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HISTORICAL DEVELOPMENT

Y LAS TIPOLOGÍAS TEXTUALES EN LA EDUCACIÓN BÁSICA PRIMARIA, TERCER GRADO

AND MODERN APPROACHES IN THE FIELD OF ARTIFICIAL INTELLIGENCE AND NATURAL LANGUAGE PROCESSING

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ABSTRACT

This article provides a comprehensive analysis of the historical development stages and scientific foundations of the fields of artificial intelligence (AI) and natural language processing (NLP). Starting from the initial philosophical and mechanical models of the formation of artificial intelligence, Alan Turing's theories of computation and the importance of the Turing test, as well as the main historical events that occurred in the field of NLP in the 20th century, are examined in detail. The rule-based systems used in the early stages of NLP and the influence of Noam Chomsky's theory of universal grammar on this field are considered. The development of statistical and neural network models in the transition to the 21st century, as well as the formation of modern NLP approaches, are analyzed in detail. In addition, the article discusses current application areas of natural language processing, such as virtual assistants, sentiment analysis, spam filtering, automated analysis of medical texts, legal information processing, machine translation, and chatbots. As a result, it is emphasized that NLP is an important tool for both scientific research and various practical fields, and that more innovative applications will emerge in the future with the integration of artificial intelligence and linguistics. The article also provides information on the current status of the Azerbaijani language in the field of natural language processing, the challenges it faces, and development prospects.

Keywords: Artificial intelligence, Natural language processing, Linguistic modeling, Technological approaches, Azerbaijani language.

RESUMEN

Este artículo ofrece un análisis exhaustivo de las etapas históricas del desarrollo y los fundamentos científicos de la inteligencia artificial (IA) y el procesamiento del lenguaje natural (PLN). Partiendo de los modelos filosóficos y mecánicos iniciales sobre la formación de la inteligencia artificial, se examinan en detalle las teorías de la computación de Alan Turing y la importancia del test de Turing, así como los principales acontecimientos históricos ocurridos en el campo del

PLN durante el siglo XX. Se consideran los sistemas basados en reglas utilizados en las primeras etapas del PLN y la influencia de la teoría de la gramática universal de Noam Chomsky en este campo. Se analiza en detalle el desarrollo de modelos estadísticos y de redes neuronales en la transición al siglo XXI, así como la formación de los enfoques modernos del PLN. Además, el artículo aborda las áreas de aplicación actuales del procesamiento del lenguaje natural, como los asistentes virtuales, el análisis de sentimientos, el filtrado de spam, el análisis automatizado de textos médicos, el procesamiento de información legal, la traducción automática y los chatbots. Como resultado, se destaca que el PLN es una herramienta importante tanto para la investigación científica como para diversos campos prácticos, y que surgirán aplicaciones más innovadoras en el futuro con la integración de la inteligencia artificial y la lingüística. El artículo también proporciona información sobre la situación actual del idioma azerbaiyano en el ámbito del procesamiento del lenguaje natural, los desafíos que enfrenta y las perspectivas de desarrollo.

Palabras clave: Inteligencia artificial, Procesamiento del lenguaje natural, Modelado lingüístico, Enfoques tecnológicos, Idioma azerbaiyano.

INTRODUCTION

The rapid development of artificial intelligence technologies in the 21st century has led to significant advances in the field of natural language processing (NLP). As a result of increased computing power and improved algorithmic approaches, the ability of computers to understand and respond to human language has moved from a theoretical concept to a practical reality. NLP, as a complex and multidisciplinary field located at the intersection of computer science, linguistics, psychology, and artificial intelligence, has had a significant impact on both scientific research and various application areas (Alqahtani et al., 2023; Zhou et al., 2024).

Historically, natural language processing has started with rule-based approaches, then continued with statistical models, and finally entered a new phase with the application of deep learning technologies. This development process has changed the foundations of this field not only at the technical level, but also at the theoretical and philosophical levels. Alan Turing's famous provocation—'can machines think?'— (Turing, 2009) not only formulated a practical test (the test that bears his name), but also guided debates about the formalization of human thought and language. From this philosophical perspective, the community was divided between those who aimed to build symbolic cognitive systems—with explicit rules and knowledge programming—and those who preferred empirical and statistical approaches.

In the early decades, pioneering work combined logic, formal grammars, and representation systems. Systems such as ELIZA demonstrated that, even with relatively simple rules and restricted domains, it was possible to produce convincing dialogues and manipulate semantic representations (Lo & Singh, 2023). These projects provided two critical lessons: (a) the need to model context and conversational state, and (b) the limits imposed by the fragility of manually coded rules when faced with open domains. Subsequently, the availability of large corpora and the development of estimation algorithms led to the consolidation of the statistical paradigm. Tools such as hidden Markov models (HMMs) and probabilistic approaches to machine translation (IBM models) transformed the practice of NLP: the attempt to codify complete linguistic rules was abandoned, and learning from empirical data was prioritized (Oralbekova et al., 2023). This stage demonstrated the practical superiority of statistical methods in tasks such as speech recognition and machine translation, but also highlighted new challenges, such as parallel data dependencies and the management of linguistic ambiguity using stochastic models.

The introduction of distributed representations (word embeddings) and neural models radically changed the landscape. From neural networks for language models to word2vec and GloVe, dense and continuous vectors were shown to capture semantic and syntactic relationships that discrete representations could not model. Sequential models (RNNs, LSTMs, GRUs) enabled more sophisticated operations on text but suffered from problems with parallelization and handling long-term dependencies. The introduction of the transformer (Vaswani et al., 2023) represented a methodological and practical breakthrough: attention allowed contextual dependencies to be modeled without resorting to explicit recursions and, thanks to its parallelization, dramatically accelerated large-scale pretraining. On this basis, pretrained models such as BERT, GPT (and their variants), and multilingual or specialized variants emerged, which, through autoregressive or masked pretraining and fine-tuning, achieved state-of-the-art results in a wide range of tasks. The shift from the scientific frontier to scaling engineering—more parameters, more tokens, more data—changed the sociology of NLP research and raised questions about resources, equity, and sustainability (Abro et al., 2023; Supriyono et al., 2024), leading to novel proposals that eliminate the use of tokens (Hwang et al., 2025).

Given the relevance of the topic, the goal of this article is to examine from a scientific and historical perspective the stages of natural language processing development, its main models, and the problems and opportunities arising from modern technologies. We also focus on the current state and development prospects of the Azerbaijani language in this field.

DEVELOPMENT

Historical and scientific foundations in the formation of artificial intelligence

Although the concept of artificial intelligence seems to be a product of the modern era, the basis of this concept is rooted in ancient philosophical and mechanical thoughts. Even in the 17th century, the idea that mechanical systems could imitate human and animal behavior was widespread. The famous mathematician and philosopher René Descartes compared humans to a complex mechanism and tried to explain their behavior through a clockwork mechanism. During this period, the idea of an "intelligent machine" became the subject of not only technological but also philosophical considerations. The "Difference Engine" developed by the English mathematician Charles Babbage in the early 19th century was one of the important steps taken toward the transformation of these ideas into practice. This mechanism was not only limited to performing mathematical operations but also had the ability to model memory capacity and game strategies to a certain extent (Schultz & Ellen-Schultz, 2007). This was considered one of the first experiments in the direction of technological modeling of the human mind. However, the major turning point in the field of artificial intelligence in the 20th century was observed during the Second World War. It was during this period that the code-breaking device "Bombe" developed by Alan Turing had a significant impact on the outcome of the war (Gladwin, 1997). Later, in 1950, Turing's famous question "Can machines think?" in his article "Computing Machinery and Intelligence" formed the theoretical foundations of artificial intelligence (Turing, 2009).

The term "Artificial Intelligence" was first proposed by John McCarthy during a scientific seminar held at Dartmouth College in 1956 (Dick, 2019). This event led to the intensification of academic research in the field of artificial intelligence. In the following decades, systems such as ELIZA, SHRDLU, and various other programs were created (Kutlusoy, 2019), and in the 1970s, the first human-like robot called WABOT-1 was introduced by Japan (Acar, 2020). However, the period from 1974 to 1980, as a result of declining interest in the field and the cessation of funding, became known as the "Artificial Intelligence Winter" (Öztürk & Şahin, 2018). Since the mid-1980s, several countries, especially the United Kingdom and Japan, began to support the development of the field of artificial intelligence again. In 1997, the defeat of world chess champion Garry Kasparov by IBM's Deep Blue program demonstrated the potential of artificial intelligence to the general public (Schultz & Ellen-Schultz, 2007).

At the beginning of the 21st century, artificial intelligence began to enter our daily lives. The use of artificial intelligence in smart home devices such as "Roomba" and the algorithms of social media platforms (Facebook, Netflix, Twitter, etc.) further expanded the scope of this technology (Acar, 2020). In 2011, IBM's Watson system defeated humans in an intellectual competition on television (Sariel, 2017), and in 2018, Google introduced the "Duplex" system, which makes phone calls with voice conversations and behaves like a human (Acar, 2020). These developments show that artificial intelligence has moved beyond being a theoretical field of research and has become a practical technology applied in medicine, transportation, education, and many other sectors. However, despite all these achievements, the extent to which artificial intelligence imitates human intelligence or can surpass it in the future remains a matter of debate (Kırpinar, 2019).

As can be seen, the development of artificial intelligence is not limited to technological progress alone; it also requires a deep study of human thought, logic, and behavioral models. The role of language and communication in this process is particularly important, since language is the main tool for intelligent systems to understand and respond like humans. For this reason, the field of Natural Language Processing (NLP) comes to the fore as one of the most important areas of artificial intelligence.

Historical development stages and scientific foundations of natural language processing

Language serves as an important means of transmitting not only thoughts and information but also feelings, uncertainties, and incompleteness. It is difficult to imagine it as a mere set of mathematical rules. Although the formation of a sentence or expression is based on the internal logical structure of language, it remains a complex task to technologically model this structure, make it understandable to computers, and ensure that they respond in the same way.

The first conceptual approaches to the processing of natural language by machines date back to the 1930s. At that time, the concept of a "translating machine" was first patented. Two different patents were filed in this direction. The first was proposed by the French engineer Georges Artsrouni and was based on translating words

from one language into another on paper tape using a bilingual dictionary. This approach was simple and did not take into account the grammatical aspects of the language. The other approach was proposed by the Russian Peter Troyansky. In addition to the bilingual dictionary, he proposed a more systematic method that provided for the processing of language grammar based on the Esperanto language (Hutchins, 1997). Although both approaches were innovative, their practical applications were limited and did not go beyond the theoretical level.

The first real applications of natural language processing began to be observed during World War II. The device called "Enigma," which the Germans used to encrypt their secret correspondence, played an important role in coordinating German military units across Europe and planning military operations. This technology was considered a major achievement in providing secret communications at the time. In 1946, the British created a device called "Colossus." This device was able to successfully decipher the cipher system called "Tunny." This event was a turning point in the course of the war, as British forces were able to take action by obtaining advance information about German positions, strategies, and forces. All of these operations were carried out at Bletchley Park, the British cryptographic center. Here, the collaboration of Alan Turing and other experts made it possible to crack the Enigma system. This event is considered an important milestone not only in the history of the war but also in the development of modern computer science and natural language processing (Gladwin, 1997).

In 1950, Alan Turing introduced the concept of the famous "Turing test" (i.e., imitation game). This test involves three participants: a man (player A), a woman (player B), and an interrogator (player C). The interrogator tries to determine the gender of the players only through written messages. Here, player B helps the interrogator by giving the correct answer, while player A tries to confuse the interrogator. Turing's proposal was that a machine be put in the place of player A. If the interrogator cannot distinguish the machine from the other player, the machine is considered to have passed the test; otherwise, it is considered to have failed. The test does not require the machine to solve complex problems or create works of art – the main criterion is the ability to conduct everyday conversations like a human and understand the context of the dialogue. For Turing, passing such a test indicated that the machine has the potential to think (Turing, 2009).

Turing's ideas were closely related to his earlier work, Gödel's incompleteness theorem, and the principles he had advanced in the theory of computation. The Turing test essentially asks the question: does the ability to appear conscious belong to the class of problems that a Turing machine can compute, or does it belong to the class of things that cannot be formally proven but are true? The test is simple, but the question it raises is extremely fundamental and profound. This question highlights not only the relationship between consciousness and computation but also the ability of machines to understand natural language, one of the areas of activity closest to human thought.

One of the main problems of artificial intelligence is to understand and process human language. This requires in-depth study of the structures and grammar of natural language. For any language to function fully and correctly, the application of grammar is necessary. The meaning of a sentence is fully understood only as a result of the correct application of grammatical rules. Until 1957, serious progress had not been made in introducing grammatical structures into machines and enabling them to understand meaning. It was in that year that Noam Chomsky's work "Syntactic Structures" became a revolutionary turning point in this field. Chomsky attempted to formulate a strong and systematic set of language rules based on a universal grammar, founded on a "formal theory of language structure". However, Charles Hockett later highlighted some of the limitations of Chomsky's approach. He argued that Chomsky's view of language as a fixed and well-defined formal system was not ideal in reality.

One of the early directions in the field of natural language processing was machine translation. The main goal of machine translation is to develop programs that can automatically translate text or speech from one natural language to another (Johri et al., 2021). For example, in 1954, as a result of a joint project between Georgetown University and IBM, an automatic text translation program was developed. Experiments showed that the program was able to successfully translate sixty Russian sentences into English. This system worked by directly mapping the sentences and using a dictionary specially developed by the researchers. The researchers claimed that in the near future the machine would be able to make consistent and reliable translations. However, development was much slower than expected, which led to a sharp decrease in funding for the project.

In the late 1960s, Terry Winograd at the Massachusetts Institute of Technology (MIT) developed a program called SHRDLU. This program was the first computer program in the field of natural language processing capable of performing functions such as moving objects, determining current state, and remembering names. All of these operations were performed in a simplified environment called a "block world." SHRDLU was considered a major advance in the field of artificial intelligence and attracted

the attention of researchers to the development of this technology. However, the program's success was limited when analyzing more complex and uncertain real-world situations, and its development was therefore somewhat stalled.

In 1969, Roger Schank introduced the concept of "conceptual dependencies" to better understand the meaning of a sentence. These dependencies include real-world objects, events, time, and space. For each sentence, these dependencies give the machine a more precise understanding of the sequence of events and the objects involved (Schank & Tesler, 1969). Until then, all the rules that had been applied to natural language processing were based on the structure of phrases (phrase structures). Researchers sought to create a clear and precise set of rules that a machine could follow to understand the meaning of a phrase. In 1970, William Woods introduced the concept of Augmented Transition Networks (ATNs) for representing natural languages. This approach uses finite automata and recursion to determine the meaning of a phrase based on the available information. ATNs can provide possible results when only a part of the phrase is known and can change the meaning of the phrase as additional information is provided. If the given phrase is ambiguous, the system makes a probabilistic conclusion and, if necessary, postpones the decision until more information is available. In this way, ATNs solve the problem recursively when there is insufficient information and hold the decision until more information is provided.

Currently, the field of natural language processing has moved away from traditional rule-based approaches and is favoring deep learning. The reason for this shift is that deep learning is more successful in solving problems that are difficult for humans to solve with predefined rules and fixed criteria. The natural feature of language is that a word can have different meanings, and these meanings can change depending on the words around it. It is impossible to cover such ambiguities with traditional rules or methods such as decision trees. Deep learning solves this problem effectively because it does not require a programmer to write separate rules—the algorithm itself learns the output based on the given input and automatically builds the decision-making process. With the transition to the 21st century, the field of natural language processing moved away from classical theoretical approaches toward modern approaches based more on statistics and neural models. These changes have led to the formation of new technologies.

Modern application areas and approaches of natural language processing

The field of Natural Language Processing (NLP) is one of the fastest growing areas of artificial intelligence, and its application possibilities have increased significantly in recent years. In particular, the widespread use of deep learning technologies has enabled the practical use of NLP in various fields. For example, voice assistants – such as Siri, Alexa, and Google Assistant – have already become part of our daily lives. They answer people's questions, perform tasks, and thus facilitate daily activities at home, at work, and even in cars.

On the other hand, thousands of opinions and comments are shared on social media platforms every day. Manually analyzing this large amount of data is impractical and time-consuming. This is where NLP comes in as a valuable tool for businesses. With the help of sentiment analysis, companies can categorize customer reviews into positive, negative, and neutral categories to gain a general picture of the market and improve their products and services. This process provides a quantitative measurement of not only individual opinions but also overall opinions, which is invaluable in building a proper business strategy.

Another important application area of NLP is spam filtering. With the expansion of the Internet, a lot of fake information and spam is generated in email, social media, and various online platforms. Machine learning methods – decision trees, Naive Bayes, SVM, and other algorithms – are used to identify and properly filter this information. For example, tools such as TubeSpam distinguish between fake and real comments on YouTube. More sophisticated methods are applied to prevent spam on web pages, which increases the security of the Internet environment (Alberto et al., 2015).

NLP also plays a major role in the medical field. Medical data generated during the diagnosis and treatment of diseases is often unstructured, and its manual analysis is both difficult and time-consuming. NLP and machine learning technologies can automatically analyze medical texts, speeding up and refining diagnostic decisions. Methods such as facet-based sentiment analysis are also used to assess individual patient behaviors and treatment responses, which helps develop personalized therapy (Chen, 2020).

In addition, NLP also facilitates human written communication. For example, programs such as Grammarly detect grammatical errors in written text, understand the general theme of the text, and suggest better ways to express it. In the legal field, Named Entity Recognition (NER) technology is applied to protect personal data in online contracts. These tools automatically recognize and protect personally identifiable information (Hiremath & Patil, 2022).

Search engines, including Google and Bing, use machine translation technologies to translate web content into different languages, thereby enabling users to access information in different languages. Chatbots for websites, on the other hand, interact with users, quickly respond to queries, improve service quality, and reduce human labor (Ferrara et al., 2016). Thus, modern approaches and applications in the field of NLP prove to be important tools that not only promote technological progress but also increase the effectiveness of activities in various areas of society. The future of this field is even brighter, and with new technologies, wider areas of application will emerge.

Current status and development prospects of the Azerbaijani language in the field of Natural Language Processing (NLP)

As stated before, the field of natural language processing (NLP) has expanded rapidly in recent decades in parallel with the rapid development of artificial intelligence technologies. High-quality language models, open-source resources, and application tools have been developed for many world languages, especially English. Although the Azerbaijani language has a rich history and expressive capabilities, it is not sufficiently represented in this field. As a result, certain gaps are observed both at the level of scientific research and in the development of practical applications. This situation limits the wider use and digital transformation of the Azerbaijani language in the artificial intelligence environment.

The first initiatives to study the Azerbaijani language using mathematical-statistical methods and technological tools date back to the middle of the last century, namely the 1960s-70s. During this period, Azerbaijani specialists who had been trained in the Soviet scientific environment and had studied abroad — including V.Y. Pines, M.A. Mahmudov, K. Valiyeva, and C.A. Rahmanov — began to create the initial scientific foundations for the formal modeling and automated analysis of the language. The work "Morphological Analysis Algorithm of Azerbaijani Texts in Machine Translation and Automated Information Systems" published by M.A. Mahmudov and V.Y. Pines in 1980 is considered one of the first significant scientific and practical contributions in this field (Mahmudov & Pines, 1980).

Another study that played an important role at this stage was the book "Mathematical Linguistics" by academician A.A. Akhundov. In addition to presenting the principles of a mathematical approach to the Azerbaijani language, this work systematically and intelligibly explained the statistical analysis of vowels, morphological modeling methods, and the main concepts used in this field (Akhundov, 1979). However, since insufficient support was provided to this field at the state level in the 1970s–1980s, the existing potential was not fully realized, and the continuity of research was not ensured.

During the period of independence, especially after the 1990s, the informatization and digitalization of the Azerbaijani language became part of state policy. During this period, projects such as the "National Corpus of the Azerbaijani Language", "Spelling and Explanatory Electronic Dictionaries", "Spell Checker", and "Speech Recognition System" were implemented. Although these initiatives are important steps, they can still be considered as an initial stage in terms of modern NLP criteria.

As for the current situation, the representation of the Azerbaijani language in the field of NLP is still limited. For example, although our language is included in the Universal Dependencies (UD) platform, the available resources are limited and do not provide a wide range of opportunities for use in international NLP projects. However, this platform serves as the main syntactic "treebank" database for spaCy, Stanza, and other popular NLP libraries. Currently, more than 200 languages are represented in UD, and the development of more extensive resources in this area for the Azerbaijani language remains necessary.

Furthermore, the large-scale and high-quality corpora required for effective application or training of advanced transformer-based models such as GPT, BERT, and T5 for Azerbaijani are either not available at all or are not publicly available. Existing initiatives — such as AzerBERT and similar models — have been developed largely as private and non-profit efforts. Increasing resources and strengthening coordination in this area will allow scientific and technological progress to accelerate further in the future.

To overcome this problem, it is important for research institutions and government agencies to take an active role in this area. In particular, the main goals should be the preparation of corpora, sharing of open-source data (for example, under the CC BY-NC-ND 4.0 license), the creation of terminology databases, and integration with international platforms for new model training. Hosting resources related to the Azerbaijani language on platforms such as Hugging Face and GitHub and establishing international collaborations can play an important role in this direction. Thus, the development of the Azerbaijani language in the field of NLP is not only of technological but also of national and strategic importance. Consistent and purposeful efforts must be made at the scientific, technological, and institutional levels to ensure that our native language is adequately represented in the era of digital transformation.

CONCLUSIONS

The field of artificial intelligence and natural language processing has developed dynamically, emerging at the intersection of scientific knowledge, technological progress, and interdisciplinary approaches. This field, which has its historical foundations in logic, philosophy of language, and formal systems, has gradually entered a new phase with the integration of statistical methods, neural networks, and deep learning algorithms. The development trajectory, from classical language theory to modern artificial intelligence systems, has created conditions for obtaining important results in the automated analysis and processing of human language, both at the theoretical and practical levels.

Currently, natural language processing is not only a subject of academic research but also a set of technological solutions aimed at solving real problems, integrated into the structure of social, economic, and legal systems. The application of NLP technologies in voice assistants, automatic translation systems, legal document analysis, and medical diagnostic systems demonstrates the multifaceted potential of this field. As a result, developments in artificial intelligence and natural language processing necessitate the mutual synthesis of engineering and computational sciences along with linguistic models. Future directions in the development of this field will be characterized by ethical regulation, improvement of multilingual systems, and bringing human-computer interaction to a more natural level. Thus, this field will retain its importance as a fundamental research direction aimed at a deeper understanding not only of technology but also of the essence of human thought and language.

In this context, the position of the Azerbaijani language in the field of natural language processing requires special attention. Although it has a rich scientific heritage from a historical perspective, our language still faces significant gaps in terms of integration into modern NLP technologies. The lack of representation of the Azerbaijani language on international platforms (for example, Universal Dependencies), the absence of open-source resources, and the lack of modern language models hinder its application in digital technologies. To overcome these problems, state-level incentives, support for research centers, and open sharing of language resources are necessary. Only in this way can the Azerbaijani language ensure its worthy existence in the age of artificial intelligence.

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