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A Critical Analysis of Scientific Productivity of the “Robotics” Research in India during 2009-2018

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ABSTRACT

This paper describes results of a scientometric study of “Robotics” research publications during the period of 10 years i.e. (2009-2018). The raw data was collected from leading citation database i.e. Scopus. The study examines and analysis various scientometrics parameter and after the analysis it has been found that the out of total 4325 research paper, the highest documents were published in 2018 i.e. 791 (18.29%) while the minimum 134 (3.1%) of research papers were found in the year 2009 and the annual growth rate of publications was in fluctuating trends. The maximum (1.23) relative growth rate was found in 2010; the highest doubling time (3.43) was recorded in 2018; the maximum papers were written by more than three authors i.e. 1657 research papers. The average degree of author’s collaborations was (0.93). Krishna, K.M. was the most productive author with (51) research papers contribution. Out of a total 16670 citations, 2718 citations were recorded in 2010 and a total 4325 publications, 2704 (62.52%) of records were conference paper. The highest publications came from computer science subject and the highest publications were published in ACM international conference proceeding series while the maximum 2508 ‘Robotics keyword was used by the authors during the period of study.

Keywords: Annual Groth Rate, Relative Growth Rate and Doubling time, Degree of Authors Collaboration, Collaboration Coefficient, Collaborative Index.

1. INTRODUCTION

The development and improvement of new technology robotics play a vital role. In the modern era robotics technique use every fields and the feature era is totally depend on it. “Robotics is an interdisciplinary branch of engineering and science that includes mechanical-engineering, electronic-engineering, information engineering, computer science, and others. Robotics deals with the design, construction, operation, and use of robots, as well as computer systems for their control, sensory feedback, and information processing.” <https://en.wikipedia.org/wiki/Robotics>. According to Creswell (1986), “research output includes research publications in professional journals and in conference proceedings, writing a book or chapter, gathering and analyzing original evidence, working with post-graduate students on dissertations and class projects, obtaining research grants, carrying out editorial duties, obtaining patents and licenses, writing of monographs, developing experimental designs, producing works of an artistic or creative nature, engaging in public debates and commentaries”. Tague-Sutcliffe (1992) defined “Scientometrics is the study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy-making. It involves quantitative studies of scientific activities including, among others, publication, and so overlaps bibliometrics to some extent”.

2. SCOPE OF THE STUDY

The present study is limited to “Robotics” research publications in “India” during the period of 10 years i.e. “2009-2018”.

3. LITERATURE REVIEW

Prakash & Arumugan (2017) carried out a study on the growth pattern of Biotechnology literature in India during the period (2002-2016). After the analysis it has been revealed that the growth rate of research papers has increased from the marked period of 2011-2016; most of the research papers were written by two or three authors; and the highest output was published by Indian Institute of Technology, Delhi during the period of study.

Amsaveni & Ramesh (2016) conducted a study on the mapping of research productivity in Forensic Science and after the analysis it has been found that 10464 research papers were contributed by scientists from the marked period of study while the relative growth rates have declined from (-0.482) in 1989 to (0.04) in 2010 and the degree of collaboration is (0.83) recorded from the marked period of study, Budowle, B. as the most prolific author from Canada; and “Journal of Forensic Science” and “Forensic Science International” were analyzed as the maximum research contributing and citations receiving journals from the marked period of study.

Krishnan & Raja (2016) carried out a study and after the analysis, it has been found that a large number of research papers has been published in the year 2013 i.e. (29.6%) and the relative growth rate is being decreased (3.401-0.94) while the doubling time was increased (0.203 – 0.998). The multi-authored contribution is more predominant with (89.8%) and journal articles were highly referenced by the contributors (51%).

Jeyasekar & Saravanan (2015) analyzed the bibliographic and citation data pertaining to global and Indian Forensic Science from the marked period (1975-2012). The raw data was collected from the Scopus and after the examination it was found that the maximum (3.46) collaborative index was recorded in the year 2012 and collaborative co-efficient was lowest (0.27) recorded in 1986 while the highest (0.65) recorded in 1994; the international cooperation index of India in Forensic Science research is (7.68) and India has the highest Affinity Index value of (34.16) in the Forensic Science with the USA during the period of study.

Sweileh et al. (2014) investigated the study on the scientific research productivity of the An-Najah National University, Palestine. The primary data was collected by the Scopus database. After the analysis, it was found that the 791 published record was found during the period of study and a total 4553 citations were received with an average of (5.8) citations per research papers. Approximately (50%) contributed research papers have foreign collaborations with 59 countries. The research output of the university showed steady growth over the years and it was high in certain scientific disciplines than others.

4. OBJECTIVES OF THE STUDY

The main objectives of the study are to:

1. Analysis of the annual growth rate of the publications.
2. Examine the relative growth rate and doubling time of the research papers.
3. Identify the year wise citations of the publications.
4. Find out authorship pattern, the degree of authors collaboration and most productive authors name.
5. Analysis the Collaboration Coefficient, Modified Collaboration Coefficient and Collaborative Index of Authorship Pattern.

5. METHODOLOGY

The primary data was collected by the Scopus database. Scopus is a huge abstract and citations database, it is owned by Elsevier and it is not free, it's available by subscription basis. The following search string was used to collect the raw data - (TITLE-ABS-KEY ("Robotics") AND (LIMIT-TO (PUBYEAR, 2018) TO (PUBYEAR, 2009)) AND (LIMIT-TO (AFFILCOUNTRY, "India"))). The raw data was downloaded on 21/Jan/2018/. The data were analysed and tabulated in MS Excel software and tested through the different scientometrics tools to achieve the objectives.

6. DATA ANALYSIS

6.1 Annual Growth Rate of Publication

Table and figure 1 shows the year-wise distribution and annual growth rate of publication in Robotics research during the period (2009-2018). The maximum 791 (18.29%) of research papers were published in the year 2018, followed by 697 (16.12%) in 2017 and the lowest productivity 134 (3.1%) was recorded in the beginning year i.e. 2009. while the highest (142.54) annual growth rate was recorded in 2010, followed by (65.48) in 2015. The overall data of year wise distributions and annual growth rate of publications has been shown in below table 1. The annual growth rate is a useful method to evaluate the yearly trends in research productivity (Kumar & Kaliyaperumal, 2015).

$$AGR = \frac{EndValue - FirstValue}{FirstValue} \times 100$$

Table 1: Annual growth rate of publications

Year	No. of Publications & (%)	AGR
2009	134 (3.1%)	0
2010	325 (7.51%)	142.54
2011	197 (4.55%)	-39.38
2012	260 (6.01%)	31.98
2013	388 (8.97%)	49.23
2014	365 (8.44%)	-5.93
2015	604 (13.97%)	65.48
2016	564 (13.04%)	-6.62
2017	697 (16.12%)	23.58
2018	791 (18.29%)	13.49
Total	4325 (100%)	

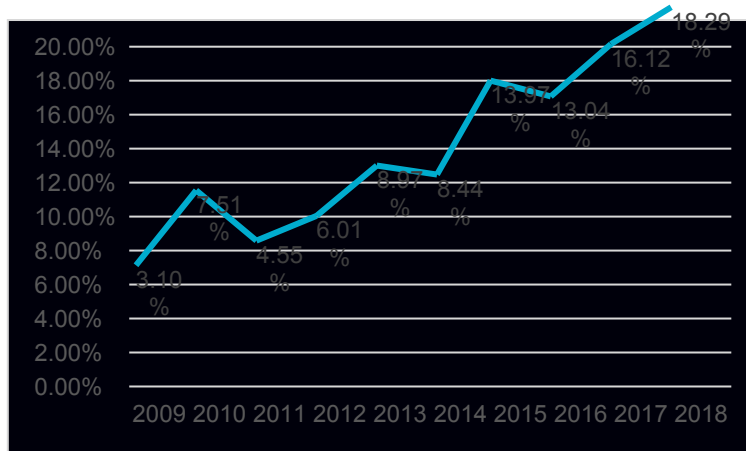


Figure 1: Year-wise distribution of publications

6.2 Relative Growth Rate and Doubling Time of Publication

Table 2 illustrates the relative growth rate and doubling time in Robotics research publications from the marked period of study. The highest (1.23) relative growth rate was recorded in the year 2010, followed by (0.36) in 2011 and the minimum (0.20) RGR was found in 2018. While the maximum doubling time (3.43) was found in the year 2018 i.e. ending year of the study, followed by (3.15) recorded in 2017 and the minimum (0.56) found in 2010. The relative growth rate of publications over a specific period is derived from the following formula given by Mahapatra, 1985:

$$RGR = \frac{W2 - W1}{T2 - T1}$$

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 final time

The following formula used to analysis the doubling time.

$$DoublingTime(Dt) = \frac{0.693}{R}$$

Table 2: Relative growth rate and doubling time of publications

Year	Total Papers	Cumulative Sum	W1	W2	RGR	Dt
2009	134	134	0	4.90	0	0
2010	325	459	4.90	6.13	1.23	0.56
2011	197	656	6.13	6.49	0.36	1.94
2012	260	916	6.49	6.82	0.33	2.08
2013	388	1304	6.82	7.17	0.35	1.96

2014	365	1669	7.17	7.42	0.25	2.81
2015	604	2273	7.42	7.73	0.31	2.24
2016	564	2837	7.73	7.95	0.22	3.13
2017	697	3534	7.95	8.17	0.22	3.15
2018	791	4325	8.17	8.37	0.20	3.43

6.3 Authorship Pattern of Publication Distributions

Table 3 depicts the authorship pattern of publication distribution in the particular research from (2009-2018) in which a maximum 1657 publications were written by more than three authors, followed by two authors with 1221 publication, and 1194 publications were published by three authors while the minimum 253 research papers were written by single authors.

Table 3: Author wise distribution of publications

Year	Single Author	Two Authors	Three Authors	3< Authors	Total
2009	14	31	44	45	134
2010	23	106	93	103	325
2011	25	66	45	61	197
2012	25	81	64	90	260
2013	23	93	125	147	388
2014	27	88	114	136	365
2015	33	181	160	230	604
2016	27	175	144	218	564
2017	26	191	179	301	697
2018	30	209	226	326	791
Total	253	1221	1194	1657	4325

6.4 Degree of Authors Collaborations

Table 4 and figure 2 depicts the degree of authors' collaborations in robotics research publications in India during the period (2009-2018). The degree of author's collaborations was fluctuated during the period of study. The maximum (0.96) degree of authors collaboration was recorded in the year 2017 and 2018 each, while the average (DC=0.93) was recorded from the marked period of study. The formula degree of author's collaboration was given by (K. Subramanyam, 1983).

$$DC = \frac{Nm}{Nm + Ns}$$

Table 4: Degree of authorship collaborations

Year	Single Author	Multiple Authors	Degree of Authors
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	(Ns)	(Nm)	collaboration DC=Nm/(Nm+Ns)
2009	14	120	0.90
2010	23	302	0.93
2011	25	172	0.87
2012	25	235	0.90
2013	23	265	0.92
2014	27	338	0.93
2015	33	571	0.95
2016	27	537	0.95
2017	26	671	0.96
2018	30	761	0.96
Total	253	3972	0.93

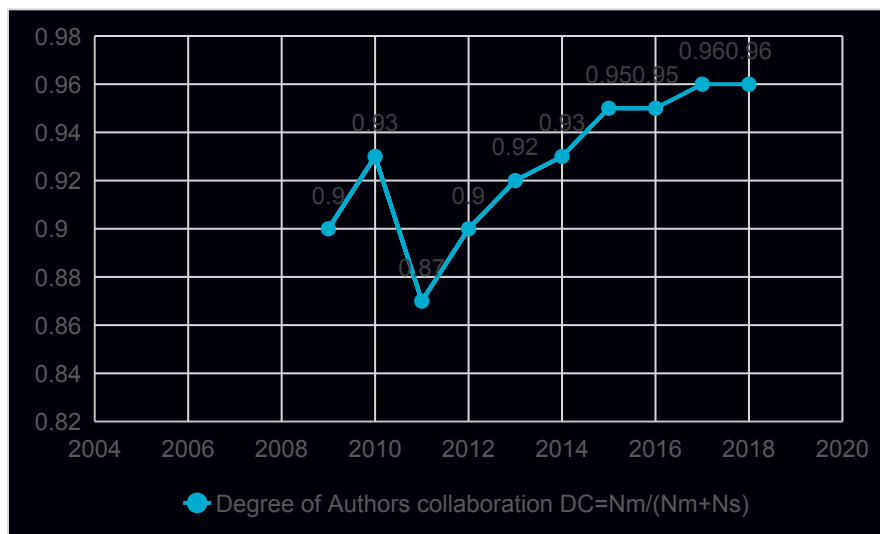


Figure 2: Degree of authorship collaborations

6.5 Collaboration Coefficient and Collaborative Index of Authorship Pattern

Table 5 shows the collaboration coefficient and collaborative index of authorship pattern in robotics research publications. The maximum (0.63) collaboration coefficient was recorded in the year 2017 and 2018 each while the maximum collaborative index (3.08) was recorded in 2017. The average collaboration coefficient and collaborative index was (0.61) and (2.98) recorded respectively. The overall data of collaboration coefficient and collaborative index of authorship pattern has been shown in below table 5. The collaboration coefficient (CC) counted by the following formula:

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

The collaboration Index (CI) counted by the following formula suggested by the (Lawani, 1980):

$$CI = \frac{\sum_{j=1}^A jf_j}{N}$$

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 5: Author wise distribution of publications

Year	Single Author	Two Authors	Three Authors	3< Authors	Total	CC	CI
2009	14	31	44	45	134	0.59	2.90
2010	23	106	93	103	325	0.59	2.85
2011	25	66	45	61	197	0.55	2.72
2012	25	81	64	90	260	0.58	2.84
2013	23	93	125	147	388	0.62	3.02
2014	27	88	114	136	365	0.61	2.98
2015	33	181	160	230	604	0.61	2.97
2016	27	175	144	218	564	0.62	2.98
2017	26	191	179	301	697	0.63	3.08
2018	30	209	226	326	791	0.63	3.07
Total	253	1221	1194	1657	4325	0.61	2.98

6.6 Profile of Top 10 Most Prolific Authors

Table 6 illustrates the profile of top ten most prolific authors in Robotics research publications during the period (2009-2018). On the observation of table, it has been shown that Krishna, K.M. was contributed a maximum (51) research papers with (11) h-index and (548) citations, followed by Saha, S.K. with (43) publication; (19) h-index; (1040) citations, while Biswal, B.B. with (37) research papers; (11) h-index; (363) citations. The overall data of the top ten most productive was shown in below table 6.

Table 6: Profile of top 10 most prolific authors

Authors Name	No. of Publications	h-index	Total Citations	Rank
Krishna, K.M.	51	11	548	1
Saha, S.K.	43	19	1040	2
Biswal, B.B.	37	11	363	3
Majumder, S.	34	10	338	4

Behera, L.	31	20	1478	5
Bhaumik, S.	31	7	124	5
Shah, S.V.	28	7	147	6
Gupta, N.P.	25	43	5623	7
Kala, R.	25	14	569	7
Parhi, D.R.	24	19	1091	8

6.7 Year Wise Distribution of Citations

Table 7 shows the year wise distribution of citations in Robotics research publications from the marked period of study. The maximum (2718) of citations were recorded in the year 2010, followed by (2354) of citations in 2015, and (2113) of citations was found in the beginning year of the study i.e. 2009 while the minimum (273) of citations was recorded in the ending year i.e. 2018 of the study.

Table 7: Year-wise distribution of citations

Year	No. of Publications & (%)	No. of Citations
2009	134 (3.1%)	2113
2010	325 (7.51%)	2718
2011	197 (4.55%)	1951
2012	260 (6.01%)	1185
2013	388 (8.97%)	2004
2014	365 (8.44%)	1861
2015	604 (13.97%)	2354
2016	564 (13.04%)	1124
2017	697 (16.12%)	1087
2018	791 (18.29%)	273
Total	4325 (100%)	16670

6.8 Document Wise Distribution of Publications

Table 8 and figure 3 illustrates the document wise distribution of publication in Robotics research from (2009-2018). The maximum 2704 (62.52%) of research papers were found in 'conference paper' type documents, followed by 1262 (29.18%) of records were 'article' type documents and 'review 158 (3.65%); book chapter 67 (1.55%); article in press 42 (0.97%); editorial 35 (0.81%); letter 24 (0.55%); book 14 (0.32%); note 10 (0.23%); short survey 7 (0.16%); and erratum 2 (0.05%)' were recorded during the period of study.

Table 8: Document wise distribution of publications

Document Type	No. of Publications & (%)
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Conference Paper	2704 (62.52%)
Article	1262 (29.18%)
Review	158 (3.65%)
Book Chapter	67 (1.55%)
Article in Press	42 (0.97%)
Editorial	35 (0.81%)
Letter	24 (0.55%)
Book	14 (0.32%)
Note	10 (0.23%)
Short Survey	7 (0.16%)
Erratum	2 (0.05%)
Total	4325 (100%)

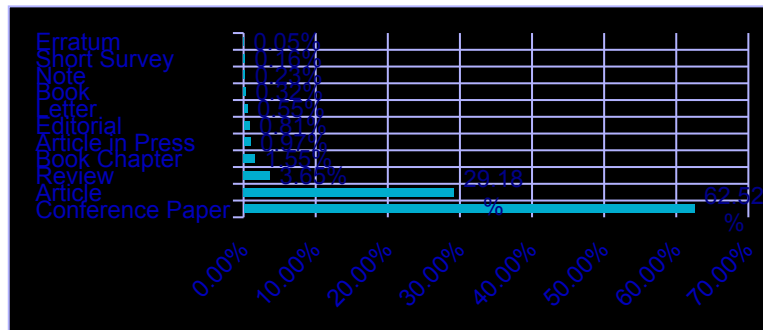


Figure 3: Document wise distribution of publications

6.9 Subject Wise Distribution of Publications

Table 9 shows the subject wise distribution of publications in Robotics research during the period of study. The maximum 2682 research papers were found in ‘computer science’ subject group, followed by 2160 publications with ‘engineering’ subject and 594 records were ‘mathematics’ subject areas while in the ‘medicine’ subject 526 research papers were found from the marked period of study. The overall data of subject wise distribution of publications was shown in below table 9.

Table 9: Top 10 subject wise distribution of publications

Subject	No. of Publications
Computer Science	2682
Engineering	2160
Mathematics	594
Medicine	526
Physics and Astronomy	272
Social Sciences	212
Materials Science	175
Biochemistry, Genetics and Molecular Biology	160
Energy	155

Pharmacology, Toxicology and Pharmaceutics	105
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6.10 Top 10 Most Prolific Source Name

Table 10 shows the top ten most prolific source name. The maximum 203 research papers were published in ‘ACM International Conference Proceeding Series’, followed by ‘Procedia Computer Science’ with 150 publications, and 88 research papers were published in ‘Advances in Intelligent Systems and Computing’. The whole data of the top ten most famous source name was shown in below table 10.

Table 10: Top 10 most prolific source name

Sl. No.	Source Name	No. of Publications
1	ACM International Conference Proceeding Series	203
2	Procedia Computer Science	150
3	Advances In Intelligent Systems And Computing	88
4	International Conference On Emerging Trends In Robotics And Communication Technologies Interact 2010	84
5	Care 2013 2013 IEEE International Conference On Control Automation Robotics And Embedded Systems Proceedings	79
6	International Journal Of Applied Engineering Research	79
7	Communications In Computer And Information Science	75
8	Proceedings Of 2015 International Conference On Robotics Automation Control And Embedded Systems Race 2015	70
9	2016 IEEE International Conference On Distributed Computing VLSI Electrical Circuits And Robotics Discover 2016 Proceedings	55
10	2010 International Conference On Industrial Electronics Control And Robotics Iecr 2010	47

6.11 Top 10 Most Common Keywords

Table 11 depicts the top ten most common keywords used in Robotics research publications during the period (2009-2018). The highest 2508 times ‘Robotics’ keywords were used, followed by ‘Robots’ with 754 and 441 times ‘Human’ keywords was used while ‘Controllers (342); Article (317); Manipulators (262); and Robot Programming (253) time used in Robotics research publications during the period of study.

Table 11: Top 10 most common keywords

Keywords	No. of Times
Robotics	2508
Robots	754

Human	441
Controllers	342
Article	317
Manipulators	262
Robot Programming	253
Robotic Arms	239
Embedded Systems	237
Algorithms	233

7. CONCLUSION

A total of 4325 research papers were found during the period of study i.e. (2009-2018). The maximum articles contributed by more than three authors and the maximum papers were published in the year 2018, followed by 2017 while the minimum articles were published in the year 2009. The annual growth rate of publication was recorded in fluctuating trends and the average degree of authors collaboration was (0.93) recorded during the period of study. The maximum relative growth rate was recorded in 2010 while the maximum doubling time was recorded in the end year of the study i.e. 2018. Krishna, K M was most prolific authors, followed by Saha, S.K. A total 16670 citations were recorded in 4325 publication from the marked period of study in which the maximum citations were recorded in the year 2010, and the highest research papers were published in a conference paper. The maximum research papers were published in ACM international conference proceeding series while the maximum 2508 'Robotics keywords were used by the authors from the marked period of study.

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