Navigating the AI Timeline: From 1995 to Today

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Abstract: In recent years, the exponential growth of Artificial Intelligence (AI) has transcended disciplinary boundaries, expanding into diverse fields beyond computer science. This study analyzes AI's distribution across disciplines using a large dataset of scientific publications. Contrary to expectations, substantial AI research extends into medicine, engineering, social sciences, and humanities. This interdisciplinary presence heralds new possibilities for collaborative innovation to tackle contemporary challenges. The analysis identifies emerging trends, contributing to a deeper understanding of AI's evolving role in society.

1 INTRODUCTION

Artificial intelligence (AI) has experienced an exponential rise in recent years, both in terms of popularity and societal impact. This is evident from the increase in scientific output in the field, with a growing number of publications, conferences, and initiatives dedicated to AI.

However, within this rapidly evolving landscape, an intriguing inquiry arises: how is AI research distributed across different disciplinary fields? Is it primarily concentrated within the computer science domain, or has it diffused into other application areas?

This analysis aims to examine scientific output in the field of AI with the goal of determining its distribution across different disciplinary sectors. Through the analysis of a large dataset of scientific publications, we will show that, contrary to what one might assume, a substantial share of AI research does not take place within the computer science field. Rather, it is found in a variety of application areas, including medicine, engineering, social sciences, and even humanities.

This finding has important implications for our understanding of AI and its potential impact on society. It demonstrates that AI is no longer confined to a narrow technical domain but is permeating a wide range of disciplines and application areas. This opens up new and exciting possibilities for interdisciplinary collaboration and for the development of innovative AI-based solutions that can address the most pressing challenges of our time.

Furthermore, this analysis will allow us to identify emerging trends in AI research and to better understand the future directions of this rapidly evolving field. Ultimately, this research will contribute to a more comprehensive understanding of AI and its role in society.

While a comprehensive analysis of the entire literature encompassing AI is an insurmountable task, we have chosen to utilize the Scopus database as the foundation for our investigation. Scopus, managed by Elsevier, stands as one of the world's most comprehensive repositories of bibliographic and abstract data within the scientific realm (Elsevier B.V., b) (Elsevier B.V., a). Its extensive disciplinary coverage, encompassing a broad spectrum of scientific fields, including natural sciences, social sciences, medical sciences, and engineering, aligns perfectly with our objective of understanding AI's impact across diverse sectors. Furthermore, Scopus provides an array of analytical tools that facilitate effective exploration of the database in alignment with our research goals.

Scopus is therefore generalist in that it covers a wide range of scientific disciplines, but there are some more specialized or niche research areas that may not be fully represented in its database. Scopus allows us to query its database through various APIs. Scopus contains approximately 82 million articles, and searches can be conducted across different fields of research.

In the literature, there are many examples of the use of the Scopus database. For instance, in (Hâncean

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et al., 2021) (De Stefano et al., 2011) (Carchiolo et al., 2022a) some examples of generating co-authorship networks are presented with the idea of representing the collaborations of the authors. In other cases (Carchiolo et al., 2022b), (Bordons et al., 2015) (Carchiolo et al., 2023), the data extracted from Scopus have been used to analyze the importance of certain researchers or their performance in terms of specific indices.

Our analysis, grounded in a robust dataset of scientific publications, maps the distribution of AI research across these diverse disciplines. The data speaks volumes: AI is not just a tool but a collaborator, opening doors to new realms of knowledge and understanding.

Section 2 introduces how the dataset was constructed, while Section 3 presents the temporal analysis and thematic distribution of the publications, and some results are discussed in detail. Section 4 provides an overview of some of the most cited articles. We finally consider further works and concluding remarks in Section 5.

2 DATASET

The study of scientific output in the field of Artificial Intelligence (AI) holds immense significance, given its prominence as a contemporary research focus that extends beyond the confines of computer science. Researchers across diverse disciplines, even those seemingly distant from computer science, are increasingly exploring the potential of AI as a viable solution for their respective fields of study. For this study, to capture the subset of articles focusing on Artificial Intelligence, a query against the Scopus database was performed using the keyword field. Instead of using only the keyword ”Artificial Intelligence,” 18 different keywords were chosen, the table 1 lists the 18 keywords used and the number of articles selected for each. With this keyword selection, a total of $2,156,387$ articles were selected, of which $2,081,397$, about 96.5% were written in English. This percentage remains relatively constant over the years; for example, in 2023, it is approximately 97%.

The analysis of these documents, totaling 2,156,387, reveals that a very small fraction (a few thousand) are incorrectly categorized and cover a topic do not related to artificial intelligence that, typically, pertain to keywords such as ”Pattern Recognition,” ”Reinforcement Learning,” ”Optimization Algorithms,” and ”Data Analysis”. However, given the small percentage, they cannot bias our analysis. Some

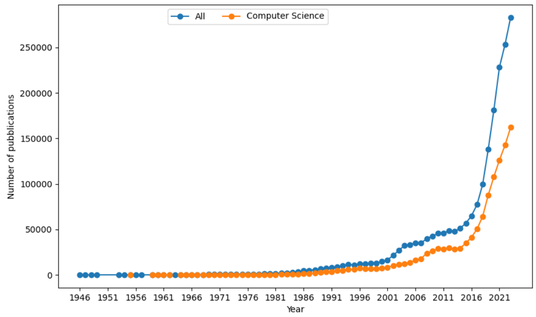
Table 1: Keywords in Artificial Intelligence.

Keyword	Document number
Artificial Intelligence	460 755
Machine Learning	455 294
Deep Learning	348 589
Data Analysis	272 258
Pattern Recognition	227 417
Convolutional Neural Networks	182 998
Computer Vision	180 619
Artificial Neural Networks	154 046
Natural Language Processing	108 584
Optimization Algorithms	80 415
Reinforcement Learning	77 935
Expert Systems	56 364
Supervised Learning	45 794
Recurrent Neural Networks	43 456
Machine Learning Algorithms	17 022
Unsupervised Learning	14 376
Artificial Intelligence Applications	950
Cognitive Robotics	796

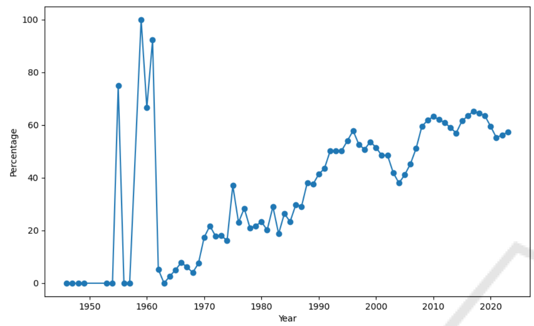
of the documents are quite old, dating back further than expected (see Figure 1.(a)) It should not be surprising to find articles from the early 1950s, as the term ”AI” was coined by John McCarthy in 1955 during a conference at Dartmouth College. McCarthy and other scholars laid the groundwork for a new research field aimed at developing machines capable of learning, reasoning, and problem-solving autonomously. However, traces of AI-related concepts can be found even before 1955 in the writings of Alan Turing, Marvin Minsky, who founded the MIT Artificial Intelligence Laboratory in 1951, one of the pioneering research centers in AI, and Arthur Samuel, who in 1959 developed the ”Gameplay” program, considered one of the earliest examples of artificial intelligence applied to a game, specifically checkers. Nevertheless, in recent decades, due to technological advancements, the availability of large amounts of data, and improvements in algorithms, AI has experienced a resurgence and has begun to influence an increasing number of societal sectors.

The initial analyses presented in this paper aimed to delineate the sectors to which the publications could be attributed. Scopus organizes its database by assigning a ”Subject Area” to each publication based on the publication venue. As depicted in Figure 1.(b), it is evident that slightly over 50% of the publications are categorized under Computer Science, a proportion that has varied between 45% and 60% over the years. This observation underscores the dominant presence of Computer Science within the dataset.

Furthermore, we conducted an analysis of the ”Subject Areas” in which Scopus classifies documents, the table 2 lists all the ”Subject Areas” present in Scopus, along with the number of publications selected by us attributed to each area. In our case, the documents are divided into Computer Science and Engineering for more than 80% of the cases. Moreover, it can be appreciated that the most relevant application fields in table 2



(a) Growth in publications over time.



(b) CS publications relative to all publications.

Figure 1: Total and Computer Science document analysis.

Table 2: Subject Area and Document Number.

Ref.	Subject Area	Document Number
CS	Computer Science	1 213 347
ENG	Engineering	720 705
MAT	Mathematics	413 249
MED	Medicine	335 620
PA	Physics and Astronomy	194 224
BGMB	Biochemistry Genetics and Molecular Biology	145 330
MS	Materials Science	123 975
DS	Decision Sciences	114 903
SS	Social Sciences	110 184
NS	Neuroscience	87 705
EN	Energy	82 665
EPS	Earth and Planetary Sciences	80 569
ES	Environmental Science	76 425
CHM	Chemistry	61 793
ABS	Agricultural and Biological Sciences	49 042
AH	Arts and Humanities	45 293
CHE	Chemical Engineering	43 689
PSY	Psychology	41 260
BMA	Business Management and Accounting	40 372
HP	Health Professions	32 916
MUL	Multidisciplinary	31 149
PTP	Pharmacology Toxicology and Pharmaceutics	30 093
IM	Immunology and Microbiology	26 421
NUR	Nursing	14 553
EEF	Economics Econometrics and Finance	12 689
VET	Veterinary	3 607
DNT	Dentistry	3 110

Finally, we investigated the affiliations of the documents, which originate from various countries; however, the predominant affiliations are located in China and the USA. Among the top 60 affiliations, significant presence is observed from France, Canada, Singapore, the UK, Bangladesh, Japan, Germany, India, Switzerland, Australia, Hong Kong, Italy, Belgium, and Brazil.

3 AI PUBLICATIONS TRENDS

The choice to focus the analysis of publications starting from 1995 in the present study is motivated by several crucial considerations to ensure the validity and relevance of our conclusions within the current research context. Firstly, it is important to note that the data obtained from Scopus for the years 1950-1995 are significantly limited in our field of investigation. This limited availability of information can be attributed to various factors, including technological and methodological constraints of the time, as well as the reduced use of bibliometric and citation systems. Secondly, we consider the dynamic evolution of our research field over the years. There has been a growing consensus regarding the increasing relevance of recent publications in reflecting the current state of knowledge and developments in the field. Therefore, recent (in our case, around 30 years) publications provide a more precise and updated picture of the current scientific landscape. Additionally, it is worth mentioning that significant trends and advancements in our field have occurred primarily during the last few decades, making publications after 1995 particularly relevant for our analysis. Finally, our decision is also motivated by the need to maintain consistency with contemporary research practices and to provide results that are fully aligned with the current scientific context, thus offering significant contributions to academic literature.

3.1 Number of Publications per Year

As a first analysis, a cumulative analysis of publications over the years was chosen, which naturally reveals a consistent growth in the number of scientific articles in the field of artificial intelligence. Examining the temporal growth of publications, a clear positive trend emerges over the years, indicative of an increasingly intense and continuous research activity. This approach also allows for the evaluation of long-term trends, revealing a steady increase in the number of publications year after year. Moreover, such analysis enables the identification of significant turning points in the growth rate, suggesting moments when research activity has undergone important changes or developments. These turning points can be indicative of innovations in the field, changes in research trends, or significant events that have influenced academic interest. Figure 2 shows the cumulative trend over the years from 1995 to 2023. It can be readily observed that around 2010, there is a knee in the curve, indicating a sudden growth in the number of publications. This year is widely recognized as a pivotal year in the field of artificial intelligence (AI) for a number of crucial reasons, such as, there were significant advancements in deep learning.

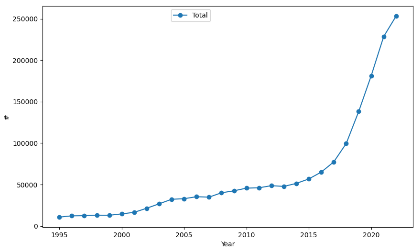


Figure 2: Cumulative trend of publications from 1995 to 2023.

3.2 Subject Areas by Year

In this section, we present the evolution of Subject Area from 1995 to 2023. As previously indicated, Scopus assigns a Subject Area to each publication based on its publication venue and the topic it covers within that source. Based on this analysis, it can be observed (see Figure 3) that the majority of publications fall within the fields of Computer Science or Engineering, with Computer Science being the predominant subject area.

As illustrated in Figure 4, Computer Science and Engineering emerge as the two primary Subject Areas, exhibiting a parallel growth pattern. This pattern suggests a close relationship between these two fields, with advancements in Computer Science often preceding similar developments in Engineering.

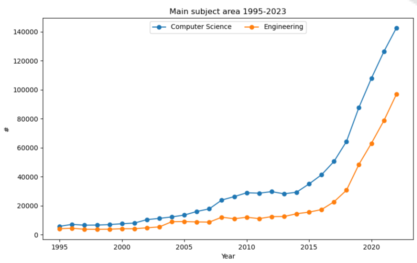


Figure 4: Trend of Computer Science & Engineering Subject Area.

To delve into the trends beyond the two dominant Subject Areas of Computer Science and Engineering, Figure 5 presents an overview of the remaining Subject Areas. This visualization aims to highlight the diverse patterns and trajectories observed across a broader range of disciplines. As evident, the Subject Areas beyond Computer Science and Engineering exhibit a more nuanced growth pattern. While some Subject Areas, display a more gradual or even plateauing growth trajectory. These observations underscore the multifaceted nature of AI research and its impact across a diverse spectrum of academic fields.

To further elucidate the distinct growth patterns observed, we present the trend of subject areas grouping them in smaller sets in order to enhance the specific behaviours that are hidden in global figure, therefore figure 6 presents the trends for the Subject Areas immediately following the two dominant fields (Mathematics Physics and Astronomy, Medicine, Biochemistry, Genetics, and Molecular Biology) and figure 7 delves into the trends of the next four prominent Subject Areas, Materials Science, Decision Sciences, Social Sciences, and Neuroscience.

As depicted in Figure 6, Mathematics displays a growth pattern akin to the top two Subject Areas. Conversely, Physics and Astronomy, as well as Biochemistry, Genetics, and Molecular Biology, exhibit a delayed onset of growth. Furthermore, Medicine initiates its upward trajectory with a slope comparable to Computer Science around 2013, while Physics and Astronomy and Biochemistry, Genetics, and Molecular Biology follow suit around 2015. Intriguingly, both Medicine and Biochemistry, Genetics, and Molecular Biology encounter a deceleration in their growth rates from 2021 onward.

Figure 7 delves into the trends of the next four prominent Subject Areas: Materials Science, Decision Sciences, Social Sciences, and Neuroscience. This visualization sheds light on the evolving dynamics of these emerging fields within the AI landscape. Interestingly, Decision Sciences stands out as an exceptional case, exhibiting a surge in growth starting from 2018. This upward trajectory suggests a growing recognition of the potential of AI in decision-making processes across various domains. In contrast, Neuroscience, which initially followed a similar growth pattern to the other Subject Areas, experienced a stagnation in its growth from 2018 onwards. This observation may warrant further investigation to understand the underlying factors contributing to this trend.

3.3 Geographical Landscape of AI Research

In the dynamic landscape of Artificial Intelligence (AI), analyzing the number of publications by country per year between 1995 and 2023 serves as a valuable lens through which to observe global research trends in this revolutionary field. Understanding the geographical distribution of scientific output in AI goes beyond mere mapping. It's a deep exploration that enables us to assess the impact of AI in different con-

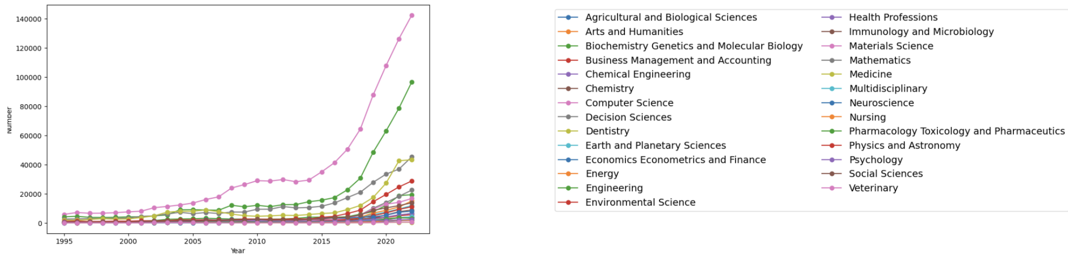


Figure 3: Trend of Subject Area from 1995 to 2023.

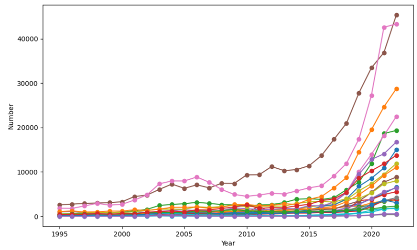


Figure 5: Trend of Subject Areas excluding dominant ones from 1995-2023.

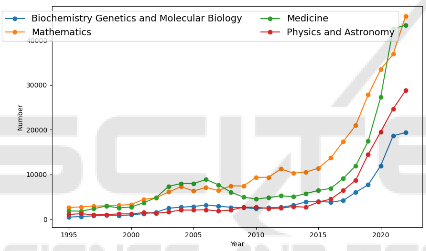


Figure 6: Trend of Mathematics Physics and Astronomy, Medicine, Biochemistry, Genetics, and Molecular Biology.

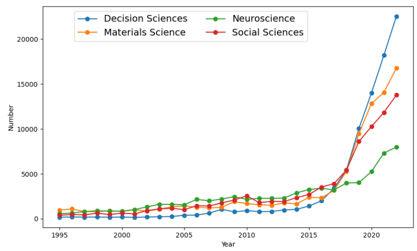


Figure 7: Trend of Materials Science, Decision Sciences, Social Sciences, and Neuroscience Subject.

texts, uncovering how this technology is shaping and influencing various societies and cultures worldwide. Through this analysis, centers of excellence in AI research become clear, acting as strategic benchmarks for international collaboration and attracting top talent in the field. The data gathered serves as a compass to guide national and international policies and strategic decisions, allowing for effective resource allocation and the development of targeted strategies to promote AI adoption in every context. Furthermore, analyzing the number of publications by country proves to be a powerful tool for monitoring the progress of AI research over time. It offers a tangible assessment of this technology's impact on society and allows for the identification of new trends and emerging research areas that will shape the future of AI. In doing so, for the sake of simplicity and efficiency, we narrowed down the analysis to the top 24 countries. This approach streamlines the data collection and analysis process, optimizing computational resources and expediting the study's completion. While this decision excludes other countries, it does not diminish the significance of their AI research endeavors. Complementary studies could be conducted to delve into the research dynamics of nations with lower levels of AI scientific output. Ultimately, the choice to focus on the 24 top AI-publishing countries represents a strategic balance between comprehensiveness and feasibility, yielding a focused and in-depth perspective on research trends and patterns within the global epicenters of this transformative field.

Figure 8 illustrates the percentage distribution of publications across the years under consideration, revealing that China and the USA collectively account for nearly 50% of the publications. Specifically, the USA's contribution peaks at 35% in 1995, while China reaches the same percentage in 2023.

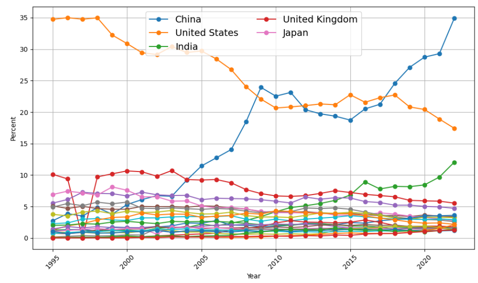
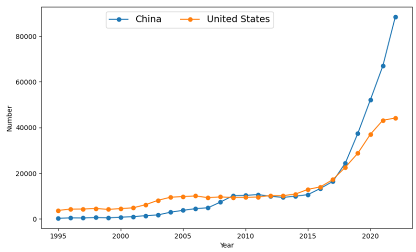
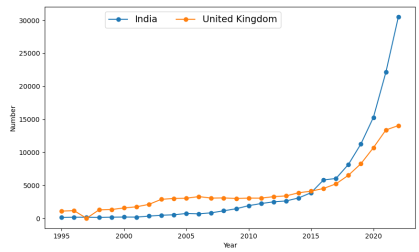


Figure 8: Percentage of Publications by Country.

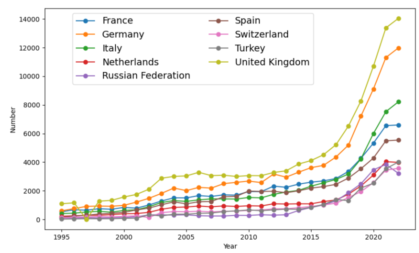
To better appreciate the trend for each of the countries, a cumulative trend analysis was conducted, displaying subsets of selected states for similarities in subsequent figures. Figure 9a shows the trend for the



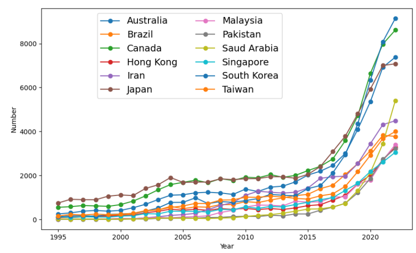
(a) China and USA



(b) India and UK



(c) Europe



(d) Other States

Figure 9: Cumulative growth of publications.

USA and China, which are the states with the highest number of publications. Figure 9b shows the trends for India and the UK, while figure 9c shows some of the European states. Finally, figure 9d displays the trends for the other states.

3.4 Keywords Analysis

The analysis of keywords in research articles on Artificial Intelligence (AI) from 1995 to 2023 represents a wealth of information for understanding global trends in this constantly evolving field. By examining the most frequent keywords in articles, we can identify the most popular themes and research areas within the field of AI during a specific period. This allows us to track the evolution of research interests over time and identify emerging trends. Keywords, that are usually inserted by authors, can also provide insights into the methodological approach used by researchers. For example, the presence of statistical terms may indicate the use of data-driven models, while keywords related to machine learning may suggest the use of machine learning algorithms. By examining the most frequent keywords in strategic years, we can identify dominant themes, prevalent methodological approaches, and the impact of AI across various spheres of society. This approach offers several advantages, including the ability to highlight long-term trends, reduce complexity, and optimize resources.

To do this, the years 2010, 2015, 2020, 2021, 2022, and 2023 were selected, all following the rapid growth of AI on the international scene. For each year, the top 160 most recurring keywords were extracted. Before conducting any analysis, the list of extracted keywords was processed using some Natural Language Processing techniques (NLP) (Cambria and White, 2014) to eliminate keywords that lexically express the same concept. To perform the filtering from this list of keywords after transforming all strings to lowercase, the following steps were carried out:

1. Synonym Identification: WordNet (Pedersen et al., 2004), a lexical database of English words, was used to identify synonyms for each keyword. WordNet provides relationships between words, including synonyms, antonyms, hyponyms (more specific words), and hypernyms (more general words).

2. Acronym Expansion: Using an acronym dictionary, the acronyms and abbreviations found in the list of keywords were expanded.

3. Similarity Calculation: For each keyword, cosine similarity with its potential synonyms or acronym expansions was calculated (Wang and Dong, 2020). A removal threshold of 0.8 was chosen.

These operations allowed for the calculation of the overall occurrence count of each keyword in a given year, shown in Table 3, thus enabling the determination of the top 10 most recurring keywords for each of the years.

To comprehend the trends of interest in specific areas of artificial intelligence, we elected to investigate the top 15 keywords appearing across approximately

Table 3: First 10 keyword for year, where AI, ML, CNN, NLP stands for Artificial Intelligence, Machine Learning, Convolutional neural networks, Natural Language Processing respectively.

2015	2010	2020	2021	2022	2023
AI	AI	ML	Human	ML	ML
Genetic Algorithm	Human	Decision Tree	ML	Human	Deep Learning
Algorithm	Algorithm	CNN	CNN	CNN	Human
Article	Pattern Recognition	Learning Systems	Deep Learning	Deep Learning	CNN
Pattern Recognition	Article	Genetics	Learning systems	Article	Learning systems
Computer Science	Learning Systems	Article	AI	Female/Male	Article
NLP	Female/Male	AI	Data Analysis	Magnetic resonance imaging	AI
Feature Extraction	Computer Vision	Feature Extraction	Neural Networks	AI	Neural Networks
Artificial Neural Network	ML	Human	Controlled study	Neural Network	Female/Male
Controllers	Multilayer Neural Networks	Classification	Female/Male	Classification	Features Extraction

2 million publications on the subject, selected independently of the year (this procedure was conducted after filtering). Table 4 presents the top keywords and their respective ranks in each year, while Figure 10 depicts the ranking trend of the top 15 keywords. To facilitate the reader, the figure 10 is divided into two parts, in each of which the change of keywords ranking over the years can be observed. It can be noted that the keywords ”Controlled Study” and ”Human,” absent in the early years, have achieved high rankings (it is worth noting that a low position value indicates a high ranking), as well as ”Neural Networks” and ”Reinforcement Learning”. On the contrary, some keywords as ”Artificial intelligence” and ”Artificial Neural Network” have lost positions in the ranking.

Table 4: Main keyword and their ranking (first 160) in each year.

	2010	2015	2020	2021	2022	2023
Adult	21	27	14	14	21	22
Algorithm	3	3	18	15	16	18
Article	4	5	6	5	5	6
Artificial Intelligence	1	1	7	7	8	7
Artificial Neural Network	9	15	32	29	27	23
Classification	64	11	10	12	10	12
Computer Vision	17	8	25	16	19	20
Controlled Study	111	19	19	10	13	16
Convolutional Neural Network	-	47	3	3	3	4
Data Analysis	41	14	24	8	12	19
Deep Learning	-	79	51	4	4	2
Female/male	18	7	11	11	6	9
Forecasting	-	30	121	20	17	15
Human	122	2	9	1	2	3
Learning Systems	16	6	4	6	7	5
Machine Learning	23	9	1	2	1	1
Natural Language Processing Systems	8	-	21	23	18	13
Neural Networks	32	29	23	9	9	8
Pattern Recognition	5	4	-	-	-	-
Reinforcement Learning6	66	120	69	20	15	11

4 HIGHLY CITED PAPER

In this brief section, we aim to demonstrate that numerous articles of great interest have been published during the period under consideration.

In particular, we would like to highlight some of the most cited articles by listing them in chronological order.

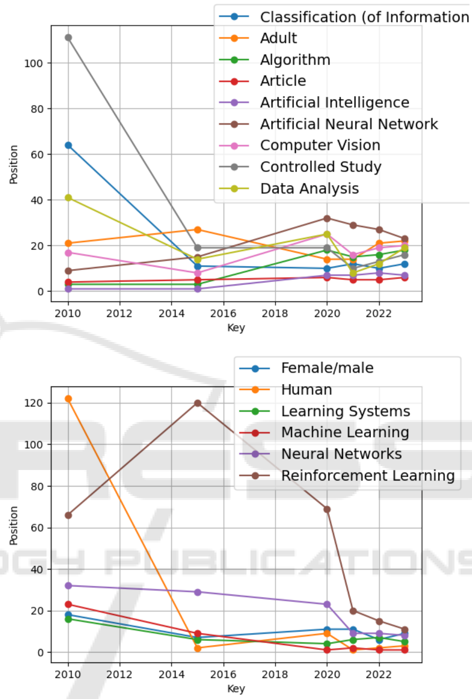


Figure 10: Trend of the top 15 keywords.

Among the 200 most cited articles in our dataset, the most cited article from 1995 (the first year of our analysis) is (Cortes and Vapnik, 1995). The main topics addressed in this article are the use of neural networks, particularly in the field of pattern recognition, which is one of the most common fields of application and on which researchers have focused their efforts in the field of AI. The most recent of the 200 most cited is (Jumper et al., 2021). The article presents a protein structure prediction approach based on deep learning and this shows how techniques have evolved and how the fields of application of greatest interest have changed

Finally, the two most cited articles with over 100,000 citations are (He et al., 2016) and (Livak and

Schmittgen, 2001). In (He et al., 2016) aims to address the challenges of training very deep neural networks and it propose a new framework called residual learning which makes it easier to train deeper networks compared to previous methods. (Livak and Schmittgen, 2001) falls within the field of molecular biology, with a specific focus on genetics and deals with the analysis of data obtained from real-time quantitative PCR (qPCR) experiments. These two articles further demonstrate that the trend in fields of application is increasingly shifting from computer vision to applications in the field of genetics.

5 CONCLUSION

The authors emphasize the value of examining reviews from previous years to gain a comprehensive understanding of the AI landscape. This longitudinal approach can reveal trends, patterns, and seminal contributions that might be missed by focusing solely on recent publications. The analysis has highlighted some peculiarities of publications in the AI field. Nevertheless, this analysis is still in its early stages. This could involve identifying emerging keywords, tracking changes in keyword usage over time, and exploring the relationships between different keywords.

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