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Research Output Analysis on Robotic Technology: A Scientometric Study

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Abstract - **Robotics Technology is a fast growing field of research. Robotics is the branch of science that includes mechanical engineering, electrical engineering, computer science and others. Robotics deals with the design, construction, operation, and use of robots. This paper assess the volume of research carried out by the scientists in world wide on robotic technology, their share of research to world literature in robotics, forms and language that they publish their results, quantum of their publications in terms of institutions involved in research in robotic technology, extent of international collaboration, etc. Data for this study was culled from the Web of Science. The period of study is from 1990 to 2016. Totally 3703 institutions resulted out the output of 5316 among them top 30 institutions' output is noteworthy. The developing countries like USA, UK and Germany concentrate in the field of robotic technology. Yet Major portion of contribution (36.30%) is from USA. The journal articles are the key factors in sharing the research values among the researchers in the forms of articles which is amounted to be top (67.40%). The language preferred in exchanging research results is English (87.70%) followed by German. The prolific authors in the field of robotic technology are highly found from USA among them the contribution by Bloss R is appreciable. The citation counts seems to be high in the year 2015 which has recorded 11,000 citations.**

I. INTRODUCTION

Robotics is the branch of science that includes mechanical engineering, electrical engineering, computer science and others. Robotics deals with the design, construction, operation, and use of robots. A robot is a programmable mechanical device that can perform tasks and interact with its environment, without the aid of human interaction. Robotics is the science and technology behind the design, manufacturing and application of robots. The word robot was coined by the Czech playwright Karel Capek in 1921. He wrote a play called "Rossum's Universal Robots" that was about a slave class of manufactured human-like servants and their struggle for freedom. The Czech word *robota* loosely means "compulsive servitude." The word robotics was first used by the famous science fiction writer, Isaac Asimov, in 1941.

Robotics Technology is a fast growing field of research. Robots can improve the quality of life, taking over dangerous or difficult jobs. Especially with the aging of population robots can help extending the independent living of elderly. With the accelerating development of enabling technologies, robotics is rapidly expanding, as recognized world wide. SARA-1 incorporates the concepts of a relatively new field known as cooperative robotics [1, 2]. Robotics deals with the study of multiple autonomous agents i.e "working together" to perform some task that is either too difficult or impossible for one agent to perform while acting alone. It merges the disciplines of computer science, electrical engineering, and artificial intelligence. Research scenarios include box-pushing [3], exploration, area mapping, fire-fighting, hazardous waste removal [4], water treatment [5], and mine detection.

II. SCIENTOMETRICS AND ROBOTIC TECHNOLOGY

The term scientometrics was invented by the Russian mathematician Vasiliy Nalimov (naukometriya in Russian, meaning the study of the evolution of science through the measurement of scientific information) (Nalimov and Mulchenko, 1969) [6] (Godin B) [7]. This term was not noticed in Western scientific circles until it was translated into English (Garfield, 2009) [8]. Scientometrics is a science about science (Price, 1961, 1963) [9]. It provides the researchers with various concepts, models, and techniques that may be applied to any discipline in order to explore its foundations, state, intellectual core, and potential future development.(Sadik Batcha M) [10]. Many studies have analyzed the scientific and technological disciplines from a scientometric perspective, (Godin B) [11] but a brief overview of these works reveals that research output on robotic technology publications lights on the trends, strength and weakness of the discipline (Moravcsik M J and Ziman S M 1975) [12] (Gunasekaran et al.2006) [13]. The Scietometrics study measures the performance based on several parameters, country annual growth rate and collaborative index. (Baskaran C and Sadik Batcha) [14] Moreover, no meta-analysis study has previously been done to aggregate the results of the seemingly independent scientometric inquiries into the research output of robotic technology world wide (Arunachalam, 1986) [15]. Therefore, the present investigation conducts a meta-analysis of scientometric research in order to consolidate Scientometric research on this burning field, to develop recommendations for future scientometric researchers and to better understand the identity of this scientific field.

This study is an attempt to assess the volume of research carried out by the scientists in world wide on robotic technology, their share of research to world literature in robotics, journals in which they publish their results, quantum of their publications in terms of institutions involved in research in robotic technology, extent of international collaboration, etc. Data for this study was culled from the Web of Science**.**

III. METHODOLOGY

Bibliographic information such as author(s), title, source with year, volume, issue and page, author affiliation, language, and document type were downloaded from the online version of Web of Science, in plain text format by giving robotic technology in the topic field. The downloaded data in text format were converted into histcite and analyzed with MS-Access. Only the first author address in the affiliation field was considered. The analyze was also made in the web of science for depth analysis of data.

IV. ANALYSIS

In terms of the total number of annual publications (including articles, notes, letters, reviews, editorials, meeting abstracts, etc.), the yearly out put shows the result of ascending ranging from single digit output of 9 to 513 during 1990-2015 . The output data of 2016 includes 10 months i.e. up to October, so it shows 496 in total yet it is progressive. The output in the years 1995, 2002, and 2005 are noted to be decreasing. Yet the out put in every five years doubles to the higher value. It shows that the field of robotic technology seems to be a burning field and it constantly attracts the minds of researcher to bring out more and more research output in the field.

TABLE 1 ANNUAL GROWTH RATE OF RESEARCH OUTPUT ON ROBOTIC TECHNOLOGY

S.No	Year of Publication	No of Publication	Percent	Cumulative of Research output	Total Local Citation Score	Total Global Citation Score	S.No	Year of Publication	No of Publication	Percent	Cumulative of Research output	Total Local Citation Score	Total Global Citation Score
1	1990	9	0.2	9	0	7	15	2004	183	3.4	1209	397	6116
2	1991	34	0.6	43	19	779	15	2004	183	3.4	1209	397	6116
3	1992	34	0.6	77	24	434	16	2005	179	3.4	1388	339	3935
4	1993	41	0.8	118	45	511	17	2006	199	3.7	1587	329	5243
5	1994	58	1.1	176	100	819	18	2007	230	4.3	1817	367	4963
6	1995	50	0.9	226	36	1012	19	2008	244	4.6	2061	370	5217
7	1996	66	1.2	292	45	863	20	2009	300	5.6	2361	404	6382
8	1997	68	1.3	360	99	1259	21	2010	301	5.7	2662	343	4875
9	1998	89	1.7	449	140	2840	22	2011	339	6.4	3001	363	5115
10	1999	89	1.7	538	199	2623	23	2012	365	6.9	3366	291	4205
11	2000	109	2.1	647	278	3619	24	2013	460	8.7	3826	259	4101
12	2001	121	2.3	768	242	3790	25	2014	481	9	4307	177	NA
13	2002	108	2	876	209	5309	26	2015	513	9.7	4820	103	1105
14	2003	150	2.8	1026	369	5070	27	2016	496	9.3	5316	12	217
								Total	5316	100		5559	1322

Research Output by Countries

In terms of the total number of publications brought out by the countries (including articles, notes, letters, reviews, editorials, meeting abstracts, etc.). The table lists the top 50 countries that have published research output in robotic technology. The analysis shows that USA ranked 1st with 36.30% and U.K ranked 2nd with 8.5% publication output followed by Germany and Italy with 6.40 and 6 percentages respectively. In this ranking order India occupies at the 18th rank in order with a mere output of 41 in total showing 0.8%. The table lists out about 50 countries in which, 30 countries fall behind India in the case of robotic technology. The analysis includes a period of 26 years ranging from 1990 to October 2016. The collaborative publication trend is observed in total output. To find out collaboration rate mapping study will give more insight. The table also highlights the total local citation index and total global citation index of every country's output in which USA stands to be top in both TLCS and TGCS. Germany occupies 2nd position in the case of TLCS yet UK registers 2nd highest in TGCS.

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TABLE 2 RESEARCH OUTPUT BY COUNTRIES ON ROBOTIC TECHNOLOGY

S.NO	Country	No of Publication output	Percent	TLCS	TGCS	S.NO	Country	No of Publication output	Percent	TLCS	TGCS
1.	USA	1929	36.3	3091	42856	26.	Iran	21	0.4	10	243
2.	UK	470	8.5	497	7871	27.	Poland	21	0.4	12	165
3.	Germany	400	6.4	503	6037	28.	Romania	20	0.4	6	124
4.	Italy	378	6	317	4524	29.	Mexico	18	0.3	0	71
5.	Canada	265	4.6	214	3536	30.	New Zealand	17	0.3	10	192
6.	Japan	227	4.3	124	3379	31.	Finland	16	0.3	7	283
7.	Peoples R China	214	4	81	2000	32.	Russia	15	0.3	5	919
8.	France	204	3.8	202	3127	33.	Saudi Arabia	15	0.3	1	27
9.	Spain	180	3.4	89	1543	34.	Norway	14	0.3	6	113
10.	South Korea	153	2.9	167	2130	35.	Malaysia	13	0.2	1	60
11.	Switzerland	131	2.5	148	3377	36.	Slovenia	13	0.2	5	98
12.	Australia	109	2.1	93	2002	37.	Argentina	11	0.2	4	106
13.	Netherlands	100	1.9	72	2131	38.	Chile	11	0.2	7	108
14.	Austria	60	1.1	123	1755	39.	Czech Republic	11	0.2	13	134
15.	Belgium	55	1	53	609	40.	Hungary	11	0.2	12	104
16.	Singapore	55	1	56	1327	41.	Ireland	11	0.2	6	94
17.	Sweden	53	1	49	980	42.	Cyprus	8	0.2	2	678
18.	India	41	0.8	15	271	43.	Egypt	8	0.2	6	70
19.	Turkey	41	0.8	33	266	44.	Serbia	8	0.2	1	14
20.	Brazil	40	0.8	15	357	45.	Slovakia	8	0.2	5	39
21.	Israel	40	0.8	43	856	46.	Colombia	7	0.1	0	8
22.	Taiwan	40	0.8	13	482	47.	Croatia	6	0.1	0	3
23.	Denmark	38	0.7	19	394	48.	Thailand	6	0.1	5	29
24.	Portugal	34	0.6	16	544	**49.**	Pakistan	5	0.1	0	2
25.	Greece	24	0.5	10	293	**50.**	U. Arab Emirates	5	0.1	2	58

Institution-Wise Research Output

Institution-wise contribution of researchers in robotic technology during the years 1990 – 2016 is given in Table 3. As mentioned above, 5316 papers were published in the study period. These came from many institutions. The top 30 institutions are analyzed in the table 3. More than a fifty papers originated from two research institutions and five Universities. The most prolific publishing institutions were MIT, Dept of Mech Eng USA, NASA, Stanford University, University Pittsburgh, John Hopkins University, and CALTECH (California Institute of Technology). A plot of the number of institutions vs. cumulative number of papers is given in Figure 4. Top 30 institutions published papers in high-impact journals. Publications of various institutions sorted in terms of the number of output ranged from 74. The table shows that the contributions made by Universities more in numbers compared to research institutions. Yet the two research institutions are ranked to 1st and 2nd with 74 and 68 publications output respectively. The table also reflects total local citation index and total global citation index of every institution's output in which John Hopkins University stands to be top in TLCS and Stanford University is found to be high in TGCS.

TABLE 3 RESEARCH OUTPUT BY TOP 30 INSTITUTIONS ON ROBOTIC TECHNOLOGY

S.No.	Institution	No of Publication	Percent	Cumulative	Total Local Citation Score	Total Global Citation Score
1.	MIT	74	1.4	74	68	2234
2.	NASA	68	1.3	142	24	1502
3.	Stanford Univ	68	1.3	210	134	3323
4.	Univ Pittsburgh	68	1.3	278	112	3064
5.	Harvard Univ	67	1.3	345	83	2499
6.	Johns Hopkins Univ	56	1.1	401	202	1720
7.	CALTECH	52	1	453	16	1271
8.	Scuola Super Sant Anna	46	0.9	499	54	902
9.	Univ London Imperial Coll Sci Technol & Med	45	0.8	544	86	908
10.	Univ Michigan	44	0.8	588	78	1503
11.	Yonsei Univ	42	0.8	630	112	933
12.	Carnegie Mellon Univ	41	0.8	671	38	1868
13.	Shanghai Jiao Tong Univ	41	0.8	712	17	242
14.	Cleveland Clin	40	0.8	752	81	989
15.	Univ Illinois	40	0.8	792	172	1217
16.	Univ Washington	39	0.7	831	99	1297
17.	Univ So Calif	37	0.7	868	64	850
18.	Univ Maryland	36	0.7	904	43	566
19.	Univ Tokyo	36	0.7	940	15	873
20.	Ohio State Univ	31	0.6	971	110	684
21.	Cleveland Clin Fdn	30	0.6	1001	213	874
22.	Georgia Inst Technol	30	0.6	1031	20	1282
23.	Mayo Clin	29	0.5	1060	96	754
24.	Univ Calif Irvine	29	0.5	1089	89	757
25.	Univ Florida	29	0.5	1118	29	373
26.	Columbia Univ	27	0.5	1145	68	556
27.	Univ Penn	27	0.5	1172	89	783
28.	ETH	26	0.5	1198	18	968
29.	Tech Univ Munich	26	0.5	1224	13	367
30.	Univ Calif Los Angeles	26	0.5	1250	37	459
	Other Institutions	4066	23.8	5316	2280	35618

Publication Performance In Different Document Types

Publications in robotic technology come in different document types such as articles, biographies, corrections, editorials, letters, meeting abstracts and reviews. Out of all document forms, articles took a major chunk of over 67.4% of the papers (3584), with 11.1% appearing as reviews (592), 8.70% appearing as proceeding papers (461). The other document types such as editorial materials are observed 90 in numbers and meeting abstracts 33, It is noted that out of 5316 records retrieved from the web of science database, about 501 document types of the record are found blank, the other forms of documents recorded have shown less than one percentage during the study

period. The table shows total local citation index and total global citation index of every type of documents to which the same rank of order is observed in descending order.

TABLE 4 PUBLICATION PERFORMANCES IN DIFFERENT DOCUMENT TYPES

S.No.	Forms of Publication	No of Publication	Percent	Cumulative	Total Local Citation Score	Total Global Citation Score
1.	Article	3584	67.4	3584	3891	55503
2.	Review	592	11.1	4176	841	16226
3.	Article; Proceedings Paper	461	8.7	4637	588	7889
4.	Editorial Material	90	1.7	4727	15	309
5.	Meeting Abstract	33	0.6	4760	1	6
6.	News Item	21	0.4	4781	1	3
7.	Review; Book Chapter	8	0.2	4789	10	311
8.	Article; Book Chapter	6	0.1	4795	1	13
9.	Note	5	0.1	4800	30	92
10.	Bibliography	4	0.1	4804	0	25
11.	Letter	4	0.1	4808	1	20
12.	Reprint	3	0.1	4811	2	6
13.	Book Review	2	0	4813	0	0
14.	Biographical-Item	1	0	4814	0	6
15.	Correction	1	0	4815	0	0
16.	Unknown	501	9.4	5316	178	0
	Total	5316	100		5559	80409

TABLE 5 PUBLICATION PERFORMANCES IN DIFFERENT LANGUAGES

S.No.	Language of Publication	No of Publication	Percent	Cumulative	Total Local Citation Score	Total Global Citation Score
1.	English	4659	87.7	4659	5352	80083
2.	German	54	1	4713	9	154
3.	Spanish	38	0.7	4751	4	39
4.	French	33	0.6	4784	15	114
5.	Portuguese	9	0.2	4793	0	3
6.	Korean	8	0.2	4801	1	11
7.	Japanese	6	0.1	4807	0	3
8.	Croatian	2	0	4809	0	0
9.	Turkish	2	0	4811	0	1
10.	Chinese	2	0	4813	0	0
11.	Czech	1	0	4814	0	1
12.	Polish	1	0	4815	0	0
13.	Russian	1	0	4816	0	0
14.	Other languages	500	9.4	5316	178	0
	Total	5316				

Publication Performance in Different Languages

Publications in robotic technology publish in various languages such as English, German, Japanese, and Russian etc. The total publications in robotic technology recorded in WOS online data base is 5316. Out of all languages of publications, English stands to be top preferred language among the researcher in publishing their research results. The total number of publication published in English language is about 4659 which reflects 87.70%. German comes next in order showing 54 publications. The other preferred languages observed are Spanish and French showing the counts of 38 and 33 respectively. The WOS on line database results a portion of records are not updated with the language. It is counted 500. Portuguese, Korean, Japanese, Croatian, Turkish, Chinese, Czech, Polish and Russian languages are recorded a minimum of nine and below publications during the study period. The table shows total local citation index and total global citation index of every language to which the same rank of order is observed in descending order.

Research Output by Prolific Authors

The author- wise contribution in robotic technology during the years 1990 – 2016 is given in Table 6. There were 5316 papers published in the study period. These were brought out by 16751 authors. The National and International Collaboration of authors resulted in 5316 publications. The average number of authors calculated randomly per publication might be 3.12. There are about 15 prolific authors who have published more number of publications are shown in table 6. Among them Bloss R of USA is ranked to 1st bringing out 32 publications. The next prolific author Dario P of Japan occupies the 2nd rank resulting 29 research output. The third rank goes to Bogue R of UK with 25 publications. Out of 15 prolific authors, about 8 authors belong to USA and from UK found 3 authors. There is a single author observed from each country of Japan, Switzerland, China and Italy in the top 15 list. . The table also reflects local citation score, year wise, self citation, and global citation score with year wise. The graph represents the published items in each year and citations of the years of study.

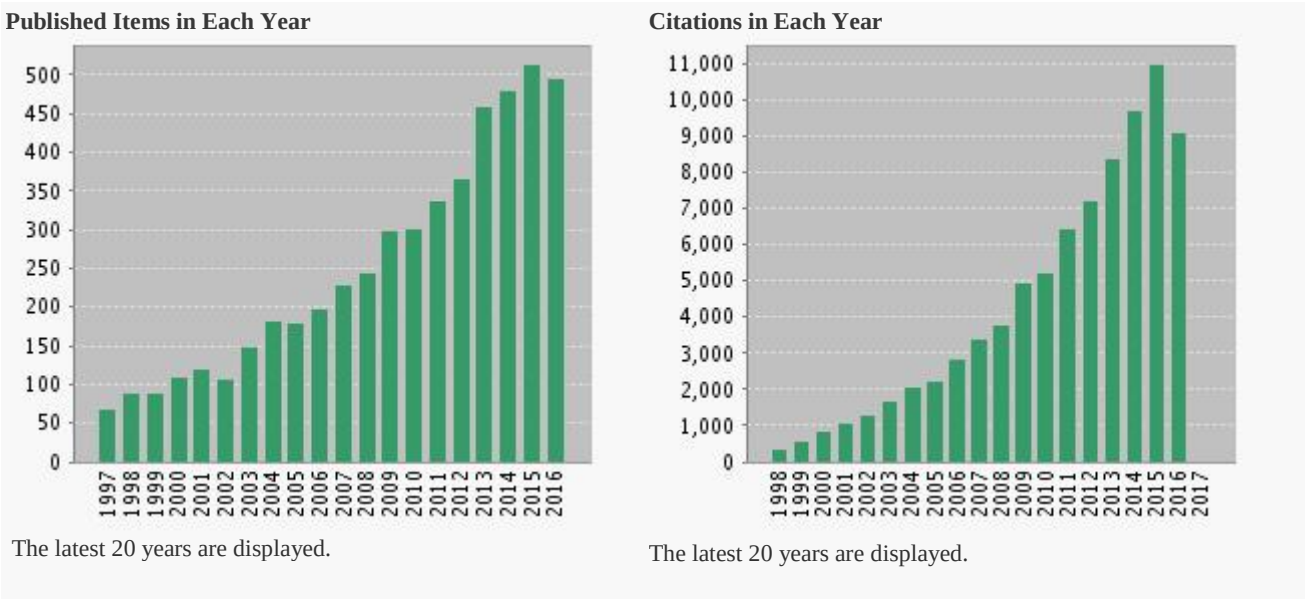

Fig.1Graph showing citations of research output

Total Research Output:	5316
Sum of the Times Cited :	82901
Sum of Times Cited without self-citations :	76096
Citing Articles :	61922
Citing Articles without self-citations :	59612
Average Citations per Item :	15.59
h-index :	111

TABLE 6 RESEARCH OUTPUT BY TOP 15 AUTHORS

Name of Author	No of Publication	Percentage /Total	LCS	LCS/t	LCSx	GCS	GCS/t	LCR	LCSb	LCSe
Bloss R, USA	32	0.6	2	0.366667	1	26	3.200469	1	0	-7
Dario P, Japan	29	0.5	34	4.170669	22	514	53.15375	27	6	-6
Bogue R, UK	25	0.5	7	1.041667	7	128	19.25675	0	3	-10
Dasgupta P, UK	23	0.4	62	9.578788	45	409	55.73604	51	20	-3
Bonatti J, USA	20	0.4	55	6.654654	23	331	41.7276	55	21	-6
Kaouk JH, USA	20	0.4	72	11.40476	49	636	99.53095	58	40	-5
Darzi A, UK	18	0.3	25	3.141026	20	177	18.39155	69	4	-2
Morel P, Switzerland	18	0.3	39	8.030952	19	215	48.18095	78	9	-13
Chitwood WR, USA	17	0.3	71	6.017933	54	474	44.84269	40	28	-2
Pransky J, USA	17	0.3	0	0	0	2	0.125	0	0	-16
Zhang Y, USA	17	0.3	11	2	7	236	33.21978	17	1	-7
Chen SB, China	16	0.3	9	1.698918	2	128	16.50744	7	0	-6
Autorino R, USA	15	0.3	39	7.857143	28	394	78.50238	38	16	-9
Menciassi A, Italy	15	0.3	17	2.966667	11	265	33.35227	16	2	-6
Satava RM, USA	15	0.3	115	7.721426	110	457	30.33769	21	14	11

V. CONCLUSIONS

An analysis of the research publication output data in WOS in the field of robotic technology shows that the robotic technology is a progressive field increasing the publication output from single digit to 513 year after year during the period from 1990 to 2016. Totally 3703 institutions resulted out the output of 5316 among them top 30 institutions' output is noteworthy. The analysis of country's output reveals the fact that Developing countries like USA, UK and Germany concentrate in the field of robotic technology. Yet Major portion of contribution (36.30%) is from USA. The analysis on types of documents lights out the fact that the journals are the key factors in sharing the research values among the researchers in the forms of articles which is amounted to be top (67.40%). The language preferred in exchanging research results is English (87.70%) followed by German. The prolific authors in the field of robotic technology are highly found from USA among them the contribution by Bloss R is appreciable. Yet Japanese author Dario P competes with more number of publication in the study. Furthermore, it is necessary to look into citation counts for each year to assess its real value and it seems 2015 has recorded 11,000 citations. The study is limited in the sense that the results and conclusion are drawn based only on papers covered in WOS. Moreover, a subfield analysis would provide a more comprehensive picture of research output in robotic technology.

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