Asian Journal of Research in Computer Science

Volume 17, Issue 12, Page 220-233, 2024; Article no.AJRCOS.124702
ISSN: 2581-8260

A Bibliometric Analysis of Global Research Trends in Artificial Intelligence from 2019 to 2023

Ellen A. Abanga [a*] and Theophilus Acquah [b]

[a] Academic City University, Accra, Ghana.
[b] Ghana Communication Technology University, Ghana.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajrcos/2024/v17i12540

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/124702

Original Research Article

Received: 14/10/2024
Accepted: 18/12/2024
Published: 26/12/2024

ABSTRACT

This bibliometric analysis examines global research trends in Artificial Intelligence (AI) from 2019 to 2023, using 7,030 Scopus indexed documents. The study found an annual growth rate of 25.93%, indicating a substantial increase in AI research effort. The majority of articles were created by collaborative teams, with an average of 4.28 authors per paper, with only 415 being single-authored. IEEE Access is the most prolific contributor, King Saud University is the leading institution, and China is the main publishing country, with 1,277 corresponding authors and the highest citation count (19,873). Thematic analysis highlights a strong emphasis on machine learning, deep learning, and neural networks as foundational topics, alongside growing interest in ethical AI and convolutional neural networks, signaling the field's evolution toward addressing societal challenges and specialized applications. International collaboration plays a significant role, with 31.31% of publications involving authors from multiple countries. While the volume of AI research grows, newer articles have lower average citations due to their recent publication date.

**Corresponding author: E-mail: ellen.abanga@acity.edu.gh;*

Cite as: *Abanga, Ellen A., and Theophilus Acquah. 2024. "A Bibliometric Analysis of Global Research Trends in Artificial Intelligence from 2019 to 2023". Asian Journal of Research in Computer Science 17 (12):220-33. https://doi.org/10.9734/ajrcos/2024/v17i12540.*

These findings highlight the interdisciplinary and worldwide nature of AI research, as well as its transformational potential for academia, industry, and policymakers. By mapping major trends and contributors, this report gives significant insights into the changing AI landscape, identifying potential for improving worldwide research collaboration and addressing growing difficulties in the field.

Keywords: Artificial intelligence; bibliometric analysis; machine learning; global collaboration; AI research trends.

1. INTRODUCTION

The theory of artificial intelligence (AI) integration focuses on leveraging AI technology to enhance and optimize existing systems or processes. AI is capable of autonomously processing data and information by utilizing predefined algorithms (Wang et al., 2021). Artificial Intelligence (AI) has transitioned from a conceptual field of study to a transformative technology that is reshaping the modern world (Dwivedi et al., 2021). Early AI research focused on symbolic reasoning and rule-based systems, where computers were programmed to follow a set of predefined rules (Calegari et al., 2021). However, these early systems were limited by their inability to handle uncertainty or learn from new data, confining their practical applications to narrow, well-defined domains (Calegari et al., 2021).

The 21st century has seen an explosion of interest in AI, driven largely by breakthroughs in machine learning, particularly deep learning, and the rise of big data (Pugliese et al., 2021). Deep learning, a subfield of machine learning that uses neural networks with many layers, has proven to be exceptionally powerful in tasks such as image recognition, natural language processing, and autonomous systems (Pugliese et al., 2021). These advances have been fueled by the availability of vast amounts of labeled data, increased computational resources through GPUs and cloud computing, and improved algorithms that allow for more efficient training of large models (Jauro et al., 2020).

The interdisciplinary nature of AI has also expanded its influence across a wide range of fields, from healthcare and finance to education, logistics, and even the arts (Dwivedi et al., 2021). In healthcare, AI is being used to develop diagnostic tools that can detect diseases at earlier stages than human doctors, while in finance, AI algorithms are employed to predict market trends and optimize investment strategies (Saraswat et al., 2022). The educational sector is seeing the rise of AI-powered personalized learning platforms, and in the creative industries, AI is being used to generate music, art, and even literature. This broad applicability of AI underscores its potential to impact nearly every aspect of modern life (Bhutoria, 2022).

At the same time, the growing integration of AI into society raises important ethical and social questions. Concerns about bias in AI algorithms, the potential for mass surveillance, and the displacement of human labor by automation are driving discussions about how to develop AI responsibly (Sarker et al., 2021). These challenges highlight the need for ongoing research into not only the technical aspects of AI but also its societal implications (Sarker et al., 2021).

Given the rapid advancements in AI and its far-reaching effects, it is crucial to track research trends within the field (Liu et al., 2021). Understanding where AI research is concentrated, who the leading contributors are, and which topics are emerging can provide valuable insights for both academic researchers and industry practitioners (Dwivedi et al., 2021). By employing bibliometric analysis, this study seeks to map the global landscape of AI research, identifying the most influential works, authors, and regions (Tran et al., 2019). This approach will help to illuminate the trajectory of AI development and highlight areas of opportunity and potential gaps in the current body of knowledge (Tran et al., 2019).

The justification and significance of this study are grounded in four key research questions that guided the analysis. The primary aim is to explore the trends in current artificial intelligence research, identifying the source titles, organizations, authors, and countries contributing the most to the academic output on this topic. Drawing from Chen et al. (Chen et al., 2022), the following research questions were developed: RQ1: What are the most cited papers in the field of AI? RQ2: What are the trends in AI research over a time of five years? RQ3: Who are the

leading researchers in the domain of AI? RQ4: How has collaboration between authors, countries evolved in the field of AI?

This paper contributes to the growing body of literature on AI by providing a comprehensive bibliometric analysis of AI research from 2019 to 2024. Using data from the Scopus Core Collection database, we will examine publication trends, identify highly cited papers and influential authors, and assess the contributions of various countries and institutions to the advancement of AI. By analyzing patterns in AI research, this study aims to provide a clearer understanding of how AI is evolving as a discipline and offer guidance for future research directions.

2. LITERATURE REVIEW

2.1 Artificial Intelligence

Artificial Intelligence (AI) has been a rapidly growing area of research, driven by the increased availability of data, advances in computational power, and breakthroughs in algorithmic design (Górriz et al., 2020). The literature on AI encompasses a broad spectrum of topics, from theoretical foundations to practical applications in various industries (Dwivedi et al., 2021). A key focus has been on machine learning (ML), particularly deep learning, which has shown remarkable progress in fields such as computer vision, natural language processing (NLP), and robotics (Soori et al., 2023).

2.2 Advancements in AI and Machine Learning

Machine learning is often regarded as the core of AI, where algorithms learn patterns from data and make predictions or decisions without being explicitly programmed (Soori et al., 2023). Early advancements in AI were primarily rule-based systems, relying heavily on human-coded logic (Ahmad et al., 2022). However, the shift towards data-driven methods, particularly through supervised learning, unsupervised learning, and reinforcement learning, has been transformative (Chakraborty et al., 2024).

Deep learning, a subfield of machine learning, has garnered significant attention due to its ability to process vast amounts of unstructured data and its success in achieving human-level performance in complex tasks (Chakraborty et al., 2024). For instance, convolutional neural networks (CNNs) have revolutionized image recognition, enabling breakthroughs in fields such as autonomous vehicles and facial recognition (Turay and Vladimirova, 2022). Similarly, recurrent neural networks (RNNs) and long short-term memory networks (LSTMs) have advanced NLP tasks like speech recognition, translation, and text generation (Fatima et al., 2022).

In recent years, the emergence of generative models, particularly Generative Adversarial Networks (GANs) has opened new avenues for AI research (Lu et al., 2022). GANs have been used to generate highly realistic images, videos, and even deepfakes, raising both excitement for creative applications and concerns over ethical implications (Lu et al., 2022).

2.3 Natural Language Processing and AI

Natural language processing (NLP) is another critical area where AI has made significant strides. Natural Language Processing (NLP) is a study and application area that investigates how computers may be used to comprehend and modify natural language text or speech to perform useful tasks (Kang et al., 2020). The introduction of transformer-based architectures has significantly improved the performance of NLP tasks (Raparthi et al., 2021). Models like BERT and GPT-3 have demonstrated unprecedented capabilities in understanding and generating human-like text. BERT’s ability to consider the context of a word from both directions in a sentence has led to state-of-the-art results in tasks such as question answering and sentence classification (Yenduri et al., 2024). GPT-3, on the other hand, with its massive 175 billion parameters, has shown impressive results in generating coherent and contextually appropriate text across various domains (Yenduri et al., 2024).

These advances in NLP have been applied to real-world problems such as virtual assistants (e.g., Siri, Alexa), automated customer service, and even content creation, highlighting AI's increasing presence in everyday life (Paliwal and Bharti, 2022). However, challenges remain in achieving true language understanding and avoiding biases embedded in training data, which can perpetuate stereotypes or discriminatory behavior (Kotek et al., 2023).

2.4 AI in Healthcare

AI's application in healthcare has been transformative, particularly in medical imaging,

drug discovery, and personalized medicine (Ahmadi et al., 2023). Studies have shown that AI systems can perform at or above the level of human experts in diagnosing diseases from medical images, such as detecting cancers from radiological scans (Secinaro et al., 2021). Furthermore, AI algorithms are being used to analyze genomic data, accelerating the development of personalized treatment plans tailored to individual patients' genetic profiles (Sollini et al., 2020).

AI-driven drug discovery is another growing area, where machine learning models are used to predict the effectiveness of new compounds, reducing the time and cost of drug development (Gupta et al., 2021). Companies like DeepMind have demonstrated AI's potential in solving complex biological problems, such as protein folding, through the application of deep learning models (Gupta et al., 2021).

Despite these successes, the adoption of AI in healthcare is accompanied by ethical and regulatory challenges. Issues of data privacy, security, and the need for explain ability in AI-driven decisions are central to ongoing debates about the role of AI in critical areas like healthcare (Amann et al., 2020).

2.5 AI in Industry

AI's impact on industries such as finance, manufacturing, and logistics is also well-documented. In finance, AI-driven algorithms are used for fraud detection, algorithmic trading, and customer service automation (Gupta et al., 2021). In manufacturing, AI is applied in predictive maintenance, quality control, and supply chain optimization, improving efficiency and reducing costs (Soori et al., 2023). Similarly, AI-powered robotics and automation systems are transforming logistics and warehousing, enabling more intelligent inventory management and faster fulfillment times (Soori et al., 2023).

2.6 AI in Education

AI-powered virtual assistants provide personalized support by answering questions, offering feedback, and recommending resources. Additionally, they automate administrative tasks like grading, scheduling, and responding to frequently asked questions, allowing educators to focus more on teaching and mentoring. Chatbots also enhance interactivity and motivation by gamifying learning experiences, as seen with tools like Georgia State University's "Pounce" and Duolingo's conversational chatbot (Harry and Jati, 2023).

AI has also significantly improved the grading and assessment process by automating tasks and delivering instant, objective feedback. Automated essay grading systems, for example, use natural language processing to evaluate written responses, ensuring consistent and unbiased assessments while reducing educator workload (Harry and Jati, 2023).

2.7 AI in Agriculture

AI is positioned as a critical tool to enhance productivity, efficiency, resilience, and sustainability in the agricultural sector (Liu, 2020). AI optimizes agricultural production management by supporting tasks such as crop rotation planning, planting schedules, water and nutrient management, pest control, disease prevention, efficient harvesting, and supply chain management (Liu, 2020).

AI-powered crop monitoring tools, utilizing deep learning, efficiently identify issues like nutrient deficiencies and plant diseases, surpassing the capabilities of traditional methods. Data science applications in farming enable real-time analysis of variables like weather, soil, and water usage, providing farmers with actionable insights to optimize resources. AI-based image recognition systems play a crucial role in early disease detection, helping to manage plant health more effectively and reduce economic losses (Liu, 2020).

2.8 AI Ethics and Security

The growing influence of AI in sensitive domains has raised concerns about fairness, accountability, and transparency (Memarian and Doleck, 2023). Research by Okeh (Okeh, 2024) and Editorial (Editorial, 2021) has highlighted how AI systems can perpetuate biases present in the training data, leading to unfair outcomes in areas such as hiring, criminal justice, and credit scoring. The rise of algorithmic decision-making systems has prompted calls for more robust frameworks to ensure that AI technologies do not reinforce societal inequalities (Sartori and Theodorou, 2022).

Fairness in AI is now a prominent research area, with scholars focusing on developing algorithms that mitigate bias and promote equitable outcomes (Sartori and Theodorou, 2022). Techniques such as fairness-aware machine

learning and adversarial debiasing are being explored to address these challenges, but there is still much work to be done in ensuring that AI systems are transparent, interpretable, and aligned with ethical norms (Yang et al., 2024).

3. METHODOLOGY

3.1 Source of Bibliometric Data and Search Strategy

The Scopus database was used to identify research articles on artificial intelligence. The search was conducted on December 15, 2024, using the following search strategy: TS = (artificial AND intelligence). A publication timespan from 2019 to 2023 was set, coinciding with the rapid technological advancements and increased world interest in this area. This period captures the most relevant studies on the topic.

3.2 Inclusion and Exclusion criteria

To ensure accurate interpretation of the results, publication language was restricted to English, while other fields were limited to computer science, engineering and social sciences and limited to conference papers and articles. The study was limited to only open access articles and limited to keywords like artificial intelligence, machine learning and deep learning. All other fields were included.

3.3 Bibliometric Data and Analysis tool

A total of 7101 documents were retrieved from the Scopus database for this study. These records were first carefully exported to CSV and BibTex. Following this, the data was analyzed using the Biblioshiny application, which provides a comprehensive graphical web interface within the RStudio environment (version 4.4.1). This tool was accessed on December 15, 2024, and allowed for an in-depth bibliometric analysis, facilitating the visualization and exploration of trends, patterns, and key metrics within the retrieved dataset. The combination of these tools ensured a robust and thorough analysis of the research landscape related to deepfakes on social media.

4. RESULTS

4.1 Distribution of Document Type

From 2019 to 2023, a total of 7,101 English publications related to artificial intelligence were indexed in the Scopus database. The 7,101 documents were further analyzed using the biblioshiny application to identify and exclude articles indexed under multiple document types. As a result, 71 anomalies were found and removed. After excluding these anomalies, the dataset was reduced to 7,030 documents for the final analysis shown in (Table 1). These documents included 5,140 original research articles and 1,890 conference papers.

Table 1. Distribution of document types on artificial intelligence published between 2019 and 2023 (N = 7030)

Document Type	Results
Article	5098
Article article	42
Article conference paper	12
Conference paper	1861
Conference paper article	9
Conference paper conference paper	8

4.2 Annual Scientific Production

Table 2 illustrates the Annual Scientific Production of articles from 2019 to 2023, as analyzed in the Biblioshiny interface of Bibliometrix. Over this five-year period, there is a noticeable upward trend in scientific production, starting with 730 articles in 2019 and peaking at 1,981 articles in 2022, representing a substantial increase in research activity. However, in 2023, the number of articles slightly declined to 1,836, following the peak in 2022. This overall growth trend, particularly the sharp rise between 2019 and 2022, suggests an increasing focus or advancements in the research domain being analyzed.

Table 2. Annual Scientific Production on artificial intelligence from 2019 to 2023

Year	Articles
2019	730
2020	1255
2021	1228
2022	1981
2023	1836

4.3 Average Citations Per Year

Table 3 summarizes the average citations per year for articles published between 2019 and 2023. It provides important metrics such as the Mean Total Citations per Article (MeanTCperArt), the number of articles published each year (N), the average citations per year (MeanTCperYear), and the total number of years these publications

have been citable (Citable Years). The data reveal a consistent reduction in the Mean Total Citations per Article, which fell from 31.82 in 2019 to 7.76 in 2023, demonstrating that earlier articles received much more citations over time. Similarly, the Mean Citations per Year falls from 5.30 in 2019 to 3.88 in 2023, indicating lower citation averages for newer articles. While the number of published papers has increased (from 730 in 2019 to 1,836 in 2023), the shorter citation window for newer articles (fewer CitableYears) is most likely responsible for the decreased average citation rates. This graph highlights the time-dependent aspect of citation accumulation, as well as the recent increase in scientific production.

4.4 Most Relevant Sources

Table 4 shows the top 10 total number of documents published by various sources. IEEE ACCESS has the greatest, publishing the most documents (1911), followed by sensors (835), lecture notes in computer science (778), procedia computer science (756), and sustainability (switzerland) (746), applied science (switzerland) (632), computational intelligence and neuroscience (394), acm international conference proceeding series (327), energies (285) and electronics (switzerland) (283).

4.5 Sources' Local Impact

Table 5 shows the H-index (impact measure) for the top 10 sources. IEEE ACCESS stands out with the highest H-index of 99, indicating its dominant influence. Sustainability (switzerland) follows with an H-index of 62, showing significant impact. sensors and procedia computer science come next, with H-index values of 46 and 44, respectively, while applied sciences (switzerland) holds an H-index of 42. ENERGIES achieves a moderate H-index of 39, while electronics (switzerland) and lecture notes in computer science show slightly lower impacts, with H-index values of 30 and 29. computational intelligence and neuroscience holds an H-index of 26, and ACM international conference proceeding series has the lowest impact with an H-index of 24.

4.6 Most Relevant Authors

Table 6 shows the most relevant authors based on the number of documents they have created. Mosavi Amir is the leading author, with a total of 27 documents, standing out significantly. Kotecha Ketan follows with 17 documents, while Aldhyani Theyazin comes in third with 15 documents. Three authors, Huh Jun-Ho, MikoŁajewski Dariusz, and Rojek Izabela, each contributed 11 documents.

Table 3. Data on the citation performance of articles published each year

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2019	31.82	730	5.30	6
2020	28.53	1255	5.71	5
2021	21.84	1228	5.46	4
2022	12.99	1981	4.33	3
2023	7.76	1836	3.88	2

Table 4. Top 10 most relevant sources

Sources	Number of Articles
IEEE ACCESS	1911
SENSORS	835
LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)	778
PROCEDIA COMPUTER SCIENCE	756
SUSTAINABILITY (SWITZERLAND)	746
APPLIED SCIENCES (SWITZERLAND)	632
COMPUTATIONAL INTELLIGENCE AND NEUROSCIENCE	394
ACM INTERNATIONAL CONFERENCE PROCEEDING SERIES	327
ENERGIES	285
ELECTRONICS (SWITZERLAND)	283

Table 5. Top 10 local sources' impact

Source	h_index	g_index	m_index	TC	NP
IEEE ACCESS	99	168	16.5	53939	1911
SUSTAINABILITY (SWITZERLAND)	62	100	10.333	18054	746
SENSORS	46	65	9.2	12156	835
PROCEDIA COMPUTER SCIENCE	44	66	7.333	9834	756
APPLIED SCIENCES (SWITZERLAND)	42	67	7	9417	632
ENERGIES	39	52	6.5	5177	285
ELECTRONICS (SWITZERLAND)	30	52	5	4475	283
LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)	29	49	4.833	5404	778
COMPUTATIONAL INTELLIGENCE AND NEUROSCIENCE	26	38	4.333	3092	394
ACM INTERNATIONAL CONFERENCE PROCEEDING SERIES	24	38	4	2323	327

Table 6. Top 10 most relevant authors

Authors	Articles	Articles Fractionalized
MOSAVI AMIR	27	6.07
KOTECHA KETAN	17	3.09
ALDHYANI THEYAZN	15	6.38
HUH JUN-HO	11	4.07
MIKOŁAJEWSKI DARIUSZ	11	2.73
ROJEK IZABELA	11	2.98
ABRAHAM AJITH	10	1.47
TANWAR SUDEEP	10	1.35
TREUR JAN	10	4
ASHRAF IMRAN	9	1.46

The authors Abraham Ajith, Tanwar Sudeep, and Treur Jan come next, each authoring ten documents and Ashraf Imran nine documents.

4.7 Most Relevant Affiliations

The Table 7 shows the top 10 affiliations, King Saud University leading with 118 articles, followed by King Abdulaziz University with 97, Bina Nusantara University with 93, Prince Sattam Bin Abdulaziz University with 82, Princess Nourah Bint Abdulrahman University with 76, King Faisal University with 68, King Khalid University with 66, Sejong University and Taif University with 63 each, and COMSATS University Islamabad with 43 articles.

4.8 Affiliations' Production over Time

Table 8 shows that Bina Nusantara University produced 78 publications in 2019 and 2020, 79 in 2021, 85 in 2022, and 93 in 2023. Meanwhile, King Abdulaziz University published 6 publications in 2019; 13 in 2020; 31 in 2021; 68 in 2022; and 97 in 2023. Prince Sattam Bin Abdulaziz University produced 1 publication in 2019, 3 in 2020, 11 in 2021, 43 in 2022, and 82 in 2023. Princess Nourah Bint Abdulrahman University produced 1 publication in 2019 and 2020, 2 in 2021, 25 in 2022 and 76 in 2023.

4.9 Most Cited Countries

Table 9 shows that China had the most citations (19,873), followed by Korea (12,552), India (7,729), Saudi Arabia (5,810), the United States (5,486), Italy (5,305), Spain (4,146), Germany (3,992), the United Kingdom (3,563), and Australia (2,929), demonstrating their respective research influence.

Table 7. Top 10 most relevant affiliations

Affiliation	Articles
KING SAUD UNIVERSITY	118
KING ABDULAZIZ UNIVERSITY	97
BINA NUSANTARA UNIVERSITY	93
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	82
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	76
KING FAISAL UNIVERSITY	68
KING KHALID UNIVERSITY	66
SEJONG UNIVERSITY	63
TAIF UNIVERSITY	63
COMSATS UNIVERSITY ISLAMABAD	43

Table 8. Affiliations' production over time

Affiliation	Year	Articles
BINA NUSANTARA UNIVERSITY	2019	78
BINA NUSANTARA UNIVERSITY	2020	78
BINA NUSANTARA UNIVERSITY	2021	79
BINA NUSANTARA UNIVERSITY	2022	85
BINA NUSANTARA UNIVERSITY	2023	93
KING ABDULAZIZ UNIVERSITY	2019	6
KING ABDULAZIZ UNIVERSITY	2020	13
KING ABDULAZIZ UNIVERSITY	2021	31
KING ABDULAZIZ UNIVERSITY	2022	68
KING ABDULAZIZ UNIVERSITY	2023	97
KING SAUD UNIVERSITY	2019	13
KING SAUD UNIVERSITY	2020	19
KING SAUD UNIVERSITY	2021	35
KING SAUD UNIVERSITY	2022	66
KING SAUD UNIVERSITY	2023	118
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	2019	1
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	2020	3
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	2021	11
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	2022	43
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY	2023	82
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	2019	1
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	2020	1
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	2021	2
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	2022	25
PRINCESS NOURAH BINT ABDULRAHMAN UNIVERSITY	2023	76

Table 9. Top 10 most cited countries

Country	Total Citation	Average Article Citation
CHINA	19873	15.60
KOREA	12552	22.10
INDIA	7729	21.70
SAUDI ARABIA	6810	24.70
USA	5486	14.70
ITALY	5051	18.20
SPAIN	4146	15.50
GERMANY	3921	16.30
UNITED KINGDOM	3631	23.00
AUSTRALIA	3295	30.80

4.10 Corresponding Author's Countries

Table 10 shows the number of articles published by corresponding authors from different countries. China leads with 1,277 articles, followed by Korea with 568, and the USA with 374. Other notable contributors include India (356), Italy (277), Saudi Arabia (276), Spain (268), Germany (241), Poland (230), and the United Kingdom with 158 articles.

4.11 Most Global Cited Documents

Table 11 shows the most globally cited documents, with Fuller A, 2020, IEEE Access leading at 1,270 citations, followed by Rasheed A, 2020, IEEE Access with 1,002 citations, and Chen L, 2020, IEEE Access with 998 citations. Other notable documents include Park SM, 2022, IEEE Access (947 citations), Akyildiz IF, 2020, IEEE Access (842 citations), and Nahavandi S, 2019, Sustainability (838 citations). The remaining documents have citation counts ranging between 675 and 469.

Table 10. Top 10 most cited countries

Country	Articles
CHINA	1277
KOREA	568
USA	374
INDIA	356
ITALY	277
SAUDI ARABIA	276
SPAIN	268
GERMANY	241
POLAND	230
UNITED KINGDOM	158
CHINA	1277

Table 11. Top 10 most globally cited documents

Paper	DOI	Total Citation	TC Per Year
FULLER A, 2020, IEEE ACCESS	10.1109/ACCESS.2020.2998358	1270	254.00
RASHEED A, 2020, IEEE ACCESS	10.1109/ACCESS.2020.2970143	1002	200.40
CHEN L, 2020, IEEE ACCESS	10.1109/ACCESS.2020.2988510	998	199.60
PARK SM, 2022, IEEE ACCESS	10.1109/ACCESS.2021.3140175	947	315.67
AKYILDIZ IF, 2020, IEEE ACCESS	10.1109/ACCESS.2020.3010896	842	168.40
NAHAVANDI S, 2019, SUSTAINABILITY	10.3390/su11164371	838	139.67
SALAH K, 2019, IEEE ACCESS	10.1109/ACCESS.2018.2890507	675	112.50
DENG W, 2019, IEEE ACCESS	10.1109/ACCESS.2019.2897580	502	83.67
XU G, 2019, IEEE ACCESS	10.1109/ACCESS.2019.2909919	470	78.33
PAN Z, 2019, IEEE ACCESS IEEE ACCESS	10.1109/ACCESS.2019.2905015 10.1109/ACCESS.2018.2879848	469	78.17

4.12 Most Frequent Words

Table 12 shows the words that appear most frequently in a dataset along with how many times they occur. With 5,443 instances, "artificial intelligence" is the most often used term. "Deep learning" (1,583) and "learning systems" (1,127) are next in line. The terms "machine learning," "neural networks," and "computers" are also commonly used, indicating an emphasis on artificial intelligence, machine learning, and associated ideas.

Table 12. Top 10 most frequent words

Words	Occurrences
Artificial intelligence	5443
Deep learning	1583
Learning systems	1127
Machine learning	991
Machine-learning	763
Human	604
Neural networks	585
Humans	556
Learning algorithms	530
Computers	511

4.13 Thematic Map

The thematic map in Fig. 1 categorizes research topics based on their development (density) and importance. Artificial intelligence, learning systems, and machine learning are highly developed and specialized in the top-right quadrant (Niche Themes), indicating a substantial research focus but only for advanced, specific applications. Deep learning and humans are shown in the bottom-right quadrant (Basic Themes) as issues of high relevance and broad importance but with relatively modest development, indicating that they are foundational and widely explored. The bottom-left quadrant (Emerging or diminishing Themes) includes computers and computer science, which have low relevance and development, implying that they are either emerging as new academic areas or diminishing in importance.

4.14 Main Information

Fig. 2 shows the dataset from 2019 to 2023 contains 7,030 papers published across 45 sources, with contributions from 26,112 writers and an annual growth rate of 25.93%. The majority of works are collaborative, with an average of 4.28 co-authors per document, while just 415 are single-authored. International collaboration is significant, comprising 31.31% of the works. The authors supplied 18,237 keywords reflecting various study themes. The average age of the documents is 2.58 years, and each receives 17.9 citations, indicating strong impact. Notably, no references were included in the dataset.

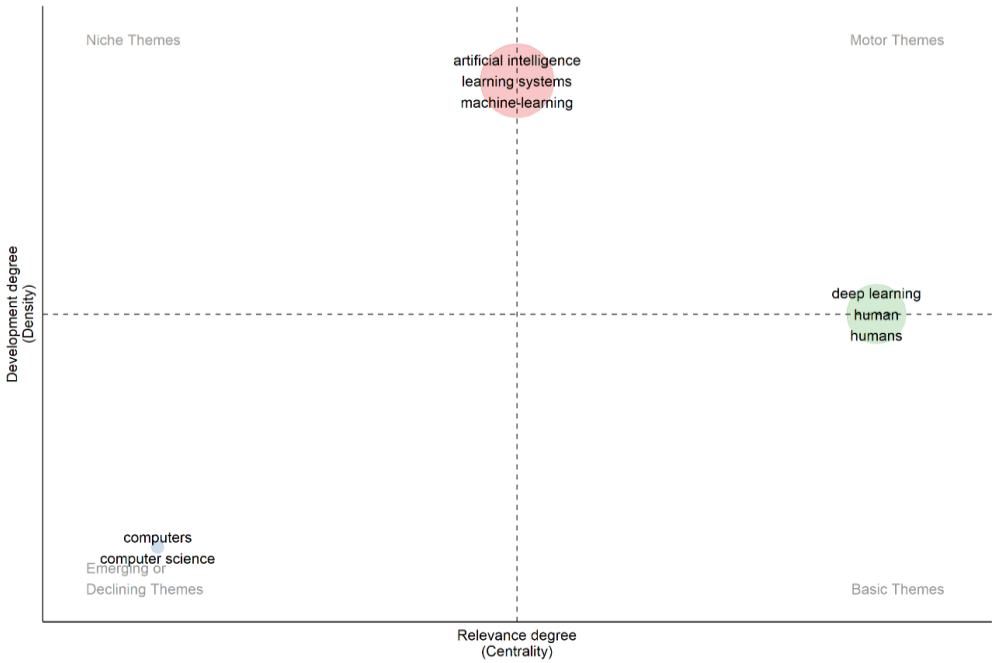

Fig. 1. Thematic Map
Source: Biblioshiny

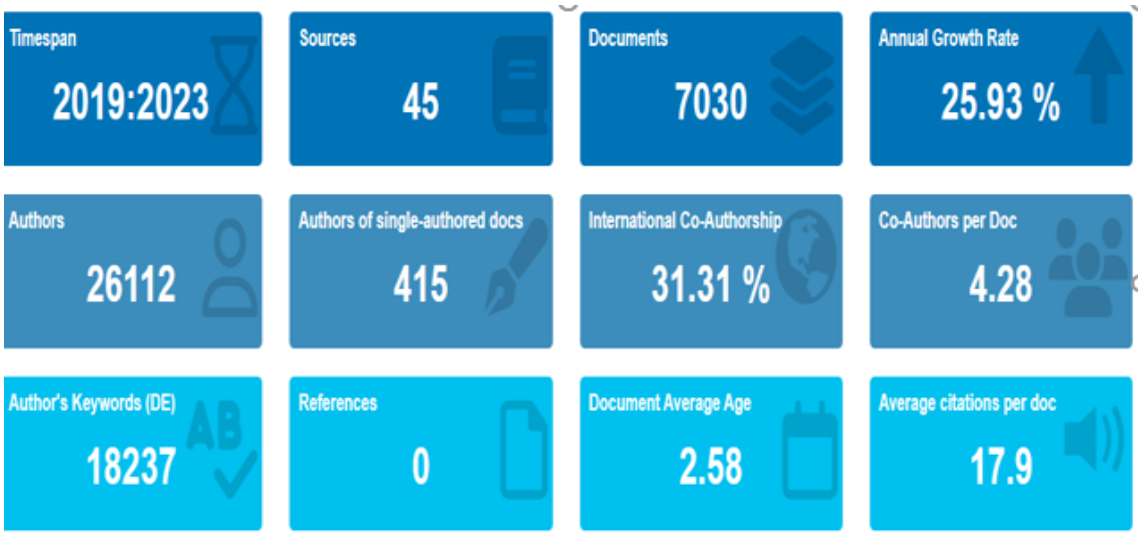

Fig. 2. Main information
Source: Biblioshiny

5. DISCUSSION

The analysis identified several highly cited papers, with Fuller A.'s 2020 publication in IEEE Access leading with 1,270 citations, followed by Rasheed A. (2020) and Chen L. (2020) in the same journal with 1,002 and 998 citations, respectively. These influential papers focus on emerging AI applications, reflecting the field's alignment with high-impact, cutting-edge topics. The concentration of citations in a select number of papers indicates the presence of seminal works that shape ongoing research and serve as foundational references for scholars globally.

The results revealed a significant annual growth rate of 25.93%, with publication output increasing from 730 papers in 2019 to 1,836 in 2023. This trend indicates the growing emphasis on AI as a research priority across disciplines. Thematic analysis revealed dominant areas like machine learning, deep learning, and neural networks, complemented by emerging trends in ethical AI, convolutional neural networks, and fairness in AI systems. Such evolution highlights the balance between advancing AI technologies and addressing societal challenges.

The study identified Mosavi Amir as the most prolific author, contributing 27 papers, followed by Kotecha Ketan and Aldhyani Theyazin with 17 and 15 papers, respectively. These researchers primarily focus on applying AI to real-world problems, reflecting the practical and interdisciplinary orientation of contemporary AI research. However, the contribution of leading researchers is complemented by a vast collaborative network, with most papers authored by teams averaging 4.28 contributors.

International collaboration plays a pivotal role, with 31.31% of publications involving cross-country co-authorship. China emerged as the leading country in AI research output, with 1,277 corresponding authors and the highest citation count (19,873). Other prominent contributors include South Korea, Saudi Arabia, and the USA. The collaboration patterns suggest that global partnerships are instrumental in driving innovation and addressing complex challenges in AI, yet research remains concentrated in a limited number of countries, pointing to an opportunity for greater inclusivity.

6. CONCLUSION

This bibliometric analysis provides a comprehensive picture of global AI research trends from 2019 to 2023, focusing on significant contributors, subject focuses, and collaboration patterns. The study shows a substantial annual growth rate of 25.93%, indicating the rapid expansion of AI research. The majority of publications are collaborative, with an average of 4.28 authors per document, demonstrating the field's interdisciplinary and team-oriented orientation. Notably, IEEE Access emerged as the most prolific source, King Saud University as the leading institution, and China as the number one publishing country in terms of volume and citations.

Thematic analysis found that machine learning, deep learning, and neural networks are the most popular study areas, with an increasing interest in ethical AI and convolutional neural networks. These themes suggest a move toward addressing societal issues with technology achievements. The substantial degree of international collaboration (31.31%) shows the global aspect of AI research, but the poor representation of particular locations implies a possibility for increased inclusivity.

Although the current increase in publications is positive, younger works have lower citation counts due to their short time to gain effect. Future study should address this restriction by investigating the long-term impact of emerging work. Furthermore, there is a need to build global research networks, increase representation from marginalized regions such as Africa, and prioritize ethical frameworks for AI development.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Wang, L., Liu, Z., Liu, A., & Tao, F. (2021). Artificial intelligence in product lifecycle management. *International Journal of Advanced Manufacturing Technology, 114*(3–4), 771–796. https://doi.org/10.1007/s00170-021-06882-1

Dwivedi, Y. K., et al. (2021). Artificial intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice, and policy. *International Journal of Information Management, 57*, 102275. https://doi.org/10.1016/j.ijinfomgt.2019.08.002

Calegari, R., Ciatto, G., Mascardi, V., & Omicini, A. (2021). Logic-based technologies for multi-agent systems: A systematic literature review. *Springer US*, 35(1). https://doi.org/10.1007/s10458-020-09478-3

Pugliese, R., Regondi, S., & Marini, R. (2021). Machine learning-based approach: Global trends, research directions, and regulatory standpoints. *Data Science and Management, 4*(August), 19–29. https://doi.org/10.1016/j.dsm.2021.12.002

Jauro, F., Chiroma, H., Gital, A. Y., Almutairi, M., Abdulhamid, S. M., & Abawajy, J. H. (2020). Deep learning architectures in emerging cloud computing architectures: Recent development, challenges, and next research trend. *Applied Soft Computing Journal, 96*, 106582. https://doi.org/10.1016/j.asoc.2020.106582

Saraswat, D., et al. (2022). Explainable AI for Healthcare 5.0: Opportunities and challenges. *IEEE Access, 10*, 84486–84517. https://doi.org/10.1109/ACCESS.2022.3197671

Bhutoria, A. (2022). Personalized education and artificial intelligence in the United States, China, and India: A systematic review using a human-in-the-loop model. *Computers in Education: Artificial Intelligence, 3*(April), 100068. https://doi.org/10.1016/j.caeai.2022.100068

Sarker, I. H., Furhad, M. H., & Nowrozy, R. (2021). AI-driven cybersecurity: An overview, security intelligence modeling and research directions. *SN Computer Science, 2*(3). https://doi.org/10.1007/s42979-021-00557-0

Liu, N., Shapira, P., & Yue, X. (2021). Tracking developments in artificial intelligence research: Constructing and applying a new search strategy. *Springer International Publishing, 126*(4). https://doi.org/10.1007/s11192-021-03868-4

Tran, B. X., et al. (2019). The current research landscape on the artificial intelligence application in the management of depressive disorders: A bibliometric analysis. *International Journal of Environmental Research and Public Health, 16*(12), 2150. https://doi.org/10.3390/ijerph16122150

Chen, Q., Wen, Y., Zhang, X., & Zhu, Z. (2022). Evolutionary overview of terrace research based on bibliometric analysis in Web of Science from 1991 to 2020. *International Journal of Environmental Research and*

Public Health, 19(13), 37796. https://doi.org/10.3390/ijerph19137796

Górriz, J. M., et al. (2020). Artificial intelligence within the interplay between natural and artificial computation: Advances in data science, trends and applications. *Neurocomputing, 410*, 237–270. https://doi.org/10.1016/j.neucom.2020.05.078

Soori, M., Arezoo, B., & Dastres, R. (2023). Artificial intelligence, machine learning and deep learning in advanced robotics, a review. *Cognitive Robotics, 3*(March), 54–70. https://doi.org/10.1016/j.cogr.2023.04.001

Ahmad, T., Madonski, R., Zhang, D., Huang, C., & Mujeeb, A. (2022). Data-driven probabilistic machine learning in sustainable smart energy/smart energy systems: Key developments, challenges, and future research opportunities in the context of smart grid paradigm. *Renewable and Sustainable Energy Reviews, 160*(January), 112128. https://doi.org/10.1016/j.rser.2022.112128

Chakraborty, C., Bhattacharya, M., Pal, S., & Lee, S. S. (2024). From machine learning to deep learning: Advances of the recent data-driven paradigm shift in medicine and healthcare. *Current Research in Biotechnology, 7*(November), 100164. https://doi.org/10.1016/j.crbiot.2023.100164

Turay, T., & Vladimirova, T. (2022). Toward performing image classification and object detection with convolutional neural networks in autonomous driving systems: A survey. *IEEE Access, 10*, 14076–14119. https://doi.org/10.1109/ACCESS.2022.3147495

Fatima, N., Imran, A. S., Kastrati, Z., Daudpota, S. M., & Soomro, A. (2022). A systematic literature review on text generation using deep neural network models. *IEEE Access, 10*, 53490–53503. https://doi.org/10.1109/ACCESS.2022.3174108

Lu, Y., Chen, D., Olaniyi, E., & Huang, Y. (2022). Generative adversarial networks (GANs) for image augmentation in agriculture: A systematic review. *Computers and Electronics in Agriculture, 200*, 107208. https://doi.org/10.1016/j.compag.2022.107208

Kang, Y., Cai, Z., Tan, C. W., Huang, Q., & Liu, H. (2020). Natural language processing (NLP) in management research: A literature review. *Journal of Management Analysis, 7*(2), 139–172. https://doi.org/10.1080/23270012.2020.1756939

Raparthi, M., Dodda, S. B., Reddy, S. R. B., Thuniki, P., Maruthi, S., & Ravichandran, P. (2021). Advancements in natural language processing - A comprehensive review of AI techniques. *Journal of Bioinformatics and Artificial Intelligence, 1*(1), 1–9.

Yenduri, G., et al. (2024). GPT (Generative Pre-Trained Transformer) - A comprehensive review on enabling technologies, potential applications, emerging challenges, and future directions. *IEEE Access, 12*(April), 54608–54649. https://doi.org/10.1109/ACCESS.2024.3389497

Paliwal, S., & Bharti, V. (2022). AI chatbots: Transforming the digital world. *ResearchGate*. https://doi.org/10.1007/978-3-030-32644-9

Kotek, H., Dockum, R., & Sun, D. Q. (2023). Gender bias and stereotypes in large language models. *Proceedings of the ACM Collective Intelligence Conference CI*, 12–24. https://doi.org/10.1145/3582269.3615599

Ahmadi, A. (2023). AI-driven medical innovations: Transforming healthcare through data intelligence. *Jobiost.com, 2*(2), 132–142. https://www.jobiost.com/article_185475.html

Secinaro, S., Calandra, D., Secinaro, A., Muthurangu, V., & Biancone, P. (2021). The role of artificial intelligence in healthcare: A structured literature review. *BMC Medical Informatics and Decision Making, 21*(1), 1–23. https://doi.org/10.1186/s12911-021-01488-9

Sollini, M., Bartoli, F., Marciano, A., Zanca, R., Slart, R. H. J. A., & Erba, P. A. (2020). Artificial intelligence and hybrid imaging: The best match for personalized medicine in oncology. *European Journal of Hybrid Imaging, 4*(1). https://doi.org/10.1186/s41824-020-00094-8

Gupta, R., Srivastava, D., Sahu, M., Tiwari, S., Ambasta, R. K., & Kumar, P. (2021). Artificial intelligence to deep learning: Machine intelligence approach for drug discovery. *Springer International Publishing, 25*(3).

https://doi.org/10.1007/s11030-021-10217-3

Amann, J., Blasimme, A., Vayena, E., Frey, D., & Madai, V. I. (2020). Explainability for artificial intelligence in healthcare: A multidisciplinary perspective. *BMC Medical Informatics and Decision Making, 20*(1), 1–9. https://doi.org/10.1186/s12911-020-01332-6

Harry, A., & Jati, G. (2023). Role of AI in education. *Injury: Interdisciplinary Journal of Humanities, 2*(3), 2963–3397. https://injurity.pusatpublikasi.id/index.php/in

Liu, S. Y. (2020). Artificial intelligence (AI) in agriculture. *IT Professional, 22*(3), 14–15. https://doi.org/10.1109/MITP.2020.2986121

Memarian, B., & Doleck, T. (2023). Fairness, accountability, transparency, and ethics (FATE) in artificial intelligence (AI) and higher education: A systematic review. *Computers in Education: Artificial Intelligence, 5*(June), 100152. https://doi.org/10.1016/j.caeai.2023.100152

Okeh, E. (2024). Transforming healthcare: A comprehensive approach to mitigating bias and fostering empathy through AI-driven augmented reality. *Proceedings of the AAAI Conference on Artificial Intelligence, 38*(21), 23753–23754. https://doi.org/10.1609/aaai.v38i21.30553

Editorial. (2021). Algorithmic bias in data-driven innovation in the age of AI. *International Journal of Information Management, 60*. https://doi.org/10.1016/j.ijinfomgt.2021.102393

Sartori, L., & Theodorou, A. (2022). A sociotechnical perspective for the future of AI: Narratives, inequalities, and human control. *Ethics and Information Technology, 24*(1), 1–11. https://doi.org/10.1007/s10676-022-09624-3

Yang, Y., Lin, M., Zhao, H., Peng, Y., Huang, F., & Lu, Z. (2024). A survey of recent methods for addressing AI fairness and bias in biomedicine. *Journal of Biomedical Informatics, 154*, 104646. https://doi.org/10.1016/j.jbi.2024.104646

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/124702