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Article

Exploring the frontiers of artificial intelligence: A bibliometric analysis of high-impact research up to 2023

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Abstract: Artificial intelligence (AI) has rapidly evolved, transforming industries and addressing societal challenges across sectors such as healthcare and education. This study provides a state-of-the-art overview of AI research up to 2023 through a bibliometric analysis of the 50 most influential papers, identified using Scopus citation metrics. The selected works, averaging 74 citations each, encompass original research, reviews, and editorials, demonstrating a diversity of impactful contributions. Over 300 contributing authors and significant international collaboration highlight AI's global and multidisciplinary nature. Our analysis reveals that research is concentrated in core journals, as described by Bradford's Law, with leading contributions from institutions in the United States, China, Canada, the United Kingdom, and Australia. Trends in authorship underscore the growing role of generative AI systems in advancing knowledge dissemination. The findings illustrate AI's transformative potential in practical applications, such as enabling early disease detection and precision medicine in healthcare and fostering adaptive learning systems and accessibility in education. By examining the dynamics of collaboration, geographic productivity, and institutional influence, this study sheds light on the innovation drivers shaping the AI field. The results emphasize the need for responsible AI development to maximize societal benefits and mitigate risks. This research provides an evidence-based understanding of AI's progress and sets the stage for future advancements. It aims to inform stakeholders and contribute to the ongoing scientific discourse, offering insights into AI's impact at a time of unprecedented global interest and investment.

Keywords: AI; bibliometric analysis; citation metric; development

1. Introduction

Artificial intelligence (AI) has continued its unstoppable advance in 2022, with significant advances in several areas that promise further expansion of its capabilities and integration into various sectors. As the field celebrates new milestones, it also grapples with emerging ethical challenges and questions surrounding the social impact of AI (Antonov and Kerikmäe, 2020; Arees, 2022; Mustapa, 2023; Whittlestone and Clarke, 2022). Therefore, mapping the landscape of AI research is crucial to

understand its progress and guide its responsible development. This study aims to summarize the state-of-the-art in AI through a bibliometric analysis focusing on the 50 most influential articles of 2023.

AI has experienced remarkable growth over the past decade, driven by increased data availability, improved algorithms, and improved computing power (Adadi and Berrada, 2018; Sundaresan, 2019). According to Scopus data, the annual scientific output related to AI increased sixfold between 1996 and 2018, reaching more than 58,000 documents in 2018 alone. This intensity of research reflects the increasing interest of academics, corporations, and governments. The AI chip market, expected to grow from $10.6 billion in 2021 to $79.8 billion by 2027. This growth is indicative of the wider trend of increasing investments in AI technologies, as tech giants and startups alike rush to develop AI capabilities, driven by the strong demand for computing power in AI and machine learning applications. The proliferation of AI applications now extends to transportation, healthcare, education, finance, agriculture, criminal justice, and other areas. The transformative potential of AI has attracted global attention, and more than 30 countries have developed national AI strategies (Gao, 2022).

Recent advances have been made possible by groundbreaking advances in machine learning. Approaches such as deep learning have led to previously unattainable capabilities in computer vision, speech recognition, and natural language processing (Choi et al., 2020; Sharif et al., 2020; Wijethunga et al., 2020). In the field of computer vision, AI can now outperform humans in classifying images and detecting anomalies in medical scans (Albu et al., 2020; Choi et al., 2020; Sarvamangala and Kulkarni, 2022). When it comes to natural language processing, advanced models like GPT-3 demonstrate surprising linguistic proficiency and syntactic variation (Nath et al., 2022). This rapid development highlights the potential for AI to match or exceed human capabilities for certain tasks.

Healthcare is an area that is experiencing an AI revolution. Applications range from accelerating drug development to improving diagnostic accuracy. Artificial intelligence-powered medical devices, such as IDx-DR, have received regulatory approval after demonstrating the diagnosis of expert-level diabetic retinopathy. Another important application area is autonomous vehicles (AVs). AI enables AVs to perceive, interpret, and respond to complex environments. Together with lidar and radar, deep learning-powered computer vision supports robust scene understanding and object detection capabilities (Caesar et al., 2020; Feng et al., 2021; Gao et al., 2018). However, despite rapid advances, AI must overcome hurdles related to model errors, cyberattacks, and validation before public trust and acceptance can emerge (Kim and Park, 2020; Sabeel et al., 2021). As the speed of AI innovation increases, it will also be essential to critically analyze the development process from a scientific perspective.

As the pace of AI innovation accelerates, it is essential to critically analyze its development trajectory from a scientific perspective. The aim of our study is to explain the state-of-the-art in 2023 and identify critical issues by examining the 50 most influential papers based on citations in Scopus. Citation counts provide a quantitative indicator of impact and are often used to assess the importance of research. Frequently cited works are recognized as groundbreaking contributions that break new ground or

strengthen understanding of important topics. The application of bibliometric techniques to examine these works provides a robust methodology to map the landscape of AI knowledge (Borgohain et al., 2022; Tran et al., 2019).

Our analysis covers multiple facets, including influential authors, institutional contributions, and geographic distribution. This multidimensional perspective will reveal the dynamics driving innovative AI advances worldwide. The results are intended to inform policymakers, researchers, and practitioners about new trends and promising directions for the further development of AI. As technology increasingly penetrates society, an evidence-based understanding of developments in this area is essential. Our targeted bibliometric analysis of AI research in 2023 will support a nuanced synthesis to support ongoing efforts to maximize benefits and mitigate risks.

Beyond scientific advancement, the study addresses critical challenges associated with AI, including ethics, safety, and societal impact. Key concerns such as algorithmic bias, privacy, and accountability are becoming increasingly prominent as AI systems influence decision-making in areas like healthcare, education, and public policy. Our research underscores the need for responsible innovation, highlighting the importance of ethical guidelines, safety protocols, and inclusive practices to ensure AI serves humanity equitably. By synthesizing these insights, we aim to support ongoing efforts to maximize AI's benefits while mitigating its risks in an increasingly interconnected world.

2. Method

This study is based on bibliometric analysis, a quantitative research methodology that provides a systematic means of reviewing and evaluating the scientific literature on a specific topic (Ahmad et al., 2023; Watrianthos et al., 2023). Bibliometric techniques are particularly suited to discerning the structure, growth, and thematic development of scientific fields, making them invaluable for studying the vast and diverse field of artificial intelligence (AI). The utility of bibliometrics lies in its ability to analyze large data sets to identify trends, major contributors, and seminal works, thus providing a macroscopic view of academic development and intellectual capital of the discipline (Samala et al., 2023; Watrianthos and Yuhefizar, 2023; Windarto et al., 2023).

The choice of bibliometric analysis is determined by its robustness in navigating the vast and complex landscape of AI research. As the AI literature is characterized by rapid expansion and interdisciplinary influences, bibliometrics provides an objective mechanism to assess the spread of knowledge, define research networks, and highlight areas of growing interest (Gorraiz, 2021; Mshvidobadze, 2021; Ninkov et al., 2022; Supriadi et al., 2023). This method is particularly suitable for our goal of mapping the latest developments within AI and enabling an organized synthesis of the scientific discourse in the field and its emerging directions.

Our analysis uses the Scopus database, a leading repository known for its comprehensive coverage of peer-reviewed literature from all academic disciplines, including the fields of technology and computer science (Burnham, 2006; Negahdary et al., 2018). Scopus is valued for its comprehensive indexing of journal articles, conference papers, and book chapters, ensuring a comprehensive aggregation of AI-

related research results. This data source was selected for its reliability, validated by rigorous indexing standards, and its ability to support advanced bibliometric calculations (Ahmad et al., 2020). The methodology includes a targeted keyword search for 'artificial intelligence' in the publication year 2023, with data extraction occurring in January 2024. This time limit ensures a targeted examination of the current discourse in AI research and captures the latest scientific contributions and innovations. The search strategy was carefully designed to cover a wide range of AI research. Specific filters were applied to narrow the search results to the most relevant publications.

After data collection, we used bibliometric indicators that included publication volume, citation counts, influential authors, sources, affiliation, and country to analyze the AI research landscape. These key figures provide information on the productivity of research contributions, the structure of scientific collaboration, and thematic concentrations within the field over 2023. The use of recognized bibliometric software facilitated the handling of large data sets and the visualization of complex networks, thus improving the clarity and interpretability of our results (Aria and Cuccurullo, 2017). Following this framework, we analyzed the results to uncover key patterns in AI research.

3. Result and discussion

As part of our bibliometric analysis covering the field of artificial intelligence in the period 2023, a comprehensive study of 50 carefully selected documents was carried out. These documents come from 46 different sources, including journals and books, and represent the pinnacle of AI research for this period. The corpus of our investigation, delineated by its unique temporal focus, provides an insightful glimpse into the dynamic and evolving world landscape of artificial intelligence research. The noticeable impact of these works is underlined by an average citation count of 74.32 per document. This metric not only underlines the scientific influence and academic recognition of the selected works, but also serves as evidence of their central role in the ongoing discourse within the AI community.

The diversity of research in this area is further illuminated through keyword analysis, with 435 Keywords Plus (ID) and 157 Author Keywords (DE) identified. This breadth of topics illustrates the extensive and multilayered nature of AI research, which covers a wide range of topics and areas of investigation. Central to our findings is the remarkable level of collaboration between researchers. With 300 authors contributing to the data set and an average coauthor rate of 6.08 per document, the data illustrate a vibrant culture of scientific collaboration. In particular, 60% of these collaborations span international borders, underscoring the global scale of AI research efforts. This aspect is particularly important because it highlights the intercultural and interdisciplinary nature of the field and promotes a rich exchange of ideas and methods. The composition of the documents, including 28 articles, 1 book chapter, 4 editorials, 2 notes, 14 reviews, and 1 short survey, reflects the various mechanisms through which AI research results are disseminated. This diversity not only meets different scientific needs and preferences but also underlines the multi-layered approach to research communication in the AI field.

The results of our bibliometric analysis of the 50 most influential papers of 2023 provide in-depth insights into the current state and future directions of artificial intelligence research. The significant citation average per document is an indication of the great influence of these publications within the academic community and suggests that they play a central role in shaping the discourse and development of AI research. The diversity of document types and high levels of international collaboration uncovered in our analysis reflect the inherently global and interdisciplinary nature of artificial intelligence as a research field. Such collaborations not only demonstrate general interest and investment in AI research but also suggest a collective movement to address complex, global challenges through the lens of artificial intelligence.

Examining the groundbreaking contributions to artificial intelligence from a 2023 perspective, our research compiled a list of key sources from which the 50 most influential publications came. This selection of sources, which includes journals and books from a wide range of disciplines, provides a rich spectrum from which to recognize the complexity of AI research. In particular, the distribution of articles across these sources paints a clear picture of the interdisciplinary reach and diverse applications of AI. The distribution of articles, including two each in Cellular and Molecular Bioengineering, Human Resource Management Review, Information Systems Frontiers and Nature, as well as individual contributions in journals such as ACM Computing Surveys and Applied Nanoscience (Switzerland), underlines the far-reaching interdisciplinary impact of AI research. This diversity means deep integration of AI technologies across different sectors and highlights the technology's versatility and adaptability to address specific domain challenges. The inclusion of fields such as bioengineering, human resource management, and sports biology highlights the growing limits of AI's applicability and demonstrates its relevance and utility beyond traditional computing domains.

The presence of articles in both high-impact, broad-based journals such as Nature and more specialized publications such as ACM Computing Surveys illustrates a solid balance between core scientific research and applied research within the AI landscape. This balance suggests a vibrant research ecosystem where fundamental advances in AI are coupled with practical, real-world applications, fostering a dynamic feedback loop that drives the field forward. The analysis also highlights emerging trends within AI, particularly in critical areas such as healthcare care, as demonstrated by the inclusion of the book "Artificial Intelligence in Health Care: The Hope, The Hype, The Promise, The Peril" (Matheny et al., 2019). This focus on healthcare underscores the growing recognition of AI's potential to revolutionize medical diagnostics, treatment planning, and patient care, among other areas. Furthermore, the geographical diversity of the publication origins, from the Central European Management Journal to the Applied Nanoscience (Switzerland), reflects the global nature of AI research efforts and contributions and emphasizes global collaboration and knowledge sharing within the field.

Applying Bradford's law to AI research in 2023 reveals a focused yet expansive field in which a core group of journals dominates the majority of the influential discourse. This concentration within core journals not only makes it easier for researchers to gain targeted access to groundbreaking work, but also underlines the efficiency of knowledge dissemination in AI. Applying Bradford's Law to the 2023

AI research landscape identified journals such as Cellular and Molecular Bioengineering, Human Resource Management Review, Information Systems Frontiers and Nature as part of the first zone. These journals are characterized by a high frequency of citations and important publications, highlighting critical avenues for AI discourse and discovery.

This table shows the 10 most prolific journals publishing AI research in 2023, across specialty areas such as bioengineering, computer science, nanotechnology, biomedicine, and management science. Nature stands out as the only broad-based multidisciplinary journal in the top group. The full concentration pattern shows that these top 10 account for 14% of all AI articles, the next 21 journals account for 42%, and the remaining 44% come from a diffuse long tail of over 20 journals. In addition, the interdisciplinary reach of AI, which is reflected in the diversity of the most important specialist journals, speaks to the transformative potential of AI technologies. The expansion to larger areas reflects a vibrant field rich in diverse contributions and perspectives. The identified core journals serve as a beacon for cutting-edge research and discussion, guiding both new and established researchers through the vast, interdisciplinary landscape of AI. This analysis not only highlights the essential role of these journals in shaping AI research but also confirms the value of Bradford's law as a tool to understand the distribution and impact of the scientific literature (**Table 1**).

Table 1. The 10 most productive journals publishing AI research in 2023.

Zone	Rank	Journal
1	1	Cellular and Molecular Bioengineering
1	2	Human Resource Management Review
1	3	Information Systems Frontiers
1	4	Nature
1	5	ACM Computing Surveys
1	6	Applied Nanoscience (Switzerland)
1	7	Artificial Intelligence in Health Care: The Hope, The Hype, The Promise, The Peril (Matheny et al., 2019)
1	8	Biology of Sport
1	9	Central European Management Journal
1	10	Chemical Science

Analysis of authorship patterns provides several important insights into the productivity and local influence of researchers in the field. In terms of productivity, a small subset of authors published most of the articles, with the top four authors (ChatGPT, Leskovec J, Liu Y, and Zhou X) each credited with two articles in 2023. ChatGPT is characterized by a high fractional count of 0.83, indicating the primary authorship of most of his works. Outside the top four, authorship is very diffuse, with 167 individual authors, but most only publish one article. Productivity analysis shows that the AI system ChatGPT is the top author by volume. This suggests that ChatGPT was responsible for the majority of the text of its published works, demonstrating the AI's ability to produce academic-style scientific texts.

In terms of local impact, ChatGPT stands out again with its fractional number of 0.83, reflecting the increasing role of AI as a primary contributor to the production of high-quality articles. The average local influence of 0.21 for human authors shows that moderate collaboration is the norm. A range of 0.1 to 0.3 corresponds to shared authorship practices in science for most researchers. The importance of ChatGPT shows the growing influence of AI as an academic "author" in computer science research. His position as a leading publishing researcher underscores the rapid advances in generative AI's ability to create compelling scholarly texts. Although AI does not conduct independent research, its role in producing complete manuscripts suitable for publication has only become notable in the last year. For human researchers, patterns of diffuse collaborative authorship reflect team science as the standard in this interdisciplinary field. Although a handful of outstanding human experts make critical contributions, moderate partial counts suggest that contributions are largely collaborative efforts. Observing whether AI like ChatGPT begins to displace or complement human authors will provide insight into AI's evolving ability to replace or support human research.

Our analysis carefully compiles and examines the contributions of academic and research institutions in the field of artificial intelligence (AI) in 2023. The State University of New Jersey is a leader in this field, with an unprecedented contribution of 28 articles that highlight its central role in AI research. The University of California San Diego and the University of California follow closely behind with notable contributions of 8 and 7 articles, respectively. This distribution not only highlights the significant achievement of these institutions, but also highlights the depth of research and development in the field of AI.

The importance of institutions such as Stanford University, Harvard University, and the Massachusetts Institute of Technology in our results underscores the central role established research universities play in the advancement of AI research. Their consistent performance and influence within the AI community exemplifies the culmination of robust research ecosystems, extensive funding, and collaborative networks that drive groundbreaking discoveries and innovations. Additionally, the global representation in our dataset, which includes contributions from the United States, the United Kingdom, Canada, Australia, Slovakia, and China, among others, highlights the widespread interest and investment in AI technologies around the world. This diverse geographical distribution reflects not only the universal appeal of AI, but also the collaborative potential across borders, cultures, and disciplines.

Our study delves into the geographical landscape of artificial intelligence (AI) research papers and citations in 2023 and provides a detailed examination of global dynamics in the field. The analysis identifies the United States as a leader in citations in AI research and underscores its prominent position in generating influential scholarly work within the AI community. Close behind are China, Canada, the United Kingdom, and Australia, each making significant contributions that have received widespread international recognition. This citation pattern not only highlights these countries' lead in AI research, but also reflects their established infrastructures, funding, and collaboration networks that support impactful studies in the field. When we turn our attention to research productivity measured by volume of publications, the United States once again emerges as the frontrunner and reaffirms its dominance in AI

research efforts. China, Canada, the United Kingdom, and Australia are following suit, reinforcing the link between high research performance and global influence. Additionally, nations such as India, Poland, South Korea, and Turkey mark their presence with notable contributions, demonstrating the diverse and widespread involvement in AI research around the world, see **Figure 1**.

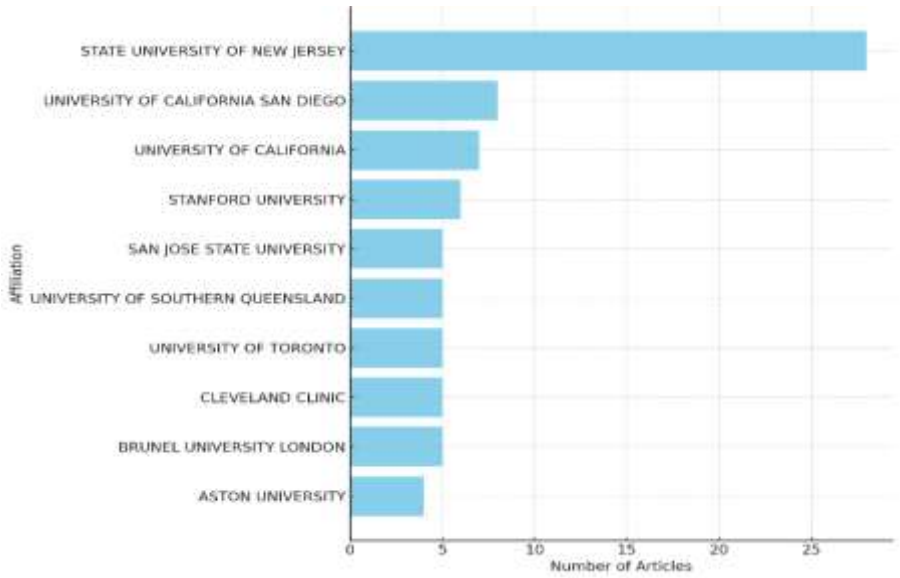

Figure 1. Top 10 affiliations by the number of articles publishing AI research in 2023.

The United States' unparalleled position in both citations and productivity underscores its integral role in steering global AI research and innovation. This dominance is due to its comprehensive ecosystem, which includes respected academic institutions, extensive research funding, and synergistic collaborations between academia and industry. China's prominent position in the rankings demonstrates its upward trajectory in AI research and reflects a robust and rapidly developing research infrastructure. Similarly, Canada, the United Kingdom, and Australia highlight the existence of fertile research environments that support groundbreaking AI work, reflecting their strategic investments and policy frameworks to support AI innovation. The inclusion of countries such as India, Poland, South Korea, and Turkey in the productivity analysis underscores the global reach and collaborative spirit of AI research. This broad participation expands the field of artificial intelligence with a wide range of perspectives, methods, and innovations, contributing to a more comprehensive and inclusive research landscape.

4. Conclusion

Our comprehensive bibliometric analysis, focused on the field of artificial intelligence (AI) research in 2023, has carefully mapped the landscape of scientific contributions, collaborations, and knowledge dissemination across a global spectrum. By looking at 50 selected documents from a variety of sources, including renowned journals and groundbreaking books, we uncover key insights that underscore the vibrant and dynamic nature of AI research at this time. This analysis has not only

highlighted the profound impact of these works, as evidenced by an average citation count of 74.32 per document, but also illuminated the rich, multi-layered discussions that permeate the AI community. Central to our findings is the identification of a rich collaboration with 300 authors contributing to a corpus that underlines a culture of vibrant scholarly exchange. In particular, this collaboration often crosses national borders, with 60% of the work involving international partnerships, highlighting the global dimension and inherently intercultural and interdisciplinary nature of AI research. The diversity in the form of dissemination, from articles and book chapters to editorials and reviews, also reflects the different channels through which AI research results are communicated to the broader scientific community.

Applying Bradford's law to our data set has revealed a concentrated but wide-ranging field of AI research, in which a core group of journals emerge as central hubs for AI discourse and discovery. This pattern not only makes it easier for researchers to gain targeted access to groundbreaking work but also illustrates the efficiency of knowledge dissemination in the AI field. Furthermore, the analysis of authorship patterns has provided interesting insights into productivity and influence within the field, particularly highlighting the emerging role of AI-generated academic contributions alongside human researchers. Our study highlights the urgent need to foster deeper international collaborations and build more inclusive research ecosystems that can leverage diverse perspectives and expertise around the world. The interdisciplinarity uncovered by our analysis suggests enormous untapped potential for cross-sector innovation that could further accelerate progress in AI. As AI continues to shape diverse sectors beyond traditional computing domains, its potential to address complex global challenges and transform industries underscores the importance of our work. In this way, our research not only enriches the academic discourse on AI, but also lays the foundation for future innovations designed to improve societal well-being and economic development around the world.

Author contributions: PHP; methodology, RR; software, ES and DA; validation, ODA, KW, RM and ET; formal analysis, IFR; investigation, ET and AR; resources, PHP; data curation, RR; writing—original draft preparation, RR; writing—review and editing, RR, ES and DA; visualization, RR; supervision, ES; project administration, DA, RM and DAM; funding acquisition, RR. All authors have read and agreed to the published version of the manuscript.

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