previously considered the exclusive domain of human intelligence. Thus, the Dartmouth Conference, which brought together leading researchers, has formally established the foundation for the emerging field of artificial intelligence.

Investigating the processes, involved in human intelligent, adaptive and creative behaviour, Newell, Shaw and Simon, created a program for a digital computer known as the General Problem Solver (GPS). This program was designed to model human problem-solving processes using heuristic strategies, which was a further development of the earlier program, the Logic Theorist. The researchers aimed to investigate intelligence by developing a computer program capable of exhibiting intelligent behaviour, analysing their structure and examining the problem-solving and other adaptive processes they generate. Nevertheless, despite its significant potential, the system had a number of limitations, mainly related to its reliance on highly formalized problem representations, simplified task representation and the complexity of its implementation [19].

Working on the further development of artificial intelligence, in their later work on heuristic problem solving, Newell and Simon put forward an ambitious prediction regarding the foreseeable future, stating that *"there are now in the world machines that think, that learn, and that create"* [18, p. 8]. The authors anticipated a significant intensification of computer development across various fields, suggesting that machines would soon be able to compete with humans in complex intellectual activities. Overall, these predictions reflected the expectation that machines would increasingly be applied to solving ill-structured problems, gradually taking on tasks that had traditionally been performed by humans [18].

A significant contribution to the early development of artificial intelligence was made by Samuel, who was among the first to consider the possibility of programming a digital computer to behave in a way that could be considered as learning. In this context, he effectively introduced the notion of machine learning. His ideas were practically implemented in a program designed to play checkers, through which he demonstrated that a computer could be programmed not only to play the game, but also to improve its performance over time. Notably, the system was able to learn to play at a level exceeding that of the person who initially programmed it. On this basis, he concluded that machines can be designed to learn from experience, and that such learning mechanisms are not limited to game playing but may be applied to a wide range of tasks. In particular, he suggested that it is possible to develop learning schemes capable of outperforming an average human and that, in the future, such approaches could be extended to solving real-world problems [24].

Thus, the growing interest of scientists in the potential of computer technologies to study and model human intellectual behaviour during the 1950s and 1960s laid the foundation for the emergence of artificial intelligence as a distinct field and contributed to its subsequent development.

The next stage in the development of artificial intelligence, which began in the 1960s, saw the growth of research initiatives, the development of programming languages tailored for artificial intelligence applications and the introduction of the first systems designed to interact directly with humans.

One of the key technological breakthroughs, marking the second stage of artificial intelligence development, was the creation of the programming language LISP, which was specifically designed to process symbolic information. LISP enabled the manipulation of symbolic expressions through recursive functions and allowed programs to handle both declarative and imperative statements, exhibiting "'common sense' in carrying out its instructions" [13].

Based on the technological advances of LISP, the 1960s saw the emergence of several new directions in artificial intelligence. One of the most prominent areas was natural language processing, exemplified by the program ELIZA (1966), which functioned as an early information retrieval system, capable of engaging in written conversation by providing responses drawn from a set of pre-programmed rules, rather than exhibiting true understanding. ELIZA was designed to simulate human dialogue and demonstrated the potential for machines to engage in interactive communication [28].

At the same time, DENDRAL program appeared, marking one of the earliest applications of expert systems in artificial intelligence. "It was one of the first large-scale programs to embody the strategy of using detailed, task-specific knowledge about the problem domain as a source of heuristics, and to seek generality through automating the acquisition of such knowledge" [12, p. 210]. Originally designed to tackle specialized problems in chemistry, it was later adapted for use in medicine and other fields, becoming the first rule-based system implemented to address a practical, real-world problems. The development of the DENDRAL program was considered as an attempt to conduct a comprehensive empirical investigation of heuristic programming techniques, aimed at revealing their strengths and limitations to exemplify the philosophical concept of automatic discovery procedures, whose validity had long been debated [12, p. 210]. Although DENDRAL was developed for a specific scientific domain, it "embodies general strategies, augmented by specialized knowledge, that give it a measure of intelligence and which can adapt to new information [12, p. 259]. Being applied with other knowledge, these strategies have proven effective across a range of domains. This reflects the contemporary understanding of artificial intelligence, a perspective that DENDRAL helped to establish and exemplify [12, p. 259].

Although the ideas introduced by the above-mentioned computer programs were highly innovative for their time and led to a significant progress, their limitations became apparent over time, contributing to a decline in interest and a slowdown in artificial intelligence research in the following period. It became evident that expert systems were difficult to develop and sustain in complex domains, as "the reasoning methods used by the systems broke down in the face of uncertainty and in part because the systems could not learn from experience" [23, p. 42]. The failure to meet high expectations led many companies to withdraw from the field, resulting in reduced funding for artificial intelligence research and contributing to the beginning of the "AI winter" in the 1970s.

Lighthill *criticized the state of early artificial intelligence* systems for their failure to address the problem of combinatorial explosion, which was "a general obstacle to the construction of a self-organising system on a large knowledge base which results from the explosive growth of any combinatorial expression representing numbers of possible ways of grouping elements of the knowledge base according to particular rules as the bases size increases" [11, p. 9].

Brooks argued that traditional *artificial intelligence* systems relied heavily on internal representations of the world, which made them inefficient in real environments, where unpredictable changes often made their algorithms inflexible and unable to adapt. He pointed out that in reality perception, reasoning and action are closely connected and cannot be easily separated. According to him, intelligent behaviour can emerge from direct interaction with the environment rather than from abstract representations. This idea led to new approaches in *artificial intelligence*, focusing on systems that respond and adapt to their surroundings [3].

In particular, Feigenbaum drew attention to the complexity of transforming human knowledge into a form that can be processed by machines, emphasizing that "the acquisition of domain knowledge was the bottleneck problem in the building of applications-oriented intelligent agents" [7].

During the "AI winter", as Nilsson observed, many researchers shifted their focus toward more realistic and attainable goals, moving away from the ambitious expectations of earlier years [20, p. 344].

After the period of the "AI winter", a new stage in the development of artificial intelligence began, which can be roughly dated from the mid-1980s to the early 1990s. During this time, research shifted toward more practical and application-oriented approaches. In particular, significant attention was paid to expert systems designed for use in specific fields of knowledge, where they could assist specialists in solving complex problems. These systems were applied in areas such as medicine and science, with well-known examples including MYCIN and similar programs. MYCIN was an expert system designed for medical diagnosis and consultation, in particular, "to provide expert-level solutions to complex problems, to be understandable, and to be flexible enough to accommodate new knowledge easily" [4, p. 3]. PROSPECTOR was an expert system developed for the analysis of geological data and for providing consultation in the exploration of mineral deposits. It was designed to support decision-making in the search for natural resources by applying a set of rules to draw inferences from available data and guide the exploration process [6]. Another notable example of the expert system was R1, also known as XCON, which was developed to automate the configuration of computer orders. It is often regarded as one of the first successful commercial expert systems, as it operated in a real production setting within a manufacturing company. The system assisted in selecting and assembling appropriate computer components based on customer requirements, demonstrating the practical value of artificial intelligence in industrial applications [15].

This period reflects a growing emphasis on the practical implementation of artificial intelligence technologies in real-world contexts. The experience gained from implementing expert systems and other applied artificial intelligence solutions, including early hybrid decision-making systems, laid the groundwork for the development of more sophisticated machine learning algorithms, opening the way for the next stage of artificial intelligence research and innovation. Based on these foundations, the next stage of artificial intelligence research began to focus on data-driven approaches, enabling machines to improve performance through learning rather than relying solely on pre-programmed rules. This period marks the fourth stage of artificial intelligence development, spanning from the early 1990s to the late 2000s.

An important step in the development of machine learning was made by Rumelhart and his colleagues, who introduced the back-propagation learning procedure for networks of neuron-like units, laying the groundwork for self-organizing neural networks [22].

During this period, a variety of machine learning approaches saw growing application among them are Quinlan's decision tree algorithms [21], Bayesian networks [2; 16] and support vector machines [26], each contributing to the expanding toolkit for data-driven problem solving in artificial intelligence.

Despite their successes, the machine learning approaches described above revealed a number of limitations. These are largely associated with their difficulty in handling complex or nonlinear data and often required rules to be carefully designed by humans. Such constraints motivated the search for more powerful methods capable of learning intricate patterns automatically, ultimately leading to the fifth stage of artificial intelligence development, dominated by deep learning techniques, which involve "machine learning using multiple layers of simple, adjustable computing elements" [23, p. 44]. This stage began in the early 2010s and continues to the present, driven by advances in computational power, availability of large datasets, and new types of neural network architectures.

During this period, deep learning techniques were widely used in both language processing and image recognition, demonstrating their versatility across different domains. Krizhevsky, Sutskever and Hinton proved that a deep convolutional neural network could significantly improve image recognition performance when trained on a very large dataset. Their results confirmed that, given sufficient data and computational resources, deep convolutional neural networks can achieve high accuracy on challenging datasets, marking a major advance in the practical application of deep learning [9].

LeCun, Bengio and Hinton systematized the main approaches to deep learning by examining how multilayer neural networks are constructed and trained. They showed how such models can automatically learn hierarchical representations from data, which enables more effective processing of complex tasks. The authors also outlined future directions for artificial intelligence development, emphasizing the growing role of deep learning in areas such as natural language understanding and highlighting the importance of combining representation learning with more advanced forms of reasoning [10].

These ideas were further expanded by Goodfellow, Bengio and Courville, who provided a comprehensive overview of deep learning, explaining how deep neural networks enable systems to improve performance through experience and large volumes of data. They emphasized that "machine learning is the only viable approach to building artificial intelligence systems that can operate in complicated, real-world environments" [8, p. 8]. In particular, they approached deep learning as "a particular kind of machine learning" that represents information through multiple layers of abstraction, where more complex concepts are constructed from simpler ones [8, p. 8].

This hierarchical structure provides both flexibility and expressive power for solving complex tasks. At the same time, the authors highlighted key difficulties associated with deep learning, including high computational demands, large data requirements and limited interpretability, as well as outlined directions for its further development and application [8].

Another important contribution to the development of deep learning was the introduction of a new network architecture, called the Transformer. This architecture eliminates both recurrent and convolutional components, "instead relying entirely on an attention mechanism to draw global dependencies between input and output" [27, p. 5999]. Thus, the Transformer allows for greater parallelization, resulting in faster training and improved performance [27].

Conclusion.

The cumulative achievements across the five stages of artificial intelligence development have shaped the discipline and built a solid foundation of knowledge and experience. From early symbolic systems and expert programs to the advances in machine learning, deep neural networks, and the Transformer architecture, each stage has contributed insights and methodologies that contribute to further development of modern artificial intelligence. Due to this accumulated experience, contemporary artificial intelligence systems are capable of performing complex tasks across language, vision and decision-making domains, achieving levels of adaptability, efficiency and accuracy.

As a result of these developments, higher education happened to be one of the key domains benefiting from advances in artificial intelligence. It is worth mentioning that the application of artificial intelligence in education is not entirely new. Earlier forms, such as intelligent tutoring systems, developed in the late twentieth century, were designed to simulate the instructional interaction of a human tutor by adapting content to a learner's needs [5]. Later research grounded in cognitive models, demonstrated how artificial intelligence could be integrated with theories of human learning to create adaptive tutoring systems that support complex problem-solving [1]. These systems relied primarily on symbolic and knowledge-based approaches to artificial intelligence rather than modern data-driven methods based on neural networks and deep learning. Nevertheless, they revealed the potential of artificial intelligence to support and partially replicate human cognitive processes in learning, laying the foundation for subsequent advancements, in particular, the emergence of adaptive and hybrid learning systems, which integrated expert knowledge with machine learning techniques, contributing to the further expansion of possibilities for applying artificial intelligence in education [16; 23].

Today, higher education increasingly relies on AI-driven tools that enhance learning processes, support personalized education and improve access to knowledge. This is particularly important, as education is inherently connected with the development and application of human intelligence. In this context, artificial intelligence acts as both a technological innovation and a transformative force in educational practices, contributing to more adaptive, efficient and accessible learning environments.

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