Performance of Artificial Intelligence Research Output: A Scientometric Analysis

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Abstract

The Performance of Artificial Intelligence Research Output: A Scientometric Analysis. The summary of this study is to present the preliminary results of a research in progress regarding the subject of artificial intelligence. The period of study was taken from 1981 to 2010. Based on this analysis the following results were concluded; it is conjecture that the research productivity on Artificial Intelligence exhibits a gradual growth from 2006 to 2010. It is inferred that the dominating source in the form of journal articles compared to the other sources. English is generally the medium of research communication, for it is widely recognized all over the world. The collection is exported to HistCite to obtain a large list of 10,795 articles and 10,37,707 times cited references along with their local and global citation scores (LCS and GCS). It is found that the mean growth rate is 0.16 and the mean doubling time for the research output on Artificial Intelligence research is 9.71 years.

Keywords

Artificial Intelligence; Research Output;Growth
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Electronic access

The journal is available at www.jalis.in

Journal of Advances in Library and Information Science
ISSN: 2277-2219 Vol. 5. No.3. 2016. pp.235-242

1. INTRODUCTION

The Scientometric analysis of scientific publications is an important aspect of research endeavour in information science in recent years. It could be attributed to the fact that Bibliometric studies are used to identify the pattern of publication, authorship, citations and secondary journal coverage. These factors can give an insight into the dynamics of the area under consideration. Consequently, this insight leads to better organization of information resources which is essential for systematic use of available information. 'Scientometrics', the branch of science that describes the output traits in terms of organizational research structure, resource inputs and outputs, develops benchmarks to evaluate the quality of information output. Scientometric studies characterize the disciplines using the growth pattern and other attributes. These studies have potential particularly in assessing the emerging disciplines. In the present study, the scientometric study of the research performance has been done on Artificial Intelligence, a significantly growing area in the knowledge-driven world.

NEED FOR RESEARCH PERFORMANCE OF ARTIFICIAL INTELLIGENCE LITERATURE

1. The Artificial Intelligence research carried out in the fields of technology, Computer Science and Information Science.
2. The evaluation of the achievements is important, because their policy decisions may affect scientific productivity and progress.
3. The evaluation on the basis of year wise growth trend in continues to depend more on research productivity performance.
4. Peer review is the most common form of evaluation of scientific performance, but application of Sceintometric measures has been proposed as a supplement.
5. There are basically two bibliometric indicators used for measuring scientific output: publication counts and citation counts. Publication output serves as an approximation to scientific activity and productivity.

REVIEW OF LITERATURE

This chapter devotes to examine the review of works relating to various aspects of Scientometric studies. It could be observed that there are various research studies highlighting the importance of Scientometric analysis. This chapter deals with the relevant Review

of Literature. h. The term, Bibliometrics, was introduced by Alan Pritchard in 1969. Although it seems that the term's history is new, its origin goes back to Campbell's Study in 1896 according to Sengupta(1992). He states that Campbell's (1896) statistical studies in publications subject categories was the first time for conduction of bibliometric study. Up to Pritchard (1969), bibliometric studies called statistical bibliography.Byit's nature, the literature of science and technology is the focus of Scientometrics as a field. According to Tague-Sutcliffe (1992), Scientometrics deals with quantitative aspects of science. Van Raan (1997) also emphasizes the quantitative study of science and technology while defining the term. Similarly, Concepcion S Wilson (1999) stated that all quantitative aspects of science of science, communication in science policy were in the content of Scientometrics. By considering this efficiency of various dimensions of Scientometric studies, the researcher has presented the literature on the basis of chronological order.

OBJECTIVES OF THE STUDY

The major objectives are framed with the exclusive notion of the present study as mentioned below:

1. To identify the source wise and year wise distribution of Artificial Intelligence research output Scientists.
2. To examine the growth rate, doubling time and exponential growth rate of Artificial Intelligence research output during period between 1981 and 2010.
3. To compare and measure the analysis of continent-wise and country-wise of Artificial Intelligence research output performance.
4. To identify the prolific journals and journal distribution of Artificial Intelligence research output.
5. To find out the historiography of LCS and GCS links for selective journals.
6. To apprehend the applicability of *Bradford's* law of scattering in the field of Artificial Intelligence research.
7. To classify the prolific authors and authorship patterns and author productivity.
8. To identify the nature of collaboration and co-authorship pattern and determine the degree of collaboration in Artificial Intelligence research.
9. To find out the historiography of LCS and GCS links for selective authors.

METHODOLOGY

The present study efforts to investigate the research output performance of Artificial Intelligence research area. It aims to identify the distribution of research output on the basis of research papers contributed by Scientists in the field of Artificial Intelligence research. The study explores to examine the growth rate and relative growth level during the study period. The author productivity and the degree of collaboration on Artificial Intelligence research output are also brought under the purview of the study. The study aims to analyse the thrust areas of research concentration on Artificial Intelligence research. This study is mainly tentative in nature in identifying the research performance of comprehensive Scientists in the field of Artificial Intelligence research and it is also analytical in nature with the suitable statistical tools applications in strengthening the empirical validity.

SAMPLING

The researcher has adopted the arbitrary procedure to select the Artificial Intelligence research literature as a representative of the present study. The choice of selection of the subject is left with its emerging familiarity out of various disciplines of science. It could be noted that the research implications of Artificial Intelligence research contribute to technological advancement of our society along with socio-economic development. Hence, the development of research on Artificial Intelligence is of enormous validity in accelerating the economic development of the every country. By keeping these facts in mind, the researcher has chosen Artificial Intelligence research as the field of research focus.

DATA COLLECTION

There are various sources contributing to the research output in the field of Artificial Intelligence research by inclusive Scientists. In this study, it has secondary sources that are taken for analysis. The necessary data was collected from the Science Citation Index (SCI) and Social Science Citation Index (SSCI) and Arts & Humanities Citation Index (ACHI) which are available via the Web of Science (WoS). The WoS is the search platform provided by Thomson Reuters (the former Thomson Scientific emerged from the Institute for Scientific Information (ISI) in Philadelphia). The SCI and SSCI database is one of the very comprehensive databases covering all aspects of science. The study period from 1981 to

2010 is selected as the database that is available. The search string "Artificial Intelligence" is used for the data from the database of SCI, SSCI and ACHI from 1981 to 2010 (totally thirty years) downloaded the records based on the above strings. A total of 10,795 records were downloaded and analyzed by using the **Histcite** software application as per the objectives of the study.

Table 1 Showing Performance of Artificial Intelligence Research Output in European Countries

S.No	Countries	81-85	86-90	91-95	96-00	01-05	06-10	Total	% of 3846	% of 10795	TCS
1	UK	39	77	252	242	228	234	1072	27.87	9.93	13945
2	France	16	51	112	84	96	90	449	11.67	4.16	3445
3	Spain	0	7	53	64	88	125	337	8.76	3.12	2994
4	Italy	2	21	73	83	77	85	341	8.87	3.16	3978
5	Germany	0	5	109	86	63	65	328	8.53	3.04	3245
6	Netherlands	6	20	34	32	47	40	179	4.65	1.66	1769
7	Greece	0	2	14	23	32	41	112	2.91	1.04	1103
8	Poland	4	4	9	13	28	30	88	2.29	0.82	1079
9	Belgium	1	6	19	25	20	22	93	2.42	0.86	2046
10	Austria	1	4	22	13	22	19	81	2.11	0.75	597
11	Switzerland	4	3	19	14	18	21	79	2.05	0.73	2560
12	Sweden	1	1	9	29	16	13	69	1.79	0.64	849
13	Russia	0	0	17	19	14	16	66	1.72	0.61	237
14	Finland	0	3	14	13	13	15	58	1.51	0.54	501
15	Portugal	0	0	4	13	12	23	52	1.35	0.48	666
16	Romania	0	3	4	1	3	20	31	0.81	0.29	217
17	Denmark	2	3	12	8	7	14	46	1.20	0.43	341
18	CzechRepublic	0	0	6	6	6	18	36	0.94	0.33	158
S.No	**Countries**	**81-85**	**86-90**	**91-95**	**96-00**	**01-05**	**06-10**	**Total**	**% of 3846**	**% of 10795**	**TCS**
19	Slovenia	0	0	3	8	11	16	38	0.99	0.35	315
20	Hungary	0	6	12	5	10	4	37	0.96	0.34	245
21	Ireland	0	0	3	2	14	10	29	0.75	0.27	205
22	Bulgaria	0	0	10	5	4	5	24	0.62	0.22	150
23	USSR	4	12	8	0	0	0	24	0.62	0.22	42
24	Norway	0	0	7	6	6	3	22	0.57	0.20	113
25	Croatia	0	0	0	5	3	11	19	0.49	0.18	30
26	Cyprus	0	0	0	3	8	8	19	0.49	0.18	231
27	FRG	10	9	0	0	0	0	19	0.49	0.18	48
28	Lithuania	0	0	0	1	3	15	19	0.49	0.18	40
29	Yugoslavia	0	2	6	3	5	0	16	0.42	0.15	145
30	Czechoslovakia	2	4	9	0	0	0	15	0.39	0.14	23
31	Serbia	0	0	0	0	0	15	15	0.39	0.14	30
32	Slovakia	0	0	4	3	4	4	15	0.39	0.14	50
33	Ukraine	0	0	0	4	0	0	4	0.10	0.04	12
34	Iceland	0	0	0	0	0	3	3	0.08	0.03	9
35	Macedonia	0	0	0	0	0	3	3	0.08	0.03	7
36	Latvia	0	0	1	0	0	1	2	0.05	0.02	15
37	Malta	0	0	0	1	0	1	2	0.05	0.02	31
38	Byelarus	0	0	1	0	0	0	1	0.03	0.01	2
39	Moldova	0	0	1	0	0	0	1	0.03	0.01	0
40	Rep of Georgia	0	0	0	1	0	0	1	0.03	0.01	0
41	SerbiaMonteneg	0	0	0	1	0	0	1	0.03	0.01	20
	Total	**92**	**243**	**847**	**816**	**858**	**990**	**3846**	**100**	**35.63**	**41493**

The countries of Sweden, Russia, Finland, Portugal and Denmark are have above one percentage of publications output among European Continent and these countries have less than one percent of publication output at global level. The remaining countries such as Romania, Czech Republic, Slovenia, Hungary, Ireland, Bulgaria, USSR, Norway, Croatia, Cyprus, FRG, Lithuania, Yugoslavia, Czechoslovakia, Serbia, Slovakia, Ukraine, Iceland, Macedonia, Latvia, Malta, Byelarus, Moldova, Rep of Georgia and Serbia Montenegwere have less than 1 (one) percent. Hence, the fifth (Among the six continents, European Continent leads from the front term contributing more research output on Artificial Intelligence) hypothesis noted in chapter 3 that has been proved.Identified from the above analysis, European countries have contributed the subject 'artificial intelligence' in the year groups from 2006 to 2010 and 2001 to 2005. The UK has the highest publications amongst the forty one countries.

Table 2: Performance of Artificial Intelligence Research Output by North American Countries

S. No	Countries	81-85	86-90	91-95	96-00	01-05	06-10	Total	% of 3188	% of 10795	TCS
1	USA	180	338	773	484	372	433	2580	80.93	23.90	45729
2	Canada	15	31	125	87	122	139	519	16.28	4.81	5951
3	Mexico	0	0	4	19	32	22	77	2.42	0.71	495
4	Cuba	0	0	0	0	4	5	9	0.28	0.08	15
5	Jamaica	0	0	0	2	0	1	3	0.09	0.03	4
		195	**369**	**902**	**592**	**530**	**600**	**3188**	**100**	**29.53**	**52194**

Table 2 indicates only five (8.48 %) North American countries (total of the 94 countries) that have 3188 (29.53 %) Artificial Intelligence research output in relation to total output. It could be noted that in the year group from 1981 to 1985 publication output that had just 195 articles and it rose to 600 in the year group from 2006 to 2010. It indicates manifold increase in the level of total research output in selected areas in the countries in North American Continent countries with 52194 TCS.Country wise analysis reveals the following facts: The USA has the highest publications 2580 (80.93 %) standing first amongst five countries and 23.9 percents amongst ninety four countries, publications with 45729 TCS measured. Canada has 519 (16.28 %) and contributes within continent and just 4.81 percent outputs from the total output with 5951 TCS. Mexico has 77 (2.42 %) publications within the continent and just 0.71 percents output at global level with 495 TCS. Cuba and Jamaica had less than ten articles and less than one percent publication at continent wise and world wise in the subject of Artificial Intelligence. At the world level, the year wise performance analysis shows the North American Continent, in the year group from 1981 to 1985 outputs that has just 195 records and it rose to 600 in the year group from 2006 to 2010. It showed that the artificial intelligence research growth rate increased many times. Overall percentage analysis establishes in the year group from 1991 to 1995, having the highest publication. This table analysis reveals that the USA is the highest productivity country of artificial intelligence in continent wise and world wise.

Table 3:Showing Research Performance of Artificial Intelligence Output by Asian Countries

S. No	Countries	81-85	86-90	91-95	96-00	01-05	06-10	Total	% of 1672	% of 10795	TCS
1	Peoples R China	3	2	33	50	79	161	328	19.62	3.04	2905
2	Japan	2	16	93	39	51	75	276	16.51	2.56	2529
3	Taiwan	0	3	39	18	42	96	198	11.84	1.83	2240
4	India	0	3	39	28	37	79	186	11.12	1.72	1222
5	South Korea	0	0	13	24	33	68	138	8.25	1.28	1046
6	Turkey	0	0	5	18	31	93	147	8.79	1.36	1568

7	Singapore	0	3	14	32	30	27	106	6.34	0.98	1211
8	Israel	2	3	21	24	17	14	81	4.84	0.75	1242
9	Iran	0	0	0	1	8	58	67	4.01	0.62	261
10	Malaysia	0	0	0	1	9	12	22	1.32	0.20	175
11	Saudi Arabia	0	0	3	5	4	9	21	1.26	0.19	338
12	Hong Kong	1	2	7	9	0	0	19	1.14	0.18	454
13	Thailand	0	0	6	0	3	6	15	0.90	0.14	298
S. No	**Countries**	**81-85**	**86-90**	**91-95**	**96-00**	**01-05**	**06-10**	**Total**	**% of 1672**	**% of 10795**	**TCS**
14	Kuwait	0	0	0	5	3	4	12	0.72	0.11	49
15	U Arab Emirates	0	0	3	1	1	7	12	0.72	0.11	80
16	Oman	0	0	0	2	4	4	10	0.60	0.09	54
17	Pakistan	0	0	0	0	3	4	7	0.42	0.06	17
18	Jordan	0	0	0	0	3	2	5	0.30	0.05	26
19	Bangladesh	0	0	0	0	2	2	4	0.24	0.04	7
20	Sri Lanka	0	0	0	0	3	1	4	0.24	0.04	15
21	Indonesia	0	0	0	1	0	2	3	0.18	0.03	23
22	Lebanon	0	0	0	0	1	2	3	0.18	0.03	4
23	Vietnam	0	0	0	0	2	1	3	0.18	0.03	5
24	Philippines	0	0	0	0	0	2	2	0.12	0.02	1
25	Azerbaijan	0	0	0	1	0	0	1	0.06	0.01	8
26	Bahrain	0	0	0	0	1	0	1	0.06	0.01	12
27	Qatar	0	0	0	0	1	0	1	0.06	0.01	7
	Total	**8**	**32**	**276**	**259**	**368**	**729**	**1672**	**100**	**15.49**	**15797**

Table 3 indicates twenty seven (28.72 %) Asian countries (totally 94 countries) with 1672 (15.49 %) Artificial Intelligence research output compared to other continents. It is noted that in the year group from 1981 to 1985 just 8 appeared and it rose to 729 in the year group from 2006 to 2010. It indicates an increase in the level of the total research output in the selected area of the Asian continent with 15797 TCS. Country wise analysis reveals the following facts: China (19.62 %), the first with total citation score being 2905 in the order of Artificial Intelligence research output and 3.04 percent output from the world output, followed by Japan having 16.51 percent output from the continent wise and just 2.56 percent output from the total sample records with 2529 TCS. The countries of Taiwan and India were have between 11 and 12 percent of research publications within the continent and between 1 and 2 percent output from the total records of sample. The countries of South Korea and Turkey have between 8 and 9 percent of publication at continent level and between 1 and 2 percent of research output at global level with 1046 and 1568 TCS. Singapore has 6.34 percent output at continent and 0.98 percent of publications at international level with 1211 TCS. The countries of Israel and Iran contribute above four percent output in this selected area. Malaysia, Saudi Arabia and Hong Kong have above one percent, contributing output publications. Remaining nineteen countries such as Thailand, Kuwait, USE, Oman, Pakistan, Jordan, Bangladesh, Sri Lanka, Indonesia, Lebanon, Vietnam, Philippines, Azerbaijan, Bahrain and Qatar have less than 1 (one) percent at Asian Continent output and global output.

Table 4.: Showing Research Performance of Artificial Intelligence Output of Australian Countries

S. No	Countries	81-85	86-90	91-95	96-00	01-05	06-10	Total	% of 325	% of 10795	TCS
1	Australia	4	15	52	59	66	83	279	85.85	2.58	1853
2	New Zealand	0	0	3	12	11	12	38	11.69	0.35	262
3	GDR	4	4	0	0	0	0	8	2.46	0.07	23
	Total	8	19	55	71	77	95	325	100	3.01	2148

Table 4 reveals that only three (3.19 %) Australian countries (out of 94 countries) at 325 (3.01 %) of publications artificial intelligence research output compared to other continents. It is further noted that in the year group from 1981 to 1985 output is just 8 articles and it has risen to 95 in the year group from 2006 to 2010. This indicates an increase in the level of total research output in the selected area in the Australian Continent with 2148 TCS.Country wise analysis reveals the following facts: Australia (85.85 %) at continent level 2.58 percents of output from the total records and it has stood the first position with 1853 TCS. New Zealand (11.69 %) within the second within continent output and 0.35 percent output from the total output, GDR has 2.46 percent output and in third within the continent output and has very low publications compared to world output.

Table 5: Showing Research Performance of Artificial Intelligence Output of South American Countries

S. No	Countries	81-85	86-90	91-95	96-00	01-05	06-10	Total	% of 259	% of 10795	TCS
1	Brazil	0	3	17	32	59	78	189	72.97	1.75	1474
2	Argentina	0	0	0	4	11	12	27	10.42	0.25	180
3	Chile	0	0	2	5	6	7	20	7.72	0.19	124
4	Colombia	0	0	0	1	1	11	13	5.02	0.12	26
5	Venezuela	0	0	2	1	5	0	8	3.09	0.07	34
6	Namibia	0	0	0	0	1	0	1	0.39	0.01	5
7	Trinid& Tobago	0	0	0	0	1	0	1	0.39	0.01	2
	Total	**0**	**3**	**21**	**43**	**84**	**108**	**259**	**100**	**2.40**	**1845**

Table 5 expressed that only seven countries (7.45 %) were from South American Continent (out of totally 94 countries) with 259 (2.4 %) of Artificial Intelligence research output. It is noted that in the year group from 1981 to 1985 has no publication output, and the year group from 1986 to 1990 has only 3 articles and it has risen to 108 in the year group from 2006 to 2010. It indicates an increase in the level of total research output in the selected area in the South American Continent with 1845 TCS. The country wise analysis reveals that the following facts: Brazil (72.97 %) within continent output and 1.75 percents of total output, followed by Argentina (10.42 %), Chile (7.72 %), Colombia (5.02 %), Venezuela (3.09 %), Namibia and Trinid& Tobago (0.39 %) of publication output in the filed of Artificial Intelligence within continent and these countries have less than one percent of publication from world output respectively. Observing the total citation scores, Brazil has the highest scores. Table 4.15 shows that 11 (11.7 %) African countries (totally 94 countries) have only 96 (0.89 %) Artificial intelligence research output compared to other continents. It is noted that in the year group from 1981 to 1985 had no publication output, and the year group from 1986 to 1990 had only one article and it rose to 39 in the year group of 2006 to 2010. It indicates increase in the level of total research output in the selected area in the African Continent with 510 TCS.

Table 6 : Showing Performance of Artificial intelligence Output by African Countries

S. No	Countries	81-85	86-90	91-95	96-00	01-05	06--10	Total	% of 96	% of 10795	TCS
1	South Africa	0	1	8	7	10	10	36	37.50	0.33	267
2	Egypt	0	0	4	5	11	7	27	28.13	0.25	128
3	Algeria	0	0	0	1	5	13	19	19.79	0.18	129
4	Tunisia	0	0	0	0	2	4	6	6.25	0.06	12
5	Cameroon	0	0	0	1	0	1	2	2.08	0.02	1
6	Ethiopia	0	0	0	0	0	1	1	1.04	0.01	1

7	Ghana	0	0	0	0	0	1	1	1.04	0.01	12
8	Morocco	0	0	0	0	0	1	1	1.04	0.01	0
9	Nigeria	0	0	0	0	1	0	1	1.04	0.01	0
10	Reunion	0	0	0	1	0	0	1	1.04	0.01	2
11	Senegal	0	0	0	0	0	1	1	1.04	0.01	12
	Total	**0**	**1**	**12**	**15**	**29**	**39**	**96**	**100**	**0.89**	**510**

Country wise analysis reveals the following facts: South African countries (37.5 %) has the highest publication and just 0.33 percen of publication at global level with total citation score of 267, followed by the countries like Egypt, Algeria, Tunisia and Cameroon have between two and twenty eight percent of publications. The remaining countries like Ethiopia, Ghana, morocco, Nigeria, Reunion and Senegal have each one article output.

FINDINGS AND CONCLUSION

The result of year-wise (thirty years) distribution by different sources of research output on Artificial Intelligence publications when examined reveals a maximum contribution in the years of 2010, 2009 and 2006. In total, 6,106 LCS exists with an average output of the subject being 203.5, which means that on an average each article, having 0.57 LCS measured. Totally 1, 01,702 GCS has measured and its average value for each year is 3,390.03. Totally 765 h - index values have measured and it is calculated at each year h – index value is 25.5. Total cited reference values for thirty years 2, 98,434 and it is measured for each year value is 9947.8. The total number of authors 26306 and its average value at each year is 876.86.The findings of country wise analysis from the European Countries, point to UK, France and Spain as being in the first, second and third ranks among the forty one countries. North American Countries, USA, Canada and Mexico Countries have the highest percentage among five countries, and occupy the first, second and third ranks. It is found from Asian countries like China, Japan and Taiwan that they stand first, second and third among twenty seven countries. It is identified from the Australia Continent that Australia and New Zealand countries are in the first and second ranks among the three countries. Brazil, Arzentina and Chile are in the first, second and third ranks among the seven South American countries. It is revealed from the African countries' analysis of South Africa, Egypt and Algeria countries that they dominate in the first, second and third ranks among the eleven countries. On examination of all the nations the USA and the UK are topping the list with the highest contribution.For all the continents, the time period taken for the analysis is thirty years (1981 - 2010). The European and North American Continents show its high priority in relation to the world output. Australian (0.91) Continent has nearly average priority relation to the word output. Asian (0.78) South American (0.77) and African (0.76) Continents showed their publication status to be much lower than the world output.From the specialization index analysis, North America has specialized relation with the world output. Europe and Australia Continents were having nearly average specialized relation to the world output. Remaining Asia, South America and Africa Continents have the lowest specialized relation in the world output. Based from this analysis, the following results were concluded; it is conjecture that the research productivity on Artificial Intelligence exhibits a gradual growth in the year group from 2006 to 2010. It is inferred that the dominating source in the form of journal articles compared to the other sources. English is generally the medium of research communication for it is widely recognized all over the world. The collection is exported to HistCite to obtain a large list of 10,795 articles and 10,37,707 times cited references along with their local and global citation scores (LCS and GCS). It is found that the mean growth rate is 0. 16 and the mean doubling time for the research output on Artificial Intelligence research are 9.71 years.

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