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A Scientometric Analysis of Drone Technology Publications

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Abstract

This study focus on the growth and development of drone technology research in forms of publications reflected in Web of Science database, during the span of 1998-2017. A total 3433 publications were found and the highest 1040 (30.29%) publications published in 2017. The average number of 343.3 publications were published per year in the study field and there was a variation in Annual Growth, because there is no constant growth of publications every year in the area of study. Out of total publications, 3123 (90.97%) contributed by collaboration of multiple authors and 310 (9.03%) by single authors. Authors from United States of America (USA) published the highest number of publications with a total of 774 (22.55%), followed by China and South Korea with 618 (18.00%) and 238 (6.93%) publications were produced respectively. It exposed that the most prolific author is Kim Y secured first place by contributing 31 (0.90%) publications, followed by Zarco 21(0.61%), and Zhang 17 (0.50%) publications were published in drone technology. The collaborative index range from 3.43 (2008) to 4.19 (2012) with an average of 3.88 and 3.79 (2013) to 4.45 (2017) with an average of 4.16 per joint authored paper. For a total of 3123 multiple authored publications has 4.13 of an average per joint authors. It implies the research team falls between 3 and 4 authorship pattern in field of drone technology. It is identified the domination of Chinese institutions by contributing 23.77% (816) of a total research output in drone technology. In respect to, 7.31% (251) form Chines Academy of Science, 6.26% (215) from Beihang University, 5.33% (183) from Nanjing University of Aeronautics and Astronautics.

Keyword: Drone technology; Scientometric Analysis; Relative Growth Rate (RGR); Doubling Time (DT); Author productivity; Collaborative Index.

1. Introduction

The outstanding developments in Science and Technology and transformative push for digital and innovative changes with the help of Artificial Intelligence, the world moving in *'the age of machines'*. The *term 'Artificial Intelligence (AI)'* was coined in 1956 to describe computer activity for problem-solving methods. Since the mid of twentieth century, Artificial

Intelligence referred to, is slowly taking over the world. Things that were unthinkable and existed only in the realm of the Sci-Fi spectrum, till a few decades ago are the reality now invented driverless cars, flying taxies, automated supermarkets, drone delivery services, medical interventions, and a fully automated application that functions everything from making restaurant reservations to movie bookings. As the technology becomes more and more advanced and casts fall, machine-oriented things are developing rapidly. However, a rising works among the scientists and researchers is whether machines will one day become mankind's worst threat.

The concept of Drone technology is not a new one. The idea first enlightened on 1849 August 22, when Austria attacked on the Italian city of Venice with *unmanned explosive balloons*. Thereafter, during the World War-I, United States developed the first pilotless aircraft I '*Aerial Target'* in 1916. As a continuation of UAV technology, US army built and successfully demonstrated automatic airplane known as *'Kettering Bug'* in 1930(15). After the success of several UAVs British developed *'Queen'* in 1931 and *'DH.82B Queen Bee'* in 1935. In 1936, the term *'drone'* was coined, it used to describe radio-controlled aerial targets. US Navy began the experiment with radio-controlled aircraft resulting in the creation of the *'Curtiss N2C-2'* in 1937(1). Nazi-Germany produced various drones during the course of World War II and later applied the drones to jet engines, the result of this adoption *'Teledyne Ryan Firebee I'* developed in 1951. In 2001, after the terrorist attack on USA, it began Central Intelligence Agency (CIA)'s first Drone flown over Afghanistan, Pakistan, Yemen, and Somalia and the program called *'Eagle Program'*. Drones were used by 50 countries which include Iran, Israel, and China etc., reported in 2013. Recently, 'Amazon' the largest online retailer launched *'drone delivery services'* to their customers and many libraries have already adopted drone technology to serve the books and reading materials to users who lived in remote places.

Drones are formally known as Unmanned Aerial Vehicles (UAVs) are automated remotely piloted vehicles, these can fly for long periods of time at a controlled level of speed and height. In the 20th Century, military research precipitated many widely used technological innovation and drones are one of them, which used for reconnaissance, Airstrikes surveillance, and targeted attacks. Drones, flying robots extend their services to the field of Filming and Journalism, Shipping and Delivery, Disaster Management, Rescue Operations and Health Care, Archaeological Survey, Geographic Mapping, Law enforcement, Safety Inspections, Agriculture, Wildlife Monitoring, Weather forecasting, etc. these are the practical and essential application of drones. In addition to, drones can be used for taking an effective selfie, which became the 'word of the decade' and also popular for drone racing (Mydronelab 2018).

Now a day, the majority of countries like United States, China, and India are engaged in an AI-driven arms race to build effective and efficient weaponry that will reduce human causalities. Thomas Friedman, in his book '*The Next 100 Years: A forecast for the 21st century'* speculates that '*the future wars will be fought in Space. Drones and pilotless aircraft are already deployed in the war zone and super soldiers may soon be a reality on the field*' (Friedman 2010).

2. Scientometrics: an overview

The growth of information has been accelerating day by day and Professionals of Science and technology, industry, academic community, and Information Scientists and Librarians are still trying to manage with the information crisis to keeping up the huge amount of literature. During the last few decades, many researchers have been used scientometrics to measure and analyse the scientific research outputs in various disciplines. Scientometric is the most reliable method to track the activities of science and technology and it helps to understand the identity of Scientific discipline. It refers to the quantitative assessment of Scientific research performance. It helps to understand the trends and growth, author productivity, authorship patterns, relative growth rate, collaborative works between countries, authors and institutions and so on (Mulla 2012). Generally, there are two approaches in Scientometrics: normative and descriptive (Neufeld, Fang, & Huff 2007). *Normative Scientometrics* defines the norms, rules and heuristic of the subjects to be covered in the field of study. *Descriptive Scientometric,* explores the entire intellectual core of scientific domain instead of simply concentrating on its individual works. (Sidorova et.al 2008).

3. Related work and Background

Shrivastava and Mahajan (2016) analysed 6529 papers during the span of 1968-2014 in the field Artificial Intelligence in Indian and found significant growth since 2004 and average citation is 3.06 per paper. A Total of 12.64% papers has been published by International collaboration. Santha Kumar and Kaliyaperumal (2015) studied on the growth of Mobile Technology for the period of 2000-2013 and collected 10638 publications. This study noted 9037 were produced by multiple authors and 1601 by single authors with an average of 4.32 joint authored papers were published. The study on cloud computing between the years of 2008-2013 covered 16042 publications which published 97.38% average in English Language. Among this the average of major subjects was contributed 57.1 by Computer Science and 16.0 by the Engineering and least 1.0 is material science studied by Heilig and Vob (2013). Walia, Singh and Singh (2016) has been taken one of the Web 2.0 application is that 'Recommender System'. This study observed out of 10709 records, 18.49% and 17.44% contributed US and China respectively. They analyzed most productive and cited authors, Smyth, B has 216 citations for 20 publications and Blei, DM has 2793 citations for his single publication. Niu, Tang, Xu, Zhou, and Song (2016) studied global research on Artificial Intelligence covered 22,072 publications during the period of 1990-2014. It is shown that the number of authors per paper increased from 2.1 to 3.4 and the number of citations increased per paper from 9.2 to 34.5. Along with 16.5 % of National and 9.4 % of International collaborative work has been done during this period. Ma (2013) analyzed co-citations of Artificial Intelligence research in Neuroscience between 1990 to 2012 and found 175 records. Elango (2017) revealed that 55% of publications were citable articles and Harvard University contributed more number of publications, a total of 50% publications were contributed by USA in the field of Nanotechnology between the years of 2006-2015. Hiremath and et.al (2016) determined the growth of Science and Technology research in India for the period of 1989-2014 and defined journal first rank for Current Science with 14245 publications and Bhabha Atomic Research Centre contributed the highest number of articles. Mulla (2012) analysed 998 publications by applying scientometric indicators of trends and Growth rate, Author productivity, authorship patterns and so on which published in the field of Information Science.

4. Objectives of the study

The main aim of the present study is to analyse the global scientific research performance of *'Drone Technology'* for the ten years between 2008-2017.

i. To study the research output on 'Drone Technology' and its growth using Relative Growth Rate(RGR), Doubling Time(DT), and Annual Growth Rate (AGR);
ii. To examine the Authorship pattern and Author Productivity of the publications;
iii. To present Geographical and Language-wise distribution of research output on Drone Technology;
iv. To determine the degree of collaboration among single and multiple authors;
v. To find out the research contribution of institutions;
vi. To Measure the rankings of Journals based on publication of research output;

5. Methodology

The relevant article for this study was collected using Web of Science an international online database which published by Thomson Reuters, United States. While searching data *'drone', 'drone technology', 'unmanned aerial vehicle', 'unmanned aerial flight'* and *'flying robots'* are used as search strings. Reseacher has been chosen only journal articles for the study. With effect of search strategy, a total of 3433 journal article were found for ten years between 2008-2017. Each record contained complete bibliographic information in English Language i.e. name of the publication, author, publication year, author affiliation, country, language and so on. Downloaded records were loaded into the Bibexcel for the analysis purpose.

6. Data Analysis and Interpretations

6.1.Growth of Publications

Table 1 and Figure 1 reveals that a total of 3433 Journal articles were published in the field of Drone Technology throughout the worldbetween the span of 2008 to 2017. The highest is 1040 publications published in 2017 and the lowest is 86 publications published in 2008. 343.3 was the average number of publications published per year. But There was steadily increasing in the growth of literature between study period.

Table 1 Growth of publications

Year	No. of Publications	% of Publications	CNP	% of CNP
2008	86	2.51	86	2.51
2009	112	3.26	198	5.77
2010	123	3.58	321	9.35
2011	157	4.57	478	13.92
2012	187	5.45	665	19.37
2013	248	7.22	913	26.59
2014	327	9.53	1240	36.12
2015	474	13.81	1714	49.93
2016	679	19.78	2393	69.71
2017	1040	30.29	3433	100.00
Total	**3433**	**100.00**		

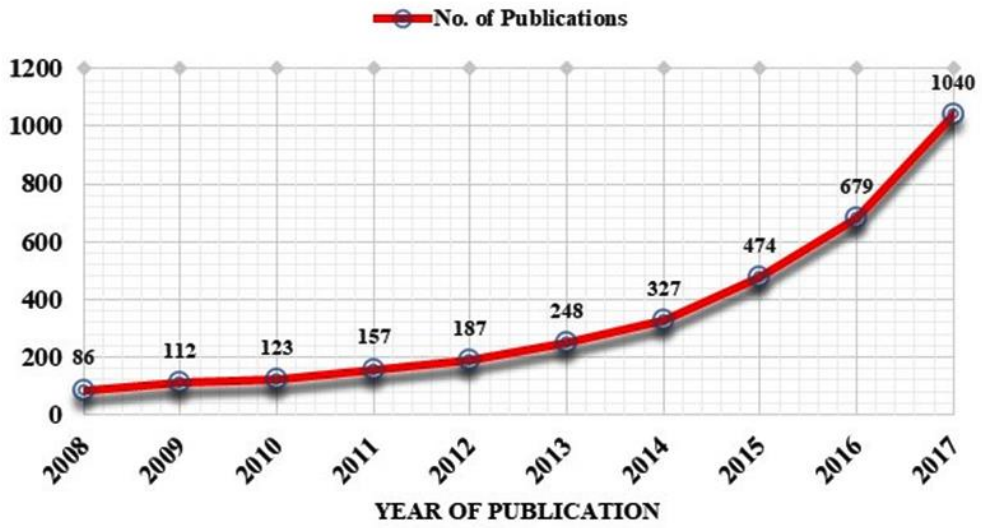

Fig. 1 Growth of Publications

6.2.Relative Growth Rate (RGR) & Doubling Time (DT)

6.2.1 Relative Growth Rate (RGR)

The primary parameters of the Scientometrics are Relative Growth Rate (RGR) and Doubling Time (DT). This study calculates the global research growth with year-wise journal articles produced on 'Drone Technology' obtained from Web of Science dataset between the span of 2008-2017. RGR indicates the escalation in number of article per unit of a time. It means Relative Growth Rate (RGR) over the specific period of interval can be represented as;

Relative Growth Rate (RGR)

$$1\text{-}2^{R} = \frac{\log_e G_2 - \log_e G_1}{t_2 - t_1}$$

Whereas, the above equation denoted that, $1\text{-}2^{R}$ (aa^{-1} $year^{-1}$), means relative growth rate over the specific period of interval; aa^{-1} = average number of articles; $\log_e G_1$ = logarithm of beginning number of articles; $\log_e G_2$ = logarithm of ending number of articles after a specific

span of interval. t_1& t_2 indicates initial time and ending time respectively. Relative Growth Rate can be calculated by following procedure:

$$2009=\frac{\log_e(198)-\log_e(86)}{2009-2008}$$

$$=\frac{5.288-4.454}{1}=\frac{0.834}{1}$$

= 0.834

$$2010=\frac{\log_e(321)-\log_e(198)}{2010-2009}$$

$$=\frac{5.771-5.288}{1}=\frac{0.483}{1}$$

= 0.483

In the same way, Relative Growth Rate calculated for other years.

As indicated in Table 2 and Figure 2, Relative Growth Rate has been gradually decreased during betweenthe year 2009 (0.834) to 0.306 (2014) and bit by bit increased from the year 2015 (0.324) to 2017 (0.361). This changes shows that, the growth of publications not fitted to exponential trend, but fitted for cumulative growth of publications and linear trend fitted for growth of publications as indicated in figure 3. The growth of literature preferable described by Cumulative number of total and it can be defined merely by summing up the yearly publications and it integration of the function of the yearly publications.

Table 2 Relative Growth Rate (RGR) & Doubling Time (DT)

Year	No. of Publications	Cumulative Total	G_1	G_2	RGR	Mean RGR	DT	Mean DT
2008	86	86	-	4.454				
2009	112	198	4.454	5.288	0.834		0.831	
2010	123	321	4.718	5.771	0.483		1.434	
2011	157	478	4.812	6.170	0.398		1.740	
2012	187	665	5.056	6.500	0.330	**0.511**	2.099	**1.526**
2013	248	913	5.231	6.817	0.317		2.186	
2014	327	1240	5.513	7.123	0.306		2.264	
2015	474	1714	5.790	7.447	0.324		2.141	
2016	6790[	2393	6.161	7.780	0.334		2.077	
2017	1040	3433	6.521	8.141	0.361	**0.328**	1.920	**2.118**
Total	**3433**							

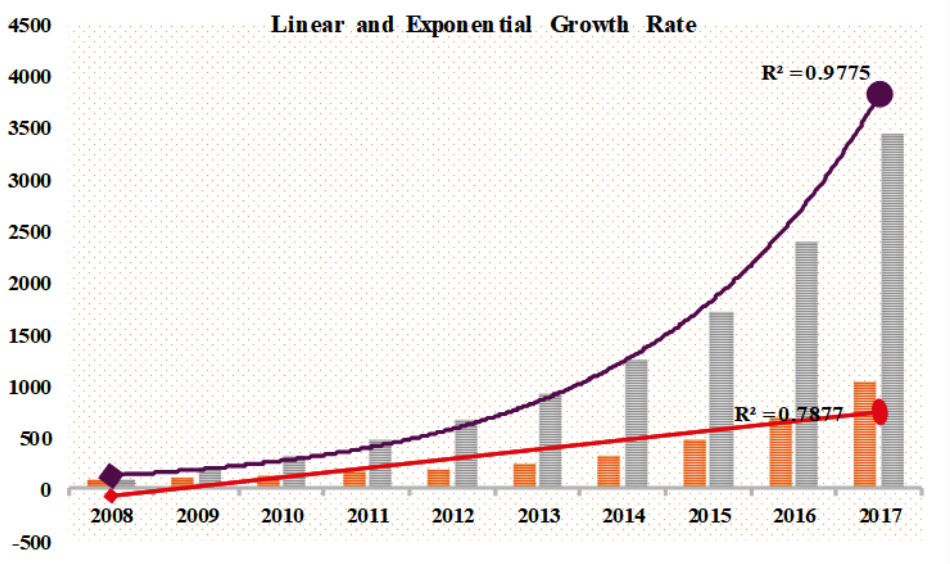

Fig. 2 Linear & Exponential trend for Relative Growth Rate

6.2.2. Doubling Time (DT)

Doubling time refers to time required for publications/articles/citations to become double of existing number of Relative Growth Rate (RGR). Generally, the number of years in which publications twice in its size and it can be approximated using growth rate. If the number of publications/ articles/citations of the particular area of subject twice over a given period, then the difference between the logarithms of numbers at the beginning and end of this period must be the logarithm of number 2. If natural logarithm is used this difference has a value of 0.693(Mahapatra 1985). Therefore, the corresponding doubling time for each definite period of interval and publications can be calculated by the following equation.

$$\textbf{Doubling Time(DT)} = \frac{\log(2)}{\log(1+r)} = \frac{0.693}{R}$$

Therefore,

Doubling time for article:

$$DT(a) = \frac{0.693}{R}$$

$$= \frac{0.693}{1\text{-}2^{R}\ (aa^{-1}\ year^{-1})}$$

$$2009 = \frac{0.693}{0.834} = \mathbf{0.831}$$

$$2009 = \frac{0.693}{0.483} = \mathbf{1.434}$$

In the same way, doubling time has been calculated for remaining years.

Relative Growth Rate and Doubling Time for research output has been calculated and presented in Table 2. Doubling time has been slowly increased during the specific period. Doubling time increased during the span of 2009 (0.831) to 2014 (2.264), and it suddenly

decreased in the year 2015 (2.141) to 2017 (1.920). Therefore, doubling time increasing but it is not showing exponential growth rate. The mean value for the first five years i.e. 2008-2012 is 1.526 and further five years, 2.118 is the mean for years 2013-2017.

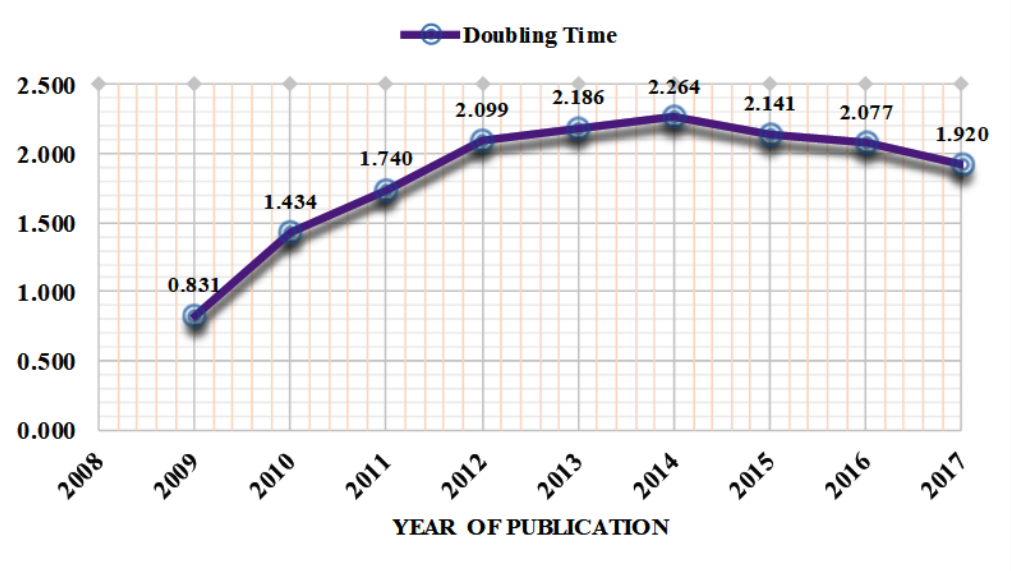

Fig. 3 Doubling time for research output

6.3. Annual Growth Rate (AGR) of the publications

Table 3 and Figure 4 indicates the Annual Growth Rate (AGR) of the number of publications for the span of 2008-2017 and calculated the total number of publications yearwise. AGR can be calculated by the following formula:

$$\text{Annual Growth Rate (AGR)} = \left(\frac{\text{Present Publications}}{\text{Past Publications}}\right)^{\left(\frac{1}{\text{Number of Years}}\right)-1}$$

There was variation in Annual Growth during the study period and suddenly decreased from 30.23 in 2009 to 9.82 in 2010. Where as in suddenly increased up to 27.64 in the year 2011, it was decreased to 19.11 in 2012 and it was increased to 32.62 in the year 2013. There was slightly decreased to 31.85 in 2014 and again increased to 44.95 in the year 2015. Likewise, there was variations after year as indicated in figure 4 in the AGR for the publications. The significant reason for variations is that there is no constant growth of publications every year in the area of study.

Table 3 Annual Growth Rate (AGR) of the Publications

Year	No. of Publications	AGR
2008	86	-
2009	112	30.23
2010	123	9.82
2011	157	27.64
2012	187	19.11
2013	248	32.62
2014	327	31.85
2015	474	44.95
2016	679	43.25
2017	1040	53.17
Total	**3433**	

Fig. 4 Annual Growth Rate of the yearwise Research output

6.4. Geographic Distribution and Collaboration

To obtain deeper insight in to contribution pattern, a total number of publications were produced by various countries is 3433 publications. It is analysed based on author affiliation, there were 94 countries contributed to the Drone Technology research during the study period. This study investigates publications distribution in top 30 countries. And these countries are listed in the Table 4 based on the total number of publications produced by the respective country. Table indicate the country with highest output in terms of global output on Drone Technology research is United States of America (USA) with 774 (22.55) publications, followed by China and South Korea with a total of 618 (18.00) and 238 (6.93) publications were produced respectively. Afterward, United Kingdom, 229 (6.67); Spain 187 (5.45), Germany 178 (5.18), and Italy 172 (5.01) occupied the positions and the remaining countries have published less than 5% of total number of research out in a specified duration. The above six countries were contributed 69.79% of publications in a total. The table reflects that there are poor contributions from European countries and developing countries to the area of study.

Table 4 Geographic Distribution of Publications (Up to Rank 30)

Country	Yearwise Distribution										Total Publications	%
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
USA	35	30	35	41	52	68	78	96	128	211	**774**	22.55
China	3	8	15	22	29	36	55	95	134	221	**618**	18.00
South Korea	3	5	10	12	16	21	25	22	47	77	**238**	6.93
UK	6	6	11	7	15	22	12	37	50	63	**229**	6.67
Spain	2	5	3	5	12	17	25	30	40	48	**187**	5.45
Germany	5	6	7	10	12	15	30	23	22	48	**178**	5.18
Italy	2	1	3	7	9	6	19	24	36	65	**172**	5.01
Australia	5	5	9	9	14	16	20	22	28	42	**170**	4.95
France	6	9	6	8	7	12	16	15	37	46	**162**	4.72
Canada	2	3	1	4	6	13	15	19	23	47	**133**	3.87
Japan	4	5	2	2	3	7	6	3	22	33	**87**	2.53
Turkey		1	3	7	11	7	5	6	17	24	**81**	2.36
Brazil	3	3	2	2	5	5	4	9	18	30	**81**	2.36
Poland	3	5	3	5	6	6	4	7	13	23	**75**	2.18
India	1	1	3	1	1	1	9	6	9	29	**61**	1.78
Singapore	1	4	1	3	5	4	5	7	9	20	**59**	1.72
Netherlands			1	1	1	3	9	13	14	16	**58**	1.69
Switzerland	1	4		2	6		6	12	10	13	**54**	1.57
Malaysia		1	1	3	1		4	21	9	14	**54**	1.57
Taiwan	1	2	4	4	5	4	3	11	8	8	**50**	1.46
Mexico	2	1	1	3	3	3	6	2	7	17	**45**	1.31
Iran			2	1	1	2	3	8	13	13	**43**	1.25
Sweden	2	3	4	1	3	2	9	3	5	8	**40**	1.17
Finland	1	2	2	1	3	3	4	3	4	14	**37**	1.08
Portugal	1	1	1	1	2	2		8	11	9	**36**	1.05
Norway					1	1	4	7	9	12	**34**	0.99
Russia	1		1	2	1	2	3	4	8	9	**31**	0.90
South Africa	3	2	2	4	1	2	4	3	6	4	**31**	0.90
Belgium		2	1	1	1		3	2	11	8	**29**	0.84
Denmark				1	1		2		9	15	**28**	0.82

6.5. Country collaboration in research output

To examine the growth of publications with collaborative works among the various countries, top 10 countries has been counted which indicated in table 4. It helps to draw the map of an international collaborative works. USA and China contributed more number of publications in field of Drone Technology and these countries extended their works by contributing 58 publications with collaboration. Followed by China published 11 with United Kingdom; 4 with Spain. Australia published majorly with China, 17; USA, 11 and Italy worked with USA for 15; Spain, 12 publications. Whereas Canada published 15 publications with USA, and 13 with China. France collaboratively published 15 with USA and by China, 13 publications and etc country published collaboratively in the field of Drone Technology Research during the period of the study.

Table 5 Country Collaboration (Top 10 as shown in Table 4) for research output.

Country	Co.Country	#Pub.	Country	Co. Country	#Pub.
China	USA	58	France	Spain	8
Australia	China	17	Germany	Spain	8
Italy	USA	17	Italy	UK	7
Canada	USA	15	South Korea	UK	7
France	USA	15	France	Germany	6
Germany	USA	15	Australia	Germany	5
UK	USA	14	France	UK	5
Canada	China	13	Italy	China	5
France	China	13	Australia	Spain	4
South Korea	USA	13	China	Spain	4
Germany	Italy	12	Canada	France	3
Germany	UK	12	Canada	UK	3
Italy	Spain	12	Germany	South Korea	3
Australia	USA	11	Australia	Italy	2
France	Italy	11	Australia	South Korea	2
Germany	China	11	Canada	Germany	2
China	UK	11	Canada	Spain	2
Spain	UK	11	Canada	South Korea	2
Spain	USA	10	Canada	Italy	2
Australia	France	8	Australia	Canada	1
Australia	UK	8	France	South Korea	1

*Co.Country=Collaborated country, #pub.= Total Number of Publications

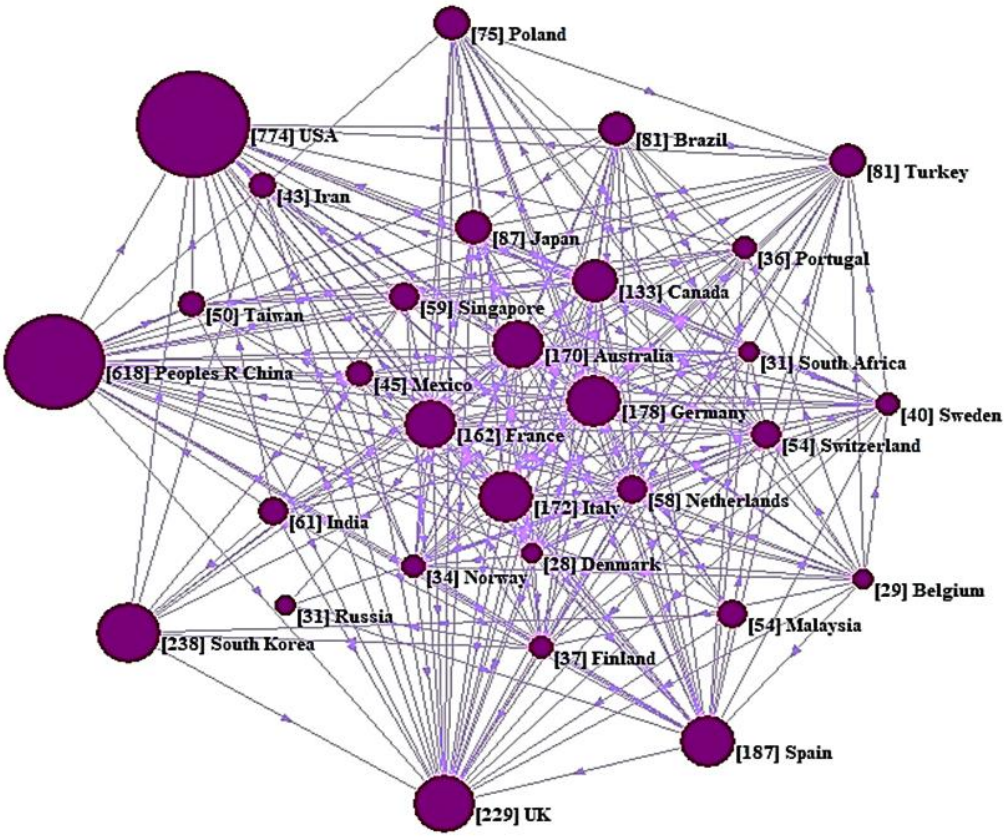

Fig. 5 Social Network for Country Collaboration in research output

6.6. Language wise Distribution of Research output

The study observes that the highest number 3329 (96.97) of publications have been published in English Language, followed by Spanish with 28 (0.82), Korean 25 (0.73), Portuguese 12(0.35) and Chinese language ranks fifth position with 9 (0.26) publications. Whereas remaining languages such other French, German, Russian founded in a small amount of contribution. Table 5 shows that the superiority of English language in contribution of study field in a specified period.

Table 6 Language wise Distribution of Research output

Sl. No.	Language	No. of Publications	%
1	English	3329	96.97
2	Spanish	28	0.82
3	Korean	25	0.73
4	Portuguese	12	0.35
5	Chinese	9	0.26
6	French	8	0.23
7	German	8	0.23
8	Russian	4	0.12
9	Italian	3	0.09
10	Turkish	2	0.06
11	Slovene	2	0.06
12	Polish	2	0.06
13	Czech	1	0.03
Total		**3433**	**100**

6.7. Authorship Pattern

Authorship pattern plays significant role in the study. The study of authorship pattern was analysed to understand the ratio of single and multiple authors. Table 6 shows that out of 3433 publications, the highest number 788 (22.95%) of publications have been produced by three authors, followed by four authors 681 (19.81%), two authors 615 (17.91%), five authors 454 (13.22%) and so on respectively. Single Authors contributed only 310 (9.03%) of publications and 47 (1.37%) of publications contributed by more than ten authors. It represents that multi authored contributions are more than that of single authored works in the field of Drone Technology Research in state period of the study. Table 7 indicates the authorship pattern in yearwise to compute the growth of contribution each year in a given period of the study.

6.7.1. Degree of Collaboration

Collaboration has been defined as the act of working with someone to contribute resource and effort for an intellectual work or research. Degree of collaboration refers the ratio of number of collaborative research publications to the total number of research publications in a specific field of subject during a certain period of time. It can be calculated by the multiple authored publications using following equation given by Subramanyam (1983):

$$\text{Degree of Collaboration} = \frac{\#MAP}{\#MAP + \#SAP} = \frac{3123}{3123 + 310} = \frac{3123}{3433} = 0.909$$

DC= Degree of Collaboration;
#MAP= Number of Multiple Authored Publications;
#SAP= Number of Single Authored Publications.

As per this equation, the degree of collaboration has been determined by the collaboration value between 0 and 1. Therefore, the degree of collaboration is 0.91of a total publications in Drone technology research. It clearly represents the frequency of research team/ collaborated authors. In this context, out of the total publications 90.97% of the publications were

collaborated with multiple authors and 9.03% of the publications were collaborated with single authors.

Table 7 Authorship Pattern

Sl. No.	No. of Authors	Total Number of Authors	%	No. of Publications	%
1	Single	310	2.32	310	9.03
2	Two	1230	9.19	615	17.91
3	Three	2364	17.66	788	22.95
4	Four	2724	20.35	681	19.84
5	Five	2270	16.96	454	13.22
6	Six	1476	11.03	246	7.17
7	Seven	847	6.33	121	3.52
8	Eight	664	4.96	83	2.42
9	Nine	477	3.56	53	1.54
10	Ten	350	2.61	35	1.02
11	> Ten Authors	675	5.04	47	1.37
Total		**13387**	**100.00**	**3433**	**100.00**

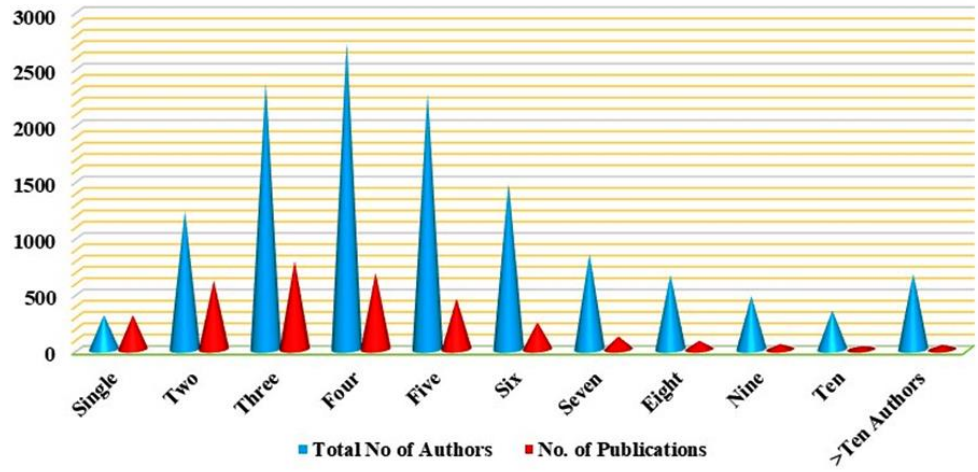

Fig. 6 Authorship pattern in research output

Table 8 Yearwise Authorship Pattern

No. of Authors	Year of Publication										Total No. of Authors	
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	%
Single	6	6	11	13	10	36	33	62	64	69	**310**	2.32
Two	21	33	28	38	37	51	61	84	96	166	**1230**	9.19
Three	33	20	29	33	49	61	81	109	147	226	**2364**	17.66
Four	11	31	27	35	39	46	68	83	134	207	**2724**	20.35
Five	8	12	15	24	23	18	38	66	104	146	**2270**	16.96
Six	4	5	8	8	12	19	20	23	65	82	**1476**	11.03
Seven		2	3		7	11	6	22	19	51	**847**	6.33
Eight	2	1	1	4	5	2	6	8	17	37	**664**	4.96
Nine	1			1	1	2	5	7	14	22	**477**	3.56
Ten		1		1	1	2	4	6	4	16	**350**	2.61
>Ten authors		1	1		3		5	4	15	18	**675**	5.04
											13387	**100.00**

6.7.2. Authorship trend Analysis

Table 8 and Figure 7 examine and analyse the number of publications produced by single and multiple authors in year wise sequence. A univariate analysis of the table represents that the productivity patterns on the drone technology are greatly contributed by multiple authors than the single authors during 2008-2017. Therefore, from this investigation it can be understood that primarily the drone technology research much dominated by multiple authors and collaborative works has been improved gradually. Interestingly there was found 35 authors collaborated in an article, therefore more than ten authors also published some extend for the literature growth in the study field. Figure 8 shows the ratio of single and multiple authored contributions to the research output. A total of 3433 publications published during 2008-2017 in the field of drone technology, it includes single authored with 9.03% (310) and multiple authored90.97% (3123) of publications.

Table 9 Authorship Trend Analysis

Single Authors			Multiple Authors		Quantum of Research Output
Year	Quantum of Output	%	Quantum of Output	%	
2008	6	0.17	80	2.33	86
2009	6	0.17	106	3.09	112
2010	11	0.32	112	3.26	123
2011	13	0.38	144	4.19	157
2012	10	0.29	177	5.16	187
2013	36	1.05	212	6.18	248
2014	33	0.96	294	8.56	327
2015	62	1.81	412	12.00	474
2016	64	1.86	615	17.91	679
2017	69	2.01	971	28.28	1040
Total	**310**	**9.03**	**3123**	**90.97**	**3433**

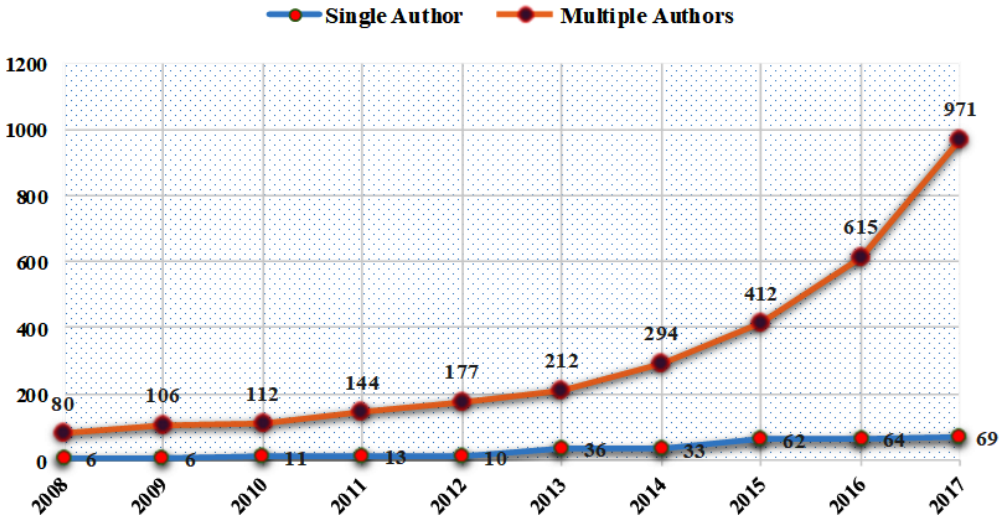

Fig. 7 Growth of Single & Multiple authored contribution to the Research output

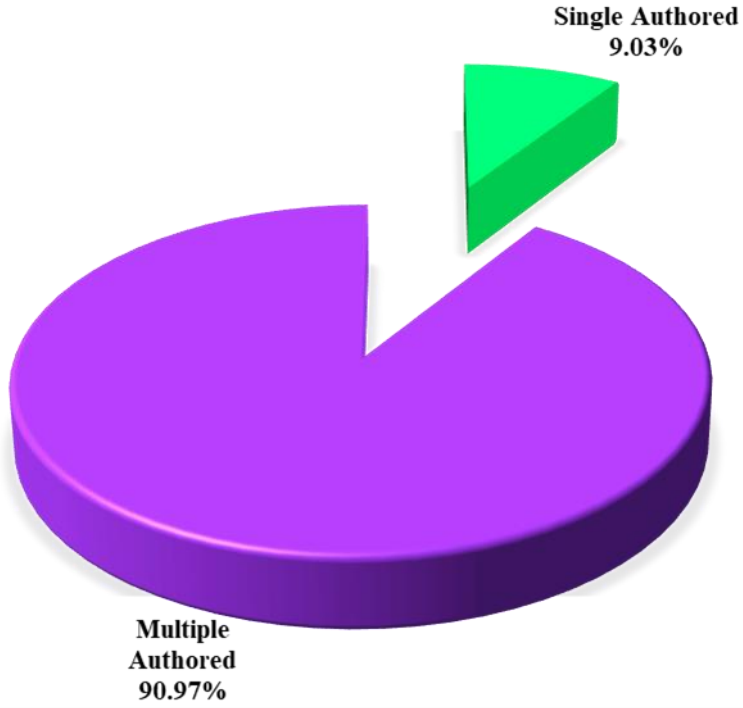

Fig. 8 Single vs Multiple authored publications in research output

6.7.3. Collaborative Index (CI)

CI refers to the number of joint authors per papers. For this analysis, we have omitted single authored publications which is equal to 1 always. To investigate the number of authors involved in joint authored papers, the following equation has been used.

$$\text{Collaborative Index (CI)} = \frac{\text{Total Number of Authors}}{\text{Total number of Joint Authors}}$$

Table 9 clearly indicates that the collaborative index range from 3.43 (2008) to 4.19 (2012) with an average of 3.88 and 3.79 (2013) to 4.45 (2017) with an average of 4.16 per joint authored paper. For a total of 3123 multiple authored publications has 4.13 of an average per joint authors. It implies the research team falls between 3 and 4 authorship pattern in field of drone technology.

Table 10 Collaborative Index

Year	MAP	TAMAP	CI
2008	80	274	3.43
2009	106	383	3.61
2010	112	224	2.00
2011	144	534	3.71
2012	177	741	4.19
2013	212	804	3.79
2014	294	1189	4.04
2015	412	1691	4.10
2016	615	2725	4.43
2017	971	4322	4.45
Total	**3123**	**12887**	**4.13**

MAP=Multi Authored Publications, ***TAMAP***=Total Authors of Multi Authored Publications, ***CI***=Collaboration Index

6.7.4. Author Productivity

The assessment of research productivity helps identify the active authors and research scholars in particular field of subject.Yoshikane et. al (2009) in their article given an equation to figure out the average author per paper (AAPP) and productivity per author (PPA). The mathematical equation represents as below:

$$\text{Average Author Per Paper (AAPP)} = \frac{\text{Number of Authors}}{\text{Number of Publications}}$$

$$\text{Productivity Per Author (PPA)} = \frac{\text{Number of Publications}}{\text{Number of Authors}}$$

Table 10 shows the analysis of author productivity and average author per publication. It is analysed that the average number of author per publication is 3.90 for a total of 3433 publications which published during the span of 2008-2017. Interestingly, it is seen from author productivity table that during year 2016 to 2017 there is an average author per publication is 4.22, it is utmost than a total averagein the field of drone technology in the study period.

Table 11 Author Productivity

Year	Total No. of Publications	Total No of Authors	AAPP	PPA
2008	86	280	3.26	0.31
2009	112	389	3.47	0.29
2010	123	425	3.46	0.29
2011	157	547	3.48	0.29
2012	187	751	4.02	0.25
2013	248	840	3.39	0.30
2014	327	1222	3.74	0.27
2015	474	1753	3.70	0.27
2016	679	2789	4.11	0.24
2017	1040	4391	4.22	0.24
Total	**3433**	**13387**	**3.90**	**0.26**

6.7.5. Identification of most Prolific Authors

The table 10 represents the rank list of top 30 prolific authors and who have contributed more than 9 publications are examined to avoid a long list. It exposes that the most productivity authors, Kim Y secured first place by contributing 31(0.90%) publications during the period and highest 7 articles published in year 2014. Followed by Zarco 21(0.61%), and Zhang 17 (0.50) published in drone technology. Remarkably, Zhang published 17 articles started from 2015 to 2017, it is highest average per year is 5.7, and Kim Ywith 3.1, Zacro with 2.3 articles published per year. Remaining, Moritz, Kim S, Kim J, and Duan published 17 articles each and Lucieer with 16 articles published during the period of the study. Apart from this, authors published below 15 article in a total research output. It is observed that these 30 prolific authors contributed a total 11.51% (395) article to the research output.

Table 12 Identification of most Prolific Authors (Up to Rank 30)

Sl.No	Authors	Productivity										Total	%
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
1	Kim Y	1	1	3	4	5	5	7	2	2	1	31	0.90
2	Zarco-Tejada PJ		2			4	5	5	1	3	1	21	0.61
3	Zhang Y								5	3	9	17	0.50
4	Moritz RFA	3	1	2	2	2	1	3		1	2	17	0.50
5	Kim S		1		2	1	4	1	3	1	4	17	0.50
6	Kim J	2		1	2	1	1	3		4	3	17	0.50
7	Duan HB					1	3	3	2	1	7	17	0.50
8	Lucieer A					3		7	2	2	2	16	0.47
9	Lozano R		3		1	2	2	2	1		3	14	0.41
10	Lee S	1		1				2	2	2	6	14	0.41
11	Oldroyd BP		1	1	1	1	2	4			3	13	0.38
12	Hamel T	3	1	2	2	1		2	1	1		13	0.38
13	Chen BM	1	3		2	1			3	2	1	13	0.38
14	Zhang YM				1	3	2	2	1	1	2	12	0.35
15	Park S			2		2	2	1		2	3	12	0.35
16	Sukkarieh S	1	1	2		2	3			2		11	0.32
17	Wang L							2	1	4	4	11	0.32
18	Torres-Sanchez J						2		5	2	2	11	0.32
19	Lopez-Granados F						2	1	5	2	1	11	0.32
20	Li J						4		5	1	1	11	0.32
21	Lee J	1		1	1	2	2		1	1	2	11	0.32
22	Wang X						1	1	1	3	4	10	0.29
23	Pena JM						1		5	2	2	10	0.29
24	Honkavaara E					2	2	2	1		3	10	0.29
25	Lee D					1	2	2	3	1	1	10	0.29
26	Zhang L				1	4				2	2	9	0.26
27	Tsourdos A	1		1	1	1	3	1			1	9	0.26
28	Hakala T			1		1	1	2	1		3	9	0.26
29	Jiang B				1	2	1			4	1	9	0.26
30	Chen J	1			1	1	1	1		3	1	9	0.26

6.7.6. Co-Authorship pattern

Co-authorship can be revealed that the network of collaborative authors, those who shared their works together to contribute for research output. Bibexcel, Pajek and VOS viewer used and top 30 prolific authors taken to the account (shown in table 10) to draw the co-authorship network.

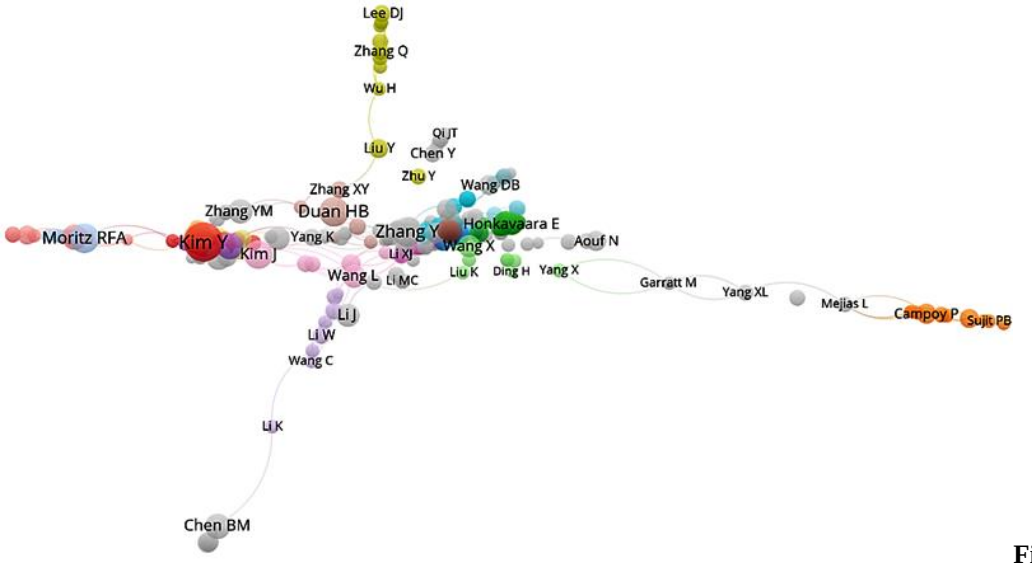

Fig. 9 Co-authorship network in drone Technology research

6.8. Identification of most productivity institutions

The study identified 2903 institutions for a total of 3433 research output and table 11 shows top ten productivity institutions has been taken to the account for analysis. The study analysed that, these top ten institutions of various countries contributed 41.30% (1418) of publications to research output. The study findings represent that the domination of Chinese institutions by contributing 23.77% (816) of a total research output in drone technology. In respect to, 7.31%(251) form Chines Academy of Science, 6.26% (215) from Beihang University, 5.33% (183) from Nanjing University of Aeronautics and Astronautics and 4.86% (167) publications contributed to the field of drone technology.Followed by Seoul National University, South Korea contributed 3.73% (128) of publications and Centre for Scientific and Industrial Consultancy (CSIC), India secured top sixth place with 3.23% (111) of publications in a quantum of research in the study period.Remaining, National University of Singapore, Singapore, Korea Advanced Institute of Science & Technology, South Korea, National Research Council (CNR), Italy, and Cranfield University, United Kingdom contributed 3% (103), 2.94% (101), 2.39%(82) and 2.24% of the works contributed respectively to the field of drone technology in the study period.

Table 13 Identification of most productivity institutions

Sl. No.	Institutions	# of Publications	%
1	Chinese Academy of Sciences, China	251	7.31
2	Beihang University, China	215	6.26
3	Nanjing University of Aeronautics and Astronautics, China	183	5.33
4	National University of Defence Technology, China	167	4.86
5	Seoul National University, South Korea	128	3.73
6	Centre for Scientific and Industrial Consultancy (CSIC), India	111	3.23
7	National University of Singapore, Singapore	103	3.00
8	Korea Advanced Institute of Science & Technology, South Korea	101	2.94
9	National Research Council (CNR), Italy	82	2.39
10	Cranfield University, United Kingdom	77	2.24

6.9. Identification of most productive journals

Table 14 Source Title of Publications (Upto 10 Ranks)

Rank	Source Title	Publications	%
1	Journal of Intelligent & Robotic Systems	140	4.08
2	Remote Sensing	127	3.70
3	Sensors	101	2.94
4	Journal of Aerospace Engineering	68	1.98
5	International Journal of Remote Sensing	51	1.49
6	Journal of Aircraft	48	1.40
7	Journal of Guidance Control and Dynamics	43	1.25
8	Apidologie	36	1.05
9	Aerospace Science and Technology	35	1.02
10	International Journal of Advanced Robotic Systems	33	0.96

The scientific journals play vital role in communication of scientific field. To determine most productivity journals in the study field, preferred sources are identified by the researcher for their publications. The most productivity journals presented in the table 12. Top 10 ranked source title listed in Table 12. It gives most productivity source titles with maximum of 140 and minimum of 33 publications covered journals. It reveals that Journal of Intelligent & Robotic System secured top position with highest number of publications 140 (4.08%). It is followed by Remote Sensing with a share of 127 (3.70%) and Sensors occupied third position with 101 (2.94%) publications. Totally, top ten ranked journals have 682 (19.86%) publications out of 3433 publications of total output.

6.10. Conclusion

It is concluded that, the purpose the study is to analyze the number of contributions brought out by researchers and scientists of the drone technology published on web of science database during the span of 2008 to 2017. The analysis showed that a total of 3433 publications were published in the field of drone technology. This study observed that the growth of contribution gradually increased, and the majority of research publications published a total of 3329 (96.97%) in English language. The author affiliations prove that the countries like USA, China, South Korea and UK are actively engaged in research in the field. The study identified that highly preferred source title to contribute their research by authors that is Journal of Intelligent & Robotic Systems with highest number of publications 140 (4.08%).

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