Historical Development of Technologies in the Field of Artificial Intelligence

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Abstract — This study traces the historical development of technologies in the field of artificial intelligence (AI). The relevance of the topic stems from the subsequent rapid development and implementation of computer technologies in various fields of human knowledge. Nowadays, the development of AI, as a leading computer technology in the last decade, creates unceasing interest among specialists in the field and the scientific community, given that the boundaries of its application are immense. The aim of this study is to trace the historical development of technologies in the field of artificial intelligence, using patent statistics as a measure of innovative creativity. In this regard, by applying empirical methods (comparison method, graphical method) and historical approach to analyzing data on the number of patented inventions through the Patent Cooperation Treaty (PCT), administered by the World Intellectual Property Organization (WIPO), the evolutionary development of artificial intelligence is illustrated. As a result of the study, the leading countries in which the inventive capacity in the selected technological field is concentrated are identified. The main conclusions we reached identify nine leading countries, in which 94.68% of the patent activity in the field of AI is concentrated for the period from 1980 to 2023, and 2.75-times higher research activity in 2022 compared to 2010. Despite the data, the Government and Industry sectors do not invest the necessary efforts in AI research (the Education sector conducts 81.07% of the research), which predetermines their inability to take advantage of the advantages that AI can generate.

Keywords—Artificial intelligence, patent grants, technology.

I. INTRODUCTION

For centuries, people's creativity has been a generator of their development and a prerequisite for high scientific and technical achievements, giving the appearance of modernity. Man, although limited in his physical and mental abilities, has unlimited ambitions and thirst for new knowledge and its implementation in innovative technological solutions that can "change the world". In parallel with human evolution, more complex and multifaceted problems are emerging to solve, the need to process ever larger volumes of data to make more accurate forecasts that support the development of society and the economy as a whole. There is a need to develop innovative machines, systems and algorithms for their work, which, on the one hand, will facilitate and on the other hand increase the efficiency of a person. This innovative process of creativity, during which in the period 1937-1942 the prototype of the modern computer was created by John Atanasoff and Clifford Berry [1], laid the foundation for the development of computer science, the digital transformation of industry [2] and modern artificial intelligence (AI).

The relevance of the topic stems from the rapid development and implementation of computer technologies in various areas of human knowledge. Nowadays, computer technologies are used in almost every economic sector, they are successfully implemented in medicine, education and support the development of science and society. This is a prerequisite for the development of AI, as a leading computer technology in the last decade, to create unceasing interest among specialists in the field and the scientific community, given that the boundaries of its application are immense.

The analysis of the specialized literature presents the wide range of research related to AI in different directions, therefore, for the purposes of this work, we will limit ourselves to analyzing some of them, using the historical approach to studying AI development trends. Fundamental research on the historical development of AI, with Hiremath & Kenchakkanavar pointing out that AI contributes to technological advances not only in the field of human management, but also as a motivator for increasing productivity in various industries and promoting

innovation. The authors also prove the role of AI in transforming educational paradigms, especially during COVID-19 [3]. Garcia-Murillo and MacInnes take a historical approach to predict the impact of AI on society and employment, analyzing examples from the past of the introduction of revolutionary computing machines in the United States [4]. Hirani et al. identified the evolution of healthcare under the influence of AI in the period 1960-2024 and reported positive trends in improving the quality of healthcare services and the possibilities for remote monitoring of patients' health status through wearable devices with integrated AI or through AI-driven telemedicine and chatbots providing support and consultation to patients [5]. Hassan, Ewis & Kamel used a historical approach to establish the application of AI in the creative industries and found that in the film industry, from an aid to AI, it became a major tool for creating scenes through automated simulation tools and generative AI techniques [6].

The above predetermines the purpose of this study, which is aimed at tracing the historical development of technologies in the field of artificial intelligence, using patent statistics as a measure of innovative creativity. The object of the study is artificial intelligence, and the subject of the study is patent statistics as an indicator of technological development.

In the next part of the paper, some of the definitions outlining the characteristics of artificial intelligence are presented. The empirical part of this work examines inventive activity in the field of computer technology, and in particular technologies related to AI. For this purpose, data on patent documents issued through the Patent Cooperation Treaty, administered by the World Intellectual Property Organization (WIPO), were used. Next, data on granted patents in the field of AI are analyzed. Information on the development of scientific publications in the field of AI is also offered. Methods of comparison and graphical representation of data are used to illustrate the evolutionary development of artificial intelligence. As a result of the study, the leading countries in which the inventive capacity in the chosen technological field is concentrated are deduced. In conclusion, the risks arising from the development and use of AI in modern times are also taken into account.

II. MATERIALS AND METHODS

A. Literature review

The field of application of artificial intelligence is extremely diverse, which is why for years it has been associated with a number of areas of computer technology, including: natural language processing – NLP [7]; machine learning [8]; computer vision- CV [9]; planning, scheduling, and optimization [10]; and robotics [11], but it is not limited to them. That is why experts from the academic community offer different definitions of the essence of artificial intelligence.

Among the first definitions is the one derived from Minsky, according to whom AI is the science of the ability of machines to perform actions that require the intelligence of humans [12]. This statement is further developed by Kurzweil [13], who goes beyond the theoretical limits set and suggests the creation of machines to perform tasks performed by intelligent human beings. Newer definitions expand the scope of artificial intelligence, due to the increase in expectations for its capabilities. According to Haenlein and Kaplan AI is *"a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation"* [14, p.5]. According to Frankenfield AI is *"simulation of human intelligence in machines that are programmed to think like humans and mimic their actions"* [15]. Zúñiga, Homero, Goyanes, and Durotoye define AI as *„the tangible real-world capability of non-human machines or artificial entities to perform, task solve, communicate, interact, and act logically as it occurs with biological humans "*[16].

Although the presented definitions constitute a limited part of the author's opinion on the question of the essence of artificial intelligence, they largely reflect the stages of its development (see Fig. 1). From a scientific point of view [17], [14], the evolution of AI goes through three main phases, each of which is accompanied by the achievement of a certain level of capabilities for artificial intelligence (see Fig. 1). The first phase (*Spring* 1940-1979) covers the birth of technology and the golden years of AI, born of the enthusiasm of researchers and inventors. During the second phase (*Summer and Winter* 1980-2010) there is a real boom in the development of technology, and the third phase (*Present* 2011-2022) is related to big data and deep learning [18].

The different evolutionary stages of development of artificial intelligence according to [18] are artificial narrow intelligence (ANI), artificial general intelligence (AGI) and artificial super intelligence (ASI). First-generation narrow artificial intelligence (ANI) is limited to performing a single task and is unable to replicate complex operations characteristic of human intelligence. AGI is designed to mimic human intelligence and behavior and can learn to solve certain problems. ASI are the third generation of the development of the future self-aware machines, surpassing human intellectual capacity and capable of scientific creativity and common wisdom [18].
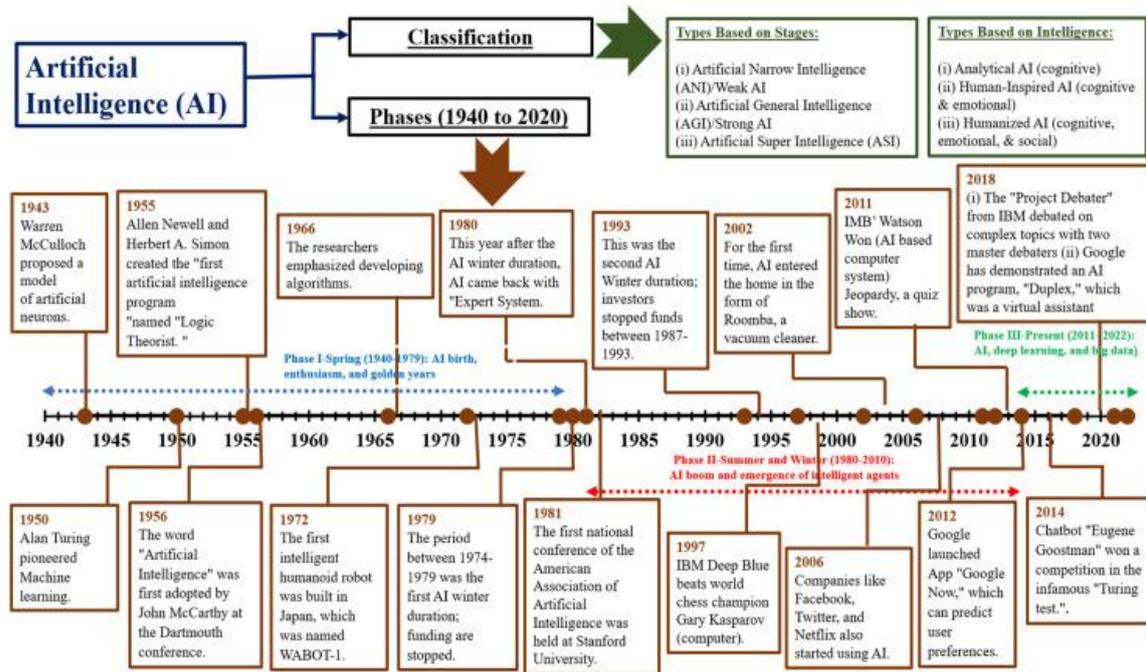
Fig. 1.   Artificial Intelligence (AI) History and Phases   [18, p.2].

B. Methodology of the research

The present paper aims to trace the historical development of artificial intelligence technologies, using patent statistics as a measure of innovative creativity. In this regard, the object of the research is artificial intelligence and its development. The subject of the study is the patent activity conducted through the Patent Cooperation Treaty in the period 1980-2023.

To achieve the formulated goal, the following tasks have been set:

1. Analysis of patent publications in the field of AI-related technologies for the period 1980-2023.
2. Study of the dynamics of patent activity for the period 1980-2023.
3. Study of patents grants related to AI technologies in the period 2010-2023.
4. Bringing out the leading AI patent holders.
5. Presenting the development of scientific publications in the field of AI.
6. Uncovering the potential problems posed using AI.

We have fulfilled these tasks through patent activity data obtained from the WIPO database [19], as well as from the Center for Security and Emerging Technology [20].

The limitation in this study is caused by the time span for which data on patents applied for and granted are collected and provided. Data on patent activity are not specified by type of AI-related technologies.

The author's research interest in the study of AI is dictated not only by its relevance and growing importance in modern times, but also by the fact that it is able to transform society and our everyday life in an unexpected and unknown direction.

The research presented and the scientific results achieved will enrich research in the field of artificial intelligence and reveal the leading innovative leaders in the field of AI and the role of scientific development in achieving technological progress.

III.   RESULTS

A. Analysis of patent publications in the field of AI technologies

The characteristics of artificial intelligence determine unlimited possibilities for its application, which is why WIPO experts, using the Computing Classification Scheme of the Association for Computing Machinery (ACM), define three main categories AI [21]:

- AI techniques: advanced forms of statistical and mathematical models, such as machine learning, fuzzy logic and expert systems, allowing the computation of tasks typically performed by humans; different AI techniques may be used to implement different AI functions.
- AI functional applications: functions such as speech or computer vision which can be realized using one or more AI techniques.
- AI application fields: different fields, areas or disciplines where AI techniques or functional applications may find application, such as

transportation, agriculture or life and medical sciences. [21]

The subsequent analysis of patent publications is tied precisely to the categories thus specified, which provide the framework for AI research. By using keywords and International Patent Classification classifications, the scope of AI technologies on which WIPO collects and processes information is defined [22].

It has been found that patent documents for the protection of artificial intelligence technologies often refer to more than one category of AI (see Fig. 2).
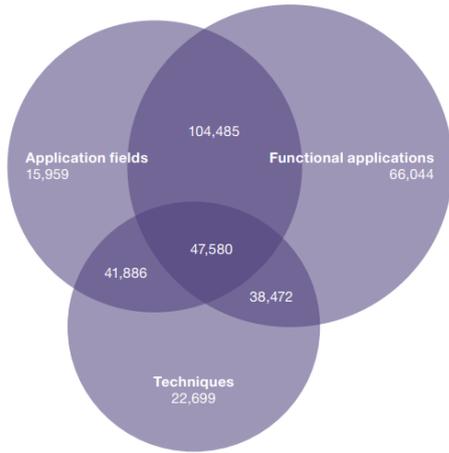
Fig. 2. Patent families related to AI techniques, functional applications, application fields and their overlaps [21, p.40].

According to WIPO data [19], 1,292,086 patent publications in the field of AI were made between 1980 and 2023. Their number is determined on the basis of an equivalent count, according to which each application/patent filed by a national intellectual property office is counted multiple times according to the number of territories on which protection is sought. The dynamics of this activity are presented in Fig. 3.
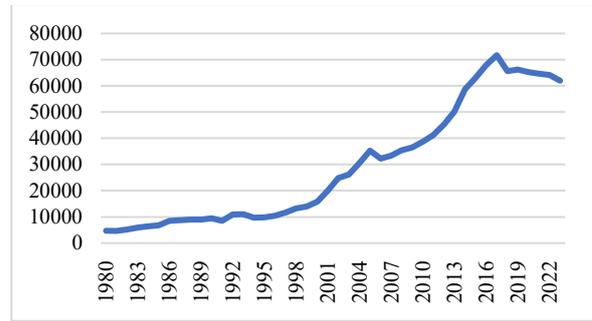

Fig. 3. Dynamics of patent activity in the field of artificial intelligence technologies [19].

The data (see Fig. 3) include information on 143 countries in which the total patent activity from 1980 to 2023 has seen a noticeable increase. From the beginning of the study period in 1980, when 4,754 publications were reported, to 2023, when they reached 61,950 pcs. there is an increase in the issued patent documents, on average by 6.54% per year. These data can be interpreted, on the one hand, as an increase in patent activity (13.03 times in 2023 compared to 1980), and on the other hand, as an extension of the territorial coverage of patent protection.

Of all 143 countries and territories reporting activity from 1980 to 2023 through the Patent Cooperation Treaty, nine countries have the highest concentration of patent documents (see Fig. 4). They form 94.68% of the patent activity established for the period (1,223,385 patent documents out of a total of 1,292,086).
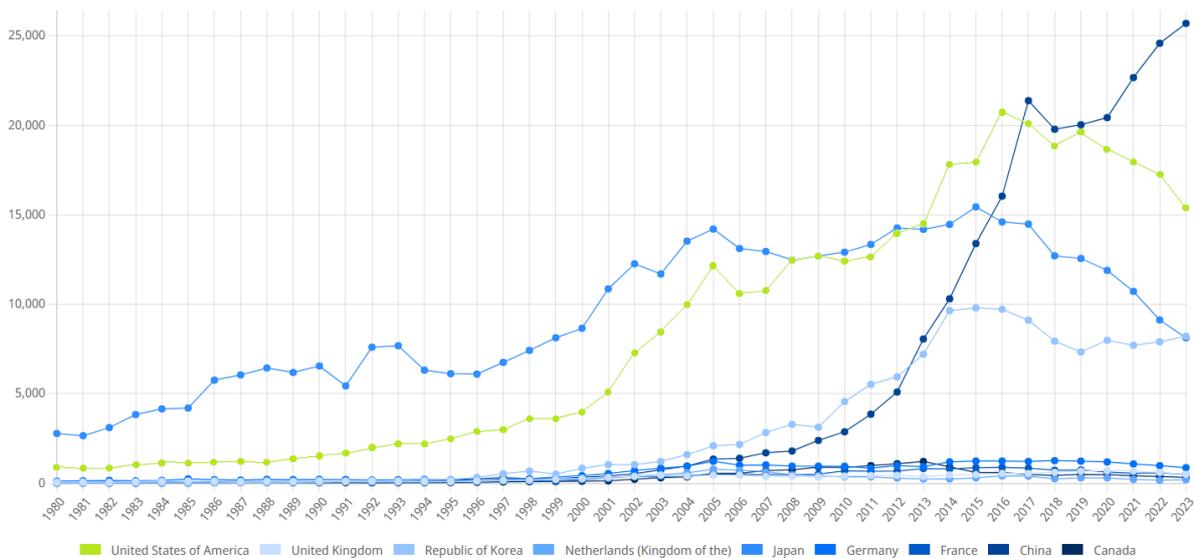

Fig. 4. Dynamics of issued patent documents in the field of artificial intelligence technologies among the top 9 countries [19].

The dynamics of the issued patent documents (see Fig. 4) is indicative of the predominance of inventors and researchers from Japan until 2012 (14,269 documents), when in 2013 they were overtaken by the United States.

The leadership of American scientific developments continued until 2016, and in 2017 a new leader appeared – China, whose researchers remained at the forefront until 2023. Observing the dynamics of the issued patent documents, Japan, the United States, China and South Korea clearly stand out as leaders in the field of technologies related to artificial intelligence.

We draw attention to the fact that not all patent applications end with a positive decision of the examination. Some of them do not receive legal protection due to non-compliance with the criteria for patentability and/or other specific regulatory requirements. There is also the possibility of infringement of other people's patent rights, which is a prerequisite for filing opposition by the owner of earlier rights, lawsuits and mediation.

The follow-up analysis is limited to the time span from 2010 to 2022 to track the trends evolving in the field of AI over the past two decades. Fig. 5 presents data on the number of refused and the number of patents granted to applicants from all over the world seeking legal protection for their technological developments in the field of AI.

The number of AI-related technologies that failed to pass patent examination (128,952) is 2.07 times higher than the patented inventions (62,264). Despite the fact that these technologies are not patented, their existence is sufficiently indicative of the desire of inventors to continue innovative developments in this field.

The emphasis in this work is placed on the issued patents, which illustrate the real and already legally protected achievements of the human mind and creativity. While not every patented invention has the same value and utility in making technological progress in this area, the total number of patents granted is indicative of the drive to develop AI-related technologies.
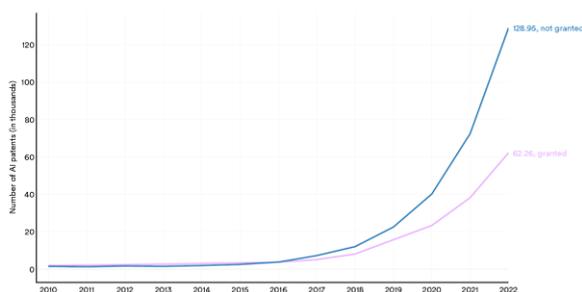

Fig. 5. AI patents by application status, 2010–2022 [23, p.39]

Fig. 6 presents information on the distribution by regions of the issued patents for technologies in the field. Data are represented in % of total AI patents granted globally.

China's leadership (see Fig. 4) undoubtedly has its impact on the distribution of issued patents by region of the world (see Fig. 6), with 75.2% of them attributed to East Asia and the Pacific. The second region is North America (21.21%), and the third Europe and Central Asia lags

behind with only 2.33% share. The remaining regions report a contribution of less than 1% of the total activity in the development of AI.
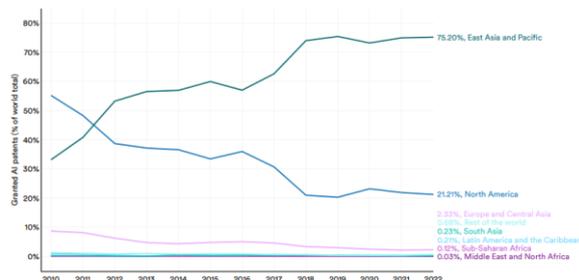

Fig. 6. Granted AI patents (% of world total) by region, 2010–22. [23, p.41]

A different perspective of analysis is presented in Fig. 7. It ranks countries by the number of patents issued for 2022 per 100,000 inhabitants.
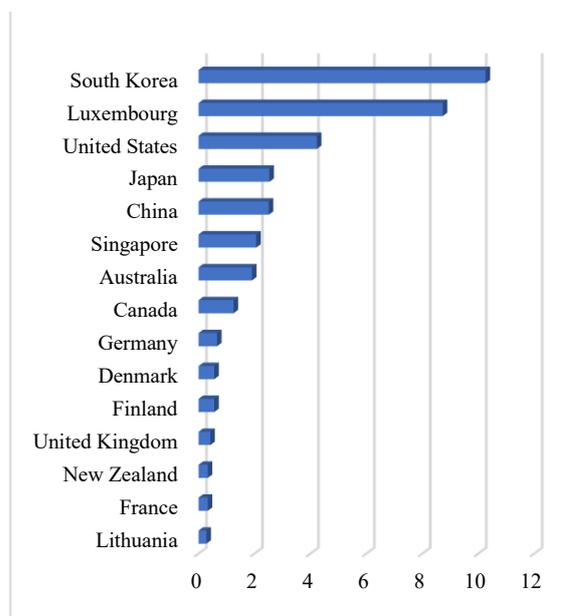

Fig. 7. Granted AI patents per 100,000 inhabitants by country, 2022 [23, p.43]

The ranking (see Fig. 7) in a sense expresses the importance of AI-related technologies for the country concerned and the concentration of inventors in a given field. Of course, countries such as China and the United States with a population of 1.4 billion, respectively and 340.1 million cannot achieve such high productivity as is found in South Korea (51.71 million) and Luxembourg (666,430 people). These data are also indicative of the commitment of the national policy of the countries in the field of scientific developments in certain technological areas, the compliance of the qualification of the employed personnel [24] with the requirements of the new digital age and the quality of the educational system, which is why in the next section of the study we will pay attention to the development of science in the field of artificial intelligence.

B. Analysis of the development of science in the field of artificial intelligence

One of the main factors that has given impetus to the evolution of technologies related to artificial intelligence is the scientific interest in the field. Of course, it dates back to the first mention of the term "artificial intelligence" by Prof. John McCarthy at the 1956 Dartmouth Summer Research Project on Artificial Intelligence [25] and has been growing ever since.

In this paper, we limit ourselves to an analysis of the last thirteen years of the development of scientific interests, using quantitative data to illustrate the dynamics of the publication activity of researchers.

Fig. 8 presents the development of scientific publications worldwide, through a number of articles published in English in journals and reports of international conferences in the field of AI.
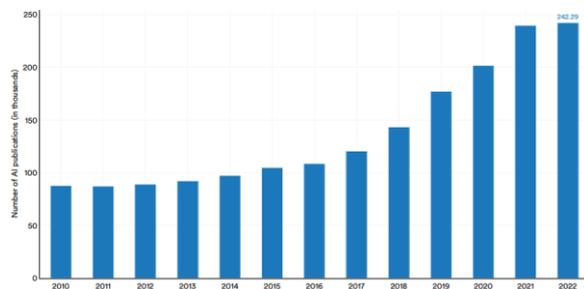

Fig. 8. AI publications in the world, 2010–22 [23, p.31].

As can be seen, the interest of researchers is 2.75 times higher at the end of the period (in 2022 the number of publications was 242,290) compared to its beginning (in 2010, 88,000 scientific studies were published). This is directly related to the expansion of the scope of AI as well as the growing interest in AI technologies, not only scientifically but also practically.

In order to identify the source of scientific publications that is indicative of the field in which AI research is developing, Fig. 9 presents the distribution of scientific publications by sectors.
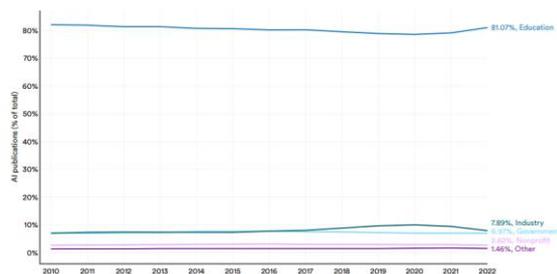

Fig. 9. AI publications (% of total) by sector, 2010–22 [23, p.34].

Globally (see Fig. 9), there is a significant predominance of research and publications carried out in the Education sector (81.07%) compared to those in other sectors: Industry (7.89%); Government (6.97%); Non-governmental sector (2.62%); Others (1.46%) [19, p.34]. These data support the view expressed above that it is the

growing scientific interest in the field of AI that gives impetus to the technological development of the field.

Looking at the activity of LEADING countries and territories in the field of AI (see Fig. 10), there is again a predominance of publications made by the education sector over other sectors in each of the analyzed economies.
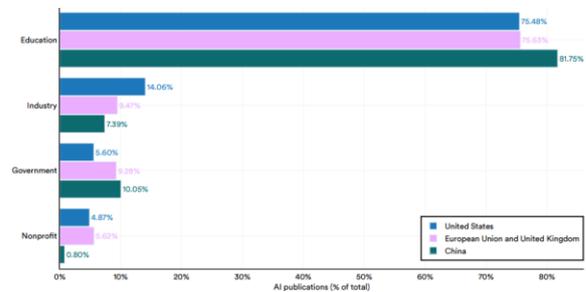

Fig. 10. AI publications (% of total) by sector and geographic area, 2022 [23, p.35].

Although limited in terms of the time span of the presented data and their nature, the current analysis of the scientific publications published in the period 2010-2022 presents them as an early indicator of technological developments in the field. Research reflects the existing societal needs at a given time and helps to solve them, as a result of which the efforts of inventors are directed towards the creation of fundamental innovative technologies.

IV. DISCUSSION

The data on patent activity in the field of AI-related technologies reviewed so far are the result of the overall efforts and policies of the listed countries in the field of development and absorption of new technologies. The increased interest of researchers and industry in the field of computer technologies in recent decades has provoked the opening of new educational programs in secondary and higher schools to prepare and create competent and motivated computer specialists [26]. Cooperation between business and science also contributes to transforming scientific knowledge into innovative and meaningful developments [27].

Increasing research into AI in modern times is fueled by its advantages of replacing some of the human activities by performing complex and time-consuming operations, supporting the decision-making process and providing informed solutions to remedy problems. But the widespread use and application of technologies in which AI is implemented and which are part of our daily lives, even if we do not realize it, are transforming our lives as we know it. And if innovations in artificial intelligence systems and advances in robotics have contributed to the development of a number of technological areas, then the existing threats should not be ignored.

Part of the problems related to AI are rooted in the misuse and unethical use of the technologies in which it is implemented. The AI Incident Database (AIID) [28] tracks cases of AI misuse, and according to their data, as the application of AI expands, cases of incidents also increase. From 2013 to 2023, there was a more than 20-fold increase

in incidents, reaching 123 in 2023. These incidents are a consequence of the risks posed by the development and use of artificial intelligence. A survey conducted by researchers [23] among 1000 organizations from all over the world developing and using AI technologies shows that the highest risk is the confidentiality of the data used and its unlawful dissemination (see Fig. 11).
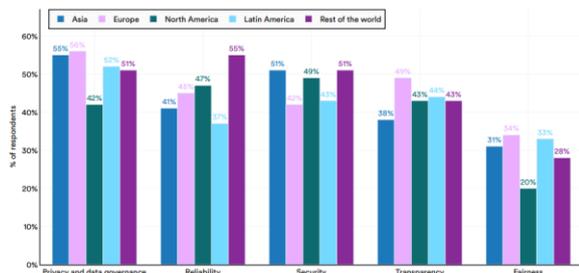

Fig. 11. Relevance of selected responsible AI risks for organizations by region [23, p.166].

Another risk of the development of AI technologies is their reliability and security of use. These threats were reported as the second and third most important among company leaders in Asia and North America. A significant percentage of respondents fear transparency in the development of these technologies (49% of respondents in Europe and 44% of those in Latin America), and the least accounted for is the risk of fair use of AI-related technologies [23].

Apart from this study, society faces the following threats regarding the use of AI:

- inability to understand the logic and mechanism of action of AI, which gives rise to distrust in the results obtained.;
- replacing human resources from robotic technologies with AI;
- continuous and unregulated surveillance of people through intelligent systems integrated into the urban environment, which creates fear for their privacy and security;
- developing dependence on AI technologies, which leads to limiting people's creative thinking and capacity to cope with routine tasks;
- the unethical use of AI can lead to disinformation and manipulation of public opinion.

In summary of the analysis prepared so far, we should note that any technological development based on striving to improve and increase the quality of life of people, in accordance with the ethical and moral values of society, needs to be stimulated and encouraged. But going beyond the human moral framework of developing AI-related technologies and providing them with unlimited and uncontrollable opportunities for self-improvement poses risks to people's lives and futures.

V. CONCLUSIONS

Through this paper, we have looked at the historical development of AI, referring to data on patent activity in the field of computer technology. As a consequence of the

analysis prepared, we can point out that technologies related to AI are the new reality to which society needs to get used to. The leaders in the development of AI (China, USA, Japan, South Korea, Germany, Great Britain, the Netherlands, France and Canada), forming 94.68% of the patent activity established for the period (1,223,385 patent documents out of a total of 1,292,086), predetermine the development trends and areas of practical application of AI. In this regard, it can be said that these are the countries that will be the first to gain a competitive advantage through the applied innovative technologies. At the same time, they also stimulate the innovative development of other countries and contribute to the diffusion of AI.

In the current study, we found that researchers' interest increased 2.75 times at the end of the analyzed period (in 2022, the number of publications was 242,290) compared to 2010 (88,000 published scientific studies), which proves the expansion of the scope of application of AI, both by the scientific community and by practice. The predominance of the education sector (81.07%) in the development of specialized publications in the field of AI indicates that the Industry sector and the Government sector are still insufficiently engaged in studying the specifics and opportunities for application of AI.

Greater awareness of the possibilities of AI among individual communities would contribute to removing existing prejudices and limiting the possible misuse of AI technologies.

ACKNOWLEDGMENT

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