

Scientometric study of Academic Publications on Artificial Intelligence

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How to cite this article:

K Praveena, Veerakumar /Scientometric study of Academic Publications on Artificial Intelligence. /Indian J Lib Inf Sci 2021;15(2):57–64.

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Abstract

The present research paper pertains to the scientometric analysis of research literature on Artificial Intelligence from the year 1999 to 2019. The main objectives of this research work is to explore the academic research/review publication contributed by the Scientists and Subject experts from the Engineering background. The data/information used in this study has been collected from the online database “Web of Science”. The following terms are used as keywords to retrieve the data from the “Web of Science” are (ALL = Artificial Intelligence, Time span = 1999-2019). This study discusses the major parameters like yearly publication, citation pattern, a bibliographic form of publication, highly contributed authors, top-ranking authors etc. The foremost results of the study have found that during the study period 21643 research publications has been contributed by the authors in the Engineering discipline.

Keywords: Scientometrics; Artificial Intelligence; Web of Science Database; Degree of Collaboration.

Introduction

Scientometric analysis of scientific publications has become an important aspect of information science research. This is due to the fact that bibliometric studies help to identify patterns of publication, authorship, citations, and secondary journal coverage. The variables provide information about the dynamics of the area under consideration. As a result of this insight, information resources are better organised, which is necessary for systematic use of available information. 'Scientometrics,' a branch of science that describes output traits in terms of organisational research structure, resource inputs and outputs, creates benchmarks to assess the quality of information output. Scientometric studies use growth patterns and other attributes to characterise disciplines. These studies have the potential to be particularly useful in assessing emerging disciplines. In the current study, a

scientometric analysis of research performance on Artificial Intelligence, a rapidly growing area in the knowledge-driven world, is conducted.

John McCarthy introduced the concept of artificial intelligence. He started researching on this subject since 1956, suggesting that each aspect of learning and other domains of intelligence can be described precisely enough for a machine to simulate. Artificial intelligence describes machine work processes that, if performed by humans, would require intelligence. The term 'artificial intelligence means investigating intelligent problem-solving behavior and creating intelligent computer systems'. AI systems, depending on their sophistication, can perform actions similar to human beings such as perception, interpretation, reasoning, learning, communication, and decision making to arrive at a solution to a given problem. Artificial neurons, like neurons in the human brain,



serve as information-processing units in artificial neural networks (Haykin, 2005). Neural networks learn through experience; that is, they generalise from previous experiences to new ones and make decisions based on those experiences. A neural network is made up of a group of neural nodes that are linked to some weighted nodes. Each node represents a brain neuron, and the connections between them are analogous to the synapses that connect brain neurons.

Since its inception, AI systems have undergone numerous developments that have broadened their applications, including pattern recognition, automation, computer vision, virtual reality, diagnosis, image processing, nonlinear control, robotics, automated reasoning, data mining, process planning, intelligent agent and control, manufacturing, and so on. Currently, most AI applications are limited, in that they can only carry out specific tasks or solve pre-defined problems. AI operates in a variety of ways, drawing on principles and tools from a variety of disciplines, including math, logic, and biology. Modern AI technologies are increasingly capable of making sense of diverse and unstructured types of data, such as natural language text and images. Machine learning has been the most successful type of AI in recent years, and it is the underlying approach in many of the applications that are currently in use. Machine learning, rather than following pre-programmed instructions, enables systems to discover patterns and derive their own rules when presented with new data and experiences.

A select few studies that were undertaken in the past focused on quantitative analysis of global output on artificial intelligence research covering different study periods and different aspects of the subject in their research analysis. Among such studies, Artificial Intelligence study carried out a multi-angle of research productivity in the area of artificial research (AI) by subject category, journal, author, country, institution and keywords covering the period during 1990 to 2014 (Niu, 2016).

It's examined global artificial intelligence research output (10795 papers) published during 1981-2010, and reported growth characteristics, continent-wise and country-wise distribution, identification of prolific authors and journals, collaborative patterns, etc. (Gunasekaran and Shanmugam, 2016).

They were analyzed global artificial intelligence research output covering the period during 2000-2011, and reported article distribution by publication year, languages, countries/regions,

authors, journals etc. (Cheng and Wang, 2012).

It's studied the artificial intelligence research in Indian context which analysed data from Scopus database published during 1968 to 2014. The study reported growth characteristics, citation per paper, keywords, national and international collaboration, and organization-wise distributions, etc. Besides, there were a few other bibliometric studies carried out in India, which assessed the overall computer science research output (including artificial intelligence) in India and covered different study aspects and periods. (Shrivastava, Rishab & Mahajan, Preeti; 2016, Gupta, B.M. & Dhawan, S.M.; 2017).

Bibliometric analysis of digital literacy research output in J-gate analyzed the pattern of growth of the research output published in the pattern of authorship, author productivity and subjects covered in the papers over the period 2009-2018. It found that 1601 papers were published during the period of study 2009-2018. The Doubling Time has shown an increasing trend and RGR has been decreased from 0.23 to 0.20. (Praveena, 2019)

Objectives of the study

The main objective of the present study is to analyze the research performance of artificial intelligence research from 1999 to 2019, based on the publications output as indexed in Web of Science database. In particular, the study focuses on the following objectives:

- To study the research output of artificial intelligence, its growth, and citation impact.
- To examine the distribution of document wise and language wise distribution of literature in artificial intelligence.
- To identify the distribution of subject areas, Publisher and Funding Agencies for research in artificial intelligence.
- To study the share of international collaborative publication in Artificial Intelligence.
- To Calculate the Collaborative Coefficient and Degree of Collaboration of Authorship Pattern in Artificial Intelligence.

Methodology

The data set has been retrieved from the science citation index database Web of Science Core Collection to analyze the research output of the Artificial Intelligence. The authors formulated searched strategy by using a search query as ALL=

("Artificial Intelligence") with a period of 1999 to 2019. A scientometric statistical analysis method was applied to the resultant data. They are discussed in this study: types of documents published, year-wise distribution of publications, language, funding Agencies, subject-wise, Publisher, institution and Country. The Histcite and Bibexcel tools were used in this study for data analysis.

Result and Discussion

Table 1: Year-wise distribution of Research Publication.

S.No	Years	Publication	Global Citation	Citation per Paper
1	1999	385	14254	37.02
2	2000	370	10391	28.08
3	2001	412	14658	35.57
4	2002	389	9087	23.35
5	2003	465	14451	31.07
6	2004	463	13855	29.92
7	2005	490	11045	22.54
8	2006	564	13912	24.66
9	2007	493	16620	33.71
10	2008	526	14806	28.15
11	2009	599	18720	31.25
12	2010	596	16068	26.96
13	2011	669	15609	23.33
14	2012	751	16447	21.90
15	2013	830	16217	19.54
16	2014	941	16844	17.90
17	2015	989	17301	17.49
18	2016	1155	21126	18.29
19	2017	1676	24818	14.81
20	2018	3027	27285	9.01
21	2019	5853	17733	3.03
	Total	21643	341247	15.77

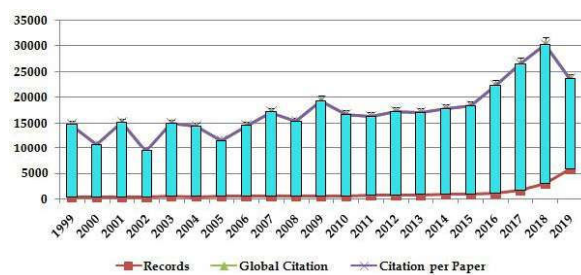


Fig. 1: Year-wise distribution of publications and citations.

Table-1 shows the year-wise distribution and total citations in Artificial Intelligence research during the period of 21 years i.e. (1999-2019) in which a total of 21643 publications are retrieved, Indian Journal of Library and Information Science / Volume 15 Number 2 / May-August 2021

a maximum 5853 research papers were published in the year 2019, followed by 3027 publications in the year 2018 and a total 341247 citations was found in publications in which a highest 27285 citations were found in 3027 records in 2018. The research contribution is in increasing trend during the study period. The overall data of the year-wise distribution of publications, citations and citation per paper are shown in table- 1 and figure- 1. The annual growth rate is a useful method to evaluate the yearly trends in research productivity (Kumar & Kaliyaperumal, 2015).

Table 2: Collaborative Coefficient and Degree of Collaboration of Authorship Pattern.

Year	Single Author	Multiple Authors	Total	Collaborative Coefficient (CC)	DC
1999	119	266	385	0.34	0.69
2000	101	269	370	0.36	0.73
2001	120	292	412	0.35	0.71
2002	109	280	389	0.36	0.72
2003	121	344	465	0.37	0.76
2004	100	363	463	0.39	0.78
2005	140	350	490	0.36	0.71
2006	124	440	564	0.39	0.78
2007	113	380	493	0.38	0.77
2008	110	416	526	0.39	0.79
2009	113	486	599	0.41	0.81
2010	104	492	596	0.41	0.83
2011	116	553	669	0.41	0.83
2012	110	641	751	0.42	0.85
2013	101	729	830	0.43	0.88
2014	125	816	941	0.43	0.87
2015	147	842	989	0.42	0.85
2016	156	999	1155	0.43	0.86
2017	310	1366	1676	0.41	0.82
2018	451	2576	3027	0.42	0.85
2019	768	5085	5853	0.43	0.87
	3658	17985	21643	0.42	0.83

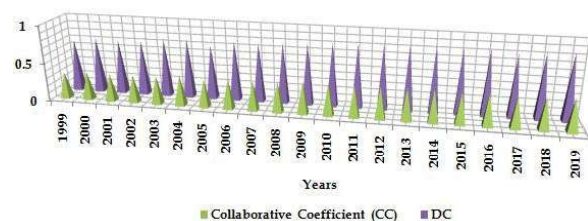


Fig. 2: Collaborative Coefficient and Degree of Collaboration of Authorship Pattern.

Table 2 illustrates the degree of author's

collaboration in Artificial Intelligence research in India from (1999-2019). The highest 17985 of publications were published by multiple authors while the rest 3658 of publications were contributed by a single author. The average degree of collaboration was (0.83) recorded during the period of study. It is also observed that the degree of author's collaboration has been shown in the fluctuating trend. The overall data of the author's collaboration was shown in below table 2. The degree of author collaboration was clearly shown its dominance on multiple author contributions. (K. Subramanyam, 1983) is given the DC formula to determine the degree of author collaboration in quantitative terms. The following formula used to analyse the degree of authors collaborations.

$$DC = Nm/Nm + Ns$$

It is also observed that the average collaboration coefficient was (0.42) recorded while the maximum (0.43) were records in the year 2013,2014,2016,2019.

(Ajiferuke, Burrel and Tague, 1988) suggested collaborative coefficient and it is used by (Karki and Garg, 1997).

The collaboration coefficient (CC) counted by the following formula:

$$CC = 1 - \sum_{j=1}^A (1/j) f_j / N$$

Where, j = the number authors in an article i.e. 1, 2, 3, more than 3.

f_j = the number of j authored articles

N = the total number of articles published, and

A = the total number of authors per articles.

Table 3: Document types distributions of publications.

S. No	Document wise	Records	%	TLCS	TGCS
1	Article	16227	75.0	15517	247122
2	Review	1795	8.2	3412	66134
3	Article; Proceedings Paper	1378	6.4	835	21495
4	Editorial Material	1182	5.5	840	5289
5	Meeting Abstract	682	3.1	21	92
6	Letter	123	0.6	47	379
7	Book Review	101	0.5	5	64
8	News Item	68	0.3	30	104
9	Correction	37	0.2	4	38
10	Article; Book Chapter	29	0.1	28	400
11	Review; Book Chapter	11	0.1	2	120
12	Biographical-Item	10	0.0	2	10
	Total	21643	100	20743	341247

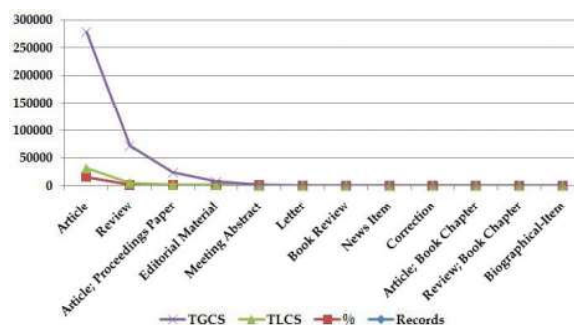


Fig. 3: Document types- distribution of publications.

Document types

Table-3 and figure-3 reveals the document wise distribution of Artificial Intelligence research during (1999-2019). The maximum 16227 (75%) of records were published in form of Articles, followed by 1795 (8.25%) of review, 1378 (6.4%) of Proceedings Paper, 1182 (5.5%) of Editorial Material, 682 (3.1%) of Meeting Abstract and below 1% records were found on Letter, Book Review, News Item, Correction, Article; Book Chapter, Review; Book Chapter and Biographical-Item.

Table 4: Language wise Distributions of publications.

S.No	Language wise	Records	%	TLCS	TGCS
1	English	21139	97.8	20669	340381
2	German	127	0.6	9	116
3	Spanish	120	0.6	6	236
4	French	60	0.3	7	46
5	Portuguese	52	0.2	37	233
6	Polish	24	0.1	3	36
7	Russian	23	0.1	0	16
8	Chinese	18	0.1	4	59
9	Croatian	14	0.1	3	18
10	Hungarian	12	0.1	1	2
11	Turkish	10	0.0	1	35
12	Czech	9	0.0	1	29
13	Japanese	8	0.0	0	2
14	Italian	4	0.0	0	3
15	Slovak	4	0.0	0	2
16	Slovene	4	0.0	2	19
17	Dutch	3	0.0	0	0
18	Korean	3	0.0	0	3
19	Icelandic	5	0.0	0	10
20	Finnish	1	0.0	0	0
21	Lithuanian	1	0.0	0	0
22	Swedish	1	0.0	0	1
23	Ukrainian	1	0.0	0	0
	Total	21643	100	20743	341247

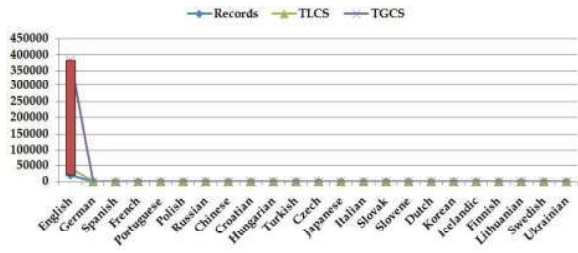


Fig. 4: Language wise Distributions of publications.

Language

Table-4 and Figure-4 reveals the fact that the literature on Artificial Intelligences from 1999 to 2017 are published in 23 languages A total 21643 documents were published. The highest contribution was made in English language 21139 (97.8%) and below (1%) languages were followed by German, Spanish, French, Portuguese, Polish, Russian, Chinese, Croatian, Hungarian, Turkish, Czech, Japanese, Italian, Slovak, Slovene, Dutch, Korean, Icelandic, Finnish, Lithuanian, Swedish and Ukrainian.

Table 5: Authors H-index.

S. No.	Authors	h-index	Citation sum within h-core	Citations	Articles
1	Raja MAZ	23	914	1171	40
2	Kisi O	22	1529	1756	48
3	Chau KW	20	1609	1727	39
4	Bui DT	20	916	1098	37
5	Shahabi H	20	916	970	24
6	Pham BT	18	697	805	28
7	Shirzadi A	18	820	871	23
8	Zhang J	17	617	768	65
9	El-Shafie A	17	828	929	31
10	Cheng MY	17	559	691	39
11	Chen W	16	762	822	27
12	Wang Y	15	740	893	48
13	Shamshirband S	15	670	758	29
14	Li X	14	563	666	41
15	Wang ZL	14	925	993	26

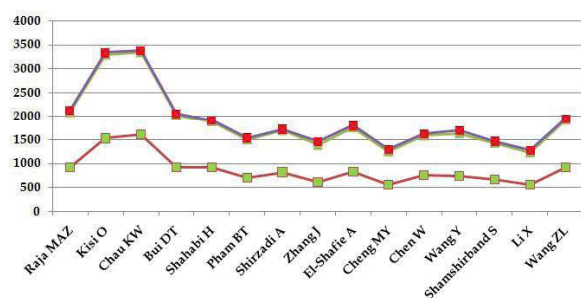


Fig. 5: Authors H-index.

Productive Authors, h-index, and total Citations

Table - 5 and Figure - 5 depicts the top Fifteen most productive authors, h-index and total citation. The maximum 40 of research papers; 23 h-index; 1171 citations were contributed by Raja MAZ, followed by Kisi Owith48 publications; 22 h-index; 1756 citations, and Chau KW contributed 39 research papers; 20 h-index; and 1727 citations while Bui DT with 37 contributions; 20 h-index; and 1098 citations. Shahabi H contributed 24 research papers; 20 h-index; and 970 citations and other authors contribution were below 20 h-index and below 900 citations.

Table 6: Subject-wise contribution of Artificial intelligence research.

Subject wise	Records
Computer Science	7834
Engineering	6376
Science & Technology	1202
Chemistry	929
Operations Research & Management Science	882
Materials Science	873
Telecommunications	872
Energy & Fuels	732
Environmental Sciences & Ecology	726
Physics	722
Automation & Control Systems	721
Mathematics	705
Business & Economics	655
Neurosciences & Neurology	566
Radiology, Nuclear Medicine & Medical Imaging	504

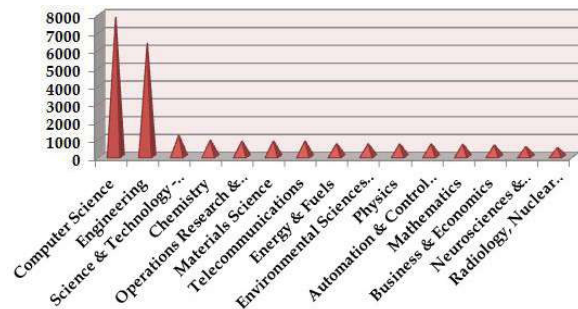


Fig. 6: Subject wise contribution of artificial intelligence research.

Subject wise

Table- 6 illustrates the subject-wise distribution of publications in Artificial Intelligence research from (1999-2019). The maximum 7834 of publications

is from computer science subject area, followed by Engineering with 6376 publications while in Science & Technology - Other Topics subject a total of 1202 publications and below 1000 records were on other subjects. The overall data of the subject-wise distribution of publications are shown in table -6.

Table 7: Institution wise contribution of Artificial intelligence research.

Institution	Records	TLCS	TGCS
Chinese Academy of Sciences	330	299	6183
Islamic Azad University	234	332	3651
Stanford University	178	645	7111
MIT	160	306	5197
Hong Kong Polytechnic University	159	267	4266
University Oxford	148	295	2472
Nanyang Technology University	139	145	2868
Tsinghua University	127	98	2310
National University Singapore	124	133	2122
Harvard Medical School	121	307	1766
University Toronto	119	132	5251
University Tabriz	118	576	2643
University Tehran	118	166	2320
University of the Chinese Academy of Sciences	116	55	1678
Zhejiang University	113	79	950

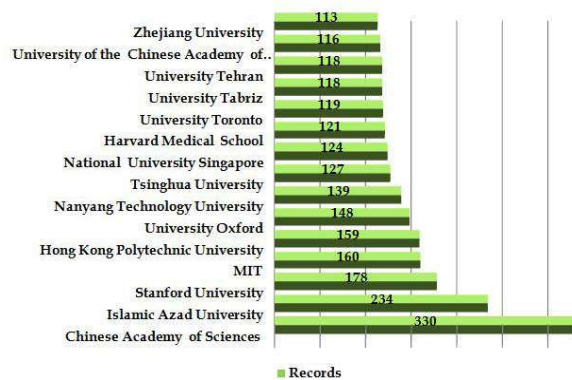


Fig. 7: Institution wise contribution of Artificial intelligence research.

The contributors from Artificial Intelligence research field with many institutions/universities of India as well other foreign countries. The list of top 15 institutions collaborating with in the period of 1999-2019 is shown on the Table- 7 and in Figure- 7 It is clear from the table that Chinese Academy of Sciences (330 papers), Islamic Azad University (234 papers), Stanford University (178

papers), MIT (160 papers), Hong Kong Polytechnic University (159 papers) and other institutions were below contribution of 150 papers.

Table 8: Country contribution of Artificial intelligence.

Country	Records	TLCS	TGCS
USA	4748	5959	98831
Peoples R China	3456	2324	42202
UK	2143	2730	45365
Spain	1301	900	16156
Iran	1038	1693	15418
India	1009	971	13529
Canada	947	956	17888
Germany	879	640	10124
Italy	837	621	14346
France	814	591	12520
Australia	804	749	11835
South Korea	660	489	7513
Turkey	654	2160	19397
Japan	629	526	7167

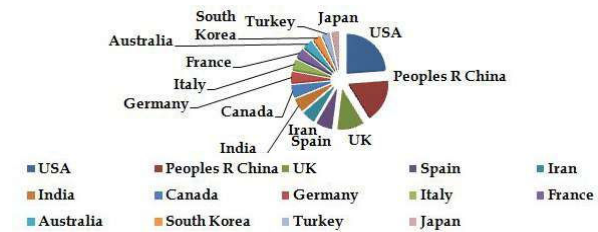
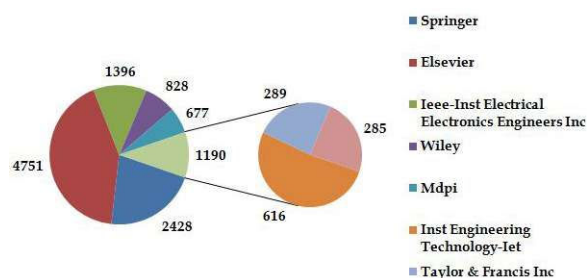


Fig. 8: Country wise contribution of Artificial intelligence research.

Top 15 Most Productive Countries in Artificial Intelligence Research. Artificial intelligence research is spread 138 countries as seen from publications data during 1999-2019. USA accounted for the largest global publication 4748, followed by China (3456), India and U.K. (2143), Spain (1301), Iran(1038) and India (1009) during 1999-2019 as shown in Table 8 and Figure 8.

Table 9: Publisher contribution of Artificial intelligence research.

Publisher	Records
Springer	2428
Elsevier	4751
Ieee-Inst Electrical Electronics Engineers Inc	1396
Wiley	828
Mdpi	677
Inst Engineering Technology-Iet	616
Taylor & Francis Inc	289
Sage Publications Ltd	285



Graph 9: Publisher distribution of Artificial intelligence research.

Table-9 and Figure-9 illustrates the Publisher contribution of publications in Artificial Intelligence research during the study period 1999 to 2019. The maximum 2428 of publications came in the Springer publisher, followed by Elsevier with 4751 publications while in Ieee-Inst Electrical Electronics Engineers Inc publisher a total of 1396 publications, Wiley 828 publications, Mdpi 677 publications, Inst Engineering Technology-Iet 616 publications, Taylor & Francis Inc 289 publications and Sage Publications Ltd 285 Publications.

Table 10: Funding Agencies sponsoring research on Artificial intelligence.

Funding Agencies	Records
National Council for Scientific and Technological Development	43
CAPES	41
Fundamental Research Funds for the Central Universities	28
Natural Sciences and Engineering Research Council of Canada	27
Consejo Nacional de Ciencia y Tecnologia	26
European Union (EU)	23
European Commission Joint Research Centre	19
Natural Sciences and Engineering Research Council of Canada	17
National Science Foundation (NSF)	16
National Institutes of Health United States Department of Health & Human Services National Institutes of Health (NIH) - USA	15
European Social Fund	15
China Scholarship Council	13
FAPEMIG Minas Gerais State Research Foundation	13
National Program for Support of Top-Notch Young Professionals	12

Funding Agencies

Table-10 reveals the Funding Agencies that Indian Journal of Library and Information Science / Volume 15 Number 2 / May-August 2021

supports the research on Artificial Intelligence during (1999-2019). The National Council for Scientific and Technological Development Funding Agencies have sponsored the maximum ie for 43 researches, followed by 41 by CAPES, 28 of Fundamental Research Funds for the Central Universities, 27 of Natural Sciences and Engineering Research Council of Canada, 26 of Consejo Nacional de Ciencia y Tecnologia and the other Funding Agencies have supported less than 25 researches.

Conclusion

The purpose of this study is to conduct a scientometric analysis of artificial intelligence research in order to understand the growth of literature in the discipline, the pattern of publications, and the impact of research. Using publications data from Web of Science database, this study provides a quantitative and qualitative description of artificial intelligence research covering a period of 21 years. India stands sixth highest in the world ranking in artificial intelligence research. If India is to become competitive with the world leaders in artificial intelligence research, academic and research organizations in the country will have to give still better performance in future. Hence, 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.

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