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Analysis of artificial intelligence technological patents through technological prospecting

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Abstract

Artificial Intelligence (AI) has become a strategic technology, driving transformations across digital, industrial, and service sectors and intensifying global patenting activity. Patent analysis offers valuable insights into technological evolution, competitive positioning, and patterns of intellectual property appropriation. This study aims to analyze the temporal evolution, technological focus, and geographic distribution of AI-related patent documents, identifying dominant technologies, leading countries, and ownership strategies. The methodology is based on technological prospection using patent documents published between 2004 and 2025. A quantitative and qualitative analysis was conducted, considering publication trends, International Patent Classification (IPC) subgroups, applicants, inventors, countries of origin, and patent family languages, supported by descriptive statistics and graphical analysis. The results show an exponential growth in AI patenting from 2016, peaking in 2020 and followed by stabilization, indicating technological maturation. Patent activity is highly concentrated in the United States and East Asian countries, particularly South Korea and Japan. Technologically, patents are predominantly related to speech and audio processing, natural language technologies, human–machine interfaces, and intelligent data processing systems. The predominance of English reflects strategies focused on international protection, while Asian languages indicate strong domestic innovation combined with global expansion. The study concludes that AI innovation and patent ownership remain concentrated in countries with mature innovation ecosystems, highlighting structural asymmetries in global knowledge generation and intellectual property appropriation.

KEYWORDS: *innovation, intellectual property, technology.*

INTRODUCTION

Globalization can be considered an influence exerted by richer economies on poorer and developing economies to protect their market and avoid barriers in the places where they want to operate. It is an irreversible process whose influence can be observed in culture, in local politics, in the technological and socioeconomic sectors. Domestic companies are greatly impacted and in order to compete with others they are forced to innovate their products and/or services as a way to perpetuate business, obtain competitive advantages, defend themselves from competitors, create market niches, produce sustainably and without harming the environment, standardize quality, reduce costs and increase profitability [1], [2], [3], [4], [5].

In the current scenario, there is a concern with technological and economic development linked to the sustainability of the planet. This condition drives public and private institutions to make investments in the areas of research and development (R&D), seeking products and technologies with these characteristics, namely, which do not harm the environment, do not cause

impacts on natural systems, manage their waste, do not emit greenhouse gases, and do not contribute to climate change. These conditions include the development of both mitigating and adaptive technologies. The government-university-industry trinomial is of fundamental importance for the development of sustainable and impactful technologies, especially for the economy and the environment [6], [7], [8], [9], [10], [11].

Today, the analysis of emerging technologies and their consequences is vital for businesses, society, and the economy. These analyses support critical decision-making at the governmental and institutional level.

Technological Prospecting (TP) is an instrument used to research the development and technological and scientific evolution of a product and/or service, its degree of maturity and innovation, key markets for the protection of the invention, possible competitors, developers, and partners, among other aspects. The analysis of patents resulting from technological prospecting also serves to identify the trend and impacts of this technology in all fields in which it is applied, as well as the innovation patterns and associated challenges. These aspects are therefore relevant for companies, researchers, and society [4], [5], [12], [13], [14], [15], [16].

According to the World Intellectual Property Organization (WIPO), about 90 to 95% of inventions can be found in patent documents. Therefore, one of the tools that can be used in the search for technological evolution is technological prospecting, usually carried out on patent office sites such as *Espacenet*, which belongs to the European Patent Office (EPO), which was used in the present study to track and analyze AI-related patent information around the world [4], [17].

Innovation is linked to the processes of knowledge generation, simultaneously with the development of new technologies and, consequently, with the implementation of new projects primarily aimed mainly at meeting human needs and enhancing comfort, in addition to its introduction and distribution in the markets aiming at final use by the potential consumer [18].

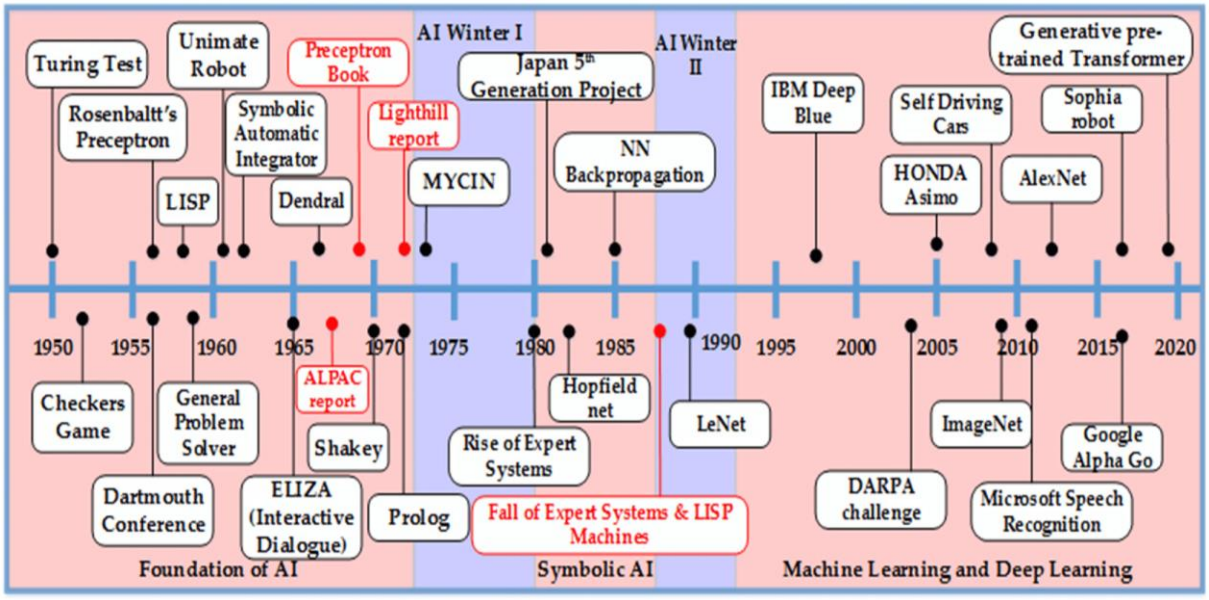
A patent is a title granted by a public agency to inventors and/or patent holders, individuals and/or legal entities, who apply at a patent office in the countries that wish to protect their invention, so its scope is limited to the place where the patent is granted. For the concession, the invention must meet three requirements: novelty, industrial application and inventive step. Possession prevents the good from being used, replicated, and/or marketed without the consent of the patent owner. In Brazil, between the request and the publication there is a grace period of 18 months, called confidentiality. The validity is 15 years for utility models and 20 years for invention patents [4], [5], [14], [15], [19], [20], [21].

Patents are generally associated with the level of development of a particular technical area over time, also serving as an indicator of a nation's technological innovation and progress. Its field of application and technology is included in the classifications of patents, which may have more than one, highlighting the International Patent Classification (IPC), instituted by the Strasbourg Agreement, signed in 1971 and which came into force in 1975, divided into eight sections, 21 subsections, 120 classes, 628 subclasses, and 69 thousand groups [4], [20], [21].

Several sectors are undergoing transformations due to Artificial Intelligence (AI), mainly in the field of health, security, education, economy, technological development, formulation of policies public and business strategies, among others, in addition to interfering in people's daily lives, especially related to its application, which can have a negative impact when used to spread false messages, which sometimes hurt the dignity and honor of a person. This technology also involves ethical and privacy issues, which is a fundamental right of the individual and companies in relation to competitiveness. Understanding the impacts of AI and its application will require the formulation of policies and strategies by corporations, public entities, and organized society [4], [5], [22], [23], [24], [25].

AI is related to computer science and its research fields include robotics, language and image recognition, expert systems, among others. Its emergence occurred during the Dartmouth Conference in 1956 and has developed over time, becoming one of the leaders in economic development and technological innovation in this area of study [4], [5], [24], [26], [27], [28], [29]. The evolution of AI can be seen in Figure 1.

Figure 1 - Artificial Intelligence over time



Fonte: Khan; Pasha; Masud (2021)

Several countries have developed this tool for use across multiple areas of human knowledge, such as finance, education, security, and health, among others. China, Japan, France, Germany, and the United States of America (USA), among other countries, have launched programs aimed at the development of AI [17], [24], [27], [30], [31].

The present study is justified by the need to understand the technological patents of AI and its evolution over time, in addition to identifying trends in technological application.

The objective of this work is to verify the development of AI between 2004 and 2025, in order to understand the technological evolution in this period.

METHODOLOGY

A systematic review of the literature on the subject was carried out in the theoretical framework, aiming at the qualitative analysis of the data to be replicated in the introduction and in the theoretical framework. Research is classified as academic because it is a study carried out in the academic environment and inspires intellectuality and the search for knowledge, where its goal is to offer answers to the questions that afflict society and companies [32], [33].

The technique used is of the indirect documentary type, as data collection is carried out from primary and secondary sources, whose goal is the interpretation and analysis of the data obtained [34].

Research is basic or pure in nature because it seeks theoretical results on the subject, using only theoretical knowledge without the results obtained being experienced, aiming to generate new knowledge about the object of research, without aiming to solve a problem or generate a product to be applied to solve a certain demand [32], [33].

Regarding its objectives, the research is exploratory and descriptive. The initial part of the research is exploratory, as it aims to know and understand the problems, creating familiarity with the problem, aiming to explain it or create plausible hypotheses on the subject. This phase also having the ability to explore new trends and incremental or disruptive technologies. It is based on a bibliographic survey [32], [33].

Descriptive research aims to describe facts or phenomena through collected or observable data, whose characteristics are related to the population, the phenomenon, or the relationship between variables, and may also describe the applications and characteristics of the applied technologies [32], [33].

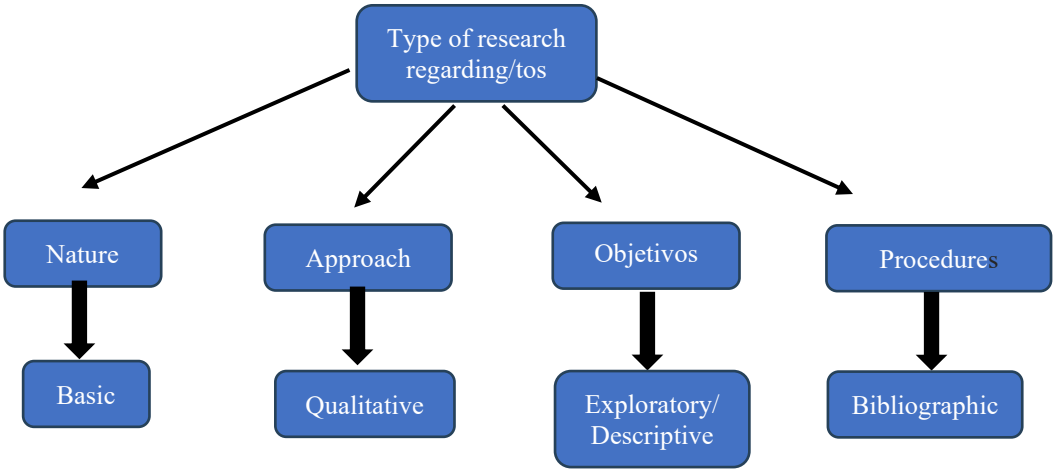
The technical procedure used was the bibliographic research that aims to support the theoretical part, involving the review of literature published and made available in scientific articles, course completion works (theses, dissertation, or monograph), books, among other means, which can also be used specialized sources related to the theme [32], [33].

Bibliometric analysis aims to visualize the patented and innovative development of AI in order to understand

technological development trends. This article uses qualitative analysis as a research method, involving the review and interpretation of data from technological patents related to AI, in addition to verifying trends and patterns. A literature review was carried out in patent documents and academic literature to verify the relevance of the theme; verification of codifications and innovations identified by category and areas of use; identification of the application of AI in different sectors and areas of innovation in the fields of health and medicine, mobility and transportation, and security and privacy, among others [32], [33].

The typology of the research can be seen in Figure 2.

Figure 2 - Typology of the research methodology



Source: Authorship (2025)

Papers that met the research objectives, related mainly to the technological prospection of AI, were considered eligible. In the Web of Science (WoS), the types of documents selected were: articles, procedure articles, review articles, early access publication, retracted publication, data articles, and book chapters, resulting in a total 6,012 documents. In the temporality between 2014 and 2025, 2,724 documents were found. The results of the research are shown in Chart 1.

The keywords used were those presented in Chart 1, using the Boolean connector in the Portuguese language "E" and "OU" and in the English language "*AND"* and "OR". The search bases were *Scielo*, *Web of Science,* and *Google Scholar,* which presented several works and the search was limited to the years 2014 to 2025.

Chart 1 – Results of the research

Base	Keywords
	((technological AND prospecting) or patent)) AND (AI OR pattern recognition OR pattern identification OR speech recognition OR voice recognition OR Cognitive computing OR image recognition OR Intelligent process OR Iris ID OR Iris Recognition OR IKSDK OR intelligent robot OR machine learning OR expert system OR Intelligent search OR Smart Search OR neural netw OR expert system OR computer vision OR Intelligent driving OR Cognitive computing OR Artificial intelligence OR pattern identification)
WoS	2,724
Scielo	27
Google Scholar	10,600

Source: Authorship based on Espacenet (2025)

Chart 1 shows that *Google Scholar* is the database that presents the most research results in the period searched, but works from the databases that fit the object of the research were used.

A review of the patent database was carried out, analysis of patent documents, identification of the most relevant in the emergency and safety segment. The technological prospecting in AI was carried out in the *Espacenet* patent

database, on 20/12/2025, using the keywords indicated in Table 2 and the use of the AND and OR Boolean connectors

Chart 2 – Results of the research

Keywords	Result
(AI OR pattern recognition OR pattern identification OR speech recognition OR voice recognition OR Cognitive computing OR image recognition OR Intelligent process OR Iris ID OR Iris Recognition OR IKSDK OR intelligent robot OR machine learning OR expert system OR Intelligent search OR Smart Search OR neural netw OR expert system OR computer vision OR Intelligent driving OR Cognitive computing OR Artificial intelligence OR pattern identification) AND (G06 AND H04 AND G10 AND G01)	334
Legend: G01 – Measurement tests G06 – Informatics; calculation or counting G10 – Musical instruments; Acoustics H04 – Telecommunications technology	

Source: Authorship based on *Espacenet* (2025)

Data collection included the identification of patents between 2004 and 2025, the main countries of protection, inventors, patent holders, and their countries of origin. The selected patents had enough information for the study, so there was no need for deletion. The 334 patents were analyzed, which constituted a representative and selectable sample for the present study. The analyzed data were tabulated in Excel in order to prepare graphs.

Patents directly related to AI and specific applications, mainly in the fields of health, safety, among others, published in the last 21 years (2004-2025), which are theoretically within the validity period, were eligible.

RESULTS AND DISCUSSION

AI is present in several problem-solving applications and in relation to emergency and security, three patents stand out, listed below:

1. Publication Number: CN210515545U;
   Publication date: 12/05/2020;

Patent title: AI Intelligent Fire Exit Indication System;

Problems/Impacts: Some fire exit systems are inadequate for handling fire scenarios, especially in older facilities. Learning about fire is dynamic, and smoke can obstruct escape routes and hinder the safety of firefighters and rescuers, as well as those present at the time of the incident. This makes it necessary to implement systems that are more adaptable to reality to ensure effective evacuation and guarantee people's safety. Therefore, the implementation of AI-based exit indication systems in these disaster locations tends to improve the efficiency of evacuation routes, making it faster and safer; reduces the risk of accidents at the disaster site and ensures the safety of those involved; and optimizes emergency resources with real-time information on the facility's conditions, thus improving the coordination of emergency, rescue, and firefighting services.

2 Publication Number: US11711648B2;
Publication date: 02/07/2020;

Patent Title: Audio-based Emergency Vehicle Detection and Tracking;

Problems/Impacts: Emergency vehicles are essential to ensure the integrity of people and meet their health and safety needs and their detection tends to improve the efficiency of emergency systems, optimize and manage flow to ensure unobstructed routes and thus save time, as well as provide faster response in emergencies to save lives and protect property.

3 Publication Number: KR102408306B1;
Publication date: 15/06/2022;

Patent title: AI-based emergency call situation monitoring system;

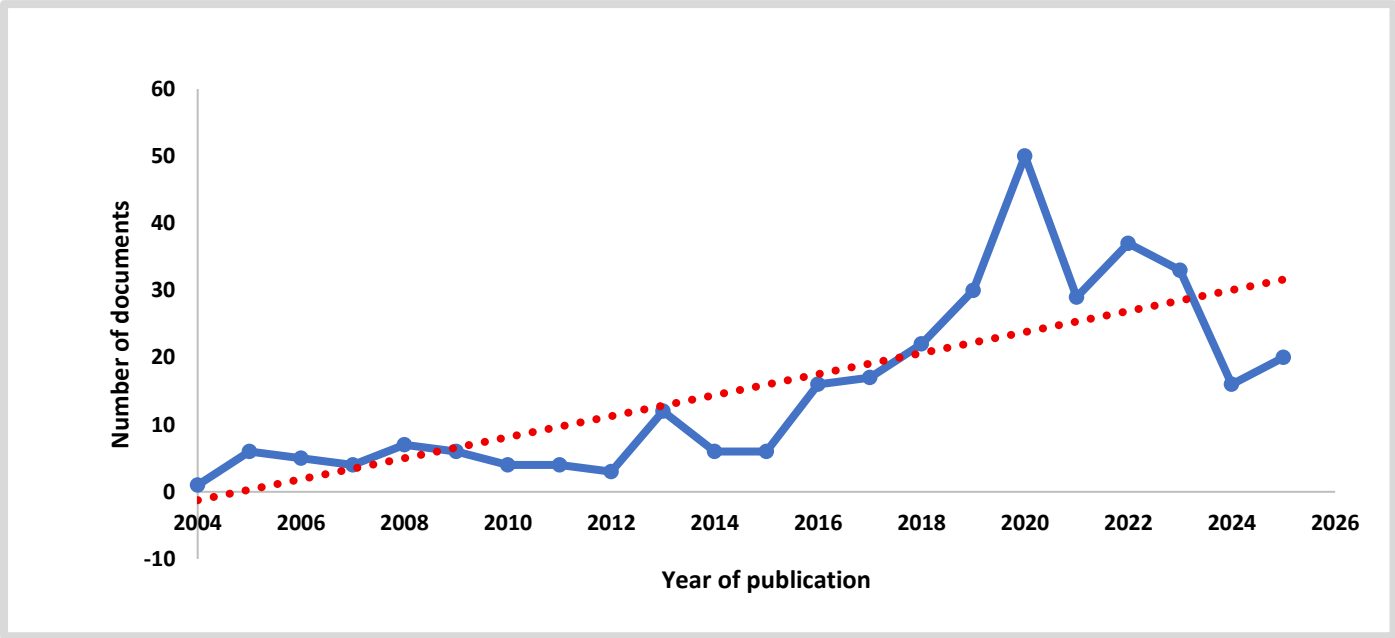
Problems/Impacts: Monitoring systems are still inefficient in detecting critical situations in real time and to improve efficiency, a system was created for this purpose, in order to provide a faster and more effective response in order to reduce human errors resulting from the need to process large volumes of data in real time.

Patents are tools that stimulate creativity and technological and economic development, as well as the socioeconomic growth of society, and the enjoyment of current and future generations. A concentration of AI patents was observed in specific fields, where large corporations predominate, while universities and the like are not relevant in the development of this technology in the parameters shown in Chart 2.

The qualitative analysis of AI demonstrates a detailed view of innovation and its areas of application, especially when technological prospecting is used for this purpose. This approach enables an understanding of the direction that is being given to technology, with its trends, limitations, innovation, and challenges.

The temporal distribution of 334 documents related to Artificial Intelligence and related technologies (such as machine learning, pattern recognition, computer vision, intelligent robotics, and expert systems), classified in the IPC subclasses G06, H04, G10, and G01, considering the oldest publication date of the patent family, can be seen in Figure 3.

Figure 3 – Temporality of AI patents between 2004 and 2025



Source: Authorship based on Espacenet (2025)

Figure 3 shows that patent publications can be divided into six periods as follows:

1. Initial and dispersed phase (2004–2012)

Between 2004 and 2012, a low annual volume of documents is observed, with numbers varying between 1 and 7 registrations per year. This period is characterized as an embryonic phase of AI technologies associated with the technical classes analyzed, reflecting; computational limitations of the time; lower maturity of learning algorithms; and applications still restricted and mostly experimental

2. Beginning of Technological Consolidation (2013–2015)

From 2013 onwards, there is a significant leap, with 12 documents indicating the beginning of a growth trajectory. This movement coincides with advances in big data; popularization of deep learning architectures; and expansion of industrial and digital applications.

3. Accelerated Expansion and Maturation (2016–2019)

The period between 2016 and 2019 shows continuous and robust growth, increasing from 16 documents in 2016 to 30 in 2019. This phase highlights: the consolidation of AI as a strategic technology; integration into sectors such as telecommunications (H04), data processing (G06), signals and images (G10, G01), and the intensification of deposits by large companies and R&D centers.

4. Technological Peak and Widespread Diffusion (2020)

The year 2020 represents the peak of the series, with 50 documents, reflecting: massive adoption of AI-based solutions; acceleration of digitization and automation of processes; and strong stimulus for recognition technologies, data analysis and intelligent systems.

5. Stabilization at a high level (2021–2023)

Between 2021 and 2023, the values remain high (29 to 37 documents/year), indicating: technological maturity; diversification of applications; and lower percentage growth, which is typical of already consolidated technologies.

6. Recent Fluctuations (2024–2025)

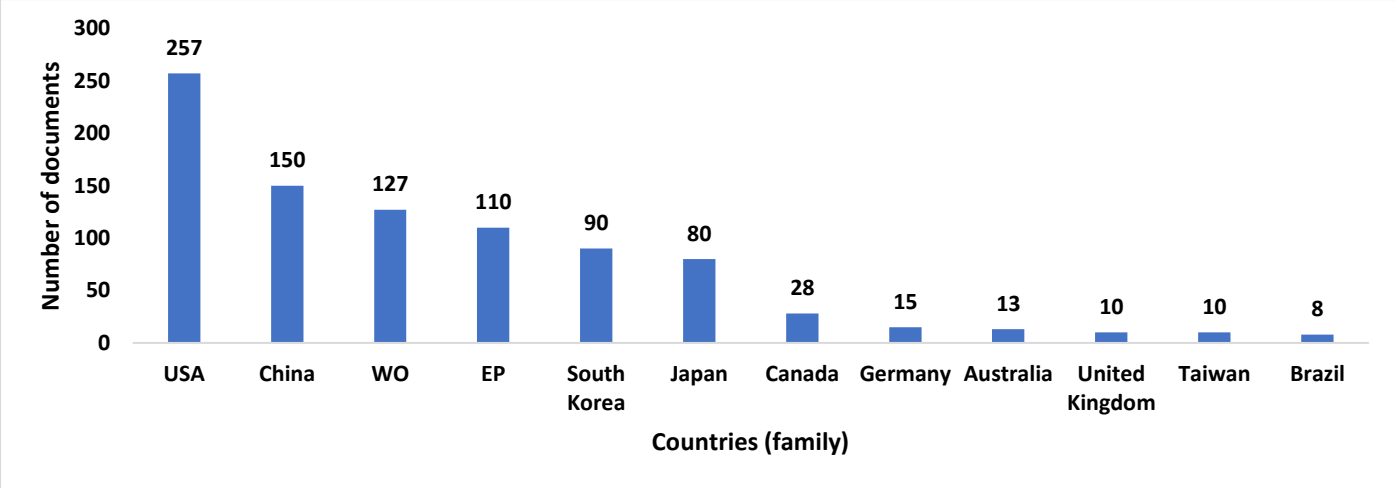
The most recent data show a reduction in 2024 (16 documents) and a slight recovery in 2025 (20 documents), which may be associated with: time lag between filing and publication; strategic reorganization of patent portfolios; and increasing focus on quality and selective protection.

The largest increase occurred in 2005, with approximately 500.00%, and the largest decrease occurred in 2024 with -51.52%. Given the 18-month confidentiality period, this may have been one of the reasons for this result.

In general, there has been a consistent evolution of AI technologies, with exponential growth starting in 2016, with the highest peak recorded in 2020, despite this being a period of lockdown due to the COVID-19 pandemic. There has also been a recent stabilization, which can be characterized as a period of technological maturation.

The geographical distribution of patent documents by family country of origin highlights the main international centers of technological development and protection in areas related to AI and associated technologies, as can be seen in Figure 4.

Figure 4 - Geographical distribution of published patents



Source: Author's own work (2025)

Figure 4 shows the leadership of the United States of America with 257 documents, demonstrating its hegemony in this technology and its position as the main market for technological protection. This result may be associated with its strong innovative ecosystem; high investments in R&D; the activity of large technological companies and universities; and aggressive intellectual property protection strategies in key markets.

The second largest patent protection market is China, with 150 documents, which may be associated with its rapid expansion of AI technology capabilities; public policies aimed at placing the country at the forefront of technology, especially in digital areas; and strong incentives for patent protection, both domestically and internationally, mainly due to its ability to replicate inventions.

International and regional offices such as WO (127) and EP (110) also stand out among the leaders, indicating a strategy of internationalizing protection via PCT (WO) and the European Patent Office (EP). This also demonstrates the interest of patent holders in expanding the coverage of inventions, especially in economically mature markets, as well as the global application of technology.

Technologically advanced Asian countries such as the Republic of Korea (KR 90) and Japan (JP 80) have a significant share, mainly due to their strong tradition in telecommunications, electronics and automation, as well as the presence of intensively technological industrial conglomerates.

Developed countries such as Canada (CA 28), Germany (DE 15), Australia (AU 13) and the United Kingdom (GB 10) have a modest share, which indicates that they use strategies directed at priority markets.

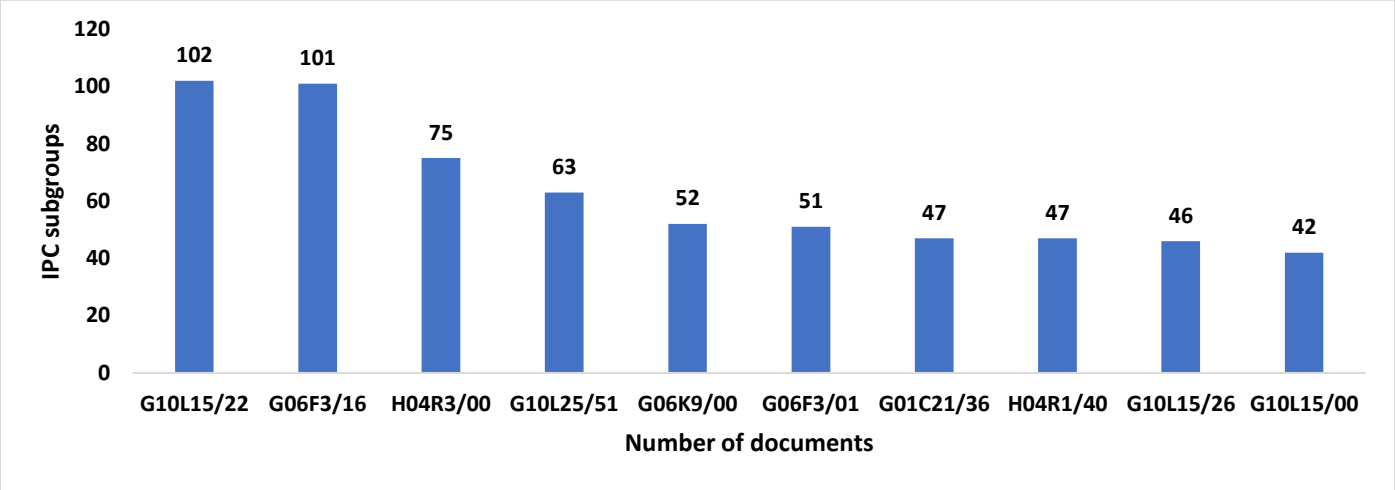
Developing countries, such as Brazil (BR 8), Mexico (MX 7), Russia (RU 6), India (IN 4), and South Africa (ZA 1), have low participation, indicating a smaller volume of technology protected by patents, which demonstrates global technological dependence, creating opportunities for public policies focused on innovation and intellectual property protection.

Therefore, technological protection has a strategic, global character and is highly concentrated in the most developed and technologically advanced countries.

Brazil had the first patent published in 2009, whose holder was a Russian company. The last one was published in 2020. The patent holders were German, Canadian and American nationals. In turn, the inventors are of German, Canadian, French and American nationality. There are three patents pending and four granted.

The distribution of patent documents by subgroups of the International Patent Classification (IPC) allows us to identify the dominant technological cores of inventions related to Artificial Intelligence, pattern recognition, signal processing, cognitive computing, and intelligent systems, as can be seen in Figure 5.

Figure 5 – Most relevant IPC code of AI technologies



Legend

G10L15/22 - Speech recognition; / Procedures used during a speech recognition process, e.g. human-machine dialogue;

G06F3/16 - Input arrangements for transferring data to be processed into a form capable of being manipulated by the computer; output arrangements for transferring data from the processing unit to the output unit, e.g. interface layout; / Sound input; Sound output;

H04R3/00 - Circuits for transducers;

G10L25/51 - Speech or speech analysis techniques not restricted to a single group; / specially adapted for particular use; / for comparison and discrimination;

G06K9/00 - Methods or arrangements for reading or identifying printed or written characters or for identifying patterns, e.g. fingerprints;

G06F3/01 - Input provisions for transferring data to be processed into a form capable of being manipulated by the computer; output provisions for transferring data from the processing unit to the output unit, e.g. interface arrangement; / Input provisions or combined input and output arrangements for interaction between user and computer;

H04R1/40 - Details of transducers; / Arrangements to obtain the desired frequency or directional characteristics; / to obtain only the desired directional characteristic; / combining several identical transducers;

G01C21/36 - Navigation; Navigation instruments not covered by the preceding groups; / specially adapted for navigation on a road network; / Looking for the route; Guiding the route; / Input/output means for on-board computers;

G10L15/00 - Speech recognition;

G10L15/26 - Speech recognition; / Speech-to-text systems;

Source: Authorship based on Espacenet (2025)

Figure 5 shows that there is a predominance of voice, audio and language technologies (G10L and H04R).

The most frequent subgroups belong mostly to the G10L class, which deals with the analysis, synthesis, and recognition of speech, audio, and sound signals:

G10L15/22 (102 documents) – speech recognition based on statistical and computational models;

G10L25/51 (63) – advanced techniques for processing and extracting features from audio signals;

G10L15/26, G10L15/00, G10L15/30, G10L15/18 – variations of speech recognition and analysis;

G10L17/00, G10L17/22 – speaker identification and recognition.

These subgroups indicate that voice and natural language technologies are the main technological axis of the

analyzed set, reflecting applications such as virtual assistants, voice command recognition, vocal biometrics, and human-machine interfaces.

The H04R class (loudspeakers, microphones and acoustic transducers) appears with the following highlights:

H04R3/00 (75), H04R1/40 (47), H04R29/00 (20), reinforcing the integration between acoustic hardware and intelligent algorithms.

The second relevant group demonstrates a substantial presence of human-machine interfaces and data processing (G06F, G06K).

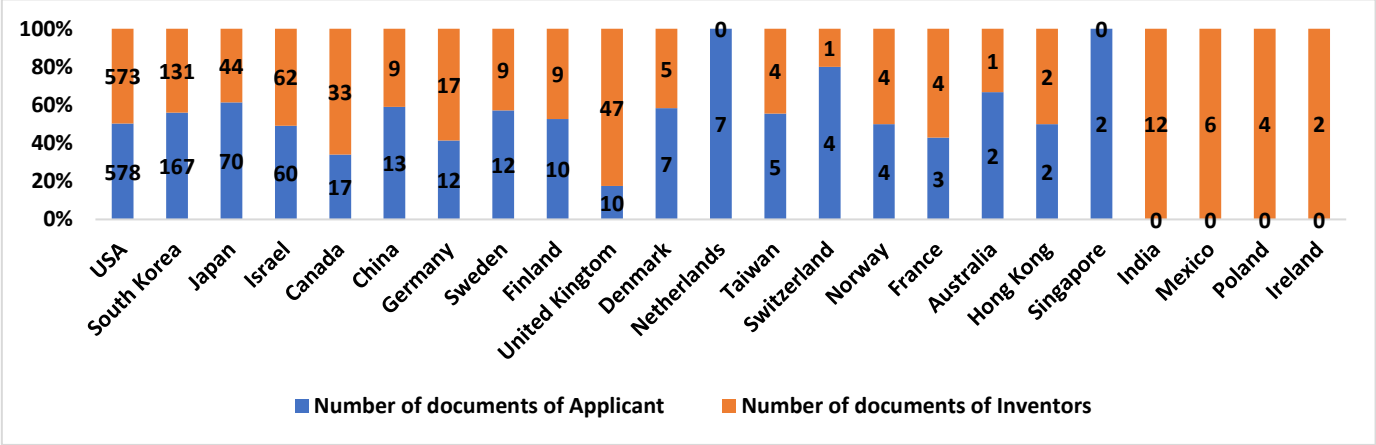
The G06F and G06K subgroups indicate the computational basis of these solutions as shown below:

G06F3/16 (101) and G06F3/01 (51) – input interfaces and human-machine interaction;
G06K9/00 (52) and G06K9/62 (15) – pattern and character recognition;
G06F17/30 (25) – information retrieval and analysis.

These results show that the AI analyzed is substantially associated with interactive systems, automatic recognition, and intelligent data processing, reinforcing its application in more modern digital systems.

The geographical distribution of patent documents according to the applicant's country and the inventors' country allows us to assess where technologies are legally appropriated versus where technical knowledge is effectively generated, as can be seen in Figure 6.

Figure 6 – Country of protection vs. country of holders



Source: Authorship based on Espacenet (2025)

Figure 6 shows the absolute predominance of the United States, which leads significantly in both dimensions: applicants with 578 documents and inventors with 573 documents.

This numerical proximity indicates strong internalization of innovation, that is, technological development and patent ownership are mostly concentrated in the same country. The result reflects that the country's innovation ecosystem is mature; there is integration between companies, universities and R&D centers; and the strategies for appropriating intellectual property are consolidated.

In Asian countries, an asymmetry is observed between ownership and invention.

South Korea has 167 applicants and 131 inventors, revealing high internal technological capacity, with some of the inventive activity possibly carried out in international collaboration.

Japan shows a more pronounced difference with 70 applicants versus 44 inventors, suggesting that Japanese companies internalize IP rights over inventions partially developed outside the country or in global R&D networks.

There are cases where inventors outnumber applicants, such as Canada (CA 17 applicants vs 33 inventors), the United Kingdom (GB 10 applicants vs 47 inventors), and Germany (DE 12 applicants vs 17 inventors), which have more inventors than applicants.

This pattern indicates knowledge export, with inventors working on projects where legal control of patents is exercised by foreign companies. It also shows strong inventive output and less appropriation of intellectual property.

This result suggests that there is high technical and scientific expertise; significant participation of inventors in international projects; and appropriation of intellectual property predominantly carried out by companies based outside the country.

There are countries with low ownership but with an inventive presence, such as India (IN 12 inventors), Mexico (MX 6), Poland (PL 4) and Ireland (IE 2), which appear exclusively as the origin of inventors, without records as applicants.

This condition highlights the peripheral insertion in global innovation chains, with knowledge generation without direct control of intellectual property assets.

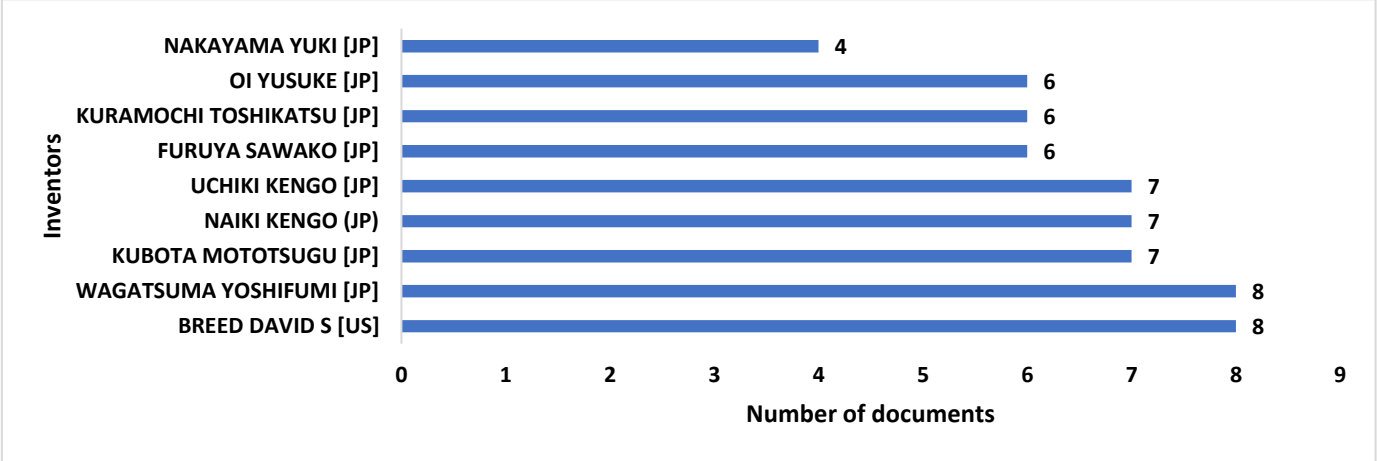
Some countries hold patents but have no inventors, such as the Netherlands (NL 7 applicants / 0 inventors) and Singapore (SG 2 / 0).

This pattern is typical of countries that function as corporate hubs, tax centers, or legal headquarters, concentrating patent ownership without necessarily concentrating inventive activity.

Therefore, there is a structural asymmetry between knowledge generation and the appropriation of intellectual property. While the United States simultaneously concentrates invention and ownership, many countries act only as suppliers of qualified human capital, such as the United Kingdom, Canada, Germany, and India, or as legal and strategic headquarters for global companies, such as the Netherlands and Singapore.

The main inventors associated with the analyzed patent documents allow us to identify key individual actors, patterns of concentration of inventive activity, and the geographical distribution of human capital in the technological domain of Artificial Intelligence and related technologies, as can be seen in Figure 7.

Figure 7 – Inventors



Source: Authorship based on Espacenet (2025)

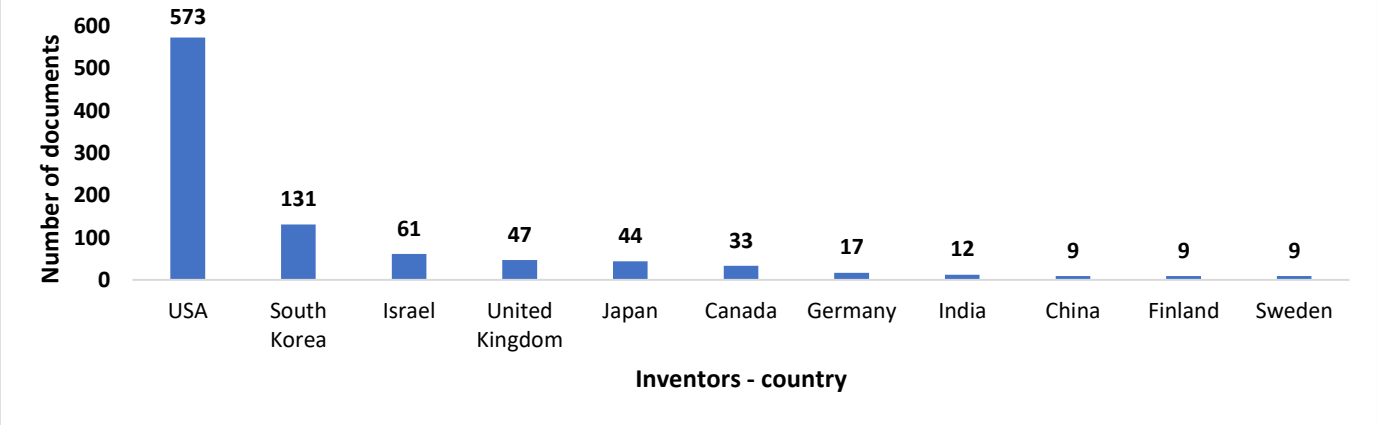
The most productive inventors submitted eight documents, with the following standing out: David S. Breed (US), who is associated with Automotive Tech Int (US); and Yoshifumi Wagatsuma (JP), who is associated with Honda Motor CO LTD (JP).

In second place, with seven documents each, are the inventors Mototsugu Kubota (JP), Naiki Kengo (JP), Uchiki Kengo (JP), associated with Honda Motor CO LTD (JP).

There is a significant presence of Japanese inventors among those with the highest number of published documents, mainly related to speech recognition, audio, and intelligent systems.

The distribution of inventors by country, based on the number of patent documents to which they are associated, allows us to analyze the geographical origin of the human capital of inventors in the field of Artificial Intelligence and related technologies, as can be seen in Figure 8.

Figure 8 - Country of inventors



Source: Authorship based on Espacenet (2025)

Figure 8 shows that the distribution reveals a significant geographical concentration, with a few countries accounting for the majority of inventive activity.

The significant participation of the United States reinforces its position as a leading and central hub of innovative activity, given that the country accounts for 573 documents, establishing itself as the world's leading center for the generation of inventive knowledge. This result indicates: a high density of highly qualified professionals; strong integration between universities, companies, and R&D centers; and the ability to attract foreign inventors and retain talent.

East Asia stands out, particularly South Korea (KR), which occupies second place with 131 documents. This volume highlights the country's substantial specialization in electronics, telecommunications, and intelligent systems, as well as its consolidated insertion in global innovation chains.

In turn, Japan (JP) appears in fifth place, with 44 documents, maintaining its historical relevance in recognition technologies, signal processing, and automation.

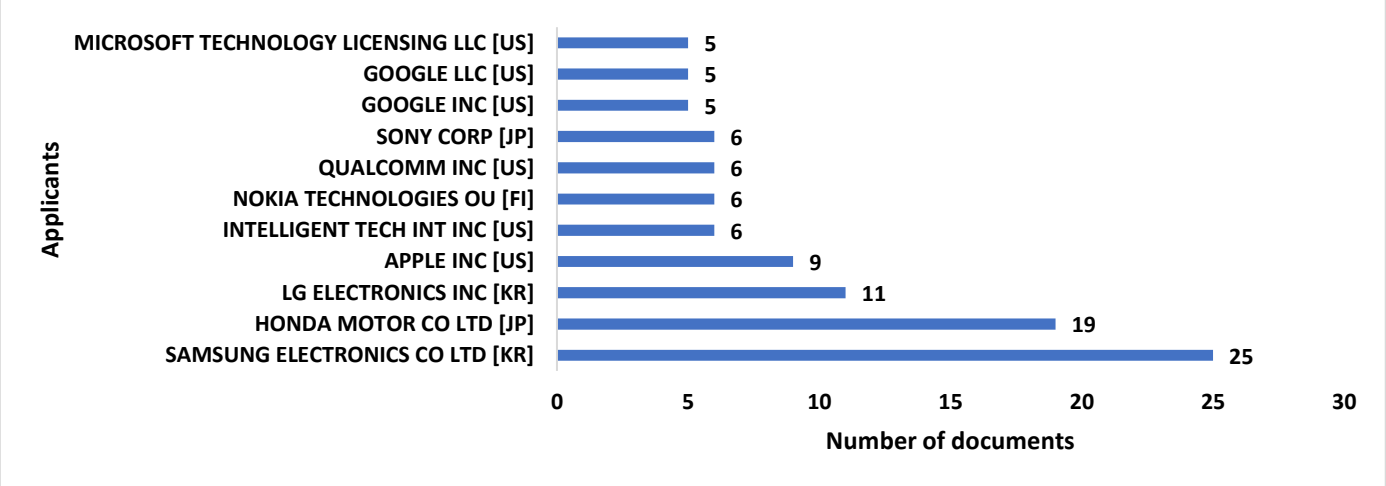
Some European countries, recognized for their high level of qualification, appear on a smaller scale. In this group, the United Kingdom (GB) stands out, with 47 documents, maintaining a significant inventive output even with less control over patent ownership. This result suggests the presence of substantial human capital and active participation in international R&D projects.

Other countries in this group are Germany (DE – 17), Finland (FI – 9), Sweden (SW – 9), Denmark (DK – 5), and France (FR – 4). This overview demonstrates a consistent, albeit fragmented, presence of the continent, and indicates that the focus of these countries is directed towards specific technological niches.

The participation of some emerging countries, such as India (IN – 12), China (CN – 9), and Mexico (MX – 6), is still peripheral as a source of inventors. This reflects a growing, but not central, insertion in global innovation networks, although their potential for future expansion is significant, especially with the maturation of their technological ecosystems.

Analyzing the main applicants for patent documents allows us to identify who legally controls intellectual property assets in the fields of Artificial Intelligence, pattern recognition, signal processing, intelligent systems, and related applications, as illustrated in Figure 9.

Figure 9 - Main applicants



Source: Authorship based on Espacenet (2025)

Figure 9 highlights Asian corporate leadership at the top of the ranking, in which the top positions reveal the prominence of large conglomerates, especially from South Korea — with Samsung Electronics (25 documents) and LG Electronics (11) — and Japan, with Honda Motor (19).

This result demonstrates the existence of an integrated systematization between hardware, software and AI, as well as its intensive application in sectors such as consumer electronics, automobiles, audio, sensors and intelligent systems. The analysis also highlights the consolidated patent protection strategies adopted by large industrial corporations.

US Big Tech companies are also relevant in this segment, occupying prominent positions, as demonstrated by Apple (9), Google (5+5), Microsoft (5), Amazon (4), IBM (4), Intel (4) and Qualcomm (6). This scenario reveals a dominance of AI based on software, algorithms, human-machine interfaces and digital services, as well as demonstrating a strategy of corporate fragmentation (e.g., Google Inc. / Google LLC) for the management of

intellectual property portfolios. Another observed characteristic is the cross-cutting role of AI in digital ecosystems, mobility, communication and cloud computing.

The relevance of the automotive and smart mobility sector is evident from the presence of large corporations such as Honda (19 documents), Hyundai (2), Toyota (2), GM (2), Ford (1), Audi (1), Volkswagen (1), Woven by Toyota (1) and Waymo (1). This concentration highlights AI as a strategic tool for smart vehicles, ADAS, navigation, embedded voice and automation, confirming the sector as one of the main vectors for the technological application of these patents.

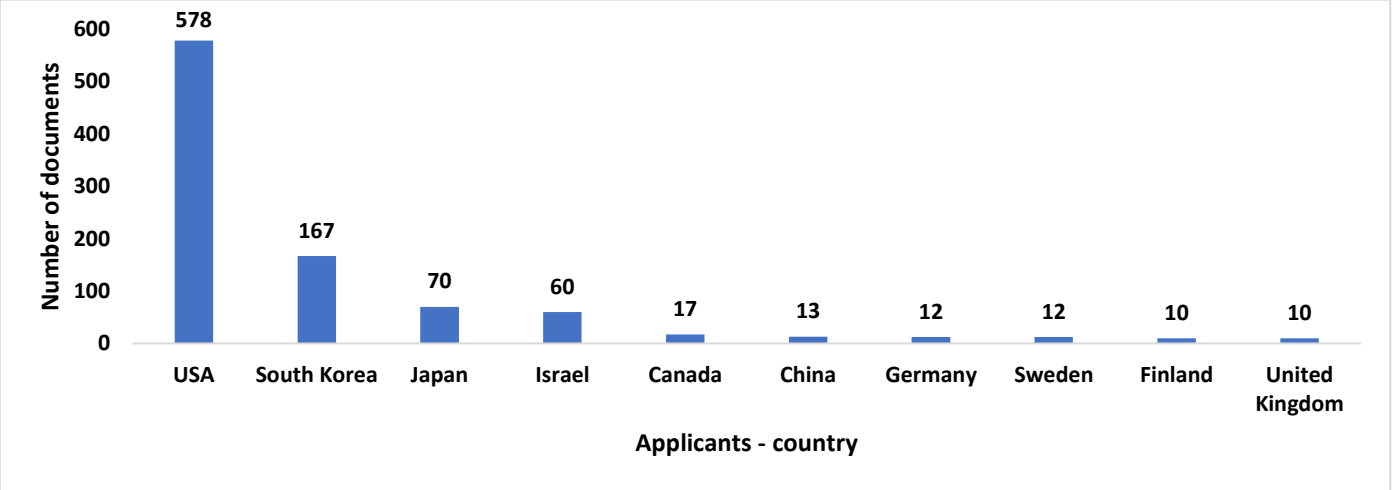
The prominence of telecommunications, audio, and semiconductor companies is noteworthy, representing a structuring axis, such as Nokia (6 documents), Sony (6), SK Telecom (2), Huawei (2), Cirrus Logic (2), Dolby (1), Sonos (1), and Bang & Olufsen (1). This presence demonstrates a systematic base in signal processing, audio, speech, networks, and connected devices. Furthermore, it highlights the integration between AI, telecommunications, and specialized hardware, thus constituting an important strategy for global acoustic and communicational dominance.

The field of study exhibits institutional fragmentation and a "long tail" of patent applicants, with approximately 436 of them holding only one related patent. This extensive list demonstrates the high fragmentation of the innovation ecosystem, which includes startups, universities, research institutes, individual inventors, and small companies. This scenario indicates a substantial dynamic of incremental innovation, typical of mature digital technologies.

Therefore, the existence of individual inventors as applicants indicates technological entrepreneurship, while the participation of universities and public institutes reflects applied research and the potential for technology transfer.

The distribution of patent applicants by country highlights the institutional concentration of ownership, revealing the geographic origin of the individuals and/or legal entities that control and economically exploit the developed Technologies, as shown in Figure 10.

Figure 10 - Country of the main applicants



Source: Authorship based on Espacenet (2025)

Figure 10 demonstrates that the economic and institutional appropriation of technologies is heavily concentrated in the United States (578 documents), followed by South Korea (167), Japan (70), and Israel (60). This concentration shows that strategic control of patents remains centralized in countries with mature innovation ecosystems, endowed with robust capital and advanced intellectual property governance.

The United States is the leading patent holder, with 578 patents, confirming its central position not only in knowledge generation but, above all, in the legal and economic appropriation of innovations.

This result highlights the substantial presence of large technology companies, universities, and R&D centers, which have consolidated intellectual property management structures and adopt aggressive patent protection strategies in global markets.

South Korea (167 documents) and Japan (70 documents) play a significant role and occupy prominent positions. This indicates the substantial prominence of industrial and technological conglomerates with a high capacity to transform applied research into patent assets. Furthermore, these countries demonstrate consolidated strategies for the internationalization of intellectual property, especially in the electronics, telecommunications, and intelligent systems sectors, where they stand out as key players.

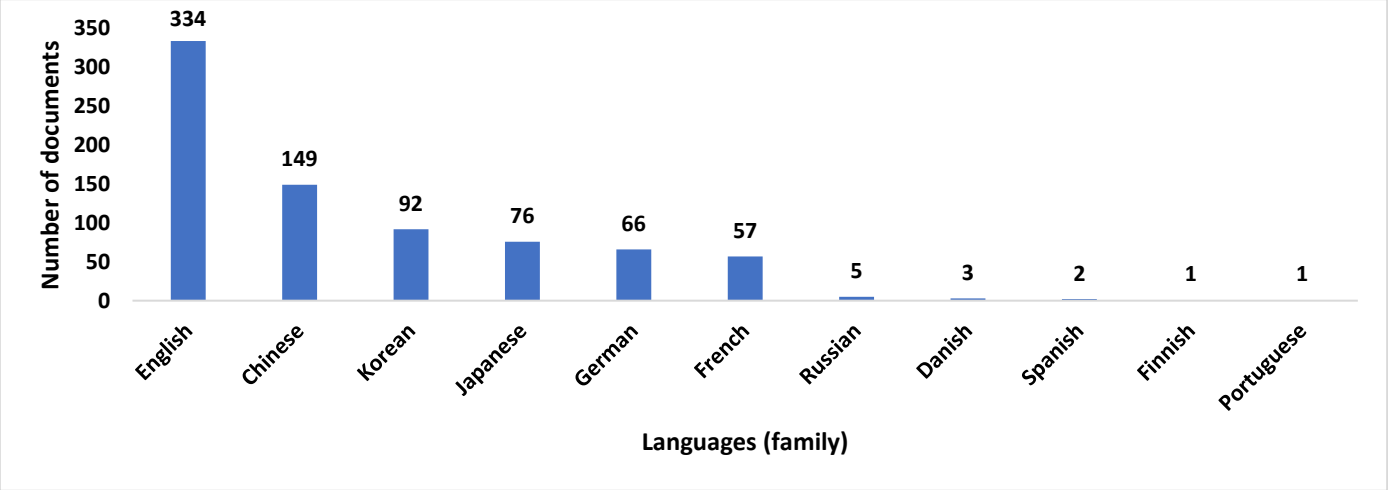
Although European participation is fragmented, countries such as Germany (12 documents), Sweden (12), Finland

(10), United Kingdom (10), Denmark (7), Netherlands (7), France (3) and Switzerland (4) are presented in a dispersed manner. This demonstrates high technical and scientific competence combined with a low institutional concentration of patents, resulting in the predominance of specialized companies and research centers, generally integrated into multinational networks.

Emerging Asian countries, such as China (13 documents), Taiwan (5), Hong Kong (2) and Singapore (2), have a moderate participation in this scenario. This condition indicates a growing participation in the international patent system and a selective focus on specific technological niches, with strategies that are even less aggressive — in terms of the volume of applications — when compared to those of global leaders.

The distribution of patent documents by language — considering patent families — allows us to understand the target markets, internationalization strategies, and global diffusion of the technologies analyzed, as illustrated in Figure 11.

Figure 11 - Distribution of patent documents by language



Source: Authorship based on Espacenet (2025)

The overwhelming predominance of English (334 documents), shown in Figure 11, highlights its role as a lingua franca in the patent system. It reveals that most documents are drafted for international protection (especially in the US and European markets), demonstrating companies' pursuit of maximum visibility, legal reach, and global commercialization of their technologies.

The significant participation of Asian languages — Chinese (149 documents), Korean (92) and Japanese (76) — indicates intense technological and patent activity in East Asia. This volume reflects the initial filings made in national offices (CNIPA, KIPO, JPO), revealing a strategy that combines domestic protection with subsequent international expansion.

The relevance of the German (66 documents) and French (57) languages reflects the significant European role in the development and protection of these technologies, based on its strong tradition in applied research and industrial innovation. This establishes the European market as a strategic destination for patent applications.

Other languages, such as Russian (5 documents), Danish (3), Spanish (2), Finnish (1) and Portuguese (1), have marginal participation, indicating a low volume of national deposits. This stems from more restrictive protection strategies or less integration into the international patent system, highlighting a strong dependence on English for global insertion.

CONCLUSIONS

This study mapped and analyzed the global landscape of patent documents related to Artificial Intelligence and associated technologies—such as pattern recognition, signal processing, cognitive computing, and intelligent systems—highlighting the geographic, institutional, and technological dynamics that structure this field. The results demonstrate a strong concentration of both inventive activity and patent ownership in a restricted group of countries, particularly the United States, South Korea, Japan, and Israel. Among them, the United States stands out for simultaneously concentrating invention, ownership, and economic appropriation of intellectual property, reflecting a mature and highly integrated innovation ecosystem.

Asian countries, especially South Korea and Japan, demonstrate a consolidated capacity to transform applied research into patent assets, driven by large industrial conglomerates in the electronics, telecommunications, automotive technologies, and intelligent systems sectors. In contrast, several European countries exhibit strong inventive capacity but relatively lower levels of patent ownership, indicating a pattern of knowledge export and

participation in multinational R&D networks, rather than centralized institutional appropriation. Emerging economies, such as China, India, Brazil, and Mexico, still play a peripheral role, although their growing inventive presence suggests potential for future expansion as their innovation ecosystems mature.

The analysis of patent applicants, inventors, and languages further reveals structural asymmetries between knowledge generation and intellectual property control. English clearly dominates as the primary language for patent families, highlighting its strategic role in global market access and international protection. At the same time, the significant use of Asian languages reflects strong domestic patenting activity combined with subsequent internationalization strategies.

Despite these contributions, the study has some limitations. First, it relies on patent data, which captures only a portion of innovative activity and may overlook unpatented knowledge, trade secrets, and open-source developments, particularly relevant in AI. Second, differences in national patenting practices and strategic behaviors may affect direct comparisons between countries. Third, the analysis is predominantly quantitative and does not deeply assess the technological quality, economic value, or practical impact of individual patents.

Future prospects point to the need for greater attention to the qualitative dimensions of AI patents, including citation analysis, patent family size, technological scope, and commercialization outcomes. Furthermore, future research could explore the role of universities, startups, and public research institutions in shaping emerging AI trajectories, as well as the influence of public policies and regulatory frameworks on patenting behavior. Comparative studies focusing on technology transfer, collaborative networks, and the relationship between patents and sustainable development goals would also enrich the understanding of the broader socioeconomic implications of AI.

In terms of future work, broadening the temporal scope of the analysis and integrating complementary data sources—such as scientific publications, funding programs, and enterprise-level innovation indicators—would provide a more comprehensive view of the global dynamics of AI innovation. These approaches can support the formulation of better-informed policies, contribute to strategic decision-making in intellectual property management, and help emerging countries strengthen their position in global AI innovation chains.

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