A Scientometric Analysis of Scientific Productivity of Artificial Intelligence Research in India

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ABSTRACT

The study presents a scientometric analsyis of publications related to 'Artificial Intelligence' research in India during 2009-2018. In today's ICT driven world, artificial intelligence has taken up some tasks of our daily life to make it easier. As a consequence, extensive research is going on "Artificial Intelligence" to find out it's potential in knowledge development. The paper analyses the bibliographic data retrieved from Scopus database extracted with a suitable search query. The study was conducted taking the chronological growth of research publications, relative growth rate, doubling time, scientometric profile of authors, document type of publications, source profile, keyword analysis, institution wise distribution of publications, funding agency wise distribution. The analysis was conducted using the MS-Excel. The study reveals that a maximum number of publications are in the form of conference procedings and articles. Artificial Intelligence, Learning system, algorithms, data mining are the keywords with maximum number of occurences. The findings of the study implies India need become more competitive with the world leaders in artificial intelligence research. To get more return from AI applications, the stakeholders are required to play a catalytic role to build and strengthen research capacity in the nation by paving quality research environment, adequate funding, research incentives, and development of IT infrastructure.

Keywords: Scientometrics, Artificial Intelligence, Collaboration Coefficient, Collaborative Index, Relative Growth Rate.

INTRODUCTION

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to suppose like humans and mimic their actions. The term may additionally be applied to any machine that exhibits traits related to a person's mind like learning and problem-solving. The characteristic of AI is its ability to rationalize and take actions that have the most effective probability of achieving a particular goal. AI is a wide-ranging branch of engineering science involved with building sensible machines capable of playing tasks that generally need human intelligence. AI is a knowledge base science with multiple approaches, however, advancements in machine learning and deep learning area unit making a paradigm shift in just about every sector of the technical school business. Artificial intelligence could be a science and technology-supported disciplines like technology, Biology, Psychology, Linguistics, arithmetic, and Engineering. A serious thrust of AI is within the development of computer functions related to human intelligence like reasoning, learning, and problem-solving. Out of the subsequent areas, one or multiple areas will contribute to making an intelligent system.

India, being the fastest growing economy with the second largest population in the world, has a significant stake in the AI revolution. Recognising AI's potential to transform economies and the need for India to strategise its approach, Hon'ble Finance Minister, in his budget speech for 2018 – 2019, mandated NITI Aayog to establish the National Program on AI, with a view to guiding the research and development in new and emerging technologies. In pursuance of the above, NITI Aayog has adopted a three-pronged approach – undertaking exploratory proof-of-concept AI projects in various areas, crafting a national strategy for building a vibrant AI ecosystem in India and collaborating with various experts and stakeholders.[1] Since the start of this year, NITI Aayog has partnered with several leading AI technology players to implement AI projects in critical areas such as agriculture and health.

Artificial intelligence has been predominant in different fields, for example, gaming, natural language processing, master frameworks, vision frameworks, speech recognition, handwriting recognition, and astute robots. The main aims of artificial intelligence are to create an expert system, to implement human intelligence in machines.

Scope of the Study

The scope of the study is limited to the "Artificial Intelligence" research publication and the period is limited to a 2009–2018 year. The study was also limited to the publications which were contributed by Indian authors indexed in the Scopus database.

Background study of Artificial Intelligence

In the past years, a few selected studies were undertaken on quantitative analysis of worldwide output on artificial intelligence research covering various periods and various aspects of the subject in their research analysis. Bhattacharjee (2019)[2] conducted a scientometric study on AI in one decade i.e., 2009 to 2018. After the analysis, it has been found that AI as an academic subject has gained tremendous momentum in the recent past which is reflected through the annual research publications in the particular field. The beginning year 13936 while in the ending year 27061 publications were recorded across the countries during the study period. He also mentinede that India has been taken the fifth position after the US, China, UK and Germany in the last 20 years with 16903 publications. He further mentioned that if the same search keyword use for the last ten years then it was found that India secured 3rd position with 13923 publications just after the US and China. This substantial growth clearly shows the popularities of AI research in India in recent years. Gupta and Dhawan (2018)[3] conducted a study a scientometric assessment on artificial intelligence research publications in India from (2009-2016) in which a total of 9730 research papers were published by Indian authors and it has gained tremendous momentum in the recent past which is reflected through the annual research productivity of the particular field of study. The most productive organization was Anna University with 294 publications, followed by Jadavpur University 270 publications and the most prolific authors was S. Das from ISI Kolkata with 36 publications, followed by B. K. Panigrahi with 32 contributions. The significant keywords were Artificial Intelligence with 9496 frequency. The most productive journals in artificial research in India during the period 2007-2016 was Applied Soft Computing Journal. Niu *et al*. (2016)[4] carried out a bibliometric analysis on global research on artificial intelligence publications during the period (1990-2014) in which a total 20715 articles were published and the maximum 344 articles were published in the Journal of Expert Systems with Applications, followed by Engineering Applications of Artificial Intelligence with 161 publications. The most productive authors were J. Neves from University Minho with 35 contributions, followed by G. Klopman from Case Western Reserve University with 30 contributions. A maximum 123 articles were contributed by Chinese Academy Sciences organization while the highest 5841 frequency is an Artificial Intelligence keyword. Shrivastava and Mahajan (2016)[5]

carried out a scientometric analysis on artificial intelligence research in India from 1968 to 2014 and found that a total of 6529 records which has grown considerably since 2004, and the last 2 years have witnessed a large publication output in the field of AI. The average citation recorded per paper is 3.06. The average number of authors per paper is three. "Artificial Intelligence" was found to be the most popular keyword, followed by "Algorithms." A total of 12.64% of the papers have been published with international collaboration. The maximum number of publications have given by Anna University. It was found that the IITs played a major role in the field of artificial intelligence research in India.

METHODOLOGY

One of the most famous products provided by Elsevier in the Scopus database, it is a very comprehensive multidisciplinary citation database indexing a large number of science and technology research papers globally, provided by subscription basis. The following search string to be used to collect the data: (TITLE-ABS-KEY ("Artificial Intelligence") AND (LIMIT-TO (PUBYEAR, 2018) TO (PUBYEAR, 2009)) AND (LIMIT-TO (AFFILCOUNTRY, "India")) AND (LIMIT-TO (PUBSTAGE, "final"))). Worldwide a total of 191362 research papers were found in which 14108 publications contributed by Indian authors, which were available on Scopus databases from the marked period of study. These research papers along with full bibliographical details like the growth of publications, relative growth rate and doubling time of publications, author's profiles, document types, source title, significant keywords, affiliations name, funding agencies have been extracted from the Scopus database. The raw data was downloaded on 13/02/2019 to conduct the study and the data were analyzed and tabulated in MS-Excel applications software.

DATA ANALYSIS

Growth of Artificial Intelligence research publication

Figure 1 depicts the growth of Artificial Intelligence research publications during the period (2009-2018). A total of 14108 research papers were published in India during the period under study. The highest publication is 2384 in 2016 with AGR 32.55, followed by 2283 papers in 2017 with AGR 23.51, 2116 publications in the year 2018 with AGR 17.65, and 2071 publications in 2015 with AGR 39.42. The lowest number of publications in the year 2009 is 394 with AGR 0. The growth of the publication was increased during the period 2009-2016 i.e., (394 to 2384) research paper and then after that, the research publications slightly decreased in the year 2017 and 2018 with (2283 to 2116) publications. The overall data of the growth of artificial intelligence research publications were shown in Figure 1. The annual growth rate is a useful method

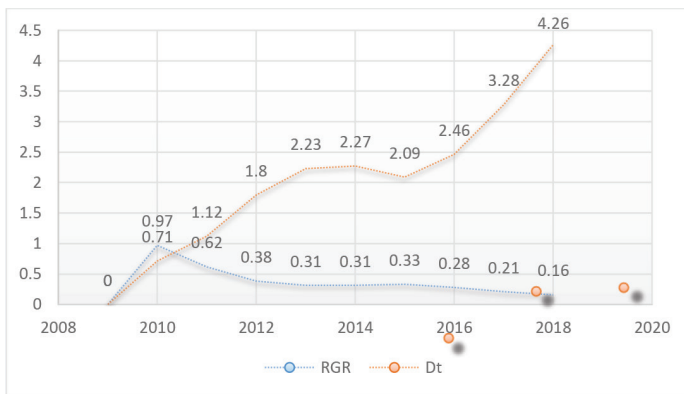**Figure 1:** Growth of Artificial Intelligence research publication.

Figure 2: Relative Growth Rate and Doubling time of the publications.

to evaluate the yearly trends in research productivity (Kumar and Kaliyaperumal, 2015).[6]

$$AGR = \frac{End\ Value - First\ Value}{First\ Value} \times 100$$

Relative Growth Rate and Doubling time of the publications

Figure 2 shows the relative growth rate and doubling time of the research paper from the marked period of study. On the observation of Figure 2, it has been shown that the relative growth rate was in decreasing order in the year 2009-2014 i.e., (0.97 to 0.31) while the next year i.e., 2015 it was increased with (0.33) and then after in 2016-2018, it was again in decreasing trend with (0.28 to 0.16). The mathematical representation of the mean relative growth rate of articles over a specific period is derived from the following formula given by (Mahapatra, 1985).[7]

$$RGR = \frac{W_2 - W_1}{T_2 - T_1}$$

Where,

RGR = Growth Rate over the specific period of the interval,

W1 = Log_e (natural log of the initial number of contributions)

W2 = Log_e (natural log of the final number of contributions)

T1 = the unit of initial time

T2 = the unit of the final time

The overall Doubling time has been shown an increasing trend in the year 2009-2018 with (0.71 to 4.26). After five years continue increasing, in the year 2015 the decreasing trend also shown i.e., (2.09) and then after doubling time was increased in the year 2016-2018 with (2.46 to 4.26). A similar scientometric study on Indian research output on genetic disorder publication investigated by (Shukla, 2019)[8] found that doubling time is increased every year. The following formula is used to analyze the doubling time.

$$Doubling\ Time\ (Dt) = \frac{0.693}{R}$$

Scientometric profile of authors publications

Table 1 shows that a scientometric profile of authors published =>25 contributions from India in artificial intelligence revealed that their productivity varied from 41 to 25 contributions. The most productive author was B.K. Panigrahi from IIT, New Delhi with 41 research papers and a total *h*-index was 38; citation 6260 recorded, followed by S. Das from ISI, Kolkata, and R. Malhotra form DTU, New Delhi with (39 publication; 47 *h*-index; 11256 citation and 36 publications; 15 *h*-index; 884 citations) recorded respectively. S. Bandyopadhyay (Jadavpur University, Kolkata), and K.P. Soman (ASE, Coimbatore) contributed 29 publications each with *h*-index (15:13; and citations 884:760) respectively. The whole data of the scientometric profile of the authors has been shown in Table 1.

Document type publications in Artificial Intelligence research

The productivity of researchers on Artificial Intelligence spreads over ten types of publication media, such that journal articles, review, conference paper, book chapters, letters, editorials, notes, short surveys, books, and erratum. Figure 3 depicts the document type publications in artificial intelligence research publications in India for 10 years i.e., (2009-2018). On the observations of a particular Figure, it has been shown that the maximum 11326 (80.28%) of records were published in Conference paper, followed by Article with 2379 (16.86%) of publications were published while the minimum 2 (0.01%) of records were published in Erratum. The overall data of document type publications in artificial intelligence research was shown in Figure 3.

Table 1: Study groups and their total mean.

Group No.	Group name	No. of items	Sum of means*	Total mean**
1	Use Case Diagrams	5	22.08	4.04
2	Scenarios	11	46.95	4.26
3	Sequence diagrams	4	16.93	4.23
4	Activity diagrams	3	12.93	4.31
5	Class diagrams	5	20.42	4.08
6	Designed prototype	3	11.67	3.89
7	Search requirements and capabilities of research centers in the system	6	26.26	4.37
8	Ability to apply filters	11	48.96	4.45
9	Page display capabilities	8	33.74	4.21
10	Reporting capabilities in the system	12	52.45	4.37
11	Storage capabilities in the system	14	56.69	4.04

* This is the sum of the means of all items presented in the each group** This is the mean of all items presented in each group
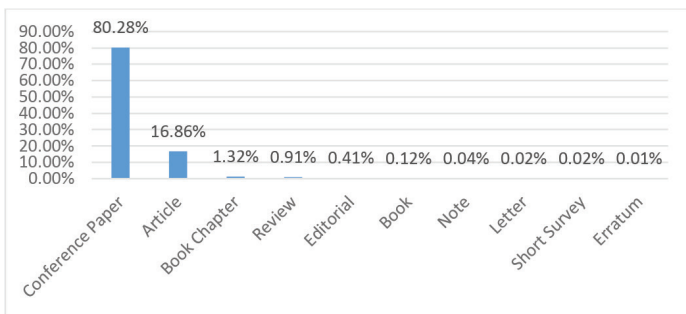

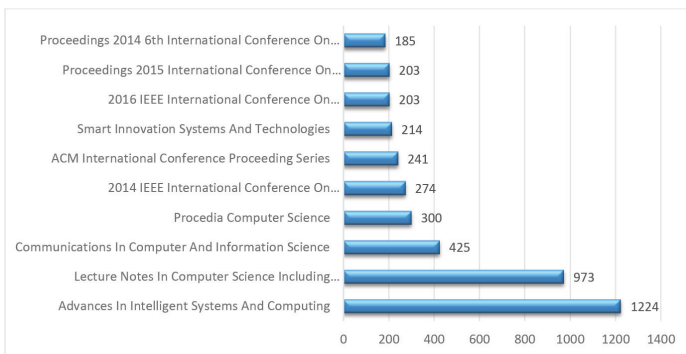**Figure 3:** Document type publications in Artificial Intelligence research.

Figure 4: Profile of source titles in Artificial Intelligence research.

Profile of source title in Artificial Intelligence research

Figure 4 helps in distinctive the sources containing the articles on the topic under my study. It's necessary to grasp the foremost productive sources for the rationale that this data is helpful for researchers and professionals to gather their information or data for varied sources. Figure 4 illustrates the profile of the top 10 source title in artificial intelligence literature during the period (2009–2018). The maximum

1224 publications were published in Advances in Intelligent Systems and Computing, followed by 973 research papers were published in Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics while the minimum number of 185 publications were published in the Proceedings 2014 of 6th International Conference on Computational Intelligence and Communication. Figure 4 depicts the overall source title in increasing order of the publications from the marked period of study.

Significant keywords use in Artificial Intelligence research

Figure 5 depicts that a scientometric profile of the top 10 significant keywords has been identified from the literature, which seeks to highlight possible trends in artificial intelligence research during the period (2009–2018). In the analysis, Artificial Intelligence dominates in the first place among these top ten keywords with 13155 publications, followed by Learning System contributed 2986 publications, 1771 publications were contributed by the Algorithm keyword and 1655 publications were contributed by Data Mining keyword. The lowest number of publications i.e., 823 was of the keyword Feature Extraction. In the observation of Figure 5, it has been listed in the decreasing order of the frequency of their occurrence in the research papers.

Institution-wise distribution of publications in Artificial Intelligence research

Figure 6 shows that a scientometric profile of the top 10 most productive institute in artificial intelligence from India depicts that their publications varied from 158 to 357 publications. Around 160 organizations have been identified from the literature, the top 10 organizations were listed in Figure 6 and it was found that the maximum 357 publications were published in the Jadavpur University and Anna University, followed by 335 research papers were published by the Vellore Institute of
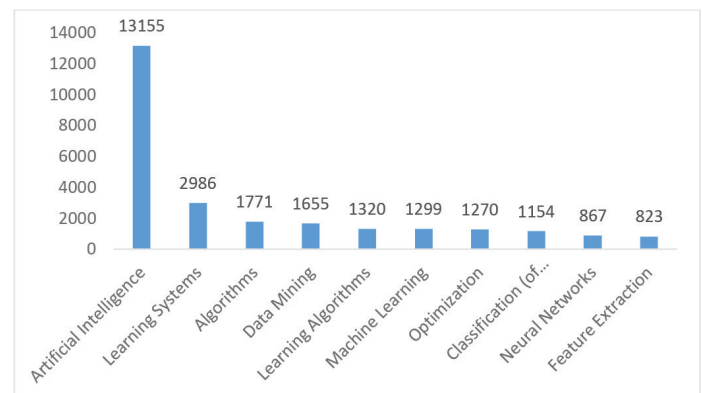

Figure 5: Scientometric profile of significant keywords use in Artificial Intelligence research publications.
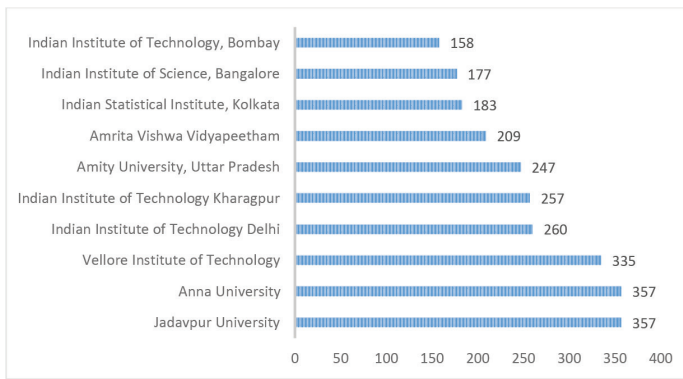
Figure 6: Institution-wise distribution of publications in Artificial Intelligence research
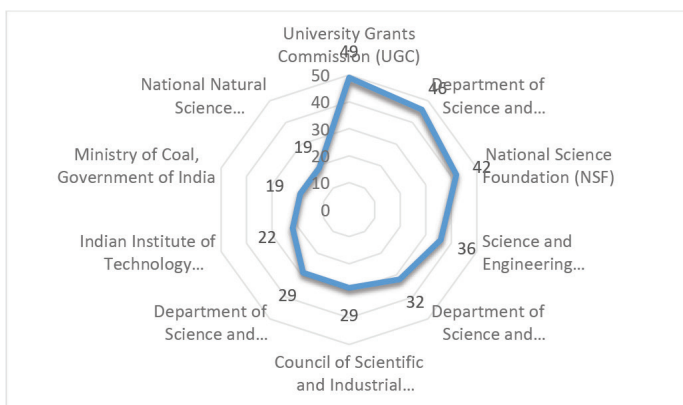

Figure 7: Profile of funding agencies.

DISCUSSION

Bibliometric analysis has turn out to be an effective tool for summarizing the current status and predicting the future development trends in any knowledge domain which differentiate it from review works.[9,10] Analysis of chronological growth of publications implies a gradual increase in the number of publications from the starting year 2009 which reaches it's peak in 2016 and gradually goes down from 2017 onwards. Increase in doubling time of literature indicates that the time taken to double the amount of literature on Artificial intelligence has increased which in turn mean low research productivity in this area.

For authors, number of citations and h–index are used as indicators to analyse their productivity. It is calculated on the basis of number of times an article is cited, according to Scopus. This is a preliminary indicator of the impact of research by the researchers.[11] h–index is a rigourious metric that has been used for quantifying a researcher's scholarly output. Morover, a number of previous studies also used it for evaluating the productivity and impact of a researcher, country, institution, or journal.[12] Our study showed that A. Abraham of Mir Labs, Aburn is the most impactful author with highest number of citations and h–index (15994, 60).

For source of publication, *Advances in Intelligent Systems and Computing*, *Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence* and *Communications in Computer and Information Science* published maximum articles on Artificial intelligence. These journals are of high impact factor and attract papers of high quality and publication of high quality articles in turn increases the impact of these journals in their respective fields. It is evident that in future also research and development works are more likely to get published in this sources.

In bibliometrics, analysis of frequently appearing keywords can also reveal the hot spot catgories and the development of a research area.[13] According to the analysis of keywords, *artificial intelligence, learning systems, algorithms, data mining, learning algorithms* are mostly occurring keywords. Occurrence of keywords like *neural network, feature extraction* implies diversification in research on artificial intelligence.

CONCLUSION

The present study aims to analyze the artificial intelligence research papers published in the Scopus database for ten years i.e., (2009-2018). Using publications data from particular database, this study provides a quantitative and qualitative description of artificial intelligence research, after the observation, it has been found that a maximum of 2384

Technology and 260 publications were published by Indian Institute of Technology Delhi while the minimum number of 158 publications were published by the Indian Institute of Technology Bombay. The analysis shows the decreasing order of the publications of their occurrence in the publications during the period of study.

Profile of funding agencies.

Figure 7 illustrates the profile of the top 10 funding agencies in artificial intelligence from India during the period (2009-2018). It is revealed from the analysis that there are large numbers of funding agencies were acknowledged by the research publications on Artificial Intelligence in India. A total of 160 funding agencies have been found on the Scopus database in which a top 10 funding agencies has been listed in Figure 7. The maximum 49 publications were funded by the University Grants Commission (UGC), followed by the Department of Science and Technology, Ministry of Science and Technology (DST) with 46 publications, and the National Science Foundation (NSF) funded by 42 research papers and the lowest numbers of publications were contributed by National Natural Science Foundation i.e., 19 publications. The overall data of the top 10 funding agencies have been shown in Figure 7.

publications was contributed by the authors in the year 2016. The maximum (164.21) annual growth rate was recorded in the beginning year of the study i.e., 2009. The relative growth rate was recorded between (0.97 to 0.16) during the period of study this shows that the RGR was in decreasing trend however, the doubling time was shown in increasing trend with (0.71 to 4.26). It is also observed that a maximum of 11326 (80.28%) artificial intelligence research papers were published in conference, followed by journal article with 2379 (16.86%) publications. A maximum of 1224 articles was published in the Journal of Advances in Intelligent Systems and Computing and the highest 357 each publication was contributed by Jadavpur University and Anna University. The most productive funding agency's name was the University Grants Commission (UGC) with 49 publications. The most prolific author's name was B.K Panigrahi from New Delhi with 41 publications, followed by S. Das (ISI, Kolkata) with 39 research papers published in artificial intelligence research. The study finds that India's qualitative performance has not been as stunning as its quantitative performance in research. It is important that stakeholders pay special attention to academic and research organizations in the country encouraging them to undertake more and more new research projects, programmes in collaboration with international hubs in artificial intelligence research.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Aayog N. National strategy for artificial intelligence. New Delhi: NITI Aayog; 2018. Available from: https://www.niti.gov.in/national-strategy-artificial-intelligence [cited 13/9/2021].

2. Bhattacharjee KK. Research output on the usage of artificial intelligence in Indian higher education - A scientometric study, IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). Macao; 2019; 916-919. doi: 10.1109/IEEM44572.2019.8978798.

3. Gupta BM, Dhawan SM. Artificial intelligence research in India: A scientometric assessment of publications output during 2007-16. DESIDOC Journal of Library and Information Technology . 2018;38(6):416-22. doi: 10.14429/djlit.38.6.12309.

4. Niu J, Tang W, Xu F, Zhou X, Song Y. Global research on artificial intelligence from 1990-2014: spatially explicit bibliometric analysis. International Journal of Geo-Information. 2016;5(5):1-19. doi: 10.3390/ijgi5050066.

5. Shrivastava R, Mahajan P. Artificial intelligence research in India: A scientometric analysis. Science and Technology Libraries . 2016;35(2):136-51. doi: 10.1080/0194262X.2016.1181023.

6. Santha kumar RS, Kaliyaperumal K. A scientometric analysis of mobile technology publications. Scientometrics. 2015;105(2):921-39. doi: 10.1007/s11192-015-1710-7.

7. Mahapatra M. On the validity of the theory of exponential growth of scientific literature In: the Proceeding of the 15th IASLIC Conference, Bangalore; 1985; p. 61-70.

8. Shukla R. Indian research output on genetic disorder publication using the Scopus database: A scientometric study. Collnet Journal of Scientometrics and Information Management. 2019;13(1):91-102. doi: 10.1080/09737766.2018.1550044.

9. Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. Health Information and Libraries Journal . 2009;26(2):91-108. doi: 10.1111/j.1471-1842.2009.00848.x, PMID 19490148.

10. Møller AM, Myles PS. What makes a good systematic review and meta-analysis? British Journal of Anaesthesia. 2016;117(4):428-30. doi: 10.1093/bja/aew264, PMID 28077528.

11. Zeinoun P, Akl EA, Maalouf FT, Meho LI. The Arab region's contribution to global mental health research(2009-2018): A bibliometric analysis. Frontiers in Psychiatry. 2020;11:182. doi: 10.3389/fpsyt.2020.00182, PMID 32265754.

12. Engqvist L, Frommen JG. The h-index and self-citations Trends in Ecology and Evolution. 2008;23(5):250-2. doi: 10.1016/j.tree.2008.01.009, PMID 18367289.

13. Wu H, Tong L, Wang Y, Yan H, Sun Z. Bibliometric Analysis of global research trends on ultrasound microbubble: A quickly developing field. Frontiers in Pharmacology. 2021;12:646626. doi: 10.3389/fphar.2021.646626, PMID 33967783.

Websites

https://www.aisb.org.uk/public-engagement/what-is-ai

https://www.investopedia.com/terms/a/artificial-intelligenceai.asp

https://builtin.com/artificial-intelligence

https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_overview.htm