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RESEARCH ARTICLE

RESEARCH TREND AND PRODUCTIVITY IN THE FIELD OF MECHATRONICS: A SCIENTOMETRIC STUDY

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ABSTRACT

The present study explores the research trend and productivity in the field of Mechatronics and the data was downloaded from the Web of Science Database for the period of 2000 – 2017. The study is aims to analysis the data in terms of year wise growth, Most Productivity Authors, Most Productivity Journals, Relative Growth Rate and Doubling time. Further study is also aims to find Form Wise, Language wise and Country wise Distribution of research data. It is evident from the table that highest number of records is published in the year 2015. The growth rate is 0.274753 in the year 2000 and it is decreased up to 0.070893 in the year 2017. The mean relative growth rate of articles for the period of 2000 to 2009 is .1705 and while, 2010 to 2017 it is found to be .1016 correspondingly, on the other hand, doubling time of the articles is 2.5222 in the year 2000 it raises to 9.7753 in the year 2017. It shows an increasing trend. On an average 6.54 citation per articles were observed during the study period and the highest number of citations were cited in the year 2005. Further, it is observed that the polynomial model or linear growth model almost fit in the field of Mechatronics. Katsura S has contributed the highest number of articles (72) during the study period. The Journal of Mechatronics has published the highest number of articles (140) and received the highest number of citations, which is emerged as most productivity journal. The large majority of the publications are published in the form of Proceedings Papers (2374) and the greater majority of the publications published in the English language (3735-97.72). USA (473) and Germany (444) were contributed highest number of publications of the among 3822 publications. Keio University and Tokyo Denki University are the most productivity institution in the field of Mechatronics. It can be concluded that Mechatronics is one of the most emerging fields in Engineering.

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INTRODUCTION

The term Scientometric and Bibliometric are synonymously used to measure researcher's Science and Technical Growth. It is one of the methods used in the field of Library and Information Science. It is a quantitative study of various aspects of literature on a topic and is used to identify the pattern of publications, Authorship, Year Wise and Document Wise Distribution of coverage with the objectives of getting an insight into the dynamics of growth of knowledge in the related area under consideration. The various Bibliometric indicators such ratio of growth, relative growth rate and doubling time are used. The term Scientometric is often used with the meaning as the Bibliometrics, originated in Russia. The application of quantitative methods to the History of Science, Scientometric is the science of measuring the science, which involves counting artifacts to the production and use of information and arriving conclusions from the counts.

Scientometric and Bibliometric research include studies related to the scattering and Growth of Literature, Author Productivity, Obsolescence of Documents, Distribution of Scientific; Literature by country by language etc, which helps to monitor the growth and pattern of research.

Mechatronics: Mechatronics is a multidisciplinary field of engineering that includes a combination of Mechanical Engineering, Robotics, Electronics, Computer Engineering, Telecommunications Engineering, System Engineering, and Control Engineering. Mechatronics is an interdisciplinary area of Engineering that combines Mechanical and Electrical Engineering and Computer Science. A typical Mechatronics system picks up signals from the environment processes them to generate output signals, transforming them for example into forces, motions, and actions. It is the extension and the completion of mechanical systems with sensors and microcomputers which is the most important aspect. The fact that such a system picks up changes in its environment by sensors, and reacts to their signals using the appropriate information processing, makes it different from conventional

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machines. Examples of Mechatronics systems are robots, digitally controlled combustion engines, machine tools with self-adaptive tools, contact-free magnetic bearings, automated guided vehicles, etc. Typical for such a product is the high amount of system knowledge and software that is necessary for its design. Furthermore, and this is most essential, the software has become an integral part of the product itself, necessary for its function and operation. It is fully justified to say the software has become an actual "machine element"

REVIEW OF LITERATURE

Mahapatra (1994) discussed the Relative Growth Rate (RGR) and Doubling time (Dt) for publications and citations which appeared in Indian library and information science journals during 1975 - 1985 were determined. The reducing trend of RGR and increasing rate for doubling time in double-publications and citations indicates that the growth is neither exponential nor linear. The size of the literature is calculated by applying logistic growth formula, intellectual and environment conditions and with the increase of the number of publications, the number of citations will also increase. Arvinda and Reddy (1990) have analyzed 3807 references contained in the 'Annual Review of Anthropology' for the period 1980-82. The bibliographic distribution of citations showed that citation to books occupied 57.53 percent of those citations, followed by Journals (37.17%), Conference Proceedings (1.94%), Theses/Dissertations (1.31%), Technical Reports (0.79%) respectively. Biradar and Premalatha (1998) have conducted a study on 14 MD psychiatric dissertations submitted to the Department of Psychiatry, NIMHANS, Bangalore, during the period, 1974-1995. Most of the citations (73.22%) are articles in periodicals. The other bibliographic forms are Books (16.32%), Reports (4.35%), Seminar/Conference Proceedings (2.32%), Manuals (0.94%) and other forms (1.8%).

In the study of Gupta et al (1999), it was observed that the application of selected growth models to the growth of world and Indian physics literature during 1898-1950. The result of the study shows that the growth of Indian physics literature follows a logistic growth model, while the growth of world physics literature can be explained by the combination of logistic and power models. Sangam and Kadi (2003) have studied the growth of research and priorities of demography research in different countries of the world i.e. USA, UK, India and China for the period 1986-2000, the study employed appropriate growth model to fit the time series data in order to study the trend of subject growth for each country. The results show that over a period of time there is an increase in the publication of literature. Neelamma and Anandhalli (2016) have studied the research output performance of Crystallography literature, which is covered in the Web of Science online version database for the period of 1989-2013. A total of 1387195 references cited in 45320 articles in 2043 journals. The study elaborates on various bibliometric components such as a distribution of citations by Documents Type, Country wise publication of citations, further the study also list out the most productivity journals in the field of crystallography. The analysis of the study reveals that out of 1387195 citations which (83.835%) Research articles contribute the highest number of citations and it is the most preferred sources of information used by researchers in the field of crystallography. Further journal of Molecular Biology is the most cited journal in the field of crystallography. The

USA is the most cited country in the world. Bradford's law well fitted into the given dataset for the present study. Finally, it can be concluded that significant research activity is taking place in the field of Crystallography. And it is one of the emerging research fields in applied science. Neelamma and Anandhalli (2016) have observed that research output performance of Botany Literature. Citation analysis of all the journal articles published in the Botany literature, which covered in Web of Science (online version database) for the period of 2005-2014. A total of 12051 references cited in 1183 articles in 572 journals. The study elaborates on various bibliometric components such as a distribution of citations for Document type, Language wise distribution of citations, and Country wise publication of citations. Further, the study also lists out the most productivity journals in the field of Botany Literature. The analysis of the results shows that out of 12051 citations, Research articles (61.96%) contribute the highest number of citations and it is the most preferred sources of information used by researchers in the field of Botany. The USA is the most cited country in the world and the English language is the most preferred language in the world. Bradford's law well fitted into the given dataset for the present study. Finally, it can be concluded that The Significant research activity is taking place in the area of Botany and it is one of the emerging research fields in the Biological Sciences. Neelamma and Gavisiddappa (2016). The purpose of this paper is to determine the materials cited in zoology literature during the year 2005–2014. Data were extracted from Web of Science (online version database) database. The study reveals that the distribution of citations for document type, language-wise distribution of citations and country-wise distribution of citations. Further, the study also lists out the most productivity journals in the area of zoology literature. The analysis of the results shows that out of 5332 citations, research articles (74.81%) contribute the highest number of citations and it is the most preferred sources of information used by researchers in the area of zoology. The USA (33.75%) is the most cited country in the world and the English language (98.59%) is the most preferred language in the world. Bradford's law well fitted into the given dataset for the present study. Finally, it can be concluded that The Significant research activity is taking place in the field of zoology and it is one of the emerging research fields in the biological sciences.

Objectives of the study

The main objectives of this study are to analyze the research performance in the field of Mechatronics as reflected in the publication output from 2000 to 2017 the study focuses on the following specific objectives.

- To quantify the scientific productivity of Mechatronics Year wise.
- To examine the various growth models fit/ followed in the field of Mechatronics.
- To investigate the Most Productivity Authors and Journals in the field of Mechatronics.
- To calculate the Relative Growth rate (RGR) and Doubling Time (DT) of articles.
- To examine the type of documents covered under study and Language wise Distribution of Publications.
- To trace the Country Wise Distribution of Publications
- To know the high productivity of Institutions in the field of Mechatronics.

MATERIALS AND METHODS

The present study aims at analyzing the research output of the researcher in the field of Mechatronics. The primary data for the research was collected from Web of Science online Database. Totally 3726 records on Mechatronics were found from the above database during the study period 2000 to 2017. The downloaded data was tabulated and analyzed on various bibliographical aspects like year wise growth, Most Productivity Authors, Most Productivity Journals, Relative Growth Rate and Doubling time, form-wise, language Wise and institution wise and country wise with help of MS Excel software package.

RESULTS AND ANALYSIS

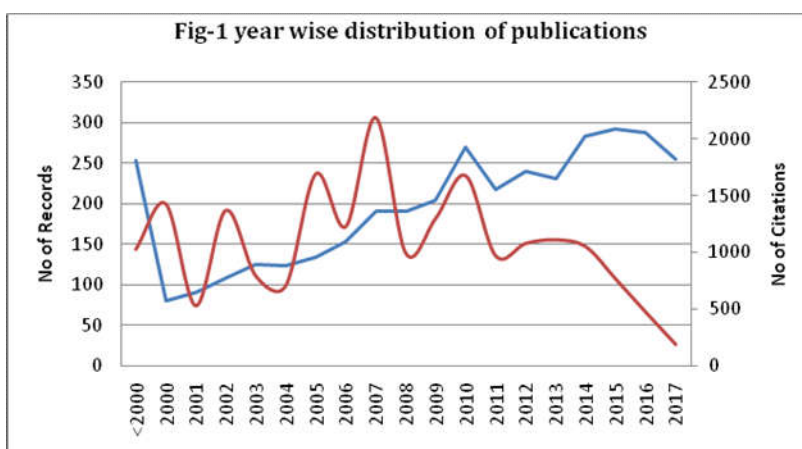
The present study has covered only about Mechatronics which is indexed by Web of Science Online Database. A total of 3726 records were collected for the period from 2000 to 2017. The data were analyzed and resulted in the form of tables and graphs as below.

Table-1 shows the growth of research publication published in the field of Mechatronics during the study period 2000 to 2017. Altogether there are 3726 publications received 20580 citations. The highest number of articles was contributed in the year 2015 i.e 292, representing 7.84% of the total number of articles and then followed by 266 articles in the year 2016. However, least articles were published in the year 2000 which amounts to 253 articles to the total publications. The average rate of citations per article (C/A) was 6.58. but the rate of citations varied from .75 to 12.71. The highest number of citations was cited in the year 2005 and least citations in the year 2017. Further descriptive statistics show that on an average 196 publications were published in each year during the study period and further, there is a variation of 70 publications over the study period. The publications are published in the range of 212 records. There is 190% of the variance in the distribution of article over the study period. There is a negative correlation ($r=-.184$) found between the number of articles and number of citation distributed year wise.

Relative Growth Rate: The relative growth rate and doubling

Table 1. Year Wise Distribution of Records and their Citations

Sl no	Year	No of Records	%	Cum %	No of Citations	%	Cum % Citations	C/A
1	<2000	253	6.79	6.79	1029	5.00	5	4.07
2	2000	80	2.15	8.94	1426	6.93	11.93	17.83
3	2001	91	2.44	11.38	532	2.59	14.51	5.85
4	2002	108	2.90	14.28	1370	6.66	21.17	12.69
5	2003	125	3.35	17.63	793	3.85	25.02	6.34
6	2004	124	3.33	20.96	708	3.44	28.46	5.71
7	2005	133	3.57	24.53	1691	8.22	36.68	12.71
8	2006	153	4.11	28.64	1228	5.97	42.65	8.03
9	2007	190	5.10	33.74	2185	10.62	53.27	11.50
10	2008	191	5.13	38.86	995	4.83	58.10	5.21
11	2009	204	5.48	44.34	1301	6.32	64.42	6.38
12	2010	269	7.22	51.56	1675	8.14	72.56	6.23
13	2011	217	5.82	57.38	970	4.71	77.27	4.47
14	2012	240	6.44	63.82	1080	5.25	82.52	4.50
15	2013	231	6.20	70.02	1111	5.40	87.92	4.81
16	2014	283	7.60	77.62	1051	5.11	93.03	3.71
17	2015	292	7.84	85.45	767	3.73	96.75	2.63
18	2016	287	7.70	93.16	476	2.31	99.07	1.66
19	2017	255	6.84	100.00	192	0.93	100.00	0.75
	Total	3726	100.00		20580	100.00	AVR	6.58



Descriptive statistics

Characteristics	Values
Mean	196.1053
Maximum	292.00
Minimum	80.00
Range	212.00
Std. Deviation	70.36405
Variance	196.1053

examine the relative growth rate of research publications. The relative growth rate is increased in the number of publication or pages per unit of time and can be calculated from the following equations.

$$R_{(1-2)} = \frac{W_1 - W_2}{T_2 - T_1}$$

Where $R_{(1-2)}$ is mean relative growth rate over the specified period.

$W_1 = \log W_1 =$ Natural log of initial number of publications/pages

$W_2 = \log W_2 =$ Natural log of final number of publications/pages.

$T_2 - T_1 =$ the unit difference between the initial time and final time.

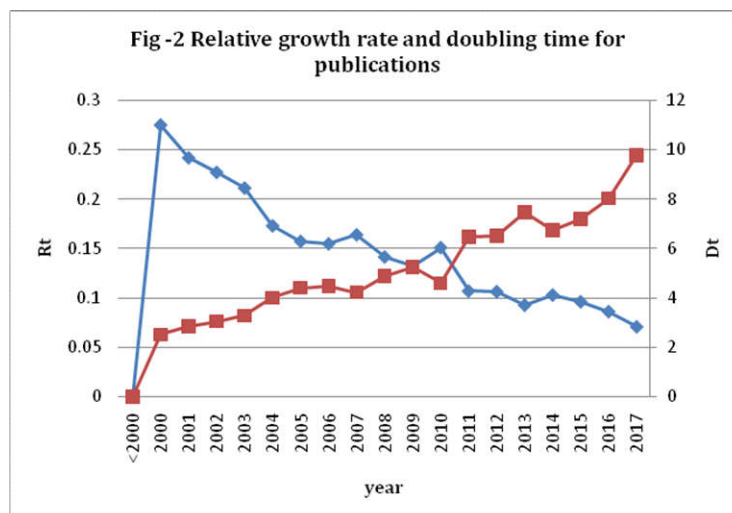
correspondence doubling time for publications and pages can be calculated by using the following formula.

$$\text{Doubling time (Dt)} = \frac{.693}{R_t}$$

The data set in the Table-2 reveals that the Relative Growth Rate and Doubling Time for Publications of Mechatronics. It is clear that the Relative Growth Rate of total research output is decreased gradually. The growth rate is .274 in 2000 and which decreased up-to .0708 in 2017. The mean relative growth rate for the period from 2000 to 2009 is .170. In the second block i.e from 2010 to 2017 is found to be .101. On the other hand, the corresponding doubling time is gradually increased from 2000 to 2017. Doubling time in the year 2000 is 2.522 and rise to 6.5122 in 2017.

Table 2. Relative Growth rate and Doubling time for Publications

Year	No of Records	Cum no of Records	Log _e 1	Log _e 2	Rt= (log _e 2-log _e 1)	Mean Rt	Dt	Mean Dt
<2000	253	253		5.533389	0		0	
2000	80	333	5.533389	5.808142	0.274753	0.170577	2.522265	3.546076
2001	91	424	5.808142	6.049733	0.241591		2.868485	
2002	108	532	6.049733	6.276643	0.22691		3.054074	
2003	125	657	6.276643	6.487684	0.211041		3.283729	
2004	124	781	6.487684	6.660575	0.172891		4.008303	
2005	133	914	6.660575	6.817831	0.157255		4.406843	
2006	153	1067	6.817831	6.972606	0.154776		4.477448	
2007	190	1257	6.972606	7.136483	0.163877		4.228782	
2008	191	1448	7.136483	7.277939	0.141455		4.899072	
2009	204	1652	7.277939	7.409742	0.131803		5.257832	
2010	269	1921	7.409742	7.560601	0.150859	0.101669	4.593687	7.099592
2011	217	2138	7.560601	7.667626	0.107025		6.475127	
2012	240	2378	7.667626	7.774015	0.106389		6.513832	
2013	231	2609	7.774015	7.866722	0.092707		7.475147	
2014	283	2892	7.866722	7.969704	0.102981		6.729377	
2015	292	3184	7.969704	8.065894	0.09619		7.204494	
2016	287	3471	8.065894	8.152198	0.086304		8.029712	
2017	255	3726	8.152198	8.223091	0.070893		9.775359	



Doubling Time

From the calculation, it is found that there is a direct relationship between relative growth rate and doubling time. If the number of publications /pages of a subject doubles during the given period, the difference between the logarithm of the numbers at the beginning and at the end of the period must be the logarithms of the number two. If one uses the natural logarithm, this difference has a value of .693 the

It shows, there is an increasing trend. Thus as the rate of growth of publication was decreased, the corresponding doubling time was increased. The Relative Growth Rate (RGR) of publications showed a decrease, which clearly indicated that the growth did not follow either exponential or linear curve. Table-3 reveals the application of various growth models applies to the field of Mechatronics for the period of 2000 to 2017. This indicates that more than one model could explain their growth. The models were evaluated in terms of their model parameters fit. Among the five models, Polynomial

Model ($r^2=.648$) and Linear Growth Model ($r^2=.648$) almost followed in the field of Mechatronics as their r^2 are near one as compared to other models. Therefore, it can be concluded that the polynomial model or linear model are fit/followed in the field of Mechatronics.

Ohnishi K 21, Furuta K and Ohishi K 20 each respectively. Table-4 reveal that the country-wise distribution of publication in the field of Mechatronics. Totally 25 countries are published articles in the field Mechatronics.

Applications of various Growth models in the field of Mechatronics

Sl no	Name of the model	r^2
1	Polynomial model	.648
2	Linear model	.622
3	Power model	.395
4	Exponential model	.616
5	Logarithmic model	.359

Table 3. High Productivity of Authors in the Field of Mechatronics

Sl no	Author	Recs	Total Citations
1	Katsura S	72	603
2	Ceccarelli M	34	358
3	Gausemeier J	28	137
4	Precap RE	23	208
5	Suzuki S	23	129
6	Ohnishi K	21	602
7	Furuta K	20	109
8	Ohishi K	20	93
9	Filipescu A	19	18
10	Aschmann H	18	115
11	Craig KC	18	24
12	Harashima F	18	59
13	Hehenberger P	15	75
14	Preitl S	15	181
15	Scruggs JT	15	128
16	Dumitrescu R	14	26
17	Figliolini G	14	92
18	Maties V	14	6
19	Pugi L	14	52
20	Carbone G	13	167

Table 4. Country Wise Distribution of Publications in the field of Mechatronics

Sl. No	Country	No of Publications	%	No of Citations	%
1	USA	473	12.34	4623	19.69
2	Germany	444	11.58	2783	11.85
3	Japan	382	9.96	2419	10.30
4	Unknown	310	8.09	637	2.71
5	Peoples R China	307	8.01	1006	4.28
6	Italy	232	6.05	1930	8.22
7	UK	148	3.86	1347	5.74
8	Canada	145	3.78	1290	5.49
9	Romania	136	3.55	396	1.69
10	France	124	3.23	523	2.23
11	Poland	106	2.76	321	1.37
12	Taiwan	98	2.56	488	2.08
13	Netherlands	74	1.93	895	3.81
14	Turkey	71	1.85	428	1.82
15	Spain	70	1.83	467	1.99
16	Mexico	63	1.64	42	0.18
17	Australia	60	1.56	398	1.69
18	Czech Republic	56	1.46	104	0.44
19	India	56	1.46	321	1.37
20	Russia	56	1.46	81	0.34
21	Singapore	52	1.36	460	1.96
22	South Korea	51	1.33	349	1.49
23	Austria	49	1.28	140	0.60
24	Sweden	49	1.28	295	1.26
25	Belgium	41	1.07	696	2.96
	Total	3834	100.00	23484	100.00

Table 3 the Most Productivity of top 20 authors have been listed in the Table-3. It is observed that Katsura S published the highest number of articles during the study period of 2000 to 2017 with 72 records received 602 citations then followed by Ceccarelli M published 32 records having 358 citations. Followed Gausemeier J 28, Precap RE 23, Suzuki S, 23,

The USA has published the highest number of publications (473) which amounts to 12.34% of the total. Further, Germany has published 444 articles occupies the second position in the list. However, very list articles are being published by Belgium country with 41 publications only. Table-5 gives an account of research publications published by top 10 research institutions

Table 5. Top Ten Research Institutions in the Field of Mechatronics

Sl no	Institution	No of Publications	%	No of citations	%
1	Keio Univ	74	20.05	698	23.63
2	Tokyo Denki Univ	47	12.74	191	6.47
3	Tech Univ Munich	40	10.84	163	5.52
4	Univ Cassino	38	10.30	388	13.13
5	Natl Univ Singapore	36	9.76	175	5.92
6	Warsaw Univ Technol	29	7.86	138	4.67
7	Delft Univ Technol	28	7.59	705	23.87
8	University Paderborn	27	7.32	102	3.45
9	Kaunas Univ Technol	25	6.78	43	1.46
10	Politecn Milan	25	6.78	351	11.88
	Total	369	100	2954	100

in the world in the field of Mechatronics. Keio University is emerged as a top research institution in the world in the field of Mechatronics by publishing 74 articles and received 698 citations during the study period. Then followed Tokyo Denki University, which occupies the second position by publishing 47 articles on Mechatronics. Similarly, Tech Univ Munich (40), University Cassino, (38), Natl Univ Singapore (36), Warsaw Univ Technol (29), Delft Univ Technol (28), University Paderborn (27), Kaunas Univ Technol (25) and Politecn Milan (25) respectively.

Findings and Conclusions

Scientometric research has developed a body of theoretical knowledge and a group of techniques and applications based on the distribution of bibliographical data. The wider application of Scientometric techniques is leading to the development of few and more precise technique. Hopefully, the ongoing theoretical work will point the way to more innovative techniques.

- The highest number of publications was published in the year 2015 and the lowest number of articles was published in the year 2000.
- Relative Growth Rate of total research output is decreased gradually. The growth rate is .274 in 2000 and which decreased up-to .0708 in 2017. The mean relative growth rate for the period from 2000 to 2009 is .170
- Doubling time in the year 2000 is 2.522 and raised to 6.5122 in 2017. It shows that there is an increasing trend.
- Katsura S published the highest number of articles for the period of 2000 to 2017 with 72 records received 602 citations then followed by Ceccarelli M published 32 records having 358 citations.
- Mechatronics" with 140 articles of the total and received 2435 citations in the given period, which occupies the topmost position among the list of journals in the field of Mechatronics which is followed by IEEE-ASME Transactions on Mechatronics with 107 articles.
- Journal articles occupy the highest position among the publication of Mechatronics which amounts to 62.11% (2374). Followed by Proceedings Papers with 1148(30.04%) Records.
- Most of the research publications in the field of Mechatronics (3735-97.72%) are being published in the English language only.
- The USA has published the highest number of publications (473) which amounts to 12.34% of the total. Further, Germany has published 444 articles occupies the second position in the list.

Keio University is emerged as a top research institution in the world in the field of Mechatronics by publishing 74 articles and received 698 citations during the study period. Then followed Tokyo Denki University, which occupies the second position by publishing 47 articles on Mechatronics. The study has highlighted quantitatively the contributions made by the researchers during the study period as available on the web of science online database during the 18 years of contribution in terms of the number of publications is significant, there is a positive steady increasing trend. The study reported that Indian contribution to the field of Mechatronics is very negligible, so an effort should be made to encourage and support to carry out the research in Mechatronics. No doubt the study will help for the policymakers and library professionals to take the judicious decision in the process of document selection. It can be concluded that Mechatronics is one of the most emerging fields in Science and Technology.

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